WHEN THE ISLAMIC STATE COMES TO TOWN

The Economic Impact of Islamic State Governance in Iraq and Syria

Eric Robinson
Daniel Egel
Patrick B. Johnston
Sean Mann
Alexander D. Rothenberg
David Stebbins

RAND CORPORATION

For more information on this publication, visit www.rand.org/t/RR1970

Library of Congress Cataloging-in-Publication Data is available for this publication.
ISBN: 978-0-8330-9855-9

Published by the RAND Corporation, Santa Monica, Calif.
© Copyright 2017 RAND Corporation
RAND® is a registered trademark.

Cover background: Sipa via AP Images.

Limited Print and Electronic Distribution Rights

This document and trademark(s) contained herein are protected by law. This representation of RAND intellectual property is provided for noncommercial use only. Unauthorized posting of this publication online is prohibited. Permission is given to duplicate this document for personal use only, as long as it is unaltered and complete. Permission is required from RAND to reproduce, or reuse in another form, any of its research documents for commercial use. For information on reprint and linking permissions, please visit www.rand.org/pubs/permissions.

The RAND Corporation is a research organization that develops solutions to public policy challenges to help make communities throughout the world safer and more secure, healthier and more prosperous. RAND is nonprofit, nonpartisan, and committed to the public interest.

RAND's publications do not necessarily reflect the opinions of its research clients and sponsors.

Support RAND
Make a tax-deductible charitable contribution at
www.rand.org/giving/contribute

www.rand.org

Preface

At its peak, the Islamic State of Iraq and the Levant (ISIL) controlled vast portions of territory in Iraq and Syria with several million inhabitants. The Islamic State's territorial ambition and desire to conduct state-like governance over this territory are integral to its global ideological appeal. By examining the group's impact on local economic activity in Iraq and Syria, this report seeks to assess the effectiveness of ISIL's governance over its self-styled caliphate.

This report leverages publicly available remote sensing data and low-cost commercial satellite imagery to develop a unique, data-driven assessment of the impact that ISIL control and governance have on local economies within ISIL's territory. It paints a bleak picture of economic life under the Islamic State, replete with shortages of electricity, massive refugee flows, reductions in agricultural output, and upticks in violence all associated with ISIL control.

At times, ISIL was able to build a dense governing apparatus that helped maintain stable local commercial activity, particularly within its strategic capitals in Raqqah and Mosul. At other times, the group inadvertently mismanaged key resources or sought to punish its citizenry rather than govern it. However, this report suggests that decaying economic conditions within the Islamic State are just as much a product of the group's inability to insulate its territory from opposing military forces. Outside pressure against the group successfully prevented the Islamic State from realizing its governing ambitions across significant parts of its caliphate, with major consequences for its ability to support functioning local economies.

This report is important for those trying to understand the group's impact on local populations in Iraq and Syria, for those seeking to counter its financing or conduct postconflict stabilization, and for broader efforts to understand the economic impact of insurgent governance.

The research was conducted within the Intelligence Policy Center of the RAND National Security Research Division (NSRD). NSRD conducts research and analysis on defense and national security topics for the U.S. and allied defense, foreign policy, homeland security, and intelligence communities and foundations and other nongovernmental organizations that support defense and national security analysis.

For more information on the RAND National Security Research Division, see www.rand.org/nsrd/ or contact the director (contact information is provided on the web page).

RAND Ventures

RAND is a research organization that develops solutions to public policy challenges to help make communities throughout the world safer and more secure, healthier and more prosperous. RAND is nonprofit, nonpartisan, and committed to the public interest. RAND Ventures is a vehicle for investing in policy solutions. Philanthropic contributions support our ability to take the long view, tackle tough and often-controversial topics, and share our findings in innovative and compelling ways. RAND's research findings and recommendations are based on data and evidence, and therefore do not necessarily reflect the policy preferences or interests of its clients, donors, or supporters. Funding for this venture was made possible by the independent research and development provisions of RAND's contracts for the operation of its U.S. Department of Defense federally funded research and development centers.

Contents

Figures

Tables

Summary

The Islamic State has proven a resilient insurgent force capable of controlling territory and administering local governance. At its peak, the Islamic State, also known as the Islamic State of Iraq and the Levant (ISIL) or the Islamic State of Iraq and Syria, controlled vast portions of territory in Iraq and Syria with several million inhabitants. The global appeal of its self-styled caliphate has been integral to the group's efforts to recruit foreign fighters and inspire attacks globally. The ideological appeal of the caliphate is based not just on the size of its borders but also on what the Islamic State has attempted to build within those borders. The group's territorial ambition and desire to conduct state-like governance make its experience in Iraq and Syria unique in the context of other jihadist insurgent groups.

Given the importance of its state-like governance, this report offers a comprehensive and wide-ranging look into life within the Islamic State at the peak of its territorial control in Iraq and Syria from January 2013 through May 2016. Although significant attention has been devoted to the humanitarian impact of ISIL's brutal rule, this report focuses on the economic impact of the group's efforts to govern the territory and population under its control. Local economic activity is a useful proxy for the effectiveness of ISIL governance, particularly because the group is reliant on local taxation for a significant portion of its revenue and has publicly linked the appeal of its caliphate to perceptions of its prosperity. This report is important for those trying to understand the group's impact on local populations in Iraq and Syria, for those seeking to counter its financing or conduct postconflict stabilization, and for broader efforts to understand the economic impact of insurgent governance.

This report offers a unique, data-driven, methodological approach to solve the problem of measuring economic activity inside areas controlled by the Islamic State. Where traditional data are unavailable to diagnose conditions on the ground from within ISIL-held cities, we instead look down on these cities from space. Through creative applications of commercial satellite imagery and remote sensing data, we develop clear, quantitative indicators of economic activity within the Islamic State. These indicators provide insights into agricultural production, market activity, commercial vehicle traffic, industrial activity, building stock, and labor supply. Through statistical modeling and mixed-methods case studies, we then correlate these economic indica-

tors with other publicly available reporting of efforts that the Islamic State has undertaken to govern its territory.

Our analysis paints a bleak picture of economic life under the Islamic State. Over the course of the group's peak territorial control and decline through mid-2016, the economy of the Islamic State writ large was clearly in decay. Across all of Iraq and Syria, we estimate that ISIL control was associated with an 80-percent reduction in urban electricity consumption in Iraq and 61-percent reduction in Syria measured through nighttime lighting. These effects correlate to a roughly 23-percent reduction in the gross domestic product of cities within its caliphate. Furthermore, we find that ISIL control was associated with a 36-percent reduction in the population of cities under its control, up to a 20-percent reduction in agricultural output, and steady upticks in violence. All of these effects—on nighttime lighting, population, agriculture, and violence—are statistically significant. Detailed case studies of Mosul, Raqqah, Ramadi, Deir ez-Zor, and Tikrit offer evidence that ISIL governance shoulders at least some blame for these poor economic conditions. At times, ISIL inadvertently mismanaged key natural resources or local businesses, sought to punish its citizenry rather than govern it, or showed sheer indifference to the status of local economic activity.

However, our analysis suggests that it is too simplistic to blame stagnant local economic conditions entirely on the quality of ISIL's governance. Across the caliphate, our satellite-based indicators of economic activity offer contrasting evidence that ISIL successfully provided public services within its territory, prioritized electricity to hospitals, successfully repaired damaged power grids, and invested in local infrastructure. In its strategic capitals—Mosul and Raqqah—dense ISIL regulatory regimes and more-stable security situations coincided with evidence of active markets, robust commercial vehicle traffic, and persistent agricultural production in the time after ISIL takeover. The service-sector and industrial components of these economies were particularly resilient, even where ISIL control was associated with larger negative impacts on electricity consumption and population outflows.

Given the heterogeneity of ISIL's economic impact across its caliphate, we find that the most consistent factor affecting local conditions was the military campaign to recapture territory from the group and deprive it of resources. ISIL faced a clear tradeoff between devoting resources to hold the city militarily and devoting resources to governing it. Mosul and Raqqah were insulated from military competition for much of the time period analyzed in this study, and our satellite-based indicators of economic activity were comparably stable throughout much of ISIL's tenure as a result.

However, in militarily contested cities, such as Ramadi and Deir ez-Zor, or in less strategic cities once on the periphery of ISIL's territory, such as Tikrit, local economic activity declined rapidly over the course of ISIL's efforts to gain a more permanent foothold. Because the group lacked sufficient military power to maintain full de facto sovereign control of these locations for an extended period, ISIL was unable or unwilling to provide public services or guarantee stable security conditions. As a result, in cities

on the contested periphery of ISIL's territory, markets emptied, agriculture suffered, and commercial vehicle traffic was minimal. Furthermore, without long-term hopes of controlling these areas, ISIL resorted to destroying key infrastructure necessary for economic activity as a punitive measure.

This is not to say that, absent military opposition, ISIL would have succeeded at fostering local economic activity everywhere within its caliphate. Although conditions were more stable in its strategic core than elsewhere, our analysis does not suggest that these economies were flourishing. It is to say, however, that outside pressure against the group successfully prevented the Islamic State from realizing its financial and governing ambitions across significant parts of its caliphate, with major consequences for the group's ability to support functioning local economies.

From an insurgent perspective, ISIL's inability to sustain a large-scale prosperous protostate represents an institutional failure by the group to capitalize on a vast territory, historically weak local governments, sympathetic local populations, and a massive financial war chest. Few insurgent groups in the past have held such a strong hand. However, this report suggests that decaying conditions within the Islamic State are just as much a product of the group's inability to insulate its territory from opposing military forces. Phrased a different way, the military campaign against the group has been integral to the Islamic State's failure to build prosperous local economies and develop a sustainable caliphate.

This analysis has clear implications for efforts to counter the Islamic State in its current form, as well as efforts to understand the governing ambitions of jihadist groups in the future. Furthermore, by documenting ISIL's economic impact throughout Iraq and Syria, this analysis offers critical insights into the stabilization needs of areas liberated from the Islamic State. Finally, this report offers clear methodological advances in the use of remote sensing and satellite imagery data for economic analysis and particularly for studies of conflict zones or denied areas more generally.

Economic Impact as a Measure of Islamic State Governance

We focus on assessing the economic impact of the Islamic State for three reasons. First, understanding the level of economic activity within ISIL-held territory provides insight into the long-term solvency of the group's revenues, which are raised largely through taxing and extorting local individuals and businesses. Second, assessing ISIL's economic impact helps measure the group's success in fulfilling its ideological promises, made in religious proclamations, to build an economically prosperous Islamic caliphate. Finally, understanding the long-term permanence of ISIL's economic impact can help inform efforts to reestablish governance over areas that the group once held and diagnose local needs for stabilization and reconstruction aid from the international community.

Existing evidence on ISIL's economic governance suggests that the group affects economic activity in three key ways. First, the group raises funds from local residents, commercial businesses, and industry using a combination of direct taxation, social regulations, and protection rackets. According to published U.S. government estimates, these practices raised several hundred million dollars annually across Iraq and Syria as of 2016. Second, ISIL directly controls portions of local economies within its territory, including extraction of oil, natural gas, and phosphates, as well as some direct control over manufacturing of goods, such as cement. ISIL also engages directly in modest public service provision, including the provision of fuel supplies to support generators, basic sanitation, and water for both consumption and irrigation. Finally, ISIL bureaucracy and military forces can both create the conditions necessary for economic activity to flourish (through strict internal stability) and worsen the prospects for economic growth to take hold (through the provision of violence). These competing influences could affect consumer confidence and the overall business climate or people's willingness to live under the Islamic State versus seek to flee ISIL-held territory.

Measuring Economic Activity from Space

This report relies on satellite-based indicators of economic activity in Iraq and Syria. Satellite-based data provide systematic and objective information on human activity observable from space. This includes economic activity observable with the human eye—for example, foot traffic at commercial markets or the number of commercial vehicles on main roads—as well as economic activity requiring highly specialized optical sensors—including measuring photosynthetic activity in large areas of cropland or thermal output of factories.

Satellite-based indicators of economic activity are of particular value for studying the Islamic State and other similar nonstate violent actors. These groups' presence does not affect our ability to gather data safely from space versus on the ground. Additionally, these indicators are collected free from potential intimidation of survey respondents or interview subjects. As such, remote sensing and satellite imagery data have become increasingly popular in empirical research and media reporting as low-cost ways to gain insight into remote areas of the world.

We derive seven satellite-based indicators of economic activity for this study, including estimates of electricity consumption (through nighttime lighting), population flows (a measure of labor supply and consumer demand), agricultural activity, industrial activity, market activity, commercial vehicle traffic, and damage to key economic infrastructure. These indicators are derived via algorithms that parse publicly available geospatial remote sensing data, as well as crowd-sourced and manual analysis of overhead satellite imagery.

We analyze these data in two distinct ways. First, we develop a new data set on ISIL territorial control city by city within Iraq and Syria for every month from 2013 through mid-2016, and we use panel regression analysis to assess how varying ISIL control across the caliphate over time affects nighttime lighting, population flows, and agricultural activity. The findings from this analysis, summarized in the next section, offer insight into the aggregate effects of Islamic State governance, controlling for economic conditions outside of areas affected by the group.

Then, to correlate these aggregate findings with local evidence of the group's governing tactics, we build five in-depth case studies of key cities in Iraq and Syria: Mosul, Raqqah, Ramadi, Deir ez-Zor, and Tikrit. Later in this summary, we provide results of each of these studies and follow those with a discussion of the implications of these findings for the counter-ISIL campaign and efforts to rebuild areas liberated from the Islamic State. Discussion on future applications of remote sensing methods for similar empirical research is provided in Chapter Eleven.

The Economic Impact of Islamic State Governance: Aggregate Effects

To measure ISIL's aggregate impact on economic activity inside the group's territory, we first build a roster of every city in Iraq and Syria with more than 10,000 inhabitants. For each of these 167 cities, we construct a month-by-month data set indicating whether ISIL unilaterally controls the city, contests control of the city with some other armed group, or has no control over the city. We then combine this time-series information on ISIL control across each city with remote sensing–derived measures of each city's electricity consumption, population flows, and agricultural activity over time. This approach allows us to systematically measure ISIL's economic impact by comparing cities that ISIL has continuously controlled and those that it never controlled, as well as those in which control was contested.

To set a baseline for our understanding of ISIL's economic impact, we first diagnosed how levels of violence, measured via attacks conducted by the Islamic State, ebb and flow prior to ISIL's takeover of cities within its territory. Through regression analysis, we find that ISIL takeover is associated with a significant increase in the number of attacks in the months leading up to full ISIL control but that violence tends to taper off over time as ISIL establishes its foothold in a new city. When cities are liberated from the Islamic State, the number of ISIL attacks in the city falls dramatically in Iraq but does not change significantly after liberation in Syria. Both these findings suggest that the economic impact of Islamic State violence could predate its actual takeover of a city and, in some cases, linger after liberation.

From data on nighttime lighting intensity, we estimate using fixed-effects regression that ISIL control of cities in Iraq and Syria is associated with a massive decline in electricity consumption. In Iraq, electricity consumption falls by more than 80 percent

in ISIL-controlled cities; in Syria, electricity consumption falls by 61 percent. These effects are economically and statistically significant, and the timing of these drops in electricity consumption is closely correlated with ISIL's first establishing a foothold in a given city. Although this effect in Iraq is partially driven by Iraqi government efforts to cut off electricity supply to ISIL-held areas in 2015, our analysis of supplementary data on electricity supply from the national grid in Iraq suggests that the impact of ISIL's takeover of a given city far outweighs the impact of these power supply cutoffs. Furthermore, we find that ISIL's impact on electricity consumption through nighttime lighting was much larger when the group was in complete control of a city. Combined, these effects indicate that the supply of fuel for generators declined significantly under Islamic State control. This is likely a direct product of efforts to deny ISIL-held areas access to energy resources and potentially evidence that the group struggled to bring to bear its own petroleum reserves to fuel generators. Alternatively, it could suggest that the group never prioritized the provision of electricity and fuel to people in its own territory.

Reductions in demand for electricity could also be driven by flows of refugees or IDPs from cities affected by the Islamic State. To this end, we estimate using fixed-effects regression that ISIL control is associated with an average 36-percent reduction in the population of a city's urban area and an average 31-percent reduction in a city's larger periphery. Although these effects are difficult to estimate precisely because of great heterogeneity in how population flows have responded to ISIL takeover across the region, the magnitudes are robust and similar across different specifications. We find no evidence that unilateral control produces more-significant IDP outflows than those produced by contested control.

We also find, based on regression estimates, significant negative effects of ISIL control on agricultural productivity in areas surrounding ISIL-held cities. The timing of these effects operates with a lag, suggesting that ISIL control has a strongly negative impact on crop production several months in the future. Overall, we find that ISIL control resulted in a statistically significant reduction of up to 20 percent in crop yields across ISIL-held territory, primarily in Syria and not in Iraq. We find marginal evidence that unilateral ISIL control produced larger disruptions to agriculture than contested control, although these effects are difficult to precisely estimate given the time lags inherent in crop harvests.

Linking the Islamic State's Economic Impact with Its City-Level Governance

In order to build on the panel data approach used to estimate ISIL's impact across every city within Iraq and Syria, we next construct mixed qualitative–quantitative case studies of five key cities within the caliphate—Mosul, Raqqah, Ramadi, Deir ez-Zor, and

Tikrit. The main purpose of these case studies is to directly connect local evidence of ISIL governance with local economic conditions derived from our satellite-based measures of economic activity.

Overall, these five detailed examinations of conditions under the Islamic State show two different sides of life inside the caliphate through mid-2016. In Mosul and Raqqah, dense ISIL bureaucracies operated safely within the core of ISIL-held territory and, for the most part, faced little threat from opposition ground forces through much of ISIL's tenure. Signs of economic life largely persisted after ISIL established control in both cities in 2014. Despite clear evidence of the group's draconian system of social regulations, taxes, and use of coercive violence in each city, satellite imagery reveals that markets remained busy, commercial trucks still drove the streets in numbers comparable to those before the Islamic State, and the fields remained cropped and productive. Although electricity availability was a persistent problem in both cities after the start of ISIL takeover, other cracks in local economic activity in Raqqah and Mosul did not begin to appear until much later in ISIL's tenure and as the prospects for liberation of each city became more realistic over the course of 2016.

Conversely, life under the Islamic State in Ramadi, Deir ez-Zor, and Tikrit offers a different picture. In these cities outside of its strategic core, ISIL struggled to cement unilateral control in the face of military opposition or strategic indifference. Whether because of disrupted supply lines, resource shortages, or a desire to punish rather than govern, our satellite-derived measures of economic activity in these cities show clear evidence of sluggish or empty markets, rapid population flight, lagging industrial activity, and major destruction of infrastructure. Across these cities, ISIL was unable or unwilling to invest in the governing apparatuses and regulatory regimes seen in Raqqah and Mosul and was unable to secure these cities to allow ordinary economic activity to resume. Instead, the group spent the bulk of its time attempting to consolidate military control and, where unsuccessful, destroyed key infrastructure and wrought violence either as punishment or to spoil efforts to stabilize and rebuild in its wake. These findings are consistent with prior research into the Islamic State's predecessor groups, which found that the group largely pulled its resources back from cities on its periphery in the face of military opposition.

These findings paint a nuanced picture of the impact that Islamic State governance has on local economies—that of an authoritarian insurgent group with some success rebuilding and governing the economy of its insulated core but struggling under the weight of the larger conflict in which it operates. We provide detailed summaries of each case study in the rest of this section.

Mosul: The Islamic State's Economic Engine

Mosul is the largest Sunni city in Iraq, with nearly 2 million residents prior to the Islamic State's takeover in June 2014. Mosul has long held strategic importance to ISIL and its predecessors, and the group is known to have operated underground in the city

prior to taking total control in 2014. The city's economy is more diverse and developed than other cities once held by the Islamic State, with an active manufacturing and industrial sector, airport, and major regional markets. As such, it has been a critical component of ISIL's extortion and taxation revenue streams, which help to fund the group's military operations and bureaucracy.

Our analysis of Mosul's economy under the Islamic State precedes the beginning of operations to liberate the city, which began in the autumn of 2016. Therefore, it focuses on the effects of ISIL's uncontested control of the city for more than two years since it first conquered Mosul in June 2014. Overall, we find that ISIL control had a relatively modest impact on the city's markets and commercial economy, which continued to function at pre-ISIL levels, but a larger detrimental impact on the city's electricity and rates of population outflow.

After establishing control, the Islamic State moved to build a dense bureaucracy capable of implementing public services; maintaining local security; and raising funds through taxation, extortion, and direct intervention in local industries and factories. ISIL's investments appear to have paid off in some sectors of Mosul's economy. Our analysis of satellite imagery suggests that Mosul's markets were more active after ISIL takeover than immediately prior and that ISIL oversaw new construction in the main market area of the city. Thermal data on the heat output of industrial areas within Mosul also suggest that local factories remained active, on average. Commercial vehicle traffic on Mosul's roads persisted. In all, commercial activity within Mosul appears to have persisted at levels roughly comparable to levels seen before ISIL takeover.

Despite this early economic stability, Mosul began to show some signs of economic strain before efforts to liberate the city began in 2016. Analysis of nighttime lighting over Mosul reveals that electricity consumption was staggeringly low within the city. The group proved unable to bring fuel resources into the city to match pre-takeover levels of electricity. Islamic State efforts to directly intervene in Mosul's cement industry appear to have dampened thermal and nighttime lighting activity at one major industrial facility (the Badush Cement Factory) in the long run. Population estimates based on remote sensing data suggest that nearly 200,000 people fled the city between February 2015 and March 2016, despite efforts by the Islamic State to prevent residents of its caliphate from fleeing.

Raqqah: Capital of the Caliphate

Raqqah was the first provincial capital that Syrian opposition forces captured from the Assad regime in early 2013, involving Free Syrian Army units and the al-Qaeda–linked Jabhat al-Nusra (now Hay`at Tahrir al-Sham). Following ISIL's successful efforts to consolidate control over the city from these groups in January 2014, Raqqah then served as the capital of ISIL's global caliphate and a stronghold for ISIL leadership and governance within the Syrian portion of ISIL's territory. The group took significant strides to rule Raqqah as one would a traditional state, including rebuilding dam-

aged infrastructure, opening schools, managing hospitals, establishing law and order through a local police force, collecting taxes, and establishing a civil service.

Overall, our satellite-based indicators of economic activity offer clear evidence that the group was a successful steward of Raqqah's economy for most of its tenure. As with Mosul, our analysis predated operations to liberate Raqqah from the Islamic State that began in mid-2017. Agricultural activity measured through satellite-based sensors showed relatively consistent harvests each year since 2013, and thermal activity in industrial areas within the city was also consistent over time. According to crowd-sourced analysis of overhead satellite imagery, Raqqah's markets remained steadily active since 2013. Commercial vehicle traffic actually increased under ISIL control relative to the pre-ISIL period of opposition infighting for control of the city in late 2013. Furthermore, our analysis of nighttime lighting across critical infrastructure within Raqqah reveals that hospitals were consistently better lit at night than markets, industrial areas, or residential areas. This suggests that the group might have prioritized health care provision over other services.

Despite these successes, parts of Raqqah's economy under the Islamic State appear to have struggled. We find that ISIL control led to significantly reduced electricity consumption in the city, with nighttime lighting as of mid-2016 falling to only 30 percent of its January 2014 levels. This is despite ISIL's uncontested control over the nearby Tabqah Dam, which produces the vast majority of Raqqah's electricity. ISIL's mismanagement of this facility in 2014 led to an insufficient supply of drinking water, water for irrigation, and electricity supplies for several months until the situation was later resolved. Although our estimates suggest that the city's population was largely constant over the course of 2015 and early 2016, we find later evidence that major refugee flows out of Raqqah began in summer 2016. This suggests that city residents were either satisfied with ISIL's early governance or fearful of leaving the city earlier as a result of ISIL-imposed restrictions on out-migration. When refugee flows out of Raqqah did begin in earnest, they coincided with increasing advances by Syrian Kurdish opposition forces throughout much of northeastern Syria over the course of 2016. Alternatively, this timing could suggest that influxes of ISIL fighters offset earlier refugee flows out of Raqqah and that the rate of foreign fighter flows into Raqqah declined over the course of 2016.

Ramadi: The Islamic State's Long Fight for Brief Control

The Islamic State established a partial foothold in Ramadi, the capital of Iraq's Sunni-dominated Anbar province, in January 2014, well prior to its main offensive into northern Iraq later that year. After 17 months of fighting against government forces within the city, ISIL forces finally took full control of Ramadi in June 2015. This unilateral control was short-lived: Iraqi forces moved back into parts of Ramadi's urban center as early as October 2015 and had wrested full control of the city back from ISIL by January 2016. On ISIL's way out of Ramadi, the group's fight against government

forces destroyed much of the city's key infrastructure—including every bridge crossing the Euphrates River. For the first six months after its liberation, few residents returned, and reconstruction of the city was limited.

Because it is an economically underdeveloped city with a government-dependent economy, control over Ramadi offered limited financial benefit to ISIL in terms of potential revenue sources. However, control of Ramadi was strategically significant to ISIL as a major government and Sunni population center along the Euphrates connecting Syria to Baghdad. The lengths to which ISIL fought to take over Ramadi are a testament to the city's significance to the group for sectarian and military reasons, rather than economic ones. Despite the short time period in which ISIL controlled the city, we find evidence that Ramadi's economy heavily deteriorated under the weight of ISIL's control.

For instance, although nighttime lighting fell only modestly while ISIL first contested the city, it fell drastically when ISIL took complete control of Ramadi in the summer of 2015 and declined to just 2 percent of pre-ISIL levels upon liberation. Although partly a result of power shutoffs by the Iraqi government, these electricity shortfalls are equally due to ISIL's inability to secure sufficient generator power for the city despite its vast oil reserves. According to nighttime lighting estimates, ISIL did appear to prioritize electricity provision surrounding several key hospitals and markets. Population estimates suggest that significant proportions of Ramadi's residents fled both before and after ISIL's control of the city. By November 2015, in the middle of the fight to liberate Ramadi, nearly half of the city's residents had fled, according to our remote sensing–based population estimates.

Crowd-sourced assessments of Ramadi's markets using satellite imagery confirm these findings. Few signs of market activity are seen in imagery from early 2016, particularly relative to pre-ISIL images of active local markets in the city's main Souq district. Estimates of commercial vehicle traffic show a dramatic decline in the presence of tractor trailers on Ramadi's roads as well after ISIL takeover. Crop estimates for Ramadi suggest that cereal cultivation in the 2013 and 2014 growing seasons remained fairly strong during the early periods of ISIL's presence in the city, before falling off in 2015, as ISIL consolidated control. Thermal signatures over Ramadi's industrial areas offer possible but inconclusive evidence that ISIL control reduced overall industrial activity in the city.

Unlike in Raqqah and Mosul, we have the opportunity to examine the permanence of ISIL's impact on Ramadi after it was liberated, based on the timing of our data collection (which ended in mid-2016). Although we have fewer data points from after the liberation of Ramadi than before its liberation, our analysis suggests that the level of damage to the city was immense and that its path to reconstruction remains long and complex. Nighttime lighting only marginally improved in the first several months following liberation, and markets remained inactive, likely, in part, because of the mas-

sive reductions in demand as a result of population flight. After liberation, Ramadi's population was down 87 percent from 2008 levels.

Deir ez-Zor: Protracted Stalemate

The Syrian city of Deir ez-Zor, a provincial capital and primary hub of Syria's oil and natural gas region, has been actively contested by Syrian regime forces and Sunni opposition groups, including the Islamic State, since 2012. Opposition groups first seized control of key neighborhoods throughout the city in June of that year, but ongoing fighting with the Syrian regime destroyed an estimated 70 percent of the city through early 2014. In August 2014, the Islamic State wrested control of these opposition-held areas, although forces loyal to the Syrian Arab Republic remained firmly entrenched in neighborhoods representing some 40 percent of the city. Throughout much of the time period used in this study, control of territory within Deir ez-Zor city has ebbed and flowed on a neighborhood-level basis.

ISIL governance in controlled areas of Deir ez-Zor relied on an early partnership with former local government officials and bureaucrats, who were co-opted into maintaining critical infrastructure on behalf of the group. These initial efforts to consolidate control were bolstered by revenues from confiscation, taxation, and sales of electricity and oil resources from Deir ez-Zor governorate's vast oil reserves. However, more-recent public reporting suggests that ISIL could not provide the same quality and quantity of public services in Deir ez-Zor than it did in other cities, such as Mosul and Raqqah.

Our analysis of satellite-derived measures of economic activity in Deir ez-Zor suggests that ISIL was ineffective at governing the neighborhoods and local economies under its control. Despite a relatively steady citywide population, market activity in ISIL-held areas remained paltry while markets in government-held areas of the city appeared to be more active, according to crowd-sourced analysis of satellite imagery. Commercial vehicle traffic was significantly more robust in regime-held areas than in ISIL-held areas, despite the fact that ISIL controls large portions of the Deir ez-Zor countryside. The intensity of agricultural activity on the outskirts of the city appears to have declined over the course of ISIL's presence in the city. Our data also demonstrate a dramatic fall in nighttime lighting in both ISIL-controlled areas and those controlled by government forces, indicating a surprising inability of ISIL forces to provide fuel for generators within the city despite its proximity to the vast majority of ISIL's oil production outside the city.

Finally, contested portions of the city also saw statistically significant reductions in population and nighttime lighting compared with those in regime-held areas. According to our crowd-sourced estimates of damage in the city, significant levels of destruction in the seams between ISIL-held and regime-held areas likely drove these reductions. This finding affirms the fact that military opposition to the Islamic State is one of the main drivers of economic stagnation within its spheres of influence.

Tikrit: The Islamic State Focuses on Punishment, Not Governance

In its June 2014 offensive shortly after the fall of Mosul, the Islamic State captured Tikrit, the capital of Iraq's Salah ad-Din province north of Baghdad. The city capitulated peacefully to ISIL control soon after a small contingent of its forces arrived, all without a single shot fired. Existing evidence of ISIL's control over Tikrit's economy suggests that the group mainly prioritized punitive violence against the city's former government officials, as well as extortion and seizure of assets, over regulation and taxation of economic activity. ISIL controlled Tikrit for a brief nine months. Given that Tikrit was one of the first cities to fall from ISIL control in early 2015, this case study offers the chance to leverage a lengthy time series of post-liberation data to assess how economic activity recovers after ISIL leaves town. Furthermore, Tikrit is a useful case study into the impact of ISIL control where the group devoted few resources to actually governing and providing stability.

Our analysis of satellite-derived measures of economic activity in Tikrit demonstrates that ISIL's tenure in the city, although short-lived, had a dramatic, chilling effect on the economy. This is best illustrated by crowd-sourced data on market activity as seen in satellite imagery, which show a rapid decline in commerce during ISIL's control of the city. Commercial vehicle counts portray an identical effect, suggesting that the presence of tractor trailers and large commercial vehicles in the city declined by up to 70 percent, on average, during ISIL's control. Data on nighttime lighting offer a similar conclusion: Electricity consumption rapidly falls within only a few months of ISIL's arrival—although the timing of this decline is, in large part, due to deliberate efforts by the government of Iraq to restrict electricity access through the national power grid.

We also explore how conditions evolved during the stabilization and reconstruction of Tikrit. Our analysis of nighttime lighting data suggests that Tikrit's electricity consumption took nearly a year to reach levels at or below its pre-ISIL levels. Although agricultural activity in the vicinity of Tikrit appears to have grown significantly post-liberation, the few industrial locations identified in the city fell well behind other types of infrastructure in terms of their nighttime lighting. Our population data provide a similarly mixed result, suggesting that less than half of Tikrit's pre-ISIL population remained in the city as of early 2016 and that this depopulation could have actually occurred after the city's liberation from ISIL forces.

Implications of This Research

At the onset of ISIL's declaration of a caliphate, the group's grip over its territorial holdings appeared stronger than ever. Its ability to govern that territory was largely untested. Now, several years in the making, the Islamic State's caliphate is on the ropes. Yet the Islamic State and its predecessor groups, al-Qaeda in Iraq and the Islamic State of Iraq, have proven resilient in the past. Despite its shrinking territory, the Islamic

State still controls thousands of square kilometers of territory and a significant population, as well as highly lucrative oil and gas reserves. Its presence along the Euphrates River valley spanning the Syria and Iraq border is likely to persist, whether overt or covert. And if history is any lesson, the territorial defeat of the Islamic State is unlikely to extinguish the possibility for similar Sunni insurgencies in the region in the future.

As such, this research has clear implications for both the continued campaign to degrade and defeat the Islamic State and efforts to stabilize and reconstruct areas that the group formerly held. Furthermore, it serves to document, for future planning purposes, the lessons learned from ISIL's experiment in providing local governance. In this section, we describe three key findings that inform current and future efforts to separate the Islamic State from its governed territory, as well as four findings related to efforts to stabilize areas liberated from the group and prevent a future recurrence of the Islamic State down the line. This research also identified lessons learned that can support future efforts to assess economic activity in denied areas using remote sensing and imagery data, which we describe in the body of this report.

Implications for Degrading and Defeating the Islamic State

- **Military pressure on ISIL-held areas has dampened economic activity and prevented ISIL from fully governing according to its stated goals.** Overall, we find that military pressure on ISIL-held territory has prevented the Islamic State from attempting to govern and stabilize local economies when contested by opposing ground forces. This pressure has contributed to significant economic decay within ISIL-held territory, which, in turn, limits ISIL's ability to profit from taxation and gain popular legitimacy by governing stable local economies. We see this pressure materialize predominantly in terms of military opposition to contest or retake control of ISIL-held cities. We also see clear evidence that intentional efforts to deny ISIL-held territory access to energy resources are correlated with reduced local electricity consumption. This includes actions taken by the government of Iraq to deny ISIL-held areas access to power through the national power grid and, moreover, efforts by the coalition air campaign to deny the Islamic State access to and revenues from local oil fields under its control.
- **ISIL's strict governance is not necessarily self-defeating. Where local economies struggled under Islamic State control, these struggles were not because taxes were too high or social regulations too restrictive.** The Islamic State's unique form of governance involves harsh social regulation, severe forms of punishment, and significant extraction of rents and taxes from the local population. Some have argued that these forms of governance are self-defeating, in that they could disincentivize economic activity and local popular support. However, we find clear evidence that market and commercial activity remained strong in Raqqah and Mosul even after ISIL fully built its bureaucratic institutions, social regulations, and public services. Where local economies struggled—in terms of

electricity availability, population outflows, and infrastructure damage—these effects largely coincided with military efforts to disrupt ISIL control over its territory. If ISIL's strict governance is not self-defeating, military efforts to retake its remaining territory and prevent a resurgence of the group remain critically important.

- **The Islamic State showed signs of successful stewardship over local economies but also signs of incompetence and indifference.** In multiple cities, ISIL prioritized electricity provision to hospitals and key infrastructure even in the face of larger electricity shortages. The group also successfully rebuilt electrical infrastructure in Raqqah following damage from air strikes, built new market facilities in Mosul, and regulated consistently active markets in both cities. Yet, in other cases, ISIL's efforts to directly intervene in local economies wreaked havoc on local economic conditions. In Raqqah, ISIL's failure to effectively manage the throughput of the Tabqah hydroelectric dam in 2014 led to water shortages and electricity problems. In Mosul, its failed efforts to take over the Badush Cement Factory appear to have driven declines in activity at that facility. In other cases, the group's desire to punish local populations or destroy key infrastructure in the face of liberating forces (such as in Ramadi) demonstrates an indifference toward providing governance in the face of military opposition.

Implications for Stabilizing Formerly Islamic State–Held Territory

- **Electricity consumption has suffered the most of all economic activity under ISIL control.** Across all the aspects of local economies assessed in this study, electricity consumption in ISIL-held areas showed the most-significant declines from pre-ISIL levels of activity. In some cases, the lack of electricity supply was due to mismanagement of electrical infrastructure or damage to power generating facilities, such as in Raqqah and Mosul. In other cases, fuel shortages or price shocks affected locals' ability to run private generators that supply large percentages of local power. After liberation, these effects linger. In Tikrit, it took nearly a year for the city reach levels of nighttime lighting close to pre-ISIL levels, in part because of ISIL-inflicted damage to the power grid. In Ramadi, nighttime lighting levels only marginally improved in the first few months after liberation from ISIL forces in January 2016. Stabilization planning for the liberation of areas still controlled by ISIL should focus on procuring power supplies and rebuilding energy infrastructure. Implementers should be prepared to provide this assistance well beyond the first few months after liberation.
- **IDP flows begin well prior to liberation.** Planning for liberation of ISIL-held cities must take into account the fact that IDP flows begin well before the first military forces enter an ISIL-held city. Before operations to liberate Mosul began in the fall of 2016, more than half of the city's residents had already fled the city. In Raqqah, nearly 40,000 residents fled the city between February 2016 and June

2016. Planning for humanitarian assistance surrounding liberation must take into account the location and unique needs of these displaced people.

- **Markets do not return to normal activity immediately after a city is liberated.** In both Tikrit and Ramadi, markets were partially damaged by fighting during ISIL's retreat from the city. Moreover, they appear largely empty in high-resolution imagery following liberation, likely because the vast majority of the residents of each city had fled the fighting.
- **Bureaucratic capacity likely remains in areas liberated from the Islamic State.** In several instances, we document evidence of ISIL successfully co-opting local civil servants and engineers to help run its bureaucracy and public services. This includes evidence of local engineers conducting successful repairs to reconstitute Raqqah's power grid following damage from air strikes, which we validate using nighttime lighting data. Furthermore, the consistency with which hospitals across ISIL territory have remained functional and well-lit over time suggests that medical expertise could remain inside ISIL-held territory as well. As such, liberating forces are likely to encounter local doctors, engineers, and bureaucrats who either voluntarily worked for the Islamic State or were co-opted into doing so. Stabilization planning should focus on working with liberating forces to effectively and fairly distinguish between ISIL sympathizers and unsympathetic locals with the needed institutional knowledge to help provide public services post-liberation.

Acknowledgments

We would like to thank many people who made significant methodological, editorial, and substantive contributions to the preparation of this manuscript and presentation of its findings. At the RAND Corporation, this includes Edmund J. Burke, James Gazis, Michelle Miro, Katherine Pfrommer, and Ricardo Sanchez. Additionally, Andrew Shaver of Princeton University offered invaluable advice and data, both of which greatly improved this analysis. At DigitalGlobe, we extend our gratitude to Tom Jones and James Sondag for their guidance into the application of satellite imagery data for empirical research of this nature.

We would also like to thank Michael D. Rich, Susan L. Marquis, and Howard J. Shatz at RAND for their support of this research through RAND Ventures. Additionally, we thank John V. Parachini and Richard S. Girven for supporting this research through the RAND Intelligence Policy Center.

We would foremost like to thank Craig A. Whiteside of the Naval Postgraduate School and Trevor Johnston of RAND for their insightful reviews of this manuscript. Their contributions greatly improved the quality of this report, its methodology, and its conclusions. This effort would have proven insufficient without their contributions.

All errors or omissions remain solely our responsibility.

Abbreviations

AQI	al-Qaeda in Iraq
FAO	Food and Agriculture Organization of the United Nations
FE	fixed effect
FSA	Free Syrian Army
GDP	gross domestic product
GoI	government of Iraq
IDP	internally displaced person
IED	improvised explosive device
ISF	Iraqi security forces
ISI	Islamic State of Iraq
ISIL	Islamic State of Iraq and the Levant
ISIS	Islamic State of Iraq and Syria
JN	Jabhat al-Nusra
NASA	National Aeronautics and Space Administration
NDVI	Normalized Difference Vegetation Index
NIR	near infrared
NOAA	National Oceanic and Atmospheric Administration
ORNL	Oak Ridge National Laboratory
OSM	Open Street Map
PMU	Popular Mobilization Unit

SD	standard deviation
SYP	Syrian pound
UN	United Nations
UNDP	United Nations Development Programme
UNITAR	United Nations Institute for Training and Research
USGS	U.S. Geological Survey
VIIRS	Visible Infrared Imaging Radiometer Suite
WFP	United Nations World Food Programme

CHAPTER ONE

Introduction

> It was not that they beheaded someone who committed a crime—that was not my issue with them. It was the way they governed.
>
> —Mohammed al-Masri, former Islamic State fighter, August 2016[1]

In June 2014, Islamic State fighters moved with lightning speed from Syria across the border into Iraq, wresting control of a large portion of Iraq's Sunni heartland with little opposition from fleeing Iraqi security forces (ISF). In short order, the Islamic State, also known as the Islamic State of Iraq and the Levant, or ISIL, gained complete control over most of northern Iraq, including the largest city in the region, Mosul, and then began to rapidly expand into western and central Iraq later in the year. Although the group had long maintained a covert presence throughout the region, its newfound domination over territory in Iraq and Syria led ISIL emir Abu Bakr al-Baghdadi to announce himself as "caliph" of a new Islamic State with the resources, population, and territory to back his claim.[2] By 2015, ISIL controlled an area roughly the size of Great Britain, including large swaths of territory in central and eastern Syria. Large portions of the group's territory have been rolled back since then, leaving in ISIL's wake devastated urban and rural economies in need of massive reconstruction. Significant territory remains under its control.

ISIL's rapid expansion across Iraq and Syria gave the group access to considerable financial resources. Official estimates from 2016 suggest that the group generates the majority of its revenue, roughly $360 million annually at that time, from taxing and extorting local businesses and individuals involved in agriculture, manufacturing, oil products, and the service sector.[3] ISIL's ability to maintain control over this territory is

---

1 Souad Mekhennet and Greg Miller, "He's the Son of Osama bin Laden's Bombmaker, Then ISIS Wanted Him as One of Their Own," *Washington Post*, August 5, 2016.

2 "Sunni Rebels Declare New 'Islamic Caliphate,'" *Al Jazeera*, June 30, 2014.

3 Yeganeh Torbati, "Islamic State Yearly Oil Revenue Halved to $250 Million: U.S. Official," Reuters, May 11, 2016.

costly. Estimates suggest that ISIL uses at least 40 to 50 percent of total expenditures to pay its fighters, and a share of its remaining funds is used to finance the provision of public services, including water, electricity, sanitation, and local security.[4] These efforts to profit off local businesses, extract resources, provide public services, and control local populations are critical components of ISIL's efforts to govern the population living within its territory.

This report seeks to assess the effectiveness of ISIL's governance over its self-styled caliphate. To do so, we measure how ISIL territorial control has shaped and affected local economic activity over time. For three reasons, we focus on economic impact as a measure of ISIL's ability to govern. First, it measures the Islamic State's promise to build an economically prosperous Islamic caliphate against the actual realities of its brutal control. Second, it helps to address the long-term solvency of the group's revenues, which are raised primarily through taxing and extorting local economic activity. To this extent, ISIL's revenues both rely on functioning local economies and are necessary to allow the group to continue to govern these areas. Finally, focusing on ISIL's economic impact will help prepare local actors to reestablish governance over areas formerly held by the group and diagnose local needs for stabilization and reconstruction aid from the international community.

The Islamic State's Vision for an Economically Prosperous Caliphate

Understanding ISIL's impact on the economic welfare of the population within its "caliphate" is an important litmus test of its promise to create a prosperous home for all Muslims. In its own religious proclamations, ISIL promises to govern its territory in accordance with sharia law in order to develop a nation-state that entices all Muslims to join the caliphate, in part because of its prosperity.[5] For instance, many analysts believe that ISIL's declaration of a caliphate is a critical reason for its success in drawing foreign fighters to join the group.[6] In one of the group's own documents, which *The Guardian* published in December 2015, the writer suggests that effective governance over local economic activity is critically important in order to build financial indepen-

---

[4] Patrick B. Johnston, *Countering ISIL's Financing*, testimony to the U.S. House of Representatives Committee on Financial Services, November 13, 2014. See also detailed ISIL financial ledgers from the group's finance ministry in Deir ez-Zor governorate (Wilayat al-Khayr) in Aymenn Jawad al-Tamimi, "The Archivist: Unseen Islamic State Financial Accounts for Deir az-Zor Province," *Jihadology*, October 5, 2015d.

[5] William Faizi McCants, *The ISIS Apocalypse: The History, Strategy, and Doomsday Vision of the Islamic State*, New York: St. Martin's Press, September 2015, pp. 79–82; "Khitta istratijiyya li-ta'ziz al-mawqif al-siyasi li-Dawlat al-'Iraq al-Islamiyya [Strategic plan for reinforcing the political position of the Islamic State of Iraq]," Mufakkirat al-Fallujah, c. December 2009–January 2010, p. 50.

[6] Kim Cragin and Ben Connable, "To Undermine ISIS, We Should Welcome Syrian Refugees," *RAND Blog*, December 3, 2015; Seth G. Jones, "Islamic State's Global Expansion," *Wall Street Journal*, June 4, 2015.

dence from less certain external sources. This document, "Principles in the administration of the Islamic State," notes,

> Jihadi groups in Iraq and Syria have lived through long bonds of humiliation pledged on conditional western support, until they seized wide areas of the land and possessed all assets of advancement. And all of that is on account of the ignorant administration that controls them and keeps them under western guardianship for all their activities, wars and expansion.[7]

This report will help measure ISIL's ability to govern its caliphate in line with its stated ideological goals and practical governing realities. ISIL governs its territory and affects local economic activity in three key ways. First, the group taxes inhabitants of the areas under its control to fill its coffers and extorts existing commercial businesses and industry in protection rackets or in exchange for access to supplies that support its wartime operations. Second, ISIL directly controls some parts of the local economy, including resource extraction of oil, natural gas, and phosphates. It also engages directly in modest public service provision of fuel supplies to support generators, basic sanitation, and provision of water for drinking and irrigation. Finally, ISIL's strict law enforcement apparatus creates relative stability within areas under its control but also could sow fear over its harsh punishments. Violent attacks from the group's combat forces against rivals could create distrust or fear as well. These competing influences could improve consumer confidence and the overall business climate or reduce people's willingness to live under the Islamic State in the first place.

Research Questions

We focus on three specific research questions, intended to explore the full scope of ISIL's economic impact on the areas under its control. We use these research questions as a framework to structure the analysis conducted in this report, in pursuit of the research goals described earlier in this chapter.

First, we ask, *what impact does ISIL governance have on the types of economic activity that occur in cities under its control?* ISIL control and governance could affect certain economic sectors differently from how it affects others. For example, the group could intentionally safeguard or bolster certain industries that are more profitable or important to the wartime economy. Alternatively, ISIL's strict control and extortion practices could be more intrusive and harmful to some areas of the economy than to others. Identifying how the sectoral distribution of economic activity varies under ISIL control will help illuminate the group's governing priorities and whether it is more successful

[7] "Principles in the administration of the Islamic State," in "The ISIS Papers: A Masterplan for Consolidating Powers," *Guardian*, December 7, 2015.

at certain aspects of governing its territory than at others. It will also help focus efforts to counter the group via public messaging and will help prepare the international community to bolster underperforming sectors following ISIL's defeat.

Second, we ask, *how does ISIL's economic impact vary over time following takeover of and retreat from a city?* Effective governance takes time to develop, and violent conflict inflicts a toll on local economies wholly independent of ISIL's exploitation of local resources. Exploring the trajectory of ISIL's economic impact over time will help to correlate changes in economic activity with ISIL's attempts to establish effective governance in specific cities over time and gauge the permanence of ISIL's economic impact following a transition to government or opposition control.[8] It will also help test ISIL's own claims regarding the economic prosperity of its caliphate and will gauge whether ISIL governance produces temporary disruptions or whether ISIL governance has lasting impacts on the areas under its control.

Finally, we ask, *how does ISIL's economic impact differ by ethnicity and within contested areas of the cities it controls*? High-resolution remote sensing data allow us to measure economic activity with a remarkable level of granularity. As a result, we can measure how economic activity varies inside cities under ISIL control across neighborhoods of different ethnicities and in contested cities across areas that ISIL controls compared with those under Syrian regime or forces from the government of Iraq (GoI). Doing so should help illuminate ISIL's willingness to harm parts of local economies as a punitive measure or protect contested parts of local economies as a means of maintaining support.

Methodology

Economic conditions within the Islamic State have received periodic media attention, but data limitations have prevented systematic empirical analysis of ISIL's economic impact.[9] To overcome the lack of traditional survey data in the region from inside ISIL-held territory, this report relies on satellite-based remote sensing methodologies to gain insight into local economic activity using both low-resolution publicly available data and high-resolution commercial imagery data.

What economic activity can we measure from space? Publicly available, low-resolution satellite data provide a baseline understanding of monthly changes in industrial activity, population density, migration, electrification, and agricultural land usage. Commercial high-resolution satellite imagery data provide measures of market activity,

---

[8] ISIL is neither regime (Iraqi government nor Syrian government) nor opposition (in lieu or rebel). This helps to gauge how permanent ISIL's economic impact is after it loses control to government or other opposition forces.

[9] Ruth Sherlock, "Why Business Is Booming Under Islamic State One Year On," *Telegraph*, June 8, 2015; see also Ben Hubbard, "Offering Services, ISIS Digs in Deeper in Seized Territories," *New York Times*, June 16, 2015.

building destruction, and commercial activity (via vehicle counts). Combined, these indicators capture a significant swath of the predominantly agrarian, manufacturing, and service sector–based local economies in Iraq and Syria.

We build a comprehensive data set, including multiple types of publicly available satellite-based data for every city in Iraq and Syria with a population of at least 10,000 inhabitants.[10] For theoretical and methodological reasons, we focus on cities as the primary unit of analysis. ISIL initially conquered territory largely on a city-by-city basis and deploys its noncombat forces that conduct local governance and security functions almost solely within major urban areas and population centers.[11] Additionally, for methodological reasons, using cities as the unit of analysis is significantly more tractable in terms of identifying locations under direct ISIL control over time than something narrower, such as neighborhoods, or broader, such as districts or provinces.[12] Where necessary, we focus on the outlying areas of each city to capture rural-based economic activity, such as agriculture.

Across this rich data set of city-level territorial control, we use statistical methods to analyze how the nature and intensity of economic activity changes when ISIL first comes to town, how local economies perform under ISIL control, and how local economies perform after ISIL retreats from a city or is militarily defeated. In an effort to isolate the economic impact of ISIL control from areas merely affected by ongoing civil conflict, we compare economic activity in ISIL-controlled cities with that in other similar cities either contested by ISIL or entirely outside of ISIL's control.

To provide a contextualized, fine-grained view of ISIL's economic impact, we also conduct in-depth case studies of ISIL's influence on economic activity in five cities: Mosul, Raqqah, Ramadi, Deir ez-Zor, and Tikrit (see Figure 1.1). The main purpose of these case studies is to attempt to directly connect ISIL's governance over a given city with its economic impact. Where the prior statistical analysis focused on measuring estimates of ISIL's impact on average, these case studies attempt to contextualize and narrate the manner in which ISIL governance is the driving force behind these effects at a more localized level. We chose these five cities to capture variation in ISIL's control and potential to affect local economies.

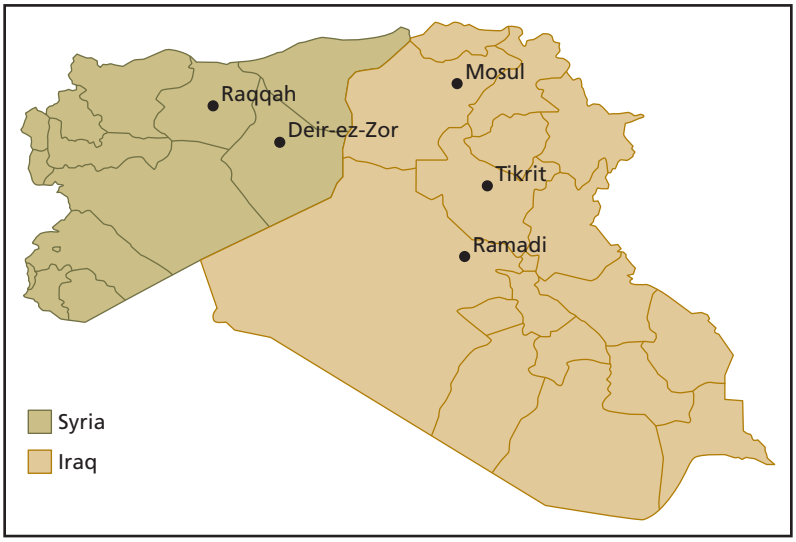
---

[10] We use a population level of 10,000 to focus our analysis on large cities and medium-size population centers rather than larger villages or rural towns. This is also intended to restrict our sample to those areas most likely to experience direct ISIL control for a sustained period of time, rather than intermittent ISIL influence.

[11] For a detailed discussion of ISIL's focus on controlling and holding cities and urban areas, see Mark Thompson, "Why the Fight Against ISIS Has to Go Through the Cities," *Time*, March 10, 2015. Additionally, it should be noted that combat to retake ISIL-held areas has also been city-centric: ISF and Popular Mobilization Unit (PMU) elements in Iraq and Kurdish forces in Syria have fought to retake city centers from ISIL control and use these fixed locations to eliminate remaining pockets of resistance elsewhere in the city, such as in Fallujah in June 2016. See "Iraqi Forces Battle ISIS Militants in Pockets of Fallujah," CBS News, June 20, 2016.

[12] Although ISIL has established larger districts and provinces (*wilayat*s), ISIL forces cannot always control the entirety of rural areas in these districts, which complicates determining relationships between changes in economic activity and changes in ISIL control.

Figure 1.1
Cities of Interest in Iraq and Syria



RAND *RR1970-1.1*

In Mosul and Raqqah, ISIL had largely uncontested control since taking over these cities through mid-2016, so changes in economic activity in these cities are more directly result of ISIL's governance and less a result of other confounding factors. In Deir ez-Zor and Ramadi, ISIL controlled portions of these cities at the same time as government forces or rebel elements held other portions. This contestation allows us to uniquely measure how economic activity differs in certain areas of each city over time, based on differences in control on a neighborhood-by-neighborhood basis. Additionally, it allows us to measure whether ISIL's economic impact is contingent on fully establishing local governance structures. Finally, in Tikrit and for Ramadi at the end of ISIL's tenure, we can measure how economic activity changes when ISIL retreats from each city and is militarily defeated. In Tikrit as well, we can measure the impact of ISIL control over a city in which the group invested few resources and had few strategic interests.

Value of This Research

We anticipate that this research will support counter-ISIL activities. Although coalition air strikes have reduced ISIL's revenues by an estimated 30 percent since November

2015,[13] the group's ability to profit from taxing and extorting local economic activity remains potent.[14] This research will help to quantify whether ISIL can profit off declining economic activity over time, guiding military planning and intelligence-gathering related to the remaining ISIL territory in Iraq and Syria. Furthermore, plans for post-ISIL stabilization and reconstruction will benefit from a clearer understanding of how ISIL control has affected local economies over time, including knowledge of key sectors that have survived ISIL control or been most hampered by the group's governance.

This report is also well positioned to provide new insights into the relationship between economic conditions and civil conflict. An extensive literature has explored how economic conditions—for example, economic inequality, unemployment, and economic volatility—affect civil conflict.[15] However, research exploring the strategic economic decisionmaking of violent political movements akin to ISIL is limited.[16]

Finally, this effort introduces several methodological innovations that have potential applications in a diverse array of fields. Although use of nighttime lighting data has permeated a variety of disciplines,[17] combining these data with other low-resolution and high-resolution imagery data sources can help researchers to objectively analyze the impact of infrastructure development programs, public health interventions, or even active labor market programs in remote or denied areas.

---

[13] Cheryl Pellerin, "OIR Spokesman: ISIL Now in Defensive Crouch in Iraq, Syria," U.S. Department of Defense, January 6, 2016. The Global Coalition to Counter the Islamic State includes 68 partner nations, of which a small number of Western and Arab nations have chosen to conduct air strikes against ISIL in Iraq and Syria.

[14] For more information on ISIL's taxation and extortion capabilities, see Eric Robinson, "Cutting the Islamic State's Money Supply," *National Interest*, July 20, 2016.

[15] See Christopher Blattman and Edward Miguel, "Civil War," *Journal of Economic Literature*, Vol. 48, No. 1, March 2010, pp. 3–57.

[16] Numerous studies have conceptualized and analyzed what scholars call "rebel governance." These studies examine the institutions, social structures, and rebel–population relationships established in areas that rebel groups control. See, for example, Zachariah Cherian Mampilly, *Rebel Rulers: Insurgent Governance and Civilian Life During War*, Ithaca, N.Y.: Cornell University Press, 2011; Ana Arjona, "Wartime Institutions: A Research Agenda," *Journal of Conflict Resolution*, Vol. 58, No. 8, 2014, pp. 1360–1389; and contributions in Ana Arjona, Nelson Kasfir, and Zachariah Cherian Mampilly, eds., *Rebel Governance in Civil War*, Cambridge, UK: Cambridge University Press, 2015. ISIL, however, differs from most rebel groups in that it not only governs more territory but also does so according to a strict Islamist doctrine that prioritizes economic and political governance. For more discussion of this doctrine, see Chapter Two.

[17] See Samuel Bazzi, Arya Gaduh, Alexander D. Rothenberg, and Maisy Wong, "Skill Transferability, Migration, and Development: Evidence from Population Resettlement in Indonesia," *American Economic Review*, Vol. 106, No. 9, September 2016, pp. 2658–2698; Daniel Egel, Charles P. Ries, Ben Connable, Todd Helmus, Eric Robinson, Isaac Baruffi, Melissa A. Bradley, Kurt Card, Kathleen Loa, Sean Mann, Fernando Sedano, Stephan B. Seabrook, and Robert Stewart, *Investing in the Fight: Assessing the Use of the Commander's Emergency Response Program in Afghanistan*, Santa Monica, Calif.: RAND Corporation, RR-1508-OSD, 2016; and Ting Ma, Yuke Zhou, Chenghu Zhou, Susan Haynie, Tao Pei, and Tao Xu, "Night-Time Light Derived Estimation of Spatio-Temporal Characteristics of Urbanization Dynamics Using DMSP/OLS Satellite Data," *Remote Sensing of Environment*, Vol. 158, March 1, 2015, pp. 453–464.

Organization of This Report

The remainder of this report is organized as follows. Chapter Two describes our key research questions and hypotheses based on our existing understanding of ISIL governance and economic control. Chapter Three discusses our different remote sensing data sources, along with the economic metrics we develop from these data. Chapter Four analyzes our low-resolution remote sensing data across every city in Iraq and Syria with more than 10,000 inhabitants, focusing on how economic activity changes when ISIL comes to town, when cities are under ISIL control, and when ISIL leaves town. Chapter Five briefly lays out our case study methodology. Chapters Six through Ten discuss ISIL's economic impact on five key cities—Mosul, Raqqah, Ramadi, Deir ez-Zor, and Tikrit. Chapter Eleven concludes the report with implications of this analysis for the counter-ISIL campaign, for efforts to rebuild areas liberated from the Islamic State, and for future research using similar data and methods. Two appendixes provide additional background on our analysis sample and methodology for assessing within-city variation in economic activity.

CHAPTER TWO

The Islamic State's Influence on Local Economies

This chapter lays out our hypotheses for the different pathways through which the Islamic State might affect economic activity in Syria and Iraq. The first section discusses how the group's territorial control and governance over local populated areas affects local economies through direct taxation and regulation, exploitation of natural resources, and indirectly through the use of violence. The second section discusses existing literature related to the time frame for ISIL's economic impact. The third section discusses ISIL's known economic impact on key sectors of local economies in Iraq and Syria, including agriculture, industry, service-sector activity, and public service provision. In the final section, we build on the discussion throughout this chapter to develop testable hypotheses related to the impact that ISIL control and governance have on local economic activity, which we then explore throughout the rest of this report.

Pathways of Islamic State Influence over Local Economies

This section lays out our current understanding of the pathways through which ISIL influences local economies. A key component of ISIL's stated governance strategy is to tightly control lucrative commercial activity within its territory.[1] Unlike most terrorist groups, ISIL does not depend on foreign donations or state sponsorship for its funding.[2] ISIL strategists have publicly stated that such reliance on external sponsorship contributed to the demise of many previous mujahideen jihadist movements.[3] This reliance on internal funding within its territory means that local economies must continue

[1] See, for example, Harleen Gambhir, *ISIS's Global Strategy: A Wargame, Institute for the Study of War*, Middle East Security Report 28, July 2015.

[2] "Testimony of A/S for Terrorist Financing Daniel L. Glaser Before the House Committee on Foreign Affair's [sic] Subcommittee on Terrorism, Nonproliferation, and Trade, and House Committee on Armed Services' Subcommittee on Emerging Threats and Capabilities," U.S. Department of the Treasury, June 9, 2016.

[3] "Analysis of the State of ISI (English Translation)," Combating Terrorism Center at West Point, c. September 2013.

to function regularly for ISIL to extract sufficient resources to fund its combat operations, salary payments, and bureaucracy.

Existing evidence suggests that ISIL tends to focus its attention on a given region's largest economic sectors—which can include oil, natural gas, hydroelectric dams, phosphates, cement production, or agriculture, depending on the location. ISIL's targeting of high-value sectors of the economy is a significant part of its broader strategic plans for the caliphate—namely, to establish financial self-sufficiency. A second focus of ISIL's efforts has been to control food and water resources, with ISIL fighting campaigns to control key dams in Mosul, Tabqah, and Hadithah and key agricultural areas surrounding the Euphrates River valley. The group has often used these resources as a form of population control—by withholding certain water resources or destroying critical infrastructure, it has sought to quell resistance or encourage acquiescence to its rule.[4]

We focus our analysis on three specific causal pathways through which ISIL control affects local economic activity: (1) active regulation and taxation of local economies, (2) direct interventions that take the form of resource extraction or public service provision, and (3) indirect economic effects as a result of violence.

Pathway One: Active Regulation, Taxation, and Extortion of Existing Economic Activity

Efforts by the Islamic State to tax, extort, and regulate private-sector businesses and local populations raise roughly $350 million annually, according to U.S. Treasury estimates from June 2016.[5] ISIL and its predecessor groups al-Qaeda in Iraq (AQI) and Islamic State of Iraq (ISI) have long relied on state-like taxation, including road tolls, import taxes, and direct taxation of the population, as a means of revenue raising, according to prior RAND research into the group's finances.[6]

After ISIL takes control over a city or village, the group quickly establishes legal and police apparatuses that levy taxes, fines, and other fees on different sectors of the economy, based on its strict interpretation of sharia law.[7] The *hisbah*, or morality police, are responsible for collecting many local taxes, some of which return to ISIL's

---

[4] For discussion of ISIL's use of "water as a weapon," see Isabel Coles, " Islamic State Militants Use Water as Weapon in Western Iraq," Reuters, June 3, 2015.

[5] See "Testimony of A/S for Terrorist Financing Daniel L. Glaser Before the House Committee," 2016, and Torbati, 2016.

[6] Patrick B. Johnston, Jacob N. Shapiro, Howard Shatz, Benjamin Bahney, Danielle F. Jung, Patrick Ryan, and Jonathan Wallace, *Foundations of the Islamic State: Management, Money, and Terror in Iraq, 2005–2010*, Santa Monica, Calif.: RAND Corporation, RR-1192-DARPA, 2016.

[7] Aaron Y. Zelin, *The Islamic State's Territorial Methodology*, Washington Institute for Near East Policy, Research Note 29, January 2016.

central treasuries (Bayt al-Mal) in Raqqah and Mosul.[8] Taxes have been levied against agriculture, on salary payments to former GoI employees, on goods shipped through ISIL-held territory, on market stalls, and on oil sales.[9] In some cases, ISIL has publicly released so-called "city charters," legitimizing the group's seizure of former government assets in the city, including buildings, land, and other property.[10]

The group often couches these tax payments under the traditional Islamic concept of *zakat*, or almsgiving, required of all Muslims as a form of charity.[11] But many of these taxes also take the form of social regulation—levying fees against people for smoking cigarettes, driving on the wrong side of the road, wearing clothes that are too tight or too long, not having a fully grown beard, or not wearing socks.[12] ISIL also charges non-Muslims a fee, or *jizya*, for not converting to Islam.[13] Together, these revenues are ISIL's primary current means of self-financing its war effort.[14] Table 2.1 presents several examples of taxes and fees from across ISIL-held territory in Iraq and Syria in 2016, as reported by *The New York Times*.

---

[8] As caliph, al-Baghdadi has assumed ultimate control of the Islamic State's most-important organizational functions, including the security, intelligence, the Shura Council, the military council, the media and communication apparatus, and religious committees, as well as the Bayt al-Mal finance department (Hassan Abu Hanieh and Muhammad Abu-Rumman, *The "Islamic State" Organization: The Sunni Crisis and the Struggle of Global Jihadism*, Amman, Jordan: Friedrich-Ebert-Stiftung, 2015, pp. 267–269).

[9] Robinson, 2016.

[10] For example, see "City Charter," in Aymenn Jawad al-Tamimi, "Archive of Islamic State Administrative Documents," *Aymenn Jawad al-Tamimi*, January 27, 2015b. An example for Iraq—likely Tikrit—is available via "Charter of the City," in Islamic State of Iraq and al Shām, [New statement from the Islamic State of Iraq and al-Shām: Charter of the city], [Jihadology], June 12, 2014. This charter also laid out guidance for protecting private property.

[11] Aaron Y. Zelin, "The Islamic State of Iraq and Syria Has a Consumer Protection Office," *Atlantic*, June 13, 2014; also see Adam Chodorow, "Even ISIS Needs to Collect Taxes: Could That Threaten Its Rule?" *Slate*, December 7, 2015.

[12] For a detailed discussion of the expanse of ISIL's social taxation schemes, see Sarah Almukhtar, "Life Under the Islamic State: Fines, Taxes and Punishments," *New York Times*, May 26, 2016.

[13] Kelly Phillips Erb, "Islamic State Warns Christians: Convert, Pay Tax, Leave or Die," *Forbes*, July 19, 2014.

[14] See "Testimony of A/S for Terrorist Financing Daniel L. Glaser Before the House Committee," 2016, and "ISIS Yearly Oil Revenue Halved to $250 mln," *Al Arabiya English*, May 11, 2016. As ISIL's control over major cities continues to decline, oil revenues could make up a larger share of the group's overall revenues in the short run while the group still holds territory in Syria's Deir ez-Zor province. In the event of total territorial defeat, ISIL's extortion and taxation revenue could become even more important as the group seeks to covertly exercise its influence over local populations in sympathetic areas formerly part of its caliphate. For more discussion, see Colin P. Clarke, Kimberly Jackson, Patrick B. Johnston, Eric Robinson, and Howard Shatz, *Financial Futures of the Islamic State of Iraq and the Levant: Findings from a RAND Corporation Workshop*, Santa Monica, Calif.: RAND Corporation, CF-361, 2017.

Table 2.1
Islamic State Taxation Rates Within Iraq and Syria, 2016

Type of Tax or Fee	Rate or Percentage	Description
Agriculture	$46	Per irrigated hectare of land per year
	10%	Percentage of the physical wheat crop produced
	10%	Percentage of the amount for which the crops sold at the local market
Social regulation	$30	Per woman not wearing socks or gloves
	$23	Per woman with a pack of cigarettes
	$10	Per woman who shows her eyes
	$25	Per person smoking a cigarette in Raqqah
	$50	Per person installing a satellite dish in Raqqah
Jizya tax on non-Sunnis	$2,500	Certificate for Shiite or non-Muslim; maximum cost for quarterly certificate
Population control	$800	Fee to leave the city in Raqqah
Public services	$43	Official Islamic State license plate
	$25	Driving on the wrong side of the road

SOURCE: Almukhtar, 2016.

Pathway Two: Direct Interventions in Resource Extraction and Service Provision

The second avenue through which ISIL contributes to and affects local economic activity is via its own resource extraction and public service provision. Early after its conquest of territory, ISIL established a ministry to govern resource extraction, the Diwan al-Rikaz.[15] This ministry has numerous subdivisions, including oil, gas, antiquities, and mining and minerals.[16] At its peak, the group extracted nearly $500 million annually in oil and natural gas products, although, because of coalition airstrikes, these revenues have, at times, declined below revenue from taxation.[17] Other sectors in which ISIL is directly involved include phosphate and cement production, as well as direct control over some agricultural resources. Estimates from 2014 suggest that these nonoil forms of direct natural resource extraction accounted for 27 percent of ISIL's revenue,

[15] Aymenn Jawad al-Tamimi, "The Archivist: Unseen Documents from the Islamic State's Diwan al-Rikaz," *Jihadology*, October 12, 2015e.

[16] ISIL documents show that these subdivisions operate as bureaucracies responsible for such tasks as leasing gas stations, distributing oil and gas to the population, granting permission for the excavation of antiquities, and mundane recordkeeping and report writing at the behest of senior leadership (al-Tamimi, 2015e).

[17] "Remarks by Assistant Secretary for Terrorist Financing Daniel Glaser at Chatham House," U.S. Department of Treasury, February 8, 2016.

although that number has likely changed as a result of coalition pressure on the group's other revenue streams.[18]

The Islamic State is also responsible for direct interventions in the local economy through modest service provision in the areas under its control. This includes water supply, sanitation services, sales of oil supplies for fuel generators and automobiles, and local hospital care.[19] Existing research argues that ISIL employs a mix of coercion and inducement to retain old and recruit new skilled labor whose expertise is necessary for technical aspects of its oil industries, hydroelectric dams, and ISIL-controlled hospitals.[20] In and around Raqqah, for instance, former municipal workers later paid by the Islamic State–staffed hydroelectric power generation facilities at the Tabqah, Ba'ath, and Tishreen Dams.[21]

Pathway Three: Indirect Economic Effects of Violence

The group has also affected local economies through combat operations and changes in control between ISIL and the myriad other armed actors involved in the conflicts in Iraq and Syria. The most significant of these impacts has been on refugee flows out of areas affected by violence linked to the Islamic State. The ongoing war in Syria has displaced 11 million Syrians, and, in Iraq, ISIL's advance in 2014 produced an estimated 2.5 million internally displaced persons (IDPs).[22] Combined, these population movements reduce the supply of labor in areas affected by the Islamic State (and other armed groups) and similarly reduce overall demand for goods and services in these areas.

For those remaining inside or in proximity to ISIL-held territory, violence led to price inflation and supply concerns as well. For instance, the United Nations (UN) World Food Programme (WFP) reported in March 2015 that fighting had disrupted supply lines throughout Anbar, Salah ad-Din, and Kirkuk provinces, greatly inflating

---

[18] Jean-Charles Brisard and Damien Martinez, "Islamic State: The Economy-Based Terrorist Funding," Thomson Reuters Accelus, October 2014, p. 9.

[19] For examples of ISIL's provision of water resources and subsequent taxation of these services, see Christiaan Triebert, "Keeping the Water Running in the Islamic State," *Bellingcat*, April 14, 2016. For discussion of ISIL's sanitation services in Mosul, see Daniel Greenfield, "New Islamic Caliphate Leads to Piles of Garbage and Hepatitis," *Frontpage Mag*, December 27, 2014. For examples of ISIL's control over local hospitals, see Jenna Lefler, "Life Under ISIS in Mosul," Institute for the Study of War, July 28, 2014.

[20] See various ISIL administrative documents in the collections on Aymenn Jawad al-Tamimi's website: al-Tamimi, 2015b; also see Aymenn Jawad al-Tamimi, "Archive of Islamic State Administrative Documents (cont.)," *Aymenn Jawad al-Tamimi*, January 11, 2016.

[21] Umar Farooq, "Raqqa: 'It Is a Very Sad Life Under ISIL,'" *Al Jazeera*, January 28, 2015.

[22] Shelly Culbertson and Louay Constant, *Education of Syrian Refugee Children: Managing the Crisis in Turkey, Lebanon, and Jordan*, Santa Monica, Calif.: RAND Corporation, RR-859-CMEPP, 2015. Also see Sibel Kulaksiz and Omer Karasapan, "Iraq's Internally Displaced Populations and External Refugees: A Soft Landing Is a Requisite for Us All," Brookings Institution, April 2, 2015.

food prices in these areas.[23] In Ramadi, active fighting between the Islamic State and GoI forces in late 2015 led to significant supply shortages,[24] despite only modest evidence of price inflation throughout Anbar province earlier in the war.[25] Following a similar pattern, food prices in Salah ad-Din province skyrocketed in 2015 as fighting throughout the province disrupted supply lines.[26] And in an extreme example, in Deir ez-Zor, ISIL's siege of the city center and the destruction of a key bridge and supply line across the Euphrates in the northern part of the city created a humanitarian crisis in parts of the city with basic supplies unable to reach the city's markets.[27]

Time Frame of the Islamic State's Economic Impact

Having established the various mechanisms through which we expect ISIL to affect local economic activity, this section briefly discusses the time frame for these impacts relative to when ISIL takes control of an area. This is important for understanding whether significant changes in economic activity before and after ISIL are a result of significant short-term disruptions due to fighting or of longer-term impacts to local economies due to ineffective ISIL governance.

Existing evidence suggests that the process by which the group cements its control over a given area could lead to major short-term disruptions. ISIL's method of establishing and consolidating control over cities in Iraq and Syria tends to follow a common pattern of coercion and violence. The initial step involves intense violence, in which ISIL fights pitched battles and conducts unconventional operations to assassinate local rivals and intimidate the population.[28] This violence has less to do with establishing a well-functioning city economy than with suppressing potential resistance. After this initial phase, however, ISIL largely seeks to transition from this violence toward more-traditional forms of governance and bureaucratic control. One of the more-compelling documents captured from the Islamic State to date lays out the group's strategy in governing areas it eventually conquers.[29] In this document, titled "Principles in the administration of the Islamic State," the group states that its role is to be an arbiter of sharia law governing a market economy. The majority of its funds are to come from taxing

---

[23] WFP, "Iraq: Food Market Monitoring," Bulletin 3, March 2015a.

[24] Elisabeth Koek and Becky Bakr Abdulla, "Civilians Trapped Inside Ramadi as Fighting Continues," Norwegian Refugee Council, January 14, 2016.

[25] WFP, "Flash Update: Iraq—Anbar," March 2016c.

[26] WFP, 2015a.

[27] UN News Centre, "UN Food Aid Reaches Besieged Syrian City of Deir Ezzor by Air," April 10, 2016.

[28] Zelin, 2016.

[29] See Chapter Seven in "Principles in the administration of the Islamic State," in "The ISIS Papers," 2015.

local commercial sectors, and the state is to have direct control only over strategic sectors, such as oil and gold. In other words, ISIL seeks to use its monopoly over violence, gained in the disruptive initial stages of its control over an area, to act as a guarantor of stability in a healthy market economy subject to sharia law.

This resembles Mancur Olson's concept of the modern territorial state as a "stationary bandit"—that is, an entity that promotes economic growth *and* political consolidation within its territory by providing order and property rights in exchange for tax revenue.[30] Although ISIL's heavy-handed regulation of the economy introduces different transaction costs and inefficiencies, it might be the least-bad option in poorly governed, war-ravaged areas. Some media reporting citing interviews with Syrian businessmen in Raqqah in June 2015 has argued that ISIL's brutality actually promotes a stable regulatory climate conducive to economic activity, particularly compared with the alternative of competing rebel groups vying for control.[31]

Sector-Specific Impacts

This section surveys existing evidence of ISIL's economic impact on different portions of local economies across Iraq and Syria. It provides broad evidence of the group's impact on key economic sectors, including agriculture, market activity, and industrial activity; on key infrastructure, including electricity supply and overall building stocks; and population movements that could affect consumer demand and labor supply. We include further information on city-specific evidence of ISIL's economic impact later in this report, where we provide case studies exploring ISIL's impact in five key cities: Mosul, Raqqah, Ramadi, Deir ez-Zor, and Tikrit.

Agriculture

The Food and Agriculture Organization of the UN (FAO) estimated in 2015 that ISIL controlled nearly 40 percent of all Syrian wheat production.[32] ISIL has been able to profit via exporting wheat products grown within its territory to Syrian regime–held locations on the western coast of Syria, confiscating portions of each truckload in exchange for ensuring safe passage.[33] In Iraq, ISIL-held areas were responsible for roughly 33 percent of Iraq's wheat production and nearly 40 percent of barley produc-

[30] Mancur Olson, *Power and Prosperity: Outgrowing Communist and Capitalist Dictatorships*, New York: Basic Books, 2000.

[31] Sherlock, 2015.

[32] Annia Ciezadlo, "The Most Unconventional Weapon in Syria: Wheat," *Washington Post*, December 18, 2015.

[33] "Wheat Diplomacy Between the Syrian Regime and the ISIS," Syrian Economic Forum (translation of *al Jazeera* original in Arabic), March 13, 2015.

tion as of late 2014.[34] After ISIL captured portions of northern Iraq in 2014, it also confiscated nearly 25 percent of national wheat and barley stockpiles from government-owned grain silos.[35]

Estimates of crop production in ISIL-held areas suggest that crop yields have fallen under ISIL control, whether because of damage from fighting;[36] lack of access to centrally subsidized seeds, fertilizer, and agricultural equipment in Iraq;[37] or lack of access to formerly government-sponsored markets.[38] Recent estimates from the National Aeronautics and Space Administration (NASA) and the U.S. Department of Agriculture using satellite imagery note that crops in ISIL-held areas of northern Iraq were significantly less healthy than those in neighboring Kurdish areas.[39] Soon after ISIL's conquest over portions of Iraq, concerns were also raised that refugee flows would affect the supply of farm labor.[40] ISIL's control over major dams along the Euphrates River likely had adverse effects on the water available for irrigation throughout the Euphrates River valley in Syria, western Iraq, and even downstream rice production in largely Shia areas of Iraq south of Baghdad.[41] Across Iraq and Syria, the group also instituted a series of taxes on agricultural inputs and outputs that placed further strain on struggling farmers.[42]

In perhaps the most comprehensive assessment of ISIL's impact on agriculture to date, Jaafar and Woertz report moderately sized effects of ISIL control on agricultural output in Syria but not for Iraq.[43] The authors argue that ISIL did not have a larger

---

[34] "Iraqi Farmers Suffer as Land Seized by Militants," *IRIN*, November 26, 2014.

[35] "Iraqi Farmers Suffer as Land Seized by Militants," 2014.

[36] UN Development Programme (UNDP) in the Arab States, "Resilient Youth in Deir Ezzor Are the Arm for Positive Change," undated.

[37] Maggie Fick, "Special Report: For Islamic State, Wheat Season Sows Seeds of Discontent," Reuters, January 20, 2015.

[38] Fick, 2015.

[39] Fick, 2015.

[40] Maggie Fick, "ISIS Now Controls 40 Percent of Iraq's Wheat Crop," *Fiscal Times*, September 30, 2014a.

[41] ISIL's mismanagement of the Tabqah Dam west of Raqqah led to dangerously low water levels in Lake Assad, which provides irrigation for large tracts of agricultural land around Raqqah and safe drinking water for locals. See Nouar Shamout, "Syria Faces an Imminent Food and Water Crisis," Chatham House, June 24, 2014. In Iraq, ISIL's closure of all but two sluice gates along the Euphrates in Ramadi in 2015 threatened significant water shortages downstream in Anbar and in Iraq's Shia-predominant areas south of Baghdad. See "ISIL Redirect [sic] Water from Ramadi Dam," *World Bulletin*, June 3, 2015. On the declines in Iraqi rice production, see Foreign Agricultural Service, U.S. Department of Agriculture, "Iraq: 2015 Rice Production Drops by More Than Half Due to Lack of Irrigation," *Commodity Intelligence Report*, August 12, 2015b.

[42] Omar al-Jaffal, "Fighting Robs Iraqi Farmers of Harvest," *Al-Monitor*, September 26, 2014.

[43] Hadi H. Jaafar and Eckart Woertz, "Agriculture as a Funding Source of ISIS: A GIS and Remote Sensing Analysis," *Food Policy*, Vol. 64, October 2016, pp. 14–25.

impact because of improved rainfall in 2015 and because ISIL is taxing agriculture for revenue purposes.[44]

Market and Commercial Activity

ISIL has placed specific emphasis on maintaining stable market conditions, hoping to preserve functioning local economies while profiting from these markets via taxing market stalls and commercial transactions. The group's propaganda arm has shown sensitivity toward the perception that markets in its territory remain bustling and active and, in one example, published brochures that show off allegedly prosperous market stalls in Mosul following its takeover of the city.[45] Despite these efforts, market transactions in ISIL-held areas have been subject to significant price inflation, supply shocks, and steady taxation by the group itself.

Price inflation of basic goods is a persistent challenge for populations living under ISIL control as a result of instability-related supply shortages. As examples, in Mosul, prices began to rise rapidly when stocks of basic commodities and food supplies dwindled and ISIL was unable to replace these supplies.[46] Early in ISIL's control of Raqqah, massive bread shortages and food price inflation led to predatory behavior on the part of some merchants.[47] Price shocks have continued over the course of ISIL's tenure, leading to anecdotal evidence of increases in remittance payments into the region to support civilian purchases of staple products, such as sugar and gasoline.[48] In several cases, food prices would fall after the GoI liberated an area from ISIL.[49]

ISIL also regularly intercedes directly in markets under its control. Early reports from June 2014 in Mosul suggested that the group had forbidden price-gouging in the city's markets by closely monitoring local sellers.[50] In other areas, the group was responsible for directly ensuring the security of goods flowing in and out of local mar-

---

[44] Jaafar and Woertz, 2016. Note that we cannot directly compare our estimates with those in Jaafar and Woertz, 2016, because these authors use the Enhanced Vegetation Index, while we study the Normalized Difference Vegetation Index (NDVI), a different measure.

[45] John Hall, "Wish You Were Here? ISIS Releases Tourist Brochure–Style Images of Bustling Food Markets in Jihadi Stronghold of Mosul," *Daily Mail*, March 4, 2015.

[46] Deborah Amos, "Under ISIS, Life in Mosul Takes a Turn for the Bleak," National Public Radio, March 21, 2015.

[47] "Bread Lines in A-Raqqa Reflect Endemic Shortages," *Syria Direct*, August 26, 2014.

[48] "Islamic State 'Hit by Cash Crisis in Its Capital Raqqa,'" *Telegraph*, February 16, 2016.

[49] WFP, "Iraq: Concerns over Rising Food Prices in Fallujah and Increasing Food Insecurity in Ninewa," Bulletin 17, April 2016d.

[50] Borzou Daragahi and Erika Solomon, "Fuel Shortages and Power Cuts Dominate Isis-Controlled Mosul," *Financial Times*, June 19, 2014.

kets.[51] For instance, in late 2014, ISIL helped facilitate cross-border trade in fruits, vegetables, wheat, and textiles between its capitals in Mosul and Raqqah.[52] The group's own fighters inject significant amounts of cash into local markets as well.[53] ISIL tightly regulates commercial transactions by setting up its own money exchange shops and informal banking networks to more closely regulate merchants.[54] Taxes on market transactions are as high as 10 percent of the total value of the transaction,[55] and the group has charged roughly $2,500 annually for any local merchant who wants to rent a market stall in Mosul's central Bab al-Toob market.[56] Combined, ISIL's direct interventions into local markets have had an unknown mitigating impact on the price and supply concerns caused by fighting and destruction of supply lines and commodities.

Electricity

ISIL's impact on access to electricity in areas that it controls has been particularly dramatic. In Iraq, where electricity is provided largely through a national power grid controlled centrally from Baghdad, the GoI has used this control to cut off access to the national grid in provinces with significant ISIL presence. The impact of ISIL's blitzkrieg advance into Anbar, Ninewa, and Salah ad-Din provinces in June 2014 can be seen clearly in Figure 2.1, which plots electricity supplied to these three provinces across the GoI-controlled power grid from August 2013 through February 2015.

In order to make up for limited power supply over the electrical grid, ISIL has sought to exploit its direct access to oil fields in Iraq and Syria by selling fuel for electrical generators that provide backup power for cities it controls. In Ramadi, the group originally sold fuel to locals to power larger neighborhood generators, but, because of fuel shortages in mid-2015, supply declined to provide only enough fuel for one or two hours of generator production per day.[57] In Mosul, the price for some fuel products increased more than tenfold under ISIL control,[58] with former residents, turned refu-

---

[51] Enab Baladi, "Variance in Control Divide Der Ezzor into Three Commercial Markets," *Enab Baladi English*, Printed Ed. 17, April 17, 2016.

[52] "Higher Prices, Shortages Create Resentment Against Islamic State in Iraq," *Japan Times*, December 13, 2014.

[53] "Higher Prices," 2014.

[54] "How ISIS Rigs Mosul's Money Markets," *Iraq-Business News*, March 19, 2016.

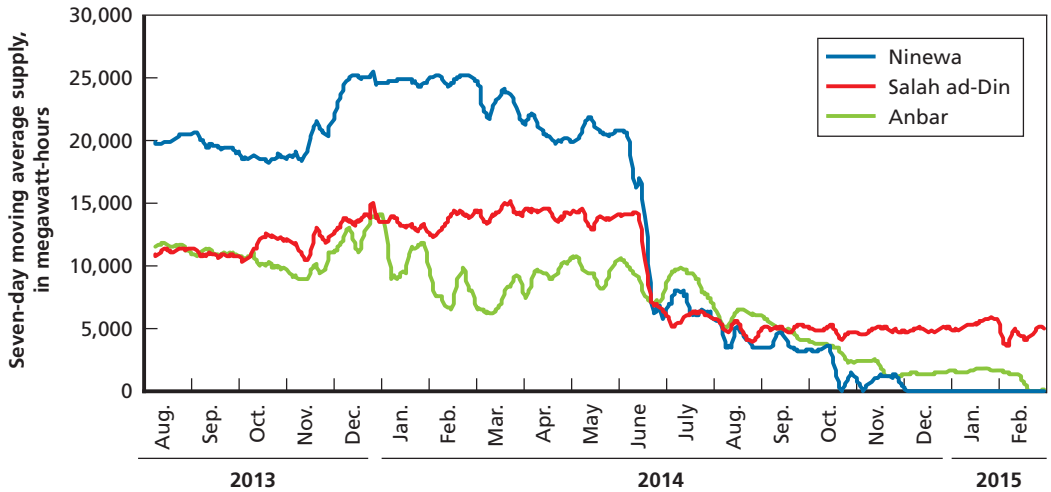
[55] Almukhtar, 2016.

[56] Matthew Rosenberg, Nicholas Kulish, and Steven Lee Myers, "Predatory Islamic State Wrings Money from Those It Rules," *New York Times*, November 29, 2015.

[57] Ahmed Rasheed, "As Forces Close in on Ramadi, ISIS Uses Thousands of Civilians as Human Shields," *Huffington Post*, December 9, 2015.

[58] Molly Hennessy-Fiske and Nabih Bulos, "Under Islamic State, Life in Mosul, Iraq, Turns Grim," *Los Angeles Times*, January 26, 2015.

Figure 2.1
Power Supply in Provinces Affected by Islamic State Control, 2013–2015



SOURCE: Andrew Shaver and D. Ensign, "Lights Off in the Islamic State: What Electricity Tells Us About ISIS' Rule," *Foreign Affairs*, 2015.

RAND *RR1970-2.1*

gees, noting that public electricity provided only half an hour of power per day beyond that provided by backup generators.[59]

In Syria, unlike in Iraq, power is not centrally controlled. Instead, most ISIL-held areas rely heavily on hydroelectric plants at key dams along the Euphrates River.[60] Contestation of these dams has led to significant reductions in access to electricity.[61] As an example, reports from August 2015 suggested that residents of Raqqah had access to only two to four hours of electricity per day despite their reliance on hydroelectric generation facilities fully controlled by ISIL.[62] In many areas, including the oil-rich Deir ez-Zor, private civilians sought to run their own generators after purchasing fuel on the open market (including from ISIL) and sell power throughout their neighborhoods for a profit. Concerned about its lack of control of this resource, ISIL levied significant taxes on the owners of these generators for permission to operate and largely

[59] Mohammed A. Salih, "Mosul Under ISIL: 'No Internet, No Shaving,'" *Al Jazeera*, March 29, 2015.

[60] Jamie Ingram, "Islamic State's Inadequate Service Provision Undermines Its Authority over Strategically Important Energy Assets in Syria and Iraq," *IHS Jane's Intelligence Review*, August 11, 2015.

[61] The Tabqah Dam, for instance, provides roughly 19 percent of Syria's entire electrical power, but broader electricity shortages throughout ISIL-held areas in Syria forced the group to operate this facility at breakneck pace throughout 2014. This resulted in radical declines in water levels in the dam's reservoir, known as Lake Assad, which only worsened the dam's ability to continue to generate electricity. See Shamout, 2014, and Danya Chudacoff, "'Water War' Threatens Syria Lifeline," *Al Jazeera*, July 7, 2014.

[62] Ingram, 2015.

priced out consumers from purchasing generator-provided electricity not from ISIL's own generators.[63]

Industrial Activity

ISIL has taken direct control over a variety of industrial facilities throughout its territory, particularly those involved in phosphate, cement, and sulfur processing. The group has taken an active role in managing these facilities, including by swapping out significant portions of the preexisting workforce for ISIL loyalists and by moving (or considering moving) some manufacturing capacity out of contested areas and into more–solidly held ISIL areas as Iraqi forces advanced on Mosul.[64] Some of these facilities represent a significant portion of the local workforce not involved in agriculture or service-sector occupations.

The group's interventions into factories and industrial facilities are perhaps most concentrated in the cement industry, in which ISIL has controlled at least three cement factories in the vicinity of Mosul and two others in Syria, with potential production capacity in the hundreds of millions of dollars.[65] ISIL is also known to control a major phosphate facility in al-Qaim, Iraq, which produces phosphate materials used in agriculture along the Euphrates and for some industrial chemicals.[66] Another facility near Rutbah, the Akashat phosphate mine, might have produced annual revenues of $50 million for the group as of 2014.[67]

Critical and Residential Infrastructure

One consequence of combat operations involving the Islamic State has been significant damage to commercial and residential building infrastructure in cities contested by the group. Particularly in Iraq, the group's retreat from certain cities has led to significantly more damage to local infrastructure than during its initial takeover in 2014, in which the group faced little local resistance in many areas. Although ISIL prioritizes violence and coercion early in its efforts to take over a city and its key infrastructure, the group appears more willing to destroy that key infrastructure when its prospects for no longer controlling it are imminent.

As an example, ISIL booby-trapped significant portions of Ramadi in late 2015 with rudimentary improvised explosive devices (IEDs) in advance of the GoI's recon-

---

[63] "ISIS Steals Money from Civilians Living Under Its Control in Deir Ezzor on the Pretext of Providing Services," *Deir Ezzor 24*, March 1, 2016.

[64] Mohammad Moslawi, Fazel Hawramy, and Luke Harding, "Citizens of Mosul Endure Economic Collapse and Repression Under ISIS Rule," *Guardian*, October 27, 2014; "ISIS Moving Mosul Cement Factories to Syria," *Rudaw*, March 24, 2015.

[65] "ISIS Moving Mosul Cement Factories to Syria," 2015.

[66] "Iraq Says ISIS Transferring Phosphate to Syria's Raqqa," *Al Arabiya English*, December 1, 2014.

[67] Brisard and Martinez, 2014.

quest of the city and left only a portion of its former fighting force to trap and ambush GoI forces on their way into the city.[68] This form of tactical retreat was relatively commonplace throughout the string of early territorial losses imposed on the group in Tikrit, Fallujah, Sinjar, and even Palmyra in Syria and often led to heavy damage to local buildings and key infrastructure as rebel or government forces reestablish control over each city on a neighborhood-by-neighborhood basis. The campaign to liberate Mosul in 2016 and 2017 brought even higher levels of damage to the city, but this damage was more a product of ISIL's active resistance rather than intentional sabotage as part of a tactical retreat.

A second leading cause of damage to commercial and residential infrastructure has been coalition air strikes or shelling from other opposition forces. No example is more striking than in Kobani, in northern Syria, where a sustained air campaign in support of Kurdish fighters defending the city from ISIL's advance largely leveled the city in 2015. But even in Mosul, which has remained under ISIL's control since its capture, coalition air strikes against ISIL's cash storage locations in early 2016 damaged a series of ISIL-held banks in dense urban population centers.[69] Damage (of unknown origin) to a key industrial facility in Mosul is clearly visible in satellite imagery of the city from July 2016. This same facility was largely undamaged as of the first few weeks post-ISIL takeover, shown in Figure 2.2.

Little systematic evidence exists to suggest that ISIL has prioritized routine construction or reconstruction activity in areas that it controls. In fact, in Ramadi, the group banned imports of Iranian goods and their sale in local markets, including construction equipment and supplies.[70] In some limited cases, the group has shown a willingness to invest in reconstruction of more-lucrative industrial facilities—namely, in recruiting oil engineers to advise its Deir ez-Zor oil-field operations[71] and briefly inviting engineers to examine the Mosul Dam in August 2014.[72]

---

[68] Stephen Kalin, "U.S. Firm to De-Mine Iraqi City of Ramadi Retaken from Islamic State," Reuters, April 4, 2016b.

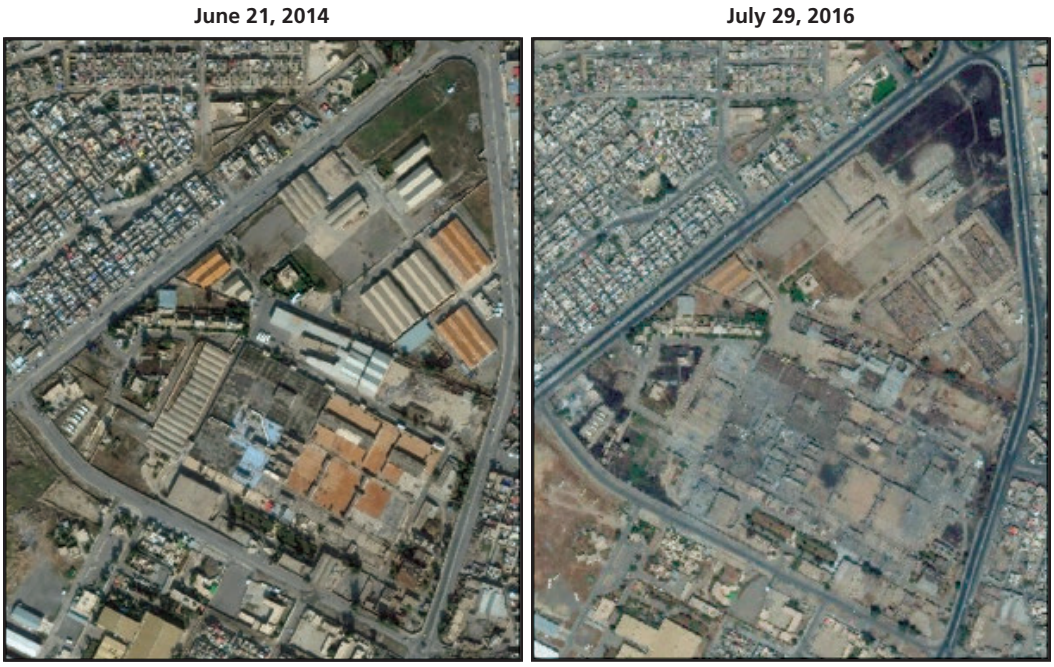
[69] Jeremy Bender, "Watch Coalition Airstrikes Obliterate 2 ISIS Financial-Storage Centers Holding Hundreds of Millions of Dollars," *Business Insider*, February 18, 2016.

[70] "ISIL Bans Iranian Goods in Ramadi Markets," Centre for a Democratic Iran, June 8, 2015.

[71] Erika Solomon, Guy Chazan, and Sam Jones, "Isis Inc: How Oil Fuels the Jihadi Terrorists," *Financial Times*, October 14, 2015.

[72] Michael Georgy, "Islamist Rebels Repairing Mosul Dam, Kurds in Rush to Arms," Reuters, August 9, 2014.

Figure 2.2
Damage to an Industrial Area in Mosul



SOURCE: Digital Globe, 2016.
RAND *RR1970-2.2*

Population Movements

ISIL has displaced millions of Syrians and Iraqis.[73] In Syria, the group has contributed heavily to the displacement of more than 11 million Syrians through civil conflict since 2011.[74] But in many areas within Syria, ISIL wrested control of its territory from other opposition groups already in the throes of active conflict with the Assad regime. For instance, ISIL claimed its capital Raqqah after co-opting local Free Syrian Army (FSA) and Jabhat al-Nusra (JN) militias and forcing their exit from the city in October 2013. These groups had been fighting Syrian regime forces for many months before the Islamic State claimed control over Raqqah and began to lay its roots. Many people across Syria had already been displaced before ISIL's territorial grabs in 2013 and 2014.

In Iraq, ISIL's advances into northern Iraq in 2014 produced an estimated 2.5 million IDPs, many of whom were prior refugees from Syria.[75] The majority of IDP flows

[73] The depth of conflict throughout Iraq and Syria has led to a brain drain, according to some analysts: Many educated professionals with the funds to do so fled the region early on in the conflict. See Gidda, Mirren, "ISIS Is Facing a Cash Crunch in the Caliphate," *Newsweek*, September 23, 2015.

[74] Culbertson and Constant, 2015.

[75] Kulaksiz and Karasapan, 2015.

in Iraq appeared to occur immediately before ISIL's arrival in key cities; an estimated 500,000 Iraqis left Mosul in the week before ISIL's conquest of the city.

Once in control of an area, ISIL often enforces strict population-control measures designed to prevent out-migration from urban areas. In Ramadi, ISIL threatened to kill civilians who tried to leave in advance of the GoI's advances on the city in late 2015.[76] Some reports suggest that, in Mosul, residents seeking to leave the city could do so for only two weeks at a time and needed to submit the title to their family homes or cars as collateral.[77] Some locals in Mosul attempted to escape ISIL's rule in small numbers through expensive and dangerous smuggling routes, although the group clamped down most personal travel from the city in late 2015.[78] Even in Raqqah, in March 2016, ISIL banned remaining Christian and Armenian families from leaving the city, according to representatives from the advocacy group Raqqah Is Being Slaughtered Silently.[79]

Following ISIL's defeat in a given city, the main obstacles to the return of IDPs have been lack of access to basic resources, such as water and electricity, the presence of explosive remnants of war, and physical destruction of residential buildings and other infrastructure. In Tikrit, the lingering presence of Shia militias that assisted in the recapture of the city from ISIL forces in 2015 raised concerns among Sunni residents seeking to return to the city.[80] By most estimates, the rate of repopulation of formerly ISIL-held areas has been slow at best.

Hypotheses

The prior sections detailed the causal pathways through which ISIL affects local economies under its control—including through taxation and extortion, direct resource extraction and public service provision, and the indirect effects of violence. They also presented broad evidence of ISIL's economic impact in key sectors of local economies across Iraq and Syria. This section builds on this discussion and lays out several basic hypotheses, which address our underlying research questions and drive the empirical analysis presented throughout the rest of the report.

---

[76] Matt Bradley and Ben Kesling, "Islamic State Prevents Civilians from Fleeing Iraqi City of Ramadi," *Wall Street Journal*, December 1, 2015.

[77] Sinan Salaheddin, "Islamic State Introduces New Restrictions to Prevent Mosul Residents from Fleeing City," *Globe and Mail*, March 13, 2015.

[78] Loveday Morris, "One Man's Escape from the Islamic State–Ruled City of Mosul," *Washington Post*, October 17, 2015b.

[79] Lizzie Dearden, "Isis 'Bans All Christians from Leaving Raqqa' as Military Operations Against Group Intensify in Syria," *Independent*, March 31, 2016.

[80] Yaroslav Trofimov, "Slowly, Post-ISIS Tikrit Regains Normalcy," *Wall Street Journal*, April 7, 2016.

Our first research question asked, *what impact does ISIL territorial control have on the distribution of different types of existing economic activity?* Given ISIL's dual economic mandate to extract revenue from local economies under its control while maintaining stable economic conditions in order to build a long-term caliphate, we should expect more-profitable forms of economic activity to outperform less profitable ones. In a resource-constrained environment, a strategic actor would increase public service provision and minimize violence directed to more-profitable ventures while taking a negative or agnostic view toward less profitable components of local economies. If ISIL is a strategic actor, we should see it devote higher amounts of electrical service provision and lower amounts of violence toward more-profitable infrastructure or sectors within cities. We should also see types of economic activity more directly under its control, such as industrial and market activity, outperform sectors more loosely subject to ISIL's influence and rent-gathering, such as agriculture or public services, including hospitals and sanitation.

- ***Hypothesis 1:*** *Following the establishment of ISIL control, types of economic activity that are directly controlled by ISIL or more critical to the group's revenues will outperform other parts of the local economy.*

Our second research question asked, *how does ISIL's economic impact evolve after takeover?* Existing evidence suggests that ISIL established its control over a given area through a brief period of intense coercion and violence meant to suppress resistance, followed by efforts to establish stable governance and modest property rights in exchange for sustainable revenues from taxing local populations. This is in line with evidence of significant short-term disruptions caused by the group, particularly in Iraq, when thousands of refugees fled areas prior to the group's takeover of Mosul in June 2014, as well as the swift GoI effort to cut off access to the national electrical grid following ISIL's invasion from Syria. Existing data offer little evidence of major returns to normalcy after ISIL establishes control. Therefore, we hypothesize the following:

- ***Hypothesis 2:*** *Local economic activity will decline rapidly in the short term after ISIL takeover and will fail to return to pre-ISIL levels even if the group establishes sustained periods of control over cities.*

Our final research question asks, *how does ISIL's economic impact differ across different areas within the same cities*? High-resolution remote sensing data allow us to measure economic activity with a remarkable level of granularity. As a result, we can measure how economic activity varies inside cities under ISIL control—across neighborhoods of different ethnicities; across areas controlled by ISIL versus those controlled by regime or opposition forces in contested cities; and near key economic infrastructure, such as factories, markets, and hospitals.

Given the massive rates with which non-Sunni populations fled ISIL in Iraq, as well as modest evidence of restrictions against non-Sunni population movements in Raqqah and the imposition of special *jizya* taxes on non-Muslim populations for not converting to Islam, we first hypothesize the following, within cities:

- ***Hypothesis 3.1:*** *Economic activity in non-Sunni areas of cities will significantly underperform that in Sunni-majority areas.*

Next, given the significant destruction wrought by fighting to retake areas held by ISIL forces and the possibility that ISIL control could bring some regulatory certainty to otherwise contested or ungoverned parts of Syria, we hypothesize the following, within cities:

- ***Hypothesis 3.2:*** *Economic activity in contested portions of cities will underperform that in areas unilaterally held by ISIL forces.*

CHAPTER THREE

Measuring Economic Activity Using Satellite Imagery

This report relies on data generated from satellite imagery to measure economic activity in Iraq and Syria over time. Satellite-collected data, commonly referred to as remote sensing data, provide systematic and objective information on human activity observable from space. This includes economic activity observable with the human eye, such as foot traffic at commercial markets or vehicles on main roads, as well as economic activity requiring highly specialized optical sensors, such as photosynthetic activity or thermal output.

Remote sensing data are of particular value for the study of ISIL and other similar nonstate violent actors because their presence does not affect our ability to gather such data safely. Additionally, unlike other data that require on-the-ground collection, ISIL's brutal influence over the local population will not bias our ability to gain objective insights into local conditions. Data are collected free from potential intimidation of survey respondents or interview subjects. As a result, remote sensing and satellite imagery data have become increasingly popular in both media reporting and empirical research.

We use two different types of remote sensing data in our analysis of ISIL and the local economies of Iraq and Syria, presented in Table 3.1. The first type of remote sensing data comes from *publicly available satellite data*, which are typically collected and made available by U.S. government agencies, such as the National Oceanic and Atmospheric Administration (NOAA) or NASA. These data have the advantage of being well studied in technical literature and systematically available across all parts of Iraq and Syria at regular time intervals. They are often collected at low or moderate resolution. We use these data to estimate four different indicators of economic activity: industrial activity, agricultural activity, population levels, and electrification.

The second type of remote sensing data used in this study is *commercially available satellite imagery*. Commercially available imagery typically provide much more granular insights into an area than publicly available remote sensing data do. One example is vehicle traffic. Although publicly available remote sensing data lack the granularity to detect vehicles, commercial satellite imagery data can be used to count the number

Table 3.1
Remote Sensing Data and Measures of Economic Activity

Type	Metric	Economic Outcome	Data Source	Frequency	Spatial Coverage
Publicly available satellite data	Nighttime lighting	Electricity consumption	NOAA VIIRS	Monthly	All cities
	Population levels	Internal migration	ORNL LandScan	Quarterly	
	NDVI	Agricultural activity	USGS Landsat	Every 16 days	
	Thermal	Industrial activity	USGS Landsat	Every 16 days	
Commercial imagery data	Market activity	Commercial activity	DigitalGlobe Tomnod	Intermittent	Mosul, Raqqah, Deir ez-Zor, Ramadi, Tikrit
	Damage and destruction	Infrastructure and building stock	DigitalGlobe Tomnod	Intermittent	
	Vehicle counts	Commercial activity	DigitalGlobe Tomnod and GBDX	Intermittent	

NOTE: VIIRS = Visible Infrared Imaging Radiometer Suite. ORNL = Oak Ridge National Laboratory. USGS = U.S. Geological Survey.

of cars in a business parking lot over time.[1] However, although these commercial data offer much greater precision and level of detail, they are captured at infrequent intervals over time, with fewer images available in remote locations of the world, and can require greater processing power and time to analyze given the amount of information captured in each image. We use these data to estimate three different indicators: market activity, building damage, and commercial vehicle counts. We primarily utilize DigitalGlobe's online crowd-sourcing platform, Tomnod, which brings imagery to an online crowd of volunteers who either identify specific objects within larger images (such as damaged buildings) or provide assessments of activity within a given location (such as intensity of market activity). Our analysis of commercial satellite imagery focuses on five key cities of interest for understanding ISIL's economic impact across Iraq and Syria: Mosul, Raqqah, Ramadi, Deir ez-Zor, and Tikrit.

[1] One advantage of high-resolution imagery over the data described earlier in this section is its level of granularity. Each pixel in an image from USGS Landsat 8 represents a 30-meter–by–30-meter area. Each pixel in the highest-resolution imagery available from DigitalGlobe's WorldView-3 satellite represents a 30-centimeter–by–30-centimeter area. And because DigitalGlobe's most advanced sensors capture the full spectrum of light (similar to the USGS Landsat 8 satellite), advanced object classification algorithms can be used to replicate what the human eye does on a daily basis—take high-resolution imagery and identify discrete objects in that imagery. Object-recognition algorithms can take this process one step further by incorporating information from nonvisible bands of light as well.

In the following sections, we describe each of our indicators of economic activity. We begin by discussing four measures derived from publicly available remote sensing data. We conclude with three measures derived from commercially available satellite imagery.

Electricity Consumption

We measure electricity consumption with data on nighttime lighting, made available by NOAA.[2] These data capture the intensity of light at night for roughly every square kilometer of the earth's surface. Although the data are captured daily, NOAA cleans and publishes nighttime lighting data in annual averages for 1992 to 2013 and in monthly averages for each month since 2014.[3]

These data have become prevalent in recent literature as a proxy to measure changes in local economic activity, as well as country-level gross domestic product (GDP) at higher levels of aggregation.[4] We focus specifically on nighttime lighting as an equilibrium measure of electrification in that it captures both the supply of power resources and demand for electricity. Nighttime lighting should fall as a result of reductions in demand as people and economic activity migrate away from a city under siege. It should also fall as a result of reductions in supply as access to major power generation facilities is restricted in the midst of conflict or ISIL is unable to provide sufficient energy resources or technical capacity to run existing power plants or private generators.

Figure 3.1 plots nighttime lighting in Iraq and Syria, comparing lighting in March 2014 and March 2016. The figure shows significant drops in electrification along the Euphrates River valley from Raqqah toward Baghdad, as well as in the areas south of Mosul in Iraq, since 2014.[5]

---

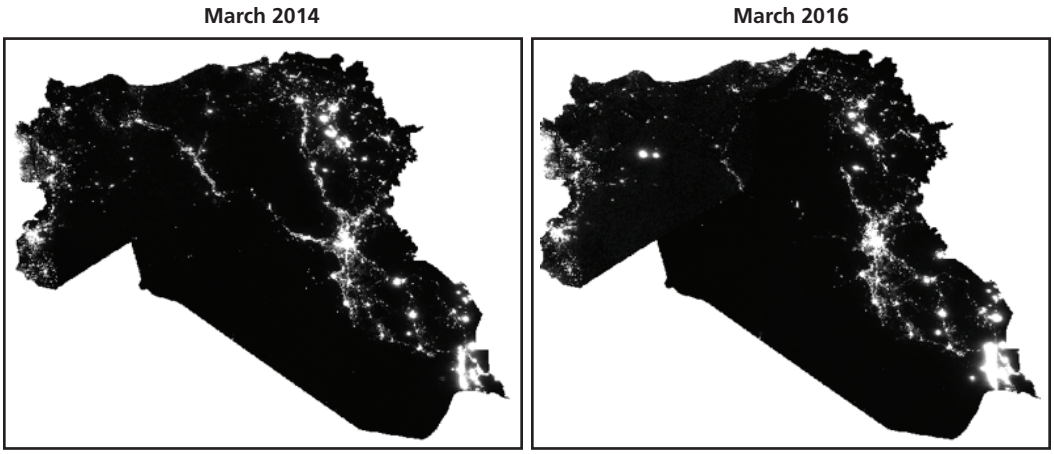
[2] The Defense Meteorological Satellite Program's Operational Linescan System and VIIRS collect nighttime lighting data. The Operational Linescan System includes annual averages for 1992–2013, while VIIRS include monthly averages for each month since 2014. For the purposes of this study, we use solely monthly VIIRS data.

[3] Data are collected for every 30–arc second square of the earth's surface (roughly 0.86 km^2).

[4] J. Vernon Henderson, Adam Storeygard, and David N. Weil, "Measuring Economic Growth from Outer Space," *American Economic Review*, Vol. 102, No. 2, April 2012, pp. 994–1028.

[5] Of note is the fact that we see large spikes in nighttime lighting in the areas around Deir ez-Zor governorate in Syria in March 2016, which correspond to gas flares at oil fields. We exclude these gas flares from our analysis of nighttime lighting so as not to bias our estimates of city-level economic activity. We spent considerable time exploring the utility of using nighttime lighting over known gas flare locations to track oil production over time. However, this approach is of minimal utility for oil fields that do not flare their gas but rather pipeline it, which is particularly prevalent in Syria's oil heartland in Deir ez-Zor governorate. Nonetheless, the approach is worthy of further research. Additionally, we control for the impact of GoI cutoffs in electricity to the national power grid, based on data provided in Shaver and Ensign, 2015.

Figure 3.1
Nighttime Lighting in Iraq and Syria, March 2014 and March 2016



SOURCE: National Oceanic and Atmospheric Administration, Visible Infrared Imaging Radiometer Suite (VIIRS).
RAND *RR1970-3.1*

Population Levels

We use ORNL's LandScan data set to measure *internal migration*. LandScan is a 1 km^2–resolution data set that provides integer population counts for each grid square in the world. These population counts are derived using a proprietary modeling approach developed by the national lab, which integrates known census data for administrative districts with visible changes in infrastructure and population movements measured using satellite imagery.[6] ORNL publishes these data annually in raster image format, and they are available to analysts supporting government-sponsored research. Although similar data sets are available publicly, including the Gridded Population of the World data from NASA's Socioeconomic Data and Applications Center, other such data sources often divide district-level population totals evenly across administrative areas and rely on forecasts of population levels where no new census data exist. LandScan's advantage lies in its ability to more precisely disaggregate district-level population totals across urban and rural areas based on the built-up infrastructure of these locations. Additionally, LandScan can capture temporal variation in population density objectively and frequently, where traditional population data sources, such as censuses, are more infrequently collected.

We leverage quarterly data sets that ORNL produces showing population levels across Iraq and Syria in February 2015, May 2015, November 2015, March 2016, and

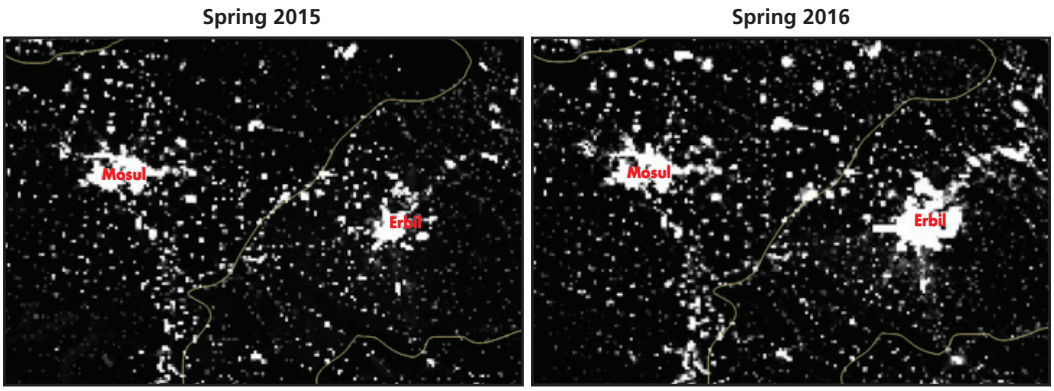
[6] ORNL, "LandScan Documentation," undated.

July 2016, along with 2008 population data as a baseline for pre-ISIL levels.[7] Although this offers a much finer-grained understanding of internal migration within Iraq and Syria than provided by other data sources, it does necessarily limit our ability to understand pre- and post-ISIL population movements in some cities because we lack data for 2013 and 2014.

Figure 3.2 shows LandScan estimates for northern Iraq in the spring of 2015 and spring of 2016. This simple comparison suggests that Erbil, the capital of the Kurdistan Region of Iraq and firmly outside of ISIL-held territory, received large IDP inflows between spring of 2015 and spring of 2016. Mosul's population appears to be largely unchanged, perhaps because of strict ISIL-imposed restrictions on civilians trying to flee ISIL territory.[8]

Of note is the fact that internal migration is an imperfect measure of economic activity. On the margins, changes in citywide populations will tell us little about changes in overall supply or demand for commercial goods or changes in the availability of labor as an industrial input. However, evidence of major population outflows could help us to disentangle the effects of ISIL governance, to the extent that it acts as a stabilizing influence in the midst of larger conflict or to the extent that its brutality leads to massive population flight. It also serves as an indicator of the impact that violence has on areas affected by the Islamic State, to the extent that the timing of IDP flows is correlated with ISIL takeover versus liberation from ISIL.

Figure 3.2
Population Distribution in Mosul and Erbil, 2015–2016



SOURCE: Oak Ridge National Laboratory, Landscan.
RAND *RR1970-3.2*

[7] Although 2014 annual LandScan estimates do exist, ORNL has updated these data for Iraq and Syria specifically to account for internal displacement in Iraq and Syria. These updates represent the quarterly variation we use in our analysis.

[8] Sofia Barbarani, "Civilians Flee ISIL-Held Territory in Iraq," *Al Jazeera*, April 4, 2016.

Agricultural Activity

Next, we use the USGS's Landsat 8 satellite and its measures of red and near-infrared (NIR) light intensity as a proxy for overall changes in *agricultural activity*. All Landsat images are captured at approximately 10:15 a.m. local time once every 16 days for the entirety of the earth's surface at a spatial resolution of 30 meters by 30 meters, and they are made publicly available through the USGS's EarthExplorer website.[9] We use Landsat data on surface reflectance in the red and NIR bands to calculate vegetative intensity using NDVI.[10] NDVI allows us to differentiate vegetated areas from other land cover types.[11] Estimates of the spatial extent of vegetated areas using this method are especially well-suited proxies for agricultural activity in the arid climates of much of Iraq and Syria, where vegetation outside of irrigated areas is generally limited.[12]

Figure 3.3 plots a raster image of the NDVI values surrounding Raqqah in March 2014, at roughly peak harvest season for the local wheat crop. Green areas indicate significant amounts of vegetation, while red areas largely highlight bodies of water (in this case, the Euphrates River).

Industrial Activity

We also use USGS Landsat 8 data to measure *industrial activity* using the thermal signature of cities overall relative to the thermal surface temperature of known factories

---

[9] See USGS, "EarthExplorer," last modified March 28, 2017. Although images of the study area are captured every 16 days, some of these images are unusable because of cloud cover, leading to missing periods in our analysis of Landsat 8 data, particularly in winter.

[10] NDVI is calculated using red reflectance derived from Landsat 8's band 4 and NIR reflectance derived from Landsat 8's band 5. The NDVI calculation is

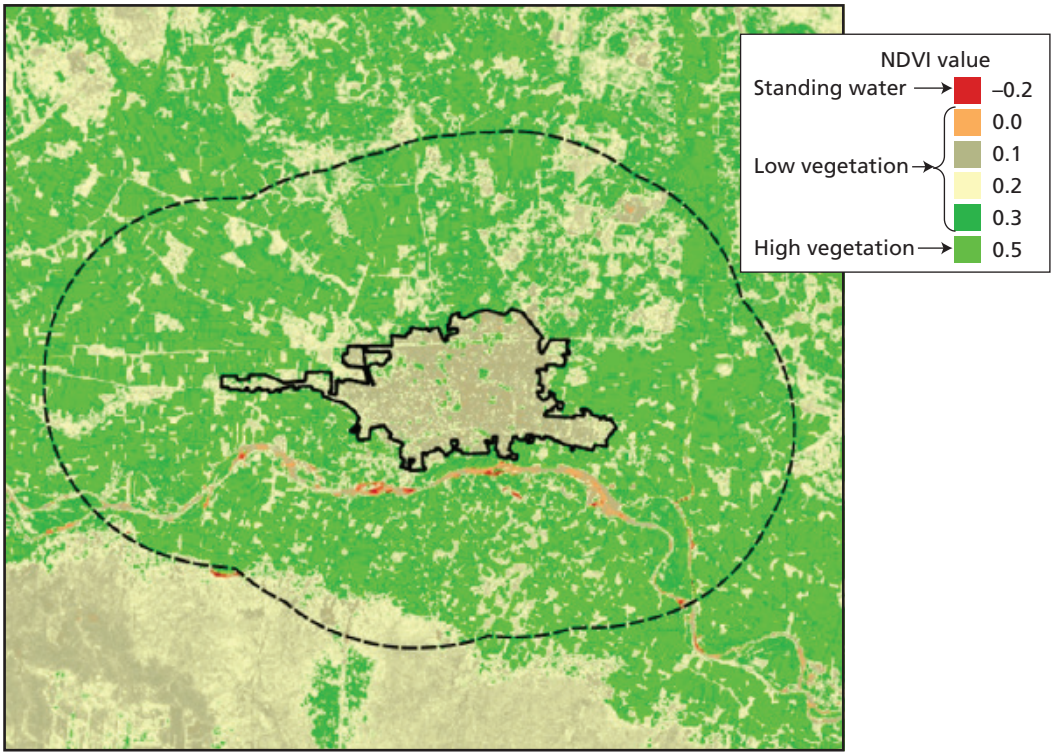
$$\frac{\rho_{NIR} - \rho_{red}}{\rho_{NIR} + \rho_{red}}.$$

See Compton J. Tucker, "Red and Photographic Infrared Linear Combinations for Monitoring Vegetation," *Remote Sensing of Environment*, Vol. 8, No. 2, May 1979, pp. 127–150.

[11] See, for example, Md. Shahriar Pervez, Michael Budde, and James Rowland, "Mapping Irrigated Areas in Afghanistan over the Past Decade Using MODIS NDVI," *Remote Sensing of Environment*, Vol. 149, June 2014, pp. 155–165; Lina Eklund, Andreas Persson, and Petter Pilesjö, "Cropland Changes in Times of Conflict, Reconstruction, and Economic Development in Iraqi Kurdistan," *Ambio*, Vol. 45, No. 1, February 2016, pp. 78–88; and Weicheng Wu and Eddy De Pauw, "A Simple Algorithm to Identify Irrigated Croplands by Remote Sensing," 34th International Symposium on Remote Sensing of the Environment, 2011.

[12] Mutlu Ozdogan, Yang Yang, George Allez, and Chelsea Cervantes, "Remote Sensing of Irrigated Agriculture: Opportunities and Challenges," *Remote Sensing*, Vol. 2, No. 9, 2010, pp. 2274–2304.

Figure 3.3
Normalized Difference Vegetation Index Near Raqqah, March 2014



SOURCE: USGS Landsat 8 Satellite.
NOTE: The solid black line represents the built-up urban core of Raqqah. The dashed black line indicates the 5-km periphery of Raqqah surrounding this urban core. Negative NDVI values indicate standing water. Low positive values indicate low vegetation. High positive values indicate high vegetation.
RAND *RR1970-3.3*

or industrial areas within our key cities of interest.[13] This analysis uses USGS-provided data on brightness temperatures derived from Landsat 8's thermal infrared band 10.[14] This method of tracking industrial activity was briefly explored in one assessment of industrial output in Daegu, Korea, but is largely untested in the broader literature.[15] It does, however, have a strong pedigree in the realm of measurement and signature intelligence collection, which can involve observing known facilities or objects with track-

[13] We measure thermal deviations across cities over time while controlling for seasonal average temperatures across the region and city fixed effects (FEs). For our five primary cities of interest, we identify known industrial areas using high-resolution imagery and compare deviations in thermal activity over these locations and the city average temperature.

[14] See USGS, Product Guide: Provisional Landsat 8 Surface Reflectance Product Version 1.8, December 1, 2015.

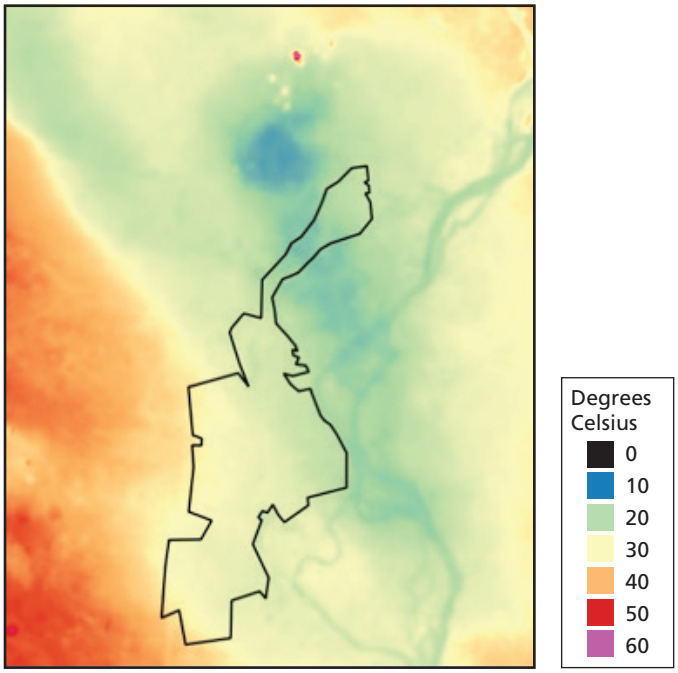
[15] See Jin A. Lee and Chi Kwang Hoon, "Modeling of Urban Industrial Economy Through Utilization of Thermal Band," *International Society for Photogrammetry and Remote Sensing*, Vol. XXXVIII-2/W11, 2009.

able thermal signatures for intelligence purposes.[16] As an example, Figure 3.4 shows the thermal signature over the Bayji oil refinery in Iraq in May 2015. The city of Bayji is outlined in black, and the red hot spot to the north of the city is the refinery. It is clearly distinguishable from its surroundings. In fact, the cooler swaths of this image (in blue) represent smoke plumes from the refinery.

Market Activity

We next turn to measures derived from high-resolution commercial satellite imagery. Our first indicator of economic activity derived from commercially available satellite imagery is market activity. Open-air markets figure prominently in the economic and social landscape of cities throughout Iraq and Syria—we use high-resolution imagery

Figure 3.4
Thermal Signature of the Bayji Oil Refinery, May 2015



SOURCE: USGS Landsat 8 Satellite.
RAND *RR1970-3.4*

[16] For further information on measurement and signature intelligence and multispectral imagery collection, see *IC21: The Intelligence Community in the 21st Century*, U.S. House of Representatives Permanent Select Committee on Intelligence, Staff Study Report, June 5, 1996.

to understand whether ISIL control has influenced overall economic activity in and around these markets.

To develop this indicator, we first identified market locations in our five key cities of interest based on publicly available data. This included published maps of cities in the region, along with publicly available information from Google Maps and OpenStreetMap (OSM), as well as manual analysis of satellite imagery data to identify market locations throughout each of our five case study cities. This resulted in a data set of 73 specific market locations in these cities, ranging from only ten in Tikrit to nearly 20 each in Mosul and Raqqah.

Second, we used a crowd-sourcing approach to measure activity at each location over time. Through its online crowd-sourcing platform, Tomnod, DigitalGlobe created a campaign of more than 100 volunteers who examined each image and rated the level of activity on a scale from "no activity" to "limited activity" and "significant activity."[17] Each image loaded into the campaign received a series of ratings from across the crowd until a sufficient consensus emerged.[18] The result of this analysis was a data set of market locations and crowd-sourced levels of market activity at each location over time. People in the crowd were given images of markets at random time periods in nonsequential order and with random assignment to specific locations across all five cities of interest in our analysis. We rely on these average crowd-sourced rankings to understand both temporal and spatial variation in the intensity of market activity across each city.

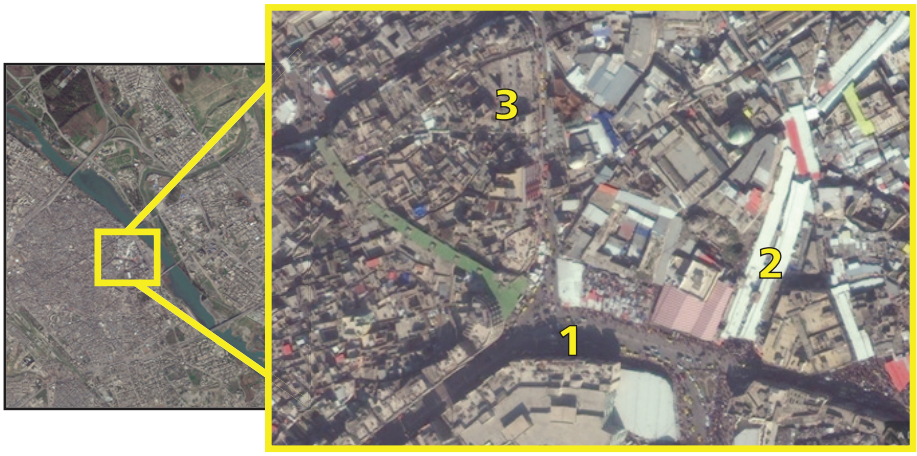
Measuring market activity is not a simple task. Figure 3.5 presents an image from January 2016 of the central market in Mosul that demonstrates the challenge faced by our volunteer crowd. In the first area noted in the image, an open-air market has formed in a paved portion of the central market area. In this location, car counts or manual counts of market stalls could act as a sufficient proxy for the level of activity over time. The second area noted in the image is a covered adjacent portion of the market. It is difficult to gauge with the naked eye the level of activity at this location, and, although infrared or nighttime lighting over this location could reveal some insight into its level of activity, the small size of this location could prove prohibitive for tracking activity of this market as distinct from its surrounding areas. In the third area of the market, a relatively traditional street market forms off the main square. At this location, car counts or counts of market stalls would prove insufficient measures of activity because the small size of the street constrains vehicle traffic.

---

[17] After breaking up each of our 73 market locations into smaller, more-tractable polygons, DigitalGlobe loaded 8,371 high-resolution satellite images of these locations into the Tomnod platform. The study team and DigitalGlobe developed a simple set of training data to show the different types of markets and invited the crowd to think through creative ways of assessing market activity in these locations.

[18] As part of the crowd-sourcing process, we gave added priority to any image analyzed by a registered Tomnod user with a track record of accurately identifying imagery in a prior crowd-sourcing campaign.

Figure 3.5
Mosul's Central Market, January 29, 2016



SOURCE: Digital Globe, 2016.
NOTE: This January 2016 image of the central market in Mosul demonstrates the challenge faced by our volunteer crowd. (1) An open-air market has formed in a paved portion of the central market area. In this location, car counts or manual counts of market stalls could act as a sufficient proxy for the level of activity over time. (2) This is a covered adjacent portion of the market. It is difficult to gauge with the naked eye the level of activity at this location, and, although infrared or nighttime lighting over this location could reveal some insight into its level of activity, the small size of this location could prove prohibitive for tracking activity of this market as distinct from its surrounding areas. (3) A relatively traditional street market forms off the main square. At this location, car counts or counts of market stalls would prove insufficient measures of activity because the small size of the street constrains vehicle traffic.
RAND *RR1970-3.5*

This comparison suggests that the human eye is arguably best able to gauge differences in activity across these locations based on not one but a combination of factors, potentially including cars, market stalls, or foot traffic that might be too subjective for more-advanced algorithms to assess without human-assisted machine learning techniques. Instead of relying on a single user to code market activity, we average inputs from more than 100 users to obtain a more reliable measure. This is the benefit of crowd-sourced analysis of imagery.

Damage and Destruction

We also use a crowd-sourcing approach to identify buildings, roads, and infrastructure in each of our five cities of interest that are damaged from fighting, shelling, or even air strikes. DigitalGlobe loaded full images covering the spatial extent of each city into the Tomnod crowd-sourcing platform and asked volunteers to identify any areas with visible signs of damage. Rather than preload locations for the crowd to analyze,

users could manually scroll through imagery of entire cities at once and tag areas with damage. Areas with repeated tags across multiple users were then output as a set of spatial points for statistical analysis.[19]

The resulting data set allows us to measure the spatial incidence of *damage and destruction* throughout each city over time.[20] We use changes in damage over time to better understand the extent to which fighting affected key economic or residential infrastructure, as well as the extent to which ISIL reconstructed damaged parts of cities, and to assess the extent of post-liberation destruction in a city.[21] Figure 3.6 provides an example of crowd-sourced points of damage within Deir ez-Zor, Syria, as of November 2014.

Car Counts

Car counts represent a powerful opportunity to gauge commercial activity. Similar methods based on high-resolution imagery are already in use by hedge funds and a limited segment of the private sector in order to track, for instance, cars parked in parking lots of retail firms over time as a means of determining firm profitability.[22]

---

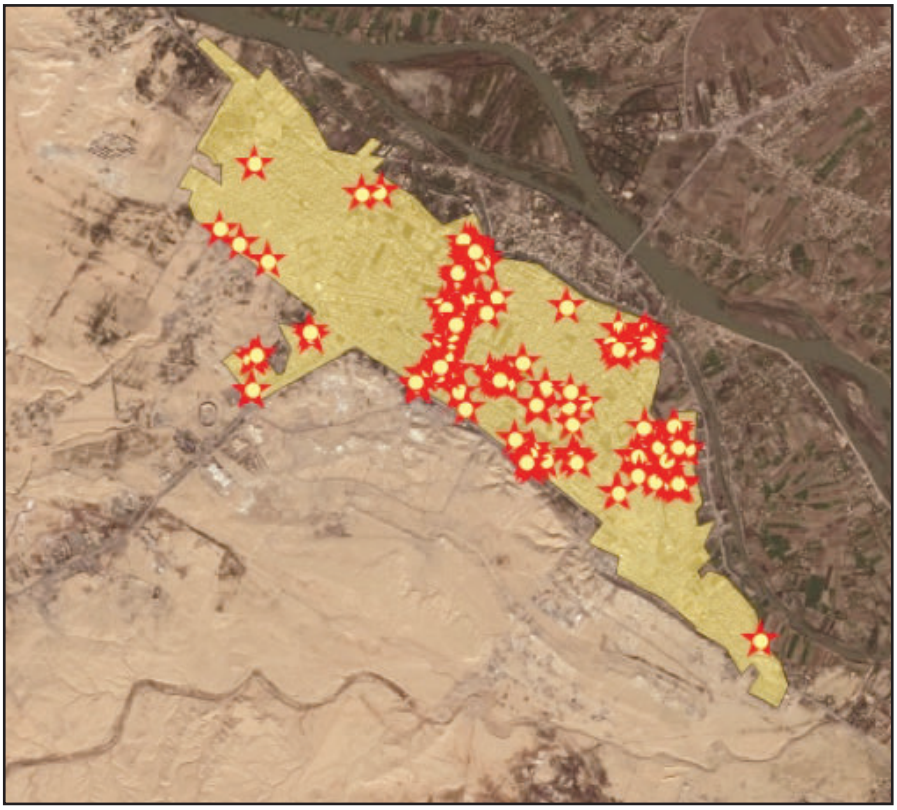
[19] In practice, given the availability of imagery for each city and each city's geographic size, DigitalGlobe loaded many images without the full spatial extent of each city into the crowd-sourcing platform. However, to provide adequate comparisons over time, we restrict our analysis to those images with near-zero cloud cover and the largest spatial extent available for each city.

[20] We also explored using an object-based recognition algorithm to identify changes in building footprints over time. The algorithm largely succeeded at tracing the outlines of major buildings in the city but was not able to adequately distinguish damaged portions within each building footprint from nondamaged portions. Existing rubble-detection algorithms can accomplish this task but require significantly higher-resolution imagery that is not commercially available from space-based imagery providers.

[21] We note that crowd-sourced estimates of damage and destruction vary to the extent that they identify solely new instances of destruction rather than capturing all damaged areas of a city regardless of when the damage occurred. The crowd-sourcing platform used in this study, DigitalGlobe's Tomnod, asks the crowd to assess levels of damage at each static point in time. However, manual review of some results suggested that older instances of destruction were not always captured in each image, perhaps because such damage no longer appeared new or because of an insufficient crowd size. Therefore, throughout this report, we often aggregate estimates from imagery captured over similar time periods to present maps of damage up to and including a certain time period, or we present select images from our entire data set that are more representative of the full extent of destruction at that point in time. We make these decisions based on our own careful manual analysis of results. For these reasons and to avoid providing false precision in our estimates, we also avoid presenting total numbers of damaged areas or destroyed buildings. Instead, we focus solely on the spatial distribution of destruction and the binary question of whether certain infrastructure is damaged. This also overcomes one potential pitfall of aggregating crowd-sourced points of destruction, which is that buildings with damage in multiple places could receive one tag from some volunteers but multiple tags from others. The former approach could understate the level of damage to a large building, while the latter could overstate the level of damage to a smaller building. Visualizing points on a map to assess spatial distribution overcomes these concerns.

[22] See Jeff Kearns, "Satellite Images Show Economies Growing and Shrinking in Real Time," Bloomberg, July 8, 2015, and Ana Swanson, "A Stunning New Look from Space at Nature, North Korea and Chipotle," *Washington*

Figure 3.6
Building Damage in Deir ez-Zor, November 2014



SOURCES: Building damage from Digital Globe's Tomnod Platform, 2016. Background imagery from Digital Globe, November 25, 2014.
NOTE: The yellow shaded area represents the city's urban extent, based on authors' estimates and a review of satellite imagery. Yellow-centered red stars denote instances of damage or destruction.
RAND *RR1970-3.6*

We use car counts as a measure of *commercial activity* in order to gauge whether inhabitants of each city have active freedom of movement within the urban core of a city and are likely engaged in commercial activity.[23] We develop two versions of car

Post, July 23, 2015.

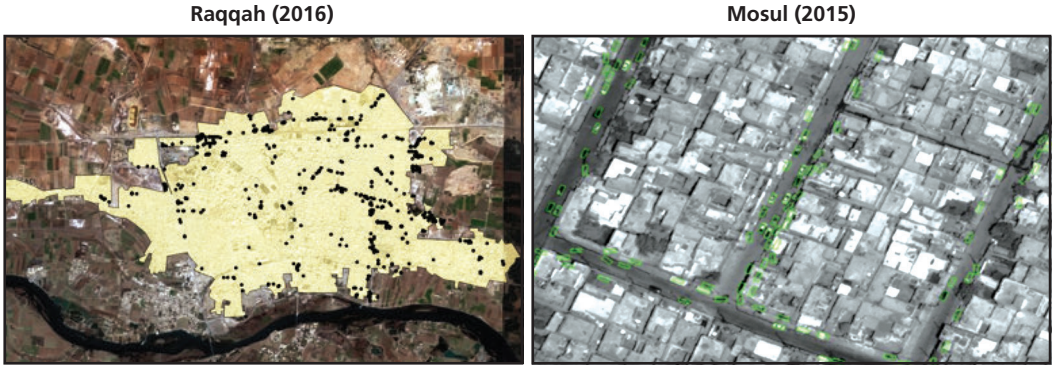
[23] To allow us to properly identify cars in satellite imagery, images must be free from cloud cover and with sufficient spatial resolution for object-recognition algorithms to distinguish cars from their surroundings. Because of the manner in which commercial high-resolution imagery is collected, relatively few images of each city capture the entirety the city's urban extent. Furthermore, car counts are highly subject to time-of-day and day-of-week variation that could affect interpretation of time-series results. As a result, we provide time-series assessments of vehicle volume only where sufficient images exist that capture the entirety of a city at roughly the same time of day.

counts for use in this study. The first is based on an object-recognition algorithm that identifies cars of all sizes within each image using the spectral and spatial signature of cars as distinct from their surroundings.[24] Our second method for counting cars focuses strictly on identifying large commercial vehicles, such as tractor trailers, in the same imagery. But rather than rely on an object-recognition algorithm, we use the same crowd-sourcing methodology used to identify damaged buildings, whereby hundreds of volunteers manually identify tractor trailers in the underlying imagery.

Figure 3.7 plots the distribution of all commercial vehicles in Raqqah, identified through crowd-sourced analysis of an image captured in January 2016. To more clearly depict how the object-recognition algorithm identifies cars in the underlying imagery, a zoomed-in version of vehicles in Mosul from 2015 is shown in the right panel, with each car surrounded by a green polygon.

Although we develop both an algorithm-based measure of car counts and a more restrictive crowd-sourced version of only commercial vehicles, we rely solely on the crowd-sourced metric of commercial vehicle counts throughout the rest of this report. First, commercial vehicles, such as tractor trailers, are arguably a more direct measure of commercial activity than passenger vehicles, and existing off-the-shelf algorithms are generally not built to distinguish between the two. Second, algorithm-based car counts are more sensitive to image-over-image differences in cloud cover, sensor reso-

Figure 3.7
Visualization of Car Counts in Raqqah and Mosul



SOURCES: Car count data for Raqqah from Digital Globe's Tomnod Platform. Car count data for Mosul from Digital Globe's GBDX Platform. Imagery of Raqqah from Digital Globe, February 20, 2016. Imagery of Mosul from Digital Globe, 2015. Authors' estimates.
NOTE: The yellow shaded area in the left image of Raqqah represents the city's urban extent, based on authors' estimates and a review of satellite imagery. In the left image, black dots denote commercial vehicles. In the right image, green polygons denote cars.
RAND *RR1970-3.7*

[24] Object-recognition algorithms use information from across visible and invisible bands of light—including red, green, blue, and infrared—in order to identify a common spectral signature of objects, such as cars or buildings, and search for similar signatures throughout the rest of each image.

lution, and image tone. In particular, most current off-the-shelf car count algorithms were built using imagery of cars on roads in Western countries with more-developed road infrastructures that offer greater contrast between cars, roads, and buildings. Absent future refinement of these off-the-shelf algorithms for application in Iraq and Syria, we believe that crowd-sourced analysis overcomes these issues with less investment in time and resources.

In order to train the crowd to identify large commercial vehicles as distinct from passenger vehicles, we provided a series of training images to highlight properly tagged commercial vehicles and tractor trailers as distinct from other vehicles. Figure 3.8

Figure 3.8
Example Training Images for Commercial Vehicle Crowd-Sourcing

SOURCES: Authors' estimates; imagery from Digital Globe, 2016.
RAND *RR1970-3.8*

shows several examples.

CHAPTER FOUR

The Economic Impact of Islamic State Governance Across the Caliphate

To capture ISIL's holistic impact on economic activity inside its self-styled caliphate, we built a panel data set of every city in Iraq and Syria with more than 10,000 inhabitants and tracked our space-based indicators of economic activity over time for each of these 167 cities since 2013. We then built a month-by-month data set indicating whether ISIL unilaterally controls each city, contests control of the city with some other armed group, or has no control over the city over the same time period. Combined, these data allow us to systematically measure ISIL's impact. We measure ISIL's effect on cities within its caliphate both relative to those that never experienced ISIL governance and within cities controlled and lost by ISIL over time.

In this chapter, we first describe the cities in our analysis sample, followed by the methodology used to identify whether each city was controlled or contested by ISIL in a given month. Then, we conduct an event study analysis on violence levels associated with takeover and liberation from ISIL inside Iraq and Syria to develop a narrative understanding of the process through which the group establishes control over a city. This discussion helps to set a baseline for our understanding of immediate changes in economic activity following ISIL takeover. Finally, we use fixed-effects regression and duration treatment modeling to examine ISIL's impact on electricity consumption, population levels, and agricultural activity across cities and over time.

Cities in the Analysis Sample

We focus on cities as the primary unit of analysis for several reasons. First, ISIL conquered territory on a city-by-city basis and built its governance structures within each city to report up through higher chains of command at the district or *wilayat* (province) level.[1] Although ISIL established larger administrative areas above the city level, ISIL forces might not always control the entirety of rural areas in these districts. Second, combat to liberate cities from ISIL has also been city-centric as ISF elements in Iraq and Kurdish forces in Syria have fought to retake city centers from ISIL control and

[1] *Province* refers to the official GoI boundaries. *Wilayat* refers to ISIL's boundaries for Ninewa.

use these fixed locations to expand influence into the countryside. Finally, for methodological reasons, cities offer a simple and tractable means through which we can identify areas under ISIL control over time. Rather than focus on smaller villages or rural areas, we focus our analysis on population centers with 10,000 or more inhabitants. Given that we seek to measure the direct impact that Islamic State control has on economic activity, we focus on medium-sized towns and large cities in that they are most likely to host contingents of ISIL fighters and be directly connected to the group's governing bureaucracy.

We developed our sample of cities using the GeoNames database and its associated population levels for each city, which are based on administrative and census data.[2] Restricting the total list of known locations in this database to only those with more than 10,000 inhabitants produces a sample of 167 total cities, with 92 in Syria and 75 in Iraq. Importantly, we do not restrict our sample to cities solely in ISIL-held areas of both countries. As a result, cities that have never experienced any direct ISIL control act as implicit control groups in our models. These include areas in Kurdish-governed Iraq (such as Erbil, Sulimaniyah, and Duhok) as well as Shia-predominant parts of southern Iraq (such as Basra). In Syria, it includes cities affected by fighting between non-ISIL Sunni opposition forces and the Assad regime in Syria (such as Homs) and cities squarely under the Assad regime's control (such as Latakia).[3] A full list of cities, population levels, and whether each city has experienced any ISIL control is presented in Appendix A.

One key difficulty of working with cities as the unit of analysis is that they must be defined in a practical way. Our analysis in this report relies on satellite data, and this means that we need to associate each of these cities with particular points in space. Typically, researchers use administrative boundaries to define the spatial extent of urban areas, but publicly available data sets that specify administrative boundaries for Syria and Iraq contain only district or subdistrict information, so they are too coarse for our purposes. Moreover, even if we had reliable maps of low-level administrative boundaries for Syria and Iraq, economic activity often spills across areas defined based strictly on political boundaries, rendering such borders inadequate.[4] Researchers often

---

[2] GeoNames, home page, undated. Additionally, we manually rectified missing population information from the GeoNames database using additional data sources for Syria and Iraq separately. For Syria, we used data from "Syria," 2015. For Iraq, we used data from "Republic of Iraq (IQ)," undated. Errors or omissions from the list of cities with more than 10,000 inhabitants are due to missingness in the underlying census and population data, likely on the lower margins of population. Absent a complete roster of cities and villages by population, we made manual efforts to rectify known missingness in major cities or administrative capitals. Our full list of cities is included in Appendix A.

[3] Inclusion of cities in Syria heavily affected by fighting but lacking any direct exposure to ISIL should act as a conservative restriction on our results. If the economic impact of ISIL control is statistically distinct from areas outside of ISIL control (which include other war-torn cities), such results would prove to be relatively robust.

[4] Thomas J. Holmes and Sanghoon Lee, "Economies of Density Versus Natural Advantage: Crop Choice on the Back Forty," Federal Reserve Bank of Minneapolis, Working Paper 668, June 2009.

defer to choices made by statistical agencies that develop groupings of related urban and suburban areas. For instance, in the United States, the Census Bureau has defined and produced maps of metropolitan statistical areas. Unfortunately, similar definitions are unavailable for our purposes.[5]

To adequately define urban areas in a practical way that addresses some of the challenges described above, we opted to draw our own borders for cities in Iraq and Syria, using pre–ISIL control satellite imagery as our guide. Our goal for constructing these borders was to create a maximally connected polygon that contained as much contiguous built-up infrastructure (including commercial, industrial, and residential buildings) as is visible in pre-ISIL satellite imagery. To do this, we first used open-source mapping software to determine the latitude and longitude coordinates of every city in our analysis sample. With these locations, we then used geospatial analysis software and pre-ISIL satellite imagery to digitally trace the boundaries of each city's *urban core*—the contiguous built-up area surrounding the city center. In order to capture activity that takes place outside of an urban core but should still be associated with a given city's economy, we created *urban periphery* borders for each of the cities using a 5-km buffer zone around the urban core polygon. We use this urban periphery to capture types of economic activity, such as agriculture, that naturally occur outside of a built-up city center.

Figure 4.1 shows an example of the borders of the urban core and periphery for the city of Ramadi, Iraq. The red polygon is the urban core, and the orange polygon is the periphery. The urban core clearly contains a large density of buildings in Ramadi, while the orange periphery captures a good portion of the agricultural activity in the surrounding area. It also includes some lower-density housing structures outside the urban core, particularly the settlements north of the Euphrates River.[6]

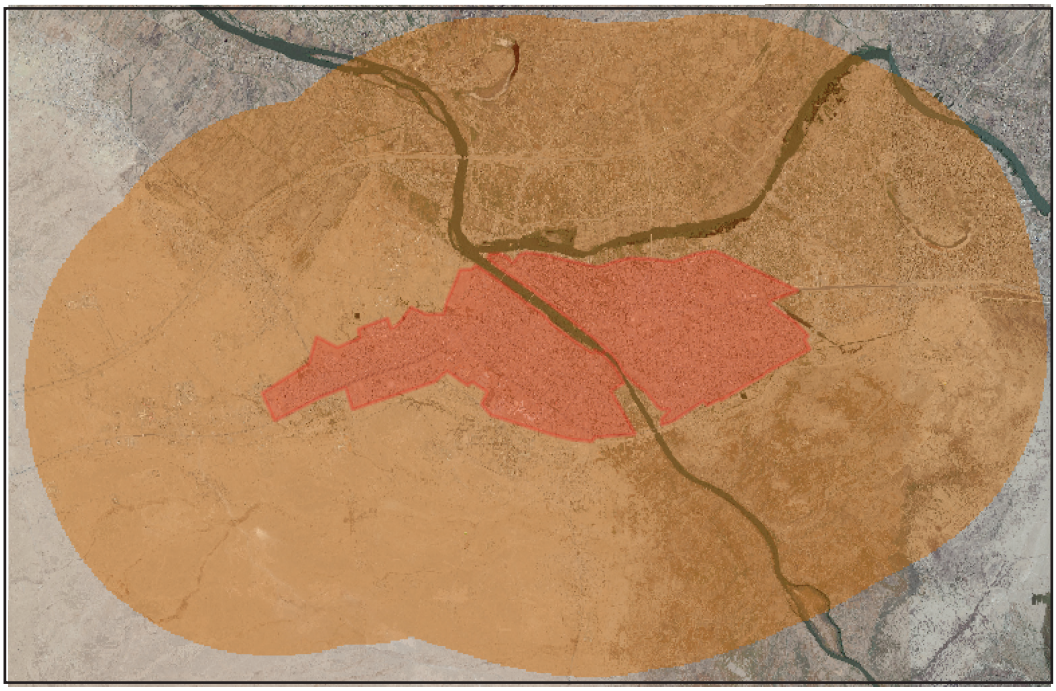
Measuring the Islamic State's Control of Territory

Several sources collect and maintain data on the evolution of ISIL's territorial control, including the Institute for the Study of War and IHS Jane's. These organizations publish maps of ISIL's territorial reach over time using data from social media, publicly available news reporting, and spatial algorithms that assign points on a map to whether ISIL controls each area or not. Although these sources are widely used in media reports, they are insufficient for our purposes to develop a complete city–month

[5] Another approach, the city clustering algorithm, requires high-resolution, spatially disaggregated population data, which are unavailable in our data-poor environment. See Hernán D. Rozenfeld, Diego Rybski, Xavier Gabaix, and Hernán A. Makse, "The Area and Population of Cities: New Insights from a Different Perspective on Cities," *American Economic Review*, Vol. 101, No. 5, August 2011, pp. 2205–2225.

[6] Note that this approach can sometimes lead to situations in which periphery borders overlap. In Appendix A, we describe our approach for partitioning the urban periphery borders using Thiessen polygons.

Figure 4.1
Urban Core and Periphery: Ramadi



SOURCE: Authors' calculations overlaid on DigitalGlobe, 2016.
RAND *RR1970-4.1*

panel of ISIL territorial control and contestation. Although some of these maps are released publicly, they are often released at irregular intervals in time and can lack sufficient spatial granularity to provide clear evidence of territorial control in some of the smaller cities in our data set. Furthermore, the methodologies used to develop these maps of territorial control are somewhat opaque.

We opt to develop our own data set of monthly territorial control for each city in our sample, from January 2013 through May 2016.[7] We use publicly available media reporting from English- and Arabic-language sources, both in the Western press and from local Iraqi and Syrian sources. Informed by these media reports, we code two separate variables of territorial control. First, we identify whether ISIL controlled any portion of each city at any point in time during each month. Then, separately, we code whether a non-ISIL armed group controlled any portion of the city at any point in

[7] Establishing submonthly territorial control measures is prohibitive given the lack of reliable and frequent reporting on ISIL presence in specific cities in the region. Separately, although ISIL uses predominantly the Hijri calendar, we use Gregorian months for ease of interpretation.

time during each month.[8] Combining these two separate control variables, we produce a three-part indicator (no control, contested control, unilateral control) that cleanly identifies the extent to which ISIL is in control of each city.

So how do we define *control of territory*? We define *control* as whether ISIL has unobstructed freedom of movement within some portion of a city and exerts majority influence over the local population and infrastructure in that same area.[9] We define *freedom of movement*, based on prior RAND research, as the "actual or perceived degree to which individuals or groups can move from place to place within a given environment or into and out of that environment."[10] Freedom of movement is important in this context to the extent that it allows ISIL to begin to establish its systems of governance within a defined urban area.

Understanding the difference between *control* and mere *presence* is important for treating ISIL as a political entity with governing ambitions rather than simply an armed group in need of local resources. ISIL, and its predecessor organizations AQI and ISI, maintained a presence throughout much of northern Iraq even after their relative defeat in the later years of the Iraq War. However, they did not *control* any of these cities until late 2014, when they could both move freely throughout the city, as well as hold a monopoly of force over critical infrastructure and population centers relative to GoI forces.[11]

Table 4.1 presents descriptive statistics on ISIL's control over cities in Syria and Iraq from January 2013 to May 2016. Of the 167 cities in our sample, 70 percent were never controlled or contested by ISIL forces. This leaves 51 cities, 31 in Syria and 20 in Iraq, that experienced at least one month of ISIL contested or unilateral control between 2013 and mid-2016. Of these cities, roughly half had been liberated from

---

[8] One potential criticism of this approach is that it could overstate the prevalence of areas contested by the Islamic State. However, our restrictive definition of *control* helps delineate between cities actually contested by the group and those in which it merely has a presence.

[9] Because we use media reporting to establish ISIL control, we are ultimately forced to apply this definition through the lens of both Western and regional news sources' own usage of the word *control*. We respond to this limitation in several ways. First, we seek to independently confirm media determinations that ISIL "controls" a given city with other qualitative evidence that describes the nature of ISIL's operations in a given city in accordance with our own definition of *control*. Second, where little qualitative evidence exists, we confirm determinations of control with multiple sources. Third, where no media reporting exists for some of the smaller towns in our sample, we rely on published control maps on a limited basis. Although coarse, these maps provide enough specificity in intervening months to fill in gaps in our sample.

[10] Ben Connable, Jason H. Campbell, Bryce Loidolt, and Gail Fisher, *Assessing Freedom of Movement for Counterinsurgency Campaigns*, Santa Monica, Calif.: RAND Corporation, TR-1014-USFOR-A, 2012.

[11] Although AQI was able to extort local businesses in Mosul in 2008 without holding a monopoly of force over the city, the breadth of its reach into local economies was smaller in amount and scope than it was able to achieve in Mosul after 2014. See Johnston et al., 2016; Michael Knights, "Al-Qa`ida in Iraq: Lessons from the Mosul Security Operation," *CTC Sentinel*, Vol. 1, No. 7, June 15, 2008; and Howard Shatz and Erin-Elizabeth Johnson, *The Islamic State We Knew: Insights Before the Resurgence and Their Implications*, Santa Monica, Calif.: RAND Corporation, RR-1267-OSD, 2015.

Table 4.1
The Islamic State's Territorial Control in Iraq and Syria, January 2013 to May 2016

City Type	Iraq	Syria	Total
Total cities with at least 10,000 inhabitants	75	92	167
Cities with no ISIL control or contestation	55	61	116
Percentage of all cities with at least 10,000 inhabitants	73%	66%	69%
Cities with any ISIL control (contested or unilateral)	20	31	51
Percentage of all cities with at least 10,000 inhabitants	27%	34%	31%
Status as of May 2016			
Unilateral ISIL control	9	13	22
Contested	1	2	3
Liberated	10	16	26
Cities with contested periods but no unilateral ISIL control	4	9	13
Cities with periods of unilateral ISIL control	16	22	38
Changes in control	1.3	1.8	1.6
Months unilaterally controlled	18.0	18.0	18.0
Months contested	3.1	2.0	2.5
Months contested prior to takeover	2.1	1.6	1.8
Months contested post-liberation	1.0	0.5	0.7

SOURCE: Authors' estimates.

ISIL control as of May 2016, with 22 cities remaining under unilateral control by the Islamic State at that time.

Of the 51 cities of which ISIL controlled at least a portion over this time period, only 38 were ever controlled unilaterally by the group at any point. The remaining 13 cities—those contested by the group but never fully controlled—include major population centers in Syria, as well as areas in Iraq around Baghdad that were briefly contested in the summer of 2014. This points to an interesting dynamic in that not all of the group's attempts to establish a foothold over a city are born equal. ISIL has shown a willingness to fight for control of only small portions of cities (such as in Damascus's Yarmouk refugee camp), to retreat from cities only briefly contested (such as in Baqubah, Iraq), or to fight protracted battles for control without ultimate success (such as in Kobani or Deir ez-Zor).

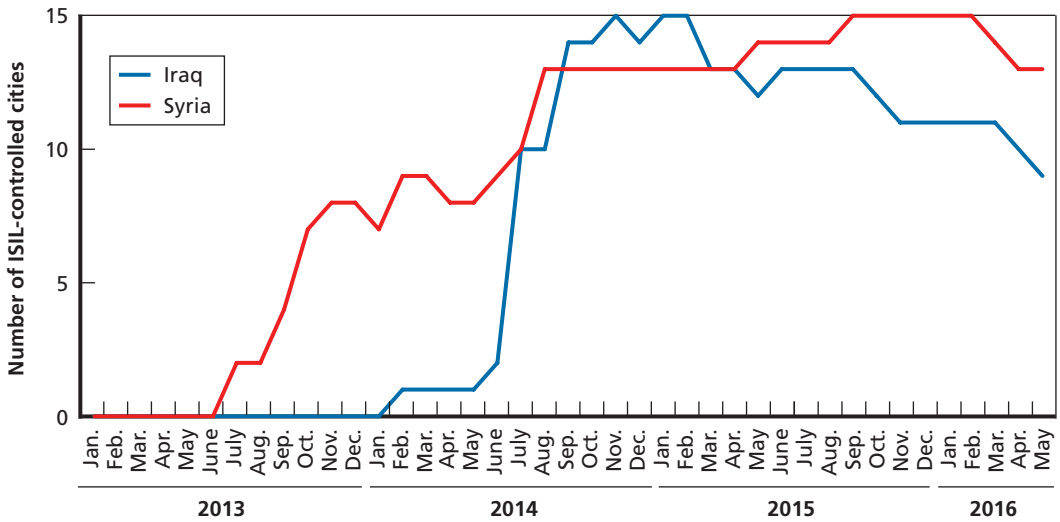
We next turn to the 38 cities that have experienced periods of unilateral control under the Islamic State. This includes areas still under ISIL control throughout 2016

(such as in Raqqah and Mosul), as well as cities where the group lost control to regime or opposition forces following takeover of the city. Of note, it took an average of two months of contestation for ISIL to establish complete control over these 38 cities.[12] For Syria specifically, control was slightly more volatile than in Iraq, perhaps reflecting the added competition from other Sunni opposition groups in that theater.

To understand how ISIL territorial control developed over time in both countries, Figure 4.2 presents a time-series plot of the number of cities ISIL controlled in each month since 2013 for Iraq (in blue) and Syria (in red).

This figure captures the lightning speed with which ISIL established control in Iraq in the summer of 2014, as well as its territorial losses at the hands of ISF elements primarily in Anbar and Salah ad-Din provinces over the course of 2015 and 2016. In Syria, ISIL's urban holdings rapidly increased in late 2013, around the same time as the group began to cement control over its capital, Raqqah. A second wave of territorial expansion occurred in late 2014, coinciding with the group's advance into Iraq. But unlike in Iraq, the number of cities unilaterally controlled by ISIL in Syria fell only slightly over the course of 2015 through mid-2016. More-recent publicly available reports suggest that ISIL has lost nearly 20 percent of its territory in Syria since 2014.[13]

Figure 4.2
Number of Islamic State–Controlled Cities in Iraq and Syria



SOURCE: Authors' calculations.
RAND *RR1970-4.2*

[12] This is partially a product of our coding scheme, which labels months in which control of a city changes hands as contested. As a result, in our data set, even such cities as Mosul (which fell to ISIL forces over the course of several days in 2014) have at least one month of contested control prior to full takeover.

[13] "Islamic State and the Crisis in Iraq and Syria in Maps," BBC News, April 28, 2017.

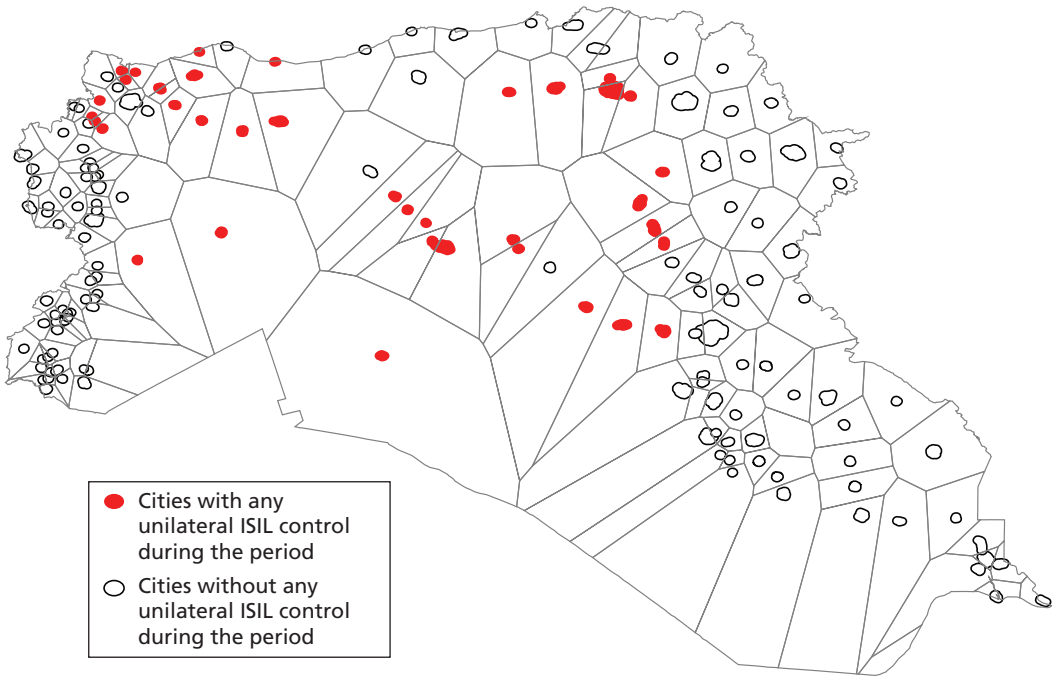
Figure 4.3 shows the cities in our sample experiencing any month of unilateral ISIL control.

Violence and Control

In this section, we describe the patterns of violence associated with ISIL takeover and retreat from cities under its control. This discussion helps to set a baseline for our understanding of immediate changes in economic activity following ISIL takeover. Significant levels of violence associated with contestation, takeover, or retreat from a city could lead to reduced economic activity, damage to key infrastructure, or population outflows. As a result, before we associate changes in economic activity before and after ISIL takeover as a direct product of the group's unilateral control, we should first understand how levels of violence vary relative to changes in ISIL control.

Our data on ISIL-related attacks come from Jane's Terrorism and Insurgency Centre's event database, which tracks attacks that ISIL initiates against civilian and military targets using social media reporting. The database geolocates each attack to

Figure 4.3
Cities with Any Unilateral Islamic State Control Experience



SOURCE: Authors' calculations.
NOTE: Each polygon represents a city's urban periphery.
RAND *RR1970-4.3*

the closest city or village where the attack occurred.[14] We connect these attack data to cities by focusing only on those that fall within 5 km of the centroid of that city's urban core polygon. As such, these attacks would fall within the borders of a city's urban core or its associated periphery.

To relate attacks to ISIL control, we use an event study methodology.[15] This involves examining the frequency of attacks in the sequence of months leading up to when ISIL first establishes unilateral control over a city and examining how average levels of violence change over time, even after ISIL establishes control. We use linear regression to flexibly estimate these effects on a panel of city–month observations. To describe our regression equation, let *i* denote index cities, let *t* denote index months, and let s_i denote the time period when ISIL first obtained uncontested control over city *i*. Next, define $s_{it} = t - s_i$ as the number of months since ISIL obtained control over city *i*. For example, if $s_{it} = 2$, at time *t*, ISIL has controlled city *i* for two months; if $s_{it} = -4$, at time *t*, city *i* has four months to go until ISIL will control the city. We regress the number of attacks in city *i* at time *t*, denoted by y_{it}, on a series of indicators for whether s_{it} is equal to some value:

$$y_{it} = \alpha_i + \alpha_t + \sum_{k=-4}^{k=5} \theta_k \mathbf{1}\{s_{it} = k\} + \theta_{-6}\mathbf{1}\{s_{it} \le -6\} + \theta_6 \mathbf{1}\{s_{it} \ge 6\} + \varepsilon_{it}, \quad 4.1$$

where $\mathbf{1}\{\cdot\}$ is an indicator function. The parameter θ_k measures the impact on attacks of city *i* being *k* months before or after ISIL control. We omit the dummy variable for $s_{it} = -5$, so that post–ISIL control effects are estimated relative to a period of five months before ISIL control takes place.[16] The term ε_{it} is an error term, assumed to be mean zero, conditional on the history of the regressors.

By including indicators for each city, denoted by α_i, this regression approach controls for any fixed, city-specific factors that could influence the level of violence over time (such as historical support for ISIL, demographic and religious composition, or local tribal and political institutions, among other traits). The indicators for each month, α_t, control for any month-specific factors that could influence the level of violence (including seasonality or trends in the flow of foreign fighters into the region over time).

---

[14] In practice, this means that most attacks in each city share the same latitude and longitude. The primary exception to this is where the village or general location of attacks in rural areas are specifically highlighted in media reporting or, in fewer cases, where neighborhoods of larger cities are mentioned in the news reports of an attack.

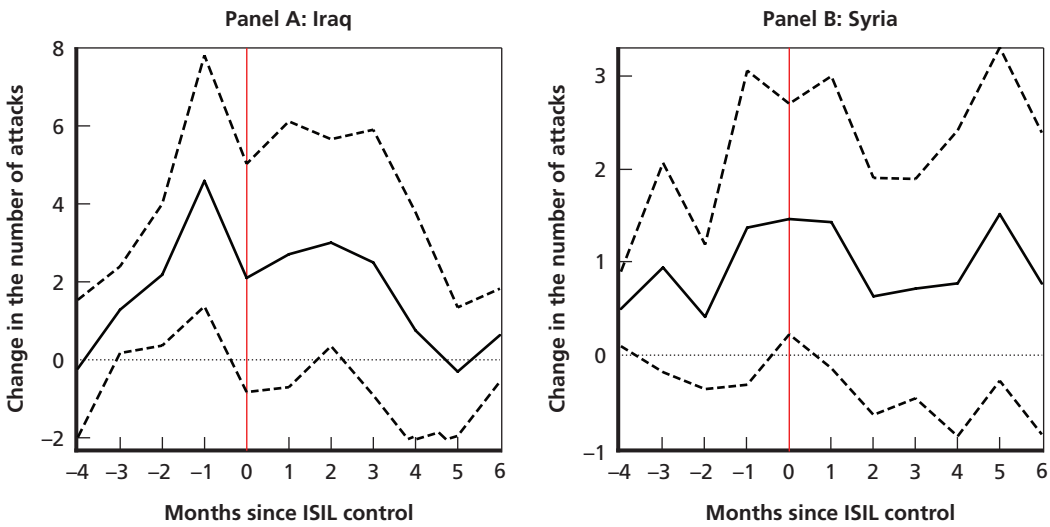
[15] For another example of the event study methodology we use, see Louis S. Jacobson, Robert J. LaLonde, and Daniel G. Sullivan, "Earnings Losses of Displaced Workers," *American Economic Review*, Vol. 83, No. 4, September 1993, pp. 685–709.

[16] Note that the terms θ_{-6} and θ_6 capture the assumed constant effect that ISIL control has on attacks in the six months prior to and six months following ISIL takeover.

Figure 4.4 shows the results of this event study analysis. These figures show the average increase (or decrease) in attacks in the months leading up to ISIL takeover, relative to the period five months before ISIL first established unilateral control. Given that the average period of time in which ISIL contested control of a city before controlling it completely was only two months, this analysis should demonstrate how violence changes over time when the group makes a concerted effort to gain control of a city. For instance, our data set includes some ISIL-affiliated terrorist attacks in Mosul in early 2014, but the pace of these attacks increased as the group began its advance into Iraq later that year. To capture these trends across the whole sample, each plot shows the average change in the number of attacks for each month leading up to and following the point at which ISIL establishes uncontested control.

For Iraq, we find that the highest levels of violence occur in the month prior to ISIL's establishment of complete control over a city—a statistically significant average of 4.6 more attacks per month than at precontrol levels of violence. After ISIL gains nominal control over the entirety of each city in Iraq, the group still continues to conduct acts of violence, although at a rate largely indistinguishable from precontrol levels. For Syria, levels of violence also seem to increase in the month of ISIL takeover but at

Figure 4.4
Levels of Violence Before Islamic State Takeover



SOURCE: Authors' calculations.
NOTE: The solid black line denotes the average change in the number of attacks relative to five months prior to the establishment of unilateral ISIL control. Dotted black lines indicate 95-percent confidence intervals around this estimate. The red vertical line at 0 indicates the month when ISIL control is established, and the thin dotted horizontal line denotes 0 on the y-axis. If there is a statistically significant effect, the confidence band will lie entirely above or below this horizontal line and will not intersect it.
RAND *RR1970-4.4*

lower levels than in Iraq, and there are no significant differences in violence before or after control takes place relative to the period five months before ISIL first established control.

We also use casualty information included in the IHS Jane's database to better understand the severity of these attacks on local populations.[17] The mean number of casualties associated with each attack is roughly seven, and the median rate is three casualties per attack.[18] If we assume that a typical attack generates the mean number of casualties, Figure 4.4 suggests that ISIL's attempts to control territory in Iraq are responsible for an additional 32 casualties per city per month while the group contests control. In Syria, ISIL's attempts to control territory result in an additional 25 casualties per city per month immediately prior to takeover.

In Figure 4.5, we use a similar duration treatment effect specification to assess trends in violence after ISIL loses control of a city.[19] In Iraq, violence tends to decrease after cities are liberated from ISIL control, but the effects are noisy, particularly in the tails, and the differences are not always significantly different from zero. We see a similar downward trend in Syria, but the differences are not significant after ISIL departs. This suggests that, although ISIL departure reduces violence in Iraq, it might not have any impact on attacks in Syrian cities.

Overall, this section raises several key findings that inform our analysis of ISIL's economic impact over time as the group establishes control over cities. First, the peak in attacks immediately prior to ISIL takeover of a city is evidence of the fact that ISIL employs an especially potent wave of violence and coercion early in its efforts to conquer a city, in an effort to intimidate opposition and cement its control. This finding is relevant to both our analysis of ISIL's economic impact and our general understanding of the manner in which insurgent groups prioritize violence as a political tactic rather than solely for terrorism. Second, we find that violence persists for several months after ISIL establishes control, primarily in Syria. Either the group is forced to use violence to maintain control or it never fully establishes complete control in the first place. Building on this discussion, we devote the next sections to understanding how ISIL control affects several different measures of economic activity.

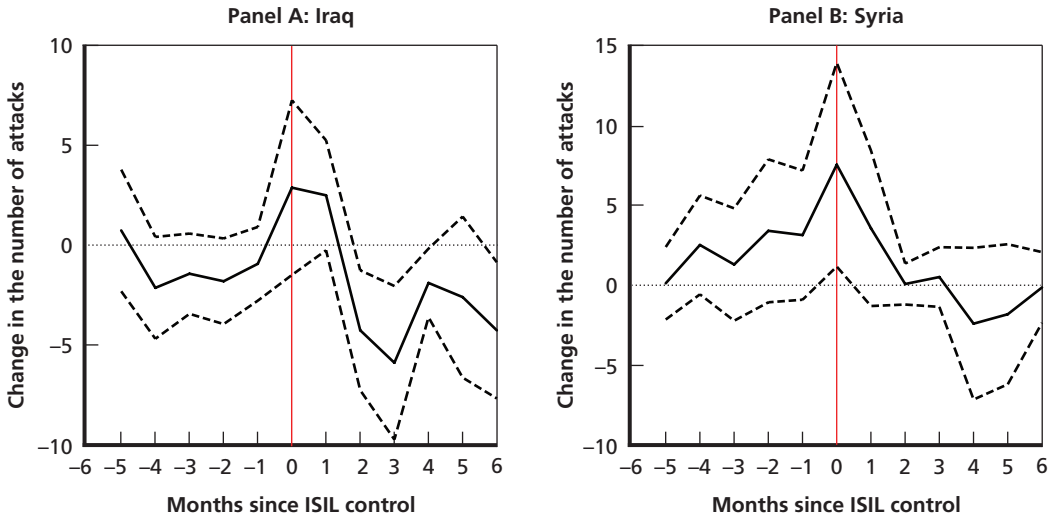
---

[17] Casualty data are missing for slightly less than 20 percent of all attacks in the database, reflecting the fact that IHS Jane's populates this database using social media and news reporting that are often incomplete.

[18] The attack data were quite heterogeneous in terms of the number of casualties per attack. The bottom 25th percentile had only one casualty, the median had three casualties, and the most-extreme attacks generated between 60 and 1,700 deaths. This latter incident, in which ISIL killed nearly 1,700 Shia recruits into the Iraqi army at a training camp near Tikrit, is known as the Camp Speicher massacre. See "IS Camp Speicher Massacre: Iraq Sentences 40 to Death," BBC News, February 18, 2016.

[19] We omit the period six months prior to ISIL departure, using that as the reference period. All estimates are shown relative to attack levels seen six months prior to ISIL's initial takeover of the city.

Figure 4.5
Levels of Violence After Islamic State Departure



SOURCE: Authors' calculations.
NOTE: The black line denotes the average change in number of attacks relative to six months prior to the end of unilateral ISIL control. Dotted black lines indicate 95-percent confidence intervals around this estimate. The red vertical line at 0 indicates the month when ISIL loses unilateral control, and the thin dotted horizontal line denotes 0 on the y-axis. If there is a statistically significant effect, the confidence band will lie entirely above or below this horizontal line and will not intersect it.
RAND *RR1970-4.5*

The Islamic State's Impact on Electricity Consumption

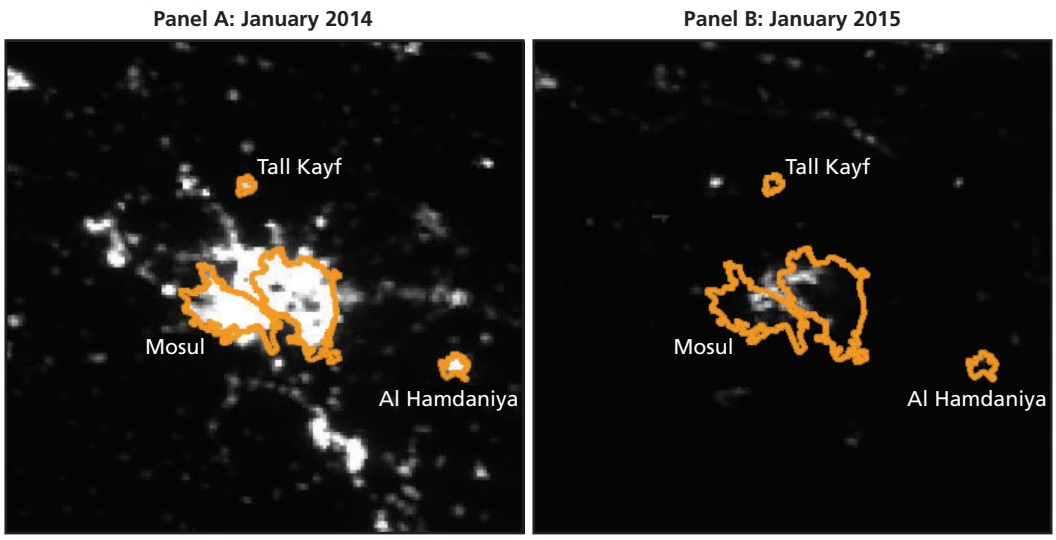
In this section, we investigate the impact that ISIL control has on electricity consumption, using data on nighttime lighting intensity. The availability of electricity is an important barometer of ISIL's ability to build a stable and economically viable caliphate. As a basic input to a variety of everyday technologies, including lights, refrigerators, air conditioners, water heaters, computers, television, and radio, electricity is crucial for modern economic activity. Without electricity, businesses can falter, economic growth can slow dramatically, people grow disconnected, and life grows uncomfortable.

Although we do not have a direct measure of the supply of electricity, we do observe lights at night, which is widely used as a measure of the amount of electricity consumed. Note, however, that our measure of consumption is an equilibrium outcome, reflecting both the *supply* of electricity from power generators and the *demand* for electricity from streetlights, cars, housing, and industrial or commercial activity. Changes in nighttime lighting can reflect both changes in the provision of electricity and changes in the demand for electricity.

In Chapter Two of this report, we discussed the different sources of electricity supply throughout Iraq and Syria, whether through a national power grid in Iraq, hydroelectric dams in Syria, or oil-based generators that are relatively ubiquitous in urban areas. Shaver and Ensign argued that, in Iraq, much of the decline in electricity consumption in ISIL-held areas is due to punitive cuts to the amount of power supplied by the Iraqi national power grid.[20] That is, when ISIL gained territory in portions of a province, the Iraqi government responded by denying those areas their usual source of electricity. In this section, it is important to disentangle the impact that ISIL's own actions have on electricity consumption versus changes in the supply of electricity that are largely outside of ISIL's direct control.

To set the stage for our empirical analysis, Figure 4.6 provides a telling example of how electricity consumption has changed dramatically under ISIL's watch. Panels A and B of this figure show nighttime lighting data for Mosul at two time periods, in January 2014 and January 2015. In these images, white areas correspond to areas with a greater intensity of nighttime lighting. In January 2014, before ISIL control, Mosul was bursting with electricity as light radiated out of the urban core of the city and into its periphery. One year later—seven months after ISIL took control of the city—Mosul

Figure 4.6
Nighttime Lighting in Mosul Before and After Islamic State Control



SOURCE: Authors' calculations. National Oceanic and Atmospheric Administration, Visible Infrared Imaging Radiometer Suite (VIIRS).
RAND *RR1970-4.6*

[20] Shaver and Ensign, 2015.

looks dark and desolate. From this one example alone, ISIL control appears clearly associated with a dramatic reduction in nighttime lighting intensity.

To examine all cities in our analysis sample in a more systematic fashion, we use a regression approach to study how changes in ISIL control are associated with changes in nighttime lighting, measured through NOAA's VIIRS satellite sensor.

Let y_{it} denote the log of the VIIRS digital number (which measures nighttime lighting intensity) variable for city *i* and time unit *t* (e.g., month, year).[21] Let T_{it} denote an indicator for ISIL control, equal to 1 if, at time *t*, ISIL has obtained uncontested control over city *i* and equal to 0 otherwise. To estimate the impact of ISIL control, we use an FE least squares panel regression in which we investigate how ISIL control affects city-level outcomes over time. This regression takes the following form:

$$y_{it} = \alpha_i + \alpha_t + \beta T_{it} + \gamma' X_{it} + \varepsilon_{it}, \qquad 4.2$$

where X_{it} is a vector of time-varying controls, α_i represents a city FE, and α_t represents a time FE. The parameter β measures how the outcome varies with changes in ISIL control. This approach controls for fixed, city-specific factors that influence both ISIL control and nighttime lighting intensity, including city-specific GDP, pre-ISIL levels of industrial infrastructure, baseline population levels of each city, and ethnic composition. It also controls for international time-varying factors that affect nighttime lighting everywhere in Iraq and Syria, including seasonal trends. Our estimates provide a constant treatment effect for one month of ISIL control.

Building on our earlier discussion of the role that violence plays in ISIL's efforts to establish control over a city in the short term, we also include time-varying controls denoted by X_{it} for the number of attacks within 5 km of each city over time, as well as a dummy variable for whether ISIL contested control of each city *i* in a given month *t*.

Table 4.2 reports regression results showing the impact that ISIL control over cities has on the nighttime lighting of those cities over time. In the first column, we pool all cities across Iraq and Syria together in one regression. We find that ISIL control has a negative and statistically significant effect on nighttime lighting in both the urban core and in the periphery surrounding the urban core. Interpreting this coefficient, we see that one month of uncontested ISIL control reduces nighttime lighting for an average urban core–month observation by 82 percent and for an average urban periphery–month observation by roughly 66 percent.[22]

These effects are massive and both statistically and economically significant. For instance, Henderson, Storeygard, and Weil related changes in national nighttime light-

[21] Note that we exclude gas flares from this measure of nighttime lighting intensity. This is important because gas flaring can be large in Iraq and Syria and seriously change the magnitude of VIIRS digital numbers.

[22] To obtain the ISIL percentage change, note that, from Equation 4.1, we have $1 \log y^{ISIL} - \log y^{NoISIL} = \beta$. Solving for the percentage change in ISIL control gives us the following:

ing intensity to changes in national GDP.[23] Using their estimate of the elasticity of nighttime lighting with respect to GDP (0.277) and extrapolating it to cities in Iraq and Syria, an 82-percent reduction in nighttime lighting in the urban core corresponds to a 22.7-percent reduction in the GDP of cities that ISIL controls.

Breaking out these effects by Iraq and Syria specifically, we find that the impact that ISIL control has on nighttime lighting in Syrian cities (column 2) is slightly smaller in magnitude than the effect of ISIL control in Iraq, although still large and significant. In Iraq, ISIL control is associated with a 90.4-percent reduction in nighttime lighting in the urban core and a 76.5-percent reduction in nighttime lighting in the urban periphery.[24]

An important question in this analysis is the extent to which changes in nighttime lighting are associated with changes in supply of electricity or demand for power resources. In column 4, we control for power supply from the Iraqi national power grid using data provided by Shaver and Ensign, 2015, via the Iraqi Ministry of Electricity. We transform these data into the log of total monthly kilowatt-hours of electricity provided to each province in Iraq and merge these province-level indicators of supply into our city-level data on nighttime lighting.[25] If we control for the massive drop in power supply from the national grid, the adverse effect that ISIL control has on electricity consumption is smaller but still large and significant.[26]

At first glance, it is counterintuitive that ISIL control can be associated with reductions in nighttime lighting beyond those caused by the near-complete shutoff of power supply from the national grid. However, it is important to note that power supply in the national grid has traditionally met only a portion of the country's overall demand for electricity.[27] This has long necessitated a wholesale reliance on private

---

$$\% \quad y = \frac{\left(y^{ISIL} - y^{NoISIL}\right)}{y^{NoISIL}} = \exp(\beta) - 1.$$

[23] Henderson, Storeygard, and Weil, 2012. Because a substantial portion of both economic activity and nighttime lighting activity takes place in urban areas, it is not unreasonable to extend the relationship between national GDP and nighttime lighting to the city level for comparison's sake.

[24] Note that, according to our examination of residual-on-residual plots, which we do not report here, outliers in the data do not drive these large effects.

[25] Note that our sample of cities shrinks because power supply data do not contain information on electricity supply in the Kurdistan Region of Iraq.

[26] The province-level data from Shaver and Ensign, 2015, provide only a coarse measure of the actual changes in supply of electricity into ISIL-held territory because ISIL control varies across city-months within a province, and these data are available only through February 2015. However, controlling for a full set of flexible province-month effects does not reduce the effect size of ISIL control, suggesting that our findings are robust nonetheless. See Shaver and Ensign, 2015.

[27] Luay al-Khatteeb and Harry Istepanian, "Turn a Light On: Electricity Sector Reform in Iraq," Brookings Doha Center, Policy Briefing, March 2015.

Table 4.2
Fixed-Effects Regression on Nighttime Lighting Intensity

	All Cities	Syria	Iraq	
Variable	**(1)**	**(2)**	**(3)**	**(4)**
Panel A: Urban core				
ISIL control	–1.715	–0.928	–2.339	–1.586
Robust standard error	(0.301)***	(0.524)*	(0.264)***	(0.430)***
Contested	–0.669	–0.608	–0.721	–0.114
Robust standard error	(0.196)***	(0.278)**	(0.263)***	(0.220)
Provincial electricity supply				0.811
Robust standard error				(0.180)***
N	4,668	2,570	2,098	878
N cities	167	92	75	64
Within R^2	0.131	0.037	0.300	0.542
ISIL percentage change	–82.0	–60.5	–90.4	–79.8
Panel B: Urban periphery				
ISIL control	–1.095	–0.636	–1.450	–0.887
Robust standard error	(0.151)***	(0.250)**	(0.154)***	(0.237)***
Contested	–0.361	–0.386	–0.273	–0.059
Robust standard error	(0.138)**	(0.225)*	(0.156)*	(0.152)
Provincial electricity supply				0.476
Robust standard error				(0.096)***
N	4,644	2,555	2,089	874
N cities	167	92	75	64
Within R^2	0.111	0.040	0.239	0.456
ISIL percentage change	–66.6	–47.1	–76.5	–58.8
City FE	Yes	Yes	Yes	Yes
Month FE	Yes	Yes	Yes	Yes
Attack controls	Yes	Yes	Yes	Yes

NOTE: Each column in each panel reports estimates from a separate regression. Column 1 shows the impact that ISIL control has on nighttime lighting in all of the cities in our study. Column 2 shows the impact that ISIL control has on nighttime lighting in Syrian cities. Column 3 shows the impact that ISIL control has on nighttime lighting in Iraqi cities, not controlling for power supply cutoffs. In column 4, we add controls for power supply from the Iraqi national power grid using data provided by Shaver and Ensign, 2015, via the Iraqi Ministry of Electricity. Significance is marked by *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. The "City FE," "Month FE," and "Attack controls" rows note that we included certain control variables in the model that controlled for cities; we just do not report those estimates.

generators throughout the country and contributed to periodic public protests during electricity shortages.[28] Our results suggest that the adverse impact that ISIL control has on nighttime lighting is much larger than mere reductions in power supplied from the national grid and has driven a decline in underlying demand for electricity inside the caliphate or shortages in the availability of generator-based power (or both).

We also find that reductions in nighttime lighting are not solely due to periods of contested control that could adversely affect economic activity; the coefficient on unilateral ISIL control is much larger than the coefficient on contested control. This is to suggest that electricity is more accessible in cities still under partial government control. This effect is driven primarily by differences in Iraq rather than Syria—where military opposition to ISIL has been provided by ISF, with follow-on stabilization support provided by the international community.

To better understand the time sensitivity of these effects, we use a duration treatment effect specification similar to that used in the "Violence and Control" section to study the evolution of nighttime lighting intensity before and after ISIL takes control.[29] These results are presented in Figure 4.7. For both Iraq and Syria, nighttime lighting intensity falls dramatically in the two months before ISIL control, and it levels off to a reduced amount after ISIL takes over. The resulting level of nighttime lighting after ISIL takeover is lower in Iraq than in Syria, on average. But in both cases, the negative effects that ISIL control has on electricity consumption are large and statistically significant.[30]

In Figure 4.8, we use a similar duration treatment effect specification to assess whether nighttime lighting intensity increases after ISIL loses control of a city.[31] This figure asks the question, how long does it take for a city's nighttime lighting to return to its pre-ISIL levels? In Iraq, nighttime lighting increases steadily after cities are liberated from ISIL control, but it takes roughly four months to return to pre-ISIL levels. In Syria, ISIL's adverse impact on nighttime lighting seems to be persistent and does not recover in any statistically significant fashion.

In summary, we see that ISIL control is associated with a dramatic reduction in nighttime lighting and electricity consumption. To the extent that this reflects ISIL's ability to provide electricity for the cities it governs through fuel for generators or access to water or petroleum-based power generation, this represents a massive failure

---

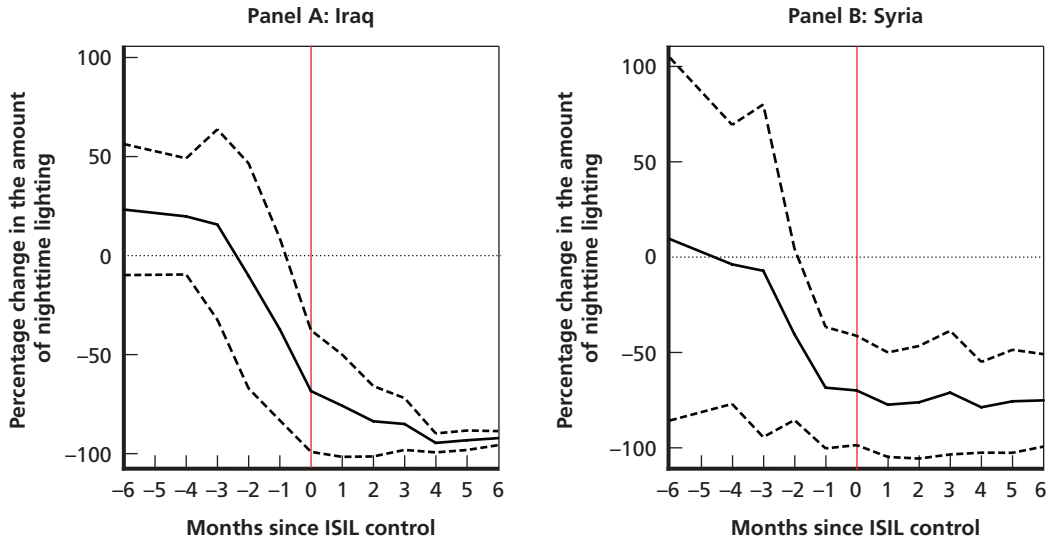
[28] Suadad al-Salhy, "Shortage of Electricity in Iraq Cripples Economy, Sparks Protests," *Middle East Eye*, August 6, 2015, last update August 7, 2015.

[29] Instead of reporting the coefficient estimates from Equation 4.1 where y_{it} is the log of nighttime lighting, we report the transformation to then calculate the percentage-change effect from ISIL control.

[30] A similar, though less dramatic, trend in nighttime lighting in the urban peripheries of Iraq and Syria can also be seen (not shown).

[31] We omit the period six months prior to ISIL departure, using that as the reference group. All estimates are shown relative to nighttime lighting levels seen six months prior to ISIL's initial takeover of the city.

Figure 4.7
Duration Treatment Effects of Islamic State Arrival: Nighttime Lighting, Urban Core



SOURCE: Authors' calculations.
NOTE: The black line denotes the average change in nighttime lighting relative to six months prior to the establishment of unilateral ISIL control. Dotted black lines indicate 95-percent confidence intervals around this estimate. The red vertical line at 0 indicates the month when ISIL control is established, and the thin dotted horizontal line denotes 0 on the y-axis. If there is a statistically significant effect, the confidence band will lie entirely above or below this horizontal line and will not intersect it.
RAND *RR1970-4.7*

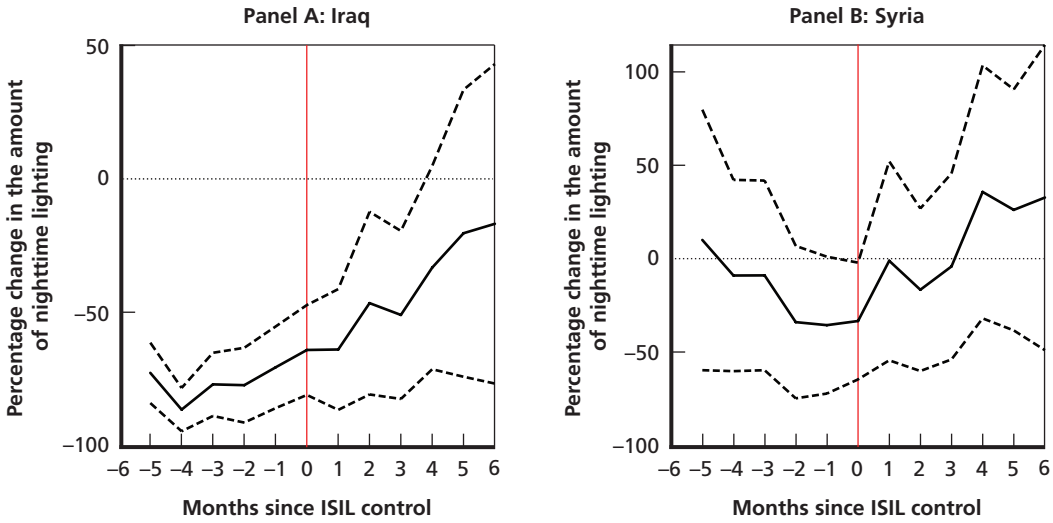
of governance. However, an important question is whether the reduction in nighttime lighting reflects reductions in supply or demand. It could be that ISIL control is associated with a massive departure of people from cities. As a result, in the next section, we investigate the impact that ISIL control has on population movements.

The Islamic State's Impact on Population Movements

As discussed in Chapter Two, roughly 11 million Syrians have been displaced by conflict since 2011, along with some 2.5 million Iraqis.[32] Few estimates have attempted to disaggregate the number of refugees and IDPs out of the larger conflict that are directly attributable to the Islamic State. At the same time, once in control of a city, ISIL is known to enforce strict population restrictions that are designed to prevent out-migration. The true effect that ISIL control has on city-level populations remains a difficult and open question, as does the timing of its impacts.

[32] Kulaksiz and Karasapan, 2015; Culbertson and Constant, 2015.

Figure 4.8
Duration Treatment Effects of Islamic State Departure: Nighttime Lighting, Urban Core



SOURCE: Authors' calculations.
NOTE: The black line denotes the average change in nighttime lighting relative to five months prior to the final month of unilateral ISIL control. Dotted black lines indicate 95-percent confidence intervals around this estimate. The red vertical line at 0 indicates the final month of ISIL control, and the thin dotted horizontal line denotes 0 on the y-axis. If there is a statistically significant effect, the confidence band will lie entirely above or below this horizontal line, and will not intersect it.
RAND *RR1970-4.8*

We use LandScan, a data set produced by ORNL, to measure the population density of each 1 km–by–1 km grid square in Iraq and Syria. Although we possess versions of this data set that measure populations at several time points throughout 2015 and 2016, the bulk of ISIL's territorial gains occurred prior to these data sets in mid- to late 2014 (as shown in Figure 4.2). As such, we lack sufficient temporal variation to link the exact timing of refugee outflows from ISIL-held territory with ISIL takeover of the cities in our full 167-city sample.[33]

[33] We attempted to estimate regression specifications that looked for whether changes in ISIL control were associated with changes in population movements across the different quarterly LandScan data sets. However, these regressions did not find any robust differences over time based on ISIL control. As discussed earlier, we believe that this is because we lack LandScan population data from 2014 immediately prior to when ISIL first captured the majority of its territory in Iraq and Syria. As such, variation between each wave of LandScan data captured in 2015 and 2016 shows more marginal changes in population that fail to demonstrate the true impact of ISIL takeover. Alternatively, cities could experience different rates of repopulation after ISIL leaves a city, which clouds the magnitude of effects measured via a panel approach using LandScan data. Given these confounding factors, we choose to focus on the long-difference specification showing changes between 2008 populations and 2016 populations of each city. Further research, with better population data, could attempt to distinguish between these competing explanations.

Instead, we focus on two data points alone to assess whether cities experiencing any ISIL control since 2013 are more prone to migrant outflows than non-ISIL cities. Our first data point is from LandScan 2008, obviously well before ISIL took control of cities in our sample. Our second data point is from March 2016, well after ISIL had either established itself in cities that remain under its control, or had been forced out of the city by rival armed groups.

Table 4.3 displays summary statistics of the percent changes in population over the 2008–2016 time period. The first column focuses on all cities, the second column focuses only on Iraq, and the third column focuses on Syria. We can see that overall, cities in Iraq and Syria experienced a 10.3 percent reduction in population. However, in Iraq, city populations tended to grow, on average, while in Syria, they tended to decline by an average of 26.3 percent. Looking at these differences by ISIL control status, we see that cities experiencing ISIL control tended to have an average reduction in population by 32.2 percent, with slightly higher population declines in Iraq than in Syria. Cities that did not have any experience of ISIL control tended to grow positively in Iraq and decline less negatively in Syria.

The above statistics suggest that ISIL control has had a strong negative effect on population growth. However, this analysis does not control for any characteristics of cities that could also explain population changes. To better estimate the impact that ISIL control has on population changes, we estimate a simple, cross-sectional regression equation, given by the following:

$$y_{i,2016} = \alpha_p + \beta T_i + \pi C_i + \theta y_{i,2008} + \gamma' X_i + \varepsilon_i, \qquad 4.3$$

where $y_{i,2016}$ denotes the log of 2016 population, α_p denotes a province effect, $y_{i,2008}$ denotes the log of 2008 population; X_i is a vector of city-specific variables, including the total number of attacks experienced and province FE; and ε_i is a mean-zero error term. The variable T_i is an indicator for whether, between 2013 and 2016, city *i* had experienced at least nine months of unilateral ISIL control. The variable C_i is another indicator for whether, between 2013 and 2016, city *i* had either experienced at least one to eight months of ISIL control or was contested. These definitions are mutually exclusive, so that, for a city, C_i and T_i cannot both be equal to 1. The parameter β measures the effect of unilateral ISIL control relative to a "peaceful" city that had no direct experience with ISIL activity, while the parameter π measures a similar effect of short-term or contested control.[34]

[34] In practice, all the cities ISIL held for nine or more months were held for lengthy and uncontested periods of time, rather than in short and distributed chunks of time. As a result, this approach cleanly delineates between cities experiencing long-term uncontested stints of ISIL control from those experiencing either short-term or intermittent exposures to ISIL governance.

Table 4.3
Percentage Changes in Population, 2008–2016

Control Status	All Cities (1)	Iraq (2)	Syria (3)
Overall	–10.343	9.291	–26.349
Standard error	(74.156)	(67.396)	(75.901)
N	167	75	92
Any ISIL control	–32.152	–36.340	–29.450
Standard error	(85.485)	(66.963)	(96.452)
N	52	20	31
No ISIL control	–0.755	25.883	–24.774
Standard error	(66.760)	(59.959)	(63.794)
N	116	55	61

Table 4.4 displays the results. We measure population values from LandScan in two different ways. In columns 1 through 3, we use the log of LandScan population as the dependent variable in order to measure changes in the overall population of cities subject to ISIL control. In columns 4 through 6, we focus on the population of each city *i* as a share of the total population of its larger administrative district. This allows us to examine potential urbanization or deurbanization as a result of ISIL control of cities—if people are moving out of urban areas and into rural ones as a result of ISIL control, we should expect to see negative coefficients.[35]

Overall, we estimate that ISIL control is associated with a 36.0-percent reduction in city-level populations, on average across all cities in Iraq and Syria based on the urban core. This is a sizable and statistically significant effect. However, contested control does not seem to have a significant impact on population levels; that said, the point estimates on π and their standard errors are large, and we cannot reject the hypothesis that both β and π are equal in any specification. This suggests that ISIL's impact on IDP flows remains high, whether it controlled a city for an extended period, only briefly, or merely contested a city.

When we restrict the sample to look at separate effects of ISIL control on cities in Iraq and Syria in columns 2 through 3 and 5 through 6, our sample sizes fall and standard errors increase. As a result, these estimates often become insignificant. However, the effect magnitudes are similar, suggesting that we simply might not have enough

[35] This specification also accounts for the methods used to derive the LandScan population estimates, which combine satellite-derived data sources with ground-based data collection, including from census data and nongovernmental-organization reporting. Given that ground-based population estimates typically occur at the district level or above, this approach controls for the fact that district-level population totals could remain artificially constant in LandScan estimates, but the spatial distribution of population within a district could change.

Table 4.4
Long-Difference Regression Results: Population Levels in 2008 and 2016

	Log Population			Log Share of City in District Population		
Variable	**All Cities (1)**	**Iraq (2)**	**Syria (3)**	**All Cities (4)**	**Iraq (5)**	**Syria (6)**
Panel A: Urban core						
Long-term ISIL control	−0.446	−0.558	−0.253	−0.365	−0.203	−0.476
Robust standard error	(0.219)***	(0.585)	(0.288)	(0.206)*	(0.351)	(0.237)**
Short-term or contested ISIL control	−0.374	−0.222	−0.333	−0.301	−0.020	−0.508
Robust standard error	(0.234)	(0.580)	(0.467)	(0.271)	(0.370)	(0.389)*
N	167	75	92	167	75	92
Within R^2	0.916	0.887	0.931	0.941	0.923	0.950
ISIL percentage change	−36.0	−42.8	−22.4	−30.6	−18.4	−37.8
Contested percentage change	−31.2	−19.9	−28.3	−26.0	−2.0	−39.8
Panel B: Periphery						
Long-term ISIL control	−0.366	−0.413	−0.304	−0.327	−0.106	−0.511
Robust standard error	(0.170)**	(0.284)	(0.273)	(0.123)***	(0.165)	(0.182)***
Short-term or contested ISIL control	−0.236	−0.097	−0.237	−0.235	−0.022	−0.405
Robust standard error	(0.182)	(0.422)	(0.360)	(0.187)	(0.232)	(0.284)
N	167	75	92	167	75	92
Within R^2	0.653	0.651	0.640	0.806	0.782	0.839
ISIL percentage change	−30.6	−33.8	−26.2	−27.9	−10.0	−40.0
Contested percentage change	−21.0	−9.3	−21.1	−21.0	−2.2	−33.3
Province FE	Yes	Yes	Yes	Yes	Yes	Yes

NOTE: Each column in each panel reports estimates from a separate regression. All regressions control for the log of 2008 population and the number of attacks experienced in the city. Significance is marked by *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

power to detect effects. Nevertheless, there is some reason to believe that these population effects are driven more by IDP outflows in Syrian cities than from cities in Iraq.[36]

Turning to the periphery (panel B), we find that, in the district share specifications, ISIL control results in a 30.6-percent reduction in the populations of peripheral areas of affected cities, with most of this effect coming from Syria. Although the other point estimates are not significant, the coefficients remain consistently negative, and the magnitudes of the ISIL effect on population sizes are comparable, ranging between 2 and 33 percent.

In general, although these results lack robustness because of small sample sizes and minimal temporal variation, they suggest that ISIL has indeed had a substantial impact on city-level populations. These results enhance our understanding of the dramatic decline in nighttime lighting seen earlier in this chapter. Although some portion of the dramatic reductions in nighttime lighting are due to reductions in power supply, demand for electricity has clearly fallen in ISIL-controlled cities as populations move away.

The Islamic State's Impact on Agricultural Activity

The above results capture ISIL's impact on economic activity and population movements in urban areas. In this section, we investigate what has happened to agricultural activity in the peripheral areas surrounding ISIL-controlled cities. To do so, we use a traditional panel data FE regression specification. We code ISIL control for each city on a yearly basis, based on whether ISIL had unilateral control of the city for at least nine months in a given year, whether it controlled some part of the city for less than nine months in a given year, or whether it had no control. We then regress the average NDVI at the city-year level on these time-varying indicators for city status. NDVI is measured using the USGS Landsat satellites and is a proxy for overall agricultural activity. Because we run these regressions at the city-year level, we include year and city FE in these specifications.[37] We regress NDVI of the urban periphery of each city (and not its core) in order to capture outlying agricultural lands most directly associated with each city.

Table 4.5 reports FE regression results for yearly NDVI on ISIL control. Overall, there is no statistically significant contemporaneous effect of ISIL long-term control or short-term control on NDVI, as shown in column 1. This is not unexpected. NDVI measures the health of vegetation, and agricultural outcomes typically respond with a

[36] These results are also robust to an instrumental variable specification (not reported), in which we instrument ISIL control with the distance of city *i* to Raqqah.

[37] Although NDVI is available at the city-biweek level, we collapse the NDVI to city-year averages, for this analysis. This is because monthly fluctuations in NDVI often arise from cloud cover and weather patterns, while annual NDVI is much more sensitive to agricultural inputs.

Table 4.5
Fixed-Effects Regression Results: Average Annual Normalized Difference Vegetation Index

	All Cities		Iraq	Syria
Variable	**(1)**	**(2)**	**(3)**	**(4)**
Long-term ISIL control	0.009			
Robust standard error	(0.010)			
Long-term ISIL control, lag 1 year	0.004	–0.031	–0.008	–0.042
Robust standard error	(0.007)	(0.010)***	(0.013)	(0.015)***
Short-term ISIL control, lag 1 year		–0.015	0.011	–0.018
Robust standard error		(0.005)***	(0.008)	(0.006)***
N	501	501	225	276
N cities	167	167	75	92
Within R^2	0.008	0.030	0.010	0.062
Percentage of SD effect (ISIL control)	9.7	–35.1	–8.8	–47.4
Percentage of SD effect (contested)	4.4	–17.1	–12.2	–21.0
City FE	Yes	Yes	Yes	Yes
Month FE	Yes	Yes	Yes	Yes
Attack controls	Yes	Yes	Yes	Yes

NOTE: Each specification also includes data on attacks in each city as a control for potential violence-induced changes in agricultural activity, but coefficients are not reported. Each column in each panel reports estimates from a separate regression. Significance is marked by *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

time lag to changes in the environment that take place in the present. If ISIL were to affect agricultural production through changes in water supply or seed provision, as discussed in Chapter Two, the adverse effects of these actions might not occur instantaneously. Instead, they would appear months after ISIL had already seized control of a city and its outlying agricultural areas.

To examine this possibility, we lagged our two ISIL control indicators backward by one year so that we can measure the association between agricultural vegetation today and ISIL's control over territory in the past. In column 2, we find that both lagged ISIL long-term control and short-term control have a statistically significant and negative effect on NDVI in the periphery of urban areas. Cities that were contested or under short-term control experienced a reduction of 17.1 percent of one standard deviation (SD) in average annual NDVI, while cities under sustained ISIL control experienced a 35.1-percent SD reduction.

To interpret the magnitude of these effects, we make use of a relationship between wheat yields and NDVI estimated in Sultana et al., 2014, which focuses on data from Pakistan.[38] Wheat yield is a good benchmark because, in both Iraq and Syria, wheat and barley are the most-prevalent crops in areas of each country controlled by ISIL.[39] Sultana et al., 2014, uses data from the 2008–2010 growing seasons to estimate a positive, linear relationship between NDVI and wheat yield, measured in tons per hectare. These authors found that wheat yield is linearly related to NDVI, with a regression coefficient of between 3.63 and 8.72, depending on the year of data they used. Our baseline point estimates on the impact of a year of ISIL control suggest that control reduces NDVI by 0.03. If we extrapolate the Sultana et al., 2014, regression estimates to Iraq and Syria, we find that one year of control reduces next year's wheat yields by 0.11 to 0.26 tons per hectare. From the U.S. Department of Agriculture's Foreign Agricultural Service, Syria had an average wheat yield of approximately 1.3 tons per hectare, so this reduction in wheat yields represents about a 10- to 20-percent reduction in agricultural productivity. This is both an economically and statistically significant impact.

Note that columns 3 and 4 of Table 4.5 show that the overall effect is almost solely driven by reductions in agricultural activity in Syria but not in Iraq. Reassuringly, these results are consistent with those in Jaafar and Woertz, 2016, in which the authors found similar, moderately sized effects of ISIL control on agricultural output in Syria (but not for Iraq). They argue that ISIL did not have a larger impact because of improved rainfall in 2015 and because ISIL has taxed agriculture for revenue purposes.[40]

Of note is that our estimates suggest that long-term unilateral ISIL control had a larger impact on agricultural production than short-term contested control, lagged one year later. However, given the yearly average approach used to produce these estimates, our estimates for short-term contested control are biased downward by any positive impact of non-ISIL control throughout the remainder of each year.

---

[38] Syeda Refat Sultana, Amjed Ali, Ashfaq Ahmad, Muhammad Mubeen, M. Zia-Ul-Haq, Shakeel Ahmad, Sezai Ercisli, and Hawa Z. E. Jaafar, "Normalized Difference Vegetation Index as a Tool for Wheat Yield Estimation: A Case Study from Faisalabad, Pakistan," *Scientific World Journal*, Vol. 2014, 2014, art. 725326.

[39] Paolo Lucani and Maurice Saade, *Iraq: Agriculture Sector Note*, Food and Agriculture Organization of the United Nations/World Bank Cooperative Programme, 2012; Wadid Erian, Bassem Katlan, and Ouldbdey Babah, *Drought Vulnerability in the Arab Region: Special Case Study—Syria*, United Nations Office for Disaster Risk Reduction, Global Assessment Report on Disaster Risk Reduction, 2010.

[40] Jaafar and Woertz, 2016. Note that we cannot directly compare our estimates with those in Jaafar and Woertz, 2016, because those authors use the Enhanced Vegetation Index rather than NDVI.

Conclusion

To set a baseline for our understanding of ISIL's economic impact, we first diagnosed how levels of violence, measured via attacks conducted by the Islamic State, ebb and flow prior to ISIL takeover of cities within its territory. Through regression analysis, we find that ISIL takeover is associated with a significant increase in the number of attacks in the months leading up to full ISIL control but that violence tends to taper off over time as ISIL establishes its foothold in a new city. When a city is liberated from the Islamic State, the number of ISIL attacks in the city falls dramatically in Iraq but does not change significantly post-liberation in Syria. Both these findings suggest that the economic impact of Islamic State violence could predate its actual takeover of a city and, in some cases, linger after liberation.

From data on nighttime lighting intensity, we estimate using FE regression that ISIL control of cities in Iraq and Syria is associated with a massive decline in electricity consumption. In Iraq, electricity consumption falls by more than 80 percent in ISIL-controlled cities, while, in Syria, electricity consumption falls by 61 percent. These effects are economically and statistically significant, and the timing of these drops in electricity consumption is closely correlated with when ISIL first establishes a foothold in a given city. Although this effect in Iraq is partially driven by Iraqi government efforts to cut off electricity supply to ISIL-held areas in 2014, our analysis suggests that the impact of ISIL's takeover of a given city far outweighs the impact of these power supply cutoffs. Furthermore, we find that ISIL's impact on electricity consumption through nighttime lighting was much larger when the group was in complete control of a city. Combined, these effects indicate that the supply of fuel for generators has declined significantly under Islamic State control. This is likely a direct product of efforts to deny ISIL-held areas access to energy resources and potentially evidence that the group struggled to bring to bear its own petroleum reserves to power generators (relative to other actors with access to generator fuel). Alternatively, it could suggest that the group never prioritized the provision of electricity and fuel to people within its own territory.

Reductions in demand for electricity could also be driven by flows of refugees or IDPs from cities affected by the Islamic State. To this end, we find that ISIL control is associated with an average 36-percent reduction in the population of a city's urban area and an average 31-percent reduction in a city's larger periphery based on FE regression. Although these effects are difficult to estimate precisely because of great heterogeneity in how population flows have responded to ISIL takeover across the region, the magnitudes are robust and similar across different specifications. Of note, we find no evidence that unilateral control produced more-significant IDP outflows than those produced by contested control.

We also find significant negative effects of ISIL control on agricultural productivity in areas surrounding ISIL-held cities based on FE regression estimates. The timing

of these effects operates with a lag, suggesting that ISIL control has a strongly negative impact on crop production several months into the future. Overall, we find that ISIL control resulted in a statistically significant 10- to 20-percent reduction in crop yields across ISIL-held territory, primarily in Syria and not in Iraq. We find marginal evidence that unilateral ISIL control produced larger disruptions to agriculture than contested control, although these effects are difficult to precisely estimate given the time lags inherent in crop harvests.

In summary, we have demonstrated that ISIL control is associated with statistically significant and economically significant reductions in economic activity, measured by nighttime lighting, population, and NDVI, a proxy for agricultural activity. This chapter has focused on ISIL's average effect on cities in Iraq and Syria, choosing breadth over depth. In the next several chapters, we drill down, in detail, on how ISIL control has disrupted the experiences of five cities.

CHAPTER FIVE

Case Study Approach

In this chapter, we lay out the methodological approach used in our case studies of ISIL's economic impact on Mosul, Raqqah, Ramadi, Deir ez-Zor, and Tikrit. The main purpose of these case studies is to attempt to directly connect ISIL's governance over a given city with its economic impact. In-depth analysis of each city individually allows us to contextualize the findings presented in Chapter Four. Rather than merely assert that nighttime lighting has fallen on average, we can correlate these changes with known conditions on the ground that might have affected the supply or demand for energy resources. We can more precisely estimate the timing of population outflows from formerly ISIL-held areas post-liberation, and we can trace different crop production cycles in different agricultural areas. Furthermore, we can leverage the significant granularity and specificity associated with commercial high-resolution imagery to understand ISIL's impact *within* and not just *across* the cities it controls. This chapter proceeds by laying out the rationale for analyzing our five cities of interest, followed by a discussion of our analytic methodology within each case study.

City Selection

Of the 167 cities included in our cross-city sample used in Chapter Four, 51 cities experienced some period of contested or unilateral Islamic State control. To capture variation in ISIL's control and potential impact on local economies, we choose five cities—Mosul, Raqqah, Ramadi, Deir ez-Zor, and Tikrit—as representative of this larger subset. In Mosul and Raqqah, ISIL had largely uncontested control ever since taking over these cities through mid-2016, so changes in economic activity should be more a result of ISIL's governance and less a result of other confounding factors. Both cities also represent strategic strongholds for ISIL, with Raqqah as its primary capital and Mosul as its de facto second city and capital in Iraq.

In Deir ez-Zor and Ramadi, ISIL controlled portions of these cities at the same time as other regime or opposition elements and fought violently to establish its footholds in each city. Particularly for Deir ez-Zor, we can uniquely measure how economic activity differs in certain areas of the city over time, based on differences in

control on a neighborhood-by-neighborhood basis. For Ramadi, ISIL contested control of the city for nearly a year and a half before it briefly held the city unilaterally at the end of 2015. As such, it represents a chance to measure the impact that ISIL control has over an area where it invested significant resources but could not fully develop its governing apparatus. Additionally, measuring Ramadi's economic recovery after the significant damage wrought by fighting to liberate the city helps to understand how local economies recover in the short run after ISIL leaves town.

ISIL forces similarly held Tikrit for a brief period of time, from the summer of 2014 through March 2015. However, the city never represented a strategic priority for ISIL, and its forces never fully developed governance structures or significantly intervened in the local economy beyond more coercive violence leading to their eventual withdrawal. The ensuing recovery and reconstruction of the city was the first litmus test for the GoI's ability to reassert control over an area liberated from the Islamic State. With a full year and a half after the city was liberated contained in our data sets, Tikrit represents the best example for understanding a city's ability to fully recover from Islamic State rule.

Case Study Structure and Methodology

Each case study follows a roughly identical structure intended to facilitate comparisons across cities more easily. The first section of each case study consists of a discussion of the history of ISIL's control and contestation of each city, as well as an assessment of each city's strategic importance to the group. These serve to help narrate how changes in economic activity over time could be affected by the group's priorities for controlling the city or level of effort required to conquer or contest each city. We then proceed with a discussion of the city's prewar economy and key infrastructure, followed by a detailed review of existing evidence of ISIL's economic governance over each city. These sections provide clear, city-specific hypotheses and set the stage for the main contribution of this report, our panel of satellite-based indicators of economic activity within each city.

The main body of each case study then analyzes each indicator over time for each city, beginning with nighttime lighting and followed in order by population, agricultural activity, industrial activity, market and commercial activity (including commercial vehicle counts), and building damage. For the majority of these measures, we first present a time series or static estimates of the average or total value of each indicator within the urban core of each city. This excludes agricultural activity, for which we measure the total intensity of vegetation within the 5-km periphery of each city.

In many cases, we delve more deeply into each of these metrics within each city to more fully understand how economic activity and ISIL governance vary in the vicinity of key infrastructure, such as hospitals, markets, industrial areas, and mosques. At times, we present, for instance, the average nighttime lighting value across all of a given

city's hospitals relative to its markets.[1] In other instances, we focus on specific hospitals or markets to try to isolate the exact pieces of infrastructure in each city affected by ISIL governance. For Mosul, we utilize an existing map of the city's ethnic populations to understand how economic activity varies across Sunni, Kurdish, Turkmen, and Assyrian neighborhoods. In Deir ez-Zor, which ISIL has contested on a neighborhood-by-neighborhood basis for some time, we use publicly available estimates of specific areas of ISIL control to compare ISIL-held, contested, and regime-held areas of the city.

Presupposed by our effort to understand ISIL's economic impact within these five cities is an ability to accurately identify key infrastructure and points of interest, such as markets, hospitals, mosques, and industrial areas. We rely on a variety of sources to identify and validate these points of interest—ranging from open-source mapping sites, such as OpenStreetMap and Wikimapia, to Google Maps and Google Earth, as well as published maps of unclassified key infrastructure within Mosul dating back to the U.S. Army's operations in the city during Operation Iraqi Freedom and informal consultations with former U.S. military personnel deployed to these cities.[2] Finally, we identified many key points of interest using manual analysis of high-resolution imagery from DigitalGlobe, both historical imagery from prior to ISIL's presence in each city and more-recent snapshots in time.[3]

Once we identified the points of interest, we made efforts to validate each point of interest or piece of critical infrastructure with other sources in Arabic and English, where feasible. One important component of this process was mapping physical locations of certain markets and commercial facilities with the actual name of the facilities. These linkages allowed for more-detailed analysis of changes in economic activity at these locations over time, given the ability to correlate these changes with media reporting on key infrastructure within these cities. Table 5.1 presents the number of specific points of interest identified for each city by type.

Note that there are obvious concerns about whether these points of interest are comprehensive within each city. Furthermore, it should be noted that not all industrial facilities can be accurately identified through visual analysis of imagery alone and that we could have missed certain markets that occur only at a certain time of day or on a certain day of the week. For these reasons, we take a conservative approach throughout the case studies against overstating the significance of differences found across these

---

[1] See Appendix B for a discussion of the methodological considerations employed in this study to analyze moderate-resolution remote sensing data at significant levels of subcity granularity.

[2] National Imagery and Mapping Agency, "Al Mawsil (Mosul), Iraq," Bethesda, Md., April 2003.

[3] To facilitate geospatial analysis with our remote sensing data, we drew the boundaries of each point of interest manually using geospatial mapping software. For many markets, to facilitate more-precise crowd-sourced estimates of activity, we drew multiple polygons if the market itself was very large (such as the Bab al-Toob market in Mosul). When presenting results, we then collapse these polygons and average market activity estimates across unique points of interest.

Table 5.1
Key Points of Interest Identified, by City

Type of Point of Interest	Mosul	Raqqah	Ramadi	Deir ez-Zor	Tikrit
Hospital	8	6	8	4	3
Industrial area	24	12	15	7	11
Market	18	19	12	14	10
Mosque	106	22	29	28	18

SOURCES: Authors' estimates informed by Wikimapia, Google Maps, Google Earth; National Imagery and Mapping Agency, 2003.

different types of infrastructure. However, we believe that the multitude of inputs compiled to create this roster makes this the most comprehensive list of economic infrastructure publicly available for each city at the time of this analysis.

CHAPTER SIX

The Islamic State in Mosul

Mosul is the largest Sunni city in Iraq, with nearly 2 million residents prior to the Islamic State's takeover in June 2014. Mosul has long held strategic importance to ISIL and its predecessors, and the group is known to have operated underground in the city prior to taking total control in 2014. The city's economy is more diverse and developed than other cities once held by the Islamic State, with an active manufacturing and industrial sector, airport, and major regional markets. As such, it has been a critical component of ISIL's extortion and taxation revenue streams, which help to fund the group's military operations and bureaucracy. Our analysis of Mosul's economy under the Islamic State precedes the beginning of operations to liberate the city in the fall of 2016. Therefore, it focuses on the effects of ISIL's uncontested control of the city for more than two years since it first conquered Mosul in June 2014.

Overall, this chapter paints a detailed portrait of the Islamic State's attempts to govern, profit from, and sustain local economic activity in Mosul. We find that ISIL control had a relatively modest impact on the city's markets and commercial economy, which continued to function at pre-ISIL levels, but a larger detrimental impact on the city's electricity and rates of population outflow. In the rest of the chapter, we explore Mosul's strategic importance to the Islamic State, the group's efforts to control the city, and its prewar economy. We then discuss how the group has sought to directly govern and influence Mosul's citizens and economic infrastructure while in control of the city, and we conclude with a complete discussion of our satellite-based indicators of economic activity.

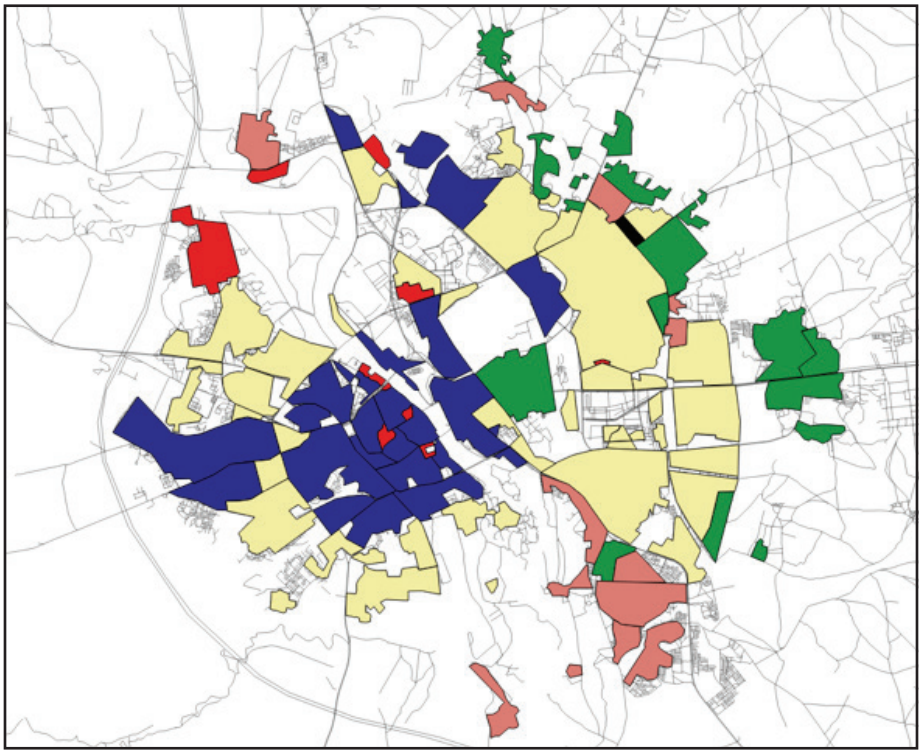
Mosul's Importance to the Islamic State

The cities of Mosul and Raqqah are the Islamic State's capitals in Iraq and Syria, respectively. The stranglehold ISIL placed on each city cannot be overstated. Mosul was not the only city that the group targeted in its summer 2014 offensive across Iraq, but it was the group's most important strategic gain. In a matter of days, ISIL seized sovereign control over the city in June 2014 and used the victory as a symbol to legitimize ISIL leader Abu Bakr al-Baghdadi's declaration of a global caliphate. ISIL

organized a relatively expansive bureaucratic state in Mosul and exerted uncontested control over the city since its capture in 2014 until operations to liberate the city began in October 2016. To this extent, Mosul provides a clear opportunity to identify the group's economic impact in its most strategically important Iraqi city.

ISIL viewed Mosul as strategically critical to its vision of a global caliphate. Mosul's size and demographic composition make it a natural home for a Sunni extremist group. With a prewar population of nearly 2 million, it is the largest Sunni city in the Shia-governed Iraqi state. Although Sunni-predominant, Mosul's population also includes significant numbers of ethnic minorities spread across the city. Figure 6.1 maps the neighborhood-level disposition of ethnicities across the city. Sunni areas are largely concentrated on the western side of the Tigris River, while Kurdish areas are largely in the northern and eastern sections of the city. A large proportion of the city lives in areas of mixed ethnicity.

Figure 6.1
Ethnic Laydown of Mosul



SOURCE: Michael Izady, "Mosul and Environs: Ethnic Composition, 2013," Columbia University Gulf 2000 Project, 2017.
NOTE: Red areas indicate Assyrian Christian neighborhoods, green areas indicate Kurdish neighborhoods, light red areas are Turkmen, black areas are Shia, and purple areas are Sunni. Yellow areas indicate neighborhoods with mixed ethnicity.
RAND *RR1970-6.1*

Mosul was also a prized target for the group because of its predecessor's expansive presence in the city in the early years of AQI and ISI. AQI and ISI relocated their headquarters from Baqubah to Mosul in 2008 under heavy pressure from coalition forces and Sunni Awakening forces in Diyala and Anbar provinces. Although AQI and ISI fighters were mostly forced underground by 2012, the group still operated freely as a mafia-like organization able to shape conditions in Mosul for its ultimate return. By 2014, the group now known as the Islamic State had significant local knowledge of Mosul and preexisting ties to parts of the Sunni Arab community that would prove beneficial upon its return.

Perhaps most importantly, Mosul's capture was strategically important to the group for the manpower and financial resources it provided to ISIL. The city offered the potential for ISIL to co-opt and solicit local recruits from its nearly 2 million inhabitants in the core of the city and outlying areas. It also allowed the group a chance to tax and extort the significant wealth that comes with such a large population.

Mosul's Economy Before the Islamic State

Mosul's economy rapidly weakened in the years before ISIL's arrival. Mosul is the provincial capital of Ninewa, and approximately 65 percent of Ninewa's population lived in Mosul before ISIL's arrival.[1] Ninewa's poverty rate surged more than 11 percentage points from 20.5 to 31.9 percent between 2007 and 2012. This increase was particularly dramatic as the poverty rate fell in the country overall by around 2 percentage points.[2] By 2012, the province accounted for nearly 16 percent of all the poor in Iraq, a dramatic rise from 8 percent in 2007.[3] The high levels of poverty seem to be driven by unusually low income levels rather than unemployment.[4] Labor force participation is among the highest and the unemployment among the lowest in Iraq.[5]

Agricultural production dominates Ninewa's economy, with an estimated 50 percent of the province's GDP coming from agriculture.[6] Mosul itself houses key regional economic infrastructure, including a major station on Iraq's north–south rail line, a major airport, and the University of Mosul with around 24,000 enrolled students

---

1 In 2008, one report notes, the population of Mosul was 1.8 million and the population of all of Ninewa was 2.8 million. See Republic of Iraq, National Investment Commission, *Investment Overview of Iraq*, undated.

2 World Bank, *The Unfulfilled Promise of Oil and Growth: Poverty, Inclusion and Welfare in Iraq, 2007–2012*, World Bank Group, Poverty Global Practice, November 7, 2014, Table A 2.1.

3 World Bank, 2014, Table A 2.1.

4 UNDP in Iraq, *Iraq Human Development Report 2014: Iraqi Youth Challenges and Opportunities*, 2014, Table 14.

5 UNDP in Iraq, 2014, Table 13.

6 Republic of Iraq, undated.

before the war.[7] And Mosul-based textile firms employ thousands, with one firm once employing 2,400 people.[8] Cement is another major industry, with the Mosul-based Northern Cement State Company employing several hundred workers in Mosul itself and nearly 2,000 more at production facilities in nearby Badush, Sinjar, and Hammam al-Alil.[9] When at full capacity, the Qayyarah oil refinery, the Middle East's largest asphalt plant, employs as many as 450 people at its facility to the south of Mosul.[10]

Figure 6.2 provides a graphical overview of Mosul's key economic infrastructure. In this figure, color-coded dots represent banks, gas stations, hospitals, power facilities, and water treatment facilities; shaded areas indicate the remaining urban infrastructure, including the overall urban populated areas of Mosul; and arrows indicate proximity to other key industrial activity (e.g., cement, oil refinery). Most economic infrastructure is located near the Tigris River, with the majority of transportation infrastructure to the west of the river, while the university and several key markets are east of the river. Key markets, the University of Mosul and the medical college, and the key transport infrastructure (e.g., bus, train, airport) are labeled with text.

The Islamic State's Governance over Mosul's Economy

This section discusses ISIL's takeover and ensuing control over Mosul and its economy since 2014. It focuses on how the group has sought to influence and control local populations and infrastructure in such a way that might affect local economic activity over time. It also includes a discussion of ISIL's provision of public services, effects on agriculture, control over manufacturing facilities, and its taxation and extortion practices in Mosul since 2014.

The group's rapid takeover of Mosul in early June 2014 offers insight into its early strategy to govern the city. ISIL's offensive began around 3:20 a.m. on Friday, June 6, with a series of suicide bombings in the Mushayrafeh area west of Mosul. ISIL fighters then breached security barriers erected by local police, who fled checkpoints in these areas for the security of their headquarters. With unfettered access to the city, ISIL forces quickly seized numerous neighborhoods, including Najar, Yarmouk, Abar,

---

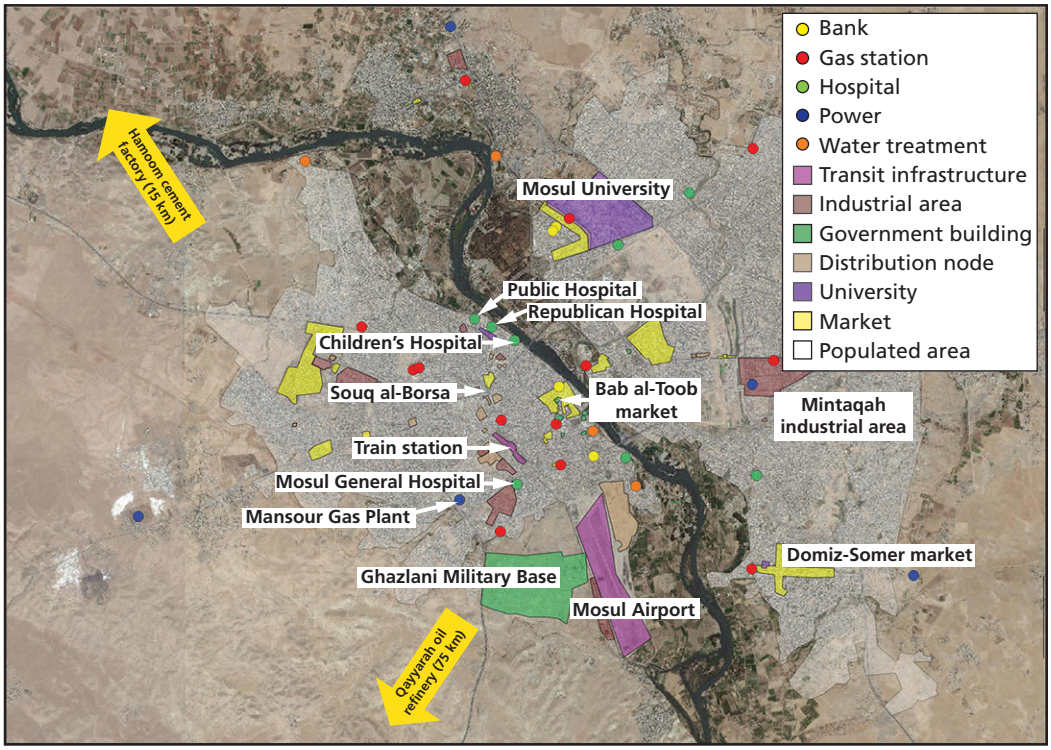
7 Republic of Iraq, undated.

8 Charlie Welsh and P. K. Semler, "Iraq Government to Restructure and Privatize Some 200 Industrial Companies," *Financial Times*, October 7, 2010. Textile firms used to account for 15 percent of the industrial labor force of all of Iraq. See Helen Chapin Metz, *Iraq: A Country Study*, Washington, D.C.: Federal Research Division, Library of Congress, 1990.

9 U.S. Agency for International Development, "An Overview of the Iraq Cement Industry," Iraq Private Sector Growth and Employment Generation, November 25, 2007. Badush is around 15 km northwest of Mosul's city center, Sinjar is around 125 km west of Mosul, and Hammam al-Alil is about 25 km south of Mosul.

10 Republic of Iraq, undated, p. 24.

Figure 6.2
Economic Laydown of Mosul



SOURCES: Authors' estimates. Imagery from Digital Globe, 2016.
RAND *RR1970-6.2*

and Tanak.[11] By June 10, ISIL had deployed large numbers of fighters in the western parts of the city, taken over military camps and arms depots west of the Tigris, and conducted a series of prison raids to both free sympathetic fighters and execute some 600 Shiite prisoners.[12]

ISIL also moved quickly to establish control over Mosul's main government centers, such as the Ninewa provincial government building in the center of the city, along with the Mosul police headquarters.[13] ISIL also seized the Mosul Airport, capturing helicopters, small arms, and heavy equipment as Iraqi forces fled.[14] By June 13, the GoI

[11] "How Did Extremists Take over One of Iraq's Biggest Cities in Just Five Days?" *Niqash*, June 10, 2014.

[12] Ziad al-Sinjary, "Insurgents Fight Iraqi Forces in City of Mosul," Reuters, June 6, 2014; "Inside Mosul: Chaos as Iraqi Army Flees al-Qaeda Held City," *Telegraph*, June 10, 2014; "Iraq: ISIS Executed Hundreds of Prison Inmates," Human Rights Watch, October 30, 2014.

[13] Bill Roggio, "ISIS Takes Control of Mosul, Iraq's Second Largest City," *Long War Journal*, June 10, 2014b.

[14] See, for example, "The Capture of Mosul: Terror's New Headquarters," *Economist*, June 14, 2014.

had ordered Fanoos Telecom, an Iraqi company providing internet service in Mosul, to shut down service to the local population.[15] Although this limited ISIL's ability to use the internet to coordinate its activities from inside Mosul, it also meant that the group quickly gained a monopoly over the flow of information in the city.

ISIL forces in Mosul also looted the city's considerable financial resources, including the cash holdings of Mosul's three largest banks, al-Rafidain, al-Rasheed, and the Central Bank of Iraq branch. ISIL reportedly looted some $429 million from the Central Bank of Iraq branch's vaults alone and unknown amounts from the others it seized.[16] Regardless of the exact value of the resources ISIL plundered, its leaders parlayed this infusion of capital to finance the costs of expanding its territorial holdings in Iraq and Syria in 2014 and 2015, which included additional manpower, weapons and ammunition, vehicles, and the costs of administering its bureaucratic state.[17]

Public Services in Mosul

ISIL established the Diwan al-Khidamat in Mosul responsible for providing public services to locals, including electricity, sanitation, water, and construction. The Diwan al-Khidamat struggled to sustain electricity supply in Mosul, in part because Baghdad was able to cut off access to the national power grid in Mosul soon after the militants seized it in June 2014.[18] By January 2015, electricity was available for only two hours every three days, according to one local report. By January 2016, the GoI had resumed provision of hydroelectric power to Mosul from the Mosul Dam, relieving some of the power shortages in the city.[19] But ISIL continued to leverage access to electricity within the city to its advantage, threatening in May 2016 to cut off access to electrical generators in the city as a means of controlling residents' access to outside news of coalition advances across Iraq, which threatened the group's information dominance over the city.[20]

In terms of sanitation, ISIL issued a public directive to Mosul's residents requiring each household and business to pay a monthly fee for trash pickup by ISIL-employed sanitation workers. One report, from July 2015, indicated that trash collection had

---

[15] Robert Mackey, "Latest Updates on the Insurgency in Iraq," *New York Times*, June 14, 2014.

[16] "Iraqi City of Mosul Falls to Jihadists," CBS News, June 10, 2014.

[17] Jack Moore, "Mosul Seized: Jihadis Loot $429m from City's Central Bank to Make Isis World's Richest Terror Force," *International Business Times*, June 11, 2014, updated October 3, 2014.

[18] Shaver and Ensign, 2015.

[19] Patrick Osgood and Rawaz Tahir, "Mosul Dam Flows, Returning Power to IS Held City Below," *Iraq Oil Report*, January 30, 2016.

[20] Stephen Kalin, "Islamic State Seeks News Blackout in Mosul as Iraqi Army Nears," Reuters, May 6, 2016d.

stopped across the city, and earlier reports suggested that trash piles throughout Mosul were raising significant public health concerns.[21]

Water provision in Mosul has also been a contentious issue. In the summer of 2014, many Iraqis fled Mosul after ISIL cut off water to the city, only to return once the water was restored.[22] Even when ISIL supplied water to Mosul, its quality was suspect. Reports from Mosul in 2015 indicated that the local drinking water supply was contaminated and that many civilians were suffering from various waterborne illnesses due to a shortage of water purifiers to clean the unfiltered water pumped into the city.[23]

Agriculture and Manufacturing Sectors

When ISIL took control of part of Ninewa and Salah ad-Din provinces in 2014, it reportedly took control of more than 1 million tons of wheat and barley, or about one-quarter of Iraq's national output of these crops.[24] Large tracts of land devoted to wheat and barley cultivation were damaged or destroyed in the fighting that occurred throughout northern Iraq in 2014, to the significant detriment of crop yields that year.[25] Mosul-area farmers who had relied on government-subsidized purchases of these crops before ISIL's seizure of Mosul largely went unpaid. The suspension of GoI services in Mosul also cut off farmers from access to centrally subsidized seeds, fuel, and fertilizer, on which they relied to make harvests profitable and provide adequate food supplies regionally.[26] Some reports suggest that this failure to match the GoI's level of investment in agriculture reduced crop yields and increased food prices over time.[27]

---

[21] Lucy Westcott, "Secretly Filmed Video Shows Life in Mosul One Year After ISIS Capture," *Newsweek*, June 9, 2015; Greenfield, 2014.

[22] "Mosul Diaries: Poisoned by Water," BBC News, December 19, 2014.

[23] John Vidal, "Water Supply Key to Outcome of Conflicts in Iraq and Syria, Experts Warn," *Guardian*, July 2, 2014.

[24] "Iraqi Farmers Suffer as Land Seized by Militants," 2014.

[25] According to statistics from an FAO assessment in 2015, 32 percent of acres in Ninewa dedicated to wheat cultivation were badly damaged from fighting and thus produced lower-than-average yields, while the rest (68 percent) were completely lost as a result of the conflict. Barley production also suffered a dramatic decline: Forty-three percent of the acres used for barley cultivation was damaged, and 57 percent was destroyed. See Naresh Singh, Dave van Zoonen, and Khogir Mohammed, *Iraq: Agriculture and Livelihoods Needs Assessment in the Newly Liberated Areas of Kirkuk, Ninewa and Salahadi*, Food and Agriculture Organization of the United Nations Iraq, February 2016, p. 6.

[26] "Iraqi Farmers Suffer as Land Seized by Militants," 2014.

[27] According to FAO, delays in and prevention of timely seed distribution during the planting period were liable to substantially decrease agricultural productivity in Ninewa. Because Ninewa residents were forced to depend on local wheat for their foodstuffs, food prices were expected to dramatically outstrip purchasing power as a result. As of January 2016, however, researchers had found little evidence of this trend. See WFP, "Iraq: Conflict-Disrupted Supply Lines Are Resulting in Shortages of Basic Food Commodities and High Food Prices in Parts of Anbar," Bulletin 15, February 2016b, p. 5. See also "Security Crisis Sees Harvests Halved in Northern Iraq," *Niqash*, May 28, 2015.

In contrast, ISIL maintained an active presence in Mosul's manufacturing sector. Most notably, the group took control of the Badush Cement Factory (a branch of the Northern Cement State Company) north of Mosul shortly after seizing the city, as well as a soft drink factory, a textile factory, a flour factory, several ice factories, and a plastics factory.[28] In the early weeks of its occupation of Mosul, ISIL reportedly replaced or eliminated personnel from a variety of these facilities to assert its control, which might have forced hundreds or thousands of local residents into lower-wage jobs or full unemployment.[29]

Nonetheless, ISIL has reportedly generated substantial revenue from manufacturing in Mosul, not to mention other parts of its so-called caliphate.[30] The Badush Cement Factory has long been a major producer of cement in the region and a key ISIL revenue source. According to one report, the factory produced an average 1,200 tons of cement daily under initial ISIL control, with each ton selling for $100.[31] As of March 2015, however, ISIL was reportedly attempting to move its cement production from Mosul to Syria in expectation of coalition and ISF military operations against the city.[32]

Taxation and Extortion in Mosul

ISIL extracted revenues locally from Mosul's inhabitants and businesses through a variety of taxes and extortion schemes. Shortly after it seized Mosul, the group began forcing non-Muslims to pay *jizya* taxes, a fee levied for not converting to Islam. On Friday, July 18, 2014, for example, ISIL issued a notice to Mosul Christians that they would be required to convert to Islam or pay *jizya* by noon on Saturday, July 19, or face "death by the sword."[33]

ISIL also collected taxes from local Sunnis in Mosul through its Diwan al-Zakah wa al-Sadaqat, or central public revenue administration. This administration was responsible for the collection of *zakat*, a compulsory tax Muslims pay under sharia law that allows ISIL to pay *sadaqat* (voluntary charity or alms).[34] Zakat taxes are charged

---

[28] Aymenn Jawad al-Tamimi, "The Islamic State's Diwan al-Rikaz in Mosul," *Aymenn Jawad al-Tamimi*, July 6, 2015c.

[29] Moslawi, Hawramy, and Harding, 2014.

[30] Laurence Bindner and Gabriel Poirot, *ISIS Financing, 2015*, Center for the Analysis of Terrorism, May 2016, p. 13.

[31] al-Tamimi, 2015c.

[32] "ISIS Moving Mosul Cement Factories to Syria," 2015.

[33] Hamdi Alkhshali and Joshua Berlinger, "Facing Fines, Conversion or Death, Christian Families Flee Mosul," CNN, July 20, 2014.

[34] On zakat's legal rationale, see Helene Lavoix, "Understanding the Islamic State's System: Money, Wealth and Taxes," Red (Team) Analysis Society, July 13, 2015, updated May 9, 2017. ISIL has self-reported some statistics on its zakat-related activities in Mosul. It claims to have distributed US$6.7 million in alms to more than 86,000 families in Wilayat Ninewa in 2015, or about US$78 per recipient household for the year, or only

across a wide variety of industries and actions, including on industrial machinery; bank or currency holdings; bank withdrawals; agricultural yields; and ISIL-provided services, such as education and sanitation.[35]

Beyond these more-official taxes, ISIL extracted significant revenue in Mosul from salary and pension payments made by the GoI to former government employees living in ISIL-held territory, which amounted to at least $130 million in revenue monthly.[36] The GoI stopped these salary payments as of July 2015, which both deprived ISIL of a key revenue source and increased its payroll costs in that the group now had to shoulder the burden of paying wages to employees previously subsidized by the GoI directly. ISIL also extorted funds from real estate transactions in Mosul, including charging fees associated with buying, selling, and owning real estate, as well as confiscating real estate from displaced families, particularly Christians and ethnic Yazidi minorities.[37]

Mosul's Markets

ISIL moved to centralize Mosul's robust informal markets by constructing covered markets and instructing vendors operating open-air markets to work specifically from ISIL-owned locations within the city.[38] This brought a considerable portion of Mosul's informal economy within the formal reach of the group's taxation schemes. At the same time, ISIL also began providing certain services, such as free public transportation on buses, which might have decreased the cost of getting to and from markets and other businesses throughout the city.[39] Indeed, reports from the spring of 2015 indicate that, "[d]espite the harsh social rules, the markets remain full . . . everything remains

US$6.50 per month. See "Islamic State Infographic: 'Zakah in Wilayat Ninawa—Statistics for the Year 1436 AH,'" Terrorism Research and Analysis Consortium, undated.

35 Aymenn Jawad al-Tamimi, "Aspects of Islamic State (IS) Administration in Ninawa Province: Part II," *Aymenn Jawad al-Tamimi*, January 20, 2015a.

36 Ahmed Rasheed and Ned Parker, "In Mosul, Islamic State Turns Captured City into Fortress," Reuters, January 22, 2015.

37 Christine Duhaime, "Terrorist Financing and the Islamic State," *Duhaime Law*, 2015.

38 The best known of these markets is one in the larger Bab al-Toob market neighborhood, near the center of Mosul's Right Bank (the western half of the city) and built directly on top of the ruins of the oldest police station in Ninewa province. ISIL converted a former police station into a market containing 60 shops selling fruits and vegetables. See Rosenberg, Kulish, and Myers, 2015. Also see Khales Joumah, "Extremists Fix Roads, Make Mosul a Nicer Place," *Niqash*, May 14, 2015.

39 Mohammed A. Salih, "Forced from Mosul, Centuries Old Christian Community Vanishes," *Al-Monitor*, July 28, 2014.

available there."[40] For its part, ISIL capitalized on centralizing local markets by charging vendors an annual rent for stalls in its markets.[41]

The Effect That Coalition Air Strikes Have on Mosul's Economy

Over time, Mosul's local economy has shown signs of slowing under the strains generated by the global coalition's actions to counter ISIL. As mentioned previously, the GoI has taken careful efforts to restrict Mosul's access to the national power grid, as well as to discontinue salary and pension payments to its employees living in ISIL-held Mosul.[42] Furthermore, ISIL suffered major losses of financial capital throughout late 2015 and 2016 because of the coalition's disruption of the group's oil revenues and destruction of ISIL's currency holdings at key financial headquarters in Mosul, including the Mosul Central Bank, al-Rafidain Bank, and al-Rasheed Bank.[43] As a direct result of this strain, ISIL cut the salaries of fighters and public employees in Mosul and other areas by 50 percent in 2015.[44] To the extent that ISIL's own spending was a key driver of local economic activity in a cash-strapped Mosul economy, outside interventions against the group likely accelerated any adverse impact that ISIL might have had on Mosul's economy.

Measuring the Islamic State's Economic Impact in Mosul

In this section, we use satellite imagery and remote sensing data to track how economic activity in Mosul has changed over time. We examine how each indicator in our sample—electricity consumption, population levels, agricultural activity, industrial activity, market activity, commercial vehicle counts, and building destruction—changes across the whole city before and ISIL established control in June 2014. We also examine how several of these indicators vary across Sunni, Kurdish, Turkmen, and Assyrian Christian neighborhoods within Mosul. We use these data to test our hypotheses described earlier in this report and in conjunction with existing reports of ISIL's economic impact and control over Mosul discussed earlier in this chapter.

---

[40] Amos, 2015.

[41] These rents were reported to be up to $1,500 (as of mid-2015) and up to $2,500 (as of December 2015). The annual rent for a market stall was reportedly 2.8 million Iraqi dinars, or roughly $2,500. See Rosenberg, Kulish, and Myers, 2015.

[42] Rasheed and Parker, 2015.

[43] See, for example, Barbara Starr, "First on CNN: U.S. Bombs 'Millions' in ISIS Currency Stock," CNN, January 13, 2016. Also see Eric Schmitt, "U.S. Says Its Strikes Are Hitting More Significant ISIS Targets," *New York Times*, May 25, 2016.

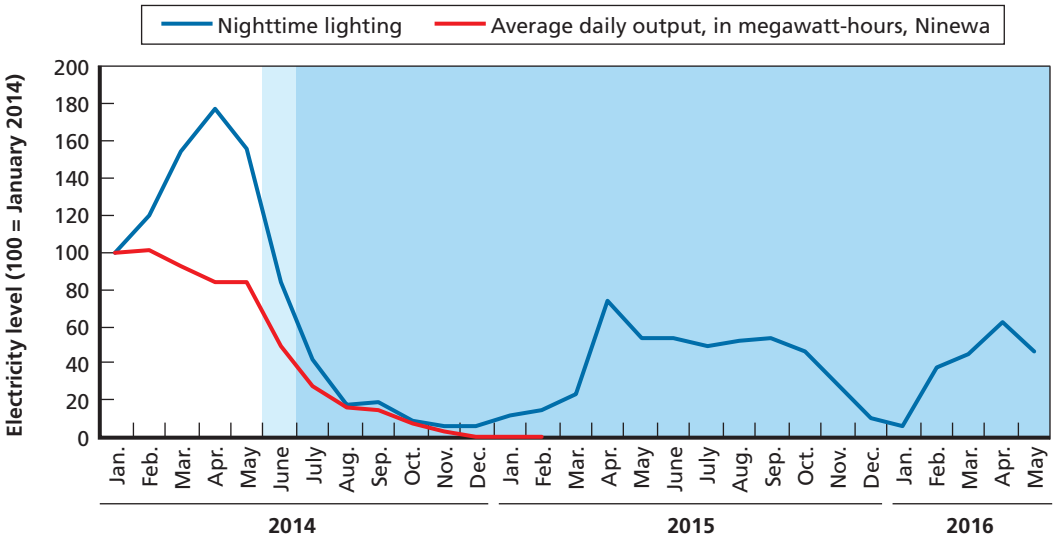
[44] Gidda, 2015.

Electricity Consumption

First, we use nighttime lighting to understand how electricity consumption has changed over time in Mosul relative to ISIL's takeover of the city. We combine this information with data from the Iraqi Ministry of Electricity, showing provincial-level power supply information from the national power grid through February 2015 (after which data are unavailable). Both time series are presented in Figure 6.3, with shading to display ISIL's takeover of the city in June 2014. This figure clearly shows the massive decline in electricity consumption corresponding with the Islamic State's takeover of the city. Year after year, nighttime lighting levels in Mosul fell nearly 89 percent between January 2014 and January 2015. This precipitous decline corresponds roughly with cutoffs in electricity supplied by GoI to Ninewa province on the national power grid, shown in red in the figure.

Although our power supply data end in February 2015, we see that electricity consumption rises in Mosul in the first two months of 2015 despite zero power supply to the region on the national grid. We see relatively constant levels of nighttime lighting throughout the remaining months of 2015 but a significant drop-off at the end of the year. Interestingly, this decline coincides with the coalition air campaign against ISIL's

Figure 6.3
ISIL's Impact on Electricity in Mosul, 2014–2016



SOURCES: Nighttime lighting data are calculated using NOAA VIIRS. Electricity supply data are from Shaver and Ensign, 2015.
NOTE: All data are normalized to the first data point in the time series so that values deviate around 100. For example, a nighttime lighting value of 50 in this figure indicates that nighttime lighting at that point in time was 50 percent below the first point at which nighttime lighting information was collected. Light blue shading corresponds to months of contested control, while dark blue shading corresponds to months of unilateral ISIL control.

RAND *RR1970-6.3*

oil facilities across Iraq and Syria, Operation Tidal Wave II, which aimed to interdict the group's organic oil production. Tidal Wave II is largely credited with reducing ISIL's overall oil production by 30 percent and driving fuel shortages throughout ISIL-held territory.[45] We see direct evidence of this effect in Mosul. The resumption of power from the Mosul Dam in January 2016 had an immediately positive effect on nighttime lighting in the city, likely helping to overcome these fuel shortages.

Next, we examine how nighttime lighting differs across different types of critical infrastructure and commercial locations in Mosul. If ISIL provided electricity to Mosul's residents through fuel supply to generators, it is possible that the group prioritized electrifying certain parts of the city over others based on its own economic interests. Panel A of Figure 6.4 displays average nighttime lighting levels over Mosul's mosques, markets, industrial areas, and hospitals. At first glance, it appears that electricity consumption at different types of infrastructure moves in relative lockstep. The most surprising revelation from this figure perhaps relates to Mosul's hospitals. Under ISIL control, electricity levels at hospitals operated much closer to their pre-ISIL levels than other types of infrastructure do. Panel B dives into four specific hospitals, looking for more-specific evidence of ISIL intervention. Mosul General Hospital, also known as the Ibn Sena Hospital, stands out in particular in that it turned almost entirely dark following ISIL's takeover of the city. Local reporting from January 2015 at this hospital noted that there was a shortage of doctors and medical supplies and that the facility could no longer provide treatment for incoming patients.[46] After March 2015, however, the hospital's lights turned back on and largely reverted to the mean relative to other hospitals. This suggests some form of intervention around that time period, perhaps by ISIL, which, at the time, was forcing doctors across the city to treat its wounded fighters.[47]

Finally, in Figure 6.5, we use our neighborhood-level ethnicity map presented in Figure 6.1 to examine how nighttime lighting over Mosul varies by the ethnic makeup of each neighborhood. Given the largely Sunni support base for the Islamic State in Mosul, as well as the harsh ways in which the group treats non-Sunni Muslims throughout Iraq, we should expect to see differences in electricity consumption by ethnic area if ISIL were strategically denying fuel resources to minority groups. Starting in July 2015, we begin to see a modest reduction in electricity in Kurdish neighborhoods that persists through early 2015. We also see a spike in nighttime lighting in Turkmen areas of the city, which are largely located in the southeast. However, this figure does not suggest wholesale denial of energy resources to any one ethnic group over another.

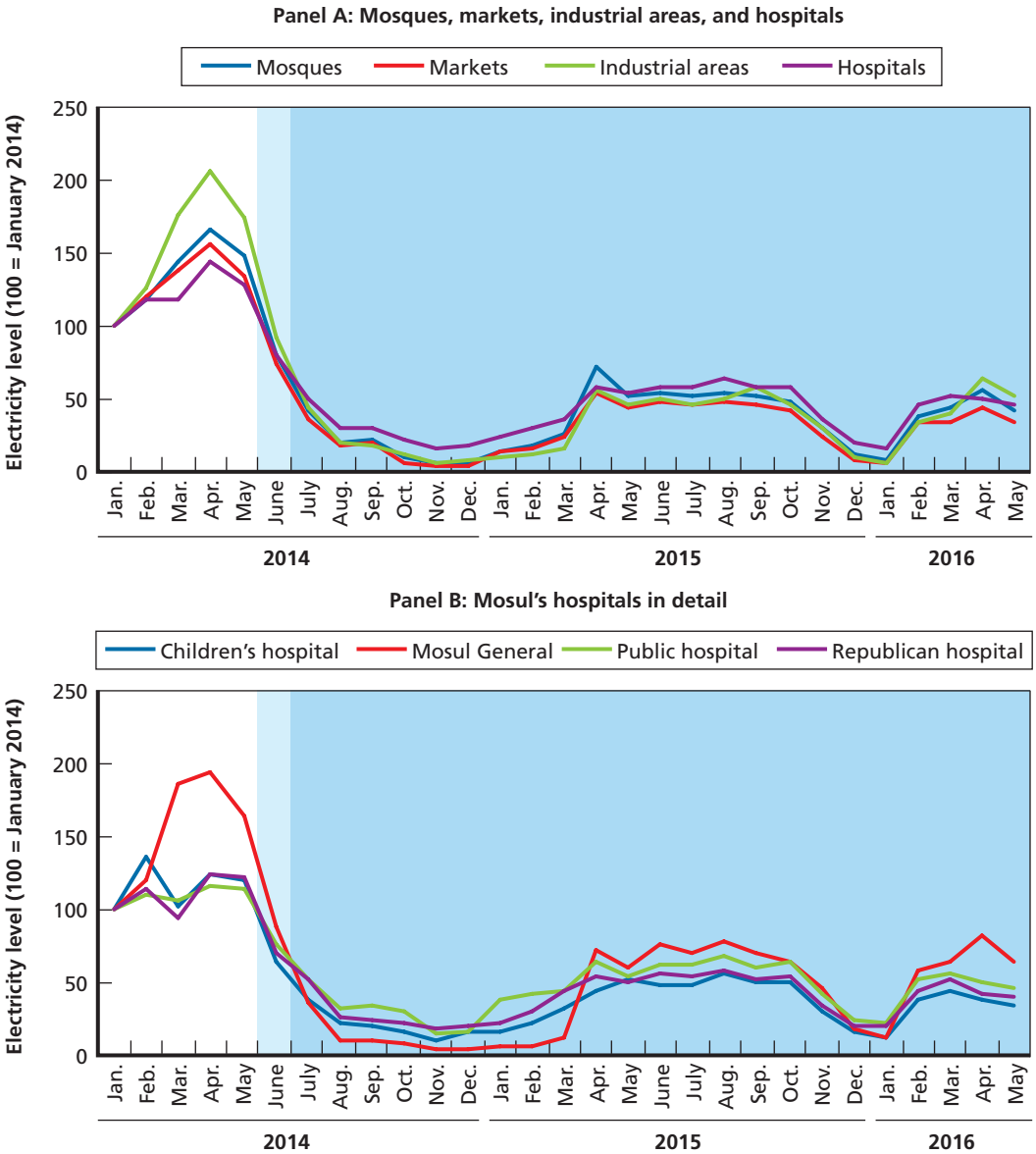
---

[45] Ben Van Heuvelen, "Armed with Intel, U.S. Strikes Curtail IS Oil Sector," *Iraq Oil Report*, December 28, 2015.

[46] Omar al-Jaffal, "Iraqi Hospitals Under IS Suffer Lack of Medicine, Staff," *Al-Monitor*, January 15, 2015.

[47] "Sources: ISIS Executed 10 Doctors in Mosul for Refusing to Treat Wounded Fighters," *Rudaw*, January 27, 2015.

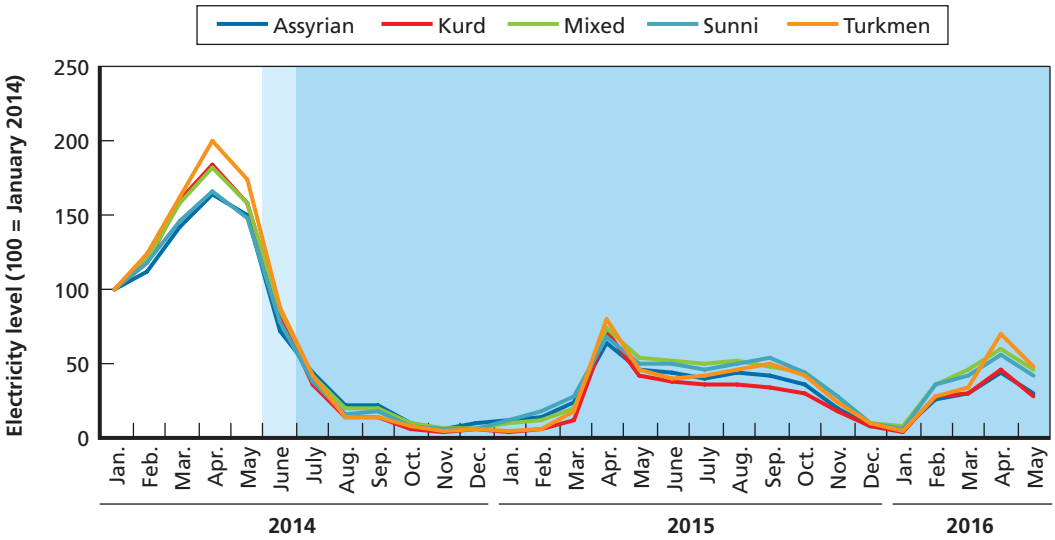
Figure 6.4
Nighttime Lighting in Mosul, by Type of Infrastructure



SOURCE: Nighttime lighting data are calculated using NOAA VIIRS.
NOTE: All data are normalized to the first data point in the time series so that values deviate around 100. For example, a nighttime lighting value of 50 in this figure indicates that nighttime lighting at that point in time was 50 percent below the first point at which nighttime lighting information was collected. Light blue shading corresponds to months of contested control, while dark blue shading corresponds to months of unilateral ISIL control.

RAND *RR1970-6.4*

Figure 6.5
Nighttime Lighting in Mosul, by Ethnic Neighborhood



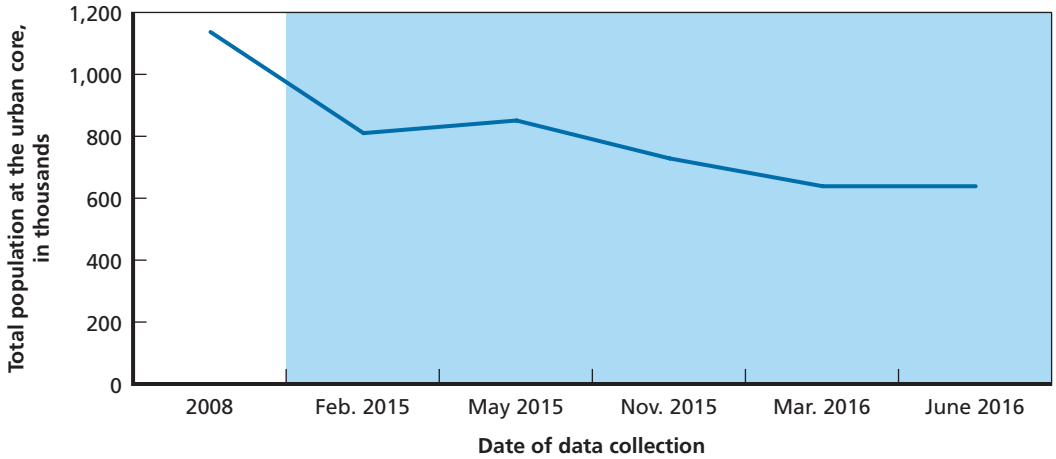
SOURCES: Nighttime lighting data are calculated using NOAA VIIRS. Ethnic area locations are calculated using maps from the Gulf 2000 Project at Columbia University.
NOTE: All data are normalized to the first data point in the time series so that values deviate around 100. For example, a nighttime lighting value of 50 in this figure indicates that nighttime lighting at that point in time was 50 percent below the first point at which nighttime lighting information was collected. We exclude the one Shia neighborhood identified in Mosul from this sample because of concerns about the smallness of the sample size. Light blue shading corresponds to months of contested control, while dark blue shading corresponds to months of unilateral ISIL control.
RAND *RR1970-6.5*

Population Levels

Next, using ORNL LandScan estimates of Mosul's population in 2008, 2015, and 2016, we explore the extent to which Mosul's population fluctuated in response to ISIL's takeover of the city. We restrict our estimates to the urban core of Mosul as opposed to its full environs, so total population figures might fall slightly below other published estimates. Figure 6.6 plots Mosul's population over time.

Pre-ISIL estimates of Mosul's population show that nearly 1.2 million people inhabited the urban core of the city in 2008. By February 2015, we estimate, the city's population fell by more than 300,000 people after only a year of ISIL control over the city, or nearly 30 percent of its pre-ISIL population. Between mid-2015 and mid-2016, we estimate, an additional 220,000 people fled Mosul. Combined, our most-recent estimates suggest that Mosul's population has been nearly cut in half under ISIL's reign. It suggests that, despite ISIL's efforts to limit population movements out of the city, Mosul's residents still fled in the hundreds of thousands and those outflows continued well into ISIL's tenure governing the city.

Figure 6.6
Mosul's Population over Time



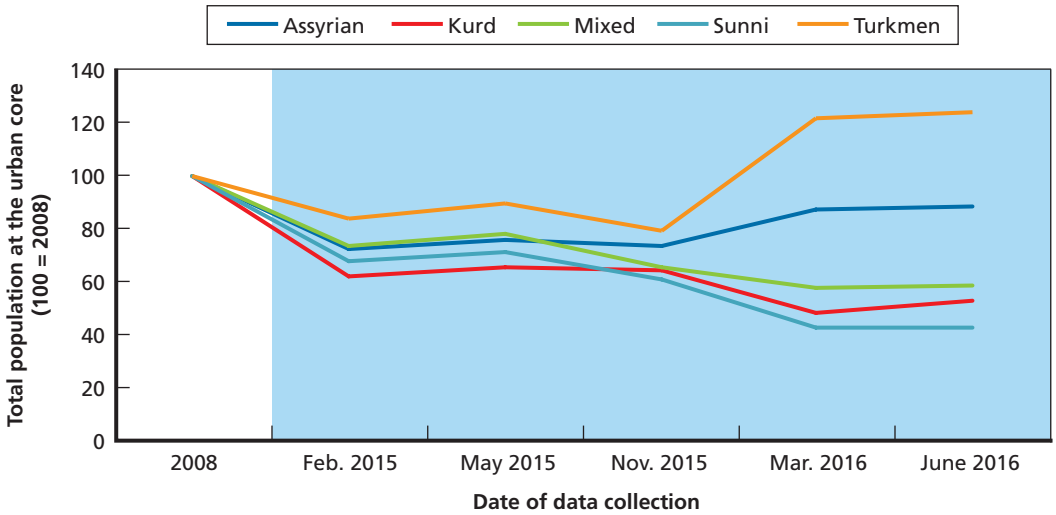
SOURCE: Oak Ridge National Laboratory, Landscan 2008–2016.
NOTE: Population totals represent the number of people living in the urban core of the city. Data were captured at irregular intervals, so we use 2008 as a baseline and lack data on exact population totals prior to ISIL arrival. Blue shading corresponds to periods of unilateral ISIL control.
RAND *RR1970-6.6*

In Figure 6.7, we examine how these population shifts differ by ethnic neighborhood. Rather than show population totals for each neighborhood, we normalize each ethnic time series by its 2008 population levels. Resulting values indicate the population living in each ethnic neighborhood relative to pre-ISIL levels. Nearly all ethnic areas of the city show similar declines in population seen for the entirety of Mosul, particularly in Sunni and Kurdish neighborhoods. Surprisingly, Turkmen and Assyrian Christian neighborhoods show increases in population between mid-2015 and early 2016. This is not to say that more of these ethnic minorities moved into Mosul to live under ISIL's reign. Rather, this might represent population movements within Mosul out of the denser city center (which is largely Sunni) and into the more-southern portions of the city's "Left Bank" east of the Tigris River, where the bulk of the city's Turkmen population lived as of 2013.

Agricultural Activity

This section explores how agricultural activity in Mosul has changed under ISIL's control over the city. We track the average NDVI for all areas within 5 km of Mosul's urban core, as a proxy for agricultural productivity in Mosul's immediate environs over time. Figure 6.8 plots this metric over time for Mosul since April 2013. ISIL's takeover of Mosul in June 2014 roughly corresponds to the harvest season for wheat and barley

Figure 6.7
Mosul's Population over Time, by Ethnic Neighborhood



SOURCES: Oak Ridge National Laboratory, Landscan 2008–2016. Ethnic area locations are calculated using maps from the Gulf 2000 Project at Columbia University.
NOTE: Population figures represent people living in the urban core of the city in each ethnic neighborhood. Data were captured at irregular intervals, so we use 2008 as a baseline and lack data on exact population totals prior to ISIL arrival. All data are normalized to the first data point in the time series so that values deviate around 100. We exclude the one Shia neighborhood identified in Mosul from this sample because of concerns about the smallness of the sample size. Blue shading corresponds to periods of unilateral ISIL control.
RAND *RR1970-6.7*

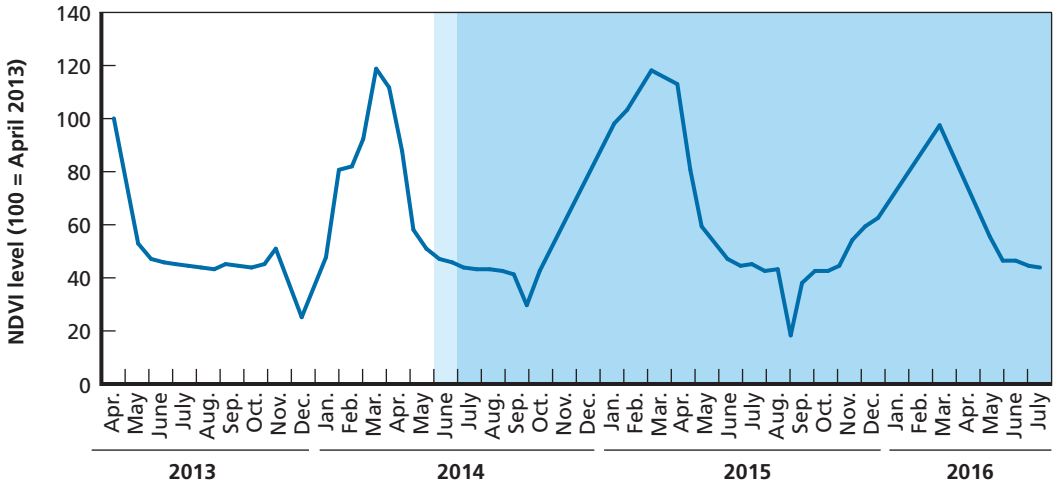
and before the fall planting season for these crops in preparation for the subsequent harvest in the spring of 2015.[48]

NDVI values in the spring of each year are driven by the extent of agricultural areas planted in the fall of the year prior, as well as irrigation and damage to these fields over the course of the winter. With this in mind, we see that our NDVI estimates suggest that ISIL's takeover of the city had little impact on the 2014–2015 growing season and harvest. Peak NDVI values in March and April 2015, representing the point in time during the growing season with the largest area of vegetated cropland, were roughly comparable to their 2014 pre-ISIL levels. Despite the disruption to seed distribution caused by ISIL's takeover of the Ministry of Agriculture in Mosul, Ninewa's farmers benefited over this growing season from an abnormally wet winter over the course of late 2014 and early 2015.[49] Moreover, Mosul receives more average precipitation than any of the other cities examined for this report, making estimates of

[48] FAO, "Country Briefs: Iraq," reference date March 7, 2016a.

[49] Matt Bradley, "Islamic State Squeezes Iraq's Food Supply," *Wall Street Journal*, July 12, 2015.

Figure 6.8
Agricultural Activity in Mosul's Urban Periphery



SOURCE: NDVI data are derived using USGS Landsat 8.
NOTE: All data are normalized to the first data point in the time series so that values deviate around 100. Light blue shading corresponds to months of contested control, while dark blue shading corresponds to months of unilateral ISIL control.
RAND *RR1970-6.8*

its NDVI values particularly sensitive to the effects of rainfall on nonirrigated natural vegetation.

Therefore, the 2015–2016 growing season represents a cleaner test of ISIL's impact on agricultural activity around Mosul. By the time farmers began planting their wheat and barley crop in the fall months of 2015, ISIL had controlled local stockpiles of seeds and fertilizers for more than a year, and out-migration from the city discussed in the prior section likely reduced both the supply of farm labor and demand for agricultural goods. Rainfall during this growing season also approximated more-normal levels.[50] As a result, we see a decline in agricultural productivity across Mosul in 2016, with peak NDVI falling nearly 18 percent below the prior two years' harvests.[51]

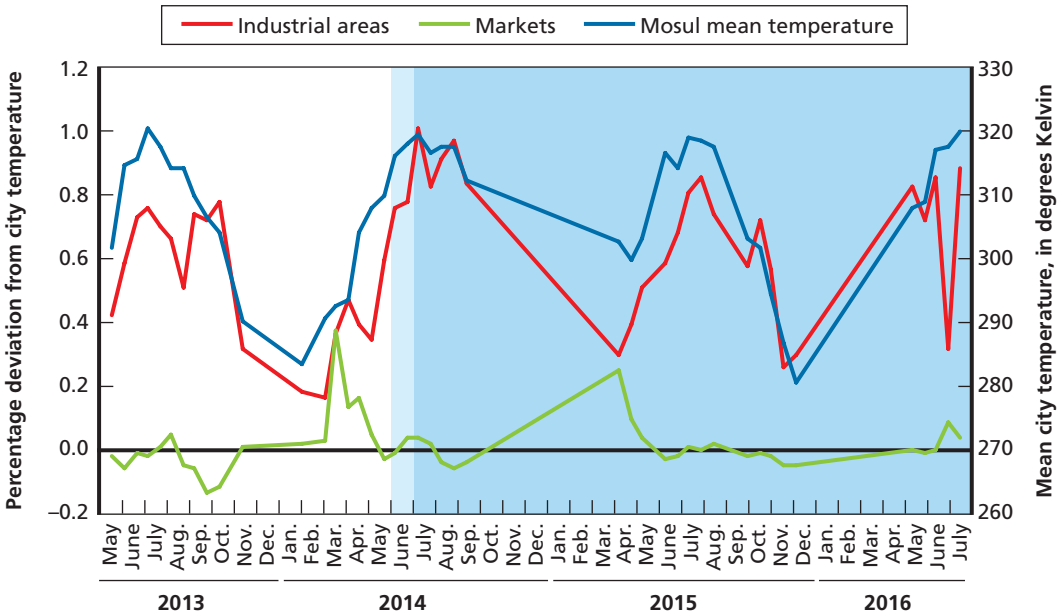
Industrial Activity

We next examine how economic activity around Mosul's industrial areas has changed over the course of ISIL's control of the city. Figure 6.9 plots thermal activity at Mosul's industrial areas (in red) relative to the average city temperature (in blue). We measure

[50] Foreign Agricultural Service, U.S. Department of Agriculture, "Iraq: 2015/2016 Wheat Production Favorable but Down from Last Year's Record Crop," *Commodity Intelligence Report*, July 10, 2015a.

[51] Given the results of our cross-city FE regressions in Chapter Four (which estimated little to no change in agricultural productivity in Iraq as a result of ISIL control), this reduction is more likely a product of declining rainfall in 2016 and less likely due to the adverse effect of ISIL rule.

Figure 6.9
Thermal Activity at Mosul's Industrial Areas



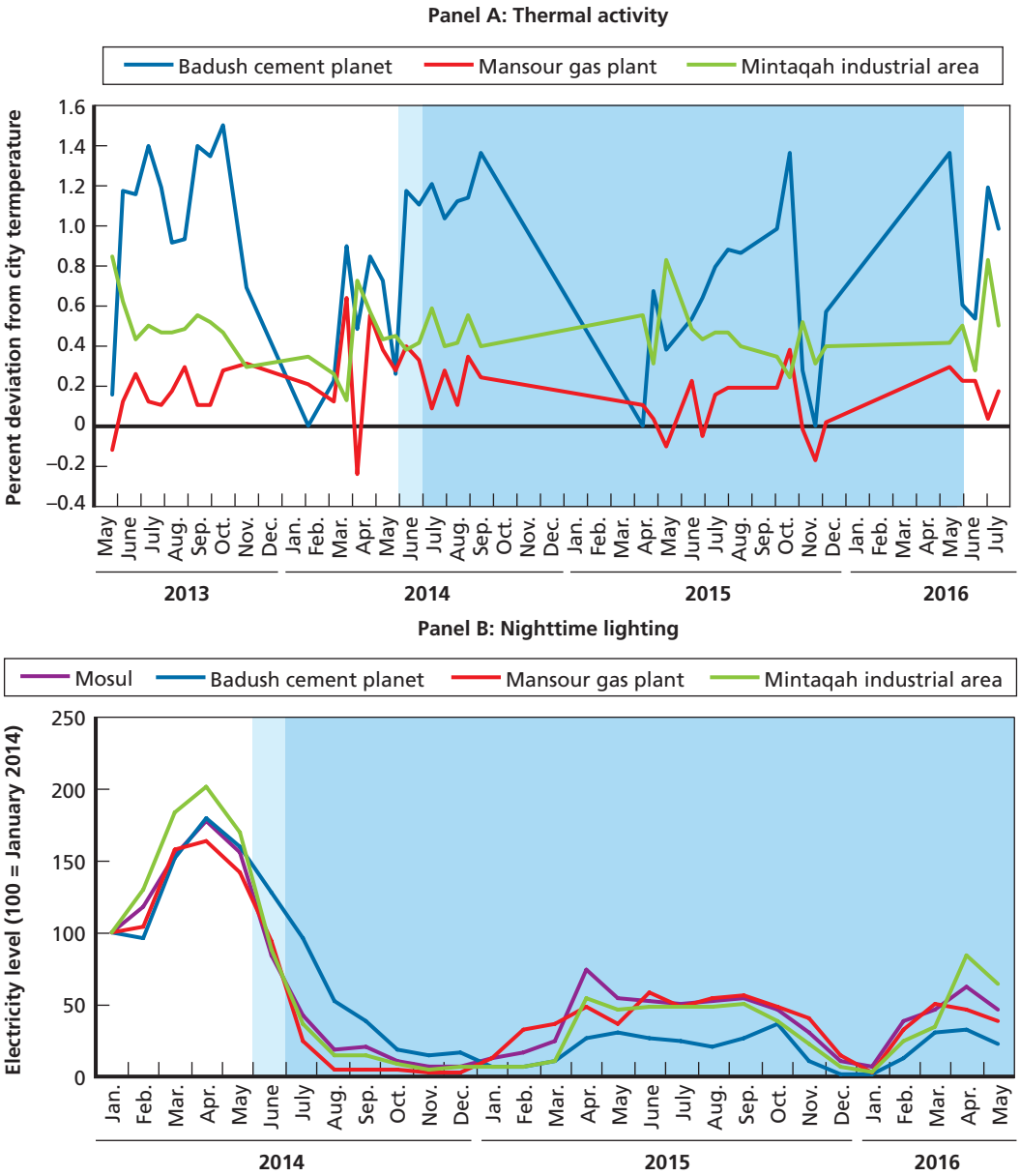
SOURCE: Thermal data are derived using USGS Landsat 8.
NOTE: Light blue shading corresponds to months of contested control, while dark blue shading corresponds to months of unilateral ISIL control.
RAND *RR1970-6.9*

industrial activity here as the mean percentage deviation across all industrial facilities in Mosul from the city's average temperature. For comparison's sake, we also plot thermal activity over Mosul's markets to demonstrate that thermal activity over industrial areas captures sufficient variation in industrial activity that is not merely noise. Mosul's market areas largely mirror the average temperature of the city itself.

The first observation, important for understanding this figure, is that Mosul's industrial facilities run significantly hotter than the city's mean temperature when it is warm outside and are much closer to the city's average temperature when it is cold outside. This could suggest that industrial activity in Mosul is more concentrated in the summer than in the winter or simply that heat capture at these industrial facilities varies by season. Second, and more importantly for our study of ISIL's impact on industrial activity, the average thermal signature of these facilities suggests that ISIL control is associated with a modest reduction in thermal activity.

To provide further granularity on the impact that ISIL's control over Mosul has on industrial activity, we focus on three specific facilities in Figure 6.10—the Badush Cement Factory, the Mansour gas plant, and the Mintaqah industrial area. At all three sites, periodic spikes in the thermal activity of each location (shown in panel A) suggest that they remained active over the course of ISIL's control of the city. Thermal

Figure 6.10
Key Industrial Facilities in Mosul



SOURCES: Thermal data are derived using USGS Landsat 8. Nighttime lighting data are calculated using NOAA VIIRS.
NOTE: Light blue shading corresponds to months of contested control, while dark blue shading corresponds to months of unilateral ISIL control.

RAND *RR1970-6.10*

estimates of the Mansour gas plant suggest a reduced level of operations post-ISIL takeover of the city. The peak thermal signature of this facility occurred in April 2014, where it operated nearly 0.6 percent warmer than the mean temperature of Mosul. By the same time in 2015 and again in 2016, the plant was operating at less than 0.2 percent above the city's mean temperature.

We can use nighttime lighting to provide additional clarity on operations at each of these facilities as well, shown in panel B of Figure 6.10. These nighttime lighting data suggest that the Badush Cement Factory, which ISIL took over in 2014 soon after its takeover of Mosul writ large, was significantly brighter than other industrial areas in Mosul relative to pre-ISIL periods. Afterwards, however, the facility reversed course and became stagnant and lit at levels far below other industrial facilities—suggesting a shutdown or partial shutdown that persists into our most-recent estimates in May 2016. ISIL's direct takeover and intervention into the facility's operations appears to have had a short-term positive but long-term deleterious impact.

Market and Commercial Activity

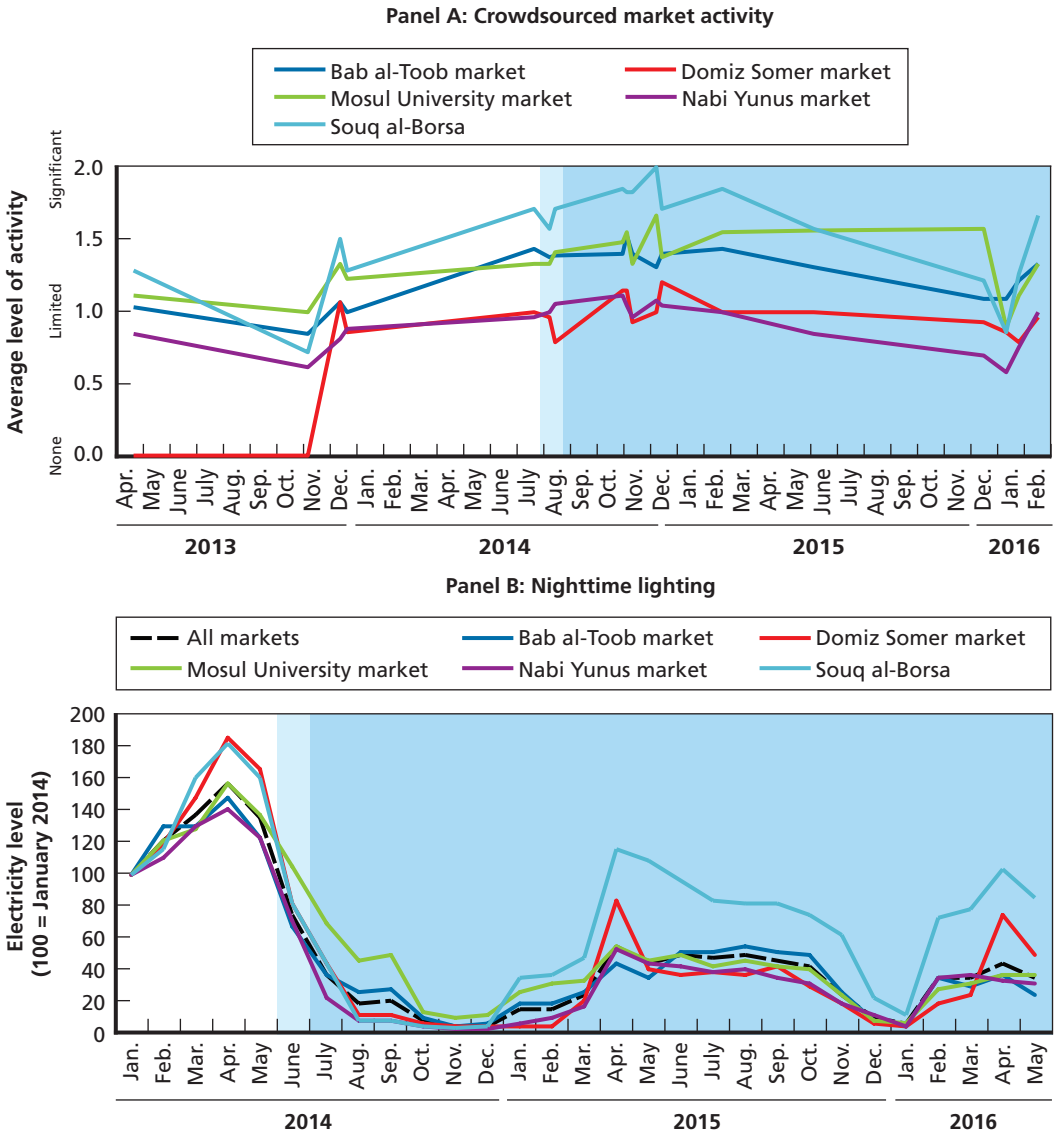
Moving forward from industrial areas, we next examine how commercial activity in Mosul has changed over time. We start by focusing on Mosul's markets. The first panel of Figure 6.11 shows our crowd-sourced estimates of market activity in Mosul over time, plotting the average intensity of market activity within several key markets on a scale from no activity (0), to limited activity (1), to significant activity (2). Panel B of this figure plots nighttime lighting over these same locations to better understand the infrastructure available to support economic activity at these locations.

Crowd-sourced estimates of market activity suggest that market activity in Mosul actually peaked under ISIL control (in late 2014) at levels well above those seen in the year and a half prior to ISIL's takeover in the city. The Souq al-Borsa, a small commodities and exchange market located northwest of the old city center of Mosul, operated at the consistently highest level of activity across the city during ISIL's tenure through mid-2016.[52]

The Souq al-Borsa also happens to be the only market in our sample demonstrating an abnormal level of electricity consumption in its vicinity, shown in red in panel B. Despite almost no electricity usage in this location following ISIL's takeover of the city, the market appears significantly brighter than any other market location in the city, rising sharply in December 2014. It is the only market in Mosul with levels of nighttime lighting under ISIL control that fall at or above pre-ISIL levels. The severity with which this location veers apart from other markets suggests a direct ISIL intervention in providing power resources to this facility over others, potentially indicating that the facility is of some financial, logistical, or operational importance to the group.

[52] Portions of Mosul's central market (Bab al-Toob) have operated at consistently high levels as well.

Figure 6.11
Market Activity in Mosul



SOURCES: Market activity data are derived from Digital Globe's Tomnod Crowdsourcing Platform. Nighttime lighting data are calculated using NOAA VIIRS.
NOTE: Crowdsourced market activity data are presented as the average crowdsourced ranking across various subpolygons making up each market. Each market location was ranked as to whether it exhibited no activity (0), limited activity (1), or significant activity (2). Nighttime lighting data are normalized to the first data point in the time series so that values deviate around 100. Light blue shading corresponds to months of contested control, while dark blue shading corresponds to months of unilateral ISIL control.

RAND *RR1970-6.11*

Beyond the Souq al-Borsa, we also see visual evidence of ISIL investing in Mosul's main market in the Bab al-Toob neighborhood. Figure 6.12 shows satellite imagery of this location immediately after ISIL takeover in June 2014, as well as two years into ISIL control in September 2016. Hard roofs have been constructed over a portion of the central square and adjoining market streets, replacing what appears to be a series of tent-covered stalls and empty public areas.[53]

We also see interesting ethnic differences across Mosul's markets. Despite relatively comparable levels of activity seen in satellite imagery of each location prior to ISIL's takeover, we see markets in minority ethnic areas underperforming relative to markets in Sunni or mixed areas under ISIL's rule. Both the Domiz-Somer market, in a Turkmen part of the city, and the Nabi Yunus market, in a Kurdish neighborhood, showed consistently limited market activity in satellite imagery throughout 2015 and 2016 and were the only two markets not to show increased signs of activity after ISIL takeover.

Our last indicator in this section consists of car counts derived from commercial satellite imagery, which can be used to better understand commercial activity in Mosul. Figure 6.13 plots the number of tractor trailers and large commercial vehicles on Mosul's roads at three points over time, calculated using crowd-sourced identification of these vehicles in satellite imagery. We plot the geographic distribution of these vehicles at three time points: December 2013, July 2014, and January 2016. Overall, we see that the spatial distribution of tractor trailers and commercial vehicles is relatively constant over time, operating predominantly in portions of Mosul's "Right Bank" to the west of the Tigris. Although we see a modest reduction in the number of vehicles identified in each image over time, we do not investigate the statistical significance of this reduction because of large time gaps between images and potential differences in day-of-week car volumes. Nonetheless, that several hundred commercial vehicles remained on the roads in Mosul within the first month after ISIL takeover and continued to do so nearly a year and a half later under ISIL control suggests that the city's commercial sector remained active, even as of early 2016, although perhaps at slightly reduced levels.

Damage and Destruction

Finally, we use crowd-sourced analysis of commercial satellite imagery to map buildings, roads, and other infrastructure in Mosul that are damaged or destroyed over time through mid-2016. Our estimates of building damage predate operations to liberate the city beginning in October 2016. As a result, they offer insight into the status of infrastructure while ISIL had total control of the city. Unlike other cities across ISIL's territory at this time, Mosul experienced relatively limited ground fighting over the course

[53] This confirms publicly available evidence suggesting that ISIL had invested in improving the Bab al-Toob market. See Rosenberg, Kulish, and Myers, 2015.

Figure 6.12
Islamic State Investment in the Bab al-Toob Market

Panel A: Immediately following ISIL takeover (June 12, 2014)

Panel B: Under ISIL control (September 8, 2016)

SOURCE: Imagery is from Digital Globe, 2016.
RAND *RR1970-6.12*

of ISIL's tenure in the city before liberation. However, it received a steady barrage of coalition air strikes against ISIL's leadership and financial nodes in the city. Local resistance within Mosul to ISIL's reign might also be responsible for some damage to city infrastructure.[54] We use data on destruction to understand how our previous indicators of economic activity might have been affected by violence either directly or indirectly levied at key infrastructure. Figure 6.14 plots two images of damage and destruction

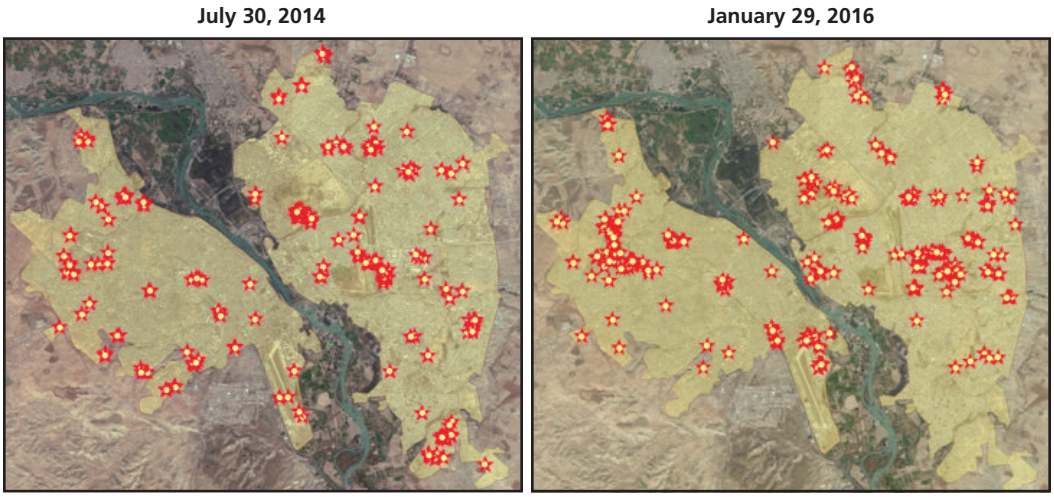
[54] See, for example, Sam Kiley, "Underground Guerrilla Force Battles IS in Mosul," *Sky News*, April 20, 2015.

Figure 6.13
Commercial Vehicles in Mosul

SOURCES: Commercial vehicle data are derived from Digital Globe's Tomnod Crowdsourcing Platform. Imagery is from Digital Globe, 2016. Road map data are from Open Street Map.
NOTE: The yellow shaded area represents the city's urban extent, based on authors' estimates and a review of satellite imagery. White lines represent the city's road network. Black dots represent commercial vehicles or tractor trailers.
RAND *RR1970-6.13*

in Mosul. The first is from July 2014, soon after ISIL established control of the city and before the air campaign against the group had begun. This image suggests that ISIL's takeover of the city, although relatively quick, did involve modest amounts of violence and destruction. Alternatively, this damage might represent ISIL's efforts to assert its control over the city after takeover, particularly to the extent that the bulk of damage is concentrated on Mosul's "Left Bank," which is where most of the city's ethnic minorities lived pre-ISIL. By January 2016, the level of damage to the city had escalated

Figure 6.14
Map of Building Destruction in Mosul, July 2014 and January 2016



SOURCE: Damage data are derived from Digital Globe's Tomnod Crowdsourcing Platform. Imagery is from Digital Globe, 2016.
NOTE: The yellow shaded area represents the city's urban extent, based on authors' estimates and a review of satellite imagery. Yellow-centered red stars denote instances of damage or destruction.
RAND *RR1970-6.14*

moderately as a result of the relatively robust air campaign against the group, which included deliberate targeting of leadership and financial facilities within Mosul city.

Much of the damage to the city through early 2016 was from precision air strikes, likely against ISIL-held facilities and infrastructure within the city. Damaged areas include several key industrial areas within and outside the city that are central components of Mosul's larger economy and public services. Figure 6.15 offers visual evidence of the current level of destruction to a major textile factory on the western side of the city in the Mansour neighborhood, the Mintaqah industrial area in the east, and the Badush Cement Factory to the north of the city. In the upper left panel, we see that nearly every building in the Mansour neighborhood textile factory has been destroyed entirely or its roof has caved. At the Badush Cement Factory, we see evidence of destroyed buildings both south of the northernmost dome on the compound and in the southwest corner of the facility. At the Mintaqah industrial area, we see several former warehouses destroyed by what appear to have been air strikes, and then we see an entire city block leveled and the rubble largely removed on the eastern end of the image. Overall, these three locations paint a grim picture for the industrial future of Mosul now that it is liberated from the Islamic State. By most estimates, operations to liberate the city have produced near-universal damage to the city's remaining infrastructure. This highlights the significant challenges that the GoI will face in long-term reconstruction of the city.

Figure 6.15
Destruction of Industrial Infrastructure in Mosul, September 2016

SOURCE: Digital Globe, September 19, 2016.
RAND *RR1970-6.15*

Conclusion

Mosul is the largest Sunni city in Iraq, with nearly 2 million residents prior to the Islamic State's takeover in June 2014. Mosul has long held strategic importance to ISIL and its predecessors, and the group is known to have operated underground in the city

prior to taking total control in 2014. The city's economy is more diverse and developed than other cities once held by the Islamic State, with an active manufacturing and industrial sector, airport, and major regional markets. As such, it has been a critical component of ISIL's extortion and taxation revenue streams, which help to fund the group's military operations and bureaucracy.

Our analysis of Mosul's economy under the Islamic State precedes the beginning of operations to liberate the city in the fall of 2016. Therefore, it focuses on the effects of ISIL's uncontested control of the city for over two years since it first conquered Mosul in June 2014. Overall, we find that ISIL control had a relatively modest impact on the city's markets and commercial economy, which continued to function at pre-ISIL levels, but a larger detrimental impact on the city's electricity and rates of population outflow.

After establishing control, the Islamic State moved to build a dense bureaucracy capable of implementing public services; maintaining local security; and raising funds through taxation, extortion, and direct intervention in local industries and factories. ISIL's investments appear to have paid off in some sectors of Mosul's economy. Our analysis of satellite imagery suggests that Mosul's markets were more active after ISIL takeover than immediately prior and that ISIL oversaw new construction in the main market area of the city. Thermal data on the heat output of industrial areas within Mosul also suggest that local factories remained active on average. Commercial vehicle traffic on Mosul's roads persisted. In all, commercial activity within Mosul appears to have persisted at levels roughly comparable to life before ISIL takeover.

Despite this early economic stability, Mosul began to show some signs of economic strain in before efforts to liberate the city began in 2016. Analysis of nighttime lighting over Mosul reveals that electricity consumption was staggeringly low within the city; the group proved unable to bring fuel resources into the city to match pre-takeover levels of electricity. Efforts by the Islamic State to directly intervene in Mosul's cement industry appear to have dampened thermal and nighttime lighting activity at one major industrial facility (the Badush Cement Factory) in the long run. Population estimates based on remote sensing data suggest that nearly 200,000 people fled the city between February 2015 and March 2016, despite Islamic State efforts to prevent residents of its caliphate from fleeing.

In Chapter Seven, we transition to a comparable assessment of ISIL's governance over Raqqah's economy. As the symbolic capital of the Islamic State, Raqqah represents a critical test of ISIL's promise to build an economically prosperous caliphate in a smaller, more ethnically homogeneous city than Mosul.

CHAPTER SEVEN

The Islamic State in Raqqah

Raqqah was the first provincial capital captured by opposition forces from the Assad regime in early 2013, including FSA units and the al-Qaeda–linked JN (now Hay`at Tahrir al-Sham). Following ISIL's successful efforts to consolidate control over the city from these groups in January 2014, Raqqah then served as the capital of ISIL's global caliphate and a stronghold for ISIL leadership and governance within the Syrian portion of ISIL's territory. The group took significant strides to rule Raqqah as a traditional state would, including rebuilding damaged infrastructure, opening schools, managing hospitals, establishing law and order through a local police force, collecting taxes, and establishing a civil service.

Overall, our satellite-based indicators of economic activity offer clear evidence that the group was a successful steward of Raqqah's economy for most of its tenure, with some modest strain beginning to appear in the availability of electricity and IDP outflows throughout late 2015 and early 2016. As with Mosul, our analysis predates operations to liberate Raqqah, which began in mid-2017. In the rest of this chapter, we explore Raqqah's strategic importance to the Islamic State, the group's history of controlling the city, Raqqah's prewar economy, and existing evidence of ISIL's governance over the city's economy since 2013. We then leverage our set of satellite-derived indicators of economic activity to more fully explore ISIL's economic impact on Raqqah.

Raqqah's Importance to the Islamic State

In March 2013, Raqqah became the first Syrian provincial capital to fall to opposition forces in the nascent rebellion against the Assad regime. On March 7, after less than a week of resistance, government forces in Raqqah capitulated to a coalition of opposition groups, including both secular FSA forces and Islamists from JN and the Islamic State.[1] After seizing control in an offensive that caused only limited damage to the city, ISIL and JN forces focused at first on maintaining local security and protecting

[1] Rania Abouzeid, "How Islamist Rebels in Syria Are Ruling a Fallen Provincial Capital," *Time*, March 23, 2013.

property and, by March 17, were "working to get civil institutions up and running."[2] Concerned for the potential for looting across the city, ISIL and JN elements reportedly kept FSA forces from entering the city. Local activists, calling Raqqah the "capital of liberation," reportedly played a key role in supporting these efforts.[3]

ISIL would eventually establish complete control throughout Raqqah in January 2014.[4] However, in the intervening months, Raqqah was contested, sometimes violently, by both government forces and the various opposition groups that had originally seized the city. Aerial bombardments by Syrian regime forces following the city's seizure resulted in what one nongovernmental organization described as the "highest level of displacement recorded to date," with an estimated 200,000 people fleeing this early violence.[5] Disagreement among the opposition forces controlling the city began in April 2013, when a planned merger between ISIL and JN failed.[6] Throughout the summer and fall, ISIL slowly expanded its control throughout the city, pushing out both rival groups (including the FSA) and local activists through targeted violence.[7] Following a "rebel uprising" against ISIL in early January 2014, ISIL was nearly completely expelled from Raqqah as part of a broader rebellion against the group that occurred throughout parts of Syria.[8] Soon thereafter, an ISIL counteroffensive allowed the group to consolidate control once again throughout the city, executing many key leaders of previously affiliated opposition groups.[9] In July and August 2014, ISIL seized control of major military bases throughout the rest of Raqqah governorate, extending its control throughout the eastern half of Syria.[10]

Although ISIL would ultimately establish in the city a "holistic system of governance that includes religious, educational, judicial, security, humanitarian, and infrastructure projects, among others," violence would remain a hallmark of ISIL's coer-

---

2 There were some limited air strikes conducted by the Syrian regime at this time. For example, see "39 Killed in Air Raids in Syria City of Raqqa as Attacks Intensify," *Independent*, March 6, 2013. However, the overall damage was reportedly minimal.

3 "Lessons from Raqqa: From Demanding Freedom to Creative State-Building," *Syria Untold*, May 28, 2013.

4 ISIL established control on January 14, 2014. See, for example, Sirwan Kajjo, "The Fight for Raqqa," Carnegie Middle East Center, June 3, 2014.

5 *Regional Analysis Syria: 28 March 2013*, Assessment Capacities Project, March 28, 2013.

6 Charles C. Caris and Samuel Reynolds, *ISIS Governance in Syria*, Institute for the Study of War, Middle East Security Report 22, July 2014.

7 Caris and Reynolds, 2014. Also see David Remnick, "Telling the Truth About ISIS and Raqqa," *New Yorker*, November 22, 2015.

8 Caris and Reynolds, 2014.

9 Caris and Reynolds, 2014.

10 Erin Banco and Alessandria Masi, "US Bombs Islamic State's Raqqa Stronghold in Syria, Begins 'Degrade and Destroy' Strategy," *International Business Times*, September 23, 2014.

cive control over Raqqah throughout 2014.[11] This included intimidation of Raqqah's civilian populace through kidnapping, public executions, and assassination of activists and others who opposed its reign;[12] bombings of government buildings, mosques, and transportation centers;[13] and the destruction of Shia infrastructure (e.g., mosques, historical monuments) throughout the city.[14]

Although there were no deliberate efforts by coalition, opposition, or regime ground forces to displace ISIL from the city between January 2014 and mid-2016, persistent air strikes struck the city and targeted key ISIL personnel and infrastructure.[15] The first major air campaign against Raqqah occurred in September 2014, with U.S. efforts to "degrade and destroy" ISIL military targets in the city.[16] Air strikes against ISIL targets would continue at a steady pace throughout ISIL's control of the city and include strikes from Syrian regime forces, French forces, and Russian forces in addition to U.S. air strikes.[17] These strikes had reportedly "devastated" Raqqah by the fall of 2015 according to some estimates, with more than 1,000 buildings throughout the city assessed as either destroyed or severely damaged.[18]

The city carries massive strategic importance to ISIL, both as its symbolic capital and as the central node for ISIL's command and control over its entire caliphate. Its efforts to build a model form of Islamic governance in Raqqah have been broadcast to the world as an exemplar of the group's religious credibility and the overall prosperity available to those who want to join the caliphate.[19] Furthermore, Raqqah lies at the crossroads of four important geographic regions in Syria: the fertile Euphrates River

---

[11] Caris and Reynolds, 2014, p. 9.

[12] "An Overview of the Islamic State (Formerly Known as the Islamic State of Iraq and Syria [ISIS])," *Raqqa Is Being Slaughtered Silently on Facebook*, July 16, 2014.

[13] "An Overview of the Islamic State," 2014; Firas al-Hakkar, "The Mysterious Fall of Raqqa, Syria's Kandahar," *Al-Akhbar English*, November 8, 2013.

[14] "Shiite Shrine Bombed by ISIS in Syria's Raqqa," *Al Bawaba*, March 26, 2014; T. Fateh, "Qaeda Terrorists Blasted Khalifa Harun al-Rashid Statue in Raqqa," *Syria Times*, October 4, 2013.

[15] Initial operations to liberate northern and western outlying areas of Raqqah governorate began in the spring of 2017, in support of a campaign to ultimately isolate and liberate the city.

[16] Banco and Masi, 2014; Thomas Barrabi, "US Airstrikes in Syria: Timeline of Events That Led Obama to Target Islamic State," *International Business Times*, September 23, 2014; Jessica Elgot, "Raqqa, The 'Boring' Syrian City Turned Caliphate Capital, Now the Target of US Bombs," *HuffPost UK*, September 25, 2014.

[17] Mark Townsend, "Inside the Islamic State's Capital: Red Bull–Drinking Jihadists, Hungry Civilians, Crucifixions and Air Strikes," *Guardian*, November 30, 2014; Diana al Rifai, "Syrians in Raqqa Tell of 'Insane Nights' of Air Strikes," *Al Jazeera*, November 17, 2015; "French Jets Pound Raqqa as G20 Pledges New ISIL Fight," *Al Jazeera*, November 16, 2015; "France Pounds IS Stronghold with 20 Bombs," *Sky News*, November 15, 2015.

[18] Rifai, 2015; UN Institute for Training and Research (UNITAR), "Damage Assessment of ar Raqqa, ar Raqqa Governorate, Syria," July 21, 2015c.

[19] S. J. Prince, "Watch: New ISIS Video Attempts to Show Functioning Society in 'Capital' Raqqa, Syria," *Heavy*, April 4, 2016.

valley and oil-rich Deir ez-Zor governorate running toward Iraq to the southeast, Syria's Kurdish-majority al-Hasakah governorate to the northeast, Aleppo and its countryside to the west, and the Turkish border to the north.[20] Raqqah's location makes it key to controlling several critical highways running along these routes, which support the movement of people, goods, and materiel to support frontline combat operations.[21] And perhaps most importantly, as the first provincial capital captured from the Assad regime and one of the first cities to fall truly under ISIL's total control, Raqqah carries a symbolic importance for the group as a test of its ability to build a viable, long-term caliphate. For these reasons, this assessment will help gauge whether uncontested control and a strong internal impetus to build economic prosperity within the city have had an effect on Raqqah's economy over time.

Raqqah's Economy Before the Islamic State

Before the onset of the Syrian conflict, Raqqah had already experienced significant economic hardship. In 2007, Raqqah governorate had the highest human poverty index of any governorate in Syria.[22] As a predominantly agricultural region, which, along with two other governorates in northern Syria, accounted for 60 percent of Syria's agricultural land, Raqqah was severely affected by a drought that lasted from 2006 to 2010.[23] This drought, which "devastated" grain and cotton production throughout Raqqah, resulted in significant depopulation of rural areas.[24]

Raqqah received an estimated 500,000 to 800,000 refugees from throughout the country in the early parts of the conflict between opposition forces and the Assad regime. These refugee influxes at least doubled, and perhaps quadrupled, Raqqah's population before the city was taken by opposition forces, including ISIL, in March 2013.[25] In January 2013, on the eve of the arrival of these forces, the vast majority of

---

[20] Lucas Winter, *Raqqa: From Regime Overthrow to Inter-Rebel Fighting*, U.S. Army Foreign Military Studies Office, March 2014.

[21] "Retaking Raqqa from the Islamic State," Stratfor, May 24, 2016.

[22] Rabie Nasser, Zaki Mehchy, and Khalid abu Ismail, "Socioeconomic Roots and Impact of the Syrian Crisis," Syrian Centre for Policy Research, January 2013.

[23] Syria Needs Assessment Project, *Impact of the Conflict on Syrian Economy and Livelihoods*, Assessment Capacities Project, July 2013. Raqqah governorate does possess modest oil deposits as well, although less than the neighboring Deir ez-Zor governorate (David Butter, *Syria's Economy: Picking Up the Pieces*, Chatham House, Royal Institute of International Affairs, June 2015).

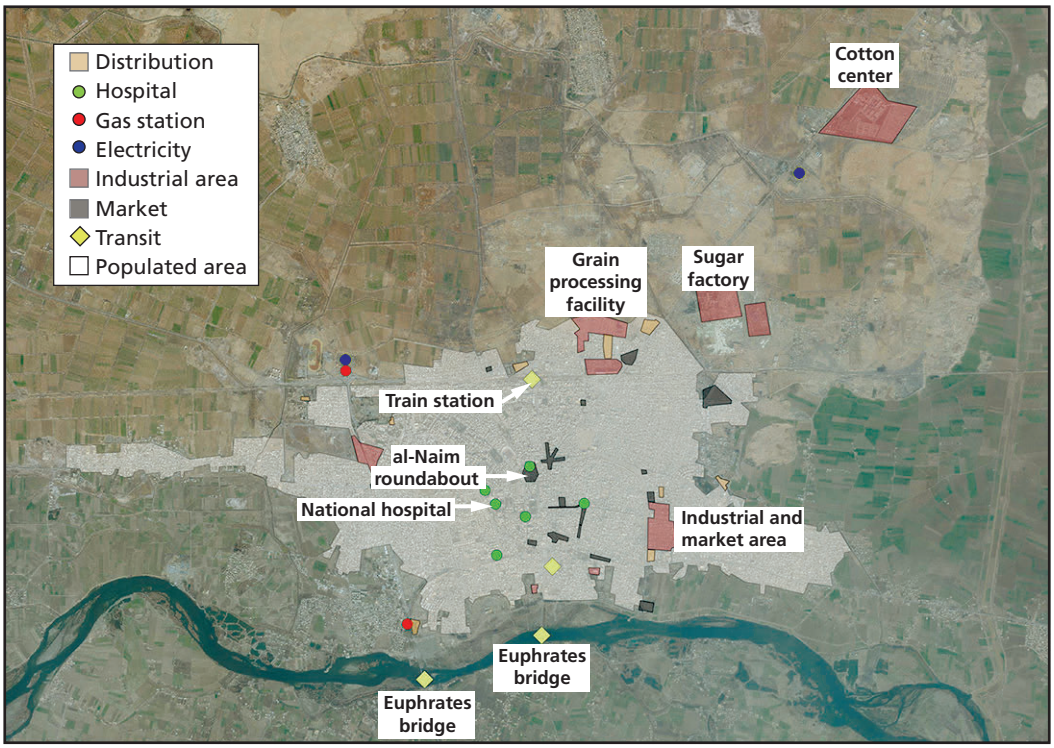
[24] "39 Killed in Air Raids in Syria City of Raqqa as Attacks Intensify," 2013; Regional Analysis Syria, 2013.

[25] Andrew Simmons, "Civilians Plead with Syrian Fighters," *Al Jazeera*, October 3, 2012; "Syria Rebels Capture Northern Raqqa City," *Al Jazeera*, March 4, 2013.

Raqqah's residents were assessed as being "at risk" in terms of food security (90 percent), health (80 percent), and shelter (80 percent).[26]

Figure 7.1 provides a graphical overview of Raqqah's key economic infrastructure. Although it is a relatively small city, with a prewar population of only some 200,000, Raqqah has six hospitals clustered in the center of the city. Reflecting its importance as a center of commerce for agriculture, Raqqah has a grain mill, a sugar factory, and a cotton center all distributed throughout the city. A train station in the northern part of the city supported commercial trade prior to ISIL's takeover of the city, and two bridges across the Euphrates to the south connected Raqqah to some of Syria's key oil production regions in the larger Raqqah governorate, as well as in Deir ez-Zor governorate.

Figure 7.1
Economic Laydown of Raqqah



SOURCES: Authors' estimates. Imagery from Digital Globe, 2017.
RAND *RR1970-7.1*

[26] Regional Analysis Syria, 2013.

The Islamic State's Economic Governance over Raqqah

Opposition forces prioritized efforts to reestablish governance in Raqqah immediately after its seizure from the Syrian regime in early 2013, with elements from the insurgent group Ahrar al-Sham specifically tasked with "securing government installations after they fell, protecting public and private property and maintaining services to the city."[27] Reportedly, opposition "sleeper cells" were established in Raqqah long in advance of the military offensive, which liberated the city from the Syrian regime, in an effort to ensure that governance and order would be maintained following its takeover.[28]

Within a month of its seizure—by April 2013—ISIL begin to compete against its former allies for control over Raqqah.[29] Although it rapidly displaced many of these former groups, ISIL would consolidate full control over Raqqah only in January 2014 when Ahrar al-Sham forces were finally displaced from the city following a failed uprising by other groups against ISIL.[30] By early 2014, ISIL would begin its efforts to build a "holistic system of governance that includes religious, educational, judicial, security, humanitarian, and infrastructure projects, among others," and Raqqah would become the "central city in ISIS's [Islamic State of Iraq and Syria, another name for ISIL] territorial network, the first city where ISIS established exclusive control."[31] And within a year, locals living in Raqqah would report that the "group is taking on the trappings of a government."[32]

Unlike the initial takeover of the city in the spring of 2013, Raqqah's economy was badly affected by ISIL's bid to unilaterally control the city in late 2013. Following several weeks of often-violent infighting between the competing opposition groups, the city's infrastructure was reportedly "completely paralyzed," with key economic infrastructure, including bakeries, inoperative and no power, water, or health services available.[33] And in one of the busiest locations in the city, near the al-Naim roundabout in the center of the city, it was reported that "daily activity has almost completely come to a halt."[34] This location would later become known as the primary public venue for ISIL's executions.[35]

---

[27] Abouzeid, 2013.

[28] Abouzeid, 2013.

[29] Caris and Reynolds, 2014, p. 11.

[30] Caris and Reynolds, 2014, p. 11.

[31] Caris and Reynolds, 2014, p. 11.

[32] Farooq, 2015.

[33] Deborah Amos, "As Rebels Fight Rebels, Grim Reports from a Syrian City," National Public Radio, January 8, 2014.

[34] Rami al-Ali, "ISIS Rules in Raqqa," *al-monitor.com*, February 26, 2014b.

[35] "Women's Secret Films from Within Closed City of Islamic State," *Expressen*, March 13, 2016.

However, ISIL moved quickly to rebuild the city. Within three months, water, electricity, and bread were readily available; schools and universities had been reopened; and the private sector began to function once again.[36] A key component of ISIL's efforts in Raqqah to drive this rapid recovery was the establishment of civil institutions to manage public services for Raqqah. This included a consumer protection office and civil judiciary; an electricity office, responsible for monitoring consumption, setting prices, and repairing electricity infrastructure; a post office; an office charged with receiving complaints about services in the city, and institutions for managing health care provision, education, and job matching, among others.[37] In some cases, the establishment of these public services was accompanied by an expulsion of existing services in the market—for instance, ISIL expelled all organizations providing health services and seized their equipment.[38] ISIL frequently appointed experienced managers to run these civil institutions. For example, the telecommunication systems in Raqqah were allegedly managed by a Tunisian with a doctorate on the subject.[39]

ISIL also began to take on several substantial projects to rebuild or improve Raqqah's physical infrastructure. This included the rebuilding of the Euphrates Bridge, the "single connection between the provincial capital and the villages in Southern Raqqa province," which had been badly damaged in early fighting.[40] ISIL also reportedly repaired sewer lines, power lines, and electrical power stations and built a new central market.[41]

In order to finance these efforts to rebuild and govern Raqqah, ISIL established a system of taxes, payment for services, and fees.[42] Taxes were levied on the commercial sector, with businesses paying monthly assessments and traders paying fees to move

---

36 "A-Raqqa Student: 'Daily Life Is Good' Under ISIS," *Syria Direct*, April 27, 2014.

37 Mariam Karouny, "Life Under Isis: For Residents of Raqqa Is This Really a Caliphate Worse Than Death?" *Independent*, September 5, 2014; "Specimen 9K: Electricity Prices in Raqqa," in al-Tamimi, 2015b; Zelin, 2014; "Specimen 7G: Opening of Office to Receive Complaints About Services, Raqqa," in al-Tamimi, 2015b.

38 "Specimen 10S: Notification on Banning Operation of Medical Aid Organizations in Raqqa Province," in al-Tamimi, 2015b.

39 Karouny, 2014.

40 Mohammed Ali al Haj Ali and Kristen Gillespie, "ISIS Attempts to Build Bridges, Literal and Metaphorical, in A-Raqqa," *Syria Direct*, March 27, 2014.

41 Caris and Reynolds, 2014; Zelin, 2014.

42 ISIL reportedly disliked the term *taxes* to describe these types of revenue, instead referring to these as *zakat* payments. See Rosenberg, Kulish, and Myers, 2015. There is significant evidence that ISIL was deliberate in hiring people to collect these taxes and fees, with efforts to staff such positions with appropriately trained professionals. Desirable skills included the following: (1) qualification in sharia sciences; (2) qualification in an economics specialty (i.e., accountancy, management, computer and information systems); (3) secondary business institute; (4) secondary education in business; (5) general secondary education in either of two divisions of sciences and humanities; and (6) preparatory education. See "Specimen J: Employment Opportunities with the Diwan al-Zakat in Raqqa Province," in al-Tamimi, 2015b.

goods, while households were charged directly for utilities, such as electricity, phone, and waste removal.[43] These revenues were supplemented with taxes on agriculture; fines for illegal activities (such as smoking, installing a satellite dish, and women wearing clothes considered too tight); and a variety of regulatory fees for such things as leaving the city or religious tax for being non-Sunni.[44] And in several cases, ISIL simply seized assets. Hotels and private homes were seized to house the burgeoning number of ISIL fighters arriving in Raqqah after their full takeover in January 2014.[45] ISIL relied heavily on its *hisbah* police units in Raqqah to ensure adherence to ISIL laws, collect these taxes, and enforce fines and violations for citizens who break ISIL's strict sharia guidelines.[46]

Although many commercial shops reopened within weeks of ISIL establishing control, one major immediate economic impact of the ISIL takeover of Raqqah was a rapid rise in food prices.[47] ISIL took deliberate action to address this particular issue, establishing flour mills throughout Raqqah and appointing a former Assad regime employee to manage flour distribution and bakeries throughout the city.[48] However, high food and commodity prices would remain a persistent challenge for ISIL over the course of its control of the city.[49] Price increases similarly affected merchants, manufacturers, and other businesses operating in Raqqah, with the logistical costs of trade between the city and regime-held areas tripling in price by mid-2015.[50] On top of these added costs, and in the wake of ISIL's takeover, the Assad regime imposed a "royalty" tax as high as 30 percent of the value of each shipment of goods into the city from its own territory.[51]

Oil prices had initially fallen after ISIL consolidated control over Syria's vast oil reserves in Deir ez-Zor and Raqqah governorates in 2014.[52] However, prices began to

---

[43] Farooq, 2015. Businesses in wealthier neighborhoods would pay higher taxes (Rosenberg, Kulish, and Myers, 2015).

[44] Almukhtar, 2016. In many cases, these taxes and fines were described as disruptive (Callum Paton, "Escape from Isis: Raqqa Family Who Fled Say 'Paradise' City Is Now 'Asphalt,'" *International Business Times*, February 9, 2016, updated February 11, 2016).

[45] R. al-Ali, 2014b.

[46] These hisbah units were reportedly paid $300 per month for their services (Farooq, 2015).

[47] Firas al-Hakkar, "ISIS Brings Life Back to Raqqa, in Its Own Way," *Al-Akhbar English*, January 23, 2014; "Food Prices Skyrocket in Syria's Raqqa," *Al Arabiya English*, March 3, 2014. See also Hamoud Almousa, "Increasing Prices of Food and Fuel in Raqqa," *Raqqa Is Being Slaughtered Silently*, December 14, 2015. Prices also rose because of poor wheat production in the year preceding the occupation. See Fick, 2015.

[48] "A-Raqqa Student," 2014; Karouny, 2014.

[49] "Islamic State 'Hit by Cash Crisis in Its Capital Raqqa,'" 2016.

[50] Almousa, 2015.

[51] Almousa, 2015.

[52] Syrian Economic Forum, "Economics of 'al-Raqqa,'" Issue 2, April 2015, p. 7.

rapidly increase in the spring of 2015, and coalition air strikes against ISIL's oil facilities as part of Operation Tidal Wave II led to dramatic decreases in the supply of oil and corresponding price increases throughout Iraq and Syria.[53]

However, despite these increased costs and the inherent insecurity of doing business in ISIL-controlled territory, many factories and businesses in Raqqah and its surrounding areas continued to operate throughout 2015.[54] An April 2015 survey of these firms indicated that the demand for their goods remained high, that the majority had sufficient labor supply, and that raw materials were readily available.[55]

Measuring the Islamic State's Economic Impact in Raqqah

In this section, we use satellite imagery and remote sensing data to track how economic activity in Raqqah changed over the course of ISIL's uncontested control of the city since January 2014. We examine how each indicator in our sample—electricity consumption, population levels, agricultural activity, industrial activity, market activity, commercial vehicle counts, and building destruction—changed as ISIL cemented its grip over the city. We use these data to test hypotheses described earlier in this report and in conjunction with existing evidence of ISIL's economic impact and control over the city discussed in the previous section.

Electricity Consumption

First, we use nighttime lighting to understand how electricity consumption changed over time in Raqqah since ISIL established control. Figure 7.2 plots nighttime lighting monthly since January 2014, with values normalized to that month to more easily understand percentage changes over time. We lack monthly nighttime lighting data from 2013 in order to establish a full pre-ISIL baseline; however, understanding changes in electricity use over the course of ISIL's tenure in the city remains illustrative. The first major shock to electricity consumption in the city occurred in October 2014, when nighttime lighting levels dropped to just 28 percent of their January 2014 levels. Despite modest gains in nighttime lighting over the course of early 2015, coinciding with ISIL's efforts to add generator capacity to the city at this time, electricity levels in September 2015 returned to around 30 percent of their January 2014 levels.

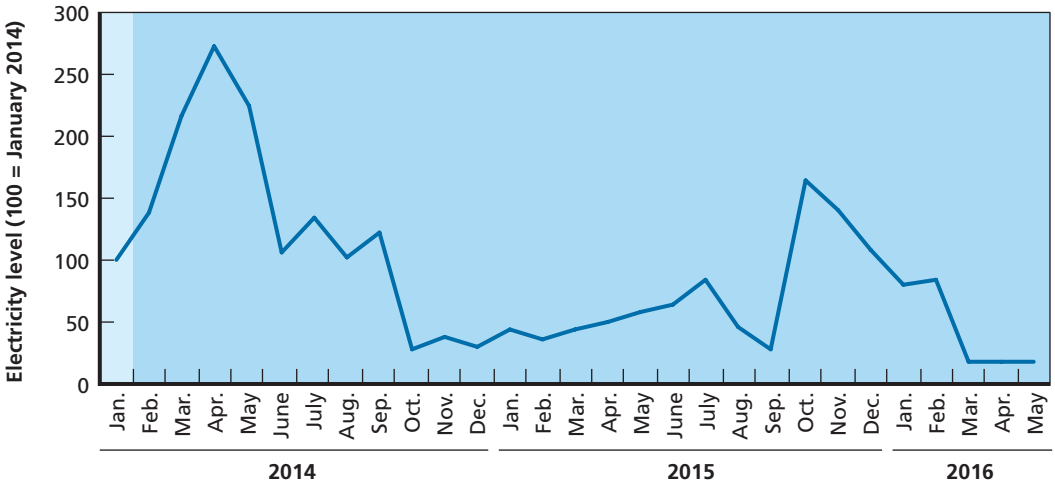
---

[53] For statistics on fuel price increases, see WFP, Syria Country Office, *Market Price Watch Bulletin*, Issue 11, September–October 2015c, Table 1. For information on air strikes' effect on ISIL oil, see, for example, Van Heuvelen, 2015.

[54] Eighty percent of factory owners reported insecurity near their facilities. See Syrian Economic Forum, 2015, p. 15.

[55] See Syrian Economic Forum, 2015, p. 15.

Figure 7.2
The Islamic State's Impact on Electricity in Raqqah, 2014–2016



SOURCE: Nighttime lighting data are calculated using NOAA VIIRS.
NOTE: All data are normalized to the first data point in the time series so that values deviate around 100. For example, a nighttime lighting value of 50 in this figure indicates that nighttime lighting at that point in time was 50 percent below the first point at which nighttime lighting information was collected. Light blue shading corresponds to months of contested control, while dark blue shading corresponds to months of unilateral ISIL control.
RAND *RR1970-7.2*

Not all of these declines in electricity consumption in the city might be due to overall fuel shortages. One report from January 2015 noted that such shortages might be the product of ISIL choosing to sell energy from its hydroelectric dams to the Syrian regime rather than provide electricity locally to Raqqah.[56] Furthermore, low levels of electricity consumption in Raqqah in September 2015 also coincide with the group shutting off water flow through the Tabqah Dam upstream on the Euphrates at this same time, which is responsible for much of Raqqah's electricity supply.[57]

ISIL appears to have reconstituted electricity supply to the city in some form through the winter of 2015 into early 2016. This is despite the overall crunch in the availability of fuel resources across the caliphate associated with coalition air strikes against the group's oil facilities, Operation Tidal Wave II, and suggests that ISIL was devoting limited fuel resources across the caliphate specifically to Raqqah or choosing to focus its hydroelectric generation capacity toward its capital. It also demonstrates the ability of ISIL's bureaucracy to rapidly and successfully repair local infrastructure—French air strikes in November 2015 briefly knocked out electricity to the entire city,

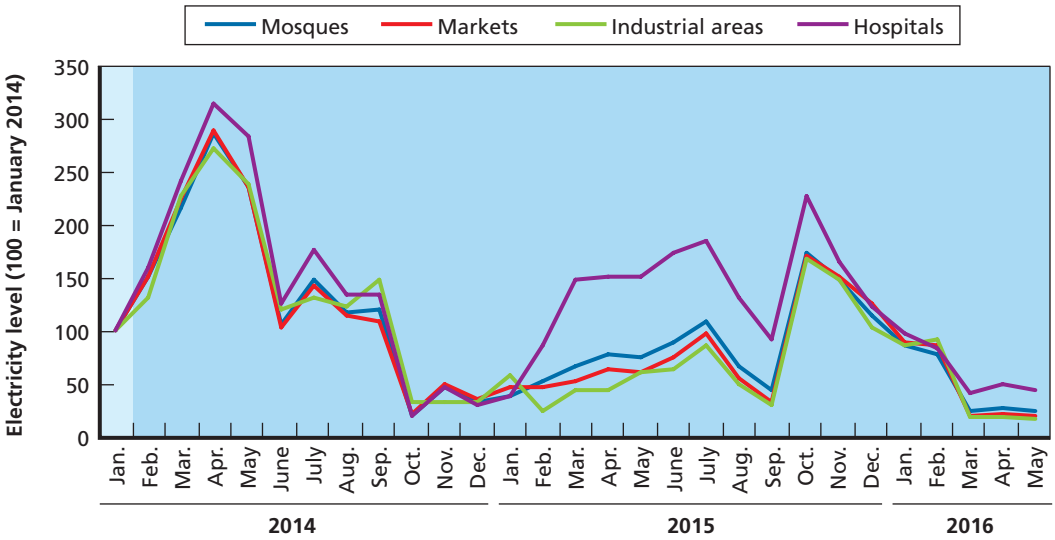
[56] Farooq, 2015.

[57] "ISIS Blocking Flow of Euphrates from Syria," *NOW*, September 15, 2015.

and local engineers working for ISIL successfully repaired the grid within a day.[58] The electricity boom over the next few months was short-lived, however, with nighttime lighting falling once again by April and May 2016 to the lowest levels seen since 2014.

We can also examine how nighttime lighting differed across types of critical infrastructure and commercial locations in Raqqah. Given power shortages, differences in nighttime lighting across different types of infrastructure offer insight into ISIL's priorities for generator-provided electricity within the city. Figure 7.3 displays average nighttime lighting levels over Raqqah's mosques, markets, industrial areas, and hospitals. The most significant finding from this figure is that, over the course of 2015, Raqqah's hospitals were overwhelmingly more electrified at night than any other types of infrastructure we tracked in Raqqah. For example, in July 2015, Raqqah's markets were operating at roughly similar levels of nighttime lighting as in January 2014. But Raqqah's hospitals were 85 percent brighter in July 2015 than they were in January 2014. This could suggest that ISIL prioritized public health provision within the city

Figure 7.3
Nighttime Lighting in Raqqah, by Type of Infrastructure



SOURCE: Nighttime lighting data are calculated using NOAA VIIRS.
NOTE: All data are normalized to the first data point in the time series so that values deviate around 100. For example, a nighttime lighting value of 50 in this figure indicates that nighttime lighting at that point in time was 50 percent below the first point at which nighttime lighting information was collected. Light blue shading corresponds to months of contested control, while dark blue shading corresponds to months of unilateral ISIL control.

RAND *RR1970-7.3*

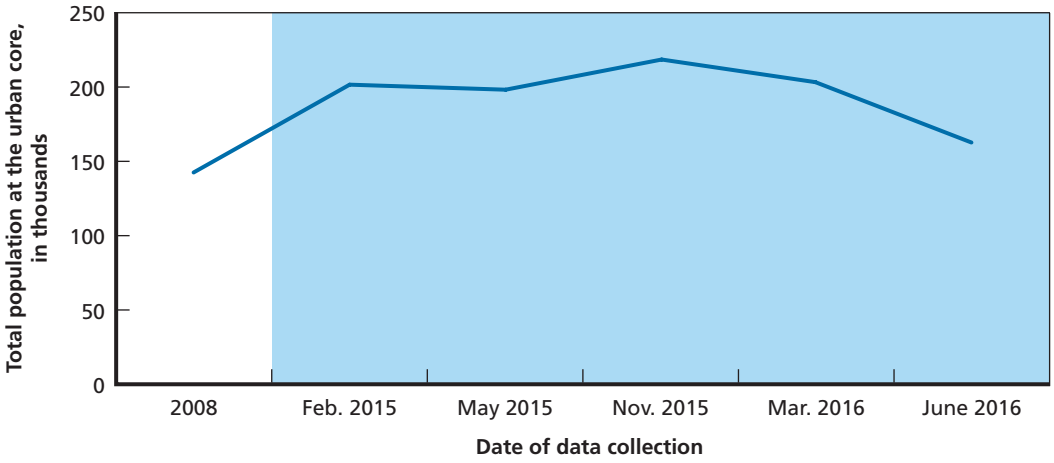
[58] Erika Solomon, "Syria's Raqqa Reaps Wind of Isis Occupation," *Financial Times*, November 17, 2015.

or that the group was using hospitals for military purposes or as a means of protecting its forces from air strikes.[59]

Population Levels

Next, we assess how the population of Raqqah has changed since ISIL took control of the city in late 2013. We restrict our estimates to the urban core of the city, as opposed to its full environs, so total population figures might fall slightly below published estimates. Figure 7.4 plots the city's population at six time points between 2008 and 2016. The significant uptick in population between 2008 and 2015 is likely due to the significant refugee inflows into the city during the first two years of the Syrian civil war. Unfortunately, we lack precise LandScan population data for 2013 and 2014 for Syria that could illuminate these changes more directly, including the extent to which ISIL's final takeover of the city from other opposition groups in January 2014 was accompanied by any IDP flows out of the city. However, over the course of ISIL's tenure through early 2016, we see relatively constant numbers of inhabitants in the urban core

Figure 7.4
Raqqah's Population over Time



SOURCE: Oak Ridge National Laboratory, Landscan 2008–2016.
NOTE: Population totals represent the number of people living in the urban core of the city. Data were captured at irregular intervals, so we use 2008 as a baseline and lack data on exact population totals prior to ISIL arrival. Blue shading corresponds to periods of unilateral ISIL control.
RAND *RR1970-7.4*

[59] Some evidence exists that the group has made military uses of certain hospital facilities in Raqqah and Deir ez-Zor, according to the UN. See UN General Assembly and UN Security Council, *Children and Armed Conflict: Report of the Secretary-General*, A/70/836-S/2016/360, April 20, 2016.

of the city. This suggests that the city's residents either did not seek to leave under ISIL control or could not leave based on ISIL-imposed restrictions.[60]

Ultimately, in our final estimates from June 2016, we begin to see evidence of a significant downturn in Raqqah's population. LandScan estimates from June 2016 suggest that Raqqah's population fell by more than 25 percent from its November 2015 peak. As Kurdish and Arab fighters from the Syrian Democratic Forces made significant headway across northern Aleppo and Raqqah governorates in this time period, and, as the first efforts to plan for liberation of the city began in earnest in mid-2016, this figure perhaps offers early evidence of IDP flows in anticipation of liberation of the city.

Agricultural Activity

Next, we explore how ISIL's control over the city has affected agricultural activity in Raqqah. Figure 7.5 plots changes in NDVI over time since April 2013. The data show seasonal spikes in spring and fall of each year, corresponding to peak harvest for wheat (in the spring) and rice (in the fall) according to data on Syrian agricultural production provided by FAO.[61] Peak NDVI values for 2014 far outstrip their 2013 values, but NDVI appears to fall afterward in 2015 and 2016. However, acknowledging massive rainfall in 2014, which might be driving these results, the intensity of agricultural activity in Raqqah's surrounding agricultural areas appears to remain relatively constant over the course of ISIL's control of the city.

Industrial Activity

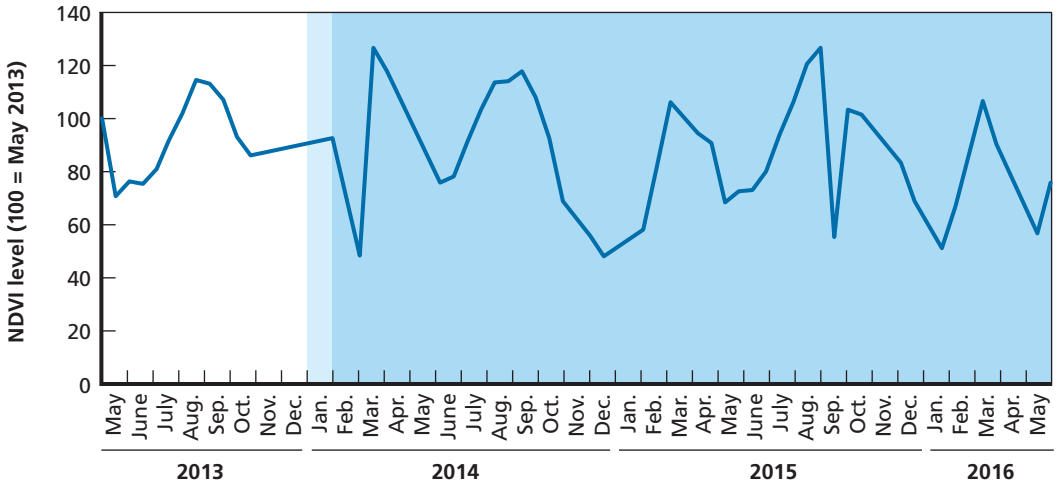
We next examine how ISIL control of Raqqah has affected economic activity around the city's industrial areas. Figure 7.6 plots the average thermal signature of Raqqah's industrial areas (in red) relative to the average city temperature (in blue). We measure industrial activity here as the mean percentage deviation across all industrial facilities in Raqqah relative to the city's average temperature. We include a similar measure for Raqqah's markets (in green) to demonstrate that the thermal signature of industrial areas rises far above the city's mean temperature. The irregular temporal frequency of our thermal data complicates interpretation of this figure; however, two observations do still emerge. The first is that Raqqah's industrial areas were consistently hotter than

---

[60] Although we lack precise population data for Raqqah from exactly prior to ISIL's takeover of the city, we can use overall population growth figures for Syria to extrapolate from our 2008 estimates. World Bank estimates for the total Syrian population indicate a growth rate of 12.3 percent across all of Syria between 2008 and 2013. This would suggest that Raqqah's population in 2013 would be only 167,000 inhabitants. This further confirms the large population inflows into Raqqah city prior to ISIL's full takeover in early 2014. See "Syria: Syrian Arab Republic," *City Population*, January 11, 2015. Census figures for 2004 published by the Syria's Central Bureau of Statistics peg Raqqah's population at 220,488 ("Results of Population and Housing Census 2004 on the Neighborhood Level," Syrian Central Statistical Bureau, undated).

[61] FAO, "Country Briefs: Syria," reference date November 15, 2016b.

Figure 7.5
Agricultural Activity in Raqqah's Periphery



SOURCE: NDVI data are derived using USGS Landsat 8.
NOTE: All data are normalized to the first data point in the time series so that values deviate around 100. Light blue shading corresponds to months of contested control, while dark blue.
RAND *RR1970-7.5*

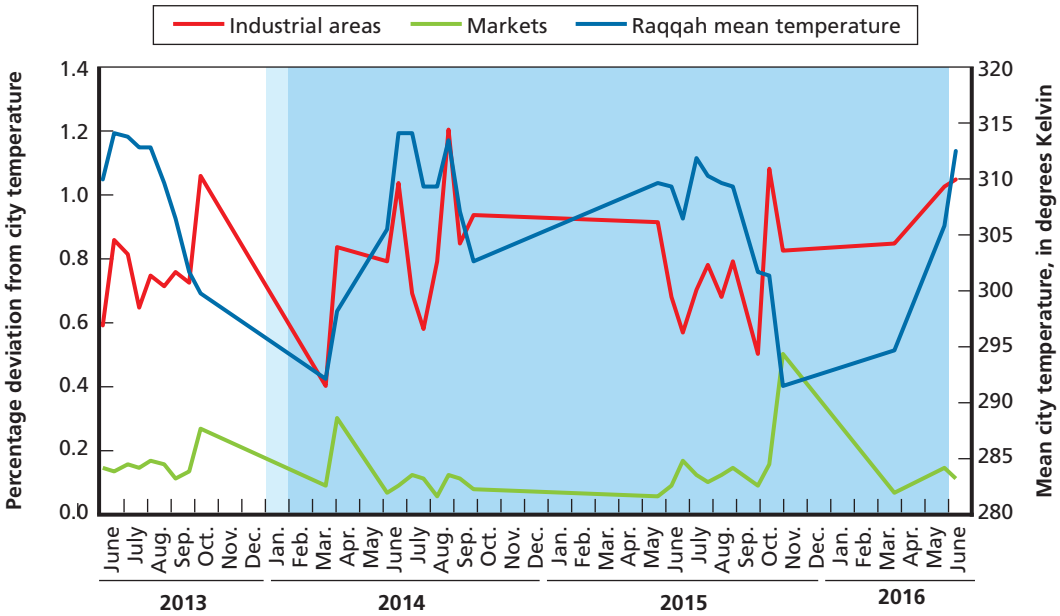
the city's mean temperature over the course of ISIL's control of the city. This suggests that they remained at least somewhat active under ISIL control. The second observation is that Raqqah's industrial areas appear to have been particularly active in the winter of 2015. We lack a full explanation for the timing of this peak in industrial activity.

Market and Commercial Activity

We next examine how ISIL's control over the city has affected commercial activity in Raqqah. We start by focusing on Raqqah's markets. Figure 7.7 shows crowd-sourced estimates of market activity visible in commercial satellite imagery of the city over time, plotting the average intensity of market activity on a scale from no activity (0), to limited activity (1), to significant activity (2). The first panel plots average levels of market activity across 18 separate market and commercial locations identified from high-resolution imagery within the city. Although the temporal frequency of these assessments is variable, the lack of a clear time trend over the course of ISIL's control of the city suggests that little has changed since the group first moved into Raqqah in 2013. Unfortunately, we lack sufficient market data from before opposition forces took over the city in 2013 to assess whether activity declined from regime-controlled levels.

In the second panel, we display nighttime lighting over two key commercial locations in the center of the city, the 23 February street market and the al-Naim roundabout. The al-Naim roundabout was traditionally one of the busiest intersections in

Figure 7.6
Thermal Activity at Raqqah's Industrial Areas



SOURCE: Thermal data are derived using USGS Landsat 8.
NOTE: Light blue shading corresponds to months of contested control, while dark blue shading corresponds to months of unilateral ISIL control.
RAND *RR1970-7.6*

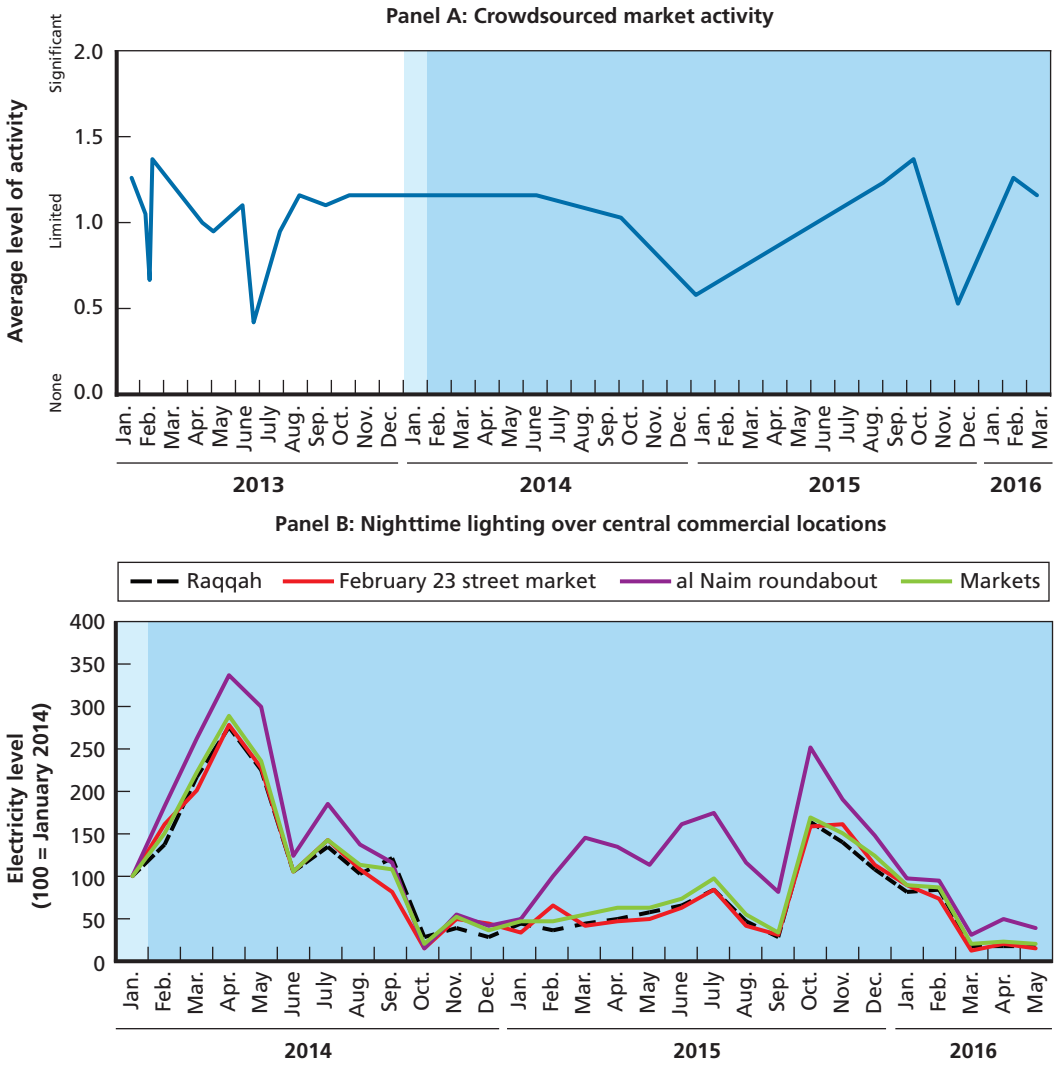
the city, but reports from February 2014 suggested that "daily activity has almost completely come to a halt."[62] Under ISIL control of the city, the roundabout was the primary location used for public executions of those accused of violating ISIL's strict religious law.[63] Nighttime lighting captures the importance of this area in the city. Relative to January 2014 levels, the al-Naim roundabout has significantly higher levels of nighttime lighting than other markets, commercial areas, and the whole city of Raqqah on average, particularly over the course of 2015, when overall nighttime lighting was reduced across the rest of the city. It should also be noted that Raqqah's main government center is located on the southern end of the roundabout, suggesting that ISIL might be using this location as part of its efforts to administer the city.

We also use estimates of commercial vehicle traffic in Raqqah based on crowdsourced analysis of satellite imagery to better understand how ISIL's control of the city affected commercial activity. A time series plotting the total number of commercial vehicles present in Raqqah's urban core over time is shown in Figure 7.8. This plot shows a comparable noisiness to many of the figures derived from high-resolution

[62] R. al-Ali, 2014b.

[63] "Women's Secret Films from Within Closed City of Islamic State," 2016.

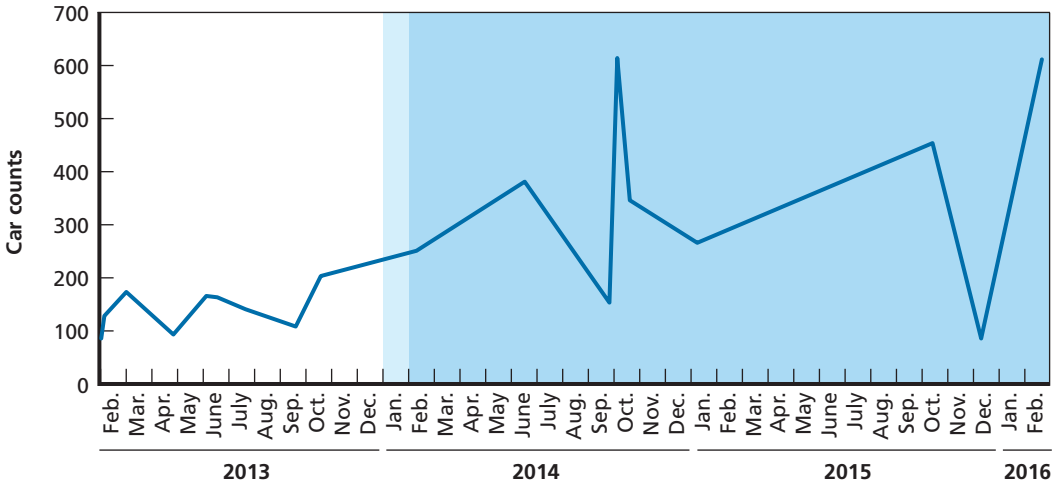
Figure 7.7
Raqqah's Markets



SOURCE: Market activity data are derived from Digital Globe's Tomnod Crowdsourcing Platform. Nighttime lighting data are from NOAA VIIRS.
NOTE: Crowdsourced market activity data are presented as the average crowdsourced ranking across various subpolygons making up each market. Each market location was ranked as to whether it exhibited no activity (0), limited activity (1), or significant activity (2). Light blue shading corresponds to months of contested control, while dark blue shading corresponds to months of unilateral ISIL control.
RAND *RR1970-7.7*

imagery throughout this report; however, the overall trend is clear. Commercial vehicles appear to be more prevalent under ISIL control of the city than when the group was merely sharing control with other opposition groups. This suggests that ISIL was

Figure 7.8
Commercial Vehicle Counts in Raqqah



SOURCE: Commercial vehicle data are derived from Digital Globe's Tomnod Crowdsourcing Platform.
NOTE: Light blue shading corresponds to months of contested control, while dark blue shading corresponds to months of unilateral ISIL control.
RAND *RR1970-7.8*

more successful at establishing a stable business environment than in the status quo contest for control of the city between various opposition forces.

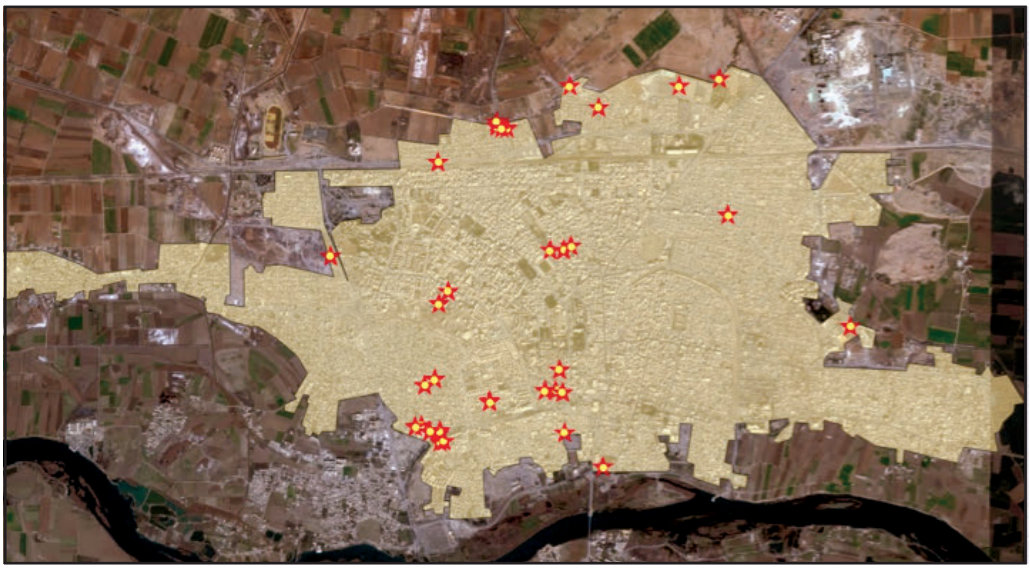
Damage and Destruction

Finally, we use crowd-sourced analysis of commercial satellite imagery to map buildings, roads, and infrastructure in Raqqah that are damaged or destroyed over time through mid-2016. We use data on damage and destruction to understand how violence might have directly or indirectly affected our previous indicators of economic activity. Figure 7.9 plots crowd-sourced locations of damage and destruction throughout Raqqah in both February 2014, shortly after the group cemented its unilateral control over the city, and February 2016 for comparison's sake. Our 2014 estimates suggest that some damage to the city did occur during ISIL's initial takeover. Interestingly, the crowd no longer identifies many of these locations as damaged two years later. By February 2016, damage to Raqqah (predominantly from air strikes) is more widespread but still largely sporadic across different clusters within the city.

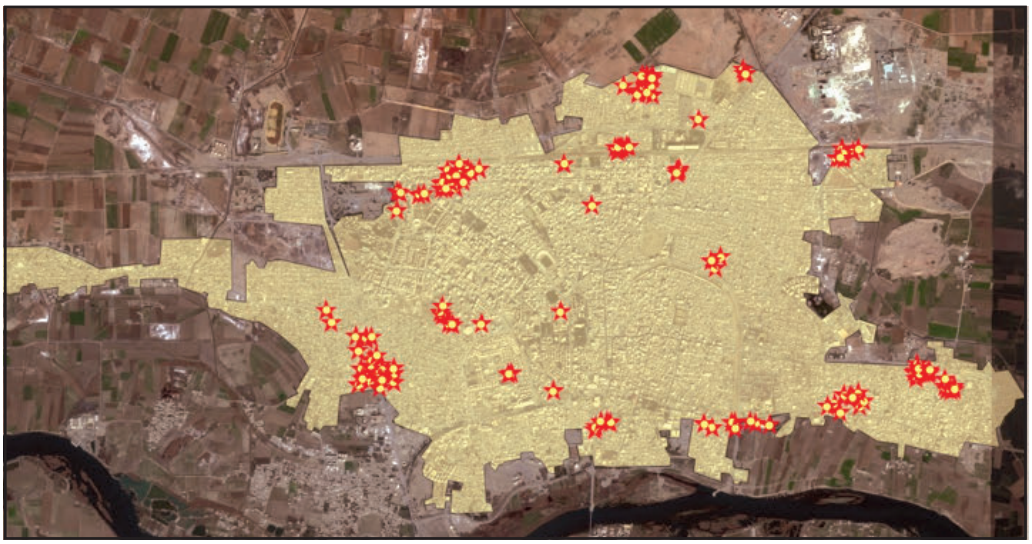
As mentioned, these instances of damage differ from levels of destruction seen in other cities in that they are primarily due to air strikes rather than ground fighting or IEDs. They often represent damage to certain buildings or pieces of infrastructure of military importance to the Islamic State, rather than wholesale, indiscriminate damage to portions of the city's residential neighborhoods. This is not to say that such damage

Figure 7.9
Damage and Destruction in Raqqah, February 2014 and February 2016

February 12, 2014



February 20, 2016



SOURCES: Damage data are derived from Digital Globe's Tomnod Crowdsourcing Platform. Imagery is from Digital Globe, 2016.
NOTE: The yellow shaded area represents the city's urban extent, based on authors' estimates and a review of satellite imagery. Yellow-centered red stars denote instances of damage or destruction.
RAND *RR1970-7.9*

had no impact on Raqqah's local economy through mid-2016. Figure 7.10 offers two illustrative examples.

The top panel of Figure 7.10 highlights damage to a grain processing facility on the northern end of Raqqah. Although much of the facility remains intact, including the silos and grain towers to the west of the highlighted area, the warehouse in the middle of the grain processing facility (highlighted in red) is entirely destroyed. Wikimapia, an open-source mapping website, alleges that this location is a former ISIL prison. Although that notion is unsurprising, this implies that ISIL leadership prioritized matters of physical security over the possibility that a key piece of economic infrastructure could be damaged via air strike.[64] As a counterpoint, in the bottom panel, air strikes appear to have destroyed three local government security offices in a compound on the southern end of Raqqah with little potential for adverse economic impact to the city. Interestingly, ISIL appears to have removed the rubble from these facilities rather than leave it publicly damaged, perhaps to avoid the appearance of susceptibility to airpower or perhaps to pave the way for future reconstruction of the location.

Conclusion

Raqqah was the first provincial capital captured by opposition forces from the Assad regime in early 2013 involving FSA units and the al-Qaeda–linked JN (now Hay`at Tahrir al-Sham). Following ISIL's successful efforts to consolidate control over the city from these groups in January 2014, Raqqah then served as the capital of ISIL's global caliphate and a stronghold for ISIL leadership and governance within the Syrian portion of ISIL's territory. The group took significant strides to rule Raqqah as one would a traditional state, including rebuilding damaged infrastructure, opening schools, managing hospitals, establishing law and order through a local police force, collecting taxes, and establishing a civil service.

Overall, our satellite-based indicators of economic activity offer clear evidence that the group was a successful steward of Raqqah's economy for most of its tenure. Agricultural activity measured through satellite-based sensors showed relatively consistent harvests each year from 2013 to 2016, and thermal activity in industrial areas in the city was also consistent over time. According to crowd-sourced analysis of overhead satellite imagery, Raqqah's markets remained steadily active since 2013. Commercial vehicle traffic actually increased under ISIL control relative to the pre-ISIL period of opposition infighting for control of the city in late 2013. Furthermore, our analysis of nighttime lighting across critical infrastructure in Raqqah reveals that hospitals were consistently better lit at night than markets, industrial areas, or residential areas. This

[64] "Ar-Raqqah," *Wikimapia*, c. March 2017.

Figure 7.10
Examples of Destruction in Raqqah

Grain processing facility and potential ISIL prison, March 2016

Political Security branch office

December 2014 **March 2016**

SOURCES: Location information from Wikimapia, "Al-Raqqah." Imagery from Digital Globe, December 12, 2014, and March 21, 2016.

RAND *RR1970-7.10*

suggests that the group might have prioritized health care provision over other services; whether for its own fighters or for local residents is unknown.

Despite these successes, parts of Raqqah's economy under the Islamic State appear to have struggled. We find that ISIL control led to significantly reduced electricity consumption in the city, with nighttime lighting as of mid-2016 falling to only 30 percent of its January 2014 levels. This is despite ISIL's uncontested control over the nearby Tabqah Dam, which produces the vast majority of Raqqah's electricity. ISIL's mismanagement of this facility in 2014 led to an insufficient supply of drinking water, water for irrigation, and electricity supplies for several months until the situation was later resolved. Although our estimates suggest that the city's population was largely

constant over the course of 2015 and early 2016, we find later evidence that major refugee flows out of Raqqah began in the summer of 2016. This suggests that city residents were either satisfied with ISIL's early governance or fearful of leaving the city earlier as a result of ISIL-imposed restrictions on out-migration. When refugee flows out of Raqqah did begin in earnest, they coincided with increasing advances by Kurdish opposition forces throughout much of northeastern Syria over the course of 2016. Alternatively, this timing could suggest that earlier refugee flows out of Raqqah were offset by influxes of ISIL's own fighters and that the rate of foreign-fighter flows into Raqqah declined over the course of 2016.

These findings paint a nuanced picture of the Islamic State and Raqqah's economy—that of an authoritarian insurgent group with some success rebuilding and governing the economy of its symbolic capital but beginning to struggle under the weight of the larger conflict in which it operates. Despite the group's draconian system of social regulations, taxes, and use of coercive violence, people still went to the market, commercial trucks still drove the streets, and the fields remained cropped. But signs of volatility and decay as of mid-2016 are troublesome for Raqqah's long-term prospects post-liberation—most notably, in terms of the city's wavering access to electricity, increasing rate of IDP flows, and the potential for strain on the city's economic infrastructure from fighting to liberate the city.

In Chapter Eight, we present our case study of Ramadi, another strategic Sunni town in Iraq that was long contested by ISIL forces before it was relinquished in January 2016. Ramadi offers the chance to expand the implications of our findings in Raqqah and Mosul to include areas only briefly controlled unilaterally by the Islamic State, as well as those already liberated and experiencing the initial stages of economic recovery.

CHAPTER EIGHT

The Islamic State in Ramadi

The Islamic State established a partial foothold in Ramadi, the capital of Iraq's Sunni-dominated Anbar province, in January 2014 well prior to its main offensive into northern Iraq later that year. After 17 months of fighting against government forces within the city, ISIL forces finally took full control of Ramadi in June 2015. This unilateral control was short-lived; Iraqi forces moved back into parts of Ramadi's urban center as early as October 2015 and had wrested full control of the city back from ISIL by January 2016. On its way out of Ramadi, ISIL's fight against government forces destroyed much of the city's key infrastructure—including every bridge crossing the Euphrates River. For the first six months after its liberation, few residents returned, and reconstruction of the city was limited.

Because Ramadi is an economically underdeveloped city with a government-dependent economy, control over Ramadi offered limited financial benefit to ISIL in terms of potential revenue sources. However, control of Ramadi was strategically significant to ISIL as a major government and Sunni population center along the Euphrates connecting Syria to Baghdad. The lengths to which ISIL fought to take over Ramadi are a testament to the city's significance to the group for sectarian and military reasons, rather than economic ones. Despite the short time period in which ISIL controlled the city, we find evidence that Ramadi's economy heavily deteriorated under the weight of ISIL's control over the city.

In the following sections, we further explore Ramadi's importance to the Islamic State and its economy before the group's arrival and then discuss existing evidence of the group's economic impact and direct governance over the city. The bulk of this chapter is then spent focused on our satellite imagery–derived indicators of economic activity, which we use to refine this discussion in greater detail.

Ramadi's Importance to the Islamic State

Ramadi is the provincial capital of Iraq's Anbar province, a largely Sunni area west of Baghdad that stretches to Iraq's western borders with Syria, Jordan, and Saudi Arabia. Islamic State forces first targeted Ramadi in late 2013, although the group and its pre-

decessors have long viewed the city as having significant strategic importance in that it offers an eastern buffer from both Iran and the Shia areas of Iraq.[1] As key grievances of Ramadi's Sunni population vis-à-vis the Shia Iraqi central government remained unaddressed over the years,[2] Ramadi offered ISIL forces a unique and early opportunity to expand their influence out of Syria into Iraq in early 2014. When ultimately in control of the city in mid-2015, ISIL reportedly tailored its governance approach to exploit these grievances and exploit fissures in local institutions, strained from years of heavy fighting and unfavorable policies enacted by the central government in Baghdad, to establish control by working through sympathetic local tribal leaders.[3]

Although ISIL forces controlled portions of the city as early as January 2014, ISF elements persistently contested ISIL's efforts to control the entire city, with some 17 months of violent conflict preceding the eventual full takeover of the city in May 2015.[4] This period was marked by citywide violence and destruction, including ISIL targeting of key government infrastructure at the outset of this period of contestation; intimidation of Ramadi civilians through kidnapping and random acts of violence; and the destruction of city infrastructure as a result of violent skirmishes, including air strikes by Iraqi air forces, throughout the city.[5]

---

[1] Kirk Sowell, "The Islamic State's Eastern Frontier: Ramadi and Fallujah as Theaters of Sectarian Conflict," *Perspectives on Terrorism*, Vol. 9, No. 4, 2015, pp. 130–141, p. 131.

[2] Ramadi was at the center of large-scale Sunni protests against the Shiite-dominated Maliki government in 2012 ("Iraq Protests Signal Growing Tension Between Sunni and Shia Communities," *Guardian*, December 26, 2012).

[3] This approach reportedly has influenced ISIL's governance style in Ramadi: The application of sharia law in ISIL-controlled Ramadi was reportedly not as strict as it was in other major ISIL-controlled cities (Sowell, 2015, p. 137).

[4] Hamza Mustafa, "Iraqi Army and Awakening Forces Say Ramadi Cleared of ISIS," *Asharq al-Awsat*, January 26, 2014; Ben Hubbard, "Ramadi, Reclaimed by Iraq, Is in Ruins After ISIS Fight," *New York Times*, January 7, 2016; Riyadh Mohammed, "The Taking of Ramadi: Behind ISIS's Bloody Assault," *Fiscal Times*, May 21, 2015.

[5] "Fighting Rages in Iraq's Anbar; 23 Killed in Clashes, Attacks," Rudaw, January 6, 2015; Amre Sarhan, "Iraqi Forces Kill Dozens of ISIS Militants Southern Ramadi," *Iraqi News*, January 25, 2015; Mohammed Tawfeeq and Jason Hanna, "11 Dead After Suspected ISIS Attacks in Western Iraq," CNN, January 14, 2015; Sinan Adnan, Patrick Martin, and Omar al-Dulimi, "Iraq Situation Report: March 18–20, 2015," Institute for the Study of War, 2015. Targeted infrastructure includes a police headquarters, the mayor's office, and a key bridge. See Yasir Ghazi and Tim Arango, "Iraq Fighters, Qaeda Allies, Claim Falluja as New State," *New York Times*, January 3, 2014, and Michael Knights, "The ISIL's Stand in the Ramadi–Falluja Corridor," *CTC Sentinel*, Vol. 7, No. 5, May 2014, pp. 8–12. This type of activity occurred in later months as well, with ISIL converting a pediatric and maternity hospital into a temporary barracks. See "After Losses to ISIS, Iraqi Army Regains Ground in Ramadi," CBS News, April 21, 2015.

On intimidation, one example is ISIL's takeover of al-Anbar University, holding "hundreds of students and staff hostage for several hours before retreating." See Bill Roggio, "Iraqi Troops Repel ISIS Assault on Mosul," *Long War Journal*, June 7, 2014a. ISIL also conducted guerrilla-style raids on citizens before retreating to areas under its control (Raed el-Hamed, "ISIS and the Anbar Crisis," Carnegie Endowment for International Peace, June 12, 2014; Zeina Khodr, "Iraqi Forces Battle Sunni Rebels for Ramadi," *Al Jazeera*, August 20, 2014; Bill

ISIL's unilateral control of Ramadi would prove short-lived. ISF elements first recaptured several of the city's outlying neighborhoods in August 2015 and had encircled the city in its entirety by October 2015, just five months after ISIL first consolidated control.[6] Progress by ISF elements responsible for retaking the city was slow, hampered by IEDs and other devices planted by the Islamic State to halt their advance.[7] With coalition air strikes in support, ISF elements and local tribal militias were ultimately able to push ISIL from the city in late December 2015, with fighting in some parts spilling over into January and February of the following year.[8]

Prior to their retreat from the city, ISIL forces sabotaged most of Ramadi's electrical grid and water treatment and distribution network and destroyed more than 60 bridges in the larger Ramadi area essential to local city traffic and commerce.[9] In all, violence from ISIL's capture and defeat in Ramadi destroyed an estimated 80 percent of the city, and, although GoI forces reestablished control by early 2016, the nearly 500,000 residents of Ramadi and its environs who had fled were initially warned not to return to their homes because fleeing ISIL forces had mined the roads.[10]

Ramadi's Economy Before the Islamic State

Ramadi, despite being the capital of Anbar province, was the second-poorest urban area in Anbar on the eve of ISIL's arrival. In 2010, unemployment in the city of Ramadi stood at 21 percent, some 50 percent higher than the average for the rest of Anbar province, and the poverty rate was second only to that of Fallujah, which had been severely

---

Roggio and Caleb Weiss, "Islamic State Ambushes Iraqi Military Column Near Ramadi," *Long War Journal*, September 30, 2014).

6 Between August and September 2015, the Iraqi Army's 8th Brigade—supported by tribal militias—began recapturing large swaths of territory ISIL had taken in May, including a train station just west of Ramadi. See Leith Fadel, "Iraqi Armed Forces Cutoff ISIS' Final Supply Route to al-Ramadi: Train Station Captured," *Al Masdar News*, August 17, 2015a, and "In Pictures: Rare Images of ISIS Hold on Ramadi," Rudaw, August 24, 2015.

7 Joseph V. Micallef, "The Battle for Ramadi: Whatever Happened to the Anbar Campaign?" *Huffington Post*, September 4, 2015.

8 Ashley Fantz and Hamdi Alkhshali, "Ramadi Has Been Taken Back from ISIS, Iraqis Say," CNN, December 29, 2015; "Iraq Army Enters Last ISIL Stronghold in Ramadi," *Al Jazeera*, February 9, 2016.

9 Stephen Kalin, "U.N. Team Calls Destruction in Iraq's Ramadi 'Staggering,'" Reuters, March 4, 2016a; Susannah George, Desmond Butler, and Maya Alleruzzo, "Iraq Routed IS from Ramadi at a High Cost: A City Destroyed," Associated Press, May 5, 2016; Thomas Fessy, "Iraq Conflict: Damage to Ramadi Hampers Return of Displaced People," BBC News, December 30, 2015.

10 Jonathan Steele, "West Weeps for Aleppo but Ignores the Refugees of Ramadi," *Middle East Eye*, February 12, 2016; Stephen Kalin, "Islamic State Mines Kill Dozens of Civilians Returning to Ramadi," Reuters, April 22, 2016c; James Andre, Amar Mohammed Sahib al Hameedawi, and Khalil Bechir, "Ramadi, from Iraq's Third City to a Ghost Town," *France 24*, March 18, 2016.

damaged during Operation Iraqi Freedom.[11] The province reportedly saw a dramatic fall in poverty rates from 2007 to 2012, with the share of the population impoverished falling by roughly half, from just over 26 percent to just under 14 percent.[12] Ramadi's pre-ISIL economy was largely centered on government spending, with nearly 50 percent of employed people working directly for the government. The service sector was the second-most prominent, representing 30 percent of all employment, followed by agriculture.[13]

Disagreements with the central government over economic issues were a significant source of local grievances in the years before ISIL's takeover of the city. This included local efforts in 2010 to control the development of a natural gas field (Akkas), which reportedly would bring "100,000 jobs to the region," efforts that the national oil ministry ignored when auctioning off rights for those gas fields.[14] Protests in Ramadi in 2011 (as well as in Baghdad, Mosul, Basra, and al-Diwaniya at the time) were reportedly economically motivated, with protesters focused on "the government's failure to improve services—electricity shortages being a major complaint—and the de facto cutbacks (because of unavailability) in the food rations the government had been distributing since well before the U.S.-led invasion."[15] These economic grievances are often cited specifically as an approach used by ISIL's predecessor groups to gain a foothold in Anbar province during Operation Iraqi Freedom.[16]

Figure 8.1 provides a spatial overview of Ramadi's key economic infrastructure. With a pre-ISIL population of roughly 300,000 people, Ramadi boasted a large university of some 10,000 to 15,000 students, 1,000 of whom ISIL reportedly held hostage during June 2014.[17] Just outside the university, Ramadi has several industrial facilities

---

[11] Inter-Agency Information and Analysis Unit, "Anbar Governorate Profile," November 2010. One estimate suggested that 75 percent of Fallujah's homes had been destroyed as a result of combat operations. See Haroon Siddique, "Bloody Response in Fallujah," *Taipei Times*, November 15, 2009.

[12] See World Bank, 2014, Table A.2.1.

[13] Central Organization for Statistics and Information Technology; Ministry of Planning and Development Cooperation, Iraq; Kurdistan Region Statistics Office, Iraq; Nutrition Research Institute, Ministry of Health, Iraq; and United Nations World Food Programme, *Comprehensive Food Security and Vulnerability Analysis: Iraq*, United Nations World Food Programme, 2008. Agriculture employed some 17 percent, while nonagriculture self-employed and skill laborers accounted for more than 30 percent. Note that Republic of Iraq, undated, provides higher estimates of the prominence of agriculture.

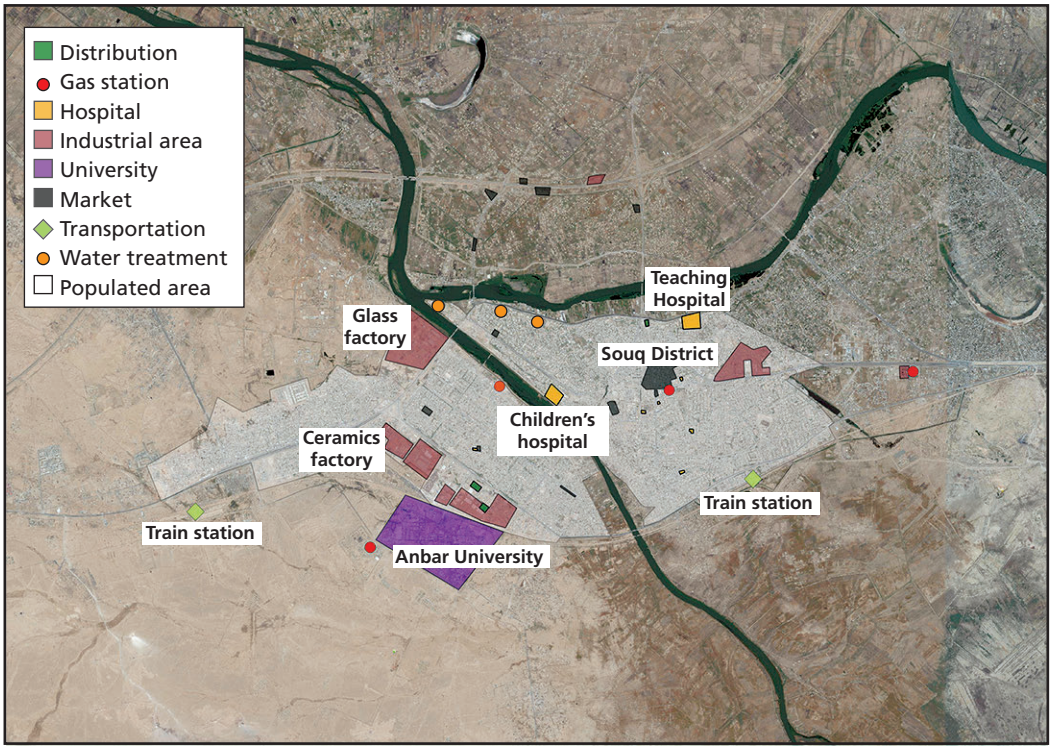
[14] John Leland and Khalid D. Ali, "Anbar Province, Once a Hotbed of Iraqi Insurgency, Demands a Say on Resources," *New York Times*, October 27, 2010.

[15] Marina Ottaway and Danial Anas Kaysi, "Iraq: Protest, Democracy, and Autocracy," Carnegie Endowment for International Peace, March 28, 2011.

[16] Myriam Benraad, "Iraq's Tribal 'Sahwa:' Its Rise and Fall," Middle East Policy Council, undated.

[17] "Breaking News . . . Source: About 1000 Students Held at the University of Anbar," Shafaaq News, June 7, 2014.

Figure 8.1
Economic Laydown of Ramadi



SOURCES: Authors' estimates. Imagery from Digital Globe, 2016.
RAND *RR1970-8.1*

responsible for concrete, ceramic, and glass production. The glass factory reportedly once employed 1,900 people, while the ceramics factory employed an additional 400.[18]

The Islamic State's Economic Governance in Ramadi

Almost immediately after establishing full control over the city in May 2015, ISIL focused its efforts on running key sectors of Ramadi's economy, including its water resources; physical infrastructure, such as electricity and roads; public services; and agricultural economy. This was a significant departure from the activities of ISIL's predecessor organization, AQI, which had focused more minimally on car theft, smug-

[18] Stephen D'Alessio, "Glass, Ceramics Factories Reopen, Restore Hope for City," U.S. Marine Corps, August 18, 2005.

gling, and looting when operating in Ramadi in 2005 and 2006.[19] However, in both cases, the group never saw Ramadi as a lucrative source of revenue because neither the city nor its surrounding area is rich in natural resources.[20]

ISIL's direct intervention into the local economy began with Ramadi's water resources. Soon after taking control, the group closed all but two the gates of the Ramadi Dam along the Euphrates River, which effectively shut off water flow downstream toward GoI-held areas of Anbar and Shia-predominated areas farther to the south of Baghdad.[21] This redirected water flow from the Euphrates southward through ISIL-controlled Ramadi toward Lake Habbaniyah, which reportedly left many towns downstream in severe drought conditions.[22] By early 2016, following the defeat of ISIL forces in the city, Ramadi's sewer and water lines were largely destroyed in fighting, and the city became reliant on trucked-in water.[23]

Rehabilitating key city infrastructure was a second component of ISIL's efforts to run Ramadi's economy under its control. This included modest efforts to restore both the road and electricity grids, which purportedly began soon after ISIL established control.[24] Facing an energy crisis—with civilians forced to use ISIL-provided wood for cooking after fuel canisters became scarce—ISIL ordered displaced employees from the Ramadi gas plant to return to work and set up a network of neighborhood generators to supply electricity for ISIL areas.[25] Restoring public services was another component of its effort to stabilize the city under its control, with ISIL calling for all hospital employees to adhere to their normal schedules.[26]

ISIL control also had a variety of indirect effects on the local economy. One prominent effect was a dramatic increase in food prices, likely a result of disruptions to agricultural supply lines throughout Anbar province from fighting. Food prices throughout Anbar surged to nearly 60 percent above prices in nearby Baghdad while ISIL controlled Ramadi.[27] As a consequence, residents in Ramadi were forced to sur-

---

[19] Benjamin Bahney, Howard Shatz, Carroll Ganier, Renny McPherson, and Barbara Sude, *An Economic Analysis of the Financial Records of al-Qa'ida in Iraq*, Santa Monica, Calif.: RAND Corporation, MG-1026-OSD, 2010, pp. 36–39.

[20] Dick Couch, *The Sheriff of Ramadi: Navy SEALs and the Winning of al-Anbar*, Annapolis, Md.: Naval Institute Press, 2008. Although some believe that significant unexplored oil reserves might exist along the western Euphrates River valley, insecurity and the area's poor business climate have scared off investors.

[21] "Isis Closes Ramadi Dam Gates, Cutting Off Water to Pro-Government Towns," *Guardian*, June 2, 2015.

[22] "ISIL Redirect [sic] Water from Ramadi Dam," 2015.

[23] Hubbard, 2016.

[24] Erin Cunningham, "In Ramadi, the Islamic State Settles in, Fixing Roads and Restoring Electricity," *Washington Post*, July 2, 2015.

[25] Rasheed, 2015; Cunningham, 2015.

[26] Cunningham, 2015.

[27] Bradley, 2015.

vive on "on meager rations of vegetables and a small quantity of flour distributed by the militants," such as "old bread and rotten tomatoes."[28]

Measuring the Islamic State's Economic Impact in Ramadi

In this section, we use satellite imagery and remote sensing data to track how economic activity in Ramadi has changed over the course of ISIL's attempts to contest and control the city. We examine how each indicator in our sample—electricity consumption, population levels, agricultural activity, industrial activity, market activity, commercial vehicle counts, and building destruction—changes across the whole city before, during, and after ISIL's presence in the city. We use these data to test our hypotheses described earlier in this report and in conjunction with existing evidence of ISIL's economic impact and control over Ramadi.

Electricity Consumption

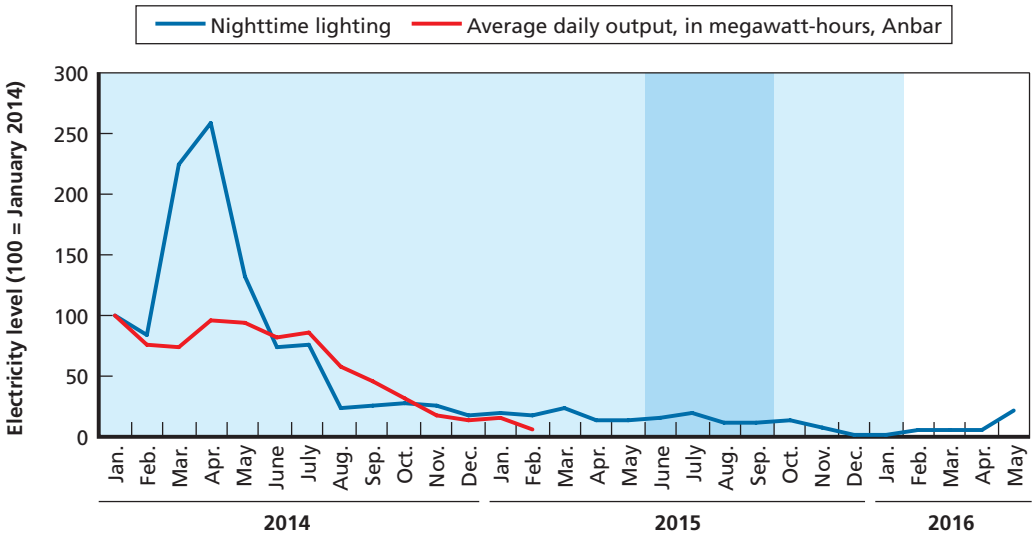
First, we use nighttime lighting to understand how electricity consumption has changed over time in Ramadi before, during, and after ISIL's control of the city. We combine this information with data from the Iraqi Ministry of Electricity, showing provincial-level power supply information to Anbar province from the national power grid through February 2015 (after which data are unavailable). Both time series are presented in Figure 8.2. Shading indicates ISIL's contestation of the city in light blue and control of the city in dark blue.

Although Ramadi was not under full control of the Islamic State at the time, it suffered from power cutoffs to the Anbar power grid beginning in June 2014 as ISIL moved throughout portions of Anbar province. GoI-directed cutoffs to power supply in Anbar were not as sharp as those seen in Ninewa or Salah ad-Din provinces, tapering off more gradually over the fall of 2014. As a result, nighttime lighting in Ramadi had fallen to just 25 percent of its January 2014 levels by August 2014. This suggests that ISIL's early contestation of the city was less impactful on the city's economy than its later, more-robust efforts to assert control throughout late 2014 and early 2015. Nighttime lighting levels during this entire period, including during ISIL's brief unilateral control of the city in late 2015 show catastrophically low levels of electricity consumption in the city. This suggests that ISIL's initial efforts to bring fuel into the city to reconstitute generator power, once the group was in full control of the city, failed to bring about any meaningful increase in electricity consumption.

Following the brutal fighting in the city that led to ISIL's ouster, electricity consumption appears to have bottomed out in January 2016. This is in line with evidence

[28] Rasheed, 2015; also see Koek and Abdulla, 2016; WFP, 2015a; and WFP, "Iraq: Trend of Increasing Food Insecurity Persists in Anbar and Ninewa," Bulletin 8, July 2015b.

Figure 8.2
The Islamic State's Impact on Electricity in Ramadi, 2014–2016



SOURCES: Nighttime lighting data are calculated using NOAA VIIRS. Electricity supply data are from Shaver and Ensign, 2015.
NOTE: All data are normalized to the first data point in the time series so that values deviate around 100. For example, a nighttime lighting value of 50 in this figure indicates that nighttime lighting at that point in time was 50 percent below the first point at which nighttime lighting information was collected. Light blue shading corresponds to months of contested control, while dark blue shading corresponds to months of unilateral ISIL control.
RAND *RR1970-8.2*

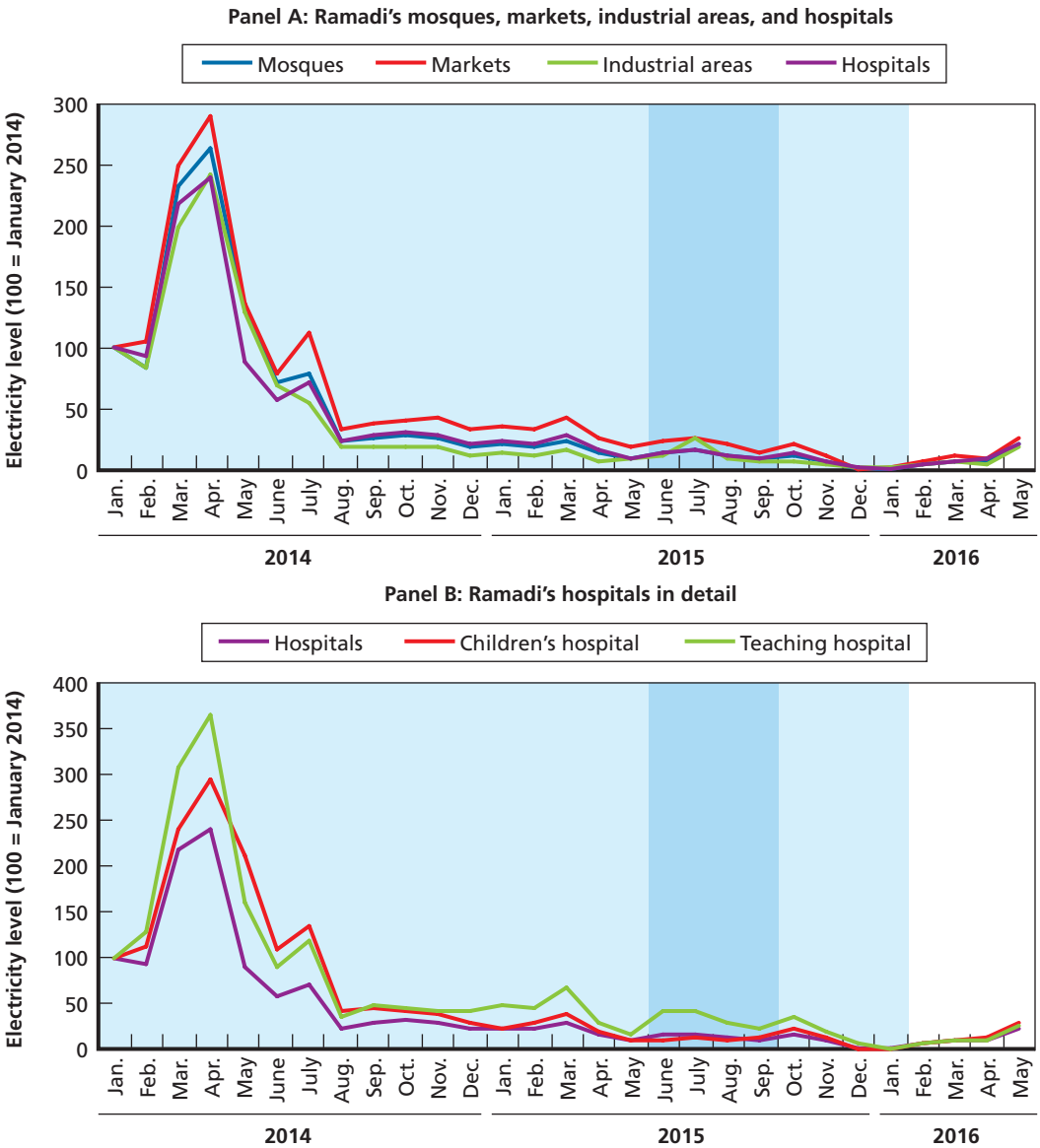
of major fuel shortages in the city as of December 2015.[29] Nighttime lighting after ISIL's defeat was just 1.5 percent of its pre-ISIL levels. Throughout early 2016, we see little improvement in the electricity consumed in Ramadi over time until May, when nighttime lighting levels recovered marginally to the levels seen prior to ISIL's unilateral control over the city in late 2015. This is likely a partial product of the fact that ISIL intentionally booby-trapped electrical facilities in the city upon its exit, hindering efforts to reconstitute power to the city.[30]

We can also examine how nighttime lighting differed across different types of critical infrastructure and commercial locations in Ramadi. Given the city's reliance on scarce oil resources to fuel its generators, differences in nighttime lighting across different types of infrastructure offer insight into ISIL's governing priorities within the city. Figure 8.3 displays average nighttime lighting levels over Ramadi's mosques, markets, industrial areas, and hospitals. Nighttime lighting at each of these types of infrastructure is closely linked over the course of ISIL's control over the city, with mar-

[29] Rasheed, 2015.

[30] George, Butler, and Alleruzzo, 2016.

Figure 8.3
Nighttime Lighting in Ramadi, by Type of Infrastructure



SOURCE: Nighttime lighting data are calculated using NOAA VIIRS.
NOTE: All data are normalized to the first data point in the time series so that values deviate around 100. For example, a nighttime lighting value of 50 in this figure indicates that nighttime lighting at that point in time was 50 percent below the first point at which nighttime lighting information was collected. Light blue shading corresponds to months of contested control, while dark blue shading corresponds to months of unilateral ISIL control.

RAND *RR1970-8.3*

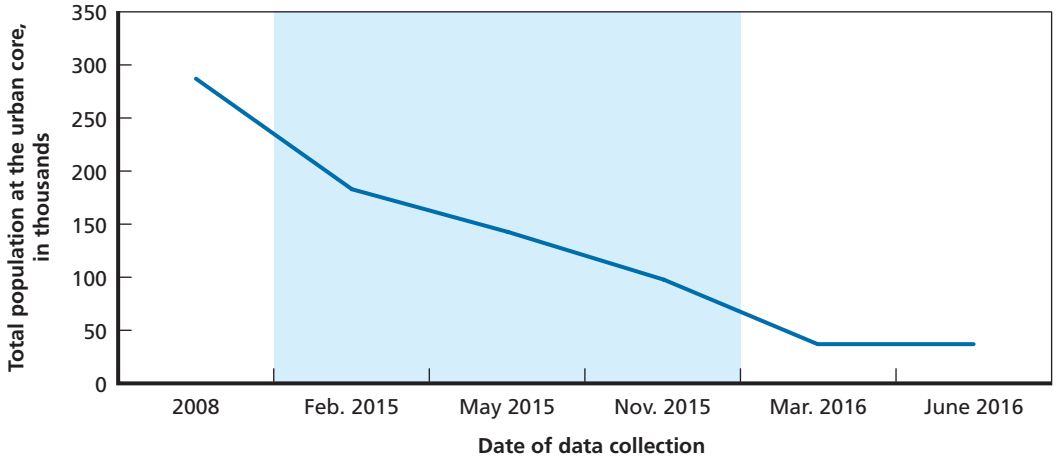
kets the most electrified.[31] The second panel of this figure highlights two key hospitals in Ramadi specifically, given evidence we have seen in other cities of the importance of hospitals to the group. At least in the case of the city's teaching hospital, located just south of the Euphrates on the northeastern end of the city, ISIL's call for workers to return to the city's hospitals after its full takeover of Ramadi in the summer of 2015 was accompanied by an increase in electricity consumption at this facility.

Population Levels

Next, we use ORNL LandScan data to measure how Ramadi's population has changed in response to ISIL's contestation and brief control over the city, as well as the dramatic destruction of Ramadi upon its liberation. We restrict our estimates to the urban core of the city as opposed to its full periphery, so total population figures fall slightly below other published estimates.

Figure 8.4 plots the city's population at six time points between 2008 and 2016. These estimates capture the dramatic depopulation of Ramadi over the course of ISIL's involvement in the city. Ramadi experienced a 37-percent reduction in its overall population between 2008 and February 2015, with more than 100,000 residents displaced

Figure 8.4
Ramadi's Population over Time



SOURCE: Oak Ridge National Laboratory, Landscan 2008–2016.
NOTE: Population totals represent the number of people living in the urban core of the city. Data were captured at irregular intervals, so we use 2008 as a baseline and lack data on exact population totals prior to ISIL arrival. Blue shading corresponds to periods of unilateral ISIL control.
RAND *RR1970-8.4*

[31] A brief uptick in electricity consumption at Ramadi's industrial facilities in July 2015 relative to other types of infrastructure can be credited to the Tamim neighborhood's industrial facilities in southern Ramadi, as well as the large industrial neighborhood in eastern Ramadi along Route 11.

from the city over this admittedly large time period. Not all of these changes can be attributed to ISIL's presence in the city beginning in January 2014. However, these data suggest that an additional 39,000 residents left Ramadi between February 2015, when ISIL only contested the city, and May 2015, when ISIL was on the brink of total control over Ramadi. Most compelling is the fact that Ramadi's population fell to only 36,000 people after its liberation from ISIL, or just 13 percent of its 2008 levels. These estimates suggest that more than 100,000 IDPs left Ramadi between May 2015 and March 2016.

Although we lack the ability to diagnose with these data the exact point at which people fled the city, the dramatic pace with which the city depopulated suggests two possible explanations, which are not mutually exclusive. First, the threat of ISIL control over the city appears to have driven IDP flows from Ramadi even before ISIL established full control in mid-2015. Second, the level of damage to Ramadi wrought by the fight to retake it made the city uninhabitable as of early 2016, at least in the short term.

Agricultural Activity

Next, we explore how agricultural activity in Ramadi was affected by ISIL's control over the city. Figure 8.5 plots average NDVI within 5 km of the urban core of Ramadi over time since April 2013. The arid climate of Anbar province makes identification of ISIL's impact on changes in NDVI much simpler than for cities in the less arid northern portion of the study area, in that crops are solely reliant on irrigation, rather than rainfall, for water.[32]

Cereal, legumes, and potatoes are the primary crops grown throughout Anbar, which are harvested in late spring and summer of each year. Wheat and barley still account for roughly one-quarter of agricultural production throughout Anbar, harvested in the first few months of the year. We see a significant decline in the intensity of vegetated land surrounding Ramadi for much of the 2015 harvest just prior to ISIL takeover.

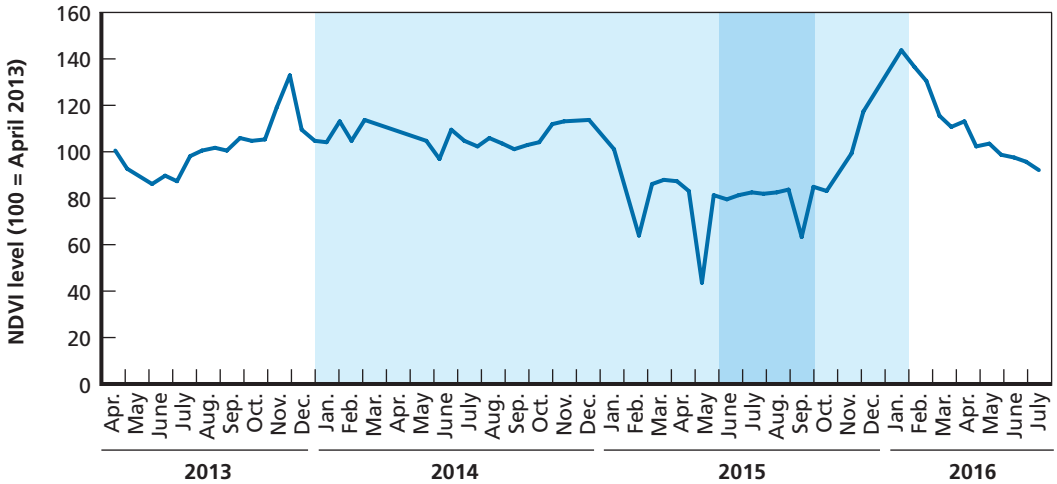
Industrial Activity

We next examine how ISIL control of Ramadi affected economic activity around the city's industrial areas. Figure 8.6 plots the average thermal signature of Ramadi's industrial areas (in red) relative to the average city temperature (in blue). We measure industrial activity here as the mean percentage deviation across all industrial facilities in Ramadi relative to the city's average temperature.

These results suggest that ISIL began to adversely affect Ramadi's industrial activity well after it began unilateral control of the city. Overall, we see periodic peaks in

[32] See Business Associations in al-Anbar Province, *Business Agenda of al-Anbar Province*, Center for International Private Enterprise, undated.

Figure 8.5
Agricultural Activity in Ramadi's Periphery



SOURCE: NDVI data are derived using USGS Landsat 8.
NOTE: All data are normalized to the first data point in the time series so that values deviate around 100. Light blue shading corresponds to months of contested control, while dark blue shading corresponds to months of unilateral ISIL control.
RAND *RR1970-8.5*

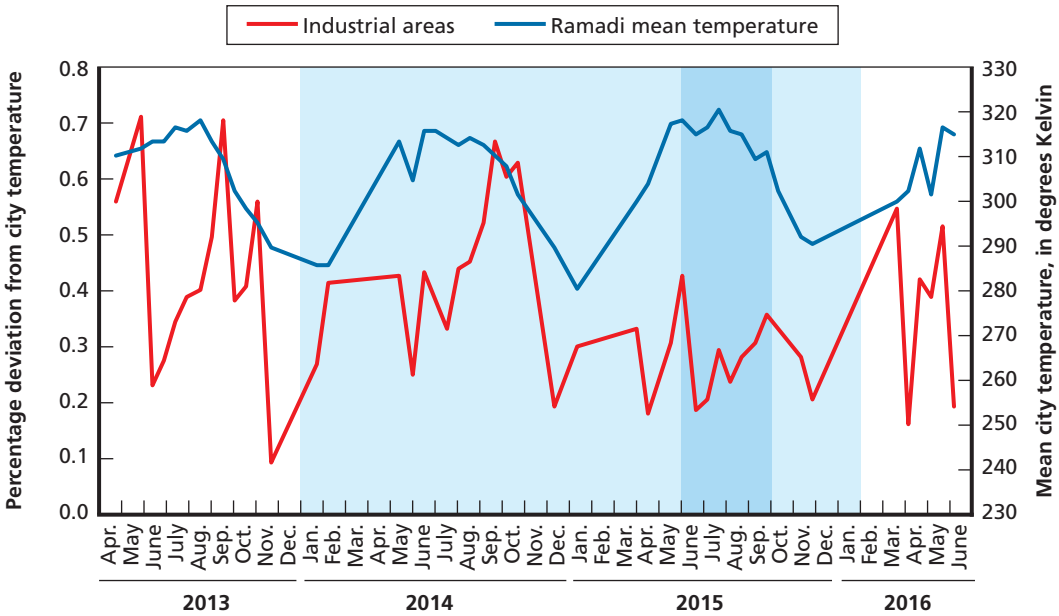
thermal activity over Ramadi's industrial areas throughout 2014, suggesting at least intermittent operations of these facilities despite ISIL attempts to control portions of the city. However, from early 2015 until the city was liberated in January 2016, we see zero thermal spikes of the same magnitude.

Additionally, this time period of reduced industrial activity in 2015 appears to break a larger trend observed here in Ramadi and earlier in Mosul and Raqqah. In general, industrial facilities in our thermal data run hotter in warmer months than the city average and operate at temperatures much closer to the city average during cooler months. Despite high average temperatures over Ramadi in the summer of 2015, the thermal signature of the city's industrial facilities was mostly steady, around 0.3 percent above the city's mean temperature. Coinciding with ISIL's unilateral control over the city, this was the first summer in which peak thermal activity did not hit 0.65 percent above the city's mean temperature. Even the months after ISIL lost control over the city saw higher levels of thermal activity in these locations, approaching 0.6 percent.

Market and Commercial Activity

We next examine how commercial activity in Ramadi was affected by ISIL's contestation and control of the city. We start by focusing on Ramadi's markets. The first panel of Figure 8.7 shows crowd-sourced estimates of market activity visible in commercial satellite imagery of Ramadi over time, plotting the average intensity of market activ-

Figure 8.6
Thermal Activity at Ramadi's Industrial Areas



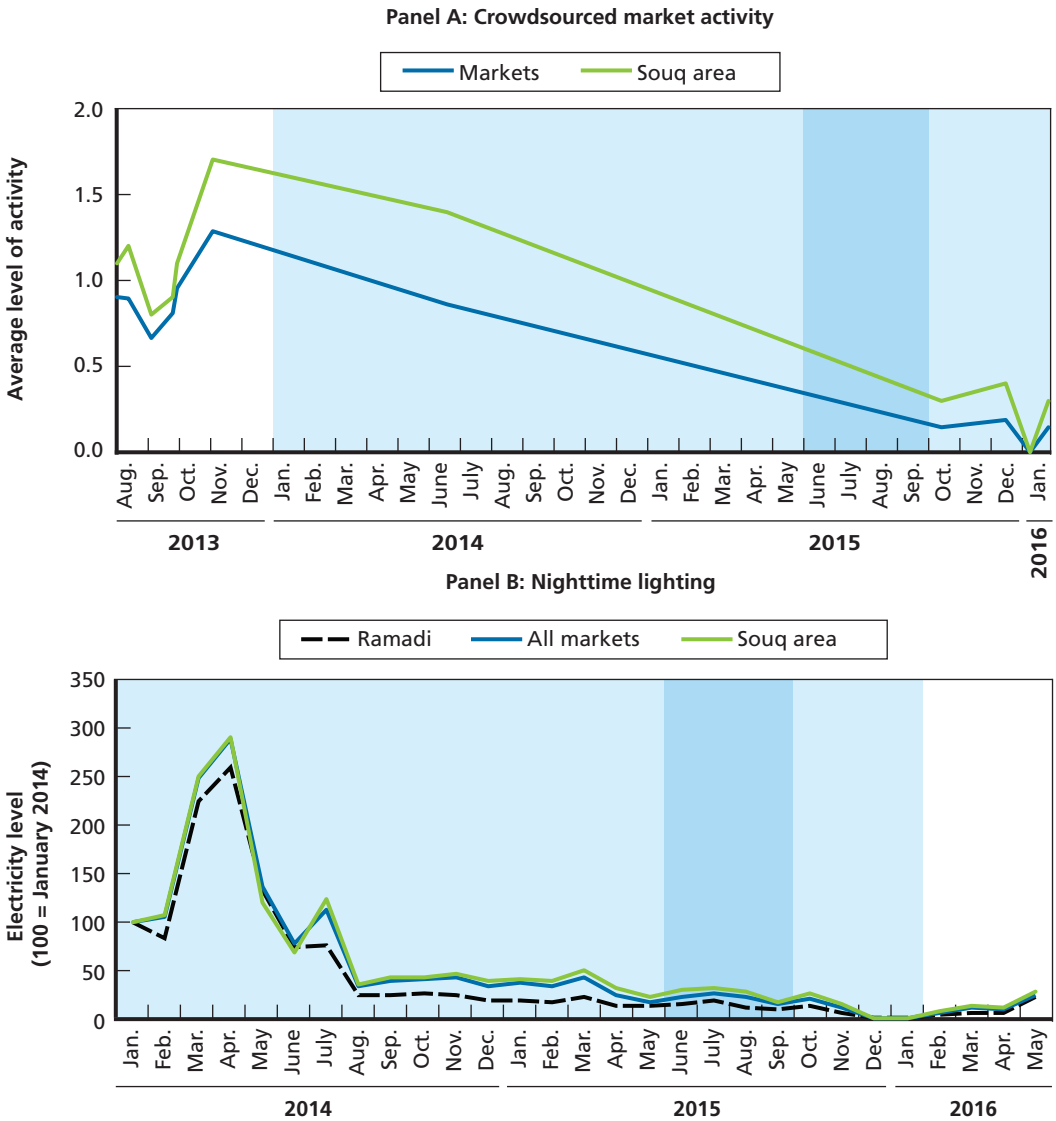
SOURCE: Thermal data are derived using USGS Landsat 8.
NOTE: Light blue shading corresponds to months of contested control, while dark blue shading corresponds to months of unilateral ISIL control.
RAND *RR1970-8.6*

ity on a scale from no activity (0), to limited activity (1), to significant activity (2). The second panel uses nighttime lighting to better understand the electricity available to support economic activity at these locations.

Although we lack frequent commercial satellite imagery over the course of ISIL's control of the city, we do have several data points that occur before ISIL arrives in 2013 and after it loses unilateral control in late 2015. This before-and-after comparison is highly revealing. In Ramadi's main Souq market area in the city center (and on average across the city's other markets), significant levels of activity pre-ISIL gave way to almost no activity after the group left town. In the one measure of market activity we do have from June 2014, we see that this effect is yet to be realized. This conforms with findings seen elsewhere in this chapter, that the damaging effects of ISIL's presence in the city come only after the group asserts unilateral control.

Nighttime lighting estimates (in panel B of Figure 8.7) over Ramadi's markets reveal that they were better lit than the rest of the city on average, including through ISIL's control in late 2015. Nighttime lighting over these markets was at 22 percent of its pre-ISIL levels in October 2015, while the entirety of Ramadi was at only 13 percent of its pre-ISIL levels. Fighting to retake the city from ISIL led to the almost zero nighttime lighting levels seen across the whole city at the end of 2015, and Ramadi's

Figure 8.7
Ramadi's Markets



SOURCE: Market activity data are derived from Digital Globe's Tomnod Crowdsourcing Platform. Nighttime lighting data are calculated from NOAA VIIRS.
NOTE: Crowdsourced market activity data are presented as the average crowdsourced ranking across various subpolygons making up each market. Each market location was ranked as to whether it exhibited no activity (0), limited activity (1), or significant activity (2). Light blue shading corresponds to months of contested control, while dark blue shading corresponds to months of unilateral ISIL control.

RAND *RR1970-8.7*

markets were not exempt from this damage. They have recovered since then at roughly comparable levels of nighttime lighting to the rest of the city.

To better visualize the dramatic decline in market activity in Ramadi, we show two satellite images of the main Souq market area in Figure 8.8. The first image was captured in October 2014, well prior to ISIL's full control of the city but while ISIL contested outlying portions of Ramadi. It shows a relatively bustling market area, with parking lots full of cars and traffic on the roads. The second image shown is from October 2015, shortly after Iraqi forces entered outlying portions of the city to liberate it. In any event, the market was entirely empty. This could demonstrate a reduction in the demand for market goods (due to population outflows) and in the supply of goods making its way into the market given the extent to which supply routes outside the city were contested. Either way, the chilling effect on Ramadi's economy is clearly visible.

We also use estimates of commercial vehicle traffic in Ramadi based on crowd-sourced analysis of satellite imagery to better understand how commercial activity was affected by ISIL's control of the city. In Figure 8.9, we show maps of commercial vehicles in Ramadi at two time points—before ISIL's arrival in the city in November 2013 and during the liberation of Ramadi in December 2015. Although we lack reliable imagery data to assess similar vehicle counts during ISIL's brief tenure of complete control over the city, measurements during liberation are still illustrative. They capture the dramatic decline in commercial activity associated with ISIL's tumultuous presence over Ramadi. Whereas, for 2013, our crowd-sourced data suggest that there were 776 discrete commercial vehicles on Ramadi's roads, our estimates from December 2015 place this number at only 55 vehicles. Unfortunately, we lack additional imagery data to verify these two point estimates with a larger time series, suggesting that these point estimates should be taken cautiously.[33] However, these results largely affirm our prior estimates of the dearth of economic activity left in ISIL's ruins.

Damage and Destruction

Finally, we use crowd-sourced analysis of commercial satellite imagery to map areas in Ramadi that were damaged or destroyed over time. This is especially important for understanding the extent to which the majority of the city was damaged in both ISIL's efforts to gain control over the city leading up to the summer of 2015 and the fight to recapture the city from the Islamic State later that year. We use data on destruction to understand how violence might have directly or indirectly affected our previous indicators of economic activity. Figure 8.10 plots buildings either damaged or destroyed in Ramadi as of December 2015 and January 2016, combined on one map to capture the full extent of damage wrought by liberation of the city. These data show the over-

[33] Furthermore, the first image was captured on a Wednesday in 2013, while the second image was captured on a Saturday in 2015. This reduces, but does not eliminate, the utility of these estimates. Future research could work with satellite imagery providers to schedule imagery collection systematically, to ensure a more consistent and complete time series of data for similar research.

Figure 8.8
Imagery of Ramadi's Main Souq Market Area

Panel A: October 29, 2014 (ISIL contests outlying portions of Ramadi)

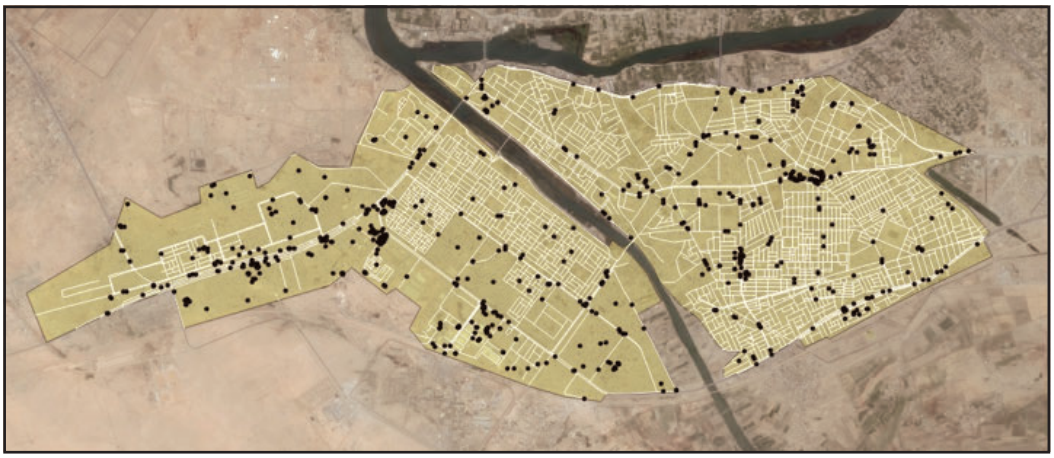
Panel B: October 16 , 2015 (beginning of liberation of the city)

SOURCES: Digital Globe, 2016.

RAND *RR1970-8.8*

Figure 8.9
Commercial Vehicles in Ramadi, Pre– and Post–Islamic State Takeover

Panel A: November 6, 2013 (776 vehicles)

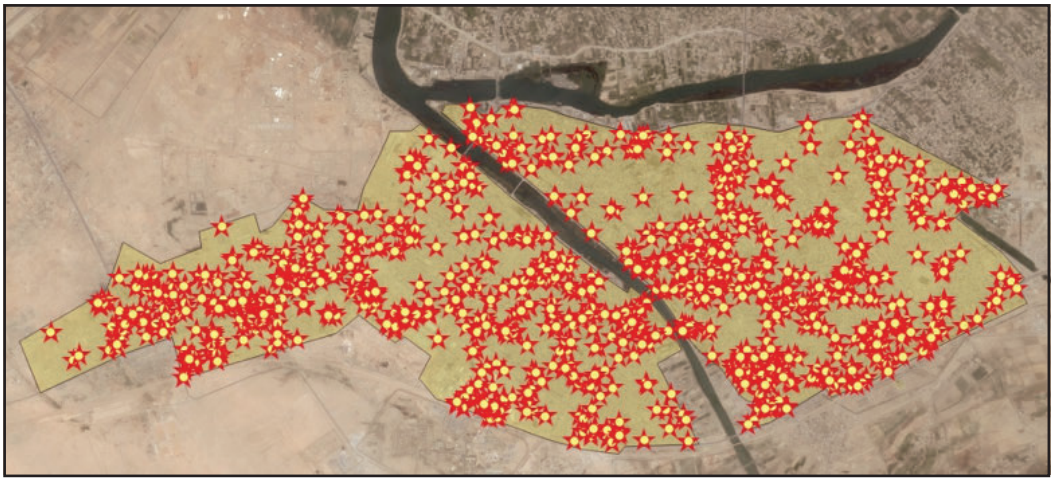


Panel B: December 19, 2015 (55 vehicles)

SOURCES: Commercial vehicle data are derived from Digital Globe's Tomnod Crowdsourcing Platform. Background imagery from Digital Globe. Road data are from Open Street Map.
NOTE: Black dots indicate the location of commercial vehicles identified from high-resolution imagery. The yellow shaded area indicates the city's urban core boundaries. Roads are highlighted in white.
RAND *RR1970-8.9*

whelming extent to which the fight to retake Ramadi affected all parts of the city, save for a few residential areas in the city's center.

Figure 8.10
Map of Building Destruction in Ramadi, December 2015–January 2016



SOURCES: Damage data are derived from Digital Globe's Tomnod Crowdsourcing Platform. Imagery is from Digital Globe, 2016.
NOTE: The yellow shaded area represents the city's urban extent, based on authors' estimates and a review of satellite imagery. Yellow-centered red stars denote instances of damage or destruction.
RAND *RR1970-8.10*

Conclusion

The Islamic State established a partial foothold in Ramadi, the capital of Iraq's Sunni-dominated Anbar province, in January 2014, well prior to its main offensive into northern Iraq later that year. After 17 months of fighting against government forces within the city, ISIL forces finally took full control of Ramadi in June 2015. This unilateral control was short-lived: Iraqi forces moved back into parts of Ramadi's urban center as early as October 2015 and had wrested full control of the city back from ISIL by January 2016. On ISIL's way out of Ramadi, its fight against government forces destroyed much of the city's key infrastructure—including every bridge crossing the Euphrates River. For the first six months after its liberation, few residents returned, and reconstruction of the city was limited.

Because Ramadi is an economically underdeveloped city with a government-dependent economy, control over Ramadi offered limited financial benefit to ISIL in terms of potential revenue sources. However control of Ramadi was strategically significant to ISIL as a major government and Sunni population center along the Euphrates connecting Syria to Baghdad. The lengths to which ISIL fought to take over Ramadi are a testament to the city's significance to the group for sectarian and military reasons, rather than economic ones. Despite the short time period in which ISIL controlled the

city, we find evidence that Ramadi's economy heavily deteriorated under the weight of ISIL's control.

For instance, although nighttime lighting fell only modestly while ISIL contested the city, it fell sharply as ISIL took full control of Ramadi in the summer of 2015 and declined to just 2 percent of pre-ISIL levels upon liberation. Although partly a result of power shutoffs by the Iraqi government, these electricity shortfalls are equally due to ISIL's inability to secure sufficient generator power for the city despite its vast oil reserves. ISIL did appear to prioritize electricity provision surrounding several key hospitals and markets, based on nighttime lighting estimates. Population estimates suggest that significant proportions of Ramadi's residents fled both before and after ISIL's control of the city. By November 2015, in the middle of the fight to liberate Ramadi, nearly half of the city's residents had fled, according to our remote sensing–based population estimates.

Crowd-sourced assessments of Ramadi's markets using satellite imagery confirm these findings. Few signs of market activity are seen in imagery from early 2016, particularly relative to pre-ISIL images of active local markets in the city's main Souq district. Estimates of commercial vehicle traffic show a dramatic decline in the presence of tractor trailers on Ramadi's roads, as well after ISIL takeover. Crop estimates for Ramadi suggest that cereal cultivation in the 2013 and 2014 growing seasons remained fairly strong during the early periods of ISIL's presence in the city, before falling off in 2015 as ISIL consolidated control. Thermal signatures over Ramadi's industrial areas offer possible but inconclusive evidence that ISIL control reduced overall industrial activity in the city.

Unlike with Raqqah and Mosul, we have the opportunity to examine the permanence of ISIL's impact on Ramadi after it was liberated, based on the timing of our data collection (which ended in mid-2016). Although we have fewer data points from after the liberation of Ramadi than before its liberation, our analysis suggests that the level of damage to the city was immense and that its path to reconstruction remains long and complex. Nighttime lighting only marginally improved in the first several months following liberation, and markets remained inactive likely in part because of the massive reductions in demand as a result of population flight. After liberation, Ramadi's population was down 87 percent from 2008 levels.

In Chapter Nine, we turn to ISIL's role in the Syrian city of Deir ez-Zor, which the group has similarly contested for a significant time period. But unlike Ramadi, ISIL forces have never fully controlled the city and so were confined to a small dense urban core of the larger city itself. Chapter Nine explores the economy of Deir ez-Zor and the Islamic State's role in it over the past several years.

CHAPTER NINE

The Islamic State in Deir ez-Zor

The Syrian city of Deir ez-Zor, a governorate capital and primary hub of Syria's oil and natural gas region, has been actively contested by Syrian regime forces and Sunni opposition groups, including the Islamic State, since 2012. Opposition groups first seized control of key neighborhoods throughout the city in June of that year, but ongoing fighting with the Syrian regime destroyed an estimated 70 percent of the city through early 2014. In August 2014, the Islamic State wrested control of these opposition-held areas within the city, although forces loyal to the Syrian Arab Republic remained firmly entrenched in neighborhoods representing some 40 percent of the city. Throughout the time period examined in this study (through mid-2016), control of territory within Deir ez-Zor city has ebbed and flowed on a neighborhood-level basis between ISIL and the Syrian regime.

Our analysis of satellite-derived measures of economic activity in Deir ez-Zor suggests that ISIL was ineffective at governing the neighborhoods and local economies under its control. In the rest of this chapter, we explore Deir ez-Zor's strategic importance to ISIL, as well as the city's economy before the arrival of the Islamic State, and then discuss existing evidence of ISIL's governance and economic impact on the city. We then test the hypotheses derived earlier in this report and in this chapter against our satellite-derived measures of economic activity.

Deir ez-Zor's Importance to the Islamic State

Located to the southeast of Raqqah along the Euphrates River, the city of Deir ez-Zor is the governorate capital of Syria's oil and natural gas heartland, the larger Deir ez-Zor governorate. The Islamic State first targeted Deir ez-Zor for expansion in the spring of 2014, capturing most of the governorate and part of the city itself, which has since remained contested. Expanding into Deir ez-Zor was of strategic significance to the Islamic State for two primary reasons. First, it provided ISIL with access to the majority of Syria's hydrocarbons in that Deir ez-Zor governorate accounts for some 70 per-

cent of Syria's entire oil and gas output.[1] Second, Deir ez-Zor city and the larger governorate served as a critical supply and transit hub for ISIL forces in Raqqah as ISIL expanded the caliphate into Iraq beginning in 2014.[2]

From April to July 2014, ISIL wrested control of portions of Deir ez-Zor from several other militant groups, including the Islamic Front, JN, and Jaysh al-Islam, which had themselves earlier driven out Syrian regime security forces.[3] Although ISIL was unable to seize complete control of the city of Deir ez-Zor during this offensive, as regime elements continued to control neighborhoods of the city, ISIL was in control of a reported "95 to 98 percent" of the rest of the governorate by mid-July.[4] This captured territory included key economic infrastructure, including the Tanak and al-Omar oil fields and other smaller oil fields, though some economic infrastructure (such as farmlands) was reportedly damaged by ISIL forces in the process.[5]

Deir ez-Zor city remained contested throughout the time period studied in this report, with both ISIL and Syrian regime security forces controlling neighborhoods from July 2014 through mid-2016. This period would see repeated, but unsuccessful, ISIL assaults against a Syrian military airport in Deir ez-Zor in September 2014, December 2014, October 2015, and April 2016 with Syrian regime security forces bolstered by Russian support in defense.[6]

This period of contestation has had dramatic humanitarian consequences for Deir ez-Zor.[7] Although ISIL reportedly controlled only 60 percent of the city, it was able

---

1 Phil Sands, "Oil, Food and Protest in Syria's Restive East," *National*, January 17, 2012. The presence of these assets also ensured that Deir ez-Zor would be a key battleground for ISIL, JN, the Syrian regime, and other actors with a strategic interest in area energy assets. See Justice for Life Observatory in Deir Ezzor, "Political and Military Control: The Siege of Deir Ezzor," *Atlantic Council*, April 20, 2016, p. 4.

2 Valerie Szybala, "The Islamic State of Iraq and al-Sham and the 'Cleansing' of Deir Ez-Zour," Institute for the Study of War, backgrounder, May 14, 2014.

3 One report suggests that ISIL began to establish control throughout the governorate much earlier, starting in March 2013. See Karen Leigh, "In Deir Ezzor, Rebels Battle for More Than Just Oil," *Syria Deeply*, May 21, 2014.

4 "'Islamic State' Expels Rivals from Syria City," *Al Jazeera*, July 14, 2014.

5 Sylvia Westall, "Islamic State Seizes Oil Field and Towns in Syria's East," Reuters, July 3, 2014. On oil fields, see "IS Takes Control of All Syrian Oil Fields," *Middle East Eye*, last update February 12, 2015. The group also seized the Kharta oil field "in northwestern Deir Ezzor" on June 12. See "ISIL Militants Block Aid and Create 'Human Tragedy' in Syria," *Middle East Eye*, June 12, 2014.

6 "ISIL 'Advances on Military Airbase in Eastern Syria,'" *Al Jazeera*, September 10, 2015; K. E. Truitte, "The Fight for the Deir Ezzor Airport," *Eastern Project*, December 22, 2014; Leith Fadel, "SAA Captures ISIS Base in Deir Ezzor; Scores of ISIS Fighters Killed," *Al Masdar News*, October 13, 2014; Leith Fadel, "ISIS Suffers Disastrous Defeat in Deir Ezzor: Over 150 Terrorists Killed in 24 Hours," *Al Masdar News*, October 5, 2015b; "The Army Foils ISIS Attack on Deir Ezzor Airport, Continue Targeting ISIS Terrorists in Palmyra," Syrian Arab News Agency, April 4, 2016. Russian forces also assisted in repelling the waves of fighters. See "ISIS Opens New Camp in Deir ez-Zor to Recruit Youth," *Al-Alam*, April 8, 2015.

7 Additionally, in an early period of its control of the city, ISIL had a deliberate campaign of destroying Armenian churches in an attempt to drive Deir ez-Zor's Christian populace from the city. See "ISIL Destroys Landmark Armenian Church in Syria," *Hurriyet Daily News*, September 14, 2014.

to besiege areas controlled by regime forces and prevent the delivery of humanitarian assistance.[8] ISIL's occupation of key villages and suburbs around Deir ez-Zor city have caused a mass exodus, increasing the unemployment rate to more than 50 percent, with some reports placing the estimate closer to 65 percent.[9]

Although ISIL hotly contested Deir ez-Zor, its lack of total control over the city meant that the group failed to develop the same depth of governance as it achieved in Raqqah or Mosul. In this chapter, we therefore explore how ISIL's economic impacts differed in a city where the group lacked uncontested influence over local populations. Furthermore, sustained neighborhood-level differences in control offer a natural experiment of sorts, which we leverage in this chapter. By assessing how economic activity in neighborhoods controlled by the Islamic State compares with that in neighborhoods controlled by the Syrian regime, we can more directly gauge the "ISIL effect" on local economies while controlling for city-specific factors that might otherwise confound our results. In the rest of this chapter, we explore Deir ez-Zor's economy before the arrival of the Islamic State and then discuss existing evidence of ISIL's governance and economic impact on the city. We then test the hypotheses derived earlier in this report and in this chapter against our satellite-derived measures of economic activity.

Deir ez-Zor's Economy Before the Islamic State

Despite being a key oil-producing region—Deir ez-Zor governorate once accounted for an estimated 70 percent of the $4.1 billion earned by the Syrian government in oil revenue—Deir ez-Zor has been persistently poor.[10] Indeed, as of 2009, the governorate ranked as one of the least developed in the country, with high rates of childhood deprivation in terms of sanitation, health care, and shelter.[11] In 2010, Deir ez-Zor was among the governorates most affected by a four-year drought that pushed millions in northeastern Syria into poverty.[12]

---

8 "ISIL 'Massacre' Reported in Syria's Deir Az Zor," *Al Jazeera*, January 17, 2016; Hamdi Alkhshali and Tim Lister, "Hundreds Dead as ISIS Makes Gains in Strategic Syrian City," CNN, January 23, 2016.

9 Chris Tomson, "ISIS Bans Television for Residents of Deir Ezzor in Eastern Syria," *Al Masdar News*, May 21, 2016. Also see Syrian Center for Policy Research, UN Relief and Works Agency for Palestine Refugees in the Near East, and UN Development Programme, *Syria: Squandering Humanity—Socioeconomic Monitoring Report on Syria: Combined Third and Fourth Quarter Report (July–December 2013)*, May 2014.

10 Hussein Almohamad and Andreas Dittmann, "Oil in Syria Between Terrorism and Dictatorship," *Social Sciences*, Vol. 5, No. 2, 2016; Sands, 2012.

11 Rabie Nasser, Zaki Mehchy, and Khuloud Saba, "Multidimensional Child Deprivation in Syria: A Comparative Research 2001, 2009," Central Bureau of Statistics, Planning and International Cooperation Commission of the Syrian Arab Republic, and United Nations Children's Fund in Syria, June 2014.

12 "Drought Pushing Millions into Poverty," IRIN, September 9, 2010.

At the very beginning of the conflict in Syria, in early 2012, analysts were already warning that poverty was contributing to "dangerous instability" in Deir ez-Zor.[13] Conditions deteriorated rapidly from 2012 through 2014, as the city's economy was badly affected by the violence and destruction preceding ISIL's rapid expansion in the spring of 2014. This violence dramatically affected access to water, resulted in very limited access to health services, and drove increases in poverty throughout the governorate.[14] The violence also saw a dramatic reduction in oil production when, by the fall of 2013, refining of oil products was shifted to relatively inefficient "tea-pot oil" refineries.[15] Within Deir ez-Zor city itself, UNDP estimated that nearly 70 percent of the city and 60 percent of its agricultural sector had been damaged on the eve of ISIL's arrival in the city in 2014.[16]

Figure 9.1 provides a spatial overview of Deir ez-Zor city's key economic infrastructure and divides the cities into neighborhoods based on the extent to which ISIL controlled or contested each area through mid-2016. Red neighborhoods indicate those predominantly controlled by the Islamic State since mid-2014, green neighborhoods indicate those contested between ISIL and Syrian regime forces, and blue neighborhoods highlight areas largely outside of ISIL's control over the course of its contestation of the city.

These zones split some of Deir ez-Zor's key economic infrastructure, with at least one major street market bifurcated across areas controlled by forces loyal to the Syrian regime and those contested by ISIL. Although government buildings and military facilities dominate most of Deir ez-Zor's urban area, a handful of industrial facilities are located on the southern end of the city. Agricultural lands predominated just to the north of the city, on the other side of the Euphrates from the major built-up areas. And Deir ez-Zor boasted a major airport, at the southeast end of the city that remained firmly in the control of the Syrian regime throughout the duration of the conflict.

The Islamic State's Governance over Deir ez-Zor's Economy

In Deir ez-Zor, ISIL forces have predominantly controlled the center of the city in neighborhoods south of the Euphrates River. ISIL's governance over these areas and within Deir ez-Zor governorate more generally has relied on a combination of family members of ISIL fighters who lived in Deir ez-Zor prior to the conflict and were instrumental in its takeover, as well as a partnership with other Syrian opposition elements

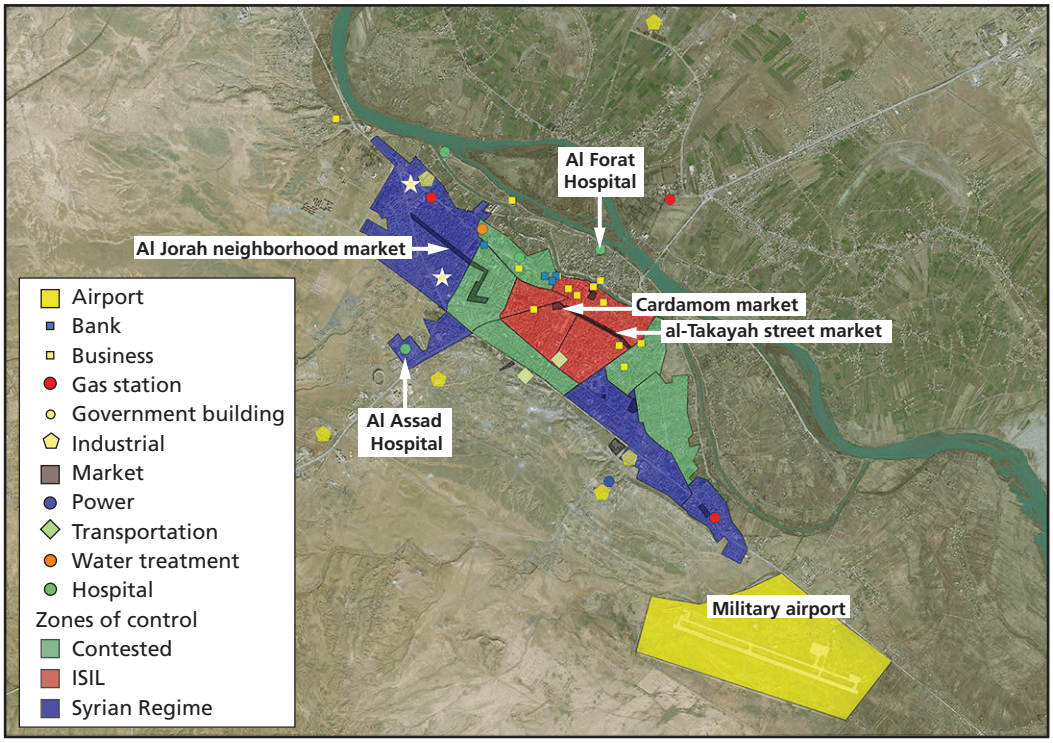
[13] Sands, 2012.

[14] Regional Analysis Syria, 2013.

[15] Ahmad al-Sayegh, "Militias Control Home-Made Oil Refineries," *Iraq-Business News*, September 28, 2013.

[16] UNDP in the Arab States, undated.

Figure 9.1
Economic Laydown of Deir ez-Zor



SOURCES: Authors' estimates. Imagery from Digital Globe, 2017. Control data are derived from maps created and published via the Twitter feed of @PetoLucem (Peto Lucem [PetoLucem], "NEW MAP (June 21): Military situation in #Deir_Ezzor Governorate #Syria," *Twitter*, June 21, 2014a, 11:31 a.m.; Peto Lucem [PetoLucem], "NEW MAP (update): Battle of #Deir_Ezzor. #Syria #SAA #Islamic_State #IS @KeepingtheLeith," *Twitter*, October 15, 2014b, 4:32 p.m.; Peto Lucem [PetoLucem], "NEW MAP: Battle of #Deir_Ezzor. #Syria #SAA #Islamic_State #IS @KeepingtheLeith," *Twitter*, October 26, 2014c, 2:09 p.m.; Peto Lucem [PetoLucem], "NEW MAP: Battle of #Deir_Ezzor. #SAA #Islamic_State #Syria," *Twitter*, December 5, 2014d, 12:53 p.m.; Peto Lucem [PetoLucem], "NEW MAP: Military situation in #DeirEzzor Governorate. #IslamicState #NDF #SAA #Syria," *Twitter*, January 12, 2015a, 1:40 p.m.; Peto Lucem [PetoLucem], "NEW MAP (update): Military situation in #DeirEzzor Governorate. #SAA #NDF #IslamicState #Syria," *Twitter*, January 27, 2015b, 1:56 p.m.; Peto Lucem [PetoLucem], "NEW MAP: Battle of #Deir_Ezzor. #Syria #SAA #NDF #IslamicState," Twitter, May 19, 2015c, 1:43 p.m.; Peto Lucem [PetoLucem], "NEW MAP: Situation in #DeirEzzor Governorate. #SAA repulsed #IslamicState attacks+secured airport perimeter. #Syria," *Twitter*, September 13, 2015d, 4:08 a.m.; Peto Lucem [PetoLucem], "NEW MAP: Military situation in #DeirEzzor Governorate. #Syria #SAA #ISIS HD version: http://imgur.com/eUUh0XX," *Twitter*, January 20, 2016a, 2:43 p.m.; Peto Lucem [PetoLucem], "NEW MAP: #SAA captured Turdah Mountain from #ISIS and advances towards Thayyem oil field. #DeirEzzor #Syria," *Twitter*, March 15, 2016b, 2:13 p.m.; Peto Lucem [PetoLucem], "NEW MAP: Military situation in #DeirEzzor Governorate. #Syria #SAA #ISIS HD version:https://imgur.com/0xQlCdp," Twitter, May 22, 2016c, 6:59 a.m.).

RAND *RR1970-9.1*

that capitulated to ISIL military pressure.[17] Former local officials with expertise in running certain sectors of the city's economy were co-opted in order to maintain essential services, such as telecommunications, electricity distribution, and some local security functions.[18]

Captured ISIL documents from Deir ez-Zor governorate report that the group generated nearly $1.1 million in monthly revenues in Deir ez-Zor city alone as of January 2015.[19] These revenues were from a combination of confiscation, taxation, and the sale of electricity, with confiscation of houses, vehicles, and land from residents who fled the city accounting for more than 65 percent the total.[20] Residents fleeing Deir ez-Zor were often forced to bribe local ISIL officials or other government officials in order to leave; these bribes have been reported at rates as low as $1,000 per person to more than $5,000 per person.[21] Confiscation and bribes represented a higher proportion of revenues in Deir ez-Zor city than from taxation, particularly relative to other cities in the governorate, such as al-Mayadin and Abu Kamal.[22]

Illicit sales of oil and natural gas from Deir ez-Zor's resource-rich oil fields bolstered ISIL's revenues in the city.[23] By September 2014, ISIL was in control of roughly 60 percent of Syria's entire oil production capacity, largely concentrated throughout southern Deir ez-Zor governorate.[24] However, a campaign of air strikes by coalition forces against these oil facilities beginning in October 2015, Operation Tidal Wave II, greatly reduced the group's ability to extract oil resources from these fields and reduced overall oil revenues by nearly 30 percent as of January 2016.[25]

The ongoing contestation of Deir ez-Zor city seems to have affected ISIL's ability and willingness to provide services of the same quality and quantity—or with the same consistency—that it has in its other strongholds. Indeed, there is little evidence of any

---

[17] Lara Setrakian and Katarina Montgomery, "Hassan Hassan on How to Uproot ISIS in Deir Ezzor," *Syria Deeply*, October 27, 2014.

[18] Setrakian and Montgomery, 2014.

[19] al-Tamimi, 2015d. This source reports total monthly revenue for the governorate at $8.4 million.

[20] al-Tamimi, 2015d.

[21] Justice for Life Observatory in Deir Ezzor, 2016. Also see Yasser Allawi and Dylan Collins, "Deir Ezzor: Facing a 'Double Blockade' from All Sides," *Syria Deeply*, January 19, 2016.

[22] al-Tamimi, 2015d; see also Avi Asher-Schapiro, "A Leaked Budget May Finally Show How the Islamic State Makes Its Money," *Vice News*, October 7, 2015.

[23] Westall, 2014. Caris and Reynolds, 2014, p. 25.

[24] Luay al-Khatteeb and Eline Gordts, "How ISIS Uses Oil to Fund Terror," Brookings Institution, September 27, 2014.

[25] Air strikes during Operation Tidal Wave II targeted oil fields, equipment, and tanker trucks, significantly limited ISIL's oil revenue starting in late October and early November 2015. Production fell from an estimated 45,000 barrels per day to 34,000 barrels per day by January 2016. See U.S. Department of Defense, "Department of Defense Press Briefing by Col. Warren via Teleconference from Baghdad, Iraq," news transcript, January 6, 2016.

true governance by ISIL of productive sectors of Deir ez-Zor city's economy. Instead, we see evidence mostly of destructive social regulation and cuts to public services. In areas of Deir ez-Zor that ISIL controls, the group repeatedly prohibited internet access, restricted water use for agriculture, and conscripted male civilians for military service while allowing public services, such as public education, health care, and electricity provision, to deteriorate.[26] ISIL disruption of food resources coming into the city from its outskirts, seizure of bakeries and other food establishments within the city, and confiscation of food aid being provided by international organizations all led to rampant inflation in food costs throughout the city.[27] By early 2016, WFP assessed that food costs in Deir ez-Zor were 12 times higher than in central Damascus.[28] And despite ISIL's massive oil enterprise throughout the southern portions of Deir ez-Zor governorate, fuel costs in Deir ez-Zor in early 2016 were roughly ten times what they had been just 12 months earlier.[29]

Deir ez-Zor's markets, both inside and outside of ISIL-held neighborhoods, have been upended by the group's presence in the city. Its strict regulations on "taboo" goods, such as alcohol and tobacco products; stringent animal slaughtering methods; and enforced dress codes have altered supply and demand of goods subject to these regulations sold in markets throughout the city.[30] In areas subject to ISIL control, such as in the al-Takayah street market, local market activity relies heavily on ISIL funding

---

[26] Gianluca Mezzofiore, "Shocking Pictures from Syrian City Under Siege Show Starving People Who Look Like Concentration Camp Victims," *Daily Mail*, January 17, 2016.

[27] The Atlantic Council reports, "Before the siege, seven bakeries operated in what is now the besieged areas of Deir Ezzor. The regime stopped supplying four of these bakeries with fuel and flour, and the bakeries were forced to shut down" (Justice for Life Observatory in Deir Ezzor, 2016). Also see "Regime, ISIS Confiscate Food Aid for Residents of Besieged Deir-ez-Zor," *Syrian Observer*, April 12, 2016. Also see "Potatoes Are Now Available Again at Markets in the Besieged Districts of Deir Ezzor," *Deirezzor 24*, February 17, 2016. And WFP, "Syria: Market Price Watch, 2016," undated. Some food drops taken by Syrian regime forces have been reportedly resold in Deir ez-Zor's Wadi street market "by traders who are known to collaborate with regime forces in the area."

[28] WFP notes,

> In Deir ez-Zor, for example, the cost of the standard food basket was SYP 240,000 [SYP = Syrian pound] which is 16 times higher compared to their pre-siege prices of SYP 15,000 and 12 times higher than the cost of the same food basket in central Damascus. . . .
>
> Despite the complex [sic] of the conflict and shortage of fuel, in Deir ez-Zor the government bakeries are still functioning. However, the production is insufficient and the bundle of bread has been shrunk to four pieces instead of the usual eight. The price is SYP 150/bundle (three times more than Damascus) but people have to wait in long queues for hours every day. . . .
>
> One of the highest prices for rice was observed in Deir ez-Zor two months ago (SYP 1900/kg); however, the price has dropped slightly to SYP 1700/kg during last month. The protracted siege combined with the depreciation of the Syrian Pound explain high prices there.

See WFP, "Syria: Worsening Food Security Conditions in Besieged Areas," Bulletin 1, January 2016a, pp. 3–4.

[29] WFP, 2016a.

[30] Baladi, 2016.

and direct resupply to continue operations.[31] Even in areas outside of ISIL-controlled neighborhoods, the group's siege of the city's outskirts have still dampened supply and made prices highly volatile.[32]

Measuring the Islamic State's Economic Impact in Deir ez-Zor

Building on our discussion of ISIL's economic governance and known impacts on the city in the prior section, we turn now to analyze our satellite-derived indicators of economic activity for Deir ez-Zor. We use these data to track how economic activity in Deir ez-Zor has changed over the course of ISIL's contested control of the city. We examine how each indicator in our sample—electricity consumption, population levels, agricultural activity, industrial activity, market activity, commercial vehicle counts, and building destruction—changes across the whole city, as well as specifically in the areas controlled by ISIL forces within the city. We use these data to test hypotheses described earlier in this report and in conjunction with existing evidence of ISIL's economic impact and control over the city.

Electricity Consumption

First, we use nighttime lighting to understand how electricity consumption has changed over time in Deir ez-Zor. Figure 9.2 plots monthly nighttime lighting data since January 2014, with values normalized to their January 2014 levels to more easily examine percentage changes over time. ISIL's arrival in the city in June 2014 appears to coincide with an immediate but short-lived drop-off in nighttime lighting. Although nighttime lighting peaked once again by October 2014, some reports suggested that the city still only had four to five hours of electricity per day as a result of fuel shortages for generators.[33] The electricity situation in Deir ez-Zor worsened through early 2015 and has since bottomed out over the course of 2016 at only 5 to 10 percent of its pre-ISIL levels of nighttime lighting. It should be noted that Deir ez-Zor city was still in the midst of an active conflict between opposition and regime forces in January 2014, suggesting that ISIL's harmful effects on the city were particularly robust.

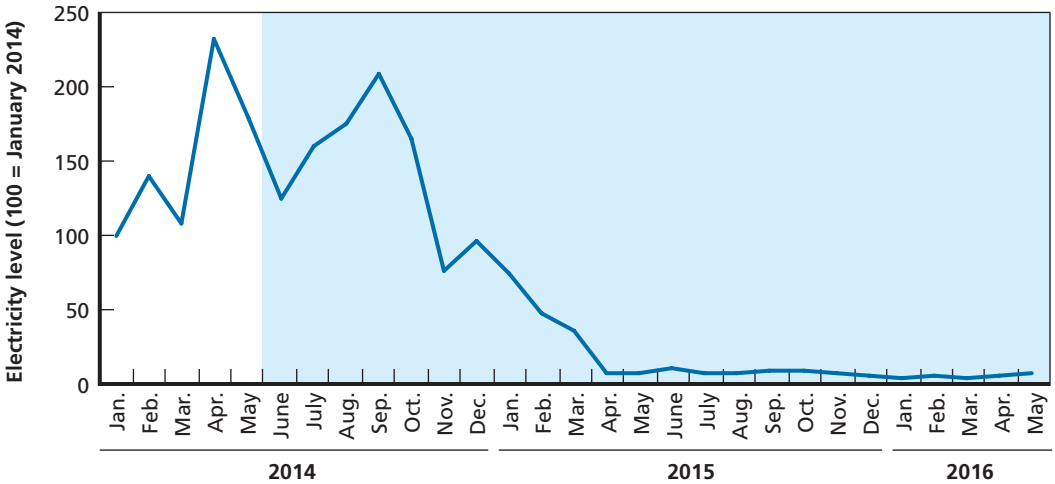
Acknowledging this rapid decline in electricity consumption within the city, we can compare how electricity consumption in ISIL-controlled Deir ez-Zor neighborhoods differs from that in neighborhoods that are contested and those that are controlled by the Syrian regime. We first measure monthly territorial control within each of the 13 discrete areas of Deir ez-Zor diagrammed earlier in this chapter in

[31] Baladi, 2016.

[32] The Syrian regime has been forced to transport goods to supply these markets (Baladi, 2016).

[33] *Urban Area Humanitarian Profile: Deir ez-Zor—Syria Crisis: Food, Health and Water Assessment*, REACH Initiative, August 2014.

Figure 9.2
The Islamic State's Impact on Electricity in Deir ez-Zor, 2014–2016



SOURCE: Nighttime lighting data are calculated using NOAA VIIRS.
NOTE: All data are normalized to the first data point in the time series so that values deviate around 100. For example, a nighttime lighting value of 50 in this figure indicates that nighttime lighting at that point in time was 50 percent below the first point at which nighttime lighting information was collected. Blue shading corresponds to months of contested control.
RAND *RR1970-9.2*

Figure 9.1.[34] Then, we use a regression approach to statistically isolate the impact that ISIL control of certain neighborhoods has on nighttime lighting.[35] Results from this regression are presented in Table 9.1. They suggest that contested areas, where neither ISIL nor Syrian regime forces control the entirety of the neighborhood, show significantly lower levels of nighttime lighting than areas controlled solely by the regime. Additionally, although nighttime lighting in ISIL-held areas of Deir ez-Zor is, on average, lower than in regime-held areas, this difference is not statistically significant.

We can also examine how nighttime lighting differs across different types of critical infrastructure and commercial locations in Deir ez-Zor. Given fuel and power shortages, these differences offer insight into local priorities for generator-provided electricity within the city. Figure 9.3 displays average nighttime lighting levels over

[34] Control data are derived from maps created and published via the Twitter feed of Peto Lucem (Lucem, 2014a, 2014b, 2014c, 2014d, 2015a, 2015b, 2015c, 2015d, 2016a, 2016b, 2016c).

[35] These regressions rely on an FE variance-weighted least squares regression implemented via Stata statistical software. Because neighborhoods, the unit of analysis, vary significantly in terms of size, the precision of the nighttime lighting varies by neighborhood. The variance-weighted least squares method gives more weight (confidence) to the larger neighborhoods, which have lower variance. See "vwls: Variance-Weighted Least Squares," Stata, undated.

Table 9.1
The Islamic State's Impact on Electricity in Deir ez-Zor's Contested Areas

Neighborhood Control Status	Nighttime Lighting
Contested control	−0.549***
Standard error	(0.135)
Unilateral ISIL control	−0.254
Standard error	(0.222)
Constant	0.178
Standard error	(0.270)
Control areas	13
Time periods	29
N	377
Calendar month FE	Y
Control area FE	Y

SOURCES: NOAA VIIRS; authors' estimates.

NOTE: Results present raw coefficient estimates from an FE variance-weighted least squares regression on nighttime lighting by control area (in levels), using variances for each control area calculated from underlying raster data sets. Significance is marked by *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

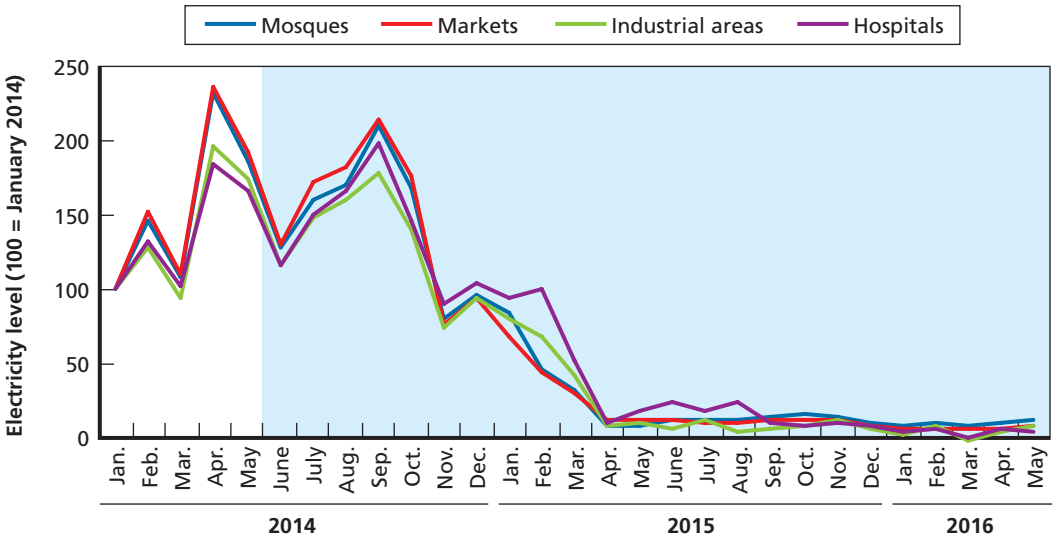
Deir ez-Zor's mosques, markets, industrial areas, and hospitals. As seen in Raqqah, hospitals appear to be a critical priority for fuel supplies within Deir ez-Zor, more so than its industrial areas, mosques, or markets. This includes al-Assad University Hospital, on the city's southern edge, which has remained largely under the control of the Syrian regime but been subject to repeated attacks by ISIL forces.[36]

Population Levels

Next, we assess how the population of Deir ez-Zor has changed before and after conflict reached the city of Deir ez-Zor. We restrict our estimates to the urban core of the city, as opposed to its full environs, so total population figures might fall slightly below published estimates. Figure 9.4 plots the city's population at four time points between 2008 and 2016. LandScan estimates reveal, somewhat surprisingly, that the

[36] For discussion of ISIL's attacks against al-Assad University Hospital, see "ISIL Seizes Government-Held Hospital in Deir Az-Zor," *Al Jazeera*, May 14, 2016. We lack sufficient fidelity on control over Deir ez-Zor's other hospitals in order to attribute this effect to ISIL fuel priorities rather than regime priorities.

Figure 9.3
Nighttime Lighting in Deir ez-Zor, by Type of Infrastructure



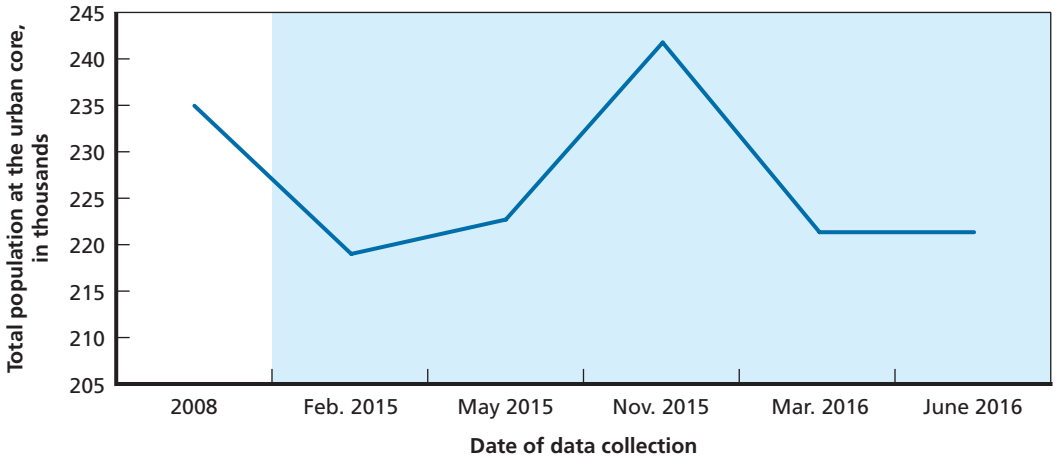
SOURCE: Nighttime lighting data are calculated using NOAA VIIRS.
NOTE: All data are normalized to the first data point in the time series so that values deviate around 100. For example, a nighttime lighting value of 50 in this figure indicates that nighttime lighting at that point in time was 50 percent below the first point at which nighttime lighting information was collected. Blue shading corresponds to months of contested control.
RAND *RR1970-9.3*

city's population has remained relatively constant over the course of ISIL's contestation of the city—ranging between 220,000 and 242,000 residents.[37]

Like with nighttime lighting, we can compare how Deir ez-Zor's population has changed within areas controlled solely by the Islamic State, controlled solely by the Syrian regime, and contested between the two opposing forces. Table 9.2 presents the results of an FE variance-weighted least squares regression on the 13 control areas within Deir ez-Zor identified previously in the chapter. It appears that areas where rival forces within the city are fighting to contest control are the most likely to see population outflows from Deir ez-Zor at statistically significant rates. These results also suggest that areas experiencing unilateral ISIL control have seen even larger population outflows, although this effect is not statistically significant.

[37] Of note is that the peak in Deir ez-Zor's population in November 2015 is common across all cities in our sample in both Deir ez-Zor and Raqqah governorates. This suggests that this peak might be a product of LandScan estimates being adjusted to account for evidence of major IDP flows into these areas as reported by humanitarian or international organizations for this time period.

Figure 9.4
Deir ez-Zor's Population over Time



SOURCE: Oak Ridge National Laboratory, Landscan 2008–2016.
NOTE: Population totals represent the number of people living in the urban core of the city. Data were captured at irregular intervals, so we use 2008 as a baseline and lack data on exact population totals prior to ISIL arrival. Blue shading corresponds to periods of unilateral ISIL control.
RAND *RR1970-9.4*

Agricultural Activity

Next, we explore how agricultural activity in Deir ez-Zor's outlying neighborhoods has been affected by ISIL's contested control over the city. Figure 9.5 plots the average NDVI for Deir ez-Zor and its periphery over time since April 2013. Two trends are apparent in this figure. The first is that the intensity of vegetated land in the immediate vicinity of Deir ez-Zor becomes highly volatile following ISIL's arrival in the city in mid-2014. The seasonal peaks and troughs that represent the growing and harvesting seasons elsewhere in the region are no longer apparent in this figure—perhaps representing significant destruction to the ordinary rhythms of the growing season in Deir ez-Zor. Second, the intensity of vegetated land in the vicinity of Deir ez-Zor has clearly been declining over time since early 2015, suggesting decreased crop production overall.

Industrial Activity

Unlike in larger cities, such as Mosul, Deir ez-Zor's prewar industrial base appears to have been relatively minimal in scope. Figure 9.6 plots the average thermal signature of six specific industrial areas (in red) that sit predominantly on the city's southern edge in contested neighborhoods, relative to the average city temperature (in blue). We measure industrial activity here as the mean percentage deviation across all industrial facilities in Deir ez-Zor relative to the city's average temperature. For comparison's sake, we also plot the relatively modest differences in thermal activity over Deir ez-

Table 9.2
The Islamic State's Impact on Population in Deir ez-Zor's Contested Areas

Characteristic	Population
Contested control	–3,560**
Standard error	(1,766)
Unilateral ISIL control	–4,294
Standard error	(5,130)
Constant	10,693
Standard error	(10,382)
Control areas	13
Time periods	6
N	78
Calendar month FE	N
Control area FE	Y

SOURCE: ORNL LandScan, 2008–2016.

NOTE: Results present raw coefficient estimates from an FE variance-weighted least squares regression on LandScan population by control area (in levels), using variances for each control area calculated from underlying raster data sets. Significance is marked by *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

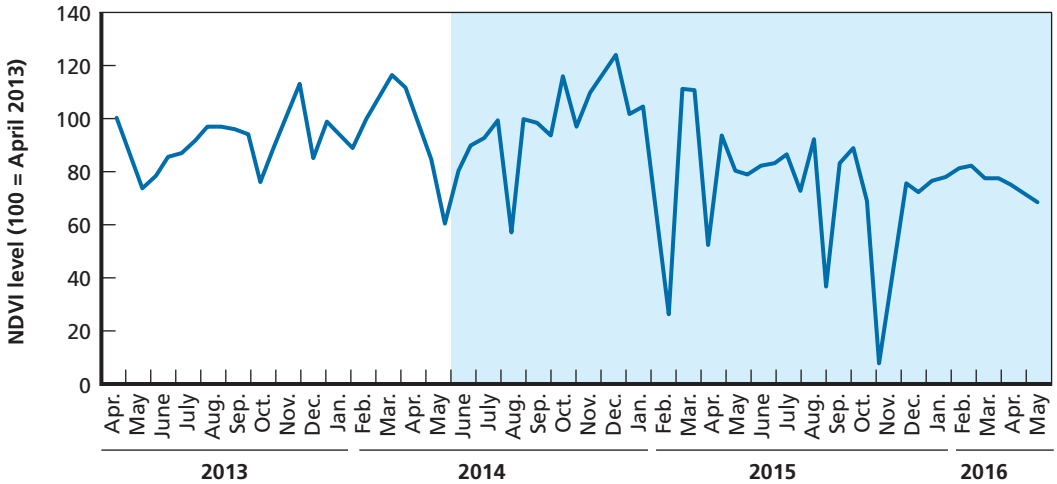
Zor's markets and the rest of the city. Comparing the before-ISIL and after-ISIL thermal signature of Deir ez-Zor's industrial facilities, we see few significant differences in the level of activity apart from some added volatility.

Market and Commercial Activity

We next examine how commercial activity in Deir ez-Zor has been affected by ISIL's control over the city. We start by focusing on the city's markets. The first panel of Figure 9.7 shows crowd-sourced estimates of market activity visible in commercial satellite imagery of the city over time, plotting the average intensity of market activity on a scale from no activity (0), to limited activity (1), to significant activity (2). The second panel uses nighttime lighting to better understand the electricity available to support economic activity at these locations.

In both panels, we examine all markets on average, as well as three specific markets within Deir ez-Zor: the al-Jorah neighborhood market (located predominantly in a regime-held neighborhood), the Cardamom market (in an ISIL-held area), and the al-

Figure 9.5
Agricultural Activity in Deir ez-Zor's Periphery



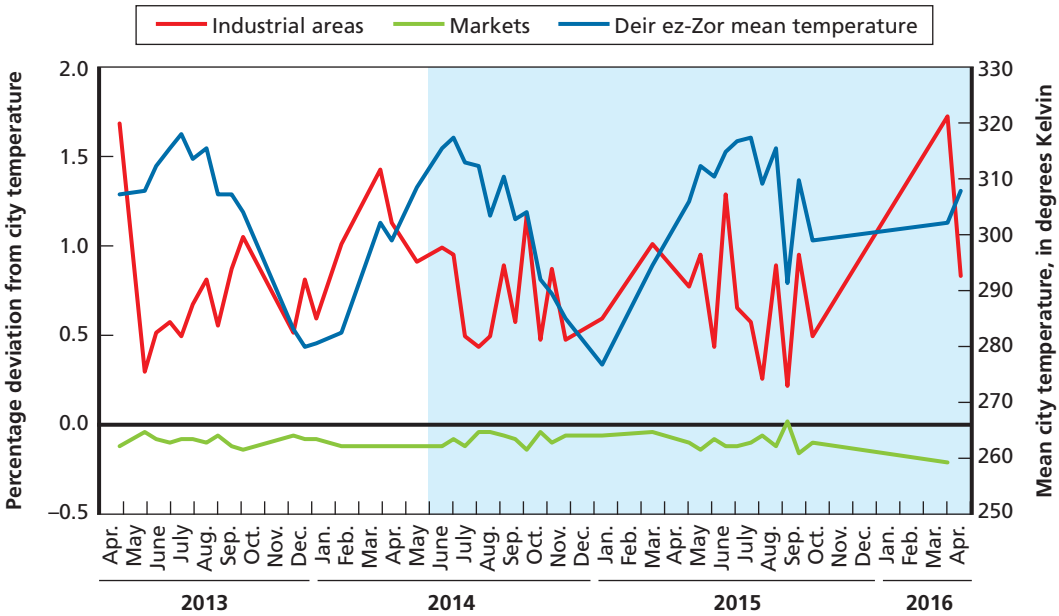
SOURCE: NDVI data are derived using USGS Landsat 8.
NOTE: All data are normalized to the first data point in the time series so that values deviate around 100. Blue shading corresponds to months of contested control.
RAND *RR1970-9.5*

Takayah street market (in an ISIL-held area). Our crowd-sourced estimates of market activity show very clearly that the al-Jorah neighborhood market is more active than either market in ISIL-held neighborhoods. In fact, our commercial high-resolution imagery shows almost no signs of activity at either ISIL-held market through the final image in our sample from late 2015. However, both ISIL-held locations are better lit than the al-Jorah market, according to nighttime lighting estimates. This suggests that nighttime lighting is not a perfect proxy for market activity, particularly in that the Cardamom market, once one of Deir ez-Zor's most active, appears to have been shuttered since as early as 2013, according to DigitalGlobe imagery and publicly available media reporting.[38]

We also use estimates of commercial vehicle traffic in Deir ez-Zor, based on crowd-sourced analysis of satellite imagery to better understand how commercial activity was affected by ISIL's control in the city. Figure 9.8 plots a time series showing the total number of tractor trailers and commercial vehicles identified within Deir ez-Zor's urban core over time while ISIL has been present in the city. At first glance, this appears to suggest that commercial traffic in the city actually peaked after ISIL began contesting parts of Deir ez-Zor, although our pre-ISIL estimates might be artificially low given that at least one data point was captured on a Friday. Acknowledging the significant gap in imagery availability between November 2014 and December 2015,

[38] "Syria's Suffering Revealed in Satellite Images," BBC News, March 18, 2015.

Figure 9.6
Thermal Activity at Deir ez-Zor's Industrial Areas



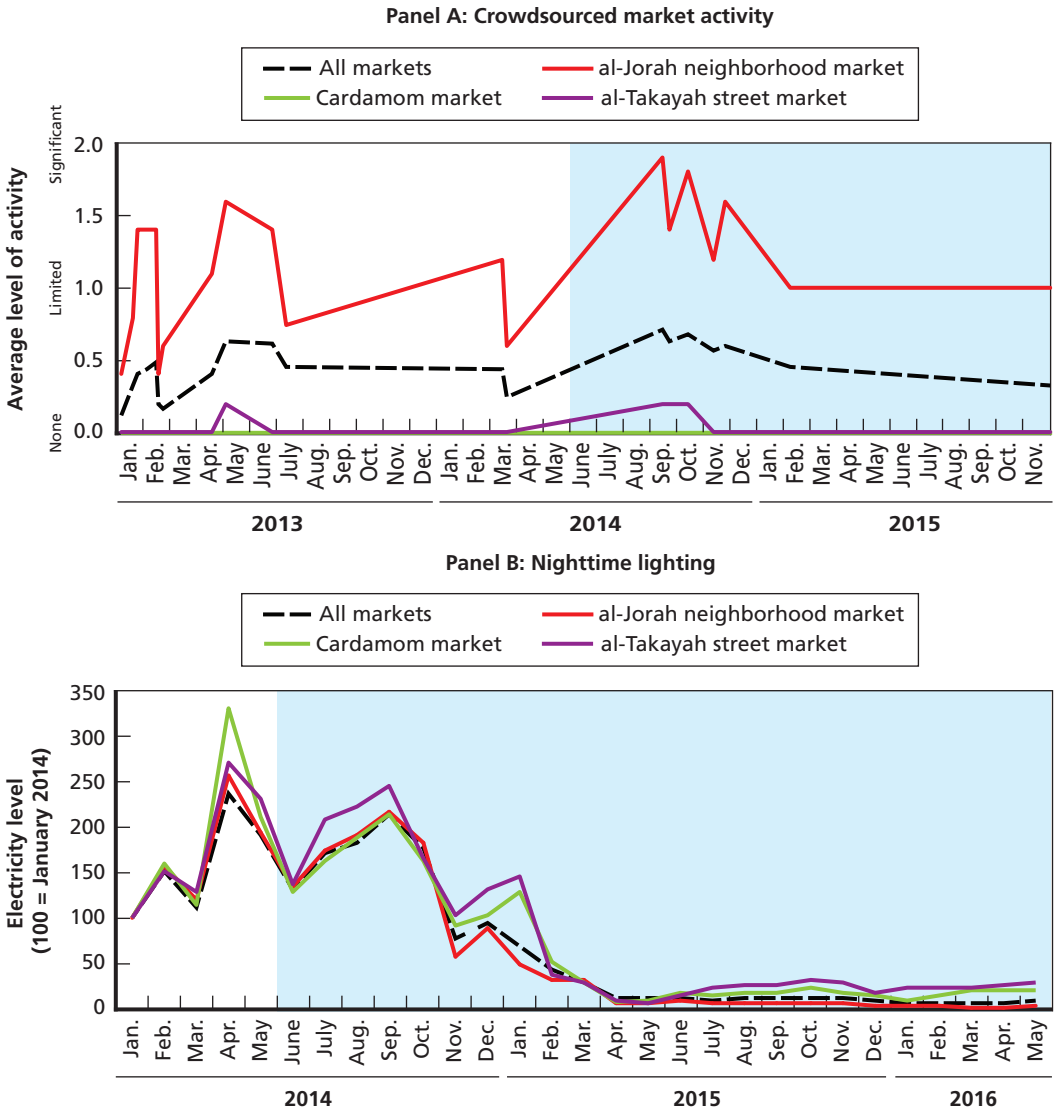
SOURCE: Thermal data are derived using USGS Landsat 8.
NOTE: Blue shading corresponds to months of contested control.
RAND *RR1970-9.6*

we note that these results at least tacitly suggest that commercial activity within Deir ez-Zor began to stagnate after ISIL's initial entry into the city—likely a product of protracted fighting and destruction within the city.

We can also examine the spatial density of commercial vehicles on Deir ez-Zor's roads to better understand whether this finding holds true upon further examination. Figure 9.9 plots the crowd-sourced location of each commercial vehicle or tractor trailer in Deir ez-Zor along its road network from March 2014, September 2014, and March 2016. These figures suggest three key things. First, there are very few tractor trailers and trucks present on Deir ez-Zor's roads. Although Deir ez-Zor is a smaller city than both Raqqah and Mosul, the paucity of vehicles in this image stands in stark contrast to the depth of commercial activity seen in comparable assessments for other cities.[39] Second, the uptick in commercial traffic seen in September 2014 is largely due to vehicles driving on a main stretch of road in the western portion of the city that leads to the main highway leading south out of the city. Third, we see very few com-

[39] For Mosul, see maps of commercial vehicles presented in Figure 6.13 in Chapter Six. For Raqqah, we do not present maps but do present a time series, in Figure 7.8 in Chapter Seven, that shows significantly higher commercial vehicle volume.

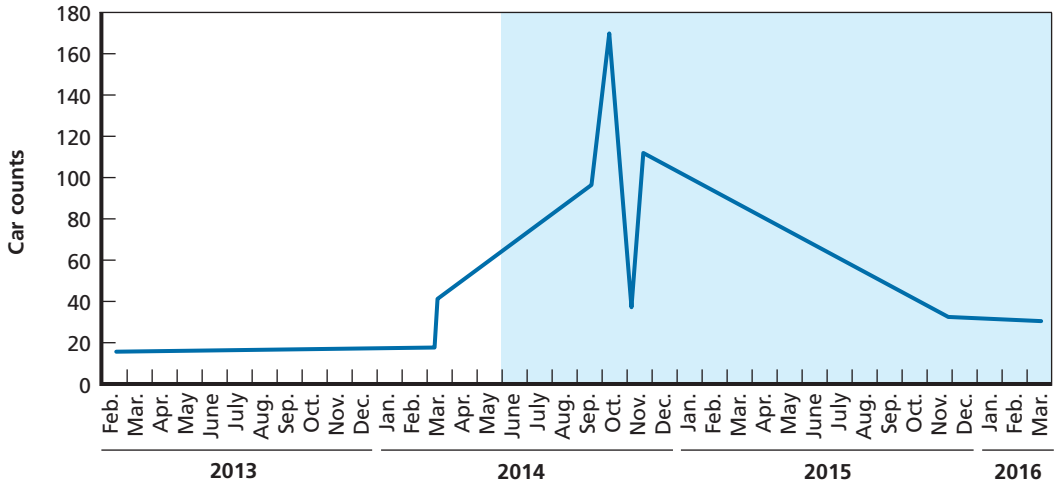
Figure 9.7
Deir ez-Zor's Markets



SOURCES: Market activity data are derived from Digital Globe's Tomnod Crowdsourcing Platform. Nighttime lighting data are calculated from NOAA VIIRS.
NOTE: Crowdsourced market activity data are presented as the average crowdsourced ranking across various subpolygons making up each market. Each market location was ranked as to whether it exhibited no activity (0), limited activity (1), or significant activity (2). Blue shading corresponds to months of contested control.

RAND *RR1970-9.7*

Figure 9.8
Commercial Vehicle Counts in Deir ez-Zor



SOURCE: Commercial vehicle data are derived from Digital Globe's Tomnod Crowdsourcing Platform.
NOTE: Blue shading corresponds to months of contested control.
RAND *RR1970-9.8*

mercial vehicles operating in the areas of the city largely held by the Islamic State—rather, commercial transit appears to be concentrated in regime-held areas of the city.

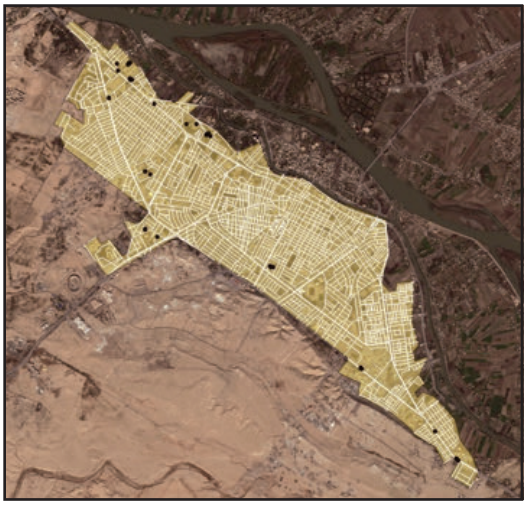
Damage and Destruction

Finally, we use crowd-sourced analysis of commercial satellite imagery to map areas in Deir ez-Zor that are damaged or destroyed over time. We use these data to understand how violence might have directly or indirectly affected our previous indicators of economic activity. This is especially important in Deir ez-Zor, given the back-and-forth nature of fighting for control over the city center. Figure 9.10 plots crowd-sourced instances of damage or destruction in the city both during the pre-ISIL period and within the first six months of ISIL contesting the city at the end of 2014.

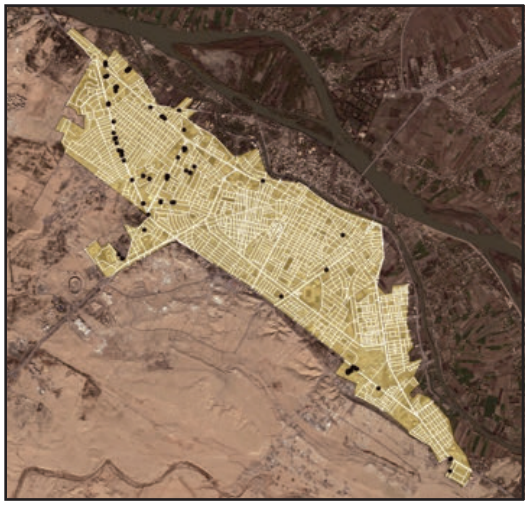
These images suggest that a moderate amount of damage was inflicted on Deir ez-Zor's infrastructure well prior to ISIL's arrival in the city but that destruction in Deir ez-Zor only worsened after ISIL came to town. Of note, the main line of destruction in the city occurs right along the north–south corridor that separates the largely ISIL-held zone in the center of the city and the largely regime-held areas to the west. The next-largest pocket of destruction occurs in the neighborhood on the eastern end of the city that separates this same ISIL-held zone from the regime-held areas to the southeast corner of the city. These levels of damage provide significant insight into our earlier findings regarding the extent to which contested areas in Deir ez-Zor show significantly reduced levels of nighttime lighting and population. They also persist over

Figure 9.9
Distribution of Commercial Vehicles Along Deir ez-Zor's Road Network

Panel A: March 20, 2014 (40 vehicles)



Panel B: September 23, 2014 (96 vehicles)



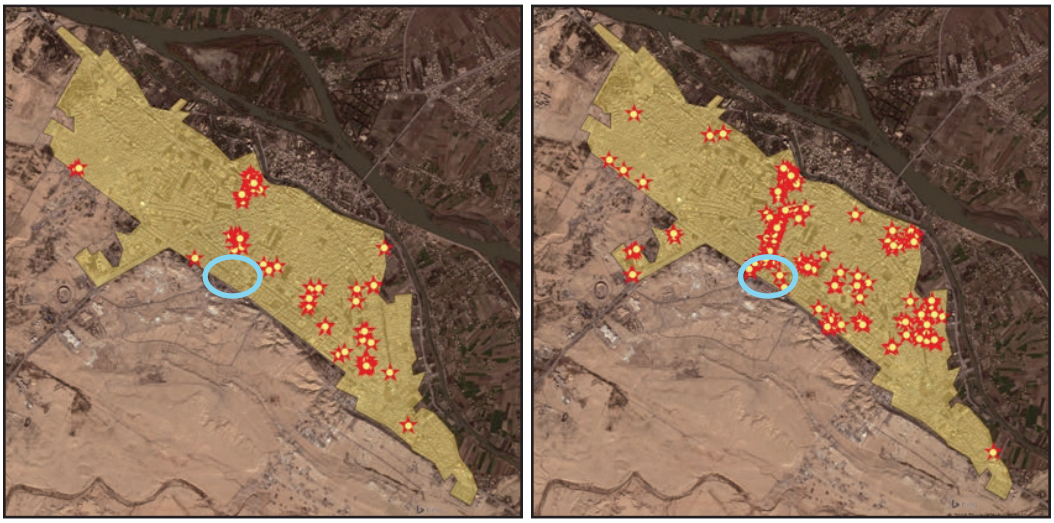
Panel C: March 22, 2016 (30 vehicles)

SOURCE: Vehicle data are derived using Digital Globe's Tomnod Crowdsourcing Platform. Imagery is from Digital Globe, 2016. Road network data are from Open Street Map.

RAND *RR1970-9.9*

time through 2016, based on our manual analysis of imagery data, although we do not present crowd-sourced estimates from this time period.

Figure 9.10
Map of Damage and Destruction in Deir ez-Zor, March 2014 and November 2014



SOURCES: Damage data are derived from Digital Globe's Tomnod Crowdsourcing Platform. Imagery is from Digital Globe, 2016.
NOTE: The first panel combines estimates of damage and destruction from February 2013 and twice in March 2014. Little evidence of rebuilding occurred between the two time points, and damaged areas from 2013 were validated with 2014 imagery to confirm. Area circled in blue is a residential location where damage has persisted and not been rebuilt. The yellow shaded area represents the city's urban extent, based on authors' estimates and a review of satellite imagery. Yellow-centered red stars denote instances of damage or destruction.
RAND *RR1970-9.10*

Conclusion

The Syrian city of Deir ez-Zor, a governorate capital and primary hub of Syria's oil and natural gas region, has been actively contested by Syrian regime forces and Sunni opposition groups, including the Islamic State, since 2012. Opposition groups first seized control of key neighborhoods throughout the city in June of that year, but ongoing fighting with Syrian regime destroyed an estimated 70 percent of the city through early 2014. In August 2014, the Islamic State wrested control of these opposition-held areas, although forces loyal to the Syrian Arab Republic remained firmly entrenched in neighborhoods representing some 40 percent of the city. Throughout the time period examined in this study (through mid-2016), control of territory within Deir ez-Zor city has ebbed and flowed on a neighborhood-level basis between ISIL and the Syrian regime.

ISIL governance in controlled areas of Deir ez-Zor relied on an early partnership with former local government officials and bureaucrats, who were co-opted into main-

taining critical infrastructure on behalf of the group. These initial efforts to consolidate control were bolstered by revenues from confiscation, taxation, and sales of electricity and oil resources from Deir ez-Zor governorate's vast oil reserves. However, more-recent publicly available reporting suggests that ISIL has been unable to provide the same quality and quantity of public services in parts of the city under its control than it did in other cities, such as Mosul and Raqqah.

Our analysis of satellite-derived measures of economic activity in Deir ez-Zor suggests that ISIL was ineffective at governing the neighborhoods and local economies under its control. Despite a relatively steady citywide population, market activity in ISIL-held areas remained paltry while markets in government-held areas of the city appeared to be more active, according to crowd-sourced analysis of satellite imagery. Commercial vehicle traffic was significantly more robust in regime-held areas than in ISIL-held areas, despite the fact that ISIL controls large portions of the Deir ez-Zor countryside. The intensity of agricultural activity on the outskirts of the city appears to have declined over the course of ISIL's presence in the city, according to our remote sensing-derived indicators. Our data also demonstrate a dramatic fall in nighttime lighting in both ISIL-controlled areas and those controlled by government forces, indicating a surprising inability of ISIL forces to provide fuel for generators within the city despite its proximity to the vast majority of ISIL oil production.

Finally, contested portions of the city also saw statistically significant reductions in population and nighttime lighting relative to those in regime-held areas. This is likely driven by significant levels of destruction in the seams between ISIL-held areas and regime-held areas, according to our crowd-sourced estimates of damage in the city. This finding affirms the fact that military opposition to the Islamic State is one of the main drivers of economic stagnation within its spheres of influence.

In Chapter Ten, our final case study, we examine the case of Tikrit—a city where the Islamic State invested few resources to capture or govern and one of the first cities to be recaptured from the Islamic State in March 2015.

CHAPTER TEN

The Islamic State in Tikrit

The Islamic State captured Tikrit, the capital of Iraq's Salah ad-Din province north of Baghdad, in its June 2014 offensive shortly after the fall of Mosul. The city capitulated peacefully to ISIL control soon after a small contingent of its forces arrived, all without a single shot fired. Existing evidence of ISIL's control over Tikrit's economy suggests that the group mainly prioritized punitive violence against the city's former government officials, as well as extortion and seizure of assets, more so than regulation and taxation of economic activity. ISIL controlled Tikrit for a brief nine months. Given that Tikrit was one of the first cities to fall from ISIL control in early 2015, this case study offers the chance to leverage a lengthy time series of post-liberation data to assess how economic activity recovers after ISIL leaves town. Furthermore, Tikrit is a useful case study into the impact of ISIL control given that the group devoted few resources to actually governing and providing stability.

Our analysis of satellite-derived measures of economic activity in Tikrit demonstrates that ISIL's tenure in the city, although short-lived, had a dramatic chilling effect on the economy. In the rest of this chapter, we explore the importance (or lack thereof) that controlling Tikrit had for ISIL, as well as the city's economy before the arrival of the Islamic State, and then discuss existing evidence of ISIL's governance and economic impact on the city. We devote the majority of this chapter to a discussion of our satellite-derived measures of economic activity as they related to Tikrit's economy before, during, and after ISIL came to town.

Tikrit's Importance to the Islamic State

After capturing Mosul, ISIL turned its forces southward toward Tikrit, a city of 160,000 and capital of Salah ad-Din province. Tikrit was the hometown of Ba'ath party dictator Saddam Hussein but more recently can be characterized by its restive Sunni population and tensions with the Shia-led government in Baghdad. Like other Sunni strongholds in Iraq eventually taken over by the Islamic State, Tikrit was the site of major Sunni protests in December 2012 over anti-Sunni crackdowns and sectarian favoritism perpetrated by the Shiite-dominated Nouri al-Maliki government in Bagh-

dad.[1] Local anti-Baghdad political dynamics in Tikrit provided ISIL with an opportunity to infiltrate the area more easily than it would have otherwise, given the military balance of forces in the area.

On June 11, 2014, ISIL deployed only a small number of fighters who arrived in Tikrit in nearly 30 unarmored trucks. They took control of the city without firing a single shot.[2] This is unsurprising given ISIL's familiarity with the city. ISIL's predecessor group, ISI, had conducted an assassination campaign against Iraqi government officials in Tikrit in 2012, severely weakening local and provincial government institutions.[3] Before its takeover, ISIL had already selected and groomed a replacement for the governor of Tikrit, former Ba'athist general Ahmed Abd al-Rashid, who assumed control of the city amid ISIL-led purges of local government officials.[4] Available data suggest that tens of thousands of residents were displaced from the city upon its takeover, although little damage to the city occurred.[5]

Despite the ease with which the group conquered the city, Tikrit was never an essential component of ISIL's state-building strategy. Unlike ISIL's capitals in Raqqah and Mosul or more–economically vital areas along the Euphrates River valley, the city carried little strategic or financial importance to the group. Ultimately, it was one of the first cities in Iraq to fall back to GoI control, when ISF, supported by coalition advisers and airpower and Iranian-backed PMUs, launched an offensive to retake Tikrit in March 2015. Between 25,000 and 30,000 ISF and militia forces surrounded the city by mid-March, severely outnumbering the remaining ISIL forces in the city.[6] ISIL fighters began to withdraw from Tikrit midway through the siege, leaving behind a few hundred fighters and a complex web of IEDs and ambushes intended to slow the advance of the Shia PMUs through the city.[7]

---

1 Protests also occurred in Fallujah, Ramadi, Mosul, Samarra, and Baghdad in December 2012. See "Make or Break: Iraq's Sunnis and the State," International Crisis Group, Middle East Report 144, August 14, 2013, p. 1.

2 Andrew Slater, "The Paper Tiger of the Tigris: How ISIS Took Tikrit Without a Fight," *Daily Beast*, June 29, 2014; Zaid al-Ali, "Tikrit: Iraq's Abandoned City," *New York Review of Books*, May 4, 2015.

3 Z. al-Ali, 2015. Also during 2012, ISI conducted a brazen assault on the city's Tasfirat prison as part of al-Baghdadi's broader "Breaking the Walls" campaign, which resulted in the escape of some 47 Islamic State of Iraq senior leaders who were on death row (Tim Arango and Eric Schmitt, "Escaped Inmates from Iraq Fuel Syrian Insurgency," *New York Times*, February 12, 2014). Also see Charles Lister, *Profiling the Islamic State*, Brookings Doha Center Analysis Paper 13, November 2014, p. 11. Also see Jessica D. Lewis, *Al-Qaeda in Iraq Resurgent*, Institute for the Study of War, Middle East Security Report 14, September 2013, pp. 15, 20.

4 Shane Harris, "The Re-Baathification of Iraq," *Foreign Policy*, August 21, 2014. Lister, 2014, p. 20.

5 "40,000 Flee Tikrit, Samarra, as Iraq Crisis Deepens," Agence France-Presse, June 13, 2014.

6 Anne Barnard, "Iraqi Campaign to Drive ISIS from Tikrit Reveals Tensions with U.S.," *New York Times*, March 3, 2015a.

7 Nancy A. Youssef, "The Big Offensive Against ISIS in Tikrit Has Stalled," *Daily Beast*, March 19, 2015; Anne Barnard, "Iraqi and Shiite Forces Seize Large Parts of Tikrit from Islamic State," *New York Times*, March 10, 2015b.

The ensuing battle to clear Tikrit saw periods of intensely heavy fighting, punctuated by hundreds of IEDs left behind by ISIL, as well as fears over reprisal killings and sectarian violence, particularly from Iranian-backed Shia militias against the local Sunni population.[8] Media reports suggest that around 90 percent of Tikrit's remaining residents left the city amid the fighting.[9] Post-liberation, one local businessman in central Tikrit reported that business was slow and property prices had fallen significantly because "the wealthy people are afraid and have not come back. There is no money and no jobs."[10] For many months after liberation, the fear over reprisals from Shia militias caused hesitation among many of Tikrit's Sunni residents at the prospect of returning.[11]

Tikrit's Economy Before the Islamic State

Prior to ISIL's arrival, the economy of the province of Salah ad-Din, dominated by agriculture and oil refining, was improving. The province saw a dramatic fall in poverty rates during 2007 to 2012, falling more than 24 percentage points, from 38.2 percent to 13.9 percent.[12] Improvements in employment opportunities and earnings contributed modestly to this fall in poverty, although a variety of other factors (such as government transfers and increases in consumption) reportedly had larger effects.[13]

Tikrit's economy is predominantly agrarian and governmental. Although only 25 percent of employed people work directly in agriculture, a reported 85 percent of people in Tikrit and its surrounding areas had agriculture as a source of income before ISIL's takeover of the city.[14] And with Tikrit being the provincial capital, Tikrit's labor force was made up of nearly 50 percent of people who worked directly for the government.[15] Although there is a small industrial area in the city, available estimates suggest

---

8 Paul Mutter, "Tikrit Torn," *U.S. News and World Report*, June 26, 2015.

9 Kareem Shaheen, "Iraq: Pro-Government Forces Struggle to Topple Isis in Tikrit," *Guardian*, March 5, 2015; Loveday Morris, "Iraq Labors to Repopulate Tikrit After Chasing Out the Islamic State," *Washington Post*, June 19, 2015a.

10 Julian Pecquet, "Slump in Oil Prices Wallops Anti-ISIS Coalition," *U.S. News and World Report*, January 13, 2016.

11 "Ruinous Aftermath: Militias [sic] Abuses Following Iraq's Recapture of Tikrit," Human Rights Watch, September 20, 2015.

12 See World Bank, 2014, Table A.2.1.

13 World Bank, 2014, pp. 122–123 and Table A.5.2. With Tikrit being the provincial capital of Salah ad-Din, we assume that conditions in Tikrit follow overall provincial trends, for the purposes of this discussion.

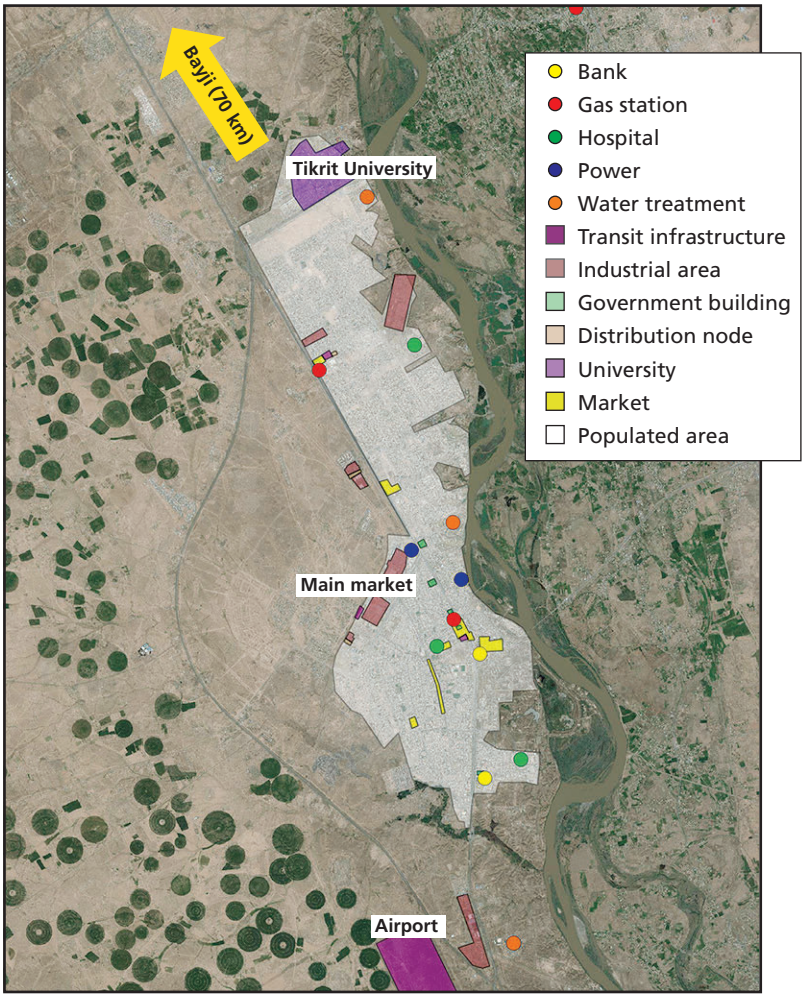
14 Central Organization for Statistics and Information Technology et al., 2008; Singh, van Zoonen, and Mohammed, 2016.

15 Central Organization for Statistics and Information Technology et al., 2008.

that only 1.5 percent of employees worked in the industrial labor force.[16] Tikrit also has a modest-sized airport and railway station, a major teaching hospital, and a university with some 2,900 students.[17]

Figure 10.1 provides a spatial overview of Tikrit's key economic infrastructure. In this figure, color-coded dots represent banks, gas stations, hospitals, power facilities,

Figure 10.1
Economic Laydown of Tikrit



SOURCES: Authors' estimates. Imagery from Digital Globe, 2017.
RAND *RR1970-10.1*

[16] Sabah Faihan Mahmud, "Proposed Criteria for Selecting Cities of Urban System in Iraq, a Case Study of Salah al-Din Governorate," *Journal of Advanced Social Research*, Vol. 4, No. 5, May 2014, pp. 1–24.

[17] Republic of Iraq, undated, p. 24.

and water treatment facilities; shaded areas indicate the remaining urban infrastructure, including the overall urban populated areas. Economic infrastructure is just west of the Tigris River, with the university located at the northern end of the city, the airport at the southern end, a small industrial area to the north of the train station, and small markets and government buildings distributed throughout the city. The important oil refinery at Bayji lies some 50 km to the north along the Tigris River, and the more industrial city of Samarra is 70 km to the south.

The Islamic State's Governance over Tikrit's Economy

ISIL moved quickly to establish its control over Tikrit. Although ISIL's initial assault force on the city was very small, on the order of some 30 fighters, the group assembled a security force from poor villages on the outskirts to provide local security. In the months following ISIL's arrival, checkpoints were reportedly "manned by scraggly and scrawny teenagers from the outlying villages."[18] Local courts were closed, with an ISIL-led Islamic court taking their place.[19] ISIL established a variety of committees to manage Tikrit, including a real estate committee that "nationalized properties belonging to the provincial council members and senior security officials" and a taxation committee, among others.[20] ISIL rapidly seized government infrastructure throughout Tikrit, including the offices of the ministries of oil and agriculture, responsible for managing the two primary local economic sectors.[21]

ISIL's initial takeover of Tikrit seems to have been brutal and corrosive. Immediately after seizing control, nearly 2,000 unarmed Iraqi air force cadets were executed in what has been called the "Camp Speicher massacre," and some 800 Iraqi soldiers were similarly executed.[22] Government officials were reportedly executed unless they chose to repent and were approved by an ISIL "repentance committee."[23] ISIL had a long history of violently extorting business owners in Tikrit and, in 2012, had conducted a similar campaign of assassinations against government officials operating in the city.[24]

---

[18] Z. al-Ali, 2015.

[19] Z. al-Ali, 2015.

[20] Z. al-Ali, 2015.

[21] Maggie Fick, "Special Report: Islamic State Uses Grain to Tighten Grip in Iraq," Reuters, September 30, 2014b. Also see Susanne Koelbl and Christoph Reuter, "Is Islamic State in Trouble in Iraq?" *Spiegel Online*, March 26, 2015.

[22] "[Official statistics: 1997 total number of missing Spieker and Badush massacres] احصائية رسمية: 1997 العدد الكلي لمفقودي مجزرتي سبايكر وباوش," *Rudaw*, November 1, 2014.

[23] Z. al-Ali, 2015.

[24] Using tactics ISIL also employed successfully in Mosul, for example, by the summer of 2012, Islamic State operatives in Tikrit demanded monthly payments of up to $100,000 from a mobile-phone company operating

Unlike in other cities, such as Raqqah or Deir ez-Zor, there seems to have been no real effort to co-opt local officials to continue operating key economic infrastructure in Tikrit on ISIL's behalf—indeed, the entire staff of the oil ministry was reportedly fired, and many other public officials in Tikrit were reportedly killed.[25] Indeed, although such executions were not out of the ordinary, they were unusually brutal, and assassinations continued throughout ISIL's control of the city. One report—from January 2015, some seven months after ISIL established control—noted reports of ongoing kidnapping and mass executions.[26]

Available evidence suggests that ISIL's presence had dramatic negative effects on the city's economy. Most dramatically, one source from January 2015 reported that the "Tikrit city center is virtually empty."[27] Food and fuel prices were also reported to have surged during ISIL control, with these high prices persisting throughout ISIL's control of Tikrit.[28]

Although damage to the city under ISIL's rule was limited, the fighting during the city's liberation in March 2015 took a moderate toll on the city's economic infrastructure. The fighting severely damaged the city's electrical grid, so the city was still not connected to the grid in June 2015 some three months after the city was recaptured, and returning residents found "buildings burned, shops looted, schools shuttered and hospitals inoperable."[29] Reportedly, much of this looting was caused by the Shia PMUs who joined with the ISF to liberate the city.[30] Despite these concerns, publicly available estimates of total building damage in the city suggest that it fell far below levels of damage in other cities once held by ISIL, such as Kobani, Ramadi, and Fallujah.[31]

---

there. See Z. al-Ali, 2015. Also during 2012, ISI conducted a brazen assault on the city's Tasfirat prison as part of al-Baghdadi's broader "Breaking the Walls" campaign, which resulted in the escape of some 47 ISI senior leaders who were on death row (Arango and Schmitt, 2014). Also see Lister, 2014, p. 11. Also see Lewis, 2013, pp. 15, 20.

[25] See Koelbl and Reuter, 2015. Also see Isabel Coles and Maggie Fick, "Kurds Report More Chlorine Attacks, Iraq Pauses Tikrit Offensive," Reuters, March 16, 2015.

[26] International Organization for Migration, Iraq Mission, "Displacement Snapshot: Salah al-Din," January 2015.

[27] International Organization for Migration, 2015.

[28] See "Tikrit Residents Complain of Rising Prices of Food and Fuel," *The I.Q.D. Team Connection*, July 16, 2014. Also see WFP, 2015a.

[29] Omar al-Jawoshy and Tim Arango, "Iraqi Families Return to Fragile Stability in Tikrit After Liberation from ISIS," *New York Times*, June 22, 2015. A UNDP project in early 2016 reportedly helped rehabilitate this electricity system (UNDP in Iraq, "Mayor of Tikrit: With the Help of UNDP, People Have Reestablished Essential Services for Our Community," February 1, 2016; also see UNDP in the Arab States, "UNDP Helps Displaced People Return to Tikrit," press release, June 25, 2015).

[30] "Iraq Tikrit: Looting and Lawlessness Follow Recapture," BBC News, April 4, 2015.

[31] For the UNITAR assessment of damage to Kobani, see UNITAR, "Damage Assessment of Kobane, Aleppo Governorate, Syria," March 6, 2015b. For Ramadi, see UNITAR, "Damage Assessment for Ramadi, al Anbar Province, Iraq," February 15, 2016a. For Fallujah, see UNITAR, "Damage Assessment for Fallujah, al Anbar

Measuring the Islamic State's Economic Impact in Tikrit

In this section, we use satellite imagery and remote sensing data to track how economic activity in Tikrit changed over time. We examine how each indicator in our sample—electricity consumption, population levels, agricultural activity, industrial activity, market activity, commercial vehicle counts, and building destruction—changes across the whole city before and ISIL established control in June 2014. We use these data to test our hypotheses described earlier in this report and in conjunction with existing media reporting of ISIL's economic impact and control over Tikrit.

Electricity Consumption

First, we use nighttime lighting to understand how electricity consumption has changed over time in Tikrit before, during, and after ISIL's control of the city. We combine this information with data from the Iraqi Ministry of Electricity, showing provincial-level power supply information to Salah ad-Din province from the national power grid through February 2015 (after which data are unavailable). Both time series are presented in Figure 10.2. Shading indicates ISIL's control of the city from June 2014 to March 2015, with the first and last months marked as contested in that the group did not control the city for the entirety of each month.

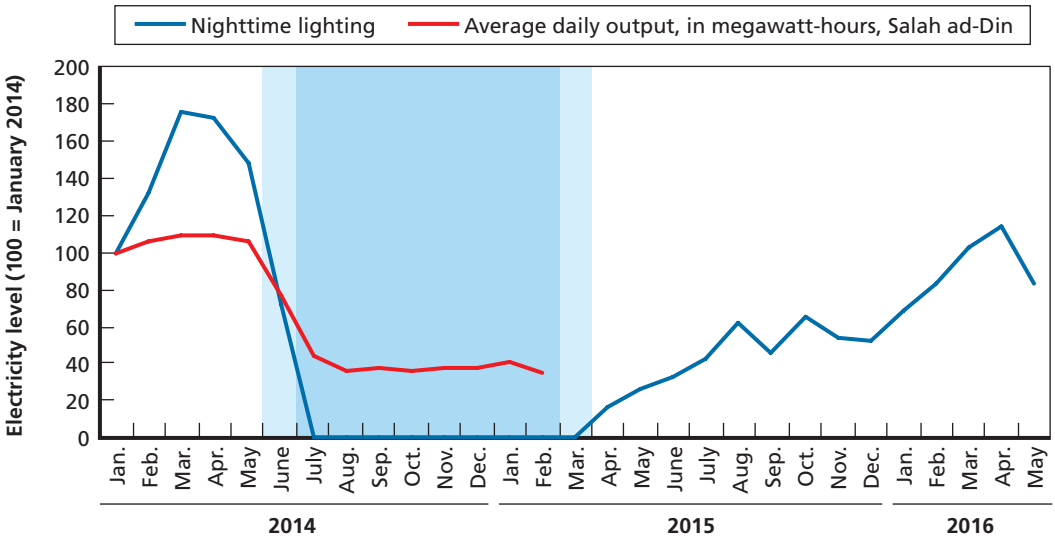
Nighttime lighting estimates suggest that very little electricity was available in Tikrit, at least at night, for the entire period of ISIL's control over the city. This is alarming evidence of ISIL's impact on the city. Interestingly, electricity data from the GoI Ministry of Electricity suggest that modest levels of power were still being supplied to Salah ad-Din province through February 2015. This contrasts with Mosul's Ninewa province, where the GoI shut the power supply off completely in June 2014, but modest levels of nighttime lighting persisted. Combined, these results suggest that Tikrit's access to the national power grid was severed or damaged immediately following ISIL's takeover of the city and that the group was unable to provide, unwilling to provide, or not interested in providing generators and fuel resources to power the city in its stead.

Following ISIL's defeat in Tikrit in March 2015, we see an immediate and steady rise in nighttime lighting. Early reporting in the city from June 2015 noted that the GoI was relying on generators for power and had been unable to reconnect to the national power grid.[32] Electricity consumption rose steadily over the course of 2015 as generators rose in capacity and Tikrit was reconnected to the national power supply.

Province, Iraq," July 11, 2016b. For Tikrit, see UNITAR, "Damage Assessment of Tikrit, Salah ad Din Governorate, Iraq," February 24, 2015a.

[32] al-Jawoshy and Arango, 2015.

Figure 10.2
The Islamic State's Impact on Electricity in Tikrit, 2014–2016



SOURCE: Nighttime lighting data are calculated using NOAA VIIRS. Electricity supply data are from Andrew Shaver and D. Ensign, "Lights Off in the Islamic State: What Electricity Tells Us About ISIS' Rule," *Foreign Affairs*, 2015.
NOTE: All data are normalized to the first data point in the time series so that values deviate around 100. For example, a nighttime lighting value of 50 in this figure indicates that nighttime lighting at that point in time was 50 percent below the first point at which nighttime lighting information was collected. Light blue shading corresponds to months of contested control, while dark blue shading corresponds to months of unilateral ISIL control.
RAND *RR1970-10.2*

However, it took a full year, until March 2016, for the city to return to its pre-ISIL levels of nighttime lighting.[33]

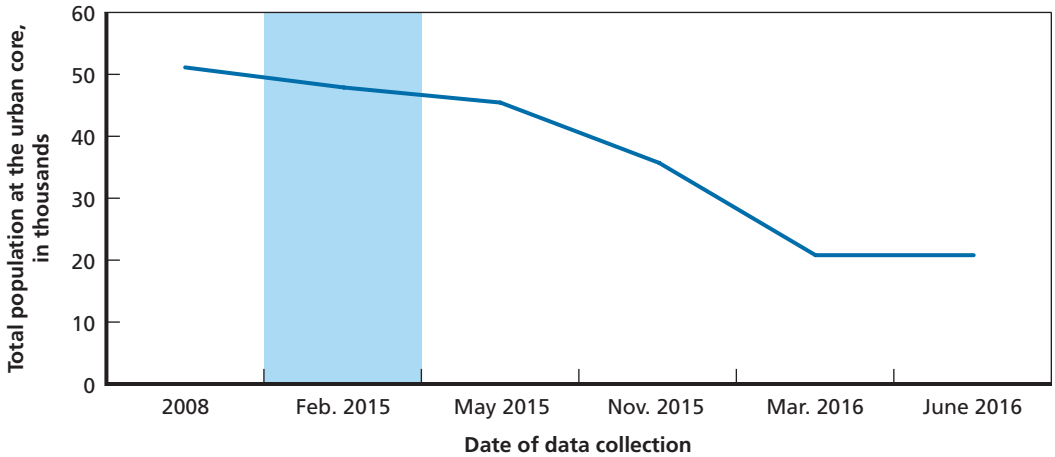
Population Levels

Next, using ORNL LandScan estimates of the city's population from 2008 to 2016, we explore how Tikrit's population fluctuated in response to ISIL's control of the city. We restrict our estimates to the urban core of Tikrit as opposed to its full periphery, so total population figures might fall slightly below published estimates. Figure 10.3 plots Tikrit's population over time.

These results show that little depopulation occurred following ISIL's takeover of the city compared with 2008 levels. This is in line with earlier discussion regarding

[33] We do not explore how nighttime lighting in Tikrit under ISIL's control differed by type of infrastructure given the zero nighttime lighting levels in the city over the course of ISIL's control. An analysis of nighttime lighting levels by infrastructure during reconstruction, not presented, notes that markets and residential areas near mosques were slightly more electrified at night than hospitals and industrial areas in the months following GoI reconquest. We discuss this further in "Industrial Activity" later in this section.

Figure 10.3
Tikrit's Population over Time



SOURCE: Oak Ridge National Laboratory, Landscan 2008–2016.
NOTE: Population totals represent the number of people living in the urban core of the city. Data were captured at irregular intervals, so we use 2008 as a baseline and lack data on exact population totals prior to ISIL arrival. Blue shading corresponds to periods of unilateral ISIL control.
RAND *RR1970-10.3*

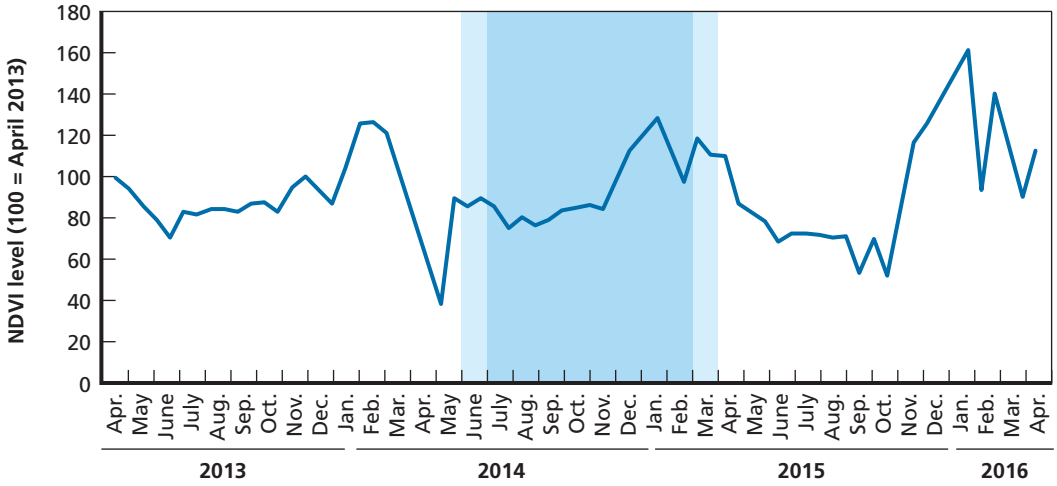
Sunni discontent with the Shiite government in Baghdad and suggests that the vast majority of Tikrit's residents chose not to flee ISIL's coming reign (or were unable to do so). Estimates from May 2015, the first data point following ISIL's retreat from the city, show relatively little depopulation immediately after the Shia militia–led recapture of the city. This might be an artifact of a time lag in the sensitivity of LandScan's measurements, particularly given that our 2016 data confirm the massive depopulation of the city at some point after liberation. One year into reconstructing the city as of June 2016, our estimates suggest, only 44 percent of those who lived in Tikrit under the Islamic State chose to remain or return under GoI control. This finding contradicts other public estimates of the near-complete repopulation of the city by the summer of 2016.[34]

[34] In public statements at the White House, the Special Presidential Envoy for the Global Coalition to Counter ISIS, Brett McGurk, has suggested that this figure is as high as 95 percent. See "Press Briefing by Press Secretary Josh Earnest and Special Presidential Envoy for the Global Coalition to Counter ISIL, Brett McGurk," White House, June 10, 2016. Also, the mayor of Tikrit suggested in February 2016 that repopulation had occurred for nearly 90 percent of families. See UNDP in Iraq, 2016. Discrepancies of this nature are also possible because of data-quality concerns both in the remote sensing data and in anecdotal estimates of repopulation from on the ground absent a true census. Furthermore, differences in the spatial denominator or exact time period at which repopulation has occurred could drive some differences in estimates.

Agricultural Activity

This section explores how agricultural activity in Tikrit was affected by ISIL's control over the city. We use NDVI, which captures changes in the intensity of vegetation using the USGS Landsat satellite. We track the average NDVI value for all areas within 5 km of the urban core of Tikrit as a proxy for agricultural activity in Tikrit over time. Figure 10.4 plots this metric over time since April 2013. ISIL's control over Tikrit from June 2014 to March 2015 roughly corresponds to one full growing season for wheat, barley, and potato crops in Iraq.[35] This suggests that changes in the spatial intensity of vegetation in March 2015 are likely due to the cultivation period after ISIL first established control over the city in June 2014. This obviously excludes any intervening damage to agricultural areas due to fighting or other physical destruction over the course of the growing season. Figure 10.4 suggests that ISIL's takeover had relatively little impact on the 2014–2015 growing season in the immediate periphery of Tikrit: Peak NDVI values approaching harvest season were comparable between the spring of 2015 and the spring of 2014. We do see, however, that NDVI values in the spring of 2016 were significantly above levels seen in the two prior years. This suggests that the resumption of GoI control over Tikrit had a significantly positive impact on agricultural activity through late 2015.

Figure 10.4
Agricultural Activity in Tikrit's Periphery



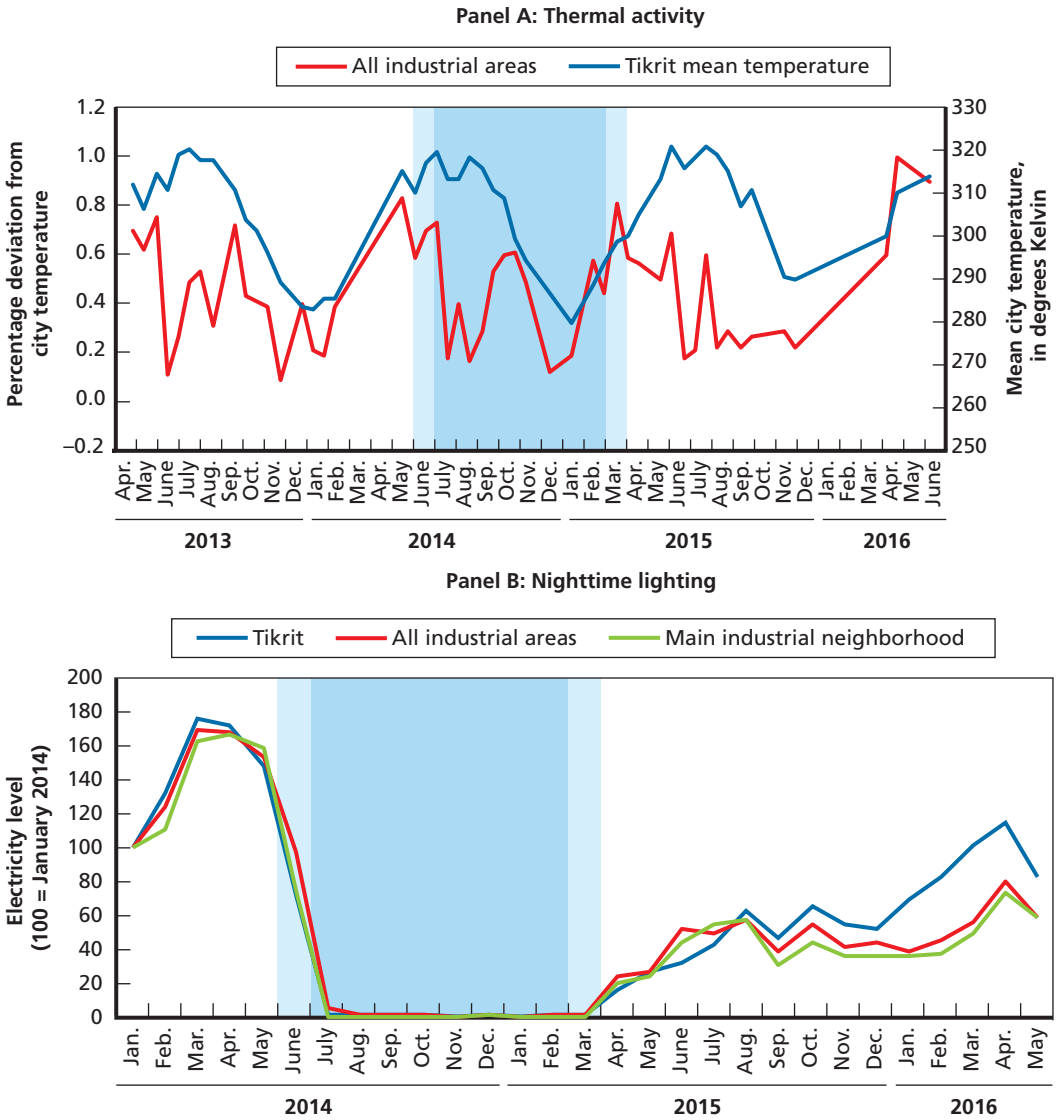
SOURCE: NDVI data are derived using USGS Landsat 8.
NOTE: All data are normalized to the first data point in the time series so that values deviate around 100. Light blue shading corresponds to months of contested control, while dark blue shading corresponds to months of unilateral ISIL control.
RAND *RR1970-10.4*

[35] FAO, 2016a.

Industrial Activity

We next examine how ISIL control of Tikrit affected economic activity around the city's industrial areas. The first panel of Figure 10.5 plots the thermal signature of Tikrit's industrial areas (in red) relative to the average city temperature (in blue). We

Figure 10.5
Tikrit's Industrial Areas



SOURCES: Thermal data are derived using USGS Landsat 8. Nighttime lighting data are derived from NOAA VIIRS.
NOTE: Light blue shading corresponds to months of contested control, while dark blue shading corresponds to months of unilateral ISIL control.

RAND *RR1970-10.5*

measure industrial activity here as the mean percentage deviation across all industrial facilities in Tikrit relative to the city's average temperature. Industrial areas operate at a temperature that is 0.4 percentage points higher than the city on average. This figure, although noisy, suggests that Tikrit's industrial areas operated with largely comparable thermal signatures before, during, and after Islamic State control of the city.

The second panel uses nighttime lighting to examine in detail how Tikrit's industrial areas recovered from ISIL control following the GoI's recapture of the city. The blue line represents the average nighttime lighting of the entire urban core of Tikrit, as shown earlier in this chapter. The red and green lines represent, respectively, the average nighttime lighting across all of Tikrit's industrial areas in our sample, as well as the main industrial neighborhood of the city. Although recovery from ISIL control for the whole city begins to increase its pace in December 2015, Tikrit's industrial areas are largely stagnant and deviate from the larger trend in the city. This suggests that ISIL had a medium-term impact on Tikrit's economic recovery.

Market and Commercial Activity

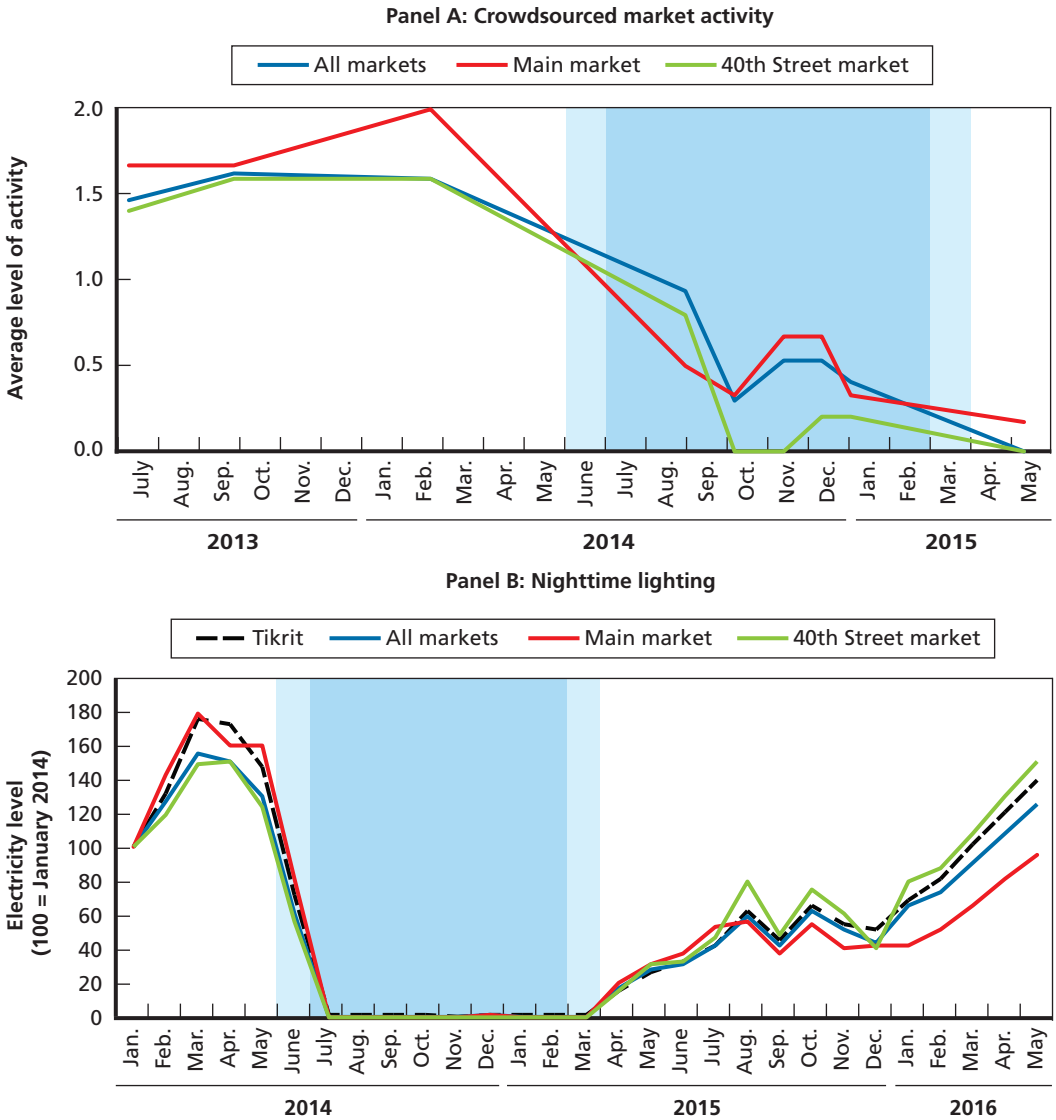
We next examine how commercial activity in Tikrit was affected by ISIL's control over the city. We start by focusing on Tikrit's markets. The first panel of Figure 10.6 shows crowd-sourced estimates of market activity visible in commercial satellite imagery of Tikrit over time, plotting the average intensity of market activity on a scale from no activity (0), to limited activity (1), to significant activity (2). The second panel uses nighttime lighting to better understand the electricity available to support economic activity at these locations.

In each panel, we focus on two of the largest market and commercial locations in Tikrit: the main market in the northwestern portion of the city and a set of shops and businesses that run along 40th Street through the heart of the city. We also plot the average level of activity across all markets identified in our sample. Our crowd-sourced estimates of market activity based on commercial imagery show the overwhelming impact of ISIL's control over the city. Prior to ISIL's arrival, markets in Tikrit were bustling. Two months into ISIL's control of the city, they show more-limited signs of activity. Through the final months of ISIL's control and immediately after the city is liberated, market activity was all but nonexistent.

Although the last available image of Tikrit was captured soon after the city's liberation, our nighttime lighting data allow us to gain insight into how Tikrit's markets fared after the GoI began its efforts to rebuild the city. This is shown in the second panel of Figure 10.6. Although most markets largely mirrored the citywide average level of electricity usage at night, Tikrit's main market area lagged well behind other locations. This is despite being the most consistently active market in our crowd-sourcing data prior to ISIL's control of the city.

We also use estimates of commercial vehicle traffic in Tikrit based on crowd-sourced satellite imagery to better understand how commercial activity was affected

Figure 10.6
Market Activity in Tikrit



SOURCES: Market activity data are derived from Digital Globe's Tomnod Crowdsourcing Platform. Nighttime lighting data are calculated using NOAA VIIRS.
NOTE: Crowd-sourced market activity data are presented as the average crowdsourced ranking across various subpolygons making up each market. Each market location was ranked as to whether it exhibited no activity (0), limited activity (1), or significant activity (2). Nighttime lighting data are normalized to the first data point in the time series so that values deviate around 100. Light blue shading corresponds to months of contested control, while dark blue shading corresponds to months of unilateral ISIL control.
RAND *RR1970-10.6*

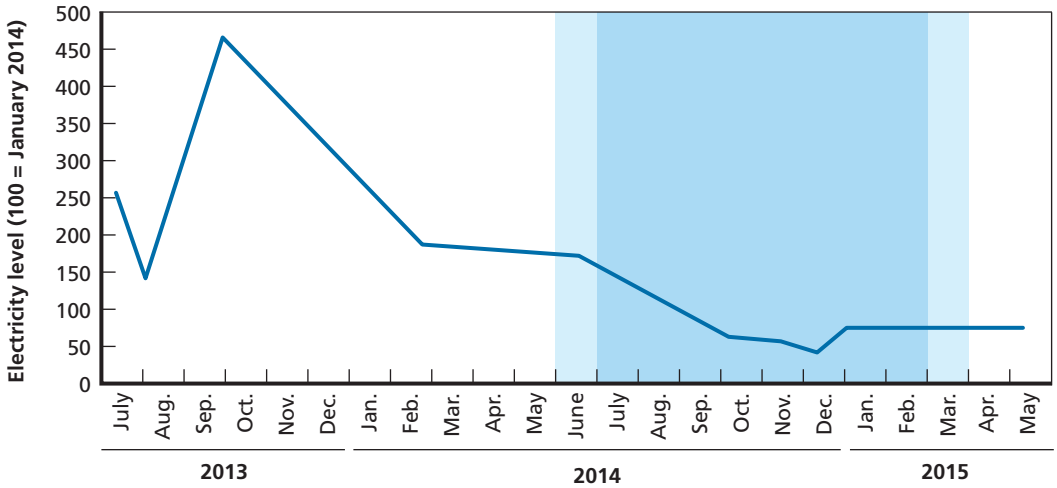
by ISIL's control of the city. Estimates of tractor trailer and large commercial vehicle counts over time are shown Figure 10.7. ISIL control over the city is clearly associated with a reduction in the prevalence of commercial trucks and tractor trailers on Tikrit's roads by 70 percent, on average.

Figure 10.8 plots the distribution of commercial vehicles across the city at two time points, one before ISIL (in July 2013) and one after ISIL takeover (in December 2014). Both estimates were captured on a Monday at roughly the same time of day, for ease of comparison. The pre-ISIL image shows clear pockets of commercial vehicles around Tikrit's industrial areas and main market area in the southwest portion of the city. The post–ISIL takeover image shows only sporadically located vehicles throughout the city, with almost no presence by the main market and industrial area in the city. The ISIL effect here is clear: The market and industrial area were not receiving truck-driven supplies, nor do they appear likely to have been distributing goods to businesses within the city from these locations.

Damage and Destruction

Finally, we use crowd-sourced analysis of commercial satellite imagery to map buildings, roads, and other areas within Tikrit that were damaged or destroyed over time. This is especially important for understanding the extent to which the city was damaged by the fight between ISF, Shia PMUs, and ISIL forces in March 2015 when the city was liberated. We use data on destruction to understand how violence might have

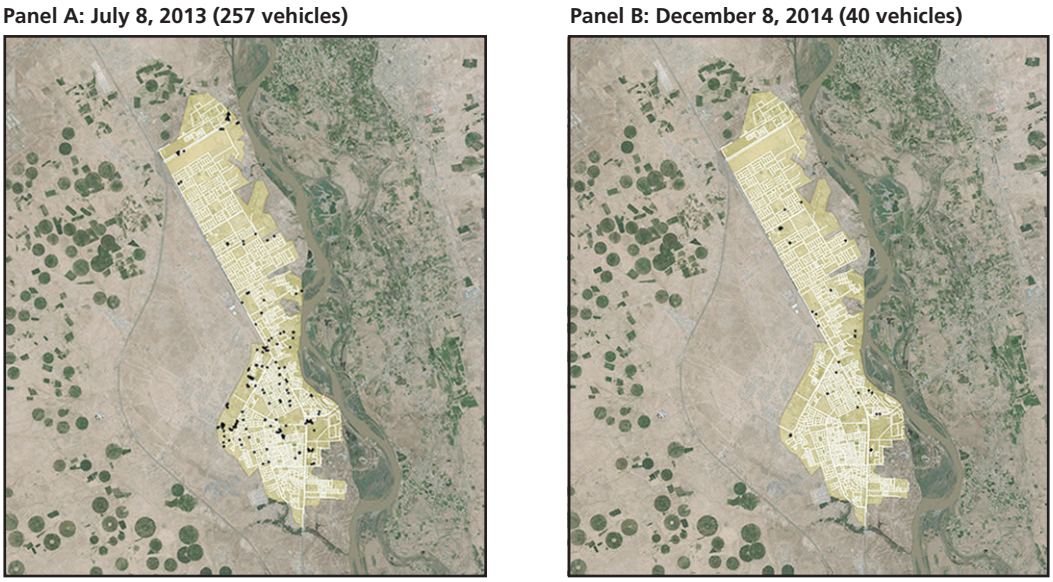
Figure 10.7
Commercial Vehicles in Tikrit



SOURCE: Commercial vehicle data are derived from Digital Globe's Tomnod Crowdsourcing Platform.
NOTE: Light blue shading corresponds to months of contested control, while dark blue shading corresponds to months of unilateral ISIL control.

RAND *RR1970-10.7*

Figure 10.8
Map of Commercial Vehicles in Tikrit, Pre– and Post–ISIL Takeover



SOURCES: Vehicle data are derived using Digital Globe's Tomnod Crowdsourcing Platform. Background maps are from Digital Globe, 2017. Road network data are from Open Street Map. Authors' estimates.
NOTE: Black dots indicate the location of commercial vehicles identified from high resolution imagery. The yellow shaded area indicates the city's urban core boundaries.
RAND *RR1970-10.8*

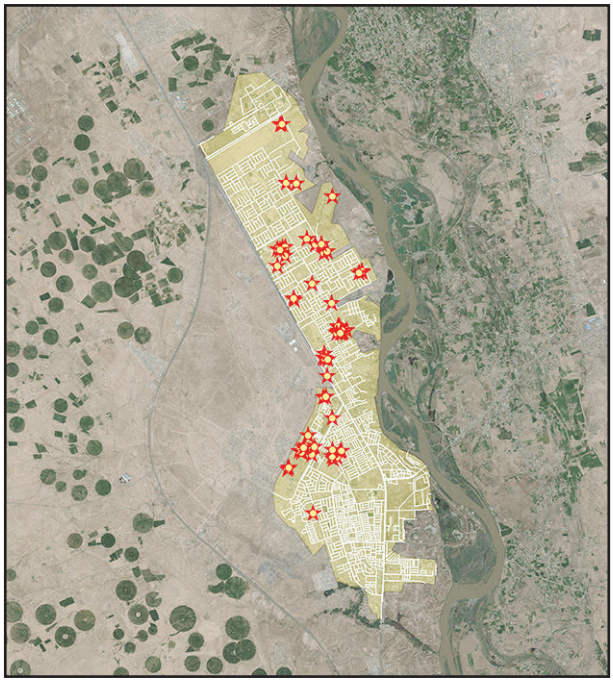
directly or indirectly affected our previous indicators of economic activity. Figure 10.9 plots areas either damaged or destroyed in Tikrit, as measured in December 2014 and May 2015. This map suggests a relatively low level of damage across the city, which is confirmed by other published estimates of damage to Tikrit post-liberation based on high-resolution imagery.[36] Of note is that relatively modest damage occurred to Tikrit's main industrial area to the southwest and hospital to the southeast and that no damage occurred to the city's university. We lack sufficient high-resolution imagery post-liberation to assess the rate at which damaged parts of the city have been rebuilt.

Conclusion

The Islamic State captured Tikrit, the capital of Iraq's Salah ad-Din province north of Baghdad, in its June 2014 offensive shortly after the fall of Mosul. The city capitulated peacefully to ISIL control soon after a small contingent of its forces arrived, all without

[36] This includes the UNITAR damage assessment of Tikrit, which found slightly higher levels of destruction citywide but still at the low to moderate level compared with other cities. See UNITAR, 2015a.

Figure 10.9
Damage and Destruction in Tikrit, 2014–2015



SOURCES: Damage data are derived from Digital Globe's Tomnod Crowdsourcing Platform. Background map is from Digital Globe, 2017. Road network data are from Open Street Map.
NOTE: This figure combines estimates of damage and destruction from December 2014 and May 2015. Little evidence of rebuilding occurred between the two time points, and damaged areas from 2014 were validated with 2015 imagery to confirm. The yellow shaded area represents the city's urban extent, based on authors' estimates and a review of satellite imagery. Yellow-centered red stars denote instances of damage or destruction.
RAND *RR1970-10.9*

a single shot fired. Existing evidence of ISIL's control over Tikrit's economy suggests that the group mainly prioritized punitive violence against the city's former government officials, as well as extortion and seizure of assets, over regulation and taxation of economic activity. ISIL controlled Tikrit for a brief nine months. Given that Tikrit was one of the first cities to fall from ISIL control in early 2015, this case study offers the chance to leverage a lengthy time series of post-liberation data to assess how economic activity recovers after ISIL leaves town. Furthermore, Tikrit is a useful case study into the impact of ISIL control given that the group devoted few resources to actually governing and providing stability.

Our analysis of satellite-derived measures of economic activity in Tikrit demonstrates that ISIL's tenure in the city, although short-lived, had a dramatic chilling effect on the economy. This is best illustrated by crowd-sourced data on market activity as seen in satellite imagery, which show a rapid decline in commerce during ISIL's control

of the city. Commercial vehicle counts portray an identical effect, suggesting that the presence of tractor trailers and large commercial vehicles in the city declined by up to 70 percent on average during ISIL's control. Data on nighttime lighting offer a similar conclusion: Electricity consumption rapidly falls within only a few months of ISIL's arrival, though the timing of this decline is in large part due to deliberate GoI efforts to restrict electricity access through the national power grid.

We also explore how conditions evolved during the stabilization and reconstruction of Tikrit. Our analysis of nighttime lighting data suggests that Tikrit's electricity consumption took nearly a year to reach levels at or below its pre-ISIL levels. Although agricultural activity in the vicinity of Tikrit appears to have grown significantly post-liberation, the few industrial locations identified in the city fell well behind other types of infrastructure in terms of their nighttime lighting. Our population data provide a similarly mixed result, suggesting that less than half of Tikrit's pre-ISIL population remained in the city as of early 2016 and that this depopulation might have actually occurred after liberation of the city from ISIL forces.

This latter result is perhaps unsurprising, given the reported violence associated with the recapturing of the city, concern over IEDs left by ISIL, and the potential for ethnic violence between Sunni residents and Shia militias that made up the main body of the GOI force that liberated Tikrit. However, damage to the city was only moderate and left much of the city's main economic infrastructure intact, including its university, hospital, main market area, and main industrial neighborhood.

This is the last case study in our overall assessment. Chapter Eleven draws out major findings and implications of this research for the counter-ISIL campaign, efforts to stabilize and reconstruct areas liberated from the Islamic State, and the application of remote sensing methods to future research.

CHAPTER ELEVEN

Findings and Policy Implications

This chapter relays the overall findings presented throughout this report related to the overarching goal of this research, which is to understand the impact that Islamic State governance had on the populations and economies within its caliphate. We discuss our three specific research questions that framed our analysis throughout this report, related to how ISIL governance has affected the type, trajectory, and distribution of economic activity within its territory. We then discuss the policy implications of this research for both the global campaign to degrade and defeat the Islamic State and for efforts to stabilize and rebuild areas liberated from the group. The chapter concludes by discussing key lessons learned related to the application of remote sensing and commercial imagery data to future research of this nature.

Can the Islamic State Govern Local Economies?

Our analysis paints a bleak picture of economic life under the Islamic State. Over the course of its peak territorial control and decline through mid-2016, the economy of the Islamic State writ large was clearly in decay. Across all of Iraq and Syria, we estimate that ISIL control was associated with an 80-percent reduction in urban electricity consumption in Iraq and 61-percent reduction in Syria, as measured through nighttime lighting. These effects correlate to a roughly 23-percent reduction in the GDP of cities within its caliphate. Furthermore, we find that ISIL control was associated with a 36-percent reduction in the population of cities under its control, up to a 20-percent reduction in agricultural output, and steady upticks in violence. All of these effects—on nighttime lighting, population, agriculture, and violence—are statistically significant. Detailed case studies of Mosul, Raqqah, Ramadi, Deir ez-Zor, and Tikrit offer evidence that ISIL governance shoulders at least some blame for these poor economic conditions. At times, ISIL inadvertently mismanaged key natural resources or local businesses, sought to punish its citizenry rather than govern it, or showed sheer indifference to the status of local economic activity.

However, our analysis suggests that it is too simplistic to blame stagnant local economic conditions entirely on the quality of ISIL's governance. Across the caliph-

ate, our satellite-based indicators of economic activity offer contrasting evidence that ISIL successfully provided public services within its territory, prioritized electricity to hospitals, successfully repaired damaged power grids, and invested in local infrastructure. In its strategic capitals—Mosul and Raqqah—dense ISIL regulatory regimes and more-stable security situations coincided with evidence of active markets, robust commercial vehicle traffic, and persistent agricultural production in the time after ISIL takeover. The service-sector and industrial components of these economies were particularly resilient, even where ISIL control was associated with larger negative impacts on electricity consumption and population outflows.

Given the heterogeneity of ISIL's economic impact across its caliphate, we find that the most consistent factor affecting local conditions was the military campaign to recapture territory from the group and deprive it of resources. ISIL faced a clear trade-off between devoting resources to hold a city militarily and devoting resources to governing it. Mosul and Raqqah were insulated from military competition for much of the time period analyzed in this study, and our satellite-based indicators of economic activity were comparably stable throughout much of ISIL's tenure as a result.

However, in militarily contested cities, such as Ramadi and Deir ez-Zor, or in less strategic cities once on the periphery of ISIL's territory, such as Tikrit, local economic activity declined rapidly over the course of ISIL's efforts to gain a more permanent foothold. Because the group lacked sufficient military power to maintain full de facto sovereign control of these locations for an extended period, ISIL was unable or unwilling to provide public services or guarantee stable security conditions.[1] As a result, in cities on the contested periphery of ISIL's territory, markets emptied, agriculture suffered, and commercial vehicle traffic was minimal. Furthermore, without long-term hopes of controlling these areas, ISIL resorted to destroying key infrastructure necessary for economic activity, as a punitive measure.

This is not to say that ISIL would have succeeded at fostering local economic activity everywhere within its caliphate absent military opposition. Although conditions were more stable in its strategic core than elsewhere, our analysis does not suggest that these economies were flourishing. It is to say, however, that outside pressure against the group successfully prevented the Islamic State from realizing its financial and governing ambitions across significant parts of its caliphate, with major consequences for the group's ability to support functioning local economies.

From an insurgent perspective, ISIL's inability to sustain a large-scale prosperous protostate represents an institutional failure by the group to capitalize on a vast territory, historically weak local governments, sympathetic local populations, and a massive

---

[1] These findings are consistent with prior research into the Islamic State's predecessor groups, which found that the group largely pulled its resources back from cities on its periphery in the face of military opposition. In Anbar province in 2008, reductions in violence in contested areas were found to be a product of Islamic State leadership pulling resources and attention out of that area, rather than ineffective attempts to fight back. See Johnston et al., 2016, pp. 99–100.

financial war chest. Few insurgent groups in the past have held such a strong hand. However, this report suggests that decaying conditions within the Islamic State are just as much a product of the group's inability to insulate its territory from opposing military forces. Phrased a different way, the military campaign against the group has been integral to the Islamic State's failure to build prosperous local economies and develop a sustainable caliphate.

Impact on the Nature, Trajectory, and Distribution of Economic Activity

At the beginning of this report, we offered three specific research questions intended to frame our analysis of the larger research question of this study, which was to assess the impact of ISIL's attempts to manage, profit off of, and grow the economies under its control. These three questions, and accompanying hypotheses, sought to explore how ISIL takeover has affected (1) the nature of economic activity in ISIL-held areas, (2) the trajectory of economic activity before and after ISIL takeover, and (3) the distribution of economic activity within cities by ethnicity and contested versus unilaterally controlled areas. This section discusses these hypotheses and evaluates them in light of our full results.

First, we hypothesized that economic activity directly controlled by ISIL or more critical to its revenues would outperform other parts of the local economy. Our results neither affirm nor refute this hypothesis. In some cases, such as in Mosul, direct intervention by ISIL into cement manufacturing appears to have reduced overall activity in that industry. Direct ISIL control over the profitable hydroelectric facilities at the Tabqah Dam near Raqqah had devastating effects on drinking water levels and electricity provision in Raqqah. In other cases, markets that were subject to taxation by the Islamic State in Raqqah and Mosul remained steadily active under ISIL control.

Next, we hypothesized that ISIL's economic impact would be abrupt, rapid, and destructive after the group established a foothold in a new city. We reject this hypothesis. For the most part, the first few months following ISIL takeover of a city resembled the final few months prior to its capture. Commercial vehicles and trucks remained on the road, markets remained active, the fields remained fertile, and industrial activity continued. The main exception to this finding is that electricity consumption in Iraq, measured through nighttime lighting, appeared to drop almost immediately after ISIL established control because of GoI power shutoffs. This was not the case in Syria. We also hypothesized that economic activity would increase after ISIL takeover of a given city. We see little to no evidence that ISIL control leads to increases in economic activity across our panel of 167 cities and in each of our five case studies. Rather, the decline in economic activity in areas held by the Islamic State builds over time, particularly as refugees and IDPs seek to leave ISIL-held areas when conditions deteriorate.

Finally, we hypothesized that, in cities held by the Islamic State, non-Sunni areas and those merely contested by the Islamic State would show reduced levels of economic activity relative to Sunni areas and those held entirely by ISIL. For Mosul, we find that markets in non-Sunni areas underperform their Sunni counterparts but that people appeared to be moving into non-Sunni residential neighborhoods of Mosul in early 2016. For Deir ez-Zor, we found that contested portions of the city were more likely than others to be destroyed or damaged in fighting between the Syrian regime and ISIL forces in the city. As such, we found that nighttime lighting and population levels in contested areas were statistically significantly below those in regime-held areas.

Implications for the Counter–Islamic State Campaign

At the onset of ISIL's declaration of a caliphate, the group's grip over its territorial holdings appeared stronger than ever. Its ability to govern that territory was largely untested. Now, several years in the making, the Islamic State's caliphate is on the ropes. Yet the Islamic State and its predecessor groups, AQI and ISI, have proven themselves resilient in the past. Despite its shrinking territory, the Islamic State still controls thousands of square kilometers of territory and a significant population, as well as highly lucrative oil and gas reserves. Its presence along the Euphrates River valley spanning the Syria–Iraq border is likely to persist, whether overtly or covertly. And if history is any lesson, the territorial defeat of the Islamic State is unlikely to extinguish the possibility for similar Sunni insurgencies in the region in the future.

As a result, this research has clear implications for the continued campaign to degrade and defeat the Islamic State. Furthermore, it serves to document for future planning purposes the lessons learned from ISIL's experiment in providing local governance. Below, we describe three key findings that inform current and future efforts to separate the Islamic State from its governed territory:

- **Military pressure on ISIL-held areas has dampened economic activity and prevented ISIL from fully governing according to its stated goals.** Overall, we find that military pressure on ISIL-held territory has prevented the Islamic State from attempting to govern and stabilize local economies when contested by opposing ground forces. This pressure has contributed to significant economic decay within ISIL-held territory, which, in turn, limits ISIL's ability to profit from taxation and gain popular legitimacy by governing stable local economies. Predominantly, we see this pressure materialize in terms of military opposition to contest or retake control of ISIL-held cities. We also see clear evidence that intentional efforts to deny ISIL-held territory energy resources are correlated with reduced local electricity consumption. This includes actions taken by the GoI to deny ISIL-held areas access to power through the national power grid and, more-

over, efforts by the coalition air campaign to deny the Islamic State access to and revenues from local oil fields under its control.

- **ISIL's strict governance is not necessarily self-defeating. Where local economies struggled under Islamic State control, these struggles were not because taxes were too high or social regulations too restrictive.** The Islamic State's unique form of governance involves harsh social regulation, severe forms of punishment, and significant extraction of rents and taxes from the local population. Some have argued that these forms of governance are self-defeating, in that they could disincentivize economic activity and local popular support.[2] However, we find clear evidence that market and commercial activity remained strong in Raqqah and Mosul even after ISIL fully built its bureaucratic institutions, social regulations, and public services. Where local economies struggled—in terms of electricity availability, population outflows, and infrastructure damage—these effects largely coincided with military efforts to disrupt ISIL's control over its territory. If ISIL's strict governance is not self-defeating, military efforts to retake its remaining territory and prevent a resurgence of the group remain critically important.
- **The Islamic State showed signs of successful stewardship over local economies but also signs of incompetence and indifference.** In multiple cities, ISIL prioritized electricity provision to hospitals and key infrastructure even in the face of larger electricity shortages. The group also successfully rebuilt electrical infrastructure in Raqqah following damage from air strikes, built new market facilities in Mosul, and regulated consistently active markets in both cities. Yet, in other cases, ISIL's efforts to directly intervene in local economies wreaked havoc on local economic conditions. In Raqqah, ISIL's failure to effectively manage the throughput of the Tabqah hydroelectric dam in 2014 led to water shortages and electricity problems. In Mosul, its failed efforts to take over the Badush Cement Factory appear to have driven declines in activity at that facility. In other cases, the group's desire to punish local populations or destroy key infrastructure in the face of liberating forces (such as in Ramadi) demonstrates indifference toward providing governance in the face of military opposition.

[2] Eli Berman and Jacob N. Shapiro, "Why ISIL Will Fail on Its Own," *Politico*, November 29, 2015.

Implications for Stabilizing Formerly Islamic State–Held Territory

Next, we discuss the implications of this research for efforts to stabilize and reconstruct areas liberated from the Islamic State:

- **Electricity consumption has suffered the most of all economic activity under ISIL control.** Across all the aspects of local economies assessed in this study, electricity consumption in areas held by the Islamic State showed the most-significant declines relative to pre-ISIL levels of activity. In some cases, the lack of electricity supply was due to mismanagement of electrical infrastructure or damage to power generating facilities, such as in Raqqah and Mosul. In other cases, fuel shortages or price shocks affected locals' ability to run private generators that supply large percentages of local power. After liberation, these effects linger. In Tikrit, it took nearly a year for the city to reach levels of nighttime lighting close to pre-ISIL levels, in part due to ISIL-inflicted damage to the power grid. In Ramadi, nighttime lighting levels only marginally improved in the first few months after liberation from ISIL forces in January 2016. Stabilization planning for the liberation of areas still controlled by ISIL should focus on procuring power supplies and rebuilding energy infrastructure. Implementers should be prepared to provide this assistance well beyond the first few months after liberation.
- **IDP flows begin well prior to liberation.** Planning for liberation of ISIL-held cities must take into account the fact that IDP flows begin well before the first military forces enter an ISIL-held city. Before operations to liberate Mosul began in the fall of 2016, more than half of the city's residents had already fled the city. In Raqqah, nearly 40,000 residents fled the city between February 2016 and June 2016. Planning for humanitarian assistance surrounding liberation must take into account the location and unique needs of these displaced people.
- **Markets do not return to normal activity immediately after a city is liberated.** In both Tikrit and Ramadi, markets were partially damaged by fighting during ISIL's retreat from the city. Moreover, they appear largely empty in high-resolution imagery following liberation, likely because the vast majority of the residents of each city had fled the fighting.
- **Bureaucratic capacity likely remains in areas liberated from the Islamic State.** In several instances, we document evidence of ISIL successfully co-opting local civil servants and engineers to help run its bureaucracy and public services. This includes evidence of local engineers conducting successful repairs to reconstitute Raqqah's power grid following damage from air strikes, which we validate using nighttime lighting data. Furthermore, the consistency with which hospitals across ISIL territory have remained functional and well-lit over time suggests that medical expertise could remain inside ISIL-held territory as well. As such, liberating forces are likely to encounter local doctors, engineers, and bureaucrats who

either voluntarily worked for the Islamic State or were co-opted into doing so. Stabilization planning should focus on working with liberating forces to effectively and fairly distinguish between ISIL sympathizers and unsympathetic locals with the needed institutional knowledge to help provide public services post-liberation.

Application of Remote Sensing Methods for Similar Research

This report represents a unique attempt to utilize both remote sensing data and commercial satellite imagery data for empirical research. As such, we offer several points of discussion and lessons learned for applications of these methods to similar research in the future.

Trade-Offs Between Remote Sensing Data and High-Resolution Imagery

Users of different types of satellite data face a variety of trade-offs. On the one hand, remote sensing data, such as nighttime lighting or NDVI, are available with high frequency and sufficient regularity to support panel data analysis. They are also publicly available and free of charge, making them a fantastic resource for researchers. However, these data can measure only a few very specific and discrete variables over time, making it difficult to track a broad array of economic indicators absent analysis of multiple separate remote sensing data sources at once. The spatial resolution of these data is also quite limited relative to that of higher-resolution, commercial satellite imagery.

High-resolution commercial satellite imagery would seem to solve some of these problems, in that these images are collected with greater spatial granularity. With such data, a researcher can observe almost everything that takes place on the ground, including whether vehicles are in parking lots, whether open-air markets are active, the number of people walking on sidewalks, or other creative ways of classifying and tracking evidence of human behavior. However, a major challenge with these data, as seen in our analysis of ISIL's economic impact, is that commercial imagery is typically collected in sporadic time intervals for a given location. This makes panel data analysis on such data exceptionally challenging. Issues, such as cloud cover, different timing of data collection during the week, and differences in spatial extents across images of the same location, mean that high-resolution imagery is more readily applicable to cross-sectional analysis or descriptive noninferential time-series analysis.

High-Resolution Imagery Can Help Validate Remote Sensing Data

One benefit of working with both remote sensing data and high-resolution imagery is the ability to validate results across data sources. As part of our analysis of ISIL's impact on Deir ez-Zor, we noted that the nighttime lighting signature of the Cardamom market in an ISIL-held portion of the city was relatively robust, yet imagery of this location showed that it had been vacant for an extended period of time. In other

cases, evidence of damage to industrial areas seen in high-resolution imagery helped explain variations in thermal activity over these locations. Absent the high-resolution imagery, the results of less granular remote sensing data could be misinterpreted. High-resolution imagery can also help explain trends seen in remote sensing data.

Lessons for Crowd-Sourced Analysis of High-Resolution Imagery

Our analysis relies heavily on crowd-sourced analysis of satellite imagery data. Crowd-sourcing comes in two different forms, both of which we employed in this research. First, it can be used to provide subjective assessments of activity at known locations. We use this approach to rate the level of market activity at known market locations across our five cities of interest. Second, crowd-sourcing can be used to track down the exact locations of specific items in a larger geographic area. We use this approach to identify instances of building damage and to count the number of commercial vehicles in each of our five cities of interest over time.

Each form of crowd-sourcing serves a different purpose, and, in some cases, each requires different caveats for applying the results to empirical research. We found that crowd-sourced assessments of market activity were more consistent over time and easier to incorporate than crowd-sourced instances of building damage or commercial vehicles. Assessments of market activity were, by nature, comprehensive, discrete, and consistently measured over time. By contrast, some damaged buildings received multiple tags from the crowd for our destruction data, while others received just one. Additionally, efforts to crowd-source through paid services such as Amazon's Mechanical Turk proved less accurate results than those generated through a crowd of geospatially inclined crowd-sourcing volunteers with experience contributing to prior crowd-sourcing campaigns.

For future applications of crowd-sourced imagery data, we recommend limiting the number of items to be located in imagery to a small set of discrete and readily identifiable tags. For larger volumes of imagery, more volunteers (in the several hundreds) will help the results be more comprehensive and internally consistent. Additionally, use of crowd-sourced imagery analysis to measure stock variables, such as building damage, are more useful for empirical research than attempts to measure flow variables, such as car counts, unless careful consideration is given to the day of week and time of day of each image.

High-Resolution Imagery Algorithms

This assessment made only brief use of object-recognition and other imagery-analysis algorithms in an attempt to identify car counts and building damage. These off-the-shelf algorithms often struggled to accurately identify cars and building damage in imagery of Iraq and Syria. This is likely because these algorithms were initially calibrated using data from the United States and Europe, where roads, vehicles, and buildings tend to look very different and stand in starker contrast against well-developed

urban infrastructure. Future technical research should invest in creating flexible algorithms that are useful across a wider variety of research applications.

APPENDIX A

Analysis Sample

Tables A.1 and A.2 list the cities included in our full analysis sample. These cities represent all cities in Iraq and Syria with populations greater than 10,000, derived from the GeoNames database.[1] The tables are sorted by province (or governorate) and population. The rightmost column of each table provides an indicator for whether or not the city was under ISIL control at any point between January 2013 and May 2016.

An important component of our analytic methodology involved identifying the boundaries of economic activity surrounding each city center. To adequately define urban areas in a practical way that addressed some of the challenges described throughout this report, we opted to draw our own borders for cities in Iraq and Syria, using pre–ISIL control satellite imagery as our guide. Our goal for constructing these urban core borders was to create a maximally connected polygon that contained as much contiguous built-up infrastructure (including commercial, industrial, and residential buildings) as is visible in pre-ISIL satellite imagery. To do this, we first used open-source mapping software to determine the latitude and longitude coordinates of every city in our analysis sample. With these locations, we then used geospatial analysis software and pre-ISIL satellite imagery to digitally trace the boundaries of each city's *urban core*—the contiguous built-up area surrounding the city center. In order to capture activity that might take place outside of an urban core but still within a reasonable distance of the city, we created *urban periphery* borders for each of the cities, using a 5-km buffer zone around the urban core polygon. We use this urban periphery to capture types of economic activity, such as agriculture, which naturally occur outside of a built-up city center.

Figure A.1 presents a map of the cities listed in Tables A.1 and A.2. In this map, each city's urban periphery polygon is shaded in blue, with darker shades corresponding to greater population totals.

[1] GeoNames, undated. Using additional data sources for Syria and Iraq separately, we manually rectified missing-population information from the GeoNames database. For Syria, we used data from "Syria," 2015. For Iraq, we used data from "Republic of Iraq (IQ)," *Tageo*, undated. Errors or omissions from the list of cities with more than 10,000 inhabitants are due to missingness in the underlying census and population data, likely on the lower margins of population. Absent a complete roster of cities and villages by population, we made manual efforts to rectify known missingness in major cities or administrative capitals.

Table A.1
List of Cities in the Analysis Sample for Iraq

Province	City	Population, in Thousands	Any ISIL Control?
Anbar	Al-Qaim	250	1
	Anat al-Qadimah	20	1
	Fallujah	190	1
	Hadithah	31	0
	Hit	32	1
	Ramadi	275	1
	Rawah	21	1
	Rutbah	22	1
Babil	Al-Musayyib	43	0
	Hillah	290	0
	Imam Qasim	37	0
	Saddat al-Hindiyah	31	0
Baghdad	Abu Ghraib	900	0
	Baghdad	7,216	0
Basra	Abu al-Khaseeb	26	0
	Al-Faw	105	0
	Al-Harithah	92	0
	Al-Qurnah	17	0
	Az-Zubayr	123	0
	Basra	2,600	0
	Umm Qasr	108	0
Diyala	Al-Khalis	35	1
	Al-Miqdadiyah	51	1
	Baqubah	153	1
	Khanaqin	61	0
	Kifri	30	0
	Mandali	30	0
Duhok	Duhok	284	0
	Zakho	95	0

Table A.1—Continued

Province	City	Population, in Thousands	Any ISIL Control?
Erbil	Erbil	933	0
	Kawiyah	45	0
	Rawanduz	23	0
Karbala	Karbala	435	0
Kirkuk	Hawijah	40	1
	Kirkuk	601	0
Missan	Al-Amarah	323	0
	Ali al-Gharbi	20	0
Muthanna	Ar Rumaythah	47	0
	Samawah	153	0
Najaf	Al Kufah	110	0
	Al-Mishkhib	23	0
	Najaf	483	0
Ninewa	Al-Aqrah	23	0
	Al-Hamdaniyah	50	1
	Mosul	3,805	1
	Sinjar	38	1
	Tal Afar	168	1
	Tall Kayf	24	1
Qadisiyah	Afak	22	0
	Al-Diwaniya	319	0
	Al-Hamzah	32	0
	Al-Shamiya	58	0
	Ash Shinafiyah	23	0
	Ghammas	31	0

Table A.1—Continued

Province	City	Population, in Thousands	Any ISIL Control?
Salah ad-Din	Ad-Dawr	30	1
	Balad	42	0
	Bayji	37	1
	Dujail	26	0
	Samarra	159	0
	Tikrit	43	1
	Tuz Kermatli	60	1
Sulimaniyah	Banjiwayn	27	0
	Chamchamal	76	0
	Halabja[a]	57	0
	Qalat Dizah	14	0
	Sulimaniyah	723	0
Thi-Qar	Al-Fuhud	22	0
	Al-Karradi	17	0
	Al-Shatrah	83	0
	Nasiriyah	400	0
Wassit	Al-Aziziyah	45	0
	Al-Bughaylah	29	0
	Al-Hay	79	0
	Al-Kut	315	0
	Al-Suwayrah	42	0

NOTE: 0 = no ISIL control or contestation between January 2013 and May 2016. 1 = some ISIL control or contestation between January 2013 and May 2016.

[a] Halabja was split off from Sulimaniyah governorate in 2014 to create a new Halabja governorate. However, we list the city as part of Sulimaniyah governorate given that we start our analysis prior to its formation.

Table A.2
List of Cities in the Analysis Sample for Syria

Governorate	City	Population, in Thousands	Any ISIL Control?
Al-Hasakah	Al-Darbasiyah	22	0
	Al-Hasakah	82	1
	Al-Malikiyah	26	0
	Qamishli	184	0
	Ras al-Ayn	29	0
Aleppo	Afrin	49	0
	Al-Bab	131	1
	Aleppo	1,602	1
	As-Safira	96	1
	Azaz	66	1
	Dayr Hafir	29	1
	Jarabulus	25	1
	Kobani	50	1
	Manbij	69	1
	Maskanah	16	1
	Noubbel	26	0
	Sawran	29	1
	Tadef	35	1
	Tall Rifaat	26	1
As-Suweida	As-Suweida	59	0
	Salakhed	13	0
	Shahabah	15	0
Damascus	Damascus	1,569	1

Table A.2—Continued

Governorate	City	Population, in Thousands	Any ISIL Control?
Dara	Al-Hirak	24	0
	Al-Sanamayn	26	0
	Al-Shaykh Maskin	26	0
	Da`il	29	0
	Dara	98	0
	Enn Nakhl	29	0
	Izra	14	0
	Jasim	30	0
	Nawa	47	0
	Tafas	31	0
Deir ez-Zor	Abu Kamal	58	1
	Al-Mayadin	55	1
	Deir ez-Zor	243	1
	Hajin	29	1
	Subaykhan	26	1
Hama	Al-Salamiyah	95	0
	Az-Zaytiyah	22	0
	Halfaya	23	0
	Hama	461	0
	Imranie	32	0
	Murak	14	0
	Sawran	31	0
	Taybat al-Imam	30	0

Table A.2—Continued

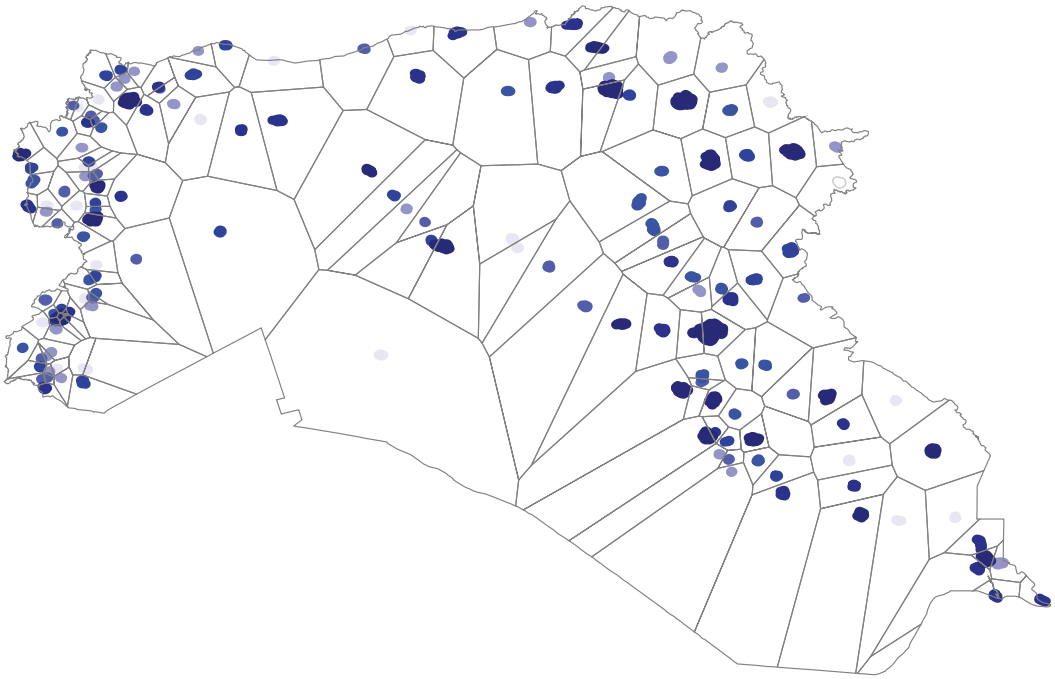
Governorate	City	Population, in Thousands	Any ISIL Control?
Homs	Al-Qaryatayn	32	1
	Al-Qusayr	41	0
	Al-Rastan	53	0
	Homs	775	0
	Kafr Laha	22	0
	Palmyra	51	1
	Tall Bisah	39	0
	Tel Kalah	30	0
Idlib	Al-Dana	22	1
	Binnish	30	1
	Idlib	129	0
	Jisr al-Shughour	39	0
	Kafr Nabl	25	1
	Kafr Takharim	22	1
	Khan Sheikhoun	49	0
	Ma`arrat Misrin	32	1
	Salkine	32	1
	Saraqib	34	1
Latakia	Jebele	66	0
	Latakia	340	0
Quneitra	Quneitra	36	0
Raqqah	Raqqah	178	1
	Tabqah	88	1
	Tal Abyad	15	1

Table A.2—Continued

Governorate	City	Population, in Thousands	Any ISIL Control?
Rif Damascus	Aarbil	43	0
	Adsaya	34	0
	Al-Dumayr	24	0
	Al-Kiswah	24	0
	Al-Nabek	50	0
	Al-Qutayfah	16	0
	Al-Ruhaybah	31	0
	Al-Tall	56	0
	Az-Zabadani	30	0
	Babbila	51	0
	Darayya	72	0
	Djeroud	32	0
	Duma	112	0
	Harasta	37	0
	Kafr Batna	23	0
	Qarah	21	0
	Qatanah	19	0
	Yabroud	41	0
Tartous	Baniyas	39	0
	Duraykish	12	0
	Satita	28	0
	Tartous	90	0

NOTE: 0 = no ISIL control or contestation between January 2013 and May 2016. 1 = some ISIL control or contestation between January 2013 and May 2016.

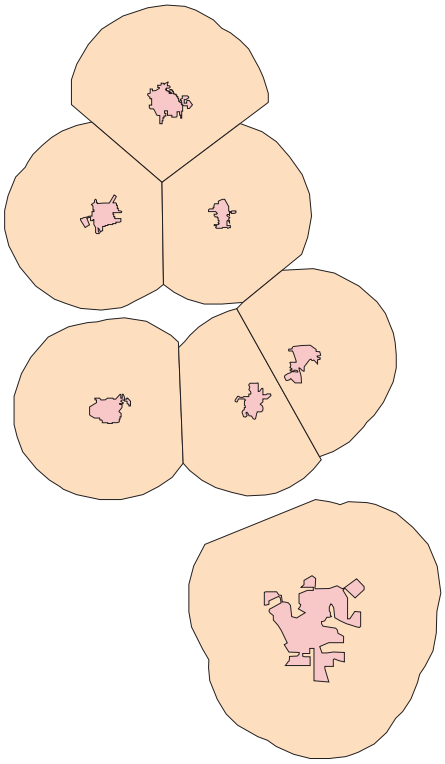
Figure A.1
Map of Cities in the Analysis Sample



SOURCES: Authors' calculations. Population data are from ORNL Landscan.
NOTE: Each polygon represents a city's urban periphery. Polygons are shaded in blue, with darker colors corresponding to greater baseline population levels. Black lines surrounding each urban periphery represent Thiessen polygons between cities, used to delineate urban peripheries in dense areas.
RAND *RR1970-A.1*

In certain cases, when cities were too close together, their periphery zones overlapped with one another. To partition them into mutually exclusive areas that could be associated with a single city, we used Thiessen polygons, drawn around the centroids of the urban cores, to partition the overlapping areas. Figure A.2 illustrates this situation for a few cities in Idlib and Hama governorates in Syria. We used both the core and periphery polygons extensively in the analysis because they enabled us to construct measures to summarize, by city, the rich and detailed remote sensing data with which we work.

Figure A.2
Overlapping Urban Peripheries: Hama and Idlib Governorates, Syria



SOURCE: Authors' calculations.
NOTE: The Northern most city is Khan Cheykoun, the only city pictured in Idlib Province. Going South and counter-clockwise around the cluster of periphery polygons, we see Az-Zaytiyah, Halfaya, Taybat al-Imam, Sawran, and Murak. The isolated city is Hama.

RAND *RR1970-A.2*

APPENDIX B

Methodological Considerations for Within-City Analysis of Remote Sensing Data

In order to take our remote sensing metrics (which are sampled at low to moderate resolutions) and calculate within-city variation across key pieces of infrastructure, we modify the process used in our citywide analysis with three key additions. First, we resampled coarse-resolution nighttime lighting and LandScan population raster data sets to improve estimates for small areas. Second, when calculating average values across specific types of infrastructure or within larger ethnic or control zones, we utilize area-weighted averages from the individual places of interest that make up each larger composite. Third, when conducting regression analysis using these data, we corrected for spatial autocorrelation in our calculations of errors and significance. In the rest of this appendix, we discuss each of these changes further.

The coarse-resolution nighttime lighting and population data sets pose a problem when we attempt to calculate the value of each raster for key locations within each city, some of which were smaller than a single raster cell. To improve estimates of these metrics for within-city areas, we resampled the nighttime lighting and population rasters down to 30 m–by–30 m resolution using a simple linear interpolation to calculate the new pixel values. Although this does not mitigate the limitations of coarse-resolution measurement in the first place, it does allow more-precise estimation of values for within-city areas that cover just part of a raster cell, especially near the cell edge, by taking into account the values of neighboring cells.

To calculate average values across specific types of infrastructure within each city, we first calculated estimates of metric values for individual places of interest and then aggregated these via area-weighted averaging. For example, our estimate of the average nighttime lighting across Mosul's industrial areas consists of the area-weighted average of the values for all 24 individual industrial sites we identified in the city. We used this same process for other places of interest (such as markets and hospitals), as well as for neighborhoods of particular ethnicities in Mosul and for neighborhoods controlled by different forces within Deir ez-Zor.

Sample size is an important consideration when using these data for regression analysis. Because of spatial autocorrelation, however, we could not simply count all of the raster cells covered by a particular place of interest and use each cell as our unit of analysis for regression analysis. If we had used that approach, our error estimates would

have been far too small and would have led to spuriously high levels of significance. Instead, we calculated Moran's I as a measure of spatial autocorrelation for each metric and used that to calculate a much smaller effective sample size.[1] We then used this effective sample size for all subsequent calculations of variance, error, and significance in regression analyses presented in the Deir ez-Zor case study.

---

[1] Moran's I is a weighted correlation measure of all adjoining grid square cells in a k-nearest-neighbors queen weight matrix, where k = 8. See P. A. P. Moran, "Notes on Continuous Stochastic Phenomena," *Biometrika*, Vol. 37, No. 1–2, June 1950, pp. 17–23. We calculated effective sample size using the equation

$$effectiveN = n \times \frac{1 - moransI}{1 + moransI}.$$

This follows the approach found in Mark R. T. Dale and Marie-Josée Fortin, "Spatial Autocorrelation and Statistical Tests in Ecology," *Écoscience*, Vol. 9, No. 2, 2002, pp. 162–167, p. 164.

Bibliography

"39 Killed in Air Raids in Syria City of Raqqa as Attacks Intensify," *Independent*, March 6, 2013. As of March 10, 2017:
http://www.independent.ie/world-news/middle-east/
39-killed-in-air-raids-in-syria-city-of-raqqa-as-attacks-intensify-29114344.html

"40,000 Flee Tikrit, Samarra, as Iraq Crisis Deepens," Agence France-Presse, June 13, 2014.

Abouzeid, Rania, "How Islamist Rebels in Syria Are Ruling a Fallen Provincial Capital," *Time*, March 23, 2013. As of March 10, 2017:
http://world.time.com/2013/03/23/how-islamist-rebels-in-syria-are-ruling-a-fallen-provincial-capital/

Abu Hanieh, Hassan, and Muhammad Abu-Rumman, *The "Islamic State" Organization: The Sunni Crisis and the Struggle of Global Jihadism*, Amman, Jordan: Friedrich-Ebert-Stiftung, 2015. As of May 7, 2017:
http://library.fes.de/pdf-files/bueros/amman/11458.pdf

Abu Mohammed, "ISIS Fights Civilians in Bread and Raises Its Price," *Raqqa Is Being Slaughtered Silently*, February 17, 2015. As of March 10, 2017:
http://www.raqqa-sl.com/en/?p=595

Adnan, Sinan, Patrick Martin, and Omar al-Dulimi, "Iraq Situation Report: March 18–20, 2015," Institute for the Study of War, 2015. As of March 10, 2017:
http://www.understandingwar.org/sites/default/files/
Iraq%20SITREP%202015-3-20%20-%20print_0.pdf

"After Losses to ISIS, Iraqi Army Regains Ground in Ramadi," CBS News, April 21, 2015. As of March 9, 2017:
http://www.cbsnews.com/news/after-losses-to-isis-iraqi-army-regains-ground-in-ramadi/

al-Ali, Rami , "ISIS Applies Its Own Laws in Raqqa," *Al-Monitor*, February 10, 2014a. As of March 10, 2017:
http://www.al-monitor.com/pulse/security/2014/02/isis-islamic-rule-raqqa-syria.html

———, "ISIS Rules in Raqqa," *al-monitor.com*, February 26, 2014b. As of March 10, 2017:
http://www.al-monitor.com/pulse/security/2014/02/
syria-isis-raqqa-quasi-government-opposition.html

al-Ali, Zaid, "Tikrit: Iraq's Abandoned City," *New York Review of Books*, May 4, 2015. As of March 10, 2017:
http://www.nybooks.com/daily/2015/05/04/tikrit-after-isis/

Alkhshali, Hamdi, and Joshua Berlinger, "Facing Fines, Conversion or Death, Christian Families Flee Mosul," CNN, July 20, 2014. As of March 10, 2017:
http://www.cnn.com/2014/07/19/world/meast/christians-flee-mosul-iraq/

Alkhshali, Hamdi, and Tim Lister, "Hundreds Dead as ISIS Makes Gains in Strategic Syrian City," CNN, January 23, 2016. As of March 10, 2017:
http://www.cnn.com/2016/01/22/world/syria-isis-deir-ezzor/

Allawi, Yasser, and Dylan Collins, "Deir Ezzor: Facing a 'Double Blockade' from All Sides," *Syria Deeply*, January 19, 2016. As of March 10, 2017:
https://www.newsdeeply.com/syria/articles/2016/01/19/deir-ezzor-facing-a-double-blockade-from-all-sides

Almohamad, Hussein, and Andreas Dittmann, "Oil in Syria Between Terrorism and Dictatorship," *Social Sciences*, Vol. 5, No. 2, 2016.

Almousa, Hamoud, "Increasing Prices of Food and Fuel in Raqqa," *Raqqa Is Being Slaughtered Silently*, December 14, 2015. As of March 10, 2017:
http://www.raqqa-sl.com/en/?p=1582

Almukhtar, Sarah, "Life Under the Islamic State: Fines, Taxes and Punishments," *New York Times*, May 26, 2016.

Amos, Deborah, "As Rebels Fight Rebels, Grim Reports from a Syrian City," National Public Radio, January 8, 2014. As of March 9, 2017:
http://www.npr.org/2014/01/08/260771319/as-rebels-fight-rebels-grim-reports-from-a-syrian-city

———, "Under ISIS, Life in Mosul Takes a Turn for the Bleak," National Public Radio, March 21, 2015. As of March 10, 2017:
http://www.npr.org/sections/parallels/2015/03/21/394322708/under-isis-life-in-mosul-takes-a-turn-for-the-bleak

"An Overview of the Islamic State (Formerly Known as the Islamic State of Iraq and Syria [ISIS])," *Raqqa Is Being Slaughtered Silently* (Facebook page), July 16, 2014. As of March 10, 2017:
https://www.facebook.com/Raqqa.Sl/posts/830787083599211

"Analysis of the State of ISI (English Translation)," Combating Terrorism Center at West Point, c. September 2013. As of March 9, 2017:
https://www.ctc.usma.edu/posts/analysis-of-the-state-of-isi-english-translation-2

Andre, James, Amar Mohammed Sahib al Hameedawi, and Khalil Bechir, "Ramadi, from Iraq's Third City to a Ghost Town," *France 24*, March 18, 2016. As of March 10, 2017:
http://www.france24.com/en/20160318-video-reporters-iraq-ramadi-islamic-state-group-mines-booby-traps

Arango, Tim, and Eric Schmitt, "Escaped Inmates from Iraq Fuel Syrian Insurgency," *New York Times*, February 12, 2014.

"A-Raqqa Student: 'Daily Life Is Good' Under ISIS," *Syria Direct*, April 27, 2014. As of March 10, 2017:
http://syriadirect.org/news/a-raqqa-student-%E2%80%98daily-life-is-good%E2%80%99-under-isis/

Arjona, Ana, "Wartime Institutions: A Research Agenda," *Journal of Conflict Resolution*, Vol. 58, No. 8, 2014, pp. 1360–1389.

Arjona, Ana, Nelson Kasfir, and Zachariah Cherian Mampilly, eds., *Rebel Governance in Civil War*, Cambridge, UK: Cambridge University Press, 2015.

"Ar-Raqqah," *Wikimapia*, c. March 2017. As of September 25, 2016:
http://wikimapia.org/#lang=en&lat=35.956332&lon=38.998547&z=13&m=b&show=/882517/Al-Raqqah&search=raqqah

Asher-Schapiro, Avi, "A Leaked Budget May Finally Show How the Islamic State Makes Its Money," *Vice News*, October 7, 2015. As of March 9, 2017:
https://news.vice.com/article/
a-leaked-budget-may-finally-show-how-the-islamic-state-makes-its-money

Bahney, Benjamin, Howard Shatz, Carroll Ganier, Renny McPherson, and Barbara Sude, *An Economic Analysis of the Financial Records of al-Qa'ida in Iraq*, Santa Monica, Calif.: RAND Corporation, MG-1026-OSD, 2010. As of March 9, 2017:
http://www.rand.org/pubs/monographs/MG1026.html

Baladi, Enab, "Variance in Control Divide Der Ezzor into Three Commercial Markets," *Enab Baladi English*, Printed Ed. 17, April 17, 2016. As of September 6, 2016:
http://english.enabbaladi.net/archives/2016/04/
variance-control-divide-der-ezzor-three-commercial-markets/

Banco, Erin, and Alessandria Masi, "US Bombs Islamic State's Raqqa Stronghold in Syria, Begins 'Degrade and Destroy' Strategy," *International Business Times*, September 23, 2014. As of March 10, 2017:
http://www.ibtimes.com/
us-bombs-islamic-states-raqqa-stronghold-syria-begins-degrade-destroy-strategy-1693341

Barbarani, Sofia, "Civilians Flee ISIL-Held Territory in Iraq," *Al Jazeera*, April 4, 2016. As of March 10, 2017:
http://www.aljazeera.com/news/2016/04/civilians-flee-isil-held-territory-iraq-160401120459813.html

Barnard, Anne, "Iraqi Campaign to Drive ISIS from Tikrit Reveals Tensions with U.S.," *New York Times*, March 3, 2015a.

———, "Iraqi and Shiite Forces Seize Large Parts of Tikrit from Islamic State," *New York Times*, March 10, 2015b.

Barrabi, Thomas, "US Airstrikes in Syria: Timeline of Events That Led Obama to Target Islamic State," *International Business Times*, September 23, 2014. As of March 10, 2017:
http://www.ibtimes.com/us-airstrikes-syria-timeline-events-led-obama-target-islamic-state-1693459

Bazzi, Samuel, Arya Gaduh, Alexander D. Rothenberg, and Maisy Wong, "Skill Transferability, Migration, and Development: Evidence from Population Resettlement in Indonesia," *American Economic Review*, Vol. 106, No. 9, September 2016, pp. 2658–2698.

Bender, Jeremy, "Watch Coalition Airstrikes Obliterate 2 ISIS Financial-Storage Centers Holding Hundreds of Millions of Dollars," *Business Insider*, February 18, 2016. As of March 10, 2017:
http://www.businessinsider.com/airstrikes-obliterate-isis-financial-centers-2016-2

Benraad, Myriam, "Iraq's Tribal 'Sahwa:' Its Rise and Fall," Middle East Policy Council, undated. As of May 7, 2017:
http://www.mepc.org/iraqs-tribal-sahwa-its-rise-and-fall

Berman, Eli, and Jacob N. Shapiro, "Why ISIL Will Fail on Its Own," *Politico*, November 29, 2015. As of March 12, 2017:
http://www.politico.com/magazine/story/2015/11/why-isil-will-fail-on-its-own-213401

Bindner, Laurence, and Gabriel Poirot, *ISIS Financing, 2015*, Center for the Analysis of Terrorism, May 2016. As of May 13, 2017:
http://cat-int.org/wp-content/uploads/2016/06/ISIS-Financing-2015-Report.pdf

Blattman, Christopher, and Edward Miguel, "Civil War," *Journal of Economic Literature*, Vol. 48, No. 1, March 2010, pp. 3–57.

Bradley, Matt, "Islamic State Squeezes Iraq's Food Supply," *Wall Street Journal*, July 12, 2015. As of March 9, 2017:
http://www.wsj.com/articles/islamic-state-squeezes-iraqs-food-supply-1436737696

Bradley, Matt, and Ben Kesling, "Islamic State Prevents Civilians from Fleeing Iraqi City of Ramadi," *Wall Street Journal*, December 1, 2015. As of March 10, 2017:
http://www.wsj.com/articles/islamic-state-prevents-civilians-from-fleeing-ramadi-1449003873

"Bread Lines in A-Raqqa Reflect Endemic Shortages," *Syria Direct*, August 26, 2014. As of March 10, 2017:
http://syriadirect.org/news/bread-lines-in-a-raqqa-reflect-endemic-shortages/

"Breaking News . . . Source: About 1000 Students Held at the University of Anbar," *Shafaaq News*, June 7, 2014. As of March 10, 2017:
http://www.shafaaq.com/en/En_NewsReader/c05c8fff-c0cf-4840-bf4b-ad4c9282c2e1

Brisard, Jean-Charles, and Damien Martinez, "Islamic State: The Economy-Based Terrorist Funding," Thomson Reuters Accelus, October 2014. As of March 10, 2017:
http://cat-int.org/wp-content/uploads/2016/06/White-Paper-IS-Funding_Final.pdf

Business Associations in al-Anbar Province, *Business Agenda of al-Anbar Province*, Center for International Private Enterprise, undated. As of May 8, 2017:
http://www.cipe.org/sites/default/files/publication-docs/Final%20English%20Anbar%20PBA%20%282%29_0.pdf

Butter, David, *Syria's Economy: Picking Up the Pieces*, Chatham House, Royal Institute of International Affairs, June 2015. As of March 10, 2017:
https://www.chathamhouse.org/sites/files/chathamhouse/field/field_document/20150623SyriaEconomyButter.pdf

Caris, Charles C., and Samuel Reynolds, *ISIS Governance in Syria*, Institute for the Study of War, Middle East Security Report 22, July 2014. As of March 10, 2017:
http://www.understandingwar.org/sites/default/files/ISIS_Governance.pdf

Central Organization for Statistics and Information Technology; Ministry of Planning and Development Cooperation, Iraq; Kurdistan Region Statistics Office, Iraq; Nutrition Research Institute, Ministry of Health, Iraq; and United Nations World Food Programme, *Comprehensive Food Security and Vulnerability Analysis: Iraq*, United Nations World Food Programme, 2008. As of March 10, 2017:
https://www.wfp.org/content/iraq-comprehensive-food-security-and-vulnerability-analysis-2008

Chodorow, Adam, "Even ISIS Needs to Collect Taxes: Could That Threaten Its Rule?" *Slate*, December 7, 2015. As of March 9, 2017:
http://www.slate.com/articles/business/moneybox/2015/12/isis_collects_taxes_and_its_effort_exposes_some_big_weaknesses.html

Chudacoff, Danya, "'Water War' Threatens Syria Lifeline," *Al Jazeera*, July 7, 2014. As of March 10, 2017:
http://www.aljazeera.com/news/middleeast/2014/07/water-war-syria-euphrates-2014757640320663.html

Ciezadlo, Annia, "The Most Unconventional Weapon in Syria: Wheat," *Washington Post*, December 18, 2015.

Clarke, Colin P., Kimberly Jackson, Patrick B. Johnston, Eric Robinson, and Howard Shatz, *Financial Futures of the Islamic State of Iraq and the Levant: Findings from a RAND Corporation Workshop*, Santa Monica, Calif.: RAND Corporation, CF-361, 2017. As of June 7, 2017:
http://www.rand.org/pubs/conf_proceedings/CF361.html

Coles, Isabel, " Islamic State Militants Use Water as Weapon in Western Iraq," Reuters, June 3, 2015. As of March 10, 2017:
http://www.reuters.com/article/us-mideast-crisis-iraq-water-idUSKBN0OJ1TN20150603

Coles, Isabel, and Maggie Fick, "Kurds Report More Chlorine Attacks, Iraq Pauses Tikrit Offensive," Reuters, March 16, 2015. As of March 10, 2017:
http://www.reuters.com/article/us-iraq-islamicstate-idUSKBN0MC0NC20150316

Connable, Ben, Jason H. Campbell, Bryce Loidolt, and Gail Fisher, *Assessing Freedom of Movement for Counterinsurgency Campaigns*, Santa Monica, Calif.: RAND Corporation, TR-1014-USFOR-A, 2012. As of March 10, 2017:
http://www.rand.org/pubs/technical_reports/TR1014.html

Couch, Dick, *The Sheriff of Ramadi: Navy SEALs and the Winning of al-Anbar*, Annapolis, Md.: Naval Institute Press, 2008.

Cragin, Kim, and Ben Connable, "To Undermine ISIS, We Should Welcome Syrian Refugees," *RAND Blog*, December 3, 2015. As of March 10, 2017:
http://www.rand.org/blog/2015/12/to-undermine-isis-we-should-welcome-syrian-refugees.html

Culbertson, Shelly, and Louay Constant, *Education of Syrian Refugee Children: Managing the Crisis in Turkey, Lebanon, and Jordan*, Santa Monica, Calif.: RAND Corporation, RR-859-CMEPP, 2015. As of March 10, 2017:
http://www.rand.org/pubs/research_reports/RR859.html

Cunningham, Erin, "In Ramadi, the Islamic State Settles in, Fixing Roads and Restoring Electricity," *Washington Post*, July 2, 2015.

Dale, Mark R. T., and Marie-Josée Fortin, "Spatial Autocorrelation and Statistical Tests in Ecology," É*coscience*, Vol. 9, No. 2, 2002, pp. 162–167.

D'Alessio, Stephen, "Glass, Ceramics Factories Reopen, Restore Hope for City," U.S. Marine Corps, August 18, 2005. As of March 10, 2017:
http://www.2ndmardiv.marines.mil/News/News-Article-Display/Article/514827/glass-ceramics-factories-reopen-restore-hope-for-city/

Daragahi, Borzou, and Erika Solomon, "Fuel Shortages and Power Cuts Dominate Isis-Controlled Mosul," *Financial Times*, June 19, 2014. As of March 9, 2017:
https://next.ft.com/content/47e251fe-f7ad-11e3-b2cf-00144feabdc0

Dearden, Lizzie, "Isis 'Bans All Christians from Leaving Raqqa' as Military Operations Against Group Intensify in Syria," *Independent*, March 31, 2016. As of March 10, 2017:
http://www.independent.co.uk/news/world/middle-east/isis-bans-all-christians-from-leaving-raqqa-as-military-operations-against-group-intensify-in-syria-a6962331.html

"Drought Pushing Millions into Poverty," IRIN, September 9, 2010. As of March 10, 2017:
http://www.irinnews.org/report/90442/syria-drought-pushing-millions-poverty

Duhaime, Christine, "Terrorist Financing and the Islamic State," Duhaime Law, 2015. As of March 10, 2017:
http://www.duhaimelaw.com/wp-content/uploads/2015/04/White-Paper-Terrorist-Financing-Methods1.pdf

Egel, Daniel, Charles P. Ries, Ben Connable, Todd Helmus, Eric Robinson, Isaac Baruffi, Melissa A. Bradley, Kurt Card, Kathleen Loa, Sean Mann, Fernando Sedano, Stephan B. Seabrook, and Robert Stewart, *Investing in the Fight: Assessing the Use of the Commander's Emergency Response Program in Afghanistan*, Santa Monica, Calif.: RAND Corporation, RR-1508-OSD, 2016. As of March 10, 2017:
http://www.rand.org/pubs/research_reports/RR1508.html

Eklund, Lina, Andreas Persson, and Petter Pilesjö, "Cropland Changes in Times of Conflict, Reconstruction, and Economic Development in Iraqi Kurdistan," *Ambio*, Vol. 45, No. 1, February 2016, pp. 78–88.

Elgot, Jessica, "Raqqa, The 'Boring' Syrian City Turned Caliphate Capital, Now the Target of US Bombs," *HuffPost UK*, September 25, 2014. As of March 10, 2017:
http://www.huffingtonpost.co.uk/2014/09/25/raqqa-islamic-state-syria_n_5872324.html

Erb, Kelly Phillips, "Islamic State Warns Christians: Convert, Pay Tax, Leave or Die," *Forbes*, July 19, 2014. As of March 10, 2017:
http://www.forbes.com/sites/kellyphillipserb/2014/07/19/
islamic-state-warns-christians-convert-pay-tax-leave-or-die/#33a564633718

Erian, Wadid, Bassem Katlan, and Ouldbdey Babah, *Drought Vulnerability in the Arab Region: Special Case Study—Syria*, United Nations Office for Disaster Risk Reduction, Global Assessment Report on Disaster Risk Reduction, 2010. As of March 11, 2017:
http://www.preventionweb.net/english/hyogo/gar/2011/en/bgdocs/
Erian_Katlan_&_Babah_2010.pdf

"Evolving Ethnic Face of Mosul," Columbia University Gulf 2000 Project, undated. As of September 11, 2016:
http://gulf2000.columbia.edu/images/maps/Iraq_Mosul_Ethnic_lg.png

Fadel, Leith, "SAA Captures ISIS Base in Deir Ezzor; Scores of ISIS Fighters Killed," *al Masdar News*, October 13, 2014. As of March 10, 2017:
https://www.almasdarnews.com/article/saa-captures-isis-base-deir-ezzor-scores-isis-fighters-killed/

———, "Iraqi Armed Forces Cutoff ISIS' Final Supply Route to al-Ramadi: Train Station Captured," *Al Masdar News*, August 17, 2015a. As of March 10, 2017:
https://www.almasdarnews.com/article/
iraqi-armed-forces-cutoff-isis-final-supply-route-to-al-ramadi-train-station-captured/

———, "ISIS Suffers Disastrous Defeat in Deir Ezzor: Over 150 Terrorists Killed in 24 Hours," *Al Masdar News*, October 5, 2015b. As of March 10, 2017:
https://www.almasdarnews.com/article/
isis-suffers-disastrous-defeat-in-deir-ezzor-over-150-terrorists-killed-in-24-hours/

Fantz, Ashley, and Hamdi Alkhshali, "Ramadi Has Been Taken Back from ISIS, Iraqis Say," CNN, December 29, 2015. As of March 9, 2017:
http://www.cnn.com/2015/12/28/middleeast/iraq-military-retakes-ramadi/index.html

FAO—*See* Food and Agriculture Organization of the United Nations.

Farooq, Umar, "Raqqa: 'It Is a Very Sad Life Under ISIL,'" *Al Jazeera*, January 28, 2015. As of March 10, 2017:
http://www.aljazeera.com/news/middleeast/2015/01/raqqa-sad-life-isil-201511110501184890.html

Fateh, T., "Qaeda Terrorists Blasted Khalifa Harun al-Rashid Statue in Raqqa," *Syria Times*, October 4, 2013. As of March 9, 2017:
http://syriatimes.sy/index.php/news/local/
8590-qaeda-terrorists-blasted-khalifa-harun-al-rashid-statue-in-raqqa

Fessy, Thomas, "Iraq Conflict: Damage to Ramadi Hampers Return of Displaced People," BBC News, December 30, 2015. As of March 10, 2017:
http://www.bbc.com/news/world-middle-east-35198538

Fick, Maggie, "ISIS Now Controls 40 Percent of Iraq's Wheat Crop," *Fiscal Times*, September 30, 2014a. As of March 10, 2017:
http://www.thefiscaltimes.com/Articles/2014/09/30/
ISIS-Now-Controls-40-Percent-Iraq-s-Wheat-Crop

———, "Special Report: Islamic State Uses Grain to Tighten Grip in Iraq," Reuters, September 30, 2014b. As of May 8, 2017:
http://www.reuters.com/article/us-mideast-crisis-wheat-idUSKCN0HP12J20140930

———, "Special Report: For Islamic State, Wheat Season Sows Seeds of Discontent," Reuters, January 20, 2015. As of May 8, 2017:
http://www.reuters.com/article/us-mideast-crisis-planting-specialreport-idUSKBN0KT0W420150120

"Fighting Rages in Iraq's Anbar; 23 Killed in Clashes, Attacks," Rudaw, January 6, 2015. As of March 10, 2017:
http://rudaw.net/english/middleeast/iraq/060120152

Food and Agriculture Organization of the United Nations, "Country Briefs: Iraq," reference date March 7, 2016a. As of March 10, 2017:
http://www.fao.org/giews/countrybrief/country.jsp?code=IRQ

———, "Country Briefs: Syria," reference date November 15, 2016b. As of May 13, 2017:
http://www.fao.org/giews/countrybrief/country.jsp?code=SYR

"Food Prices Skyrocket in Syria's Raqqa," *Al Arabiya English*, March 3, 2014. As of March 9, 2017:
http://english.alarabiya.net/en/webtv/reports/2014/03/04/
Food-prices-skyrocket-in-Syria-s-Raqqah.html

Foreign Agricultural Service, U.S. Department of Agriculture, "Iraq: 2015/2016 Wheat Production Favorable but Down from Last Year's Record Crop," Commodity Intelligence Report, July 10, 2015a. As of March 10, 2017:
http://www.pecad.fas.usda.gov/highlights/2015/07/Iraq_20150710/Index.htm

———, "Iraq: 2015 Rice Production Drops by More Than Half Due to Lack of Irrigation," Commodity Intelligence Report, August 12, 2015b. As of March 10, 2017:
http://www.pecad.fas.usda.gov/highlights/2015/08/Iraq/Index.htm

"France Pounds IS Stronghold with 20 Bombs," *Sky News*, November 15, 2015. As of March 10, 2017:
http://news.sky.com/story/france-pounds-is-stronghold-with-20-bombs-10339428

"French Jets Pound Raqqa as G20 Pledges New ISIL Fight," *Al Jazeera*, November 16, 2015. As of March 9, 2017:
http://www.aljazeera.com/news/2015/11/france-isil-raqqa-g20-151115211105532.html

Gambhir, Harleen, *ISIS's Global Strategy: A Wargame*, Institute for the Study of War, Middle East Security Report 28, July 2015.

GeoNames, home page, undated. As of March 10, 2017:
http://www.geonames.org/v3/

George, Susannah, Desmond Butler, and Maya Alleruzzo, "Iraq Routed IS from Ramadi at a High Cost: A City Destroyed," Associated Press, May 5, 2016. As of March 10, 2017:
http://bigstory.ap.org/article/627a3057be2544d68aa75897e299a162/
iraq-routed-ramadi-high-cost-city-destroyed

Georgy, Michael, "Islamist Rebels Repairing Mosul Dam, Kurds in Rush to Arms," Reuters, August 9, 2014. As of March 10, 2017:
http://in.reuters.com/article/iraq-security-idINKBN0G818720140809

Ghazi, Yasir, and Tim Arango, "Iraq Fighters, Qaeda Allies, Claim Falluja as New State," *New York Times*, January 3, 2014.

Gidda, Mirren, "ISIS Is Facing a Cash Crunch in the Caliphate," *Newsweek*, September 23, 2015. As of March 10, 2017:
http://europe.newsweek.com/isis-are-facing-cash-crunch-caliphate-333422

Greenfield, Daniel, "New Islamic Caliphate Leads to Piles of Garbage and Hepatitis," *Frontpage Mag*, December 27, 2014. As of March 10, 2017:
http://www.frontpagemag.com/point/248237/
new-islamic-caliphate-leads-piles-garbage-and-daniel-greenfield

Haj Ali, Mohammed Ali al, and Kristen Gillespie, "ISIS Attempts to Build Bridges, Literal and Metaphorical, in A-Raqqa," *Syria Direct*, March 27, 2014. As of March 10, 2017:
http://syriadirect.org/news/isis-attempts-to-build-bridges-literal-and-metaphorical-in-a-raqqa-1/

al-Hakkar, Firas, "The Mysterious Fall of Raqqa, Syria's Kandahar," *Al-Akhbar English*, November 8, 2013. As of March 10, 2017:
http://english.al-akhbar.com/node/17550

———, "ISIS Brings Life Back to Raqqa, in Its Own Way," *Al-Akhbar English*, January 23, 2014. As of March 10, 2017:
http://english.al-akhbar.com/node/18354

Hall, John, "Wish You Were Here? ISIS Releases Tourist Brochure–Style Images of Bustling Food Markets in Jihadi Stronghold of Mosul," *Daily Mail*, March 4, 2015. As of March 10, 2017:
http://www.dailymail.co.uk/news/article-2979248/
Wish-ISIS-releases-tourist-brochure-style-images-bustling-food-markets-jihadi-stronghold-Mosul.html

el-Hamed, Raed, "ISIS and the Anbar Crisis," Carnegie Endowment for International Peace, June 12, 2014. As of March 9, 2017:
http://carnegieendowment.org/sada/?fa=55907

Harris, Shane, "The Re-Baathification of Iraq," *Foreign Policy*, August 21, 2014. As of March 10, 2017:
http://www.foreignpolicy.com/articles/2014/08/21/the_re_baathification_of_iraq

Henderson, J. Vernon, Adam Storeygard, and David N. Weil, "Measuring Economic Growth from Outer Space," *American Economic Review*, Vol. 102, No. 2, April 2012, pp. 994–1028.

Hennessy-Fiske, Molly, and Nabih Bulos, "Under Islamic State, Life in Mosul, Iraq, Turns Grim," *Los Angeles Times*, January 26, 2015. As of March 10, 2017:
http://www.latimes.com/world/middleeast/la-fg-islamic-state-mosul-20150126-story.html

"Higher Prices, Shortages Create Resentment Against Islamic State in Iraq," *Japan Times*, December 13, 2014. As of March 10, 2017:
http://www.japantimes.co.jp/news/2014/12/13/world/
higher-prices-shortages-create-resentment-against-islamic-state-in-iraq/

Holmes, Thomas J., and Sanghoon Lee, "Economies of Density Versus Natural Advantage: Crop Choice on the Back Forty," Federal Reserve Bank of Minneapolis, Working Paper 668, June 2009. As of March 10, 2017:
https://www.minneapolisfed.org/research/wp/wp668.pdf

"How Did Extremists Take over One of Iraq's Biggest Cities in Just Five Days?" *Niqash*, June 10, 2014. As of March 10, 2014:
http://www.niqash.org/en/articles/security/3455/
how-did-extremists-take-over-one-of-iraq's-biggest-cities-in-just-five-days.htm

"How ISIS Rigs Mosul's Money Markets," *Iraq-Business News*, March 19, 2016. As of March 10, 2017:
http://www.iraq-businessnews.com/2016/03/19/how-isis-rigs-mosuls-money-markets/

Hubbard, Ben, "Offering Services, ISIS Digs in Deeper in Seized Territories," *New York Times*, June 16, 2015.

———, "Ramadi, Reclaimed by Iraq, Is in Ruins After ISIS Fight," *New York Times*, January 7, 2016.

IC21: The Intelligence Community in the 21st Century, U.S. House of Representatives Permanent Select Committee on Intelligence, Staff Study Report, June 5, 1996. As of March 9, 2017:
https://www.gpo.gov/fdsys/pkg/GPO-IC21/content-detail.html

"In Pictures: Rare Images of ISIS Hold on Ramadi," *Rudaw*, August 24, 2015. As of March 10, 2017:
http://rudaw.net/english/middleeast/iraq/24082015

Ingram, Jamie, "Islamic State's Inadequate Service Provision Undermines Its Authority over Strategically Important Energy Assets in Syria and Iraq," *IHS Jane's Intelligence Review*, August 11, 2015.

"Inside Mosul: Chaos as Iraqi Army Flees al-Qaeda Held City," *Telegraph*, June 10, 2014. As of March 9, 2017:
http://www.telegraph.co.uk/news/worldnews/middleeast/iraq/10889802/
Inside-Mosul-chaos-as-Iraqi-army-flees-al-Qaeda-held-city.html

Inter-Agency Information and Analysis Unit, "Anbar Governorate Profile," November 2010. As of March 10, 2017:
http://reliefweb.int/sites/reliefweb.int/files/resources/
FF648724878184ACC12577EB0050C36D-Full_Report.pdf

International Organization for Migration, Iraq Mission, "Displacement Snapshot: Salah al-Din," January 2015. As of March 10, 2017:
http://www.iomiraq.net/file/1518/

"Iraq Army Enters Last ISIL Stronghold in Ramadi," *Al Jazeera*, February 9, 2016. As of March 9, 2017:
http://www.aljazeera.com/news/2016/02/
isis-iraq-army-enters-isil-stronghold-ramadi-160209155321007.html

"Iraq: ISIS Executed Hundreds of Prison Inmates," Human Rights Watch, October 30, 2014. As of May 13, 2017:
https://www.hrw.org/news/2014/10/30/iraq-isis-executed-hundreds-prison-inmates

"Iraq: Islamic State Executions in Tikrit," Human Rights Watch, September 2, 2014. As of March 10, 2017:
https://www.hrw.org/news/2014/09/02/iraq-islamic-state-executions-tikrit

"Iraq Protests Signal Growing Tension Between Sunni and Shia Communities," *Guardian*, December 26, 2012. As of March 2017:
https://www.theguardian.com/world/2012/dec/26/iraq-protests-tension-sunni-shia

"Iraq Says ISIS Transferring Phosphate to Syria's Raqqa," *Al Arabiya English*, December 1, 2014. As of March 9, 2017:
http://english.alarabiya.net/en/News/middle-east/2014/12/01/
Iraqi-says-ISIS-transferring-phosphate-to-Syria-s-Raqqa.html

"Iraq Tikrit: Looting and Lawlessness Follow Recapture," BBC News, April 4, 2015. As of March 9, 2017:
http://www.bbc.com/news/world-middle-east-32181503

"Iraqi City of Mosul Falls to Jihadists," CBS News, June 10, 2014. As of March 9, 2017:
http://www.cbsnews.com/news/
iraq-city-of-mosul-falls-into-hands-of-isis-jihadists-after-police-army-abandon-posts/

"Iraqi Farmers Suffer as Land Seized by Militants," IRIN, November 26, 2014. As of March 10, 2017:
http://www.irinnews.org/report/100886/iraqi-farmers-suffer-land-seized-militants

"Iraqi Forces Battle ISIS Militants in Pockets of Fallujah," CBS News, June 20, 2016. As of March 9, 2017:
http://www.cbsnews.com/news/iraqi-forces-battle-isis-militants-in-pockets-of-fallujah/

"Iraq Protests Signal Growing Tension Between Sunni and Shia Communities," *Guardian*, December 26, 2012. As of July 1, 2017:
https://www.theguardian.com/world/2012/dec/26/iraq-protests-tension-sunni-shia

"IS Camp Speicher Massacre: Iraq Sentences 40 to Death," BBC News, February 18, 2016. As of March 9, 2017:
http://www.bbc.com/news/world-middle-east-35607179

"IS Takes Control of All Syrian Oil Fields," *Middle East Eye*, last update February 12, 2015. As of March 10, 2017:
http://www.middleeasteye.net/news/takes-control-all-syrian-oil-fields-691895048

"ISIL 'Advances on Military Airbase in Eastern Syria,'" *Al Jazeera*, September 10, 2015. As of March 9, 2017:
http://www.aljazeera.com/news/2015/09/
isil-advances-military-airbase-eastern-syria-150910141157852.html

"ISIL Bans Iranian Goods in Ramadi Markets," Centre for a Democratic Iran, June 8, 2015.

"ISIL Destroys Landmark Armenian Church in Syria," *Hurriyet Daily News*, September 14, 2014. As of March 10, 2017:
http://www.hurriyetdailynews.com/
isil-destroys-landmark-armenian-church-in-syria.aspx?pageID=238&nid=72141

"ISIL 'Massacre' Reported in Syria's Deir Az Zor," *Al Jazeera*, January 17, 2016. As of March 9, 2017:
http://www.aljazeera.com/news/2016/01/
isil-massacre-reported-syria-deir-ez-zor-160116192050214.html

"ISIL Militants Block Aid and Create 'Human Tragedy' in Syria," *Middle East Eye*, June 12, 2014. As of March 10, 2017:
http://www.middleeasteye.net/news/
isil-militants-block-aid-and-create-human-tragedy-syria-1307216812

"ISIL Redirect [sic] Water from Ramadi Dam," *World Bulletin*, June 3, 2015. As of March 10, 2017:
http://www.worldbulletin.net/news/160170/isil-redirect-water-from-ramadi-dam

"ISIL Seizes Government-Held Hospital in Deir Az-Zor," *Al Jazeera*, May 14, 2016. As of March 9, 2017:
http://www.aljazeera.com/news/2016/05/
isil-seizes-government-held-hospital-deir-az-zor-160514135141600.html

"ISIS Blocking Flow of Euphrates from Syria," *NOW*, September 15, 2015. As of March 10, 2017:
https://now.mmedia.me/lb/en/NewsReports/565913-isis-blocking-flow-of-euphrates-from-syria

"Isis Closes Ramadi Dam Gates, Cutting Off Water to Pro-Government Towns," *Guardian*, June 2, 2015. As of March 10, 2017:
https://www.theguardian.com/world/2015/jun/03/
isis-closes-ramadi-dam-gates-cutting-off-water-to-pro-government-towns

"ISIS Moving Mosul Cement Factories to Syria," *Rudaw*, March 24, 2015. As of March 9, 2017:
http://rudaw.net/english/middleeast/iraq/240320151

"ISIS Opens New Camp in Deir ez-Zor to Recruit Youth," *Al-Alam*, April 8, 2015. As of March 9, 2017:
http://en.alalam.ir/news/1693100#sthash.Cowhss1X.dpuf

"ISIS Steals Money from Civilians Living Under Its Control in Deir Ezzor on the Pretext of Providing Services," Deir Ezzor 24, March 1, 2016. As of March 10, 2017:
http://en.deirezzor24.net/isis-steals-money-from-civilians-living-under-its-control-in-deir-ezzor-under-the-pretext-of-providing-services/

"ISIS Yearly Oil Revenue Halved to $250 mln," *Al Arabiya English*, May 11, 2016. As of May 12, 2017:
http://english.alarabiya.net/en/business/2016/05/11/ISIS-yearly-oil-revenue-halved-to-250-mln-.html

"Islamic State and the Crisis in Iraq and Syria in Maps," BBC News, April 28, 2017. As of May 9, 2017:
http://www.bbc.com/news/world-middle-east-27838034

"'Islamic State' Expels Rivals from Syria City," *Al Jazeera*, July 14, 2014. As of March 9, 2017:
http://www.aljazeera.com/news/middleeast/2014/07/
state-expels-rivals-from-syria-city-2014714134248239815.html

"Islamic State Group: Crisis in Seven Charts," BBC News, August 23, 2016.

"Islamic State 'Hit by Cash Crisis in Its Capital Raqqa,'" *Telegraph*, February 16, 2016. As of March 9, 2017:
http://www.telegraph.co.uk/news/worldnews/islamic-state/12160676/
Islamic-State-hit-by-cash-crisis-in-its-capital-Raqqa.html

"Islamic State Infographic: 'Zakah in Wilayat Ninawa—Statistics for the Year 1436 AH,'" Terrorism Research and Analysis Consortium, undated.

Islamic State of Iraq and al Shām, [New statement from the Islamic State of Iraq and al-Shām: Charter of the city], [Jihadology], June 12, 2014. In Arabic, as of March 9, 2017:
https://azelin.files.wordpress.com/2014/06/
islamic-state-of-iraq-and-al-shc481m-charter-of-the-city.pdf

Izady, Michael, "Mosul and Environs: Ethnic Composition, 2013," Columbia University Gulf 2000 Project, 2017. As of July 12, 2017:
http://gulf2000.columbia.edu/images/maps/Iraq_Mosul_Ethnic_lg.png

Jaafar, Hadi H., and Eckart Woertz, "Agriculture as a Funding Source of ISIS: A GIS and Remote Sensing Analysis," *Food Policy*, Vol. 64, October 2016, pp. 14–25.

Jacobson, Louis S., Robert J. LaLonde, and Daniel G. Sullivan, "Earnings Losses of Displaced Workers," *American Economic Review*, Vol. 83, No. 4, September 1993, pp. 685–709.

al-Jaffal, Omar, "Fighting Robs Iraqi Farmers of Harvest," *Al-Monitor*, September 26, 2014. As of March 10, 2017:
http://www.al-monitor.com/pulse/tr/sites/almonitor/contents/articles/originals/2014/09/
iraq-agriculture-production-decrease-military-operations.html

———, "Iraqi Hospitals Under IS Suffer Lack of Medicine, Staff," *Al-Monitor*, January 15, 2015. As of March 10, 2017:
http://www.al-monitor.com/pulse/originals/2015/01/iraq-anbar-mosul-hospitals-islamic-state.html

al-Jawoshy, Omar, and Tim Arango, "Iraqi Families Return to Fragile Stability in Tikrit After Liberation from ISIS," *New York Times*, June 22, 2015.

Johnston, Patrick B., *Countering ISIL's Financing*, testimony to the U.S. House of Representatives Committee on Financial Services, November 13, 2014. As of May 9, 2017:
https://www.rand.org/pubs/testimonies/CT419.html

Johnston, Patrick B., Jacob N. Shapiro, Howard Shatz, Benjamin Bahney, Danielle F. Jung, Patrick Ryan, and Jonathan Wallace, *Foundations of the Islamic State: Management, Money, and Terror in Iraq, 2005–2010*, Santa Monica, Calif.: RAND Corporation, RR-1192-DARPA, 2016. As of March 11, 2017:
http://www.rand.org/pubs/research_reports/RR1192.html

Jones, Seth G., "Islamic State's Global Expansion," *Wall Street Journal*, June 4, 2015. As of March 10, 2017:
https://www.wsj.com/articles/islamic-states-global-expansion-1433459574

Joumah, Khales, "Extremists Fix Roads, Make Mosul a Nicer Place," *Niqash*, May 14, 2015. As of March 10, 2017:
http://www.niqash.org/en/articles/society/5005/
Extremists-Fix-Roads-Make-Mosul-A-Nicer-Place.htm

Justice for Life Observatory in Deir Ezzor, "Political and Military Control: The Siege of Deir Ezzor," Atlantic Council, April 20, 2016. As of March 10, 2017:
http://www.atlanticcouncil.org/blogs/syriasource/political-military-control-the-siege-of-deir-ezzor

Kajjo, Sirwan, "The Fight for Raqqa," Carnegie Middle East Center, June 3, 2014. As of March 10, 2017:
http://carnegieendowment.org/syriaincrisis/?fa=55782

Kalin, Stephen, "U.N. Team Calls Destruction in Iraq's Ramadi 'Staggering,'" Reuters, March 4, 2016a. As of March 9, 2017:
http://www.reuters.com/article/us-mideast-crisis-iraq-ramadi-idUSKCN0W61S1

———, "U.S. Firm to De-Mine Iraqi City of Ramadi Retaken from Islamic State," Reuters, April 4, 2016b. As of March 10, 2017:
http://www.reuters.com/article/us-mideast-crisis-usa-ramadi-idUSKCN0X123U

———, "Islamic State Mines Kill Dozens of Civilians Returning to Ramadi," Reuters, April 22, 2016c. As of March 10, 2017:
http://www.reuters.com/article/us-mideast-crisis-iraq-ramadi-idUSKCN0XJ1IZ

———, "Islamic State Seeks News Blackout in Mosul as Iraqi Army Nears," Reuters, May 6, 2016d. As of March 10, 2017:
http://www.reuters.com/article/us-mideast-crisis-iraq-communications-idUSKCN0XV0XF

Karouny, Mariam, "Life Under Isis: For Residents of Raqqa Is This Really a Caliphate Worse Than Death?" *Independent*, September 5, 2014. As of March 10, 2017:
http://www.independent.co.uk/news/world/middle-east/
life-under-isis-for-residents-of-raqqa-is-this-really-a-caliphate-worse-than-death-9715799.html

Kearns, Jeff, "Satellite Images Show Economies Growing and Shrinking in Real Time," Bloomberg, July 8, 2015. As of March 10, 2017:
http://www.bloomberg.com/news/features/2015-07-08/
satellite-images-show-economies-growing-and-shrinking-in-real-time

al-Khatteeb, Luay, and Eline Gordts, "How ISIS Uses Oil to Fund Terror," Brookings Institution, September 27, 2014. As of March 10, 2017:
https://www.brookings.edu/on-the-record/how-isis-uses-oil-to-fund-terror/

al-Khatteeb, Luay, and Harry Istepanian, "Turn a Light On: Electricity Sector Reform in Iraq," Brookings Doha Center, Policy Briefing, March 2015. As of March 10, 2017:
https://www.brookings.edu/wp-content/uploads/2016/06/Alkhatteeb-Istepanian-English-PDF.pdf

"Khitta istratijiyya li-ta'ziz al-mawqif al-siyasi li-Dawlat al-'Iraq al-Islamiyya [Strategic plan for reinforcing the political position of the Islamic State of Iraq]," Mufakkirat al-Fallujah, c. December 2009–January 2010. In Arabic, as of March 9, 2017:
https://ia802604.us.archive.org/16/items/Dirasa_dawla_03/khouta.pdf

Khodr, Zeina "Iraqi Forces Battle Sunni Rebels for Ramadi," *Al Jazeera*, August 20, 2014. As of March 9, 2017:
http://www.aljazeera.com/video/middleeast/2014/08/
iraqi-forces-battle-sunni-rebels-ramadi-2014820131343292122.html

Kiley, Sam, "Underground Guerrilla Force Battles IS in Mosul," *Sky News*, April 20, 2015. As of March 10, 2017:
http://news.sky.com/story/underground-guerrilla-force-battles-is-in-mosul-10362741

Knights, Michael, "Al-Qa`ida in Iraq: Lessons from the Mosul Security Operation," *CTC Sentinel*, Vol. 1, No. 7, June 15, 2008. As of May 10, 2017:
https://www.ctc.usma.edu/posts/al-qaida-in-iraq-lessons-from-the-mosul-security-operation

———, "The ISIL's Stand in the Ramadi–Falluja Corridor," *CTC Sentinel*, Vol. 7, No. 5, May 2014, pp. 8–12. As of May 10, 2017:
https://www.ctc.usma.edu/posts/the-isils-stand-in-the-ramadi-falluja-corridor

Koek, Elisabeth, and Becky Bakr Abdulla, "Civilians Trapped Inside Ramadi as Fighting Continues," Norwegian Refugee Council, January 14, 2016. As of May 10, 2017:
https://www.nrc.no/news/2016/january/civilians-trapped-inside-ramadi-as-fighting-continues/
#.Vpg2JxXhChc

Koelbl, Susanne, and Christoph Reuter, "Is Islamic State in Trouble in Iraq?" *Spiegel Online*, March 26, 2015. As of March 10, 2017:
http://www.spiegel.de/international/world/
reconquest-of-tikrit-in-iraq-shows-islamic-state-weaknesses-a-1025138.html

Kulaksiz, Sibel, and Omer Karasapan, "Iraq's Internally Displaced Populations and External Refugees: A Soft Landing Is a Requisite for Us All," Brookings Institution, April 2, 2015. As of March 10, 2017:
https://www.brookings.edu/blog/future-development/2015/04/02/
iraqs-internally-displaced-populations-and-external-refugees-a-soft-landing-is-a-requisite-for-us-all/

Lavoix, Helene, "Understanding the Islamic State's System: Money, Wealth and Taxes," Red (Team) Analysis Society, July 13, 2015, updated May 9, 2017. As of March 10, 2017:
https://www.redanalysis.org/2015/07/13/
understanding-the-islamic-states-system-money-wealth-and-taxes/

Lee, Jin A., and Chi Kwang Hoon, "Modeling of Urban Industrial Economy Through Utilization of Thermal Band," *International Society for Photogrammetry and Remote Sensing*, Vol. XXXVIII-2/W11, 2009. As of May 10, 2017:
http://www.isprs.org/proceedings/XXXVIII/2-W11/Lee_Chi.pdf

Lefler, Jenna, "Life Under ISIS in Mosul," Institute for the Study of War, July 28, 2014. As of March 10, 2017:
http://iswresearch.blogspot.com/2014/07/life-under-isis-in-mosul.html

Leigh, Karen, "In Deir Ezzor, Rebels Battle for More Than Just Oil," *Syria Deeply*, May 21, 2014. As of March 2010:
http://www.syriadeeply.org/articles/2014/05/5440/deir-ezzor-rebels-battle-oil/

Leland, John, and Khalid D. Ali, "Anbar Province, Once a Hotbed of Iraqi Insurgency, Demands a Say on Resources," *New York Times*, October 27, 2010.

"Lessons from Raqqa: From Demanding Freedom to Creative State-Building," *Syria Untold*, May 28, 2013. As of March 10, 2017:
http://www.syriauntold.com/en/2013/05/
lessons-from-raqqa-from-demanding-freedom-to-creative-state-building/

Lewis, Jessica D., *Al-Qaeda in Iraq Resurgent*, Institute for the Study of War, Middle East Security Report 14, September 2013. As of March 9, 2017:
http://www.understandingwar.org/report/al-qaeda-iraq-resurgent

Lister, Charles, *Profiling the Islamic State*, Brookings Doha Center Analysis Paper 13, November 2014. As of March 10, 2017:
https://www.brookings.edu/wp-content/uploads/2014/12/en_web_lister.pdf

Lucani, Paolo, and Maurice Saade, *Iraq: Agriculture Sector Note*, Food and Agriculture Organization of the United Nations/World Bank Cooperative Programme, 2012. As of March 11, 2017:
http://www.fao.org/docrep/017/i2877e/i2877e.pdf

Lucem, Peto (PetoLucem), "NEW MAP (June 21): Military situation in #Deir_Ezzor Governorate #Syria," *Twitter*, June 21, 2014a, 11:31 a.m. As of June 16, 2017:
https://twitter.com/petolucem/status/480372429848854529

———, "NEW MAP (update): Battle of #Deir_Ezzor. #Syria #SAA #Islamic_State #IS @KeepingtheLeith," *Twitter*, October 15, 2014b, 4:32 p.m. As of June 16, 2017:
https://twitter.com/petolucem/status/522485278800617472

———, "NEW MAP: Battle of #Deir_Ezzor. #Syria #SAA #Islamic_State #IS @KeepingtheLeith," *Twitter*, October 26, 2014c, 2:09 p.m. As of June 16, 2017:
https://twitter.com/petolucem/status/526435372184920065

———, "NEW MAP: Battle of #Deir_Ezzor. #SAA #Islamic_State #Syria," *Twitter*, December 5, 2014d, 12:53 p.m. As of June 16, 2017:
https://twitter.com/petolucem/status/540927064321585152

———, NEW MAP: Military situation in #DeirEzzor Governorate. #IslamicState #NDF #SAA #Syria," *Twitter*, January 12, 2015a, 1:40 p.m. As of June 16, 2017:
https://twitter.com/petolucem/status/554709456723128320

———, "NEW MAP (update): Military situation in #DeirEzzor Governorate. #SAA #NDF #IslamicState #Syria," *Twitter*, January 27, 2015b, 1:56 p.m. As of June 16, 2017:
https://twitter.com/petolucem/status/560149475243880448

———, "NEW MAP: Battle of #Deir_Ezzor. #Syria #SAA #NDF #IslamicState," *Twitter*, May 19, 2015c, 1:43 p.m. As of June 16, 2017:
https://twitter.com/PetoLucem/status/600718451204878338

———, "NEW MAP: Situation in #DeirEzzor Governorate. #SAA repulsed #IslamicState attacks+secured airport perimeter. #Syria," *Twitter*, September 13, 2015d, 4:08 a.m. As of June 16, 2016:
https://twitter.com/petolucem/status/642973004268445696

———, "NEW MAP: Military situation in #DeirEzzor Governorate. #Syria #SAA #ISIS HD version: http://imgur.com/eUUh0XX," *Twitter*, January 20, 2016a, 2:43 p.m. As of June 16, 2017:
https://twitter.com/PetoLucem/status/689896108907220992

———, "NEW MAP: #SAA captured Turdah Mountain from #ISIS and advances towards Thayyem oil field. #DeirEzzor #Syria," *Twitter*, March 15, 2016b, 2:13 p.m. As of June 16, 2017:
https://twitter.com/PetoLucem/status/709804733087817733

———, "NEW MAP: Military situation in #DeirEzzor Governorate. #Syria #SAA #ISIS HD version:https://imgur.com/0xQlCdp," *Twitter*, May 22, 2016c, 6:59 a.m. As of June 16, 2017:
https://twitter.com/PetoLucem/status/734337866986364928

Ma, Ting, Yuke Zhou, Chenghu Zhou, Susan Haynie, Tao Pei, and Tao Xu, "Night-Time Light Derived Estimation of Spatio-Temporal Characteristics of Urbanization Dynamics Using DMSP/OLS Satellite Data," *Remote Sensing of Environment*, Vol. 158, March 1, 2015, pp. 453–464.

Mackey, Robert, "Latest Updates on the Insurgency in Iraq," *New York Times*, June 14, 2014. As of March 10, 2017:
http://news.blogs.nytimes.com/2014/06/14/latest-updates-on-the-insurgency-in-iraq/

Mahmud, Sabah Faihan, "Proposed Criteria for Selecting Cities of Urban System in Iraq, a Case Study of Salah al-Din Governorate," *Journal of Advanced Social Research*, Vol. 4, No. 5, May 2014, pp. 1–24.

"Make or Break: Iraq's Sunnis and the State," International Crisis Group, Middle East Report 144, August 14, 2013. As of May 10, 2017:
https://www.crisisgroup.org/middle-east-north-africa/gulf-and-arabian-peninsula/iraq/make-or-break-iraq-s-sunnis-and-state

Mampilly, Zachariah Cherian, *Rebel Rulers: Insurgent Governance and Civilian Life During War*, Ithaca, N.Y.: Cornell University Press, 2011.

Mashhour, Faisal Dahmoush al, *The Impact of International Coalition Operations on the Economy of "Islamic State" in Syria*," Justice for Life Observatory in Deir Ezzor, January 2016. As of March 9, 2017:
https://jfldz.org/wp-content/uploads/2016/02/The-Impact-of-International-Coalition-Operations-on-the-Economy-of.pdf

McCants, William Faizi, *The ISIS Apocalypse: The History, Strategy, and Doomsday Vision of the Islamic State*, New York: St. Martin's Press, September 2015.

Mekhennet, Souad, and Greg Miller, "He's the Son of Osama bin Laden's Bombmaker, Then ISIS Wanted Him as One of Their Own," *Washington Post*, August 5, 2016.

Metz, Helen Chapin, *Iraq: A Country Study*, Washington, D.C.: Federal Research Division, Library of Congress, 1990. As of March 10, 2017:
https://www.loc.gov/item/89013940/

Mezzofiore, Gianluca, "Shocking Pictures from Syrian City Under Siege Show Starving People Who Look Like Concentration Camp Victims," *Daily Mail*, January 17, 2016. As of March 10, 2017:
http://www.dailymail.co.uk/news/article-3403857/The-town-20-people-day-die-starvation-200-000-Syrians-face-food-shortage-areas-siege-ISIS-government-forces.html

Micallef, Joseph V., "The Battle for Ramadi: Whatever Happened to the Anbar Campaign?" *Huffington Post*, September 4, 2015. As of March 10, 2017:
http://www.huffingtonpost.com/joseph-v-micallef/the-battle-for-ramadi-wha_b_8085242.html

Mohammed, Riyadh, "The Taking of Ramadi: Behind ISIS's Bloody Assault," *Fiscal Times*, May 21, 2015. As of March 10, 2017:
http://www.thefiscaltimes.com/2015/05/21/Taking-Ramadi-Behind-ISISs-Bloody-Assault

Moore, Jack, "Mosul Seized: Jihadis Loot $429m from City's Central Bank to Make Isis World's Richest Terror Force," *International Business Times*, June 11, 2014, updated October 3, 2014. As of March 10, 2017:
http://www.ibtimes.co.uk/
mosul-seized-jihadis-loot-429m-citys-central-bank-make-isis-worlds-richest-terror-force-1452190

Moran, P. A. P., "Notes on Continuous Stochastic Phenomena," *Biometrika*, Vol. 37, No. 1/2, June 1950, pp. 17–23.

Morris, Loveday, "Iraq Labors to Repopulate Tikrit After Chasing Out the Islamic State," *Washington Post*, June 19, 2015a.

———, "One Man's Escape from the Islamic State–Ruled City of Mosul," *Washington Post*, October 17, 2015b.

Moslawi, Mohammad, Fazel Hawramy, and Luke Harding, "Citizens of Mosul Endure Economic Collapse and Repression Under ISIS Rule," *Guardian*, October 27, 2014. As of March 10, 2017:
https://www.theguardian.com/world/2014/oct/27/
citizens-mosul-iraq-economic-collapse-repression-isis-islamic-state

"Mosul Diaries: Poisoned by Water," BBC News, December 19, 2014. As of March 9, 2017:
http://www.bbc.com/news/world-middle-east-29600573

Mustafa, Hamza, "Iraqi Army and Awakening Forces Say Ramadi Cleared of ISIS," *Asharq al-Awsat*, January 26, 2014. As of March 10, 2017:
http://english.aawsat.com/2014/01/article55328016/
iraqi-army-and-awakening-forces-say-ramadi-cleared-of-isis

Mutter, Paul, "Tikrit Torn," *U.S. News and World Report*, June 26, 2015. As of March 10, 2017:
http://www.usnews.com/opinion/blogs/world-report/2015/06/26/
after-liberation-from-islamic-state-group-tikrit-faces-harsh-militia-rule

Nasser, Rabie, Zaki Mehchy, and Khalid Abu Ismail, *Socioeconomic Roots and Impact of the Syrian Crisis*," Syrian Centre for Policy Research, January 2013. As of March 10, 2017:
http://www.fao.org/docs/eims/upload/310686/
SyrianCentrePolicyResearch%20SocioEconomicRootsAndImpactOfSyrianCrisisJan2013.pdf

Nasser, Rabie, Zaki Mehchy, and Khuloud Saba, *Multidimensional Child Deprivation in Syria: A Comparative Research 2001, 2009*," Central Bureau of Statistics, Planning and International Cooperation Commission of the Syrian Arab Republic, and United Nations Children's Fund in Syria, June 2014. As of March 10, 2017:
http://www.cbssyr.sy/Child_Poverty_Multidimensional/
Multidimensional_Child_Deprivation_in_Syria_EN.pdf

National Imagery and Mapping Agency, "Al Mawsil (Mosul), Iraq," Bethesda, Md., April 2003. As of March 9, 2017:
https://www.loc.gov/item/2008625482/

Oak Ridge National Laboratory, "LandScan Documentation," undated. As of March 10, 2017:
http://web.ornl.gov/sci/landscan/landscan_documentation.shtml

"[Official statistics: 1997 total number of missing Spieker and Badush massacres] احصائية رسمية: 1997 العدد الكلي لمفقودي مجزرتي سبايكر وباوش," *Rudaw*, November 1, 2014. In Arabic, as of March 10, 2017: http://rudaw.net/arabic/middleeast/iraq/011120148

Olson, Mancur, *Power and Prosperity: Outgrowing Communist and Capitalist Dictatorships*, New York: Basic Books, 2000.

ORNL—*See* Oak Ridge National Laboratory.

Osgood, Patrick, and Rawaz Tahir, "Mosul Dam Flows, Returning Power to IS Held City Below," *Iraq Oil Report*, January 30, 2016. As of March 10, 2017: http://www.iraqoilreport.com/news/mosul-dam-flows-returning-power-held-city-17843/

Ottaway, Marina, and Danial Anas Kaysi, "Iraq: Protest, Democracy, and Autocracy," Carnegie Endowment for International Peace, March 28, 2011. As of March 10, 2017: http://carnegieendowment.org/2011/03/28/iraq-protest-democracy-and-autocracy-pub-43306

Ozdogan, Mutlu, Yang Yang, George Allez, and Chelsea Cervantes, "Remote Sensing of Irrigated Agriculture: Opportunities and Challenges," *Remote Sensing*, Vol. 2, No. 9, 2010, pp. 2274–2304.

Paton, Callum, "Escape from Isis: Raqqa Family Who Fled Say 'Paradise' City Is Now 'Asphalt,'" *International Business Times*, February 9, 2016, updated February 11, 2016. As of March 10, 2017: http://www.ibtimes.co.uk/escape-isis-raqqa-family-who-fled-say-paradise-city-now-asphalt-1542888

Pecquet, Julian, "Slump in Oil Prices Wallops Anti-ISIS Coalition," *U.S. News and World Report*, January 13, 2016. As of March 10, 2017: http://www.usnews.com/news/articles/2016-01-13/slump-in-oil-prices-wallops-anti-isis-coalition

Pellerin, Cheryl, "OIR Spokesman: ISIL Now in Defensive Crouch in Iraq, Syria," U.S. Department of Defense, January 6, 2016. As of March 10, 2017: http://www.defense.gov/News-Article-View/Article/641750/oir-spokesman-isil-now-in-defensive-crouch-in-iraq-syria

Pervez, Md. Shahriar, Michael Budde, and James Rowland, "Mapping Irrigated Areas in Afghanistan over the Past Decade Using MODIS NDVI," *Remote Sensing of Environment*, Vol. 149, June 2014, pp. 155–165.

Peto Lucem, Twitter. As of September 26, 2014: https://twitter.com/petolucem?lang=en

"Potatoes Are Now Available Again at Markets in the Besieged Districts of Deir Ezzor," *Deirezzor* 24, February 17, 2016. As of March 10, 2017: http://en.deirezzor24.net/potatoes-are-now-available-again-at-markets-in-the-besieged-districts-of-deir-ezzor/

"Press Briefing by Press Secretary Josh Earnest and Special Presidential Envoy for the Global Coalition to Counter ISIL, Brett McGurk," White House, June 10, 2016. As of May 8, 2017: https://obamawhitehouse.archives.gov/the-press-office/2016/06/10/press-briefing-press-secretary-josh-earnest-and-special-presidential

Prince, S. J., "Watch: New ISIS Video Attempts to Show Functioning Society in 'Capital' Raqqa, Syria," *Heavy*, April 4, 2016. As of March 10, 2017: http://heavy.com/news/2016/04/new-isis-islamic-state-news-pictures-videos-a-tour-in-the-administrations-of-the-state-ar-raqqa-wilayat-syria-full-uncensored-video/

Rasheed, Ahmed, "As Forces Close in on Ramadi, ISIS Uses Thousands of Civilians as Human Shields," *Huffington Post*, December 9, 2015. As of March 9, 2017: http://www.huffingtonpost.com/entry/iraq-isis-ramadi_us_56684106e4b0f290e5214423

Rasheed, Ahmed, and Ned Parker, "In Mosul, Islamic State Turns Captured City into Fortress," Reuters, January 22, 2015. As of March 9, 2017:
http://www.reuters.com/article/us-mideast-crisis-iraq-mosul-idUSKBN0KV13320150122

"Regime, ISIS Confiscate Food Aid for Residents of Besieged Deir-ez-Zor," *Syrian Observer*, April 12, 2016. As of March 9, 2017:
http://syrianobserver.com/EN/News/30853/
Regime_ISIS_Confiscate_Food_Aid_Residents_Besieged_Deir_Zor

Regional Analysis Syria: 28 March 2013, Assessment Capacities Project, March 28, 2013. As of March 10, 2017:
http://reliefweb.int/report/syrian-arab-republic/regional-analysis-syria-28-march-2013

"Remarks by Assistant Secretary for Terrorist Financing Daniel Glaser at Chatham House," U.S. Department of Treasury, February 8, 2016. As of March 10, 2017:
https://www.treasury.gov/press-center/press-releases/Pages/jl0341.aspx

Remnick, David, "Telling the Truth About ISIS and Raqqa," *New Yorker*, November 22, 2015. As of May 13, 2017:
http://www.newyorker.com/news/news-desk/telling-the-truth-about-isis-and-raqqa

"Republic of Iraq (IQ)," *Tageo*, undated. As of March 10, 2017:
http://www.tageo.com/index-e-iz-cities-IQ.htm

Republic of Iraq, National Investment Commission, *Investment Overview of Iraq*, undated. As of March 10, 2017:
http://www.mofamission.gov.iq/documentfiles/InvestmentOverview.pdf

"Results of Population and Housing Census 2004 on the Neighborhood Level," Syrian Central Statistical Bureau, undated. In Arabic, as of March 10, 2017:
http://www.cbssyr.sy/new%20web%20site/General_census/census_2004/NH/TAB11-1-2004.htm

"Retaking Raqqa from the Islamic State," Stratfor, May 24, 2016.

Rifai, Diana al, "Syrians in Raqqa Tell of 'Insane Nights' of Air Strikes," *Al Jazeera*, November 17, 2015. As of March 10, 2017:
http://www.aljazeera.com/news/2015/11/
syrians-insane-nights-french-bombing-151117052945111.html

Robinson, Eric, "Cutting the Islamic State's Money Supply," *National Interest*, July 20, 2016. As of March 9, 2017:
http://nationalinterest.org/blog/the-buzz/cutting-the-islamic-states-money-supply-17046

Roggio, Bill, "Iraqi Troops Repel ISIS Assault on Mosul," *Long War Journal*, June 7, 2014a. As of March 9, 2017:
http://www.longwarjournal.org/archives/2014/06/iraqi_troops_repel_i.php

———, "ISIS Takes Control of Mosul, Iraq's Second Largest City," *Long War Journal*, June 10, 2014b. As of March 9, 2017:
http://www.longwarjournal.org/archives/2014/06/isis_take_control_of.php

Roggio, Bill, and Caleb Weiss, "Islamic State Ambushes Iraqi Military Column Near Ramadi," *Long War Journal*, September 30, 2014. As of March 9, 2017:
http://www.longwarjournal.org/archives/2014/09/islamic_state_overru_4.php

Rosenberg, Matthew, Nicholas Kulish, and Steven Lee Myers, "Predatory Islamic State Wrings Money from Those It Rules," *New York Times*, November 29, 2015.

Rozenfeld, Hernán D., Diego Rybski, Xavier Gabaix, and Hernán A. Makse, "The Area and Population of Cities: New Insights from a Different Perspective on Cities," *American Economic Review*, Vol. 101, No. 5, August 2011, pp. 2205–2225.

"Ruinous Aftermath: Militias [sic] Abuses Following Iraq's Recapture of Tikrit," Human Rights Watch, September 20, 2015. As of March 10, 2017:
https://www.hrw.org/report/2015/09/20/ruinous-aftermath/
militias-abuses-following-iraqs-recapture-tikrit

Salaheddin, Sinan, "Islamic State Introduces New Restrictions to Prevent Mosul Residents from Fleeing City," *Globe and Mail*, March 13, 2015. As of March 10, 2017:
http://www.theglobeandmail.com/news/world/
islamic-state-introduces-new-restrictions-to-prevent-mosul-residents-from-fleeing-city/
article23443591/

al-Salhy, Suadad, "Shortage of Electricity in Iraq Cripples Economy, Sparks Protests," *Middle East Eye*, August 6, 2015, last update August 7, 2015. As of March 10, 2017:
http://www.middleeasteye.net/news/
shortage-electricity-cripples-economy-and-sparks-demonstrations-iraq-58980501

Salih, Mohammed A., "Forced from Mosul, Centuries Old Christian Community Vanishes," *Al-Monitor*, July 28, 2014. As of March 10, 2014:
http://www.al-monitor.com/pulse/originals/2014/07/
iraq-mosul-christians-assyrians-islamic-state-isis.html

———, "Mosul Under ISIL: 'No Internet, No Shaving,'" *Al Jazeera*, March 29, 2015. As of May 10, 2017:
http://www.aljazeera.com/news/2015/03/mosul-isil-internet-shaving-150323061307541.html

Sands, Phil, "Oil, Food and Protest in Syria's Restive East," *National*, January 17, 2012. As of March 10, 2017:
http://www.thenational.ae/news/world/middle-east/oil-food-and-protest-in-syrias-restive-east

Sarhan, Amre, "Iraqi Forces Kill Dozens of ISIS Militants Southern Ramadi," *Iraqi News*, January 25, 2015. As of March 10, 2017:
http://www.iraqinews.com/iraq-war/iraqi-forces-kill-dozens-isis-militants-southern-ramadi/

al-Sayegh, Ahmad, "Militias Control Home-Made Oil Refineries," *Iraq-Business News*, September 28, 2013. As of March 9, 2017:
http://www.iraq-businessnews.com/2013/09/28/militias-control-home-made-oil-refineries/

Schmitt, Eric, "U.S. Says Its Strikes Are Hitting More Significant ISIS Targets," *New York Times*, May 25, 2016.

"Security Crisis Sees Harvests Halved in Northern Iraq," *Niqash*, May 28, 2015. As of March 9, 2017:
http://www.niqash.org/en/articles/economy/5008/
Security-Crisis-Sees-Harvests-Halved-in-Northern-Iraq.htm

Setrakian, Lara, and Katarina Montgomery, "Hassan Hassan on How to Uproot ISIS in Deir Ezzor," *Syria Deeply*, October 27, 2014. As of March 10, 2017:
http://www.syriadeeply.org/articles/2014/10/6299/hassan-hassan-uproot-isis-deir-ezzor/

Shaheen, Kareem, "Iraq: Pro-Government Forces Struggle to Topple Isis in Tikrit," *Guardian*, March 5, 2015. As of May 10, 2017:
http://www.theguardian.com/world/2015/mar/05/
iraq-pro-government-forces-struggle-topple-isis-tikrit

Shamout, Nouar, "Syria Faces an Imminent Food and Water Crisis," Chatham House, June 24, 2014. As of March 10, 2017:
https://www.chathamhouse.org/expert/comment/14959

Shatz, Howard, and Erin-Elizabeth Johnson, *The Islamic State We Knew: Insights Before the Resurgence and Their Implications*, Santa Monica, Calif.: RAND Corporation, RR-1267-OSD, 2015. As of March 10, 2017:
http://www.rand.org/pubs/research_reports/RR1267.html

Shaver, Andrew, and David Ensign, "Lights Off in the Islamic State: What Electricity Tells Us About ISIS' Rule," *Foreign Affairs*, October 23, 2015. As of March 9, 2017:
https://www.foreignaffairs.com/articles/syria/2015-10-23/lights-islamic-state

Sherlock, Ruth, "Why Business Is Booming Under Islamic State One Year On," *Telegraph*, June 8, 2015. As of March 10, 2017:
http://www.telegraph.co.uk/news/worldnews/islamic-state/11657918/
Why-business-is-booming-under-Islamic-State-one-year-on.html

"Shiite Shrine Bombed by ISIS in Syria's Raqqa," *Al Bawaba*, March 26, 2014. As of March 9, 2017:
http://www.albawaba.com/news/syria-al-qaeda-564407

Siddique, Haroon, "Bloody Response in Fallujah," *Taipei Times*, November 15, 2009. As of March 10, 2017:
http://www.taipeitimes.com/News/feat/archives/2009/11/15/2003458505

Simmons, Andrew, "Civilians Plead with Syrian Fighters," *Al Jazeera*, October 3, 2012. As of May 9, 2017:
http://www.aljazeera.com/video/middleeast/2012/10/201210215395058626.html

Singh, Naresh, Dave van Zoonen, and Khogir Mohammed, *Iraq: Agriculture and Livelihoods Needs Assessment in the Newly Liberated Areas of Kirkuk, Ninewa and Salahadi*, Food and Agriculture Organization of the United Nations Iraq, February 2016. As of March 9, 2017:
http://www.fao.org/fileadmin/user_upload/FAO-countries/Iraq/ToR/FAO_Assessment1.pdf

al-Sinjary, Ziad, "Insurgents Fight Iraqi Forces in City of Mosul," Reuters, June 6, 2014. As of March 10, 2017:
http://uk.reuters.com/article/uk-iraq-security-idUKKBN0EH1YD20140606

Slater, Andrew, "The Paper Tiger of the Tigris: How ISIS Took Tikrit Without a Fight," *Daily Beast*, June 29, 2014. As of March 9, 2017:
http://www.thedailybeast.com/articles/2014/06/29/
the-paper-tiger-of-the-tigris-how-isis-took-tikrit-without-a-fight.html

Solomon, Erika, "Syria's Raqqa Reaps Wind of Isis Occupation," *Financial Times*, November 17, 2015.

Solomon, Erika, Guy Chazan, and Sam Jones, "Isis Inc: How Oil Fuels the Jihadi Terrorists," *Financial Times*, October 14, 2015. As of March 10, 2017:
https://next.ft.com/content/b8234932-719b-11e5-ad6d-f4ed76f0900a

"Sources: ISIS Executed 10 Doctors in Mosul for Refusing to Treat Wounded Fighters," *Rudaw*, January 27, 2015. As of March 10, 2017:
http://rudaw.net/english/middleeast/iraq/27012015

Sowell, Kirk, "The Islamic State's Eastern Frontier: Ramadi and Fallujah as Theaters of Sectarian Conflict," *Perspectives on Terrorism*, Vol. 9, No. 4, 2015, pp. 130–141. As of May 10, 2017:
http://www.terrorismanalysts.com/pt/index.php/pot/article/view/449

Starr, Barbara, "First on CNN: U.S. Bombs 'Millions' in ISIS Currency Stock," CNN, January 13, 2016. As of March 9, 2017:
http://www.cnn.com/2016/01/11/politics/us-bombs-millions-isis-currency-supply/index.html

Steele, Jonathan, "West Weeps for Aleppo but Ignores the Refugees of Ramadi," *Middle East Eye*, February 12, 2016. As of March 10, 2017:
http://www.middleeasteye.net/columns/
aleppo-and-ramadi-refugees-fall-wrong-side-wests-syrian-narrative-620925257

Sultana, Syeda Refat, Amjed Ali, Ashfaq Ahmad, Muhammad Mubeen, M. Zia-Ul-Haq, Shakeel Ahmad, Sezai Ercisli, and Hawa Z. E. Jaafar, "Normalized Difference Vegetation Index as a Tool for Wheat Yield Estimation: A Case Study from Faisalabad, Pakistan," *Scientific World Journal*, Vol. 2014, 2014, art. 725326.

"Sunni Rebels Declare New 'Islamic Caliphate,'" *Al Jazeera*, June 30, 2014. As of March 9, 2017:
http://www.aljazeera.com/news/middleeast/2014/06/
isil-declares-new-islamic-caliphate-201462917326669749.html

Swanson, Ana, "A Stunning New Look from Space at Nature, North Korea and Chipotle," *Washington Post*, July 23, 2015.

"Syria Army Enters City Close to Iraq Border," *Ynet News*, June 13, 2012. As of March 10, 2017:
http://www.ynetnews.com/articles/0,7340,L-4242065,00.html

Syria Needs Assessment Project, *Impact of the Conflict on Syrian Economy and Livelihoods*, Assessment Capacities Project, July 2013. As of March 9, 2017:
http://www.acaps.org/sites/acaps/files/products/files/
23_impact_of_the_conflict_on_syrian_economy_and_livelihoods_july_2013.pdf

"Syria Rebels Capture Northern Raqqa City," *Al Jazeera*, March 4, 2013. As of March 9, 2017:
http://www.aljazeera.com/news/middleeast/2013/03/201334151942410812.html

"Syria: Syrian Arab Republic," *City Population*, January 11, 2015. As of September 11, 2016:
http://www.citypopulation.de/Syria.html

Syrian Center for Policy Research, United Nations Relief and Works Agency for Palestine Refugees in the Near East, and United Nations Development Programme, *Syria: Squandering Humanity—Socioeconomic Monitoring Report on Syria: Combined Third and Fourth Quarter Report (July–December 2013)*, May 2014. As of March 9, 2017:
https://www.unrwa.org/sites/default/files/scpr_report_q3-q4_2013_270514final_3.pdf

Syrian Center for Policy Research, UN Relief and Works Agency for Palestine Refugees in the Near East, and UN Development Programme—*See* Syrian Center for Policy Research, United Nations Relief and Works Agency for Palestine Refugees in the Near East, and United Nations Development Programme.

Syrian Economic Forum, "Economics of 'al-Raqqa,'" Issue 2, April 2015. As of March 10, 2017:
http://www.syrianef.org/En/economics-of-al-raqqa/

"Syria's Suffering Revealed in Satellite Images," BBC News, March 18, 2015. As of March 9, 2017:
http://www.bbc.com/news/world-middle-east-31871568

Szybala, Valerie, "The Islamic State of Iraq and al-Sham and the 'Cleansing' of Deir Ez-Zour," Institute for the Study of War, backgrounder, May 14, 2014. As of March 10, 2017:
http://www.understandingwar.org/backgrounder/
islamic-state-iraq-and-al-sham-and-%E2%80%9Ccleansing%E2%80%9D-deir-ez-zour

al-Tamimi, Aymenn Jawad, "Aspects of Islamic State (IS) Administration in Ninawa Province: Part II," *Aymenn Jawad al-Tamimi*, January 20, 2015a. As of March 9, 2017:
http://www.aymennjawad.org/15952/aspects-of-islamic-state-is-administration-in

———, "Archive of Islamic State Administrative Documents," *Aymenn Jawad al-Tamimi*, January 27, 2015b. As of March 9, 2017:
http://www.aymennjawad.org/2015/01/archive-of-islamic-state-administrative-documents

———, "The Islamic State's Diwan al-Rikaz in Mosul," *Aymenn Jawad al-Tamimi*, July 6, 2015c. As of March 9, 2017:
http://www.aymennjawad.org/2015/07/the-islamic-state-diwan-al-rikaz-in-mosul

———, "The Archivist: Unseen Islamic State Financial Accounts for Deir az-Zor Province," *Jihadology*, October 5, 2015d. As of March 9, 2017:
http://jihadology.net/2015/10/05/
the-archivist-unseen-islamic-state-financial-accounts-for-deir-az-zor-province/

———, "The Archivist: Unseen Documents from the Islamic State's Diwan al-Rikaz," *Jihadology*, October 12, 2015e. As of March 9, 2017:
http://jihadology.net/2015/10/12/
the-archivist-unseen-documents-from-the-islamic-states-diwan-al-rikaz/

———, "Archive of Islamic State Administrative Documents (cont.)," *Aymenn Jawad al-Tamimi*, January 11, 2016. As of March 9, 2017:
http://www.aymennjawad.org/2016/01/archive-of-islamic-state-administrative-documents-1

Tawfeeq, Mohammed, and Jason Hanna, "11 Dead After Suspected ISIS Attacks in Western Iraq," CNN, January 14, 2015. As of May 10, 2017:
http://www.cnn.com/2015/01/06/world/iraq-violence/

"Testimony of A/S for Terrorist Financing Daniel L. Glaser Before the House Committee on Foreign Affair's [sic] Subcommittee on Terrorism, Nonproliferation, and Trade, and House Committee on Armed Services' Subcommittee on Emerging Threats and Capabilities," U.S. Department of the Treasury, June 9, 2016. As of March 10, 2017:
https://www.treasury.gov/press-center/press-releases/Pages/jl0486.aspx

"The Army Foils ISIS Attack on Deir Ezzor Airport, Continue Targeting ISIS Terrorists in Palmyra," Syrian Arab News Agency, April 4, 2016. As of March 9, 2017:
http://sana.sy/en/?p=73616

"The Capture of Mosul: Terror's New Headquarters," *Economist*, June 14, 2014. As of March 9, 2017:
http://www.economist.com/news/leaders/
21604160-iraqs-second-city-has-fallen-group-wants-create-state-which-wage-jihad

"The ISIS Papers: A Masterplan for Consolidating Powers," *Guardian*, December 7, 2015. As of March 10, 2017:
https://www.theguardian.com/world/2015/dec/07/islamic-state-document-masterplan-for-power

Thompson, Mark, "Why the Fight Against ISIS Has to Go Through the Cities," *Time*, March 10, 2015. As of March 10, 2017:
http://time.com/3739758/isis-iraq-syria-military-strategy/

"Tikrit Residents Complain of Rising Prices of Food and Fuel," *The I.Q.D. Team Connection*, July 16, 2014. As of March 9, 2017:
http://www.theiqdteamconnection.com/iraq-news/
tikrit-residents-complain-of-rising-prices-of-food-and-fuel

Tomson, Chris, "ISIS Bans Television for Residents of Deir Ezzor in Eastern Syria," *Al Masdar News*, May 21, 2016. As of March 10, 2017:
https://www.almasdarnews.com/article/isis-bans-television-residents-deir-ezzor-eastern-syria/

Torbati, Yeganeh, "Islamic State Yearly Oil Revenue Halved to $250 Million: U.S. Official," Reuters, May 11, 2016. As of March 9, 2017:
http://www.reuters.com/article/us-mideast-crisis-islamic-state-revenue-idUSKCN0Y22CW

Townsend, Mark, "Inside the Islamic State's Capital: Red Bull–Drinking Jihadists, Hungry Civilians, Crucifixions and Air Strikes," *Guardian*, November 30, 2014. As of March 10, 2017:
https://www.theguardian.com/world/2014/nov/30/
raqqa-isis-capital-crucifixions-civilians-suffer-jihadis-red-bull

Triebert, Christiaan, "Keeping the Water Running in the Islamic State," *Bellingcat*, April 14, 2016. As of March 10, 2017:
https://www.bellingcat.com/news/mena/2016/04/14/keeping-the-water-running-in-the-islamic-state/

Trofimov, Yaroslav, "Slowly, Post-ISIS Tikrit Regains Normalcy," *Wall Street Journal*, April 7, 2016. As of March 10, 2017:
http://www.wsj.com/articles/slowly-post-isis-tikrit-regains-normalcy-1460021403

Truitte, K. E., "The Fight for the Deir Ezzor Airport," *Eastern Project*, December 22, 2014. As of August 5, 2016:
https://medium.com/the-eastern-project/the-fight-for-the-deir-ezzor-airport-360e3236d3

Tucker, Compton J., "Red and Photographic Infrared Linear Combinations for Monitoring Vegetation," *Remote Sensing of Environment*, Vol. 8, No. 2, May 1979, pp. 127–150.

UNDP in Iraq—*See* United Nations Development Programme in Iraq.

UNDP in the Arab States—*See* United Nations Development Programme in the Arab States.

UN General Assembly and UN Security Council—*See* United Nations General Assembly and United Nations Security Council.

UNITAR—*See* United Nations Institute for Training and Research.

United Nations Development Programme in Iraq, *Iraq Human Development Report 2014: Iraqi Youth Challenges and Opportunities*, 2014. As of May 9, 2017:
http://www.iq.undp.org/content/dam/iraq/img/Publications/
UNDP-IQ_IraqNHDR2014-English.pdf

———, "Mayor of Tikrit: With the Help of UNDP, People Have Reestablished Essential Services for Our Community," February 1, 2016. As of March 10, 2017:
http://www.iq.undp.org/content/iraq/en/home/ourwork/Stabilization/our-stories/
mayor-of-tikrit--with-the-help-of-undp--people-have-reestablishe.html

United Nations Development Programme in the Arab States, "Resilient Youth in Deir Ezzor Are the Arm for Positive Change," undated. As of September 6, 2016:
http://www.arabstates.undp.org/content/rbas/en/home/ourwork/crisispreventionandrecovery/
successstories/Resilient_Youth_inDeirEzzor_Arm_Positive_Change.html

———, "UNDP Helps Displaced People Return to Tikrit," press release, June 25, 2015. As of March 10, 2017:
http://www.arabstates.undp.org/content/rbas/en/home/presscenter/pressreleases/2015/06/25/
undp-helps-displaced-people-return-to-tikrit.html

United Nations General Assembly and United Nations Security Council, *Children and Armed Conflict: Report of the Secretary-General*, A/70/836-S/2016/360, April 20, 2016. As of March 10, 2017:
http://www.un.org/ga/search/view_doc.asp?symbol=s/2016/360&referer=/english/&Lang=E

United Nations Institute for Training and Research, "Damage Assessment of Tikrit, Salah ad Din Governorate, Iraq," February 24, 2015a. As of March 10, 2017:
http://www.unitar.org/unosat/node/44/2172

———, "Damage Assessment of Kobane, Aleppo Governorate, Syria," March 6, 2015b. As of March 10, 2017:
http://www.unitar.org/unosat/node/44/2174

———, "Damage Assessment of ar Raqqa, ar Raqqa Governorate, Syria," July 21, 2015c. As of March 10, 2017:
http://www.unitar.org/unosat/node/44/2239

———, "Damage Assessment for Ramadi, al Anbar Province, Iraq," February 15, 2016a. As of March 10, 2017:
http://www.unitar.org/unosat/node/44/2335

———, "Damage Assessment for Fallujah, al Anbar Province, Iraq," United Nations Institute for Training and Research, July 11, 2016b. As of March 10, 2017:
http://www.unitar.org/unosat/node/44/2417

United Nations News Centre, "UN Food Aid Reaches Besieged Syrian City of Deir Ezzor by Air," April 10, 2016. As of March 10, 2017:
http://www.un.org/apps/news/story.asp?NewsID=53649#.V51tUoMrLIV

United Nations World Food Programme, "Syria: Market Price Watch, 2016," undated. As of May 10, 2017:
https://www.wfp.org/content/syria-market-price-watch-2016

———, "Iraq: Food Market Monitoring," Bulletin 3, March 2015a. As of May 7, 2017:
http://documents.wfp.org/stellent/groups/public/documents/ena/wfp272603.pdf

———, "Iraq: Trend of Increasing Food Insecurity Persists in Anbar and Ninewa," Bulletin 8, July 2015b. As of March 10, 2017:
https://www.wfp.org/content/
iraq-bulletin-8-trend-increasing-food-insecurity-persists-anbar-ninewa-july-2015

———, Syria Country Office, *Market Price Watch Bulletin*, Issue 11, September–October 2015c. As of March 10, 2017:
http://documents.wfp.org/stellent/groups/public/documents/ena/wfp279549.pdf

———, "Syria: Worsening Food Security Conditions in Besieged Areas," Bulletin 1, January 2016a. As of March 10, 2017:
http://documents.wfp.org/stellent/groups/public/documents/ena/wfp281528.pdf

———, "Iraq: Conflict-Disrupted Supply Lines Are Resulting in Shortages of Basic Food Commodities and High Food Prices in Parts of Anbar," Bulletin 15, February 2016b. As of March 10, 2017:
http://documents.wfp.org/stellent/groups/public/documents/ena/wfp282042.pdf

———, "Flash Update: Iraq—Anbar," March 2016c. As of March 10, 2017:
http://documents.wfp.org/stellent/groups/public/documents/ena/wfp282606.pdf

———, "Iraq: Concerns over Rising Food Prices in Fallujah and Increasing Food Insecurity in Ninewa," Bulletin 17, April 2016d. As of March 10, 2017:
http://documents.wfp.org/stellent/groups/public/documents/ena/wfp283833.pdf

UN News Centre—*See* United Nations News Centre.

Urban Area Humanitarian Profile: Deir ez-Zor—Syria Crisis: Food, Health and Water Assessment, REACH Initiative, August 2014. As of March 10, 2017:
http://reliefweb.int/sites/reliefweb.int/files/resources/
REACH_SYR_Factsheet_DeirEzZorCity_27082014.pdf

U.S. Agency for International Development, "An Overview of the Iraq Cement Industry," Iraq Private Sector Growth and Employment Generation, November 25, 2007.

U.S. Department of Defense, "Department of Defense Press Briefing by Col. Warren via Teleconference from Baghdad, Iraq," news transcript, January 6, 2016. As of March 10, 2017:
http://www.defense.gov/News/Transcripts/Transcript-View/Article/641754/
department-of-defense-press-briefing-by-col-warren-via-teleconference-from-bagh

U.S. Geological Survey, *Product Guide: Provisional Landsat 8 Surface Reflectance Product Version 1.8*, December 1, 2015.

———, "EarthExplorer," last modified March 28, 2017. As of September 11, 2016:
http://earthexplorer.usgs.gov/

USGS—*See* U.S. Geological Survey.

Van Heuvelen, Ben, "Armed with Intel, U.S. Strikes Curtail IS Oil Sector," *Iraq Oil Report*, December 28, 2015. As of March 9, 2017:
http://www.iraqoilreport.com/news/armed-intel-u-s-strikes-curtail-oil-sector-17473/

Vidal, John, "Water Supply Key to Outcome of Conflicts in Iraq and Syria, Experts Warn," *Guardian*, July 2, 2014. As of March 10, 2017:
https://www.theguardian.com/environment/2014/jul/02/water-key-conflict-iraq-syria-isis

"vwls: Variance-Weighted Least Squares," Stata, undated. As of September 26, 2016:
http://www.stata.com/manuals13/rvwls.pdf

Welsh, Charlie, and P. K. Semler, "Iraq Government to Restructure and Privatize Some 200 Industrial Companies," *Financial Times*, October 7, 2010. As of March 10, 2017:
http://www.ft.com/cms/s/2/d0b9b9fe-d1e1-11df-965c-00144feabdc0.html

Westall, Sylvia, "Islamic State Seizes Oil Field and Towns in Syria's East," Reuters, July 3, 2014. As of August 4, 2016:
http://www.reuters.com/article/us-syria-crisis-islamicstate-idUSKBN0F80SO20140703

Westcott, Lucy, "Secretly Filmed Video Shows Life in Mosul One Year After ISIS Capture," *Newsweek*, June 9, 2015. As of March 10, 2017:
http://www.newsweek.com/
secretly-filmed-video-shows-life-mosul-one-year-after-islamic-state-capture-341158

WFP—*See* United Nations World Food Programme.

"Wheat Diplomacy Between the Syrian Regime and the ISIS," Syrian Economic Forum (translation of *Al Jazeera* original in Arabic), March 13, 2015. As of March 10, 2017:
http://www.syrianef.org/En/2015/03/wheat-diplomacy-between-the-syrian-regime-and-the-isis/

Whiteside, Craig, "Mosul: A Bridge Too Far?" *War on the Rocks*, March 18, 2015. As of March 10, 2017:
http://warontherocks.com/2015/03/mosul-a-bridge-too-far/

Winter, Lucas, *Raqqa: From Regime Overthrow to Inter-Rebel Fighting*, U.S. Army Foreign Military Studies Office, March 2014. As of May 11, 2017:
http://fmso.leavenworth.army.mil/documents/Raqqa.pdf

"Women's Secret Films from Within Closed City of Islamic State," *Expressen*, March 13, 2016. As of March 10, 2017:
http://www.expressen.se/nyheter/womens-secret-films-from-within-closed-city-of-islamic-state/

World Bank, "Syrian Arab Republic," undated. As of September 26, 2016:
http://data.worldbank.org/country/syrian-arab-republic

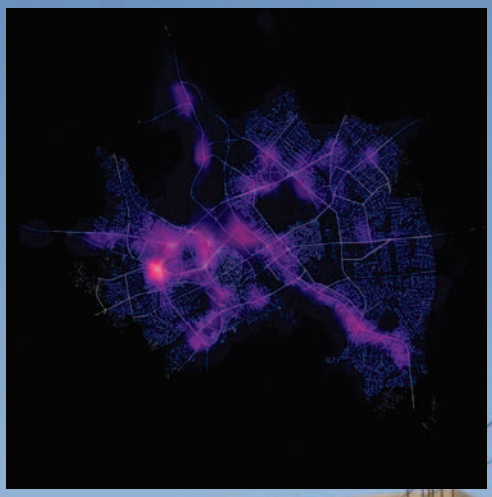
———, *The Unfulfilled Promise of Oil and Growth: Poverty, Inclusion and Welfare in Iraq, 2007–2012*, World Bank Group, Poverty Global Practice, November 7, 2014. As of March 10, 2017:
http://www.worldbank.org/en/country/iraq/publication/unfulfilled-promise-of-oil-and-growth

Wu, Weicheng, and Eddy De Pauw, "A Simple Algorithm to Identify Irrigated Croplands by Remote Sensing," 34th International Symposium on Remote Sensing of the Environment, 2011. As of March 10, 2017:
http://www.isprs.org/proceedings/2011/ISRSE-34/211104015Final00930.pdf

Youssef, Nancy A., "The Big Offensive Against ISIS in Tikrit Has Stalled," *Daily Beast*, March 19, 2015. As of March 10, 2017:
http://www.thedailybeast.com/articles/2015/03/19/
the-big-offensive-against-isis-in-tikrit-has-stalled.html

Zelin, Aaron Y., "The Islamic State of Iraq and Syria Has a Consumer Protection Office," *Atlantic*, June 13, 2014. As of March 9, 2017:
http://www.theatlantic.com/international/archive/2014/06/
the-isis-guide-to-building-an-islamic-state/372769/

———, *The Islamic State's Territorial Methodology*, Washington Institute for Near East Policy, Research Note 29, January 2016. As of March 9, 2017:
http://www.washingtoninstitute.org/uploads/Documents/pubs/ResearchNote29-Zelin.pdf



RAND CORPORATION

This report leverages remote sensing data and satellite imagery to assess the impact that Islamic State control and governance have on local economies in Iraq and Syria. It paints a bleak picture of life under the Islamic State. Although the group was able to maintain stable conditions in parts of Mosul and Raqqah, conditions in other cities deteriorated under poor governance and an inability to hold territory in the face of military opposition.

$64.00

ISBN-10 0-8330-9855-1
ISBN-13 978-0-8330-9855-9
56400
9 780833 098559

RR-1970-RC