A dynamic macroeconomic analysis of NAFTA

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On December 8, 1993, President Clinton signed into law the North American Free Trade Agreement Implementation Act. The United States' action was soon followed by Canada and Mexico and the North American Free Trade Agreement (NAFTA) came into force on January 1, 1994. NAFTA represents the first far-reaching free trade agreement between major industrial countries and a developing country. Throughout the development of NAFTA, there was intense domestic debate about the desirability of pursuing expanded trade ties within North America.

From the U.S. perspective, one of the foremost objectives of NAFTA was to ensure that Mexico would lock in the economic and political reforms it has instituted since 1985. These reforms have created a more predictable business environment for U.S. exporters and investors. The U.S. negotiators believed that the agreement would also benefit the U.S. economy by accelerating Mexico's trade liberalization process and give U.S. exporters and investors increased access to Mexico's growing marketplace.

Canada hopes NAFTA will improve its access to the Mexican market. NAFTA avoids separate U.S. agreements with Canada and Mexico. Canadian negotiators realized that trade reforms between the U.S. and Mexico (along the lines of the U.S.–Canada Free Trade agreement [CFTA] signed in 1989) would affect Canada's share of the North American market whether Canada participated in NAFTA or not. Canadian officials believed that by joining NAFTA, Canada would be better positioned to keep what it achieved through the CFTA and to take advantage of closer economic ties with the growing Mexican marketplace.

For Mexico, NAFTA offered an opportunity to lock in the extensive market-oriented policy reforms of the late 1980s. Mexico hoped to gain credibility for its reform process and encourage foreign investment in Mexican industry and trade. At the same time, Mexico viewed NAFTA as a means of reducing the threat of U.S. protectionism and further enhancing export opportunities in the U.S. and Canadian markets. Mexico also anticipated greater access to U.S. and Canadian technology and capital.

In its most basic form, the trilateral agreement will eliminate all tariffs and significantly reduce nontariff barriers (NTBs), such as quotas and import licenses, between the U.S., Canada, and Mexico. Tariff duties will be phased out in stages over a period of 15 years, with the majority of tariff reductions taking place within ten years. In addition to tariff reform, there are three broad agreements on NTBs. First, all countries will eliminate prohibitions and quantitative restrictions applied at the border, such as quotas and import licenses. Second, the three countries have agreed not to impose new user fees and to phase out existing

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user fees by June 1999. Third, NAFTA will permit eligible businesspeople to bring in the tools of their trade, such as professional samples and other goods, on a duty free basis. NAFTA also includes investment provisions that reduce the barriers to capital flows between the parties.

One of the costs of a limited-participation free trade area is that agreements like NAFTA must develop rules of origin that define which goods are entitled to preferential tariff treatment. As such, goods that are wholly produced in the U.S., Canada, or Mexico will qualify for NAFTA treatment. Most goods containing nonagricultural components will qualify, if those goods are sufficiently transformed in the NAFTA region that the ultimate article undergoes a specified change in tariff classification. In some cases, NAFTA establishes set percentages of North American content in addition to the tariff classification requirement.

NAFTA adds to the worldwide trend toward regional trade agreements, which is no doubt related to the General Agreement on Tariffs and Trade (GATT). Over its long history, GATT has fostered and achieved a lowering of trade barriers across most countries/regions. These gains have largely been achieved through the efforts of a small number of influential participants that actively sought free trade. In recent years, the number of players has increased, which has made it harder to achieve the type of consensus of the early GATT days. Regional preferential trading arrangements are seen by many as a natural outgrowth of the GATT process. In contrast to GATT, regional trading groups are typically smaller and better able to deal with a narrow, but very difficult trade liberalization agenda. Moreover, limited participation in a free trade group makes monitoring less costly for all participants. The architects of regional trade agreements argue that the long-term objective of regional free trade is a union of these regions that would ultimately lead to global free trade.

Although NAFTA has been in place for more than two years, it is too early to gauge the long-run impact of its far-reaching trade liberalization program. The short-run impact of NAFTA is also difficult to gauge, since accurate measurement of its short-run effects would require disentangling cyclical features not directly related to NAFTA from those that are driven by NAFTA. At this time the only guide to the short- and long-run impact of NAFTA is analysis involving quantitative models of international trade. In this article, I study the impact of NAFTA on the three North American economies and a composite of their trading partners. My results suggest NAFTA will lead to welfare gains for all North American participants, with the greatest gains accruing to Mexico.

My analysis differs from earlier trade liberalization analysis along one important dimension.[1] In contrast to earlier research which works exclusively with *static* trade models, I work within the framework of a *dynamic* model of North American trade. The dynamic approach overcomes three weaknesses of traditional static analyses. First, static models limit the world supply of capital to that available in the pre-liberalization steady state. Therefore, welfare and output gains associated with free trade come from a reallocation of capital across sectors and countries in a static model. Static models ignore the fact that capital accumulation is more efficient under free trade and, therefore, understate the potential welfare and output gains that accrue from trade liberalization. In a dynamic model, production gains flow from greater investment in capital and a reallocation of these factors across sectors and countries. Through simulations of the dynamic model developed in this article, I show that removing trade barriers does indeed lead to greater North American capital accumulation, which in turn leads to output gains that are roughly twice as large as those predicted by static models.

Second, traditional static trade models rule out trade in financial assets by restricting current account balances to zero. International capital flows serve three basic purposes: 1) by trading international assets, agents can achieve a higher level of welfare by maintaining smooth consumption paths, while undertaking major capital investment and sectoral reallocation of factors following trade liberalization; 2) international capital flows allow for more rapid adjustment to the new policy environment; and 3) by trading international assets, agents can achieve a more efficient allocation of resources across countries. I depart from static analyses by allowing countries/regions to trade financial assets internationally. Simulation results suggest that in the long run, there is a sizeable inflow of capital to the Mexican economy, largely from countries outside North America.

Finally, static models limit the analysis of free trade agreements to a comparison of long-run equilibria (or steady states)—specifically, a comparison of the pre-liberalized economy with the liberalized economy after it settles to its new long-run equilibrium. These models offer no estimate of the length of time it takes to get to the new steady state or the path of adjustment. Dynamic models provide this information. Simulations of my dynamic trade model suggest that the adjustment to NAFTA will be virtually completed by the free trade date of 2004. Moreover, the model suggests that the transition to the NAFTA steady state will be characterized by smooth output, trade, and expenditure paths.

Quantifying NAFTA

There is an extensive quantitative literature on regional free trade agreements and NAFTA. Typically, authors use computable general equilibrium (CGE) models.[2] It is difficult to incorporate NTBs in these models, so researchers use so-called tariff-equivalent measures of NTBs in their quantitative analysis (that is, the level of tariff protection that yields the same levels of output and trade as the NTB). Table 1 provides an overview of Roland-Holst, Reinert, and Shiells' (1992) estimates of the levels of tariff and tariff-equivalent NTB protection that existed in 1988 prior to the signing of the CFTA and NAFTA. Tariff-equivalent NTBs greatly exceed explicit tariff levels, which suggests that NTBs represent the highest barrier to free trade. NAFTA calls for the removal of all North American trade barriers. My results show that the gains from the removal of NTBs under NAFTA far outweigh the gains from removing explicit tariffs.

NAFTA followed the signing of a far-reaching CFTA in 1989, which was designed to eliminate all trade barriers between Canada and the U.S., described in table 1. Therefore, I model NAFTA as the joint free trade agreement between Canada and Mexico and between the U.S. and Mexico. In practical terms, NAFTA involves the removal of barriers to 1) Mexican exports to Canada and the U.S. and 2) Canadian and U.S. exports to Mexico. As the majority of tariff reductions will take place within ten years,

TABLE 1

Levels of protection in North America prior to implementation of CFTA and NAFTA

Tariff rates

Primary products

Importer	Exporter: Canada	Mexico	U.S.	ROW
Canada		0.01	0.01	0.00
Mexico	0.00		0.02	0.00
U.S.	0.01	0.01		0.01

Nondurable manufactured goods

Importer	Exporter: Canada	Mexico	U.S.	ROW
Canada		0.18	0.07	0.14
Mexico	0.04		0.05	0.10
U.S.	0.04	0.05		0.10

Durable manufactured goods

Importer	Exporter: Canada	Mexico	U.S.	ROW
Canada		0.04	0.02	0.04
Mexico	0.01		0.03	0.02
U.S.	0.01	0.03		0.03

Composite protection rates (tariffs and NTBs)

Primary products

Importer	Exporter: Canada	Mexico	U.S.	ROW
Canada		0.20	0.61	0.27
Mexico	0.80		0.81	0.72
U.S.	0.61	0.88		0.77

Nondurable manufactured goods

Importer	Exporter: Canada	Mexico	U.S.	ROW
Canada		0.68	0.34	0.44
Mexico	0.78		0.41	0.47
U.S.	0.16	0.22		0.20

Durable manufactured goods

Importer	Exporter: Canada	Mexico	U.S.	ROW
Canada		0.25	0.26	0.31
Mexico	0.01		0.13	0.22
U.S.	0.39	0.07		0.28

Notes: Roland-Holst et al. (1994) report estimates for 26 sectors. Sectoral aggregates reported in this article are weighted by 1988 import shares. ROW is rest of the world.
Source: Roland-Holst, Reinert, and Shiells (1994).

I model NAFTA as the uniform reduction of protection levels over a ten-year period (that is, protection levels are reduced by 10 percent each year), starting in the first quarter of 1994.

Model simulations begin in the period following the signing of the initial NAFTA agreement, first quarter of 1993. I conduct the NAFTA simulations as if agents in the world economy fully anticipated the path of trade liberalization described above. This assumes that agents knew at the date of the initial signing, December 17, 1992, that NAFTA would be ratified in late 1993, implemented in the first quarter of 1994, and phased in slowly over ten years.

North American trade flows

Figure 1 describes North American trade flows prior to the signing of NAFTA in 1992. There are three things to note. First, Canada–Mexico trade is quite small. Their bilateral trade accounts for 1 percent to 2 percent of their export and import baskets. Second, trade with the U.S. represents a large share of Canadian and Mexican trade (in the order of 70 percent of their import and export baskets). Finally, trade with Canada and Mexico is less important to the U.S.; more than 70 percent of U.S. trade is with countries outside North America. This primarily reflects the U.S.'s considerably larger size relative to its North American counterparts.

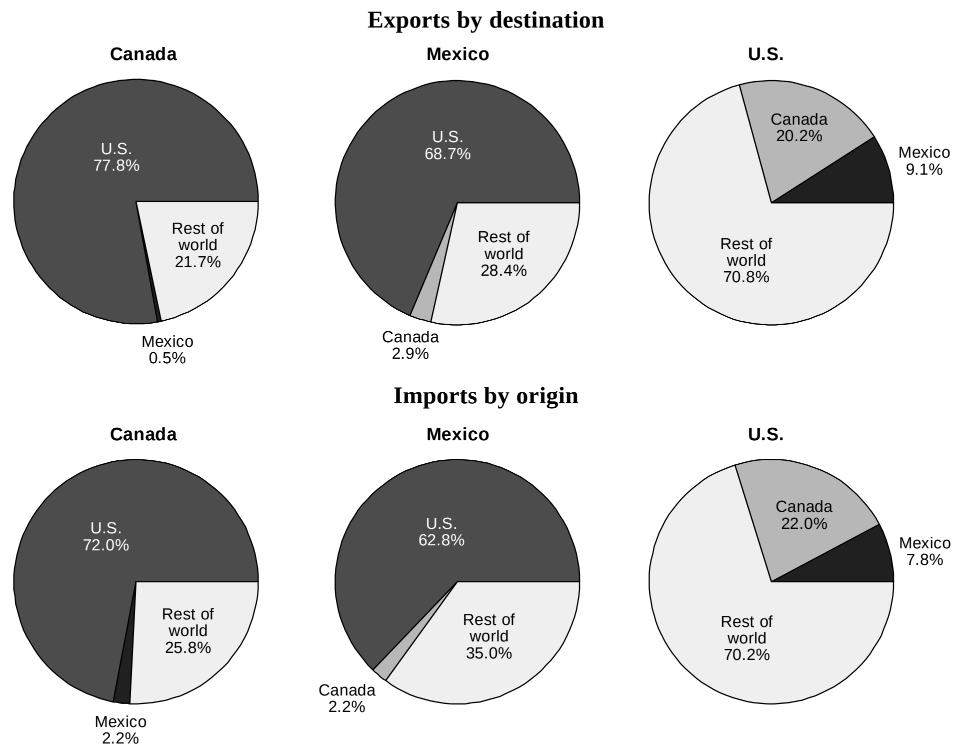
Based on these statistics, NAFTA was expected to have a small impact on the U.S. and Canadian economies and a large impact on the Mexican economy, because of Mexico's strong dependence on North American trade. Simulation results reported in this article support this conjecture.

A dynamic model of North American and world trade

The model developed in this article combines the multisector characteristics of static CGE models with the dynamic characteristics of one-sector, international real business cycle (IRBC) models.[3] Countries in the world economy are sorted into two groups. The North American countries (Canada, Mexico, and the U.S.) are modeled individually, while the

FIGURE 1

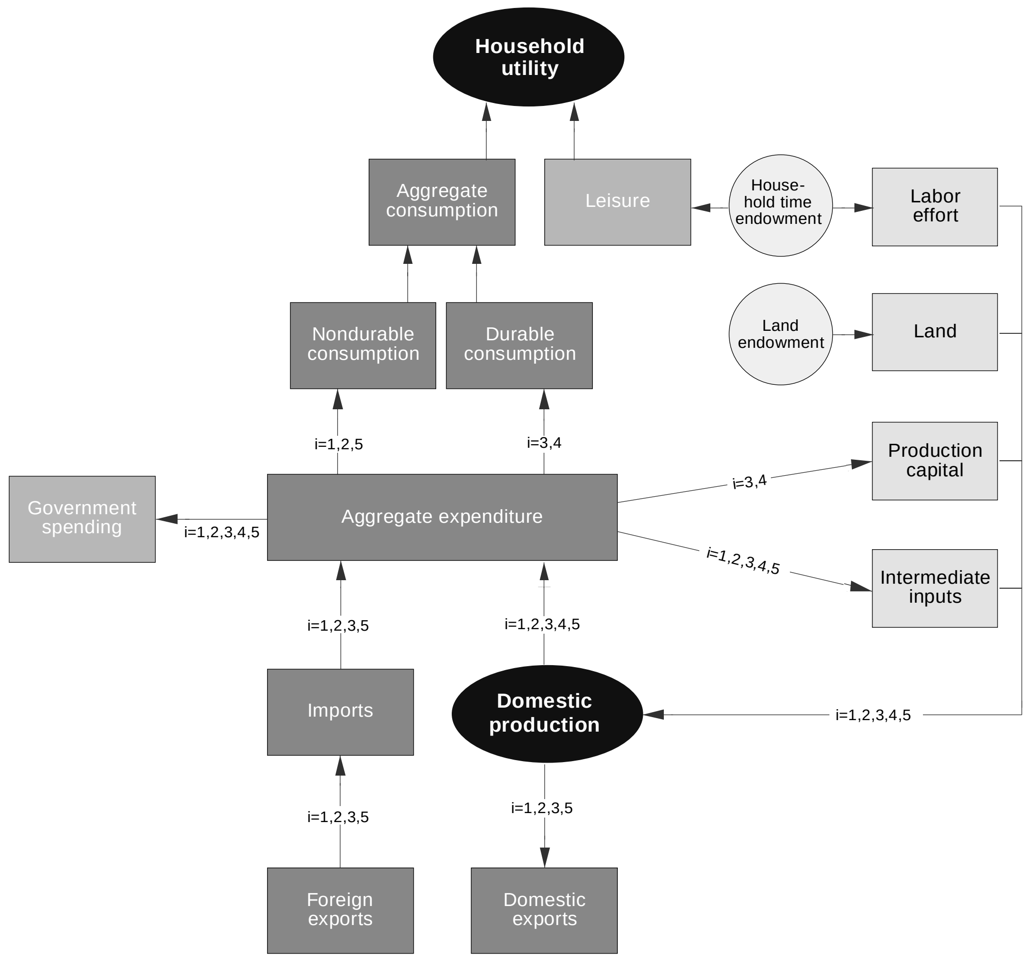
Direction of North American trade prior to NAFTA (1992)



Source: International Monetary Fund, *Direction of Trade Statistics: Yearbook*, Washington, DC: IMF, 1994.

FIGURE 2

Model flow diagram for a representative country



Notes: i denotes industry—primary, i=1; nondurable manufacturing, i=2; durable manufacturing, i=3; construction, i=4; services, i=5.

remaining countries are consigned to a residual rest of the world (ROW) aggregate. All countries, including the ROW, are fully specified, in the sense that production, consumption, work effort, and trade decisions are the result of well-defined optimization problems. The inclusion of a fully specified ROW avoids the need for ad hoc residual ROW supply and demand equations and ensures endogenous determination of all prices and quantities.

Figure 2 provides a summary of the domestic and international goods and factor flows in the model (a detailed description of the model is provided in the appendix). Each country/region has five production industries: primary raw materials, nondurable manufactures, durable manufactures, construction, and services. Output in all sectors is described by a production function that has two basic inputs. The first factor of production is the value-added component, which reflects that part of output attributable to primary factors of production, such as capital, labor, and land. The other factor of production is an aggregate intermediate component, which represents the volume of goods consumed in the production of other goods. For example, nondurable manufacturing goods, such as food, require the input of primary raw materials, such as grains.

The model assumes households in the world economy have a fixed endowment of time, which they can consume as leisure or supply to the market in the form of labor services in return for a wage. Labor is mobile between sectors within in a country, subject to small adjustment costs, but immobile internationally.

Households are also assumed to have an endowment of land. Land only enters the model as an important factor of production in the primary sector. The supply of land is held fixed throughout the policy experiments.

There are two types of investment goods in the model. The first is durable capital goods that gradually depreciate over time. Capital goods are either used as inputs in the production of goods or household durable services. Production capital and household durable investment is a composite of equipment and structures. Equipment is produced in the durable-manufacturing sector, while structures are produced in the construction sector. Capital is mobile between sectors within a country and across countries, subject to small adjustment costs.

The second investment goods category is intermediate goods, which are held as inventories and completely consumed in the production of future goods. Empirical evidence (see Ramey [1989] for details) suggests intermediate goods require one quarter to put in place. The time period in the model is quarterly, so I assume that period $t + 1$ intermediate inputs are produced in period t. All sectors produce intermediate goods, so the aggregate intermediate goods component that appears in the production function is a composite of goods from all five sectors.

The model allows for trade between all three North American countries and the ROW. Construction is the only nontraded good. Private final expenditure on a given good is an aggregate of all imports of that good and domestically produced levels of that good. These aggregates are then broken up into four final expenditure components: consumption, investment, government spending, and intermediate goods. Using this aggregation procedure, I limit the number of expenditure goods to five and the number of output goods to five. The difference is that the output good is country specific, while the expenditure aggregate is a composite of output from all four trading areas.

Each country/region has a government that imposes explicit tariffs on imported goods in proportion to their value. I take the standard approach of imposing tariff-equivalent NTBs. Therefore, all barriers to trade are in the form of tariffs. The tax revenue from the tariff and the quota rents from the NTBs are rebated by lump-sum payments to households. For simplicity, I assume the government levies a lump-sum tax to finance its current spending on goods. Real government spending is held constant throughout the policy simulations.

Each country/region is assumed to have a single infinitely lived representative household, whose objective is to maximize its expected lifetime utility. Households in all countries/regions derive utility from consuming a composite consumption good and leisure. The composite consumption good is an aggregate of nondurable consumption goods, such as food and the flow of services from household durables like transportation services. In particular, nondurable consumption is an aggregate of goods from the primary, nondurable manufacturing, and service sectors.

The representative households in all four countries/regions own all productive inputs, labor, capital, and land. Each period, the households rent these productive inputs to the various firms in the same economy. Firms produce all five goods and sell the output to the households. For simplicity, I assume that the only financial assets available to the households are noncontingent one-period bonds. The competitive world equilibrium is described by the processes for capital, labor, consumption, and investment and their associated prices, which satisfy the representative households' optimization problems and the world resource constraints. I follow Baxter and Crucini's (1995) approach to solving dynamic trade models, in which foreign assets are restricted to one-period bonds. In general, it is not possible to generate an analytical solution for this class of model, so their methodology uses numerical techniques to solve for the model's dynamic equilibria. Specifically, the log-linear approximation technique advanced in the real business cycle literature by King, Plosser, and Rebelo (1988, 1990).

Model calibration

The model's parameters must be defined before I can apply numerical solution methods. Direct estimation of all the model's parameters is ruled out because there is insufficient international data to estimate all preference, production, and trade parameters. Researchers working with static multisector, multicountry CGE models have overcome this problem using so-called model calibration (see, for example, Shoven and Whalley, 1992). More recently, this approach has been extended to dynamic models of international trade. Calibration essentially involves two steps. First, the researcher chooses a set of elasticities that describe the degree of substitution in consumption, production, and trade. Second, given this set of elasticities, the researcher chooses weighting terms in preference, production, and trade aggregation functions, so that the model's steady state corresponds to a specific point in time. In this case, the model's base year or pre-liberalization steady state is assumed to be 1992, when the three countries signed the initial NAFTA proposal.

Household preference parameters are based on national accounts data from each country/region and parameters widely used in the IRBC literature (see Backus, Kehoe, and Kydland [1995] and Baxter [1995] for surveys of this literature). I set the parameters of the model's production functions using U.S. manufacturing sector cost function estimates from Ramey (1989) and the most recent input–output tables for Canada, Mexico, and the U.S. Because the ROW is dominated by major industrial countries, such as Japan and Germany, which have similar input–output tables to the U.S., the ROW production function is calibrated to U.S. input–output data.

Following Baxter and Crucini (1993), I set the parameters defining the capital adjustment cost function so that: its steady state value is equal to the steady state ratio of investment to capital; in the steady state, *Tobin's q* (the ratio of the price of existing capital to the price of new capital) is one; and the elasticity of sectoral investment–capital ratios with respect to their sectoral *Tobin's q* is consistent with relative sectoral and aggregate investment volatility levels. I measure relative investment volatility using sectoral investment data (see Kouparitsas, 1996, for details). The sectoral labor adjustment cost functions are calibrated in a similar fashion. The primary sector has the highest adjustment costs, which is consistent with the view that primary capital and labor tend to be industry specific.

The trade aggregation parameters are calibrated to match the trade flow statistics described in figure 1. For comparability with earlier static analyses, I set the level of pre-liberalization protection in my model to match Roland-Holst et al.'s estimates reported in table 1. These estimates were constructed using trade aggregation functions calibrated to match estimates from Shiells and Reinert (1993) for Canada and the U.S. and Sobarzo (1994) for Mexico. I maintain consistency between the protection rates and trade aggregation functions by adopting Canadian, Mexican, and U.S. elasticities of substitution between home and imported goods to match Shiells-Reinert's and Sobarzo's estimates. There is a wide range of estimates used in the literature, so the sensitivity analysis section addresses the model's sensitivity to this parameter choice.

Measuring the impact of trade liberalization

Below, I report the results of simulations of the quantitative North American trade model under three trade liberalization scenarios. The first experiment looks at a limited North American free trade agreement (LNAFTA), in which I remove only the explicit tariffs between Canada, Mexico, and the U.S. The second experiment examines the removal of all North American tariffs and NTBs (NAFTA). The third scenario focuses on another limited trade liberalization agreement, which involves only Mexico and the U.S., a hub and spoke arrangement (HASP).[4] The U.S. is the hub, having free trade agreements with Canada and Mexico, while Canada and Mexico are the spokes, each having a free trade agreement only with the U.S. The HASP is implemented by lowering barriers to Mexican imports in the U.S. and to U.S. imports in Mexico.

Welfare analysis

Table 2 describes the long-run effects of the LNAFTA, NAFTA, and the HASP. I calculate the welfare implications of the free trade agreements using the compensating variation measure from tax analyses of Cooley and Hansen (1989) and McGrattan (1994). Following McGrattan, I define δ_{ck} as the solution to the following problem:

$$1)\quad u(\bar{c}_k(1+\delta_{ck}), \bar{h}_k) = u(\tilde{c}_k, \tilde{h}_k)$$

where u is the representative household's momentary utility function, and $(\bar{c}_k, \bar{h}_k)$ and $(\tilde{c}_k, \tilde{h}_k)$ are country k's representative household's respective steady state levels of consumption and leisure in the pre-liberalization and liberalized environments. By calculating δ_{ck}, I can determine the percentage change in pre-liberalization steady state consumption ($\bar{c}_k$), that would make households in country k indifferent to the

TABLE 2

Long-run effects of competing North American trade liberalization schemes
(percentage deviation from pre-NAFTA steady state)

Variable	LNAFTA Canada	LNAFTA Mexico	LNAFTA U.S.	LNAFTA ROW	NAFTA Canada	NAFTA Mexico	NAFTA U.S.	NAFTA ROW	HASP Canada	HASP Mexico	HASP U.S.	HASP ROW
Welfare (CV)	–0.02	0.15	0.03	–0.00	0.01	0.96	0.12	0.01	0.10	0.86	0.11	0.01
Real GDP	0.02	0.52	0.03	0.00	0.11	3.26	0.24	0.01	0.02	3.10	0.24	0.01
Real consumption	0.00	0.38	0.04	0.00	0.08	2.52	0.25	0.01	0.09	2.35	0.24	0.01
Labor hours	0.02	0.29	0.01	0.00	0.07	1.99	0.14	0.00	–0.02	1.90	0.14	0.00
Real wage	0.00	0.37	0.03	0.00	0.09	2.12	0.25	0.01	0.08	1.98	0.24	0.01
Capital investment	0.01	0.90	0.06	0.00	0.16	5.05	0.37	0.01	0.09	4.80	0.36	0.01
Real rental rate	0.00	–0.32	–0.02	–0.00	–0.03	–1.44	–0.03	–0.00	–0.03	–1.37	–0.02	0.00
Total imports	0.04	1.45	0.17	0.01	0.29	12.47	1.40	0.14	0.14	11.76	1.37	0.12
Exports to world	0.08	1.79	0.14	0.03	0.37	13.87	1.46	0.02	–0.04	13.29	1.46	0.03
to Canada		4.76	–0.05	–0.04		20.49	–0.02	–0.14		1.42	0.15	0.05
to Mexico	1.31		2.16	0.29	18.63		19.10	1.24	0.90		18.72	0.87
to U.S.	0.08	2.20		0.02	0.22	18.28		–0.04	–0.05	18.50		–0.03
to ROW	0.06	0.13	–0.01		0.23	0.22	0.13		–0.04	0.43	0.12	
Terms of trade	–0.07	–0.24	0.04	0.01	–0.15	–0.72	–0.04	0.17	0.15	–0.99	–0.07	0.15
Net foreign assets/GDP	0.35	–1.26	–0.04	0.04	1.30	–8.09	–0.14	0.26	0.50	–6.57	–0.14	0.25

Notes: LNAFTA is a limited North American free trade agreement. HASP is a hub and spoke arrangement.

liberalized steady state ($\tilde{c}_k$, $\tilde{h}_k$). In other words, $\bar{c}_k\delta_{ck}$ measures the amount of additional consumption you would have to give the household in the pre-liberalized environment to make it as well off as under the liberalized environment.

The compensating variation in consumption required to leave households indifferent between the initial steady state and the LNAFTA steady state is 0.15 percent for Mexico, 0.03 percent for the U.S., and small and negative for Canada and the ROW. This suggests that removing explicit tariffs slightly raises the welfare of Mexican and U.S. households, but leads to a negligible loss of welfare in Canada and the ROW.

In the middle panel, I calculate the welfare implications of NAFTA. The compensating variation in consumption required to leave households indifferent between the initial steady state and the NAFTA steady state is 0.96 percent for Mexico, 0.12 percent for the U.S., 0.01 percent for Canada, and 0.01 percent for the ROW. Based on these results, NAFTA leads to welfare improvements for all participants.

Finally, the right panel describes the effects of a HASP arrangement, in which the U.S. and Mexico negotiate a bilateral trade agreement that excludes Canada. Mexico's welfare gain under the HASP is lower than under NAFTA, while the U.S.'s is roughly unchanged. In contrast, Canada's gain under the HASP is larger than under NAFTA, reflecting NAFTA's negative impact on Canada's terms of trade. Under NAFTA, Canada's terms of trade deteriorate by 0.15 percent, while under the HASP, Canada's terms of trade improve by 0.15 percent. This result highlights the important role of relative price movements in determining the individual country gains from trade liberalization.[5] I elaborate on this point in my discussion of unilateral trade liberalization.

The welfare analysis in this article is not directly comparable to the welfare calculations from static trade models. In general, static analyses do not include leisure as a component of household utility. However, these models typically allow for variable labor effort or endogenous labor supply responses. This explicitly ignores the loss of welfare a household suffers from additional labor effort (less leisure time) and implicitly raises the level of the welfare gain associated with trade liberalization. For example, static models surveyed here typically report welfare improvements that are roughly twice as large as those reported for the dynamic model. This is despite the fact that the dynamic model generates output and consumption increases that are roughly twice as large as those of static analyses.

Aggregate effects of trade liberalization

Table 2 shows that the three liberalization scenarios lead to an expansion of output, investment, consumption, labor hours, and trade in all three North American economies. NAFTA generates the largest expansion of the North American region, with Mexico enjoying the largest expansion within the region. Under NAFTA, Mexico's steady state gross domestic product (GDP) is predicted to rise by 3.26 percent. Underlying this increased output is greater capital accumulation and increased labor effort. This expanded output is also reflected in increased steady state consumption of 2.52 percent and double-digit increases in export and import volumes. The model predicts NAFTA will also lead to capital inflows to Mexico. Over the simulation period, Mexico's ratio of net foreign assets to GDP falls by 8 percentage points. It is clear from table 2 that the Mexican capital inflows are largely driven by capital flows from the ROW. NAFTA has a smaller impact on the U.S., with U.S. steady state GDP rising by 0.24 percent. U.S. trade is predicted to rise by about 1.5 percent over the steady state level. Given the small volume of Mexican–Canadian trade, it is not surprising that NAFTA has a negligible impact on the Canadian economy, with steady state output expected to rise by 0.11 percent. According to the model, NAFTA will have a negligible impact on the ROW.

Although there is a wealth of quantitative research on NAFTA, studies are not directly comparable because they generally consider different policy experiments. My model's calibration draws on the parameters used in Roland-Holst et al. (1992, 1994), which makes their study a logical static benchmark for my dynamic analysis. However, Roland-Holst et al. take a somewhat broader view by allowing NAFTA to include the CFTA. Brown, Deardorff, and Stern (1992), Cox and Harris (1992), Cox (1994), and Sobarzo (1992, 1994) define NAFTA in roughly the same way as this article. Brown et al. is a static CGE analysis, in which North America is fully modeled as in this article. Cox-Harris and Sobarzo use partial equilibrium models, fully modeling Canada and Mexico, respectively, but closing the model by employing rest-of-the-world demand and supply equations.

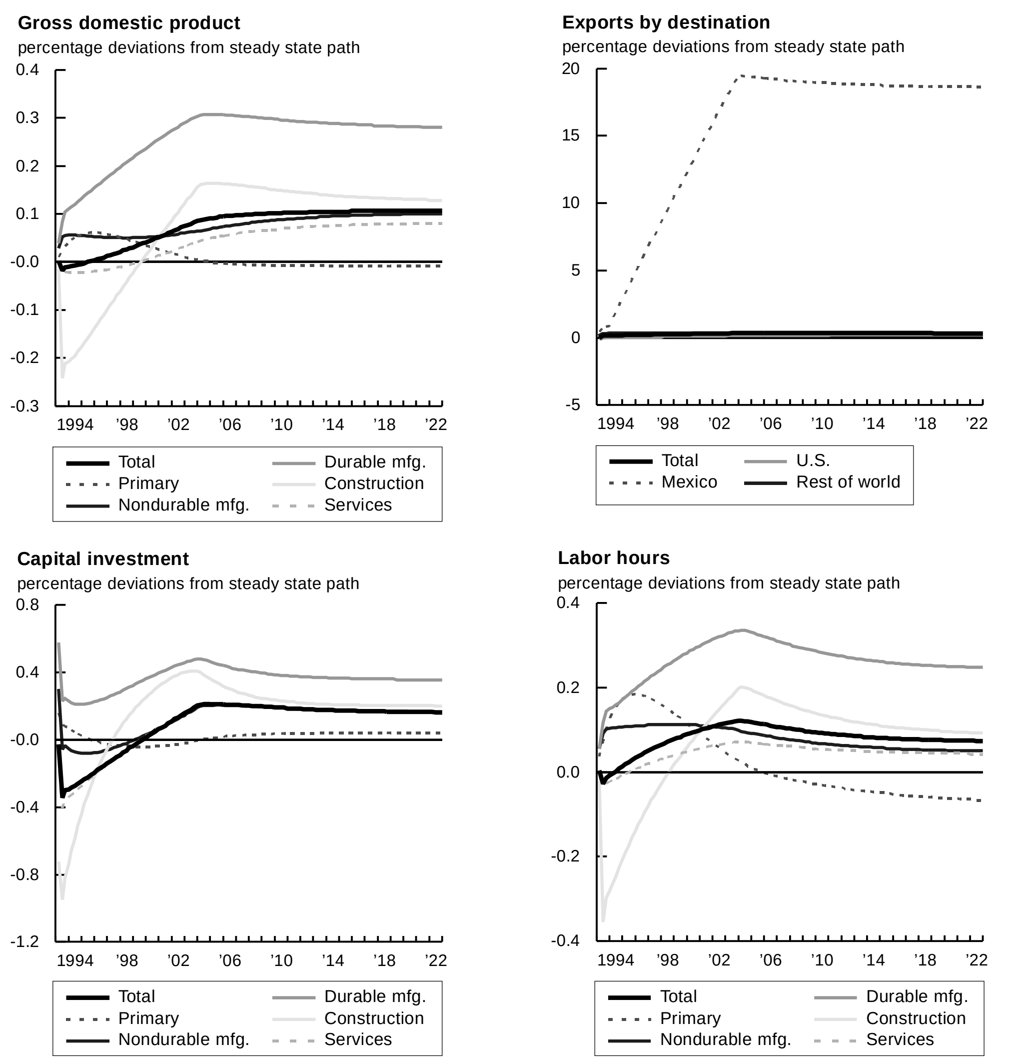
Brown et al. (1992) find, as I do, that NAFTA has a large impact on the Mexican economy, but a negligible impact on the Canadian, U.S., and ROW economies. Their static model predicts that Mexican steady state GDP will rise by 2.2 percent and that Canadian and U.S. steady state GDP will be 0.1 percent higher following NAFTA. All three estimates are below those predicted by my dynamic trade model. Cox and Harris (1992) and Cox (1994) focus on the effects of NAFTA and a HASP on the Canadian economy. Cox-Harris find that NAFTA and the HASP have a negligible impact. Their results are similar to mine, in that NAFTA stimulates greater real activity than the HASP. Under the assumption of fixed capital stocks and a zero current account, Sobarzo's (1992, 1994) model predicts NAFTA will raise Mexican steady state GDP by 1.7 percent. This is roughly half the change predicted by my dynamic model. Overall, the direction of change predicted by the static and dynamic models following NAFTA is the same. However, the predicted size of the impact is roughly twice as large in the dynamic model. This is because the static models limit the world capital stock to its pre-NAFTA level and rule out international capital flows. Greater capital accumulation in the dynamic model explains roughly two-thirds of the change in North American steady state output. For example, Mexico's steady state GDP is predicted to rise by roughly 3 percent of its pre-NAFTA level. Changes in Mexico's capital stock alone explain roughly 2 percent of this change, while increased labor effort accounts for the remaining 1 percent.

Sectoral effects of NAFTA

Figures 3–5 describe in much greater detail the paths of adjustment of each of the North American economies under NAFTA. One striking feature of these figures is that the adjustment to NAFTA is virtually complete by the free trade date, 2004. Agents in this model know the exact path of the NAFTA program one year before its implementation in 1994. Households in all countries/regions desire smooth consumption paths and this is achieved by responding to the anticipated changes in NAFTA before its implementation date. All nonprimary sectors (nondurable manufacturing, durable manufacturing, construction, and services) are predicted to expand in Canada and the U.S. in the long run. Canada's response to NAFTA is to temporarily shift factors from nontraded to traded sectors in the early years and boost traded goods production. U.S. sectors respond more smoothly, with all nonprimary sectors expanding over the period. In

FIGURE 3

Effects of NAFTA on Canadian economy



Source: Model simulation.

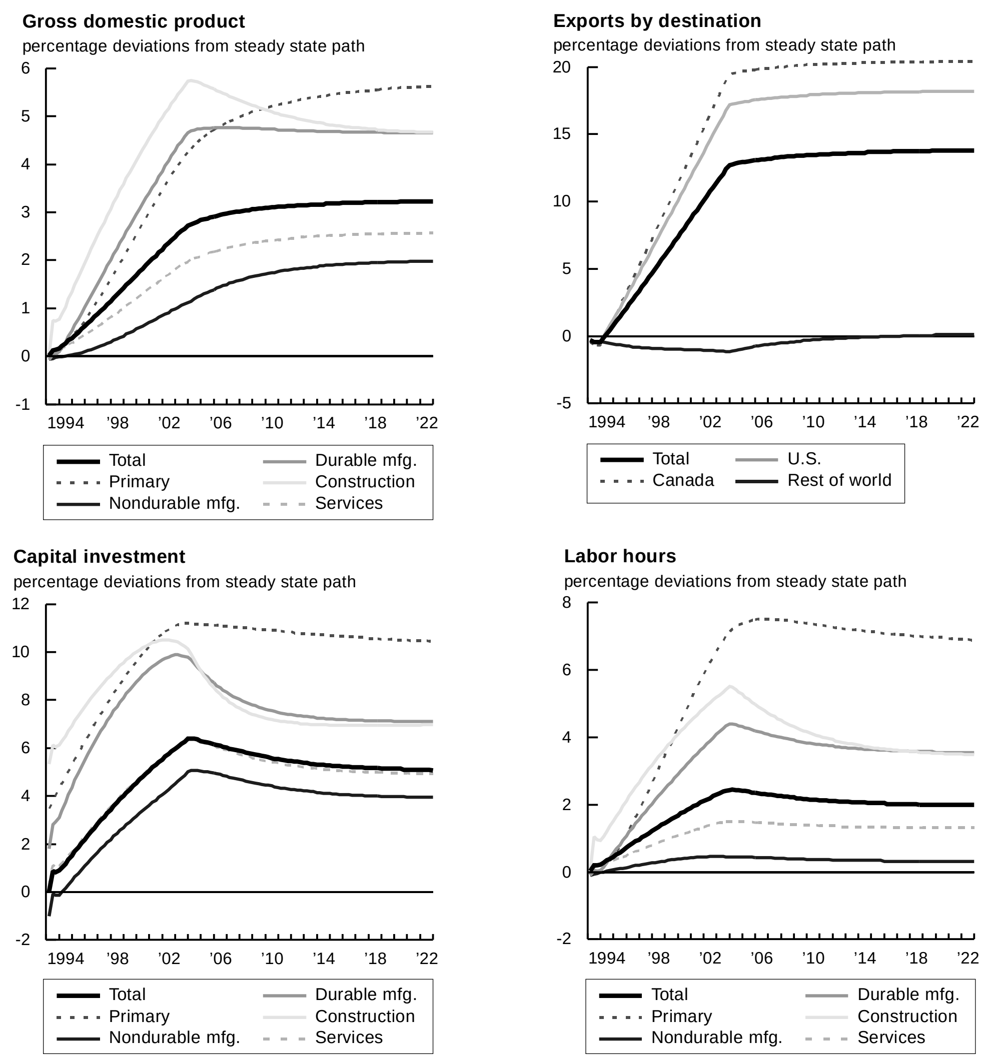
contrast to its northern partners, Mexico's primary sector is expected to expand under NAFTA. Mexico's response is much like that of the U.S., in that all sectors expand over the course of the adjustment to free trade. Sectoral changes in labor hours and capital investment tend to mimic changes in sectoral GDP.

NAFTA greatly expands the flow of all goods from Canada and the U.S. to Mexico and from Mexico to the U.S. and Canada. In general, bilateral Mexican–North American trade is predicted to increase by about 20 percent. In contrast, the model predicts NAFTA will have a negligible impact on bilateral trade flows between the U.S. and Canada and between North America and the ROW. The expansion of North American trade is distributed across all traded goods sectors. Primary goods flows expand by roughly twice as much as manufactured goods flows. For example, Mexican primary goods exports rise by roughly 20 percent of their pre-NAFTA level, while Mexican manufactured goods exports rise by roughly 10 percent of their pre-NAFTA level.

Sectoral comparisons between my work and the static studies cited above are complicated by the fact that my model is highly aggregated in comparison to these static analyses. Specifically, Brown et al.'s (1992) model has 29 sectors, while the models of Cox and Harris

FIGURE 4

Effects of NAFTA on Mexican economy



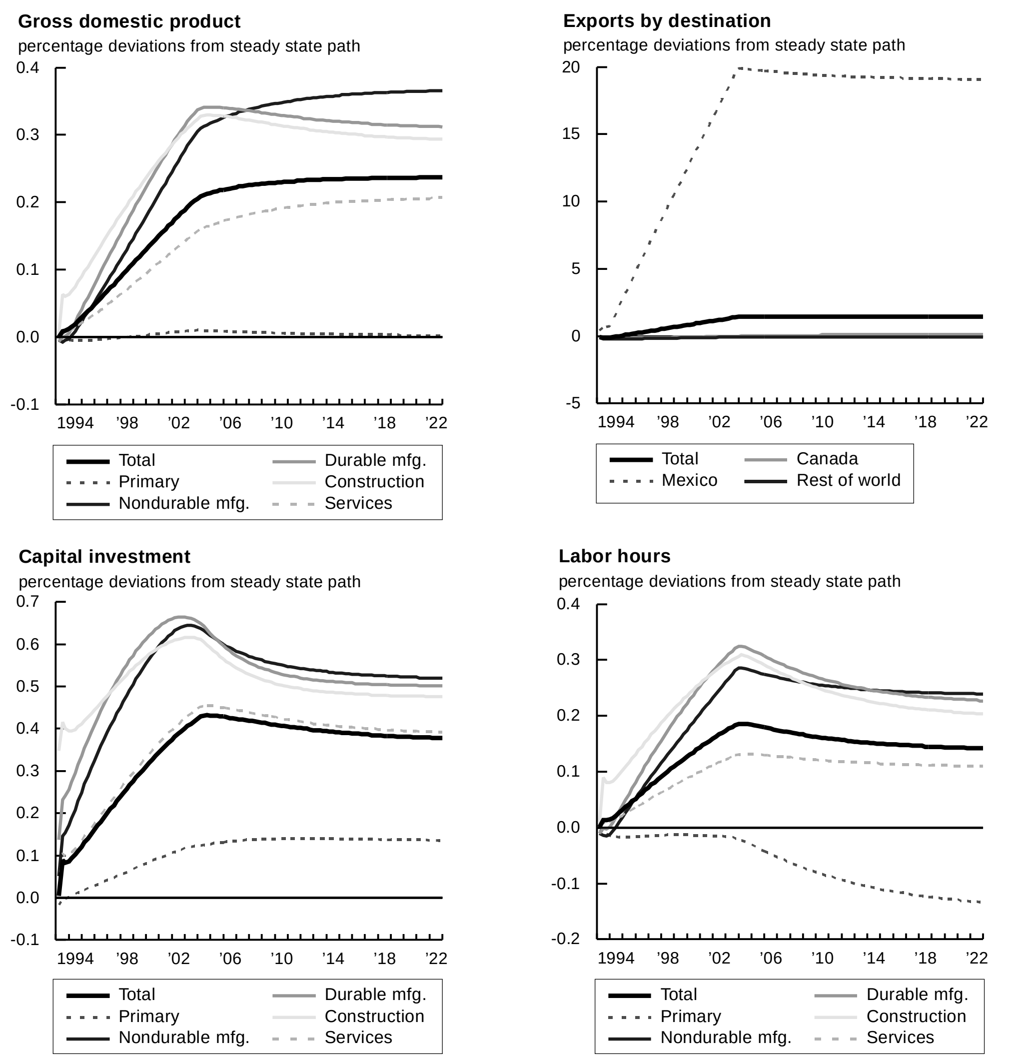
Source: Model simulation.

(1992), Cox (1994), and Sobarzo (1992, 1994) have 19 sectors. The Cox-Harris and Sobarzo models predict an expansion of all Canadian and Mexican sectors under NAFTA. In contrast, Brown et al. find that all Canadian and U.S. sectors expand under NAFTA, but only a few major industries expand in Mexico. Aggregating their results to the level of the dynamic model, I find similar directions of change, but the changes are typically larger than in the static models.

Static models hold the stock of world capital fixed, so production gains flow in part from the reallocation of capital across sectors and countries. In a dynamic model, production gains flow from greater investment in capital and a reallocation of these factors across sectors and countries. Static models make different assumptions about the supply of labor, ranging from perfectly inelastic supply to perfectly elastic supply. Brown et al. and Cox-Harris assume the former, while Sobarzo assumes the latter. Sobarzo's model appears to generate its increased output in large part through greater supply of effort and a minor reallocation of capital. The dynamic model displays some sectoral reallocation of labor and capital in the short run, although it is negligible compared with the long-run sectoral reallocations in the static models.

FIGURE 5

Effects of NAFTA on U.S. economy



Source: Model simulation.

The economics of trade liberalization

This section addresses a number of policy experiments that are designed to shed light on the mechanisms at work in the North American trade model.

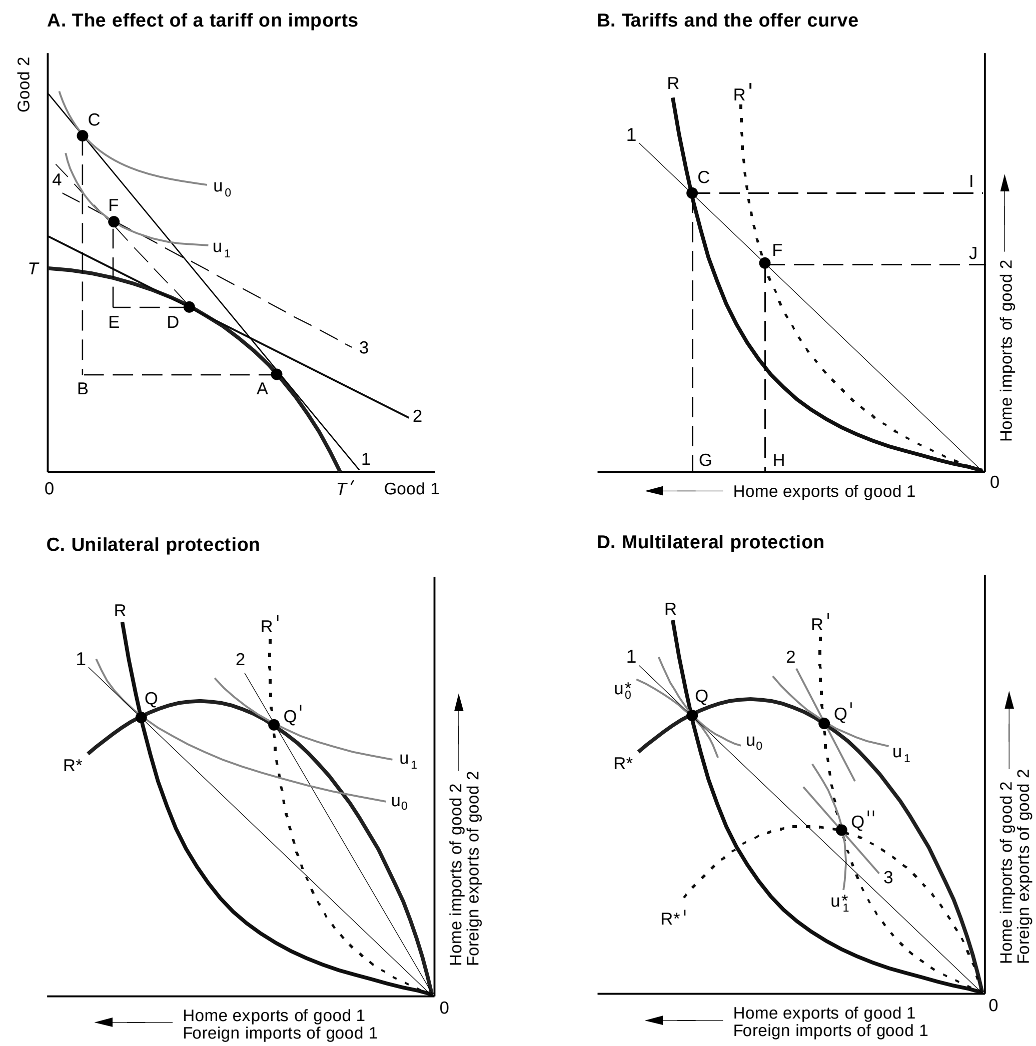
Basic tools of analysis

Classic trade theory provides some insight into the economics behind the results of the previous section.[6] Figure 6 develops the basic tools of analysis. The analysis is simplified by assuming that there are two countries, home and the foreign country. Each country produces two goods, denoted goods 1 and 2. The home and foreign varieties of goods 1 and 2 are assumed to be perfect substitutes. Without loss of generality, the home country is assumed to be an exporter of good 1 and an importer of good 2 (vice versa for the foreign country).

Panel A of figure 6 displays the home country's production, consumption, and trade decisions for goods 1 and 2, given world terms of trade of $p1/p2$ (where $p1$ denotes the price of good 1 and $p2$ denotes the price of good 2), in the free trade and tariff-ridden cases. In free trade, the home country faces a relative price of $p1/p2$. At these prices, production occurs at point A, where the home country's *production frontier*, TT', is tangent to a line of slope $p1/p2$ (line 1). Free trade consumption is at point C, where the home country's *indifference curve*,

FIGURE 6

The effect of trade barriers in a simple two-good, two-country model



u_0, is tangent to its budget constraint (line 1). At these terms of trade, the home country exports *AB* of good 1 and imports *BC* of good 2. Panel B of figure 6 describes trade patterns using an *offer curve*, which essentially summarizes the home country's optimal trade bundles for given terms of trade. For example, in free trade the home country's offer curve is *OR*. At the given world terms of trade $p1/p2$, the home country exports *OG* (=*AB* in panel A of figure 6) and imports *OI* (=*BC* in panel A of figure 6).

Consider what happens to the offer curve when the home country imposes a tariff at rate τ on imports of good 2. The home country's effective relative price of good 1 falls to $p1/(1+\tau)p2$.

Home production shifts from *A* to point *D* (in panel A of figure 6), where the home country's production frontier, *TT′*, is tangent to a line of slope $p1/(1+\tau)p2$ (line 2). This encourages greater domestic production of good 2. Line 4 is parallel to line 1, and shows combinations of goods 1 and 2 that have the same value at world prices as the production point, *D*. The home country's consumption bundle must lie along line 4; specifically it must lie at *F* where indifference curve u_1 has slope equal to the domestic price ratio (line 3 is parallel to line 2). The volume of trade falls under the tariff. Exports of good 1 fall from *AB* to *DE*, while imports of good 2 fall from *BC* to *EF*. The tariff has also lowered domestic welfare from the u_o curve to u_1. This is a well-known result in trade theory. A country that has influence over the price of its traded goods can be made better off when it imposes a tariff on its importable goods, but a small economy that faces given world prices for its traded goods is unambiguously made worse off when it imposes a tariff on its importable goods. In panel B of figure 6, this new trade bundle is represented by a point like *F* on the *tariff-ridden offer curve* OR′. At given terms of trade, the home country exports *OH* (=*DE* in panel A of figure 6) and imports *OJ* (=*EF* in panel A of figure 6). It is important to note that the home country's tariff-ridden offer curve always lies to the right of its free trade offer curve.

The effect of imposing a tariff in the home country

Panel C of figure 6 displays the solution to a simple, static two-good, two-country model, where the home and foreign countries have some influence over the world price of their traded goods. I consider this case because Mexico and Canada are small countries in the dynamic model but the product differentiation assumption allows them to influence the world price of their traded goods. *OR* and *OR** describe the home and foreign country's offer curves before they impose tariffs on the exports of the foreign and home goods. The free trade equilibrium occurs at the point where the offer curves intersect, *Q*. The home country's free trade terms of trade are shown by the slope of line 1. Assume that the home country imposes a tariff on the foreign country's exports. The home country tariff shifts its offer curve to *OR′*, with the new equilibrium at *Q′*, where the home country's tariff-ridden offer curve intersects the foreign country's free trade offer curve. This improves the home country's terms of trade, which are shown by the slope of line 2. The home country is better off at the new equilibrium since it has moved from indifference curve u_0 to u_1. The foreign country is made worse off by the home country's tariff.

Foreign country retaliation

Panel D of figure 6 describes the case where the foreign country retaliates to the home country's imposition of a tariff by imposing a tariff on home-country exports. The underlying economic environment is the same as in panel C. The home country initially imposes a tariff on foreign exports that shifts its offer curve from *OR* to *OR′* and the equilibrium from *Q* to *Q′*. The foreign country retaliates by imposing a tariff on home exports that shifts its offer curve from *OR** to *OR*′* and the world equilibrium from *Q′* to *Q″*. At the new equilibrium, *Q″*, both countries are worse off than they were under free trade, *Q*, but the removal of their own tariff would leave them worse off relative to *Q″*. Given that the foreign country will maintain its tariff, it is optimal for the home country to maintain its tariff (and vice versa).

Unilateral trade liberalization in the dynamic model

Table 3 shows the results of various unilateral trade liberalizations in the dynamic trade model (note, I solve the model using a log-linear technique, so the sum of the three unilateral trade liberalizations equals the total effect of the trilateral NAFTA). In the left panel, I report the model's response to a reduction in the level of protection on imports of Mexican goods in Canada. The middle panel considers

TABLE 3

Long-run effects of unilateral liberalization
(percentage deviation from pre-NAFTA steady state)

	Removal of barriers to Mexican exports in Canada				Removal of barriers to North American exports in Mexico				Removal of barriers to Mexican exports in U.S.			
Variable	Canada	Mexico	U.S.	ROW	Canada	Mexico	U.S.	ROW	Canada	Mexico	U.S.	ROW
Welfare (CV)	**–0.16**	0.19	0.01	0.00	0.13	**–2.74**	0.35	–0.05	0.04	3.50	**–0.24**	0.06
Real GDP	**0.06**	0.16	0.00	0.00	0.05	**0.69**	0.13	–0.01	–0.00	2.41	**0.11**	0.01
Real consumption	**–0.07**	0.23	0.01	0.00	0.12	**–1.50**	0.32	–0.04	0.03	3.79	**–0.07**	0.05
Labor hours	**0.09**	0.04	–0.00	–0.00	–0.01	**1.58**	–0.03	0.02	–0.01	0.36	**0.17**	–0.01
Real wage	**–0.05**	0.20	0.00	0.00	0.11	**–1.18**	0.27	–0.03	0.02	3.11	**–0.02**	0.04
Capital investment	**–0.03**	0.37	0.01	0.00	0.17	**–1.43**	0.44	–0.06	0.02	6.11	**–0.08**	0.07
Real rental rate	**0.04**	–0.14	–0.01	–0.00	–0.07	**1.21**	–0.17	0.04	–0.01	–2.51	**0.15**	–0.04
Total imports	**0.03**	0.67	0.02	0.03	0.23	**1.28**	1.21	–0.39	0.03	10.52	**0.16**	0.50
Exports to world	**0.39**	0.28	0.00	–0.01	0.03	**10.72**	–0.05	0.17	–0.05	2.87	**1.51**	–0.14
to Canada		18.64	–0.28	–0.30		**11.36**	–0.20	0.62		–9.52	**0.46**	–0.45
to Mexico	**1.04**		0.66	0.67	7.20		7.76	–9.71	10.39		**10.67**	10.27
to U.S.	**0.38**	–0.52		–0.02	0.13	**11.00**		0.74	–0.30	7.80		–0.76
to ROW	**0.40**	–0.50	0.02		–0.60	**9.80**	–0.79		0.43	–9.08	**0.90**	
Terms of trade	**–0.45**	0.63	0.02	0.03	0.25	**–12.69**	1.65	–0.41	0.05	11.35	**–1.71**	0.55
Net foreign assets/GDP	**1.56**	–2.75	–0.00	0.00	–0.88	**39.27**	–2.34	0.05	0.62	–44.60	**2.20**	0.21

a reduction in the level of protection on imports of Canadian and U.S. goods in Mexico; and the right panel looks at a reduction of protection on Mexican exports to the U.S. Four basic results emerge from these experiments. First, unilateral liberalization makes the liberalizing country worse off. This suggests that, given that its trading partners maintain their trade barriers, it is optimal for the liberalizing country to maintain its trade barriers. Second, the liberalizing country's trading partners are made better off by its trade liberalization program. Third, the liberalizing country's terms of trade worsen following liberalization. Finally, the liberalizing country's exports and imports rise with the lowering of its trade barriers.

Using the tools developed in the previous section, I can shed some light on the mechanisms at work in the more complicated dynamic model. Using panel D of figure 6, I analyze the effects of a unilateral liberalization, in which the foreign country removes its tariff on the home country's exports. Tariff elimination raises the foreign country's relative price of its exportable good (good 2). Under the liberalization, the foreign country's optimum lies on its free trade offer curve, OR^*, so Q'' is no longer the equilibrium. This creates excess demand for the home exportable good and excess supply for the foreign exportable. The new equilibrium, Q' (where the home tariff-ridden and foreign free trade offer curves intersect), lowers the foreign country's terms of trade (shown by the shift from line 3 to line 2) but increases the volume of trade. However, the deterioration in the terms of trade outweighs the increase in trade volumes and the foreign country's real income/wealth falls, so it is worse off at Q', while the home country's wealth rises, so it is better off at Q'.

The loss of liberalizing country wealth is clearly reflected in the statistics in table 3. Lower wealth leads households in the liberalizing country to consume less and raise their supply of labor effort. Increased effort leads to higher domestic output. The liberalizing country responds to the wider trade gap by raising its output and lowering its levels of investment and consumption to increase exports of its traded goods. The increase in labor effort also increases the demand for capital inputs. The increased supply of labor leads to a fall in the liberalizing country's real wage, while the increased demand for capital inputs leads to a rise in the real rental rate of capital.

On the other side of the coin, the unilateral tariff reduction has the reverse implication for the liberalizing country's trading partners. The tariff reduction improves the terms of trade of the liberalizing country's trading partners and raises their wealth. Again, the statistics in table 3 support this intuition. For example, a tariff reduction in Mexico raises the wealth of Canada and the U.S., which leads to greater consumption and less labor effort. A decrease in the supply of effort raises real wages in these countries. The decreased labor effort also lowers the demand for capital inputs, while cheaper imports raise the supply of capital, which results in a fall in the real rental price of capital. Increased consumption and investment are partly satisfied by increased imports from the liberalizing country. In the other cases, Mexico's labor input rises because the increased demand for labor, stemming from the increased consumption demand, dominates the reduction in the supply of effort. This is reflected in the strong increases in Mexican real wages.

Multilateral trade liberalization in the dynamic model

The unilateral liberalization experiments suggest that in the pre-NAFTA equilibrium, it was optimal for the North American countries to maintain their trade barriers, given that their North American trading partners also had trade barriers. In this environment, a mutual trade liberalization agreement, such as NAFTA, is necessary for trading parties to improve their joint welfare.

Ultimately, multilateral trade liberalization leads to welfare gains for an individual country, if the losses from its own trade liberalization program are offset by gains from its trading partners' liberalization programs. For example, in panel D of figure 6, the foreign country gains from multilateral trade liberalization because the welfare loss from its own liberalization program (that is, the loss associated with the shift from Q'' to Q') is offset by the gain from the home country's liberalization program (that is the welfare gain associated with the shift from Q' to Q). Model simulations suggest that the loss of welfare associated with unilateral liberalizations is more than offset by the gains from the rest of the region's liberalization programs, so the trilateral NAFTA leads to welfare gains for all North American economies. In terms of panel D of figure 6, NAFTA represents a joint welfare improving shift from a point like Q'' to Q.

Sensitivity analysis

To what extent are the results sensitive to the parameters of the model? For the trade liberalization experiments, a key parameter is the elasticity of substitution between home and imported goods. In table 4, I report results from simulations of the model using different elasticities of substitution between home and foreign goods. In the left panel, I report the benchmark model's results (scaling coefficient is 1.0), which are the values estimated by Roland-Host and Reinert (1993) and Sobarzo (1992). In the middle panel, I double the elasticities of substitution between home and foreign goods (scaling coefficient 2.0). In the right panel, I multiply the benchmark elasticity by 3.0, which brings the model's elasticities closer to those of Brown et al.'s (1992) uniform elasticity of 3.

Table 4 shows that many of the aggregate features of the model are not sensitive to this parameter choice. The most sensitive area of the model is trade flows. The percentage increase in post-NAFTA steady state trade volumes rises dramatically with the elasticity of substitution. Specifically, in the high-elasticity case, North American trade volumes are predicted to rise by roughly twice as much as in the benchmark model following NAFTA.

TABLE 4

Long-run effects of NAFTA under different parameters
(percentage deviation from pre-NAFTA steady state)

Variable	Benchmark model (x 1.0)				Low elasticity of substitution (x 2.0)				High elasticity of substitution (x 3.0)			
	Canada	Mexico	U.S.	ROW	Canada	Mexico	U.S.	ROW	Canada	Mexico	U.S.	ROW
Welfare (CV)	0.01	0.96	0.12	0.01	0.04	1.06	0.12	0.01	0.05	0.89	0.13	0.01
Real GDP	0.11	3.26	0.24	0.01	0.10	3.71	0.24	–0.00	0.09	3.91	0.25	–0.01
Real consumption	0.08	2.52	0.25	0.01	0.10	2.81	0.26	0.00	0.10	2.77	0.26	0.00
Labor hours	0.07	1.99	0.14	0.00	0.06	2.22	0.14	–0.00	0.05	2.39	0.14	–0.01
Real wage	0.09	2.12	0.25	0.01	0.10	2.36	0.26	0.00	0.11	2.32	0.27	0.00
Capital investment	0.16	5.05	0.37	0.01	0.16	5.85	0.39	–0.01	0.15	6.08	0.40	–0.02
Real rental rate	–0.03	–1.44	–0.03	–0.00	–0.03	–1.77	–0.03	0.01	–0.03	–1.87	–0.03	0.01
Total imports	0.29	12.47	1.40	0.14	0.42	23.18	2.47	–0.02	0.55	33.43	3.52	–0.14
Exports to world	0.37	13.87	1.46	0.02	0.43	24.97	2.60	–0.15	0.52	36.14	3.74	–0.37
to Canada		**20.49**	–0.02	–0.14		**38.48**	–0.22	–0.24		**56.69**	–0.43	–0.39
to Mexico	**18.63**		**19.10**	1.24	**35.43**		**36.28**	0.96	**51.79**		**52.99**	0.23
to U.S.	0.22	**18.28**		–0.24	0.11	**33.82**		–0.21	0.01	**49.45**		–0.40
to ROW	0.23	0.22	0.13		0.27	–2.40	0.06		0.37	–5.12	0.02	
Terms of trade	–0.15	–0.72	–0.04	0.17	–0.15	0.80	–0.06	0.00	–0.16	1.28	–0.08	–0.04
Net foreign assets/GDP	1.30	–8.09	–0.14	0.26	2.43	–31.24	–0.46	1.10	3.25	–48.28	–0.85	1.80

Underlying these figures are stronger Canada–Mexico and U.S.–Mexico trade responses. In the benchmark model, Mexican exports to Canada and the U.S. were predicted to rise by 20 and 18 percent, respectively, of their steady state level. In the high-elasticity case, these values rise to 56 and 49 percent. Canada–Mexico and U.S.–Mexico trade in the benchmark model was predicted to rise by about 19 percent of the steady state level. In the high-elasticity case, this figure rises to 52 percent.

Conclusion

NAFTA is a landmark commercial trade policy because it represents the first far-reaching free trade agreement between major industrial countries and a developing country. My results suggest that NAFTA will generate welfare gains for all North American participants, with the greatest gains accruing to Mexico. The dynamic analysis also suggests NAFTA generates real output and trade flow increases that are roughly twice as large as those predicted by previous analyses, which relied on static trade models. Sectoral analysis suggests NAFTA will lead to an expansion of all non-primary sectors in Canada, Mexico, and the U.S. In contrast, NAFTA is expected to have a negligible impact on the real output of Canadian and U.S. primary sectors but to lead to sizable expansion of primary activity in Mexico.

This article has taken the study of multilateral trade liberalization one step further by building a dynamic model of North American trade, which overcomes some of the weaknesses of traditional static analysis, such as fixed capital stocks and zero current accounts.[7]

There are two significant limitations to the current analysis that future work must address. First, the underlying growth rate of the dynamic model economy is exogenous and cannot be influenced by policy. Second, NTBs are incorporated into the numerical analysis by way of tariff-equivalent NTBs.

Future work must remove these limitations by developing dynamic trade models that allow for endogenous growth and explicit quantity constraints. Only then will we be in a position to measure the true gains from multilateral free trade agreements.

NOTES

[1]See, for example, the recent conference volumes on NAFTA by Greenway and Whalley (1992), Lustig, Bosworth, and Lawrence (1992), Francois and Shiells (1994), and survey by Kehoe and Kehoe (1994).

[2]See references in footnote 1 for examples of static computable general equilibrium models.

[3]See the surveys of Backus, Kehoe, and Kydland (1995) and Baxter (1995) for examples of one-sector, international real business cycle models.

[4]See Wonnacott (1996) for a more general discussion of hub and spoke systems.

[5]See Whalley (1984) for a thorough discussion of the terms of trade effects associated with the abolition of tariff and NTBs, in a model of North–South trade (that is, a model describing trade between industrial and developing regions of the world economy).

[6]This section draws heavily on the discussion presented in Caves, Frankel, and Jones (1990), chapters 11–15.

[7]See Kehoe (1994) for a thorough discussion of the limitations to current static analyses and the steps needed to develop a state of the art dynamic model suitable for analyzing free trade agreements.

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APPENDIX: Detailed description of North American trade model

There are four countries/regions in the model: Canada (c), Mexico (m), the United States (u), and the rest of the world (r). Each country/region has five production industries: primary raw materials (1), nondurable manufactures (2), durable manufactures (3), construction (4), and services (5). Note, countries are indexed by k and l, while industries are indexed by i and j.

Preferences

Each country k has a single infinitely lived representative household that maximizes its expected lifetime utility, U_k, from consuming a composite consumption good (c_{kt}) and leisure (h_{kt}):

$$U_k = E_0 \sum_{t=0}^{\infty} ß^t \frac{\left(c_{kt}^{\theta_{ck}} h_{kt}^{1-\theta_{ck}}\right)^{1-\sigma}}{1-\sigma} \text{ for } \sigma > 0 \text{ and } \sigma \neq 1,$$

and

$$\text{A.1)} \quad U_k = E_0 \sum_{t=0}^{\infty} ß^t \left(\theta_{ck} \ln(c_{kt}) + (1-\theta_{ck})\ln(h_{kt})\right)$$

for $\sigma = 1$ and $0 < ß < 1$, $0 < \theta_{ck} < 1$ for $\forall k$. Note, ß denotes the household's subject rate of time discount. Consumption is an aggregate of nondurable consumption goods (c_{nkt}) and the flow of services from consumer durables (d_{kt}). Nondurable goods and the durable service flow are aggregated according to a constant elasticity of substitution (CES) function:

$$\text{A.2)} \quad c_{ckt} = \left(\omega_{ck} c_{nkt}^{1-\eta} + (1-\omega_{ck}) d_{kt}^{1-\eta}\right)^{\frac{1}{1-\eta}}$$

for $0 \leq \omega_{ck} \leq 1$ and $\eta > 0$ for $\forall k$. The elasticity of substitution between nondurable consumption goods and durable services is $1/\eta$, while ω_{ck} reflects the bias toward nondurables. Nondurable consumption goods are also aggregated by a CES function:

$$\text{A.3)} \quad c_{nkt} = \left(\sum_i \omega_{cik} c_{ikt}^{1-\kappa}\right)^{\frac{1}{1-\kappa}}$$

for $0 \leq \omega_{cik} \leq 1$, $\Sigma_i \omega_{cik} = 1$ and $\kappa > 0$ for $\forall k$. The elasticity of substitution between individual nondurable consumption goods (c_{ikt}) is $1/\kappa$, while ω_{cik} reflects the bias toward nondurable good i.

Production technology

I make the standard multisector assumption that gross production in sector i (y_{ikt}) is described by a two-level CES function (see, for example, Shoven and Whalley, 1992):

$$\text{A.4)} \quad y_{ikt} = A_{ikt} \left\{\omega_{yik} va_{ikt}^{1-\varepsilon} + (1-\omega_{yik}) m_{ikt}^{1-\varepsilon}\right\}^{\frac{1}{1-\varepsilon}}$$

for $0 \leq \omega_{yik} \leq 1$, and $\varepsilon > 0$ for $\forall i, k$. The first level of production involves a value-added index (va_{ikt}) and an aggregate intermediate goods component (m_{ikt}). The value-added production index is described by Cobb-Douglas technology, which uses capital (k_{ikt}), labor (n_{ikt}^s) and land (l_{ikt}) as inputs:

$$\text{A.5)} \quad va_{ikt} = k_{ikt}^{\alpha_{ik}} n_{ikt}^{s\theta_{ik}} l_{kt}^{1-\alpha_{ik}-\theta_{ik}}$$

for α_{ik}, $\theta_{ik} \geq 0$ and $\alpha_{ik} + \theta_{ik} \leq 1$ for $\forall i, k$.

The other factor of production is the aggregate intermediate input, which is a composite of intermediate inputs from all sectors. Specifically, these factors are aggregated according to the following CES function:

$$\text{A.6)} \quad m_{ikt} = \left(\sum_j \alpha_{ijk} m_{ijkt}^{1-\varepsilon}\right)^{\frac{1}{1-\varepsilon}}$$

for $0 < \alpha_{ijk} < 1$, $\Sigma_j \alpha_{ijk} = 1$, and $\varepsilon > 0$ for $\forall i, k$. The variable m_{ijkt} denotes the flow of intermediate goods from sector j to sector i. The elasticity of substitution between value-added and all intermediate inputs in sector i is $1/\varepsilon$. A_{ikt} is an exogenous productivity shift parameter in sector i.

Investment behavior

Capital goods

There are two types of investment goods in this model. The first type is durable capital goods that depreciate at rate $0 < \delta \leq 1$. Capital goods are either used as inputs in the production of sector j goods (k_{jkt}) or as household durables (d_{kt}). Production capital (i_{jkt}) and household durable (i_{dkt}) investment is a composite of equipment (s_{3kt}) and structures (s_{4kt}). Equipment is produced in the durable-manufacturing sector and structures are produced in the construction sector. Equipment and structures are aggregated according to a constant elasticity of substitution (CES) function:

$$\text{A.7)}\quad \sum_j i_{jkt} + i_{dkt} = \left(\omega_{ik} s_{3kt}^{1-v} + (1-\omega_{ik}) s_{4kt}^{1-v}\right)^{\frac{1}{1-v}}$$

for $0 < \omega_{ik} < 1$ and $v > 0$ for $\forall j, k$. The elasticity of substitution between equipment and structures is $1/v$, while ω_{ik} reflects the bias toward equipment. Note, i_{jkt} denotes investment in sector j capital.

I assume there are costs of adjusting sectoral capital stocks in all regions. Following Baxter and Crucini (1993), I employ a concave cost of adjustment function where: $\phi_{kj}(x) > 0$, $\phi'_{kj}(x) > 0$, and $\phi''_{kj}(x) < 0$. Using this notation, I describe accumulation of sector j capital and household durables by the following:

$$\text{A.8)}\quad k_{jkt+1} = (1-\delta)\, k_{jkt} + \phi_{kj}\left(\frac{i_{jkt}}{k_{jkt}}\right) k_{jkt} \text{ for } \forall j, k$$

$$\text{A.9)}\quad d_{kt+1} = (1-\delta)\, d_{kt} + \phi_{kd}\left(\frac{i_{dkt}}{d_{kt}}\right) d_{kt} \text{ for } \forall k.$$

Intermediate goods

The second investment goods category is intermediate goods (m_{ijkt}), which are held as inventories and completely consumed in the production of future goods. The time period in the model is quarterly. Empirical evidence (see Ramey [1989] for details) suggests intermediate goods require one period to put in place. Based on this I assume period $t + 1$ intermediate inputs are produced in period t.

Trade flows

The model allows for trade between the North American countries and the rest of the world, ROW, where the ROW is a composite of Canadian, Mexican, and U.S. trading partners. Specifically, let x_{iklt} denote country k's private consumption/use of good i produced in country l. In other words, x_{iklt} denotes country k's imports of good i from country l. The private final expenditure aggregation function for good i is a CES function given by the following:

$$\text{A.10)}\quad c_{ikt} + s_{ikt} + \sum_j m_{jikt+1} = \left(\sum_{l=u,c,m,r} \omega_{ikl} x_{iklt}^{1-\mu_i}\right)^{\frac{1}{1-\mu_i}}$$

for $0 \le \omega_{ikl} \le 1$, $\Sigma_l \omega_{ikl} = 1$ and $\mu_i > 0$ for $\forall i,k$. [1] Recall c_{ikt} describes nondurable consumption of good i, s_{ikt} capital investment, and m_{jikt} the flow of intermediate goods from sector i to sector j. The elasticity of substitution between home-produced and all imported goods is $1/\mu_i$, while ω_{ikl} reflects bias toward country l's good i.

Government

Each country has a government that imposes tariffs on imported goods. The explicit tariff rate in country k for good i imported from country l is τ_{iklt}. It is difficult to model nontariff barriers (NTBs) directly, so I take the standard approach of imposing tariff-equivalent NTBs. The tariff-equivalent NTB for good i imported from country l is ρ_{iklt}. The tax revenue from the tariff and the quota rents from the NTBs are rebated by lump-sum payments, denoted by TR_{kt} and QR_{kt}, respectively. The government also levies a lump-sum tax, T_{kt}, to finance its current spending. By allowing p_{ilt} to denote the price of country l's good i in terms of the numeraire good, I can describe country k's government budget constraint:

$$\text{A.11)}\quad \sum_{l=u,c,m,r} \sum_i p_{ilt}\, g_{iklt} + TR_{kt} + QR_{kt} = \sum_{\substack{l=u,c,m,r\\ l\neq k}} \sum_i (\tau_{iklt} + \rho_{iklt})\, p_{ilt}\, x_{iklt} + T_{kt}$$

$$\text{A.12)}\quad TR_{kt} = \sum_{\substack{l=u,c,m,r\\ l\neq k}} \sum_i \tau_{iklt}\, p_{ilt}\, x_{iklt}, \text{ and}$$

$$\text{A.13)}\quad QR_{kt} = \sum_{\substack{l=u,c,m,r\\ l\neq k}} \sum_i \rho_{iklt}\, p_{ilt}\, x_{iklt}.$$

The last element of final expenditure is government spending. For simplicity I assume that the public sector has the same aggregation function as the private sector.[2]

$$\text{A.14)}\quad g_{ikt} = \left(\sum_{l=u,c,m,r} \omega_{ikl}\, g_{iklt}^{1-\mu_i}\right)^{\frac{1}{1-\mu_i}} \text{ for } \forall i, k$$

where g_{iklt} is the country k government's consumption of good i from country l. Combining these results implies $T_{kt} = \Sigma_{l=u,c,m,r} \Sigma_i\, p_{ilt}\; g_{iklt}$.

Resource constraints

The model contains two non-reproducible factors, labor (n_{ikt}) and land (l_{ikt}). Labor is mobile between sectors within a country, subject to small adjustment costs. In particular, labor services (n^s_{ikt}) are described by the following dynamic relationship:

$$\text{A.15)}\quad n^s_{ikt+1} = \phi_{ni}\left(\frac{n_{ikt+1}}{n^s_{ikt}}\right) n^s_{ikt} \text{ for } \forall i, k.$$

I assume ϕ_{ni} has properties similar to the capital adjustment cost functions (that is, $\phi_{ni}(x) > 0$, $\phi'_{ni}(x) > 0$, and $\phi''_{ni}(x) < 0$), although the actual cost of adjusting labor and capital will be different. Total hours are normalized to unity so that agents face the following labor constraints:

A.16) $1 - h_{kt} - \sum_i n_{ikt} = 0$ for $\forall k$.

Land is an important factor of production in the primary sector. The supply of land is assumed to be exogenous. The supply of land is fixed in the NAFTA experiments.

The only financial assets available to agents in country k are noncontingent one-period bonds b_{kt}. The price of these assets in terms of the numeraire good is p_{bt} (note, throughout the article I maintain ROW nondurable manufactured goods as the numeraire, $p_{2rt} = 1$). With this notation, I can describe country k's representative household's intertemporal budget constraint as:

A.17) $\sum_i p_{ikt}\, y_{ikt} + b_{kt} + QR_{kt} + TR_{kt} =$
$\sum_{\substack{l=u,c,m,r \\ l \neq k}} \sum_i (1 + \tau_{iklt} + \rho_{iklt})\, p_{ilt}\, x_{iklt} +$
$\sum_i p_{ikt}\, x_{ikkt} + p_{bt}\, b_{kt+1} + T_{kt}$, for $\forall k$.

Each regional economy is also subject to the following sectoral resource constraints:

A.18) $y_{ikt} = \sum_{l=u,c,m,r} x_{iklt} + g_{iklt}$ for $\forall i, k$.

Equilibrium and model solution

I follow Baxter and Crucini's (1995) approach to solving dynamic trade models, in which foreign assets are restricted to one-period bonds. In each country, the representative household owns all productive inputs. Each period, the household rents these productive inputs to the various firms in the same economy. Firms produce all five goods and sell the output to households in all four countries/regions. In each country/region, the representative household's dynamic optimization problem is to maximize the expected lifetime utility described by A.1, subject to the constraints given by equations A.2 to A.17. The competitive equilibrium is described by the processes for capital, labor, consumption, and investment and their associated prices, which satisfy the regional representative households' optimization problems and the resource constraints given by A.18. I use numerical techniques to solve for the models dynamic equilibria. Specifically, the log-linear approximation technique advanced in the real business cycle literature by King, Plosser, and Rebelo (1988, 1990).

[1]Differentiating goods by location is necessary to rule out complete specialization. See Baxter (1992) for a discussion of how complete specialization, along the lines of Ricardian comparative advantage, emerges in a dynamic Heckscher-Ohlin-Samuleson model where goods are not differentiated by production location.

[2]Backus, Kehoe, and Kydland (1995) make a similar assumption in a dynamic one-sector model of international trade.