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The Economic Costs to the U.S. of Closing Its Borders: A Computable General Equilibrium Analysis

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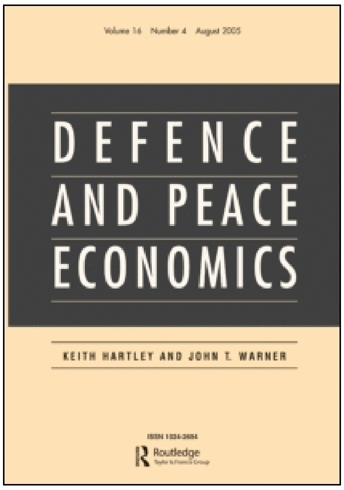

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THE ECONOMIC COSTS TO THE U.S. OF CLOSING ITS BORDERS: A COMPUTABLE GENERAL EQUILIBRIUM ANALYSIS

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We use a CGE model to simulate the effects of a one-year US border closure. Relative to previously used input–output modeling, CGE modeling offers a flexible framework for capturing bottleneck and labor-market effects. Our analysis suggests that the costs of a prolonged closure could be much greater than indicated by input–output studies. We find that cutting all imports by 95% in an environment of sticky real wages would reduce GDP by 48%. However, if bottleneck imports (mainly oil) were exempt and workers accepted real wage cuts then the GDP reduction would be only 11%.

Keywords: Border closure; Strategic reserves; Bottleneck imports; Dynamic CGE; Terrorism; Pandemics

JEL Codes: F52, C68

1. INTRODUCTION

The original motivation for this paper was a request by the US Departments of Homeland Security and Treasury to analyze the economic impacts of a partial or complete shutdown of US borders to movements of people and goods. Such a policy could be considered as a response to threats to US welfare from a pandemic or from international terrorism. Here, we calculate the costs of border closure: the benefits must be assessed by public health and security experts in the context of specific threats. Our calculations suggest that the costs of a complete closure would be extreme, involving a sharp loss of GDP and either greatly reduced wage rates or employment. This leads to the conclusion that if a closure policy were implemented, then it should be targeted, with the border activities that are restricted matching the nature of the threat. The design of targeted policies should also take account of the disproportionate economic damage caused by restricting bottleneck imports such as crude oil. The importance of these commodities highlights the value of strategic reserves.

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In our central calculations we look at a case in which the border shutdown is almost total. In other calculations we allow for exemptions of mineral (includes crude oil) imports. In all calculations we assume that the shutdown lasts for one year. Two recent studies that have analyzed the effects of a major shutdown of US borders are by Gordon *et al.* (2009) and Rose *et al.* (2009),[1] who, like us, examine the effects of shutdowns lasting for one year. Essentially, they use techniques based on input–output modeling, whereas we use a computable general equilibrium (CGE) approach.

A one-year shutdown of US borders should be considered an upper bound on the duration of such a policy. For the case of a severe influenza outbreak, the duration would likely be only 3–6 months, although a true pandemic could require more than 6 months (Germann *et al.*, 2006). These durations are primarily dependent on epidemiological considerations of disease incubation, contagion, and seasonality (Epstein *et al.*, 2007). They also depend on the intensity and success of public health actions such as vaccination and on the effectiveness of other strategies such as restriction of international air travel (Brownstein *et al.*, 2006). Shutdown to terrorist threats could last as little as 2 weeks, but it could require many months to deal with a widespread onslaught or insidious weaponry (US Department of Homeland Security, 2007). For example, new explosive devices placed in shipping containers or airline passenger luggage may defy detection and require manual inspection or the design and implementation of new screening technologies. Rose *et al.* (2009) offered only a linear interpolation of their one-year results as a way of looking at shorter periods. We can do no better on our results. As implied by Rose *et al.* (2007, 2009), linear interpolation may not be adequate because certain aspects of resilience are time dependent. For example, shorter duration events are likely to have greater negative impacts on a per unit time basis because the economy has less time to substitute among inputs to production or to implement conservation strategies. On the other hand, some forms of resilience are likely to wane as duration increases. For example, the ability to recapture lost production after the self-imposed embargo is lifted by working overtime or extra shifts would decline over time.

The remainder of the paper is organized as follows. In section 2 we review the input–output approach to the border closure problem and compare it with the CGE approach. In making this comparison we set out a transparent, diagrammatic general equilibrium model. Then in Section 3 we use a full-blown CGE model to conduct border-closure simulations. The diagrammatic model from Section 2 provides a basis for understanding results from the full-blown model. Concluding remarks are given in Section 4.

2. MODELING THE ECONOMIC COSTS OF A BORDER CLOSURE: INPUT–OUTPUT AND CGE

For analyzing the effects of a border closure we need an economy-wide approach. This is because restricting trade has diverse effects across the economy. Import-competing industries may benefit whereas import-using and export-supplying industries suffer. Wage effects are also critical: without imports, productivity is reduced and implications for employment depend on the response of real wage rates. Employment and wage outcomes in turn affect consumer demands with further rounds of effects for industries.

[1] Few other studies of border shutdown have been undertaken. The major exception is the case of oil embargoes, see for example Greene *et al.* (1998). However, these studies provide little insight on the likely effects of a comprehensive border shutdown of the type considered in this paper.

2.1. Input–Output Modeling

Input–output modeling was the first quantitative framework for economy-wide analysis (Leontief, 1936, 1941) and is still popular. Using an input–output approach, Gordon *et al.* (2009) estimate that a one-year border closure applying to all goods apart from energy imports would reduce US GDP by 13%.

Their study starts with a demand-side input–output model:[2]

$$X = (1 - A)^{-1} * (C + I + G + E - M) \quad (1)$$

where X is the vector of outputs by commodity; A is the technology coefficient matrix; and C, I, G, E and M are vectors of final demands. In calculating the effects of cessation of goods trade, they divide commodities into two groups, those for which exports exceed imports and those for which imports exceed exports. For the surplus-export group, they assume that imports are entirely replaced by a costless diversion of exports and that the surplus exports are lost. They compute the effects of cessation of trade for this group of goods via equation (1) with the E-M vector reset so that all positive entries are wound back to zero and all negative entries are left unchanged.

For the surplus-import group, Gordon *et al.* recognize that using equation (1) with all components of E-M reset at zero would be inappropriate. Such an approach would rest not only on the assumption that exports can be diverted costlessly to replace imports but also on the assumption that domestic production can be increased costlessly to meet shortfalls left by the cessation of trade in surplus-import goods. For a trade-deficit country such as the US, resetting the entire E-M vector at zero generates the unrealistic prediction that a border closure would benefit the economy.

Gordon *et al.* try to solve the problem of the surplus-import goods by adopting a supply-side input–output model[3] in which a shortfall in the availability of surplus-import goods causes bottlenecks and contraction in outputs. If for a typical industry the ratio of imported inputs of surplus import goods to value added is 20% and export diversion replaces only 40% of the lost imports, then their supply-side input–output model suggests that cessation of trade will on average reduce industry outputs by 12%.

Gordon *et al.*'s calculations depend on the degree of mismatch between imports and exports. If there were perfect matching ($E_i = M_i$ for all i), then their method would give zero cost from cessation of international trade. We would expect the degree of mismatching to increase with disaggregation for both commodities and regions. Thus, the Gordon *et al.* method has the unattractive feature that the macro results are likely to depend critically on the level of disaggregation.

More generally, the problem is that input–output analysis is not well suited for studying supply-side bottlenecks. It is difficult to interpret results from the supply-side input–output model[4] and it is not clear what justification can be given for use of a demand-side model for some commodities and a supply-side model for others.

Rose *et al.* (2009) estimate the effect on GDP of a one-year cessation of goods trade (including energy products) at about –10%. In making their estimates, they use the REMI model (2006) which, in this context, operates much like a demand-side input–output model. Consequently when they applied the REMI model in an initial calculation of the effects of a cessation of just imports, the results were highly positive. Therefore they found it necessary to

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[2] Gordon *et al.* use a regional input–output model. Here we ignore the regional dimension.
[3] The demand- and supply-side input–output models are set out in a helpful way by Bon (1988).
[4] See Oosterhaven (1988, 1989) and Dietzenbacher (1997).

‘incorporate constraints such as capacity and production cost differentials into the REMI model to reflect the difficulty in expanding domestic production’ (Rose et al. p. 236). However, they recognized that the *ad hoc* introduction of constraints and costs into REMI was unsatisfactory. In the final footnote to their paper, they called for a CGE analysis of a border closure.

2.2. CGE Modeling

CGE modeling developed out of input–output modeling, starting with Johansen (1960).[5] Relative to the input–output framework, the CGE framework is convenient for incorporating: optimizing, price-responsive behavior by producers and consumers; primary-factor constraints; and financial constraints arising from government budgets and the balance of payments. CGE modelers routinely specify imported and domestic products as imperfect substitutes.[6] This is an important innovation for the present analysis because it implies that imports cannot be replaced costlessly by either diverted exports or expanded output.

In this subsection we describe a simple back-of-the-envelope (BOTE) model that illustrates how CGE models incorporate the features mentioned above. While BOTE serves as a generic introduction to CGE theory, we have tailored it to highlight aspects relevant to analysis of a border closure. In Section 3 we use computations with a specifically parameterized version of BOTE to help explain border-closure results from a full-blown CGE model.

In describing BOTE, we start with the supply side. We assume that the economy produces two goods: a domestic good and an import good. By the production of a unit of import good we mean the production of sufficient exports to pay for that good. We assume that the economy is constrained in its production of the two goods by a CET[7] transformation frontier (convex from below) specified by:

$$Z = CET(X_1,\ X_2) \tag{2}$$

where X_1 and X_2 are production of the domestic and import good; and Z is the overall capacity to produce, determining the distance of the transformation frontier from the origin.

Z is determined according to:

$$Z = X_0 g(X_3 / X_0) \tag{3}$$

In equation (3), X_0 is a composite of inputs of capital and labor. It can be thought of as an ordinary production function. X_3 is the input of ‘bottleneck’ imports. Scarcity of these imports inhibits the economy’s ability to use capital and labor (X_0) to generate capacity to produce (Z). The most obvious example of X_3 imports are mining products that are not readily producible in the US in sufficient quantities to satisfy the economy’s requirements. The particular specification we use for the bottleneck function g is:

$$g(X_3 / X_0) = \alpha_0 + \alpha_1\left(\frac{X_3}{X_0}\right) + \alpha_2\left(\frac{X_3}{X_0}\right)^2 \quad \text{for } \frac{X_3}{X_0} \le \left(\frac{X_3}{X_0}\right)_I \tag{3a}$$

[5] Dixon and Parmenter (1996) provide a history of CGE modeling.

[6] Typically they use the specification first introduced by Armington (1969).

[7] The CET form is the same as the CES form: $\mathrm{CET}(X_1, X_2) = \left[\Sigma_i \gamma_i X_i^{-\rho}\right]^{-1/\rho}$ where $\gamma_i > 0$ and ρ are parameters. The difference between the two is that for CES ρ is greater than −1 whereas for CET ρ is less than −1. CET was introduced by Powell and Gruen (1968).

and

$$g(X_3 / X_0) = 1 \;\text{ for } \frac{X_3}{X_0} > \left(\frac{X_3}{X_0}\right)_I \tag{3b}$$

where $\left(\frac{X_3}{X_0}\right)_I$ is the initial (that is before border closure) ratio of bottleneck imports to use of primary factors; and α_0, α_1 and α_2 are parameters specified so that

$$\alpha_0 + \alpha_1\left(\frac{X_3}{X_0}\right)_I + \alpha_2\left(\frac{X_3}{X_0}\right)_I^2 = 1.$$

In the BOTE computations in Section 3 we set the αs so that the economy's output is inhibited by: 20% when bottleneck imports are unavailable, that is $g(0)$=0.8; and 5% when the ratio of bottleneck imports to primary factor inputs is reduced by 50%, that is $g(0.5(X_3 / X_0)I) = 0.95$.

On the demand-side of BOTE, we assume that the economy maximizes a CES combination of consumption of goods 1 and 2:

$$U = CES(C_1, C_2) \tag{4}$$

Consumption of good 1 is the production of good 1, that is:

$$X_1 = C_1 \tag{5}$$

Consumption of good 2 is given by:

$$C_2 = X_2 + (D - X_3) \tag{6}$$

where D is the trade deficit and, for convenience, we assume that product prices are 1.

In parameterizing BOTE for the computations in Section 3, we set the initial values for the variables at: $C_1 = X_1 = 0.9$; $X_2 = 0.1$; $C_2 = 0.153$; $X_3 = 0.017$; $D = 0.07$. In choosing these values we were guided by data for 2005 in which: exports are 10% of GDP; total imports are 17% of GDP leaving the balance of trade deficit as 7% of GDP; and bottleneck imports (mining) are 1.7% of GDP. For convenience we chose units so that the initial value for X_0 is 0.017, implying that the initial value for X_3/X_0 is 1. Thus, the initial value for Z, determined in equation (3) is also 0.017. The only other information required to complete the numerical specification of BOTE is the transformation elasticity (τ) in the CET function, equation (2), and the substitution elasticity (σ) in the CES function, equation (4). As reported in Section 3, with $\tau = 2$ and $\sigma = 2$ the BOTE model produces results similar to those in our full-blown CGE model.

The operation of BOTE is illustrated in Figure 1. Initially, consumption is at point 1a and production at point 1b. In our main simulation with the full-blown CGE model (Section 3), we reduce all imports by 95%[8] and assume that the balance of trade moves to 5% of its initial level. In terms of BOTE, this means that C_2 moves from 0.153 to 0.00765, X_3 moves from

[8] With imported and domestic products modeled as CES substitutes, import volumes can be pushed close to, but not equal to zero. With import volumes heavily restricted, the returns from evading border security are high. We can interpret the residual 5% as successful evasion of the border closure.

0.017 to 0.00085, and D moves to 0.0035. The balance of trade constraint, equation (6), implies that X_2 must move to 0.005. Via the g function the border closure causes a bottleneck contraction in the economy's capacity to produce. There may be a further contraction through unemployment (a reduction in X_0). The contraction in capacity to produce is illustrated in Figure 1 by the inward movement in the transformation frontier with Z declining from Z_I to Z_F. Consumption and production in the new situation are at points 2a and 2b. The border closure causes utility or real consumption to decline from U_I to U_F.

3. SIMULATING BORDER CLOSURE WITH THE USAGE MODEL

3.1. The USAGE Model

This section reports results from a 40-industry version of the USAGE model for the effects of a one-year border closure. USAGE is a dynamic CGE model of the US developed at Monash University in collaboration with the US International Trade Commission.[9] It incorporates standard CGE assumptions. Each industry minimizes unit costs subject to given input prices

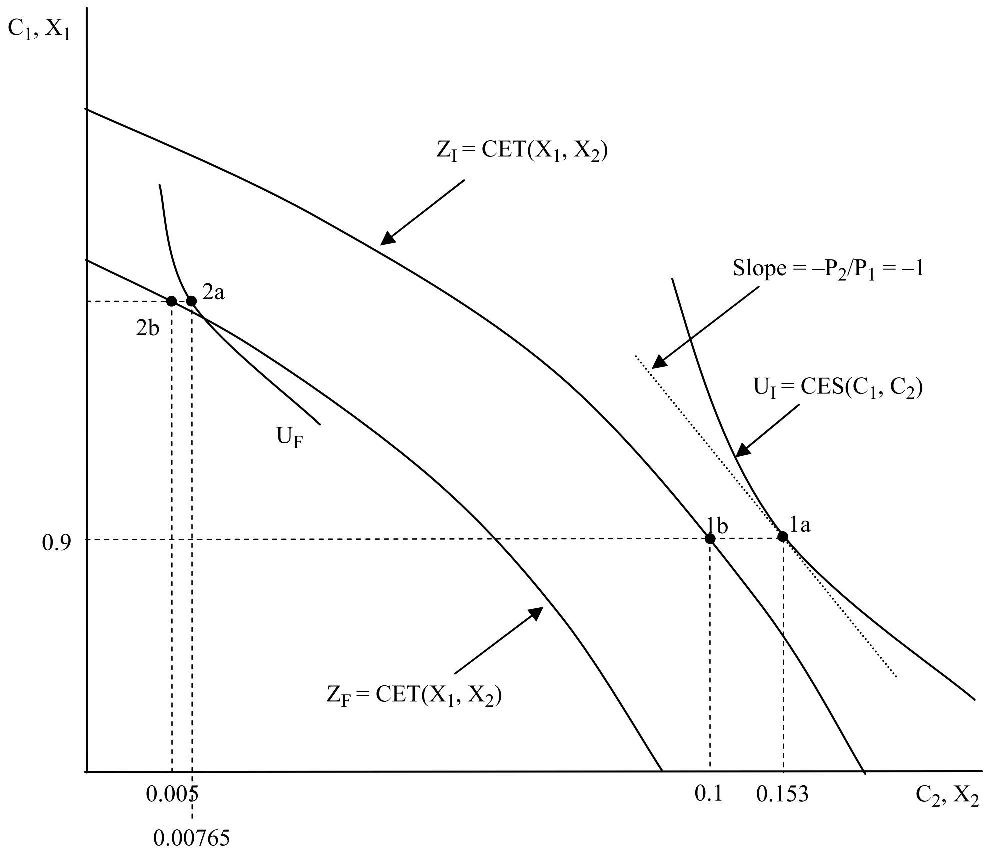

FIGURE 1 A 95% reduction in exports and imports in the BOTE model

[9] USAGE is an adaptation of the MONASH model (Dixon and Rimmer, 2002). Prominent applications of USAGE include USITC (2004, 2007) and Dixon and Rimmer (2004, 2009).

and a constant-returns-to-scale production function. Consumer demands are modeled via a representative utility-maximizing household. Units of new industry-specific capital are formed as cost minimizing combinations of construction, machinery and other capital goods. Imperfect substitutability between imported and domestic varieties of each commodity is modeled using the Armington CES specification. Export demand for any given US commodity is inversely related to its foreign-currency price. Capital accumulation is specified separately for each industry. An industry's capital stock at the start of year $t+1$ is its capital at the start of year t plus its investment during year t minus depreciation. Investment during year t is determined as a positive function of the expected rate of return on the industry's capital.[10]

A USAGE simulation of the effects of a shock (such as border closure) requires two runs of the model: a business-as-usual run and a perturbed run. The business-as-usual run is intended to be a plausible forecast, while the perturbed run generates deviations away from the forecast caused by the shock under consideration.

Because of their size and complexity, multi-purpose CGE models such as USAGE cannot be fully described in a journal-length article. Fortunately, for understanding results from such models, a complete description is unnecessary. A tradition has developed in the CGE literature of supplementing results from a full-blown CGE model with those from a back-of-the-envelope model.[11] An effective back-of-the-envelope model for a particular application is transparent enough to allow readers to understand and assess the results from the full-blown model without requiring them to embark on the impractical task of working through copious documentation. The supplementary model for our USAGE simulations of border closures is BOTE, set out in the previous subsection.

3.2. Simulation Design

We conduct five border closure simulations, each with the same business-as-usual run but with a different perturbation run. In all perturbation runs, borders are substantially closed in 2006 and reopened in 2007. As summarized in Table I, the perturbation runs differ in their assumptions concerning mining imports (mainly oil), strategic reserves and employment.

In simulations 1 to 3, mining imports are restricted by 95% in the closure year, the same as all other imports. In simulations 4 and 5, the 95% restriction applies to all imports except mining. In all simulations, the trade deficit is reduced by 95%. Thus, exports are reduced by 95% in simulations 1 to 3 but by smaller percentages in simulations 4 and 5. Having the same trade deficit in all perturbation runs facilitates comparison of welfare effects. In addition to the cuts in trade, in all simulations we impose a cessation of immigration in 2006. Immigration

TABLE I USAGE border closure simulations: assumptions

Simulation	*Mining imports*	*Strategic reserves*	*Real wage rates*
1	Restricted	Not used	Sticky
2	Restricted	Used	Sticky
3	Restricted	Used	Flexible
4	Allowed	Not used	Sticky
5	Allowed	Not used	Flexible

[10] The investment specification for the MONASH model, adopted in USAGE, is discussed in detail in Dixon *et al*. (2005).

[11] Early efforts at explaining CGE results via back-of-the-envelope models can be found in Dixon *et al*. (1982, 1984). A more recent example is Adams (2005).

recommences in 2007 but labor supply is permanently reduced by about 0.4%, reflecting the lost immigrants from 2006.

In simulations 2 and 3 we assume that the US draws down its strategic petroleum reserve, which is currently worth approximately two month's of oil imports. In simulation 1, the strategic reserve is not used. Similarly in simulations 4 and 5 the strategic reserve is not used but in these simulations it is largely irrelevant because mining imports are unrestricted.

In simulations 1, 2 and 4 we adopt the normal USAGE specification for movements in wage rates. Under this specification, wage rates in perturbation runs adjust in a sticky fashion to the rate of unemployment. If the rate of unemployment in the perturbation run moves above (below) its business-as-usual path then real wage rates decline (increase) relative to their levels in the business-as-usual run. However, wage movements in the perturbation run are not sufficient to immediately force the unemployment rate back onto its business-as-usual path. In the perturbation runs of simulations 2 and 5, wage rates are fully flexible and the unemployment rate remains on its business-as-usual path.

Results from the five simulations are presented in Table II for the border closure year, 2006, the reopening year, 2007 and the long run, which we take to be 2013. All of the results are percentage deviations from the business-as-usual run. For example, the first result in the table implies that the border closure reduces employment in 2006 by 48.1% relative to its level in the business-as-usual run.

3.3. Results from Simulation 1

Why does employment fall so sharply in the perturbation run of simulation 1? The 95% reduction in availability of imports sharply increases their price in the US and also the price of import-competing US products. Industries in the US relying on imported inputs and import substitutes suffer cost increases. This reduces the value to these industries of employing an extra worker; that is, at the initial level of employment there is a reduction in the net value (net of the cost of intermediate inputs) of the marginal product of labor. In USAGE, as in most other CGE models, it is assumed that the net value of the marginal product of labor is equal to the wage rate. With cost increases, this equality can only be restored by either a reduction in real wage rates or a reduction in employment that allows the marginal product of labor to increase. Under the sticky real wage assumption in simulation 1, the scope for wage reduction is limited. Thus, most of the adjustment is via a fall in employment.

Because returns to labor represent about 70% of GDP, the 48.1% reduction in employment in the closure year in simulation 1 directly reduces GDP by about 34% (= 0.7×48.1). However, the total reduction in GDP is 49.0%. The extra 15 percentage points reflect inefficiencies caused by the replacement of imports by higher-cost domestic products. The percentage decline in GNE in the closure year is slightly greater than that in GDP (52.3% compared with 49.0%). This reflects the assumed improvement in the balance of trade (a 95% reduction in the deficit).

The last column of Table II shows BOTE results for the effects of border closures on utility, which is a CES function of consumption of goods 1 and 2. Utility in BOTE is equivalent to real GNE in USAGE. In generating the BOTE result corresponding to simulation 1, we introduced the USAGE result for employment and imposed a 34% reduction in the BOTE variable X_0. We also introduced the USAGE result for the reduction in mining imports to GDP and imposed this in BOTE as a reduction in X_3/X_0. The utility or real GNE result from BOTE is close to the USAGE result for the closure year (−52.5% compared with −52.3%) indicating that the BOTE depiction of a border closure is an adequate description of how a border closure works in the full-blown USAGE model.

TABLE II The effects of a border closure (% deviations from business-as-usual forecast)

	USAGE results			
	2006	*2007*	*2013*	*BOTE results*
Simulation 1				
Employment	–48.1	1.3	–0.4	
Capital stock	0.0	–6.2	–3.6	
Real GDP	–49.0	–0.5	–1.0	
Real wage	–8.9	–3.7	–1.0	
Real GNE	–52.3	0.7	–0.1	–52.5
Real investment	–69.5	1.8	1.1	
Import volumes	–95.3	1.6	–2.1	
Export volumes	–95.3	–9.2	–10.3	
Simulation 2				
Employment	–37.6	1.2	–0.4	
Capital stock	0.0	–5.1	–3.8	
Real GDP	–40.4	–0.3	–1.1	
Real wage	–8.2	–3.4	–1.7	
Real GNE	–43.2	0.6	–1.0	–42.6
Real investment	–56.1	0.5	–2.1	
Import volumes	–95.3	0.4	–3.8	
Export volumes	–95.3	–7.5	–5.4	
Simulation 3				
Employment	–0.4	–0.4	–0.4	
Capital stock	0.0	–1.9	–4.1	
Real GDP	–26.9	–0.5	–1.0	
Real wage	–57.9	0.3	–0.7	
Real GNE	–27.0	–0.2	–1.7	–23.8
Real investment	–15.6	–3.1	–4.6	
Import volumes	–95.3	–2.4	–3.9	
Export volumes	–95.3	–6.9	0.1	
Simulation 4				
Employment	–12.8	0.8	–0.4	
Capital stock	0.0	–4.3	–3.2	
Real GDP	–19.3	–0.4	–0.9	
Real wage	–3.2	–2.5	–1.1	
Real GNE	–24.8	0.2	–1.0	–21.0
Real investment	–50.2	0.4	–1.9	
Import volumes	–84.0	0.7	–2.1	
Export volumes	–76.9	–4.9	–2.5	
Simulation 5				
Employment	–0.4	–0.4	–0.4	
Capital stock	0.0	–3.5	–2.6	
Real GDP	–11.3	–1.1	–0.8	
Real wage	–11.4	–1.1	–0.6	
Real GNE	–17.3	–0.3	–0.7	–13.4
Real investment	–43.1	–0.4	–1.3	
Import volumes	–82.1	0.5	–1.7	
Export volumes	–73.9	–5.5	–2.7	

It might seem surprising that the BOTE model closely reproduces the USAGE result for GNE. Superficially, the theoretical structure of USAGE is quite different from that of BOTE. USAGE has neither a bottleneck function nor an economy-wide transformation frontier. However, in USAGE the role of the bottleneck function is played by the Armington specification, which ensures that a scarcity of imported inputs inhibits domestic production. At the same time, an economy-wide transformation frontier is implicit in USAGE because each industry has a specific factor (capital) that is fixed in the short run. Thus, in USAGE, a shift in production from commodity *i* to commodity *j* is achieved at a diminishing marginal rate of transformation.[12]

Beyond the closure year, USAGE implies rapid recovery. Simulation 1 shows a positive deviation for employment in 2007 (1.3%). The wage reduction in 2006 leaves the US in a highly competitive position in 2007 so that once the restrictions on trade are removed employment overshoots. Despite the increase in employment, GDP remains 0.5% below its business-as-usual path. This reflects the reduction in capital (6.2%). Capital in 2007 is below its business-as-usual path because the border closure has a sharply negative effect (–69.5%) on investment in 2006. With low wages in 2007, rates of return are high, stimulating investment. Strong investment in 2007 strengthens the US exchange rate and crowds out exports (–9.2%). Wages remain below their business-as-usual path out to 2013 and investment continues to crowd out exports. Employment moves a little below its business-as-usual path (0.4%). This reflects a permanent loss in labor supply imposed in 2006 with the one-year cessation of immigration.

3.4. Results from Simulations 2 to 5

Comparison of the simulation-2 results with those for simulation 1 shows that drawing on strategic petroleum reserves (equivalent to two months of mining imports) has a valuable damage-limiting effect. Rather than reducing employment, GDP and GNE by around 50% as in simulation 1, in simulation 2 the border closure reduces these variables in 2006 by around 40%.

In simulation 3, the damage to the economy in 2006 from border closure is further reduced by introducing enough wage flexibility to allow maintenance of the baseline level of employment (apart from the lost immigration). However, the results in simulation 3 are disturbing in two ways. First, the real wage reduction required for maintenance of employment is huge, 57.9%. This would be extremely difficult to achieve, indicating that with a comprehensive border closure, high levels of unemployment would be almost inevitable. Second, even with maintenance of employment, the reduction in GDP in 2006 is 26.9%. On the basis of simulation 1, it might have been expected that simulation 3 would show a GDP reduction of only about 15%: this was the contribution to GDP reduction in simulation 1 of inefficiencies caused by the replacement of imports by higher-cost domestic products. The availability of imports in the perturbation run of simulation 3 is the same as that in simulation 1 (imports are cut by 95% in both cases). However, with more employment and higher GDP, imports are even scarcer in simulation 3 than in simulation 1. Thus, in simulation 3 the inefficiency effect is more serious than in simulation 1.

Simulation 4 underlines the importance of the status of bottleneck imports in determining the damage of border closure. Even with sticky wages and considerable unemployment, the damage is limited to about 20% of GDP or 25% of GNE if the closure does not encompass mining imports. The damage falls to about 11% of GDP or 17% of GNE in simulation 5 in

[12] In the short run, marginal costs are increasing in each industry implying that more units of commodity *i* must be given up to get successive extra units of commodity *j*.

which mining imports are allowed and employment is maintained. With no restriction on mining imports, the wage reduction required to maintain employment is a relatively manageable 11.4%.

Beyond 2006 the results for simulations 2 to 5 are like those in simulation 1. They imply rapid recovery and small long-run effects.

The BOTE results for real GNE in simulations 2 to 5 continue to be close to the USAGE results. As for simulation 1, we generated the BOTE results for simulations 2 to 5 by using 0.7 times the USAGE percentage-change result for employment to move the BOTE variable X_0. In simulations 4 and 5 where mining imports were unrestricted we left X_3/X_0 equal to one in the BOTE calculation. In simulations 2 and 3 mining imports were restricted by 95% but this was partially mitigated by the use of strategic reserves accounting for one-sixth of a year's supply of mining products. Thus, we imposed in BOTE a reduction in X_3 of 78.3% [=100×(0.95–1/6)].

5. CONCLUDING REMARKS

In this paper we used a CGE model to investigate five border-closure scenarios. The most restrictive involved cutting all imports by 95% under a labor-market regime of sticky real wages. In these circumstances, a one-year closure of US borders generates a reduction in real GDP of 48%. We find that restrictions on the import of certain commodities contribute disproportionately to this dramatic result. These commodities, which we label 'bottleneck imports', are characterized by the absence of readily available domestic alternatives. The most prominent example is energy. In our simulations with USAGE, we found that the mining commodity possesses the characteristics of a bottleneck import. A draw-down in domestic inventories of two-month's worth of the mining import (mainly oil) alleviated the GDP impact of border closure by 8 percentage points. Exempting mining imports from the policy altogether alleviated the GDP impact of border closure by 30 percentage points. The real GDP contraction can be reduced further if workers accept real wage cuts. Combined with exemption of mining imports, an 11.4% reduction in the average real wage rate limits the real GDP reduction of border closure to 11.3%.

In generating these results we used a detailed CGE model, USAGE, but in explaining them we relied largely on a small transparent back-of-the-envelope model, BOTE. We are sometimes asked why we need both types of models. The answer reflects our CGE process. First we run the detailed model. Then we try to figure out why we got the results we did. Towards this objective we often build a model of the detailed model; that is, we build a BOTE model. Our BOTE models vary across applications. In the present paper we found that the behavior of the full-blown model in border-closure simulations is consistent with that of a three-commodity model in which: commodity 1 is a domestically produced commodity used entirely in domestic absorption; commodity 2 is an imported commodity that is 'produced' by devoting resources to export activities; and commodity 3 is a bottleneck import, scarcity of which inhibits domestic production. This BOTE model is small enough to be presented in a journal article and tells us quite accurately what is going on in the full-blown model. Of course, we could not have built the BOTE model in the absence of the full-blown model: the BOTE model emerges from our efforts to understand the mechanisms that drive the results in the full-blown model. Nor would it be possible, having built the BOTE model, to throw away the full-blown model. The full-blown model remains essential for two reasons. First, it explains the calibration of the BOTE model and second it produces a much wider range of results.

Results of the type described in this paper can be an input to the 'cost' side of a border-closure cost-benefit calculation. Given the great cost of a general closure policy, our results highlight the importance of limiting the scope of a closure. In particular, the roles of bottleneck imports and strategic reserves should be recognized. Just as we have done for the mining commodity in this paper, a model like USAGE can be used to calculate the value of strategic reserves of other commodities in an environment of a border closure.

Previous studies of comprehensive border closure rely on input–output techniques. Relative to the input–output approach, we found that CGE modeling offers a flexible framework for capturing both bottleneck and labor-market affects. This is not to suggest that CGE modeling is without limitations. When we simulate the effects of a dramatic shock such as border closure, there must be considerable doubt about the appropriateness of behavioral assumptions and parameters that were worked out from data largely reflecting business-as-usual conditions. For example, our CGE simulations make no allowance for increased transactions costs associated with the development of black markets and criminal activity. Nor have we allowed for likely policy reactions such as attempted bail-outs for trade-oriented businesses that would face bankruptcy. Finally, our analysis is for a one-year closure. This is rather an extreme case and is dictated by the one-year periodicity of the USAGE model. While these caveats should be kept in mind, our analysis suggests that the costs of a prolonged border closure could be much greater than was previously indicated on the basis of input–output analysis.

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