The Macroeconomic Impact of NAFTA Termination

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Abstract. U.S. President Trump has threatened to leave the North American Free Trade Agreement. How much would each member country gain or lose if this threat is carried out? Would trade imbalances within the region diminish? What would the transition to new production and expenditure patterns look like? I provide quantitative answers to these questions using a dynamic general equilibrium model with a multi-sector input-output production structure, heterogeneous firms that make forward-looking export participation decisions, and adjustment frictions in trade and factor markets. Regional trade flows would fall dramatically, and while the U.S. trade deficit with Canada would decline, the deficit with Mexico would grow. Welfare would fall by 0.04%, 0.12%, and 0.2% in the United States, Canada, and Mexico, respectively, and transition dynamics would significantly affect welfare in both the short run and the long run.

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We are in the NAFTA (worst trade deal ever made) renegotiation process with Mexico & Canada.Both being very difficult,may have to terminate?

–U.S. President Donald Trump, Twitter, August 27, 2017

1. Introduction

The North American Free Trade Agreement is under threat. Shortly after taking office, U.S. President Donald Trump called the agreement "the worst trade deal in history, " blaming it for persistent U.S. trade deficits and falling

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manufacturing employment, and threatened to pull out if it could not be renegotiated to his administration's satisfaction. Although trade negotiators from the three NAFTA member countries have recently agreed upon a replacement framework, there is considerable uncertainty about whether this agreement will be passed by their legislatures, and so NAFTA termination remains a possibility. In this paper, I use a dynamic general equilibrium model to quantify the short- and long-run effects of terminating NAFTA on trade flows, welfare, sectoral reallocation, and trade imbalances.

Signed in 1992 and implemented in 1994, NAFTA created the largest free trade area the world had ever seen. Since the agreement's inception, trade between its members has grown dramatically and their economies have become heavily intertwined. Canada and Mexico trade significantly more with the United States than they do with any other country, and the United States only trades more with China than it does with its neighbors. Extensive regional supply chains have blossomed as trade has grown. In the transportation equipment sector, for example, intermediate input trade with the United States accounts for 30% Canada's gross output and more than 50% of Mexico's.

Recently, however, trade relationships in the region have become strained. President Trump has pointed to U.S. trade deficits with Canada and Mexico as evidence of the deal's "unfairness" and his administration has forced talks to renegotiate the agreement, threatening to leave it entirely if a satisfactory deal is not reached. Canada's trade policies, in particular, have earned the President's ire. Soon after he took office, his Commerce Department imposed countervailing duties of a whopping 292% on imports of Bombardier aircraft[1] and promised to impose 24% duties on softwood lumber. More recently, the President has complained vociferously about Canada's dairy supply management system and levied tariffs on Canadian steel and aluminum.[2] Although renegotiation talks have proceeded slowly, trade negotiators from the three countries signed a "new NAFTA," the United States-Mexico-Canada Agreement (USMCA), in November 2018. Since then, however, these countries' legislatures have made little progress towards passing this agreement. There remains widespread concern that they will fail to do so, which could prompt the Trump adminstration to make good on its termination threats. In this paper, I quantify the macroeconomic consequences that would follow NAFTA's dissolution, providing answers to key questions such as: how

1 These duties were levied in September, 2017. In January, 2018, the U.S. International Trade Comission rejected the duties, however, finding in favor of Bombardier in the dispute.

2 The Trump administration announced tariffs of 25% on steel and ten% on aluminum in March, 2018, citing national security interests. Despite their NAFTA membership, Canada and Mexico were not exempted from these tariffs. The United States imports negligible amounts of these products from Mexico.

much would each country's welfare rise or fall? Which industries would gain and which would lose? Would trade imbalances within the region shrink? How long would the transition to a post-NAFTA equilibrium take? Would this transition play a significant role in determining the welfare consequences of NAFTA termination?

To answer these questions, I develop a dynamic general equilibrium model with a detailed input-output production structure, heterogeneous firms that make forward-looking export participation decisions, and convex costs of adjusting factor allocations and imports over time. The model has four countries: the United States, Canada, Mexico, and the rest of the world. Households in each country work, consume, invest, and borrow or lend by trading bonds. Each country has five production sectors: agriculture, resource extraction, transportation equipment, other manufacturing, and services. Firms in each sector are heterogeneous in productivity and produce output using capital, labor, and intermediate inputs sourced from around the world. Firms are also heterogeneous in access to export markets. A firm must pay a large sunk cost to start exporting and it must pay a smaller cost to continue exporting in the future. I calibrate the model's parameters so that it replicates an input-output matrix from the World Input Output Database (Timmer et al. 2015) that contains data on NAFTA countries' current production and trade relationships, and a set of facts about the size distribution and dynamics of exporting firms.

I use the calibrated model to quantify the impact of NAFTA termination by comparing two equilibria: the *benchmark*, in which NAFTA remains in force forever; and the *termination* equilibrium, in which NAFTA ends permanently in 2019. When NAFTA is terminated, NAFTA members levy the same most-favored-nation (MFN) import tariffs on each other's products that they levy on products from other World Trade Organization members. MFN tariffs are particularly high in the transportation sector, and Mexico also levies high tariffs on agricultural products. In the long run, bilateral trade flows between NAFTA members would fall by 6.7–15.6% if NAFTA is terminated. Trade would fall most in agriculture and resources, which have high trade elasticities, and least in the transportation sector, which has a very low trade elasticity. Production and consumption in the transportation sector, however, would fall substantially, illustrating the importance of intermediate input trade for this sector. Contrary to the Trump Administration's claims, NAFTA termination would not lead to a rebalancing of regional trade flows; the U.S. trade deficit with Canada would shrink but the deficit with Mexico would grow.

The long-run welfare consequences of NAFTA termination are of similar magnitude to estimates in the literature of the welfare effects of other trade reforms. Consumption would fall by 0.05% in the United States, 0.13% in Canada, and 0.26% in Mexico. The economy would take many years to transition to its post-NAFTA steady state, but this adjustment process would not be costly: including these transition dynamics, the welfare losses from

NAFTA termination would be 5.6–14.3% lower than the long-run declines in consumption. The fact that the post-termination transition would not be costly does not, however, imply that the model's dynamic ingredients are not important; these ingredients have significant effects in the long run, not just during the transition. Import adjustment frictions and international borrowing and lending significantly reduce welfare losses—more so in the long run than in the short run, in fact—while extensive-margin dynamics amplify welfare losses. Conversely, several of the model's "static" ingredients, like input-output linkages and production complementarities, have dramatic effects on transition dynamics that alter the timing of the welfare losses from NAFTA termination as well as the long-run consequences.

This paper contributes to several strands of literature. First, it contributes to the growing literature on the effects of protectionist trade policies. A number of recent studies have analyzed the implications of the United Kingdom's impending departure from the European Union (Dhingra et al. 2016c;b;a, McGrattan and Waddle 2018, Ebell et al. 2016, Baker et al. 2016, Steinberg 2019). Barattieri et al. (2019) and Ruhl (2014) study the macroeconomic consequences of temporary trade barriers like antidumping and countervailing duties. Conconi et al. (2018) show how rules of origin requirements in free trade agreements like NAFTA increase the cost of trading with the rest of the world. My paper is the first to quantify the consequences of NAFTA termination for macroeconomic dynamics.

More generally, my paper contributes to the recent literature that quantitifies the effects of trade policy reforms using models with many countries, many sectors, and international input-output linkages (Caliendo and Parro 2015, Costinot and Rodríguez-Clare 2014, Giri et al. 2017). These studies highlight the importance of intersectoral and international heterogeneity in determining the aggregate effects of trade policy changes. My paper builds on this literature by embedding a rich, input-output production and demand structure into a dynamic model, which allows me to analyze quantitatively the transition dynamics that would follow NAFTA termination as well as the long-term consequences. My results indicate that input-output linkages, production complementarities, and other "static" model ingredients that shape the international production and demand structure have significant effects on transition dynamics as well as in the long run. These findings highlight the importance of analyzing trade policy reforms in a dynamic context.

Finally, a number of other recent studies have analyzed the macroeconomic effects of trade policy reforms and other shocks in dynamic, open-economy models with adjustment frictions on investment (Bajona and Kehoe 2010, Brooks and Pujolas 2018, Ravikumar et al. 2019, Eaton et al. 2011), employment (Dix-Carneiro 2014), and trade (Baldwin 1992, Krugman 1986, Engel and Wang 2011, Alessandria and Choi 2007; 2014, Ruhl 2008, Alessandria and Choi 2019, Alessandria et al. 2018). My model features all three, and is the first to integrate them into a multi-country, multi-sector setting with a realistic input-output production structure. My analysis makes a particularly significant methodological contribution by embedding the export participation dynamics framework of Das et al. (2007), in which heterogeneous firms pay sunk costs to begin exporting, into this setting. Other studies that analyze export participation dynamics in general equilibrium, such as Alessandria and Choi (2007; 2014), restrict their attention to symmetric, two-country models without intermediate input trade,[3] limiting their ability to draw quantitative conclusions about real-world policy changes. More broadly, my study shows that these dynamic ingredients can have significant consequences in the long run as well as the short run, further highlighting the importance of using dynamic models in quantitative trade analysis.

2. What's at stake: key facts about tariffs, trade, and production

To set the stage for my analysis of the consequences of NAFTA termination, I first turn to the data to summarize what's at stake: how much tariffs on trade between NAFTA members could rise and how important this trade is for their economies.

2.1. Tariffs

How much could tariffs rise if NAFTA is terminated? The United States, Canada, and Mexico are all members of the World Trade Organization, and the WTO's most-favored-nation (MFN) rule stipulates that in the absence of a regional free trade agreement, each WTO member should levy the same tariffs on all other WTO members' products. The WTO reports each member country's MFN tariff schedule at the 6-digit HS industry level. I combine these schedules with COMTRADE data on bilateral trade between the three NAFTA countries at the same 6-digit level to compute import-weighted bilateral tariff rates for four broad goods sectors: agriculture, resource extraction, transportation equipment, and other manufacturing. Table 1 lists the HS code ranges included in each sector and table 2 shows the results of the analysis.

The transportation equipment sector, whose international supply chain has featured prominently in media coverage of the NAFTA debate, would have relatively high post-NAFTA tariffs compared to other manufactured goods. The elasticity of subsitution between domestic and foreign products in this

3 One recent exception is Mix (2018), who includes a Das et al. (2007)-based export participation framework in a multi-country model. His model, however, features only one sector and does not have trade in intermediate inputs. Additionally, it does not feature firms that are heterogeneous in productivity, and so trade policy changes do not reallocate resources across firms as in Melitz (2003).

sector is very low (Caliendo and Parro 2015), which indicates that a reduction in trade in this sector triggered by NAFTA termination could be particularly painful. The resource sector, which is particularly important for Canada and Mexico, would have low post-NAFTA tariffs. The trade elasticity in this sector is very high, however, which suggests that even a small increase in tariffs could lead to a large drop in trade. Finally, Mexico would levy very high post-NAFTA tariffs on agricultural products, and because the trade elasticity in agriculture is also relatively high this could lead to a large reduction in agricultural trade.

This analysis may understate the extent to which trade costs could rise as a result of NAFTA termination. The literature on trade costs has found that non-tariff barriers like transportation costs, differences in product regulations, and search costs are often larger than tariffs (Anderson and van Wincoop 2004, Allen 2014, Lim 2018). This is particularly true in the services sector, which I have excluded from the analysis above because tariffs on services trade are essentially nonexistent. Data limitations make it difficult to conclusively determine the potential effects of NAFTA termination on bilateral non-tariff barriers in trade between NAFTA members, but it is important to recognize that, because these costs do not generate any tariff revenue, they can have larger welfare costs than tariffs.[4]

2.2. Trade flows and production

The macroeconomic consequences of NAFTA termination depend not only on potential increases in tariffs, but also on the importance of intra-NAFTA trade for member countries, particularly in sectors like agriculture and transportation equipment in which trade costs could rise substantially.

To depict NAFTA members' key production and demand relationships, I use the World Input Output Database (Timmer et al. 2015), henceforth abbreviated as WIOD. This dataset, which has been widely used in recent international trade studies, contains annual data on production, intermediate inputs, and final demand for 43 countries and 56 industries. Unlike national input-output tables that are reported by national statistical agencies like the U.S. Bureau of Economic Analysis and Statistics Canada, the WIOD data break down each reporter country's imports by source country and use (intermediate input or final expenditure), and thus provide a complete picture of the world input-output structure. I aggregate all countries other than the United States, Canada, and Mexico into a single "rest of the world" country, and I aggregate the 56 industries into the same four sectors described in section 2.1, plus a fifth services sector. I use the data for 2014, which is the last year in the dataset and several years before NAFTA termination entered the realm of possibility. Table 3 summarizes the macroeconomic importance

4 In a simple experiment with my model in which I increased iceberg transportation costs instead of tariffs, welfare losses were significantly larger than in my baseline analysis.

of these relationships by listing trade and production figures as a fraction of each country's GDP, and figures 1–3 provide visual illustrations.

2.2.1. Aggregate trade openness

Figure 1 shows that NAFTA members differ substantially in their exposure to international trade. Overall, the United States is less open to trade than Canada and Mexico. International trade (measured as the sum of exports and imports) was 24.7% of U.S. GDP in 2014, compared to 64.9% and 58.9% for Canada and Mexico, respectively. Further, trade with other NAFTA members is less important for the United States. Trade with Canada and Mexico accounts for a quarter of total U.S. trade, while trade with other NAFTA countries—primarily the United States—accounts for more than 60% of total trade for Canada and Mexico. These facts suggest that Canada's and Mexico's stakes in the future of NAFTA are much higher than the United States'.

2.2.2. Sectoral production and trade

Figure 2 shows that NAFTA members also differ substantially in the sectoral composition of their trade and output. Panel (a), which shows overall regional trade flows relative to sectoral GDP, illustrates the importance of NAFTA trade for each sector. Panel (b), which shows regional intermediate input trade, illustrates the importance of regional supply chains. Panels (c) and (d), which show the sectoral composition of each country's GDP and regional trade flows, respectively, illustrate the macroeconomic significance of regional trade flows in each sector.

The agriculture sector is less open to regional trade than other sectors and accounts for a small fraction of GDP in all three NAFTA countries. Consequently, high post-NAFTA tariffs in this sector may have small aggregate consequences. In Canada and Mexico, however, trade with the United States accounts for 62 and 45% of agricultural value added, respectively, and so the sector-level stakes for these countries are high. This is particularly true in Mexico where agriculture tariffs stand to rise dramatically.

NAFTA countries all trade resources intensively—this sector accounts for a larger share of their trade than their value added—but resource trade within NAFTA is particularly important for Canada. Resource trade with the United States, in particular, is close to 100% of Canadian value added in this sector and almost 8% of Canadian GDP. Post-NAFTA tariffs in this sector are likely to be low, but because resources are highly substitutable across countries (Caliendo and Parro 2015), even these low tariffs could have a significant impact on Canada's resource sector and Canada's economy as a whole.

The transportation equipment sector is about the same size as the agriculture sector in all three NAFTA countries but is more exposed to international trade, particularly trade in intermediate inputs within the NAFTA region (see panel (b) of figure 2). In all three countries, trade in transportation equipment is larger than value added due to these extensive international input-output linkages. In Canada's transportation equipment sector, trade with the United States and Mexico is more than four times value added; imported intermediates of U.S.-made transportation equipment alone are almost three-quarters of Canada's value added in this sector. Combined with high post-NAFTA tariffs on transportation equipment and a very low trade elasticity (Caliendo and Parro 2015), these facts imply that NAFTA termination could cause significant disruption in this sector that could have aggregate consequences despite the sector's small size.

Trade is also important for the rest of the manufacturing sector, where trade exceeds value added in all three NAFTA countries. Compared to transportation equipment, this sector accounts for a significantly larger share of GDP in each of these countries, but the consequences of NAFTA termination are lower; tariffs in other manufacturing will rise less than in transportation equipment and the trade elasticity is higher.

The services sector, the largest sector in each of the three countries, is unlikely to be significantly affected by NAFTA termination. Services are tradable—each country trades more services than agricultural products, for example—but the services sector is significantly less open to trade than other sectors. Further, terminating NAFTA should have little effect on services trade costs since tariffs on services do not exist.

2.2.3. Trade imbalances

One of the key issues at play in the debate over NAFTA is trade imbalances. U.S. president Trump has stated repeatedly that U.S. trade deficits with Canada and Mexico suggest that NAFTA is "unfair" to the United States, and that shrinking, or even reversing, these deficits is his administration's primary goal in renegotiating or terminating NAFTA.

Recently, as figure 3 shows, the United States has indeed run trade deficits with both Canada and Mexico, but these deficits are small relative to the aggregate U.S. trade deficit. The U.S. trade deficit with the rest of the world is more than three times larger than the deficit with Mexico and almost six times larger than the deficit with Canada. Consequently, whatever the effects of NAFTA termination on bilateral U.S. deficits with Canada and Mexico, the effect on the aggregate U.S. trade deficit (not to mention aggregate U.S. production, employment, and welfare) is likely to be small.

These imbalances are more important when viewed from the Canadian and Mexican perspectives, however. The trade surplus with the United States in 2014 was 3.5% and 7.3% of GDP in Canada and Mexico, respectively. Thus, rebalancing trade within the NAFTA region could have significant macroeconomic consequences for these two countries.

It is not clear ex ante how NAFTA termination will affect these imbalances. Canada's trade surplus with the United States consists mostly of natural resources which will likely be taxed lightly when NAFTA is terminated but are highly substitutable across countries. Mexico's trade surplus consists mostly of transportation equipment and other manufacturing. While post-NAFTA trade in transportation equipment will be taxed more heavily, the trade elasticity in this sector is low, and tariffs will not rise significantly on other manufacturing. Additionally, although Mexican agriculture trade with the United States is currently balanced, Mexico will levy much higher post-NAFTA tariffs in this sector than the United States.

3. Model

The model I use to analyze the consequences of NAFTA termination is a dynamic general equilibrium environment with four countries: the United States, Canada, Mexico, and the rest of the world. The length of a period is one year—period 0 in the model corresponds to the year 2014 in the data—and there is no uncertainty.[5] Each country has a representative household and five production sectors that correspond to the sectors analyzed above: agriculture, resource extraction, transportation equipment, other manufacturing, and services. Countries are indexed by $i, j \in I$ and sectors are indexed by $r, s \in S$. Households work, consume, invest, and save. Firms in each sector produce differentiated varieties using capital, labor, and intermediate inputs. Firms are heterogeneous in productivity, which is exogenous, and access to foreign markets, which is endogenous. As in Das et al. (2007) and Alessandria and Choi (2007; 2014), firms must pay a large fixed cost to begin exporting to a foreign market and a smaller cost to continue exporting in the future. Thus, the model features both intensive and extensive trade adjustment margins. Trade policy is modeled as import tariffs that are rebated lump-sum to households.

Transition dynamics in the model are driven by several ingredients. First, export participation rates adjust gradually to price changes or changes in tariffs as firms start and stop exporting in response to idiosyncratic productivity shocks. Second, households can shift resources intertemporally by accumulating or decumulating physical capital, and by borrowing or lending internationally. Third, the model features convex costs of adjusting sectoral factor allocations and import quantities, which prolong the sectoral reallocations and changes in trade patterns that are caused by trade policy reforms. Because the fixed costs of exporting and the costs of adjusting imports and factor allocations are denominated in units of labor, the amount of labor available for production decreases during transitions.

5 Steinberg (2019) finds that trade policy uncertainty associated with Brexit has had small macroeconomic and welfare consequences, even though the overall impact of Brexit on the UK economy may be substantially larger than the effect that NAFTA termination will have on the United States, Canada, or Mexico.

3.1. Households

The representative household in each country i chooses consumption, $C_{i,t}$, investment, $X_{i,t}$, labor supply, $L_{i,t}$, and bond holdings, $B_{i,t+1}$, to maximize its lifetime utility,

$$\sum_{t=0}^{\infty} \beta^t \frac{1}{\psi} \left[C_{i,t}^{\gamma}(\bar{L}_i - L_{i,t})^{1-\gamma}\right]^{\psi}, \tag{1}$$

subject to a sequence of budget constraints

$$P_{i,t}^c C_{i,t} + P_{i,t}^x X_{i,t} + Q_t B_{i,t+1} = W_{i,t} L_{i,t} + R_{i,t} K_{i,t} + B_{i,t} + D_{i,t} + T_{i,t}, \tag{2}$$

a law of motion for capital,

$$K_{i,t+1} = (1-\delta) K_{i,t} + X_{i,t}, \tag{3}$$

and initial conditions for capital, $K_{i,0}$, and bonds, $B_{i,0}$. The parameter γ governs the share of consumption in flow utility and ψ governs the intertemporal elasticity of substitution. $W_{i,t}$ and $R_{i,t}$ denote the wage and capital rental rate, and $\bar{L}_i$ is the household's time endowment. $P_{i,t}^c$ and $P_{i,t}^x$ are the prices of consumption and investment. $T_{i,t}$ denotes the lump-sum transfer of import tariff revenue and $D_{i,t}$ represents aggregate dividend payments from firms, whose behavior I describe below. The discount factor used to value these dividends is

$$\Lambda_{i,t} = \beta \frac{P_{i,t}^c}{P_{i,t+1}^c} \frac{U_{i,c,t+1}}{U_{i,c,t}}, \tag{4}$$

where $U_{i,c,t}$ is the household's marginal utility of consumption in period t.

3.2. Aggregation across sectors

The aggregate consumption and investment goods purchased by households are constant-elastiticity-of-substitution (CES) composites of final goods from each of the five sectors. The aggregate consumption bundle, $C_{i,t}$, is given by

$$C_{i,t} = A_i^c \left[\sum_{s \in S} \varepsilon_i^{c,s} (C_{i,t}^s)^{\frac{\rho^c - 1}{\rho^c}}\right]^{\frac{\rho^c}{\rho^c - 1}}, \tag{5}$$

where $C_{i,t}^s$ is consumption of sector-s goods. The parameter $\varepsilon_i^{c,s}$ governs sectoral consumption shares, ρ^c is the elasticity of substitution between sectors in consumption, and A_i^c is a constant scaling factor used to facilitate calibration. The price of consumption is given by the ideal price index,

$$P_{i,t}^c = \frac{1}{A_i^c} \left[\sum_{s \in S} (\varepsilon_i^{c,s})^{\rho^c} \left(P_{i,t}^{f,s}\right)^{1-\rho^c}\right]^{\frac{1}{1-\rho^c}}, \tag{6}$$

where $P^{f,s}_{i,t}$ is the price of final goods in sector s. The aggregate investment good is produced and priced in a similar fashion with parameters A^x_i, $\varepsilon^{x,s}_i$, and ρ^x.

3.3. Aggregation within sectors

The sectoral final goods that make up aggregate consumption and investment are purchased from competitive distributors that combine domestic and foreign products. Distributors' techologies have a nested CES structure. The inner layer combines differentiated varieties from each source country into source-specific bundles, and the outer layer combines these bundles into a single sectoral composite. Distributors also sell intermediate inputs to firms; sectoral final goods and sectoral intermediate goods are aggregated separately. In what follows, I describe the aggregation of sectoral final goods. The aggregation process for sectoral intermediates works in the same manner with m superscripts in place of f superscripts.

3.3.1. Inner layer

The inner-layer technology, which combines a set of varieties, $\Omega^s_{i,j,t}$, from source country j's s-sector into a bundle, $Y^{f,s}_{i,j,t}$, is given by

$$Y^{f,s}_{i,j,t} = A^{f,s}_{i,j} \left[\int_{\Omega^s_{i,j,t}} y^{f,s}_{i,j,t}(\omega)^{\frac{\theta-1}{\theta}} \, \mathrm{d}\omega \right]^{\frac{\theta}{\theta-1}} . \tag{7}$$

The parameter $A^{f,s}_{i,j}$ is another scaling factor and θ is the elasticity of subsitution between varieties. The inner-layer intermediate aggregation technology takes the same form.

The inner-layer problem of a distributor is to choose inputs of each variety to minimize the cost of producing the bundle taking as given the varieties' prices, $p^{f,s}_{i,j,t}(\omega)$. Consequently, the bundle's price is given by

$$P^{f,s}_{i,j,t} = \frac{1}{A^{f,s}_{i,j}} \left[\int_{\Omega^s_{i,j,t}} p^{f,s}_{i,j,t}(\omega)^{1-\theta} \, \mathrm{d}\omega \right]^{\frac{1}{1-\theta}} . \tag{8}$$

The set of varieties, $\Omega^s_{i,j,t}$, which is specific to the purchasing country i as well as the source country j, is endogenous: it depends on decisions of firms in j to start or stop exporting to i. These decisions, which I describe in section 3.4, generate the model's extensive-margin trade adjustment dynamics. It will be useful to express a final distributor's demand for a particular variety ω as a function of its price, which I denote by $\tilde{y}^{f,s}_{i,j,t}(p)$, which takes the standard downward-sloping form:

$$\tilde{y}^{f,s}_{i,j,t}(p) = Y^{f,s}_{i,j,t} \left(\frac{P^{f,s}_{i,j,t}}{p} \right)^{\theta} . \tag{9}$$

3.3.2. Outer layer

The outer-layer technology, which combines the source-specific bundles produced in the inner layer into the sectoral final good, $Y_{i,t}^{f,s}$, is given by

$$Y_{i,t}^{f,s} = A_i^{f,s} \left[\sum_{j \in I} \mu_{i,j}^{f,s} \left(Y_{i,j,t}^{f,s} \right)^{\frac{\zeta_i^{f,s}-1}{\zeta_i^{f,s}}} \right]^{\frac{\zeta_i^{f,s}}{\zeta_i^{f,s}-1}}. \tag{10}$$

The parameter $\mu_{i,j}^{f,s}$ governs this bundle's expenditure share and $\zeta_i^{f,s}$ is the elasticity of substitution between bundles from different source countries. These elasticities, which are allowed to vary by country, sector, and use, govern the intensive margin of trade adjustments. $A_i^{f,s}$ is another scaling factor.

Distributors are responsible for paying import tariffs, denoted by $\tau_{i,j,t}^{s}$, on the bundles of foreign products they purchase, but they must also pay convex costs to adjust these bundles over time as in Krugman (1986). These costs are a parsimonious way of modeling import adjustment frictions like search costs required to find new foreign suppliers (Lim 2018). As I describe in the next section, the model features microfounded export adjustment frictions. The presence of these adjustment costs makes the distributor's outer-layer problem dynamic: distributors choose sequences of domestic and foreign bundles to maximize the present value of their dividends,

$$\sum_{t=0}^{\infty} \Lambda_{i,t} D_{i,t}^{f,s}, \tag{11}$$

subject to (10), where dividends are given by

$$\begin{aligned} D_{i,t}^{f,s} = P_{i,t}^{f,s} Y_{i,t}^{f,s} - \sum_{j \in J \setminus \{i\}} (1 + \tau_{i,j,t}^{s}) P_{i,j,t}^{f,s} Y_{i,j,t}^{f,s} \\ - W_{i,t} \sum_{j \in I \setminus \{i\}} \phi^f \left(\frac{Y_{i,j,t}^{f,s}}{Y_{i,j,t-1}^{f,s}} - 1 \right)^2 Y_{i,j,t-1}^{f,s}. \end{aligned} \tag{12}$$

The parameter ϕ^f governs the import adjustment cost for final distributors; there is an analogous parameter ϕ^m for intermediate distributors. Import adjustment costs, which are denominated in units of labor, cause the intensive margin of trade to adjust gradually to price changes or, in the case of NAFA termination, changes in tariffs. There are no import tariffs or adjustment costs on domestic purchases.

3.4. Firms

Each country i has a unit measure of monopolistically competitive firms in each sector s that produce differentiated varieties as in Melitz (2003) and Chaney (2008). Firms are heterogeneous in two dimensions: productivity, which is exogenous and evolves stochastically over time; and export status in each foreign market, which is endogenous. Each firm is identified with a particular variety ω, but because all firms with the same productivity and export status will make the same decisions, I index firms by these variables rather than by their varieties. In order to export, a firm must pay a fixed cost that depends on the firm's status as an exporter as in Das et al. (2007) and Alessandria and Choi (2007; 2014). These costs are independent across destinations, and consequently in this multi-country environment a firm may decide to export to one destination but not another. All firms can sell costlessly to the domestic market.

3.4.1. Production

Each period, firms draw productivities from a distribution $F_i^s(a)$; productivities are iid across firms and over time. A firm with productivity a produces its output using capital, k, labor, ℓ, and intermediate inputs from each sector, $(m^r)_{r\in S}$, according to the Leontief technology,[6]

$$f_i^s\left(a, k, \ell, (m^r)_{r\in S}\right) = a \min\left\{\frac{k^\alpha \ell^{1-\alpha}}{\lambda_i^{s,v}}, \min_{r\in R}\left[\frac{m^r}{\lambda_i^{s,r}}\right]\right\}. \tag{13}$$

The direct requirement coefficients, $\lambda_i^{s,v}$ and $\lambda_i^{s,r}$, govern the shares of value added and intermediates from each sector, respectively, in gross output. α is the share of capital in value added. Firms rent factors at sector-specific prices $R_{i,t}^s$ and $W_{i,t}^s$ from an intermediary, which I describe in section 3.5, and purchase intermediate inputs from distributors at prices $P_{i,t}^{m,r}$, $r \in S$.

3.4.2. Static profit-maximization problem

Conditional on access to a given market $j \in I$—and note that all firms have access to their own domestic markets—a firm in country i's s-sector chooses prices at which to sell its goods to that market's final and intermediate distributors, p^f and p^m, along the inputs required to satisfy those distributors' demands, to maximize its flow profits in that market:[7]

$$\pi_{j,i,t}^s(a) = \tag{14}$$
$$\max_{p^f, p^m, k, \ell, (m^r)_{r\in S}} \left\{p^f \tilde{y}_{j,i,t}^{f,s}(p^f) + p^m \tilde{y}_{j,i,t}^{m,s}(p^m) - W_{i,t}^s \ell - R_{i,t}^s k - \sum_{r\in S} P_{i,t}^{m,r} m^r\right\},$$

subject to

6 This specification is based on the findings of Atalay (2017), who estimates elasticities of substitution between value added and intermediates of approximately zero, and Kehoe et al. (2018), who show that these elasticities account for the recent dynamics of U.S. intermediate expenditure shares. In section 7.2 I analyze the sensitivity of my results to this assumption.

7 The firm's profit-maximization problem can be solved destination by destination because firms' production technologies have constant returns to scale.

$$f_i^s\left(a,k,\ell,(m^r)_{r\in S}\right)=\tilde{y}_{j,i,t}^{f,s}(p^f)+\tilde{y}_{j,i,t}^{m,s}(p^m). \tag{15}$$

The solution to this problem is characterized by the constant-markup pricing rule,

$$p^f=p^m=\left(\frac{\theta}{\theta-1}\right)\left(\frac{MC_{i,t}^s}{a}\right), \tag{16}$$

where $MC_{i,t}$, which denotes the marginal cost of a firm with productivity one, is given by

$$MC_{i,t}^s=\lambda_i^{s,v}\left(\frac{R_{i,t}^s}{\alpha}\right)^{\alpha}\left(\frac{W_{i,t}^s}{1-\alpha}\right)^{1-\alpha}+\sum_{r\in S}\lambda_i^{s,r}P_{i,t}^{m,r}. \tag{17}$$

Denote by $k_{j,i,t}^s(a)$, $\ell_{j,i,t}^s(a)$, and $m_{j,i,t}^{s,r}(a)$ the demand for factors and intermediate inputs required to produce output for market j at these optimal prices.

3.4.3. Dynamic export-participation problem

Firms enter each period with a vector of export status indicators, $e_j\in\{0,1\}$, $j\in I\setminus\{i\}$, that denote access ($e_j=1$) or lack thereof ($e_j=0$) to each foreign market. After drawing their productivities, firms decide whether or not to gain access to each export market. In order to sell to market j, a firm in country i's s-sector must pay a cost, $\kappa_{j,i}^s(e_j)$, that depends on its current status as an exporter in that market. Like the costs that distributors must pay to adjust imports, firms' exporting costs are denominated in units of labor. The firm's dynamic program for market j is[8]

$$V_{j,i,t}^s(a,e_j)= \tag{18}$$
$$\max_{e'_j\in\{0,1\}}\left\{\pi_{j,i,t}^s(a)e'_j-W_{i,t}\kappa_{j,i}^s(e_j)+\Lambda_{i,t}\int V_{j,i,t+1}^s(a',e'_j)\,\mathrm{d}F_i^s(a')\right\}.$$

The solution to this problem is characterized by two productivity threshholds, $a_{j,i,t}^{s,+}$ and $a_{j,i,t}^{s,-}$, such that

$$W_{i,t}\kappa_{j,i}^s(0)=\pi_{j,i,t}^s(a_{j,i,t}^{s,+})+\Lambda_{i,t}\int_{-\infty}^{\infty}\Delta V_{j,i,t+1}^s(a')\mathrm{d}F_i^s(a'), \tag{19}$$

$$W_{i,t}\kappa_{j,i}^s(1)=\pi_{j,i,t}^s(a_{j,i,t}^{s,-})+\Lambda_{i,t}\int_{-\infty}^{\infty}\Delta V_{j,i,t+1}^s(a')\,\mathrm{d}F_i^s(a'), \tag{20}$$

where $\Delta V_{j,i,t+1}^s(a')=V_{j,i,t+1}^s(a',1)-V_{j,i,t+1}^s(a',0)$. Firms that begin the period as non-exporters ($e_j=0$) with productivity above $a_{j,i,t}^{s,+}$ will start exporting, while firms that begin the period as exporters ($e_j=1$) with productivity below $a_{j,i,t}^{s,-}$ will stop.

8 As with the static problem, the firm's dynamic problem can be solved destination by destination because the exporting costs are independent.

3.4.4. Aggregation across firms

The measure of firms in i's s-sector that export to j, $\Omega^s_{j,i,t}$, evolves according to the following law of motion:

$$\Omega^s_{j,i,t} = \Omega^s_{j,i,t-1}\left[1 - F^s_i(a^{s,-}_{j,i,t})\right] + \left(1 - \Omega^s_{j,i,t-1}\right)\left[1 - F^s_i(a^{s,+}_{j,i,t})\right]. \quad (21)$$

The aggregate demand for productive labor[9] of firms in this sector is

$$\hat{L}^s_{i,t} = \int_{-\infty}^{\infty} \ell^s_{i,i,t}(a)\ \mathrm{d}F^s_i(a) + \sum_{j\in I\backslash i}\left\{\Omega^s_{j,i,t-1}\left[\int_{a^{s,-}_{j,i,t}}^{\infty} \ell^s_{j,i,t}(a)\ \mathrm{d}F^s_i(a)\right] + \left(1-\Omega^s_{j,i,t-1}\right)\left[\int_{a^{s,+}_{j,i,t}}^{\infty} \ell^s_{j,i,t}(a)\ \mathrm{d}F^s_i(a)\right]\right\}. \quad (22)$$

The first term in this expression is the labor required to serve domestic distributors' demand. The second term is the labor required by existing exporters to serve foreign demand, and the third term is the labor required by new exporters to serve foreign demand. Firms' aggregate demand for capital, $\hat{K}^s_{i,t}$, and demand for sector-r intermediates, $\hat{M}^{s,r}_{i,t}$, are computed in a similar manner.

3.5. Factor rental and adjustment costs

Households rent capital and productive labor to firms through competitive intermediaries that repurpose the aggregate factors of production for sector-specific uses.[10] Reallocating factors from one sector to another is costly: intermediaries must pay convex costs to increase or decrease a sector's factor allocations. Intermediaries take the aggregate factor prices, $R_{i,t}$ and $W_{i,t}$, and the sectoral factor prices, $(R^s_{i,t}, W^s_{i,t})_{s\in S}$, as given, and choose aggregate factor demand from households, $\tilde{K}_{i,t}$ and $\tilde{L}_{i,t}$, and the supply of factors to firms in each sector, $(K^s_{i,t}, L^s_{i,t})_{s\in S}$, to maximize the present value of their dividends,

$$\sum_{t=0} \Lambda_{i,t} D^I_{i,t}, \quad (23)$$

subject to the resource constraints,

$$\tilde{K}_{i,t} = \sum_{s\in S} K^s_{i,t}, \quad \tilde{L}_{i,t} = \sum_{s\in S} L^s_{i,t}. \quad (24)$$

9 Labor used to pay for the fixed exporting costs appears in the labor market clearing condition (30)

10 The purpose of this modeling construct is to simplify the description of the model. This setup is equivalent to one in which the sectoral factor allocation problem is assigned to households, but the latter is significantly more cumbersome to describe.

An intermediary's dividends are given by

$$D^I_{i,t} = \sum_{s\in S}\left(R^s_{i,t}K^s_{i,t} + W^s_{i,t}L^s_{i,t}\right) - R_{i,t}\tilde{K}_{i,t} - W_{i,t}\tilde{L}_{i,t} \\ - \sum_{s\in S} W_{i,t}\left[\phi^k\left(\frac{K^s_{i,t}}{K^s_{i,t-1}} - 1\right)^2 K^s_{i,t-1} + \phi^\ell\left(\frac{L^s_{i,t}}{L^s_{i,t-1}} - 1\right)^2 L^s_{i,t-1}\right]. \tag{25}$$

The parameters ϕ^k and ϕ^ℓ govern the cost of adjusting sectoral factor allocations. Like the other adjustment costs in the model, these costs are denominated in units of labor; in addition to hiring aggregate productive labor, $\tilde{L}_{i,t}$, intermediaries must hire some workers to perform the tasks involved in increasing or decreasing each sector's factor allocation. In equilibrium, sectoral rental prices reflect the marginal cost of adjusting factors as well as households' intra- and intertemporal marginal rates of substitution, which are turn reflected by the aggregate factor prices.

3.6. Market clearing

There are several markets that must clear in each period. First, households' final demand for sectoral consumption and investment goods must equal final distributors' supply of these goods:

$$Y^{f,s}_{i,t} = C^s_{i,t} + X^s_{i,t}, \quad \forall i \in I,\ \forall s \in S \tag{26}$$

Similarly, firms' demand for intermediates must equal intermediate distributors' supply:

$$Y^{m,s}_{i,t} = \sum_{r\in S}\hat{M}^{r,s}_{i,t}, \quad \forall i \in I,\ \forall s \in S \tag{27}$$

Third, firms' demand for sectoral factors must equal intermediaries' supply:

$$K^s_{i,t} = \hat{K}^s_{i,t}, \quad L^s_{i,t} = \hat{K}^s_{i,t}, \quad \forall i \in I,\ \forall s \in S. \tag{28}$$

Fourth, households' supply of aggregate capital must equal intermediaries' demand:

$$K_{i,t} = \tilde{K}_{i,t}, \quad \forall i \in I. \tag{29}$$

Fifth, households' supply of labor must equal intermediaries' demand for productive labor, demand for labor to pay for distributors' import adjustment costs, demand for labor to pay for intermediaries' sectoral factor reallocations, and firms' demand for labor to pay for the fixed costs of exporting:

$$\begin{aligned} L_{i,t} &= \tilde{L}_{i,t} \\ &+ \sum_{s\in S}\sum_{j\in I\setminus i}\left[\phi^f\left(\frac{Y^{f,s}_{i,j,t}}{Y^{f,s}_{i,j,t-1}}-1\right)^2 Y^{f,s}_{i,j,t-1} + \phi^m\left(\frac{Y^{m,s}_{i,j,t}}{Y^{m,s}_{i,j,t-1}}-1\right)^2 Y^{m,s}_{i,j,t-1}\right] \\ &+ \sum_{s\in S}\left[\phi^k\left(\frac{K^s_{i,t}}{K^s_{i,t-1}}-1\right)^2 K^s_{i,t-1} + \phi^\ell\left(\frac{L^s_{i,t}}{L^s_{i,t-1}}-1\right)^2 L^s_{i,t-1}\right] \\ &+ \sum_{s\in S}\sum_{j\in I\setminus\{i\}}\Big\{\Omega^s_{j,i,t-1}\left[1-F^s_i(a^{s,-}_{j,i,t})\right]\kappa^s_{j,i}(1) \\ &\qquad + \left(1-\Omega^s_{j,i,t-1}\right)\left[1-F^s_i(a^{s,+}_{j,i,t})\right]\kappa^s_{j,i}(0)\Big\}, \quad \forall i\in I. \end{aligned} \tag{30}$$

Finally, the bond market must clear:

$$\sum_{i\in I} B_{i,t+1} = 0. \tag{31}$$

3.7. Equilibrium

An equilibrium consists of infinite sequences of

- aggregate quantities, $C_{i,t}, X_{i,t}, K_{i,t}, L_{i,t}, B_{i,t}, \tilde{K}_{i,t}, \tilde{L}_{i,t}$, and prices, $P^c_{i,t}, P^x_{i,t}, W_{i,t}, R_{i,t}$,
- sectoral quantities, $C^s_{i,t}, X^s_{i,t}, Y^{f,s}_{i,t}, Y^{m,s}_{i,t}, K^s_{i,t}, L^s_{i,t}$, and prices, $P^{f,s}_{i,t}, P^{m,s}_{i,t}, R^s_{i,t}, W^s_{i,t}$,
- sector-source bundles, $Y^{f,s}_{i,j,t}, Y^{m,s}_{i,j,t}$, and prices, $P^{f,s}_{i,j,t}, P^{m,s}_{i,j,t}$,
- and firm value functions, $V^s_{j,i,t}(a, e_j)$, policy functions, $k^s_{j,i,t}(a), \ell^s_{j,i,t}(a), m^{s,r}_{j,i,t}(a), a^{s,-}_{j,i,t}, a^{s,+}_{j,i,t}$, and export participation rates, $\Omega^s_{j,i,t}$,

that solve the households', distributors', firms', and intermediaries' problems and satisfy the market clearing conditions. In the long run, if trade costs are constant, an equilibrium converges to a steady state in which the objects listed above are constant. As in Kehoe et al. (2018) and Steinberg (2019), there is not a unique steady state, however; there is a continuum of possible steady states indexed by the vector of long-run bondholdings, $(B_{i,\infty})_{i\in I}$. Thus, trade imbalances during the transition, which can permanently alter a country's net foreign asset position, can have permanent effects. Below, I show that allowing for endogenous trade imbalances has a significant impact on the long-run welfare consequences of NAFTA termination. Additionally, even though the model's adjustment costs do not directly affect any of the steady-state equilibrium conditions, these ingredients also affect the steady state to which the economy converges. Thus, the model's dynamic ingredients can have implications for the long run as well as the short run.

I construct two equilibria in my model. In the first, the *benchmark*, tariffs on intra-NAFTA trade are zero forever. In the second, the *termination* equilibrium, tariffs between NAFTA countries permanently rise by the values shown in table 2 in period $t = 5$, which corresponds to 2019. I assume that this policy change is unanticipated: in periods 0–4 of the termination equilibrium, model agents believe that trade costs will not change from their benchmark values.[11] With these two equilibria in hand, we can measure the impact of NAFTA termination on each country's macroeconomic and trade dynamics by comparing the trajectories of model variables in the termination equilibrium to their benchmark counterparts.

4. Calibration

My calibration proceeds in four stages. First, I assign common parameters like discount factors and elasticities of substitution to standard values. Second, I set the parameters that govern production technologies and expenditure shares so that the benchmark equilibrium—the one in which NAFTA is never terminated—matches the 2014 WIOD input-output data that underlies figures 1–3 and table 3. Third, I jointly calibrate the parameters that govern firm productivity distributions and exporting costs to match facts about export participation dynamics from the literature. Fourth, I set the import adjustment cost parameters so that short-run trade elasticities in the termination equilibrium are also consistent with findings from the literature.

4.1. Assigned parameters

Several of the model's parameters have standard values. I set β, the discount factor, so that that the steady-state real interest rate is 2% per year. I set ψ, which governs the intertemporal elasticity of substitution, to -1. I set the depreciation rate, δ, to 6% and the capital share, α, to one-third. I set γ, the share of consumption in households' utility, so that households supply one-third of their labor endowments in a steady state.

I assign a number of other parameters to estimates reported by studies in the literature. I set ρ^c and ρ^x, the elasticities of substitution between sectors in consumption and investment, to 0.65 and 1.0, respectively, based on the findings of Bems (2008), Atalay (2017), and Kehoe et al. (2018). I set ϕ^k and ϕ^ℓ, the capital and labor adjustment cost parameters, to 6.5, the values used by Kehoe and Ruhl (2009) in their study of Mexico's 1995 sudden stop; these values are similar to those estimated by Sargent (1978). I set θ, the elasticity of substitution between varieties from the same source country, to 5 based

11 This assumption is benign; welfare losses are the same if the policy change is anticipated.

on Alessandria and Choi (2019). To set initial bondholdings, $B_{i,0}$, for the three NAFTA countries, I use data on their 2014 net foreign assets reported in the Lane and Milesi-Feretti (2007) dataset. The rest of the world's initial bondholdings are implied by market clearing. Panel (a) of table 4 lists these assigned parameter values. Note that initial bondholdings are expressed as percentages of U.S. GDP.

To set the Armington elasticities, $\zeta_i^{m,s}$ and $\zeta_i^{f,s}$, I also use estimates from the literature. These parameters, which govern the intensive-margin response of imports to price changes, are not equivalent to long-run trade elasticities because the model also features an extensive margin. I set my model's Armington elasticities to the trade-elasticity estimates of Caliendo and Parro (2015), which are computed using a single year of trade data in which the set of exporting firms is fixed, not long-run responses to price changes. The 2-digit ISIC classification used by Caliendo and Parro (2015) maps directly to the set of industries in the WIOD database that comprise the four goods sectors in the model. For each country i and goods sector s, I set the intermediate (final) elasticity, $\zeta_i^{m,s}$ ($\zeta_i^{f,s}$), to the average of the Caliendo and Parro (2015) estimates for the industries that comprise that sector, weighted by these industries shares' in country i's overall intermediate (final) imports of goods in that same sector. For the services sector, I follow Costinot and Rodríguez-Clare (2014) and set all elasticities to five, the average of the Caliendo and Parro (2015) estimates. Panel (b) of table 4 lists the assigned Armington elasticities, which range from 0.8 in transportation equipment to more than 40 in resources.

4.2. Parameters calibrated to input-output data

Once I have assigned the parameters listed above, I calibrate the expenditure share parameters, $\varepsilon_i^{c,s}$, $\varepsilon_i^{x,s}$, $\mu_{i,j}^{m,s}$, $\mu_{i,j}^{f,s}$, $\lambda_i^{s,v}$, $\lambda_i^{s,r}$, the scaling factors, A_i^c, A_i^x, $A_i^{m,s}$, $A_i^{f,s}$, and the time endowments, $\bar{L}_i$, so that the first period of the benchmark equilibrium exactly matches the aggregated 2014 WIOD data described in section 2.2. 2014 is the most recent year available in the dataset and serves as a good no-termination counterfactual because President Trump's election, and thus the possibility of NAFTA termination, was not foreseen at this time.

This portion of the calibration procedure uses marginal product pricing equations and other equilibrium conditions to infer the values of these parameters that are consistent with the input-output data. The scaling factors are chosen so that, without loss of generality, all prices in the first period are one, which implies that the input-output data can be interpreted as both quantities and expenditures. For example, to calibrate the parameters of the consumption aggregator (5) for a given country i, I first set the expenditure share parameters, $\varepsilon_i^{c,s}$, using the ratios of the first-order conditions for sectoral consumption,

$$\frac{P_{i,0}^{f,s}}{P_{i,0}^{f,r}} = 1 = \frac{\varepsilon_i^{c,s}}{\varepsilon_i^{r,s}} \left(\frac{C_{i,0}^s}{C_{i,0}^r} \right)^{-\frac{1}{\rho^c}}, \;\; s, r \in S, \tag{32}$$

and the restriction that the expenditure share parameters sum to one: $\sum_{s \in S} \varepsilon_i^{c,s} = 1$. Given the input-output data for $C_{i,0}^s$, we can solve this system for the values of $\varepsilon_i^{c,s}$. Next, I use the calibrated values of $\varepsilon_i^{c,s}$ with the input-output data for sectoral consumption, $C_{i,0}^s$, and aggregate consumption, C_0^i, to find the scaling factor, A_i^c, that satisfies (5). Note that this choice also satisfies the ideal price index formula (6) when the prices on the left- and right-hand sides are set to one

Once the expenditure share and scaling parameters have been calibrated so that the input-output data satisfy the model's first-order conditions and aggregation technologies, the data naturally form an intratemporal equilibrium.[12] This is because the WIOD data are constructed to satisfy all of the market-clearing conditions and budget constraints that must hold in the model. For example, gross output of U.S. agricultural goods equals global demand for these goods. For more details on this stage of the calibration procedure, see Kehoe et al. (2018). As in Steinberg (2019), I set all import tariffs, $\tau_{i,j,t}^s$, to zero in the benchmark equilibrium, including on trade with the rest of the world. This implies that the Armington share parameters, $\mu_{i,j}^{m,s}$ and $\mu_{i,j}^{f,s}$, absorb all trade costs reflected in the 2014 input-output data as well as subjective home bias. This is without loss of generality since tariffs are rebated lump-sum to households. The parameters calibrated in this section contain many elements (for example, $\mu_{i,j}^{m,s}$ has $80 = 4 \times 5 \times 4$ elements) so I do not report them in the paper. They can be found in the supplemental materials available on my website.

4.3. Parameters calibrated to match exporter dynamics facts

After setting the assigned parameters and calibrating the expenditure shares and scaling factors listed above, I calibrate the exporting costs, $\kappa_{j,i}^s(e_j)$, and the productivity distributions, $F_i^s(a)$, so that the model matches a set of facts from the literature about the distribution and dynamics of exporters. I also calibrate the inner scaling factors, $A_{i,j}^{f,s}$ and $A_{i,j}^{m,s}$, during this stage of the procedure. I target the following list of facts:

- 25% of firms in each sector export[13] (Alessandria et al. 2018, based on data from the 1992 U.S. Census of Manufactures);

12 An intratemporal equilibrium is a collection of prices and quantities for a single year that satisfy all of the model's static equilibrium conditions.

13 I assume that 100% of firms in the resources sector export which implies that the exporting costs in this sector are zero. The high Armington elasticity in this sector makes the exporter dynamics framework numerically intractable, and the assumption of monopolistic competition is a poor fit for this sector; natural resources are, by and large, homogeneous commodities.

- 45% of exporters exit from a bilateral trade relationship each year (Steinberg 2019, based on data from 70 countries during 2006–2008 from the World Bank Exporter Dynamics Database);
- and the share of exports in each sector accounted for by the top 5% of exporters is 58% (Steinberg 2019, based on the same Exporter Dynamics Database data).

I also ensure that the distributors' inner-layer aggregation technologies (7) are satisfied and the inner-layer price indices (8) are one, as I do with the aggregate and sectoral aggregators. As in the aforementioned papers, I assume that firms' productivities are distributed lognormally with standard deviation σ_i^s.

The parameters chosen in this stage of the process must be jointly calibrated, as each parameter affects several of the facts listed above to some degree. Roughly speaking, however, the productivity dispersions, σ_i^s control the concentration of exports, the entry costs, $\kappa_{j,i}^s(0)$, control the export participation rate, the continuation costs, $\kappa_{j,i}^s(1)$, control the exit rate, and the scaling factors, $A_{i,j}^{f,s}$ and $A_{i,j}^{m,s}$, ensure that the inner-layer aggregation technologies are satisfied. Like the previous stage of the calibration procedure, this stage sets the values of several hundred parameters so I do not report them in the text of the paper. They can be found in the supplemental materials linked above. On average, productivity dispersion, σ_i^s, is about 0.6 and the entry cost, $\kappa_{j,i}^s(0)$ is about four times the continuation cost. The large sunk cost of beginning to export makes the decision to start exporting forward-looking, creating persistence in export participation rates as in Alessandria and Choi (2007; 2014; 2019), Ruhl and Willis (2017), and other general-equilibrium analyses of export participation dynamics.

4.4. Import adjustment costs

The last parameters that must be calibrated are ϕ^m and ϕ^f, which govern import adjustment costs. There are no direct estimates in other studies for these parameters, so I calibrate them to generate trade elasticity dynamics in the termination equilibrium that are consistent with the literature. I set them so that the average aggregate short-run trade elasticity in the period immediately following NAFTA termination is one, the standard value in the international macro literature (Heathcote and Perri 2002). It is important to point out that the extensive-margin dynamics generated by the sunk-cost export participation framework also reduce short-run trade elasticities; a model without this feature would require higher import adjustment costs to match this calibration target.

I measure short-run trade elasticities following Alessandria et al. (2018). For each country i, I measure the bilateral short-run trade elasticity in sector s with trade partner j as the log change in country i's imports of sector-s products from country j divided by the log change in import tariffs:

$$TE^s_{i,j,t} = \log\left(\frac{P^{f,s}_{i,j,t}Y^{f,s}_{i,j,t} + P^{m,s}_{i,j,t}Y^{m,s}_{i,j,t}}{P^{f,s}_{i,j,0}Y^{f,s}_{i,j,0} + P^{m,s}_{i,j,0}Y^{m,s}_{i,j,0}}\right) \Big/ \log\left(\frac{1+\tau^s_{i,j,t}}{1+\tau^s_{i,j,0}}\right). \quad (33)$$

To measure each country's aggregate trade elasticity, I take the average of its sector-partner elasticities weighted by pre-termination imports. I exclude trade with the rest of the world from these calculations; since trade costs with the rest of the world do not change the trade elasticity with the rest of the world measured in this way is undefined.

5. Effects of NAFTA termination

Having described the model and its calibration, I turn now to the results of the quantitative analysis. Table 5 summarizes the long-run effects of NAFTA termination on trade, production, and consumption, and figures 4–5 illustrate the macroeconomic implications of these effects. Figure 6 illustrates the transition dynamics that follow NAFTA termination and table 6 lists welfare losses, which include the effects of these transition dynamics as well as long-run changes.

5.1. Long-run trade and macroeconomic consequences

In the long run, trade flows between NAFTA members would fall by 6.7–15.6%. Mexican imports of NAFTA products would fall most because Mexico would levy the highest post-NAFTA tariffs, and Canadian imports would fall least. At the sectoral level, trade in agriculture would fall most because agricultural goods from different countries are highly substitable and Mexico, in particular, would levy high tariffs in this sector; Mexican imports of agricultural products from the United States and Canada would fall by 91.1% and 62.3%, respectively. Trade in the resource extraction sector would also fall dramatically despite low post-NAFTA tariffs because different countries' resources are almost perfect substitutes. By contrast, despite high post-NAFTA tariffs in transportation equipment, trade in this sector would fall only slightly because transportation equipment from different countries is poorly substitutable. Trade in other manufacturing would fall modestly because manufactured goods from different countries are moderately substitutable and post-NAFTA tariffs in this sector would be low.

All NAFTA members would substitute towards trade with the rest of the world in reponse to NAFTA termination. Trade with the rest of the world in resource extraction, in particular, would burgeon: Canadian and Mexican exports of resources to the rest of the world would rise by 9.1 and 7.5%, respectively. Mexico would significantly increase its imports from the rest of the world, especially in agriculture and other manufacturing. This substitution would not fully mitigate the decline in intra-NAFTA trade, however; NAFTA members' aggregate trade flows would decline by 2.1–7.5%.

As panels (a), (c), and (e) of figure 4 show, the macroeconomic significance of these effects would be larger for Canada and Mexico, whose economies rely heavily on NAFTA trade, than for the United States, whose economy does not. The other manufacturing sector would account for most of the decline in intra-NAFTA trade, even though trade in this sector would not fall as precipitously as trade in agriculture or resources, because of this sector's size (recall panel (d) in figure 2). For Canada, the decline in resources trade would also be macroeconomically significant.

The top two rows of each panel in table 5 list the ultimate long-run macroeconomic consequences of NAFTA termination. Production and consumption would fall in the long run in all three countries. For the United States, the long-run welfare loss from NAFTA termination of 0.05% is similar to the gain from implementating NAFTA estimated by Caliendo and Parro (2015) (henceforth CP) in their seminal study. For Canada and Mexico, however, the long-run welfare losses differ from CP's estimates. In my analysis, Canada would lose in the long run after NAFTA is terminated, whereas CP estimate that implementing NAFTA in the first place actually harmed Canada rather than benefiting it. For Mexico, the long-run welfare loss of 0.26% is substantially lower than CP's estimate of 1.31%. I analyze the sources of these differences in section 8.4 below.

5.2. Long-run trade imbalances

Although NAFTA termination would have a significant impact on gross trade flows in the long run, it would have only a small effect on long-run trade imbalances. As panels (b), (d), and (f) of figure 4 show, the U.S. trade deficit with Mexico would grow larger due to the dramatic decline in Mexican imports of U.S. agricultural products, while the U.S. trade deficit with Canada would shrink due the decline in U.S. imports of Canadian resources. These changes, however, would be small relative to the deficits' initial sizes.

From the perspective of the United States, the changes in long-run trade imbalances caused by NAFTA termination would be macroeconomically negligible because the initial U.S. trade deficits with Canada and Mexico are small relative to the size of the U.S. economy. From Canada's and Mexico's perspectives, even though the initial trade imbalances with the United States are large, these imbalances would still change by no more than a few tenths of a percent of GDP. Moreover, the changes in Canada's and Mexico's trade imbalances with the United States would be offset by increased trade imbalances with the rest of the world. Mexico, whose surplus with the United States would grow, sees an increased trade deficit with the rest of the world driven by increased imports of agricultural products and other manufactured goods. Canada, whose surplus with the United States would shrink, sees an increased surplus with the rest of the world driven by natural resources and, to a lesser extent, services trade.

5.3. Long-run sectoral reallocation

The asymmetric responses of sectoral trade flows to NAFTA termination would cause production to reallocate across sectors, as shown by the first row in each panel of table 5, which report long-run changes in sectoral value added. In the United States, the largest drop in sectoral production would be seen in the agriculture sector due to the significant reduction in agricultural exports to Mexico. Production in the resources sector would rise slightly, while production in other sectors would decline. In Canada, production woudl fall most in transportation, followed by resources and other manufacturing. In Mexico, which would experience the most significant reallocation of production across sectors, transportation and other manufacturing production would fall significantly, while agricultural production would boom to offset Mexico's massive decline in imports in this sector. Panel (a) of figure 5 illustrates the macroeconomic implications of these sectoral reallocations. In all three countries, the other manufacturing sector would play the largest role in driving long-run declines in GDP; as shown in panel (c) of figure 4, this sector would account for the bulk of the decline in intra-NAFTA trade.

Panel (b) of figure 5 illustrates how each country's consumption basket would change in response to these sectoral reallocations. Notably, consumption of transportation equipment would fall significantly more than production due to the low trade elasticity and extensive international input-output linkages in this sector. Consumption of other manufactured goods would also fall significantly, in line with the large declines in trade and output in this sector. Finally, despite the significant increase in Mexican agricultural production, Mexican consumption of agriculture would still decline; domestic production and imports from the rest of the world would not fully make up for the decline in imports from the United States.

5.4. Trade and macroeconomic dynamics

The first two panels of figure 6 illustrate the transition dynamics of trade flows that would follow NAFTA termination. Panel (a) shows that the short-run effects of NAFTA termination on trade would be more muted than the long-run effects; it would take more than ten years for trade flows to adjust to their post-NAFTA steady states. This is due to the presence of import adjustment costs and export participation dynamics, which cause short-run trade elasticities to differ endogenously from their long-run values. Panel (b) shows how each country's trade elasticity would respond to NAFTA termination. By construction, each country's short-run trade elasticity is one in the period following termination, and it would take many years to reach their long-run values, which range from 7 to 10.

Panels (c)–(f) illustrate the effects of NAFTA termination on macroeconomic dynamics. Like trade flows, GDP and investment would fall gradually in all three countries. In the United States and Canada, consumption would adjust more quickly than output. In Mexico, however, consumption would adjust more slowly. Mexico's trade and production patterns would change more significantly than the other two countries' in the long run—Mexico's agricultural imports, in particular, would shift dramatically from the United States to the rest of the world—and the model's adjustment frictions draw this process out over many years.

5.5. Welfare

The long adjustment process to the post-NAFTA steady state shown in figure 6 suggests that the welfare losses associated with NAFTA termination could differ from the long-run changes in consumption, especially for Mexico. I measure welfare losses in the usual consumption-equivalent way, which asks households in each country what fraction of their annual consumption baskets they would give up to remain in the benchmark equilibrium in which NAFTA remains in force forever. Table 6 shows that when transition dynamics are taken into account, welfare losses would be lower than long-run changes in consumption for all three countries. Dynamic welfare losses from NAFTA termination would be 5.6% lower than long-run losses for Canada, and about 14% lower for both the United States and Mexico. Thus, modeling transition dynamics is important to accurately quantifying the welfare losses from NAFTA termination, especially for Mexico, which would have both the largest overall welfare loss and the largest difference between dynamic and long-run losses.

6. Short- and long-run effects of dynamic ingredients

The results of the quantitative analysis indicate that NAFTA termination would be followed by a long transition to the eventual post-NAFTA steady state, and that it is important to take this transition into account when computing the welfare losses from this policy change. Here, I ask: how do the model's dynamic adjustment margins—extensive-margin dynamics, international borrowing and lending, and factor and import adjustment costs—shape the the transition dynamics and welfare losses associated with NAFTA termination? To answer these questions, I repeat my quantitative exercise using alternative versions of my model without some of these features and compare the results of these sensitivity analyses, shown in panel (a) of table 6, to the baseline results. As one might expect, these ingredients affect the timing of welfare losses from NAFTA termination by altering transtion dynamics. I also find, however, that these ingredients have significant effects in the long run; in some cases, the long-run effects are actually larger than the short-run effects.

6.1. Factor adjustment costs

Capital and labor adjustment costs do not dramatically alter the transition dynamics that would follow NAFTA termination, but they do reduce all three countries' welfare losses. In a version of the analysis without capital adjustment costs, overall welfare losses are 16.3% higher than in the baseline analysis for the United States, 6.5% higher for Canada, and 4.6% higher for Mexico. The welfare consequences of labor adjustment costs are an order of magnitude smaller for all three countries.

Although factor adjustment costs do not enter the conditions that characterize a steady state—in which factor allocations are constant by definition—they still shape the long-run consequences of NAFTA termination. For the United States and Canada, capital adjustment costs reduce welfare losses in the long run as well as in the short run; the long-run effect of capital adjustment costs is actually larger than the short run effect for the United States. For Mexico, on the other hand, capital adjustment costs increase the long-run welfare loss, even though they reduce the overall loss that takes transition dynamics into account. In other words, capital adjustment costs have a significant effect on the timing of Mexico's welfare losses from NAFTA termination. Labor adjustment costs have negligible effects in the long run as well as the short run for all three countries.

6.2. Import adjustment costs

Import adjustment costs, unlike factor adjustment costs, significantly affect transition dynamics, especially the dynamics of trade flows. Figure 7, which plots transition dynamics in the version of the analysis without import adjustment costs, shows that trade adjusts almost immediately; while long-run trade elasticities are the same in this version of the analysis as in the baseline, short-run trade elasticities are much higher. Net exports and investment also adjust significantly more quickly to their long-run values.

Like factor adjustment costs, however, import adjustment costs also reduce the overall welfare losses from NAFTA termination. For the United States and Canada, the welfare effect of these costs is modest, lying in between the effects of capital and labor adjustment costs, but the effect of import adjustment costs for Mexico is significant. In the version of the analysis without import adjustment costs, Mexico's overall welfare loss is 9.1% higher than in the baseline analysis. The long-run effect of import adjustment costs for Mexico is even higher: Mexico's long-run welfare loss in the analysis without import adjustment costs is 14.8% higher than in the baseline.

6.3. Extensive-margin dynamics

It is well-known in the trade literature that the extensive margin of trade amplifies the effects of trade policy reforms. In the context of NAFTA termination, trade flows respond more as firms exit the export market, and aggregate productivity falls as factors of production reallocate towards less productive firms. In a version of the analysis without an extensive margin, in which all firms can costlessly export, the overall welfare cost of NAFTA termination is lower for all three countries than in the baseline analysis: 2.3%

lower for the United States; 8.1% lower for Canada; and 8.2% lower for Mexico. The differences in long-run welfare losses are similar, indicating that extensive-margin dynamics do not play a significant role in shaping the transition.

My analysis also reveals that these extensive-margin effects are larger when export participation is modeled as a dynamic, forward-looking decision. In a version of the analysis in which the decision to export is static—a Melitz (2003)-style setup in which the fixed cost of exporting is the same for new and continuing exporters—the welfare losses from NAFTA termination are less than in the baseline analysis in both the short run and the long run. As Alessandria and Choi (2014) point out, this is driven by the fact that trade policy changes induce larger extensive-margin adjustments when a larger fraction of the cost of exporting is sunk. This finding illustrates that modeling export participation as a dynamic decision is important for quantifying the welfare effects of trade policy changes, even in the long run. For Mexico, for example, the long-run welfare loss from NAFTA termination is 5% lower in the static-exporting version of the analysis than in the baseline.

6.4. Trade imbalances

Unlike many of the other dynamic ingredients, which have similar effects on welfare in the short and long run, the ability to borrow and lend internationally by running trade imbalances, which allows households to smooth consumption, has significant effects on the timing of welfare losses from NAFTA termination. To illustrate this, I conduct my quantitative exercise in a version of the model in which each country's trade balance trajectory in the termination equilibrium remains the same as in the benchmark no-termination equilibrium. In this version of the analysis, households cannot change their borrowing or lending behavior when NAFTA is terminated.

In the version of the analysis with fixed trade balances, overall welfare losses from NAFTA termination are lower in each country than in the baseline: 2.3% lower in the United States; 9.7% lower in Canada; and 5.0% lower in Mexico. However, the long-run losses are significantly higher: 24.0%, 32.6%, and 14.5% higher in the United States, Canada, and Mexico, respectively. As households cannot smooth out their consumption over time in response to the change in trade costs, consumption falls more gradually along the transition but falls more dramatically in the long run.

7. Short- and long-run effects of static ingredients

Quantitative trade policy analyses often find that input-output linkages and elasticities of substitution within and between sectors play important roles in determining the long-run consequences of trade policy reforms (Caliendo and Parro 2015, Costinot and Rodríguez-Clare 2014, Giri et al. 2017). Here, I ask: how do these ingredients affect the welfare consequences of NAFTA termination? Do they affect transition dynamics as well as the long run? To answer these questions, I repeat my quantitative analysis several more times using versions of my model with different assumptions about intermediate inputs and elasticities of substitution. The results of these analyses are shown in panel (b) of table 6. Consistent with other studies in the literature, I find that input-output linkages, substitutability between intermediate inputs from different sectors, and heterogeneity across sectors in substitutability between products from different countries are important determinants of the long-run effects of NAFTA termination. I also find, however, that these ingredients have significant effects along the transition.

7.1. Input-output linkages

To study the role of input-output linkages in determing the welfare cost of NAFTA termination, I analyze a version of my model in which there are no intermediate inputs. In the calibration procedure in this version of the model, I zero out all intermediate input cells in my input-output matrix before calibrating the expenditure share parameters.[14] Thus, in this version of the model, gross output equals value added in all sectors and international trade consists only of final expenditures.

Without intermediate inputs, NAFTA termination is less costly for all three countries. In the long run, welfare losses in Canada and Mexico are 90.1 and 84.0% lower than in the baseline analysis, respectively, and the U.S. welfare loss actually becomes a small gain. The timing of each country's welfare loss is also different in the no-intermediates version of the analysis. In the United States, once transition dynamics are taken into account, the welfare effect of NAFTA termination in the no-intermediates analysis is approximately zero. For Canada, too, dynamic welfare losses fall more than long-run losses. Canada's dynamic loss is in the no-intermediates version of the analysis is 8.1% lower than its long run loss, compared to 5.6% in the baseline analysis. For Mexico, the effect is the opposite: its dynamic welfare loss in the no-intermediates analysis is only 0.4% lower than its long-run loss, compared to 14.3% in the baseline.

7.2. Substitution across sectors

In the baseline calibration, value added and intermediate inputs from each sector are perfect complements and there is also strong complementarity in consumption. These choices are based on evidence about expenditure share dynamics from the macroeconomics literature (Atalay 2017, Kehoe et al. 2018), but many quantitative trade studies assume unitary elasticities of substitution across sectors. To study the importance of these choices for

14 I use the RAS procedure Bacharach (1965) to "balance" the alternative input-output matrix to make sure that all markets clear, ensuring that this matrix can represent an equilibrium in my model.

my results, I analyze the effects of NAFTA termination using Cobb-Douglas aggregation technologies instead of the baseline calibration. The elasticity of substitution between sectors in consumption has little impact on the results, so I focus my discussion on the version of the analysis with Cobb-Douglas production.

Long-run welfare costs in all three countries are substantially larger in the Cobb-Douglas version of the analysis than in the baseline: 70.0% larger for the United States, 115.2% larger for Canada, and 87.9% larger for Mexico. Like input-output linkages, this elasticity also affects transition dynamics. For all three countries, dynamic welfare losses are higher relative to long-run losses than in the baseline. For Mexico, especially, the difference is significant. Mexico's dynamic welfare loss is only 5.7% lower than its long-run loss in the version of the analysis with Cobb-Douglas production; this number is, once again, 14.3% in the baseline version.

7.3. Substitution within sectors

In the baseline calibration, the ability of distributors to substitute between products from different countries, which governs the intensive margin of trade, differs significantly across sectors. Natural resources and agricultural products from different countries are highly substitutable, while transportation equipment from different sectors is actually complementary. There is also significant heterogeneity across sectors in post-NAFTA tariffs. Some high-elasticity sectors like natural resources have low tariffs while others, like agriculture, have high tariffs. Conversely, some low-elasticity sectors like transportation equipment have high tariffs while others, like manufacturing, have low tariffs. To study how this form of sectoral heterogeneity affects my results, I analyze the effects of NAFTA termination in an alternative calibration in which all sectors have an Armington elasticity of five, the average of the Caliendo and Parro (2015) estimates.

In the long run, U.S. welfare losses are 22% lower in the symmetric-elasticity version of the analysis than in the baseline, while Canadian and Mexican losses are 65.6 and 153.1% higher. For the U.S., the decline in transportation equipment imports is less costly for consumers in this calibration than in the baseline, while declines in agricultural imports are more costly for Canada and Mexico. Like the other two "static" ingredients analyzed above, heterogeneity across sectors in substitutability between products from different countries also has a significant dynamic impact. In this version of the analysis, dynamic welfare losses are higher relative to long-run losses than in the baseline for the United States and Mexico, and lower for Canada. Again, the difference is most important for Mexico, whose dynamic loss is only 6.9% lower than its long-run loss in this version of the analysis, compared to the baseline's 14.3%.

8. Replacing NAFTA with another trade agreement

In my baseline analysis I have assumed that NAFTA is terminated entirely, and when this happens its members will levy the same most-favored-nation tariffs on each others' imports that they levy on imports from other World Trade Organization members. Trade policies towards other countries are unaffected, and no renegotiated deal is reached between even a subset of NAFTA members. Here, I explore the effects of several alternative scenarios that could arise in place of, or in addition to, NAFTA termination, including the recently-negotiated USMCA, which imposes stricter rules of origin in transportation equipment. I also show, by analyzing what would happen if tariffs between NAFTA countries reverted to their pre-NAFTA levels instead of current MFN rates, why my welfare results differ from CP's. The results of these analyses are shown in panel (c) of table 6.

8.1. USMCA

After extensive negotiations, the United States, Canada, and Mexico recently reached an agreement that will, according to the office of the U.S. Trade Representative, "modernize NAFTA into a 21st-century, high-standard agreement [that] will support mutually beneficial trade leading to freer markets, fairer trade, and robust economic growth in North America." The United States-Mexico-Canada agreement, or USMCA, retains NAFTA's duty-free trade provisions but strengthens domestic content requirements on trade in transportation equipment.[15] The USMCA has not yet been passed by the three countries' legislatures—there remains considerable uncertainty about whether it will ultimately be implemented—but it is important to determine whether the new agreement would have a significant macroeconomic impact.

To analyze the impact of the USMCA using my model—or any standard quantitative trade model used in the literature—the change in domestic content requirements must be mapped to ad valorem trade costs. To be precise, I model this policy change as an increase in iceberg transportation costs on intermediate inputs of transportation equipment from non-NAFTA countries. Like tariffs, domestic content requirements discourage imports of intermediate inputs from these countries, but unlike tariffs, these policies do not generate any revenue. My approach is based on Conconi et al. (2018), who find that domestic content requirements under NAFTA significantly reduced Mexican imports of intermediate goods from non-NAFTA countries. I proceed in two steps. First, I use the Conconi et al. (2018) estimates to compute the

15 The USMCA also includes new previsions on intellectual property protection, dispute settlement, and labor-market obligations. Additionally, Canada has agreed to slightly increase its import quotas in supply-managed agricultural industries. These changes are, for the most part, minor tweaks to existing NAFTA provisions and are unlikely to have a measurable macroeconomic impact. See the USTR's fact sheets on the USMCA for more detail at `https://ustr.gov/usmca`.

ad-valorem-equivalent of the rules of origin under NAFTA. They estimate that but for these requirements, Mexican imports of intermediates from these countries would be 45% higher. This implies an ad-valorem equivalent trade barrier on imported intermediate inputs from non-NAFTA countries of $0.113 = 0.45/4$, where the denominator is one minus the average trade elasticity estimated by CP. Second, I compute the increase in ad-valorem-equivalent trade costs in transportation equipment implied by the USMCA. To qualify for duty-free treatment under NAFTA, 62.5% of the value added embedded in transportation equipment must originate within the region, and the USMCA raises this threshold to 75%. Thus, the implied increase in the ad-valorem-equivalent trade barrier on non-NAFTA intermediates in this sector is $0.023 = 0.113 \times (75/62.5 - 1)$. In short, implementing the USMCA would increase iceberg trade costs on intermediate inputs of transportation equipment from non-NAFTA countries by 2.3%. This figure is exactly the same as the tariff that the United States would levy on imports of Canadian transportation equipment if NAFTA was terminated according to the current U.S. MFN tariff schedule (see table 2).

In my USMCA scenario, I assume that tariffs and other barriers to trade between NAFTA members do not change but, based on my calculations above, a new iceberg transportation cost of 2.3% is imposed on intermediate inputs of transportation equipment produced in the rest of the world. I find that implementing the USMCA would have small welfare consequences, but all three countries would be worse off than under the status quo. The ratios of dynamic losses to long-run losses are similar to the baseline results.

The USMCA's changes to domestic content requirements are small, so it is no surprise that it would have only minor macroeconomic consequences. To better illustrate the macroeconomic consequences that domestic content requirements can have, I conduct another analysis in which I impose a 10% iceberg cost on all intermediate inputs from the rest of the world, rather than the 2.3% cost that is levied only on transportation equipment in the USMCA analysis. This hypothetical policy change would reduce welfare by 0.03–0.06%. Relative to NAFTA termination, the welfare losses from this policy change are more evenly distributed. Mexico's loss is less than twice that of the United States in this scenario, whereas Mexico's loss is more than five times greater in the baseline.

8.2. Bilateral free trade agreements

If the USMCA or another trilateral agreement is not eventually implemented and NAFTA is indeed terminated, Canada could attempt to mitigate its losses by entering into a bilateral free trade agreement with one of its former NAFTA partners instead. To analyze whether this could be effective, I consider two alternative scenarios: in the first, NAFTA is terminated but the United States and Canada sign a bilateral free trade agreement. In the second, Canada forms a free trade agreement with Mexico, instead.

The results of the first exercise show that Canada's welfare losses from NAFTA termination would be significantly smaller if it formed a bilateral free trade agreement with the United States. The second exercise shows, however, that forming a similar agreement with Mexico would do little to mitigate Canada's losses. These results follow from the fact that Canada's primary trade partner is the United States. Canada trades little with Mexico so it has little to gain from a Canada-Mexico free trade agreement. The same logic holds true for Mexico; a bilateral free trade agreement with the United States could mitigate Mexico's welfare losses from NAFTA termination, but an agreement with Canada could not.

8.3. Higher U.S. tariffs

The next alternative scenario is motivated by recent U.S. policies to increase tariffs on steel, aluminum, and other imported products from around the world, not just Canada and Mexico. In this version of the analysis I assume that when NAFTA is terminated the United States also doubles its most-favored-nation tariffs. Thus, U.S. tariffs on Canadian and Mexican products rise twice as much as in the baseline model, and U.S. tariffs on imports from the rest of the world rise as well. Canadian and Mexican import tariffs are the same in this scenario as in the baseline.

As expected, U.S. imports from Canada and Mexico fall more in this scenario than in the baseline analysis, and its imports from the rest of the world fall as well. U.S. welfare actually rises, however, instead of falling; this result follows from an optimal tariff argument. Conversely, welfare losses in Canada and Mexico are larger than in the baseline analysis; it is Canada and Mexico, not the United States, that bear the burden of increased U.S. protectionism. Compared to the baseline scenario, the Canadian and Mexican transportation sectors shrink significantly more in terms of both production and consumption in this scenario, suggesting that input-output linkages play a role in driving these results.

8.4. Comparison with CP

The welfare losses from NAFTA termination that I find in this study differ significantly from some estimates in the literature of the welfare effects of implementing NAFTA in the first place. In their seminal study, CP estimate that the United States gained 0.08% from implementing NAFTA, Canada lost 0.06%, and Mexico gained 1.31%. In my analysis, welfare in the United States and Mexico falls when NAFTA is terminated, consistent with CP's findings, but their welfare losses are smaller, particularly for Mexico, than CP's estimated gains. For Canada, my analysis indicates that terminating NAFTA would reduce welfare, whereas CP estimate that Canada was actually harmed when NAFTA was implemented. Part of the difference between my results and CP's is accounted for by transition dynamics—dynamic welfare losses are lower than long-run losses, especially for Mexico—but as discussed above in section 5.1, even the long-run welfare losses in my analysis differ substantially from CP's estimates.

One key reason that my results differ from CP's, even in the long run, is that the three NAFTA countries' current MFN tariffs differ substantially from the tariffs they applied to one another in the early 1990s before NAFTA was implemented. Table 7 shows applied tariff rates in 1993 at the country pair-sector level, computed using the same methodology as the current MFN tariffs shown in table 2. The average tariffs that NAFTA countries applied to each others' products in the early 1990s were higher than their current MFN tariffs, especially tariffs on trade between Mexico and the other two NAFTA countries. At the sectoral level, Mexican applied tariffs on U.S. and Canadian resources, transportation equipment, and manufacturing were especially high relative to current MFN rates, while the reverse is true for Mexico's tariffs on agricultural products. In light of the differences between pre-NAFTA applied tariffs and current MFN tariff rates, it is not surprising the the welfare costs of terminating NAFTA today differ from the benefits of implementing the agreement in the 1990s. To quantify the importance of the tariff structure on the welfare effects of terminating NAFTA, I analyze another alternative scenario in which I assume that when NAFTA is terminated, tariffs revert to the 1993 applied rates in table 7 instead of the current MFN rates in table 2. In this version of the analysis, the results are closer to CP's: welfare losses for the United States and Mexico are substantially larger than in the baseline and Canada now sees a welfare gain instead of a loss.

Some of my modeling and calibration choices also contribute to the differences between my results and CP's. In particular, CP assume unitary elasticities of substitution between sectors and exogenous trade balances; there are no production complementarities and no role for consumption-smoothing behavior in their analysis. My results in sections 6.4 and 7.2 indicate that both of these assumptions have significant consequences for the welfare effects of NAFTA termination. Production complementarities reduce all three countries' welfare losses and endogenous trade imbalances significantly reduce Mexico's welfare loss. In the last alternative scenario, I assess the combined roles of tariff structures, production complementarities, and endogenous trade imbalances in driving the differences between my results and CPs. This scenario, labeled "CP specification" in table 6, differs from the baseline in three ways: Cobb-Douglas production technologies; fixed trade balances; and 1993 applied tariffs instead of current MFN rates. As in the previous scenario, U.S. and Mexican welfare losses are higher than in the baseline, while Canadian losses are lower, although Canada no longer gains from NAFTA termination. The combined effect of these three changes is particularly striking for Mexico, whose long-run loss rises to 1.030%, more than 400% higher than in the baseline. Thus, these three differences between my analysis and CP's account for the vast majority of the differences in our results for Mexico, the country for which our results differ most dramatically.

However, because Mexico's dynamic losses are substantially lower than its long-run losses in this version of the analysis—Mexico's dynamic welfare loss rises by only 257%—which indicates that modeling transition dynamics is even more important under CP's specification.

9. Conclusion

In this paper I have used a dynamic general equilibrium model with an input-output production structure, endogenous export participation dynamics, and adjustment frictions in factor markets and trade to assess the consequences of terminating the North American Free Trade Agreement. When NAFTA is terminated, NAFTA members charge the same import tariffs on each other's products that they charge on products from other World Trade Organization members. Tariffs rise most in the transportation equipment sector and, in the case of Mexico, agriculture.

In the long run, NAFTA termination would reduce aggregate trade flows between NAFTA members by 6.7–15.6% and would cause output and consumption to fall in all three member countries. Terminating NAFTA would have little effect on regional trade imbalances, however; in fact, the U.S. trade deficit with Mexico would grow. At the sectoral level, Mexican imports of U.S. agricultural products would fall most because Mexico charges high tariffs in this sector and can easily substitute towards its own products and those produced in the rest of the world. Trade in natural resources, which is also highly substitutable across countries, would also fall significantly. Despite high tariffs, trade in transportation equipment would fall the least because the trade elasticity in this sector is low. Precisely because of this low elasticity, however, the small drop in trade is costly; transportation value added and consumption fall significantly in all three countries. My results indicate that strong international input-output linkages in this sector also play an important role in how it is affected by NAFTA termination.

In the short run, trade would fall gradually after NAFTA is terminated because export participation rates fall gradually and importers slowly adjust the quantities they purchase from foreign suppliers. Taking into account these transition dynamics, welfare would fall by 0.04% in the United States, and 0.12% in Canada, and 0.22% in Mexico after NAFTA is terminated. These dynamic welfare losses are 5.6–14.3% smaller than the long-run changes in consumption, indicating that transition dynamics mitigate the long-run welfare costs of this policy change. However, the dynamic ingredients that shape this transition—adjustment costs, trade imbalances, and export participation dynamics—also have significant long-run consequences. Conversely, "static" ingredients like input-output linkages and production complementarities also have important dynamic effects.

In addition to the baseline NAFTA termination scenario, I have analyzed a range of alternatives: the recently-negotiated—but not yet ratified—USMCA, which imposes stricter domestic content requirements in the transportation equipment sector; a scenario in which the United States raises all import tariffs unilaterally in addition to leaving NAFTA; scenarios in which Canada forms bilateral free trade agreements with its former NAFTA partners; and a scenario in which tariffs revert to pre-NAFTA levels instead of current MFN rates. I find that the USMCA is worse than the status quo, although not as harmful as terminating NAFTA entirely, Canada and Mexico would bear the brunt of increased U.S. protectionism, and that forming a free trade agreeement with Mexico would do little to mitigate Canada's welfare losses from NAFTA termination. Finally, I find that the costs of terminating NAFTA today differ dramatically from the benefits—or, in Canada's case, loss—from implementing the agreement in 1994 because the NAFTA countries' current MFN tariffs differ significantly from the tariffs that they applied in the early 1990s.

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TABLE 1
Sectoral aggregation scheme

Sector	HS codes	WIOD industries
Agriculture	1–14	Crop and animal production, hunting and related service activities; Forestry and logging; Fishing and aquaculture
Resources	25–27	Mining and quarrying; Manufacture of coke and refined petroleum products
Trans.	86–89	Manufacture of motor vehicles, trailers and semi-trailers; Manufacture of other transport equipment
Mfg.	15–24; 28–85; 90–97	Manufacture of food products, beverages and tobacco products; Manufacture of textiles, wearing apparel and leather products; Manufacture of wood and of products of wood and cork, except furniture, manufacture of articles of straw and plaiting materials; Manufacture of paper and paper products; Printing and reproduction of recorded media; Manufacture of chemicals and chemical products; Manufacture of basic pharmaceutical products and pharmaceutical preparations; Manufacture of rubber and plastic products; Manufacture of other non-metallic mineral products; Manufacture of basic metals; Manufacture of fabricated metal products, except machinery and equipment; Manufacture of computer, electronic and optical products; Manufacture of electrical equipment; Manufacture of machinery and equipment n.e.c.; Manufacture of furniture, other manufacturing
Services	N/A	Repair and installation of machinery and equipment; Electricity, gas, steam and air conditioning supply; Water collection, treatment and supply; Sewerage, waste collection, treatment and disposal activities, materials recovery, remediation activities and other waste management services; Construction; Wholesale and retail trade and repair of motor vehicles and motorcycles; Wholesale trade, except of motor vehicles and motorcycles; Retail trade, except of motor vehicles and motorcycles; Land transport and transport via pipelines; Water transport; Air transport; Warehousing and support activities for transportation; Postal and courier activities; Accommodation and food service activities; Publishing activities; Motion picture, video and television programme production, sound recording and music publishing activities, programming and broadcasting activities; Telecommunications; Computer programming, consultancy and related activities, information service activities; Financial service activities, except insurance and pension funding; Insurance, reinsurance and pension funding, except compulsory social security; Activities auxiliary to financial services and insurance activities; Real estate activities; Legal and accounting activities, activities of head offices, management consultancy activities; Architectural and engineering activities, technical testing and analysis; Scientific research and development; Advertising and market research; Other professional, scientific and technical activities, veterinary activities; Administrative and support service activities; Public administration and defence, compulsory social security; Education; Human health and social work activities; Other service activities; Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use; Activities of extraterritorial organizations and bodies

TABLE 2
Change in import tariffs after NAFTA termination

Partner	Agriculture	Resources	Trans.	Mfg.	Total
(a) United States					
Canada	1.74	0.74	2.30	1.79	1.51
Mexico	3.19	0.52	7.75	1.76	3.14
(b) Canada					
United States	3.28	0.61	4.55	1.55	2.14
Mexico	0.57	0.38	5.20	1.47	2.56
(c) Mexico					
United States	29.18	0.18	7.62	3.65	5.40
Canada	13.29	0.08	12.22	2.97	6.19

TABLE 3
Sectoral production and trade in NAFTA (2014 data, percent GDP)

Quantity	Agriculture	Resources	Trans.	Mfg.	Services	Total
(a) United States						
Value added	1.24	3.67	1.57	9.66	83.86	100.00
Exports	0.31	0.98	1.31	3.93	4.48	11.01
to Canada	0.04	0.23	0.35	0.86	0.18	1.66
to Mexico	0.04	0.14	0.13	0.67	0.04	1.01
to rest of world	0.23	0.61	0.83	2.41	4.26	8.33
Imports	0.30	1.94	1.75	7.24	2.52	13.76
from Canada	0.06	0.69	0.29	0.76	0.21	2.00
from Mexico	0.06	0.19	0.35	0.84	0.08	1.52
from rest of world	0.19	1.06	1.11	5.64	2.23	10.23
Net exports	0.01	-0.96	-0.44	-3.31	1.95	-2.74
with Canada	-0.01	-0.45	0.06	0.10	-0.03	-0.34
with Mexico	-0.01	-0.05	-0.22	-0.18	-0.05	-0.51
with rest of world	0.04	-0.45	-0.28	-3.23	2.03	-1.89
(b) Canada						
Value added	1.63	8.99	1.53	9.44	78.41	100.00
Exports	1.44	8.32	3.76	11.58	7.93	33.03
to United States	0.58	7.03	2.96	7.79	2.17	20.53
to Mexico	0.07	0.00	0.04	0.28	0.09	0.48
to rest of world	0.80	1.28	0.76	3.51	5.67	12.02
Imports	0.62	3.42	5.55	17.54	4.74	31.87
from United States	0.43	2.41	3.60	8.79	1.83	17.07
from Mexico	0.02	0.09	0.32	0.66	0.06	1.15
from rest of world	0.17	0.92	1.63	8.09	2.85	13.65
Net exports	0.82	4.89	-1.78	-5.96	3.20	1.16
with United States	0.15	4.62	-0.64	-1.00	0.34	3.46
with Mexico	0.05	-0.09	-0.28	-0.38	0.03	-0.67
with rest of world	0.63	0.36	-0.87	-4.58	2.83	-1.63
(c) Mexico						
Value added	3.29	7.98	3.51	14.33	70.88	100.00
Exports	1.02	4.55	6.08	16.42	1.73	29.80
to United States	0.83	2.71	4.97	11.97	1.17	21.65
to Canada	0.03	0.13	0.44	0.91	0.08	1.59
to rest of world	0.17	1.71	0.66	3.54	0.48	6.56
Imports	0.89	2.29	3.47	19.29	3.17	29.11
from United States	0.64	1.98	1.80	9.45	0.51	14.37
from Canada	0.09	0.00	0.06	0.39	0.12	0.67
from rest of world	0.16	0.30	1.61	9.45	2.53	14.07
Net exports	0.13	2.26	2.60	-2.87	-1.44	0.69
with United States	0.19	0.73	3.18	2.53	0.66	7.28
with Canada	-0.07	0.13	0.38	0.52	-0.04	0.92
with rest of world	0.00	1.41	-0.95	-5.92	-2.05	-7.51

TABLE 4
Assigned parameters

(a) Common parameters and initial conditions

Parameter	Meaning	Value	Source/target
β	Discount factor	0.98	2.00% Long-run interest rate
ψ	Intertemporal elasticity	-1.00	Standard
δ	Depreciation rate	0.06	Standard
α	Capital share	0.33	Standard
ρ^c	Cons. elasticity	0.65	Kehoe et al. (2018), Atalay (2017)
ρ^x	Inv. elasticity	1.00	Kehoe et al. (2018), Bems (2008)
γ	Cons. utility share	0.33	Standard
θ	EoS across varieties	5.00	Alessandria and Choi (2019)
ϕ^k, ϕ^ℓ	Factor adj. costs	6.50	Kehoe and Ruhl (2009), Sargent (1978)
ϕ^m, ϕ^f	Import adj. costs	2.90	Short-run trade elasticity = 1.0
$B_{USA,0}$	US initial bonds	-40.60	Lane and Milesi-Feretti (2007)
$B_{CAN,0}$	Canada initial bonds	0.52	Lane and Milesi-Feretti (2007)
$B_{MEX,0}$	Mexico initial bonds	-2.85	Lane and Milesi-Feretti (2007)

(b) Armington elasticities

Country	Use	Agriculture	Resources	Trans.	Mfg.	Services
USA	Intermediate	8.11	30.82	0.80	5.46	5.00
USA	Final	8.11	37.23	0.88	4.78	5.00
CAN	Intermediate	8.11	29.80	0.87	5.48	5.00
CAN	Final	8.11	39.74	0.82	4.62	5.00
MEX	Intermediate	8.11	35.01	0.97	5.64	5.00
MEX	Final	8.11	31.49	0.97	3.71	5.00
ROW	Intermediate	8.11	27.25	0.87	5.75	5.00
ROW	Final	8.11	45.72	0.84	4.61	5.00

TABLE 5
Long-run effects of NAFTA termination (percent changes)

Quantity	Agriculture	Resources	Trans.	Mfg.	Services	Total
(a) United States						
Value added	-1.68	0.20	-0.52	-0.32	-0.03	-0.08
Consumption	-0.33	-0.06	-0.67	-0.16	-0.02	-0.05
Investment	-1.58	0.05	-0.60	-0.39	-0.17	-0.19
Exports	-13.24	-4.05	-1.72	-3.67	0.36	-2.18
to Canada	-24.02	-18.43	-3.11	-6.40	-1.40	-7.64
to Mexico	-91.06	-9.66	-6.29	-13.93	-2.29	-15.36
to rest of world	0.43	0.32	0.07	0.02	0.38	0.25
Imports	-8.66	-6.09	-1.91	-2.18	-0.18	-2.40
from Canada	-14.66	-12.93	-1.71	-9.11	0.96	-8.43
from Mexico	-27.45	-8.03	-6.03	-11.79	1.28	-9.89
from rest of world	0.46	0.90	0.16	0.57	-0.37	0.34
(b) Canada						
Value added	-0.65	-0.66	-2.16	-1.66	0.01	-0.25
Consumption	-0.62	-0.07	-2.09	-0.52	0.01	-0.13
Investment	-0.87	-0.90	-2.30	-1.70	-0.42	-0.56
Exports	-7.54	-7.68	-2.83	-6.27	1.57	-4.39
to United States	-14.66	-12.93	-1.71	-9.11	0.96	-8.43
to Mexico	-62.34	1.38	-9.56	-10.51	-1.33	-15.58
to rest of world	0.60	9.11	0.21	0.12	1.37	1.99
Imports	-17.64	-15.52	-2.35	-2.92	-1.55	-4.36
from United States	-24.02	-18.43	-3.11	-6.40	-1.40	-7.64
from Mexico	-4.26	-6.07	-3.66	-8.79	0.00	-6.65
from rest of world	3.67	-1.33	0.66	2.30	-1.65	1.10
(c) Mexico						
Value added	8.52	1.69	-3.99	-3.56	-0.27	-0.45
Consumption	-1.46	-0.13	-1.32	-0.86	-0.01	-0.26
Investment	7.03	0.95	-3.97	-3.41	-0.74	-0.66
Exports	-22.96	-0.08	-6.53	-10.40	1.75	-7.54
to United States	-27.45	-8.03	-6.03	-11.79	1.28	-9.89
to Canada	-4.26	-6.07	-3.66	-8.79	0.00	-6.65
to rest of world	-5.06	7.52	0.20	-3.10	1.73	1.04
Imports	-71.79	-9.31	-3.75	-5.20	-2.60	-7.21
from United States	-91.06	-9.66	-6.29	-13.93	-2.29	-15.36
from Canada	-62.34	1.38	-9.56	-10.51	-1.33	-15.58
from rest of world	26.33	-4.77	-0.11	5.54	-2.67	3.45

TABLE 6
Welfare effects of NAFTA termination

	Dynamic (pct. change)			Long-run (pct. change)			Ratio dynamic to long-run		
Model	USA	Canada	Mexico	USA	Canada	Mexico	USA	Canada	Mexico
Baseline	-0.043	-0.124	-0.220	-0.050	-0.132	-0.256	0.859	0.944	0.857
(a) Effects of dynamic ingredients									
No capital adj. costs	-0.050	-0.132	-0.230	-0.062	-0.140	-0.253	0.808	0.941	0.910
No labor adj. costs	-0.043	-0.125	-0.221	-0.050	-0.132	-0.255	0.857	0.942	0.865
No import adj. costs	-0.046	-0.129	-0.240	-0.054	-0.137	-0.294	0.849	0.939	0.815
Static exporting	-0.041	-0.116	-0.211	-0.050	-0.124	-0.248	0.833	0.937	0.850
No extensive margin	-0.042	-0.114	-0.202	-0.050	-0.122	-0.239	0.831	0.934	0.844
Fixed trade balances	-0.042	-0.112	-0.209	-0.062	-0.175	-0.293	0.683	0.640	0.714
(b) Effects of static ingredients									
No intermediate inputs	0.000	-0.011	-0.040	0.002	-0.012	-0.041	0.129	0.919	0.996
Cobb-Douglas production	-0.076	-0.275	-0.454	-0.085	-0.284	-0.481	0.888	0.971	0.943
Sym. trade elasticities	-0.033	-0.205	-0.603	-0.039	-0.217	-0.648	0.860	0.942	0.931
(c) Alternative scenarios									
USMCA	-0.001	-0.002	-0.002	-0.002	-0.002	-0.002	0.875	0.906	0.883
Stricter dom. content reqs.	-0.031	-0.055	-0.057	-0.038	-0.064	-0.066	0.810	0.858	0.871
US-Canada FTA	-0.031	-0.017	-0.229	-0.035	-0.023	-0.262	0.875	0.766	0.871
Canada-Mexico FTA	-0.043	-0.112	-0.201	-0.049	-0.119	-0.235	0.862	0.942	0.856
Higher U.S. tariffs	0.071	-0.324	-0.453	0.059	-0.350	-0.521	1.200	0.925	0.869
1994 tariffs	-0.118	0.066	-0.293	-0.126	0.058	-0.334	0.933	1.139	0.879
CP specification	-0.162	-0.073	-0.787	-0.191	-0.135	-1.030	0.848	0.540	0.764

TABLE 7
Change in import tariffs to pre-NAFTA levels

Partner	Agriculture	Resources	Trans.	Mfg.	Total
(a) United States					
Canada	0.86	0.00	0.04	0.74	0.33
Mexico	5.26	0.70	3.83	4.76	4.02
(b) Canada					
United States	1.39	1.79	3.72	2.18	2.44
Mexico	5.48	1.56	5.19	5.26	5.05
(c) Mexico					
United States	9.35	8.74	14.04	12.32	11.77
Canada	3.97	9.19	13.75	12.57	10.91

FIGURE 1 NAFTA members' bilateral trade flows in 2014

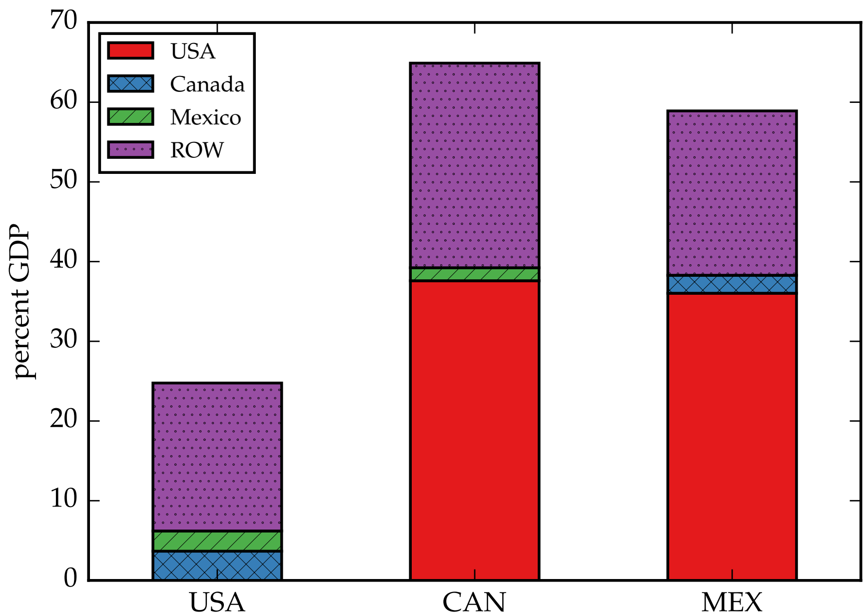

FIGURE 2 NAFTA members' sectoral trade flows in 2014

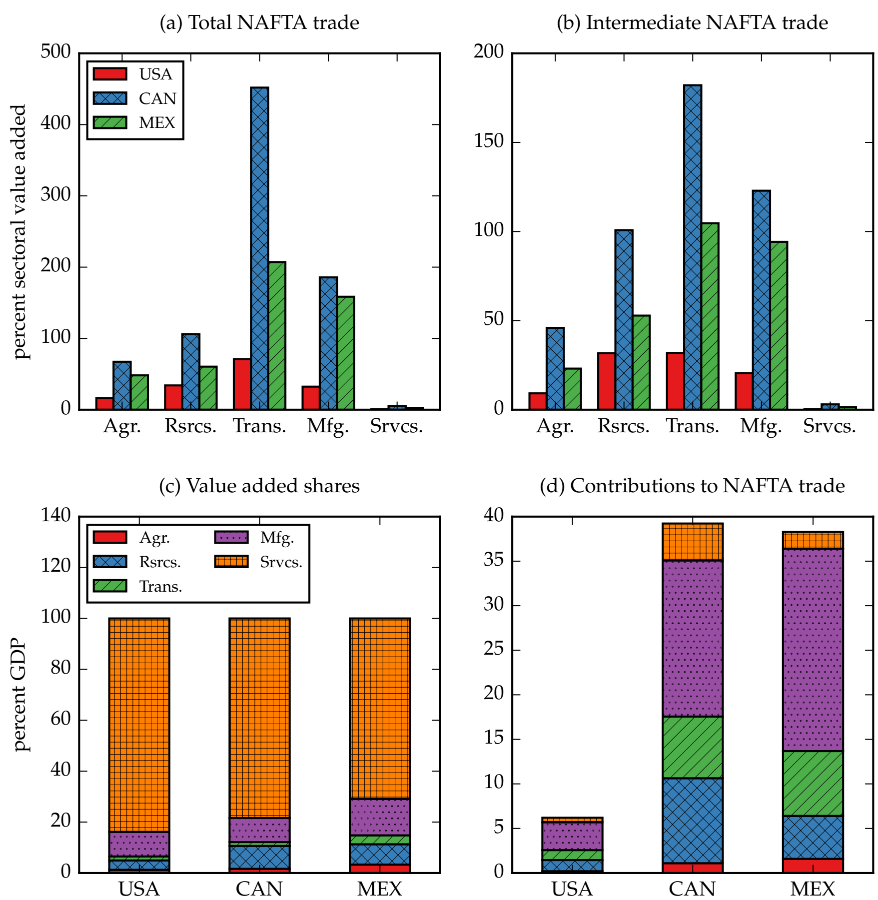

FIGURE 3 NAFTA trade imbalances in 2014

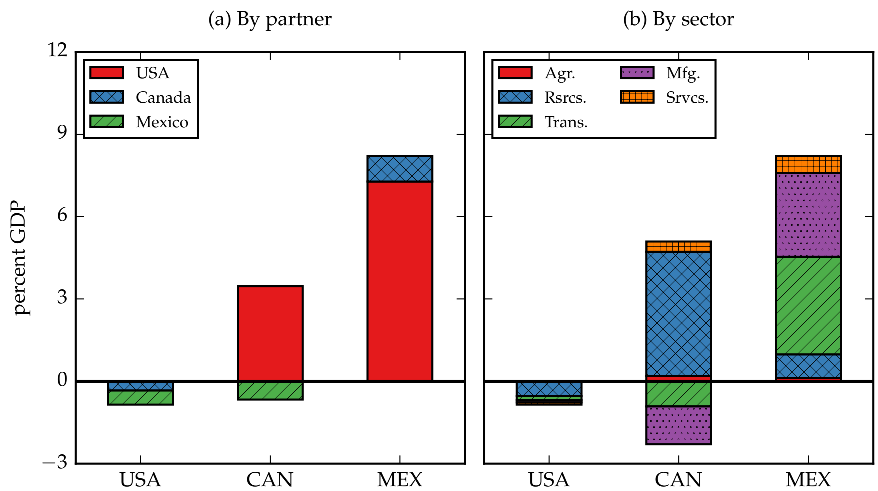

FIGURE 4 Long-run effects of NAFTA termination on trade

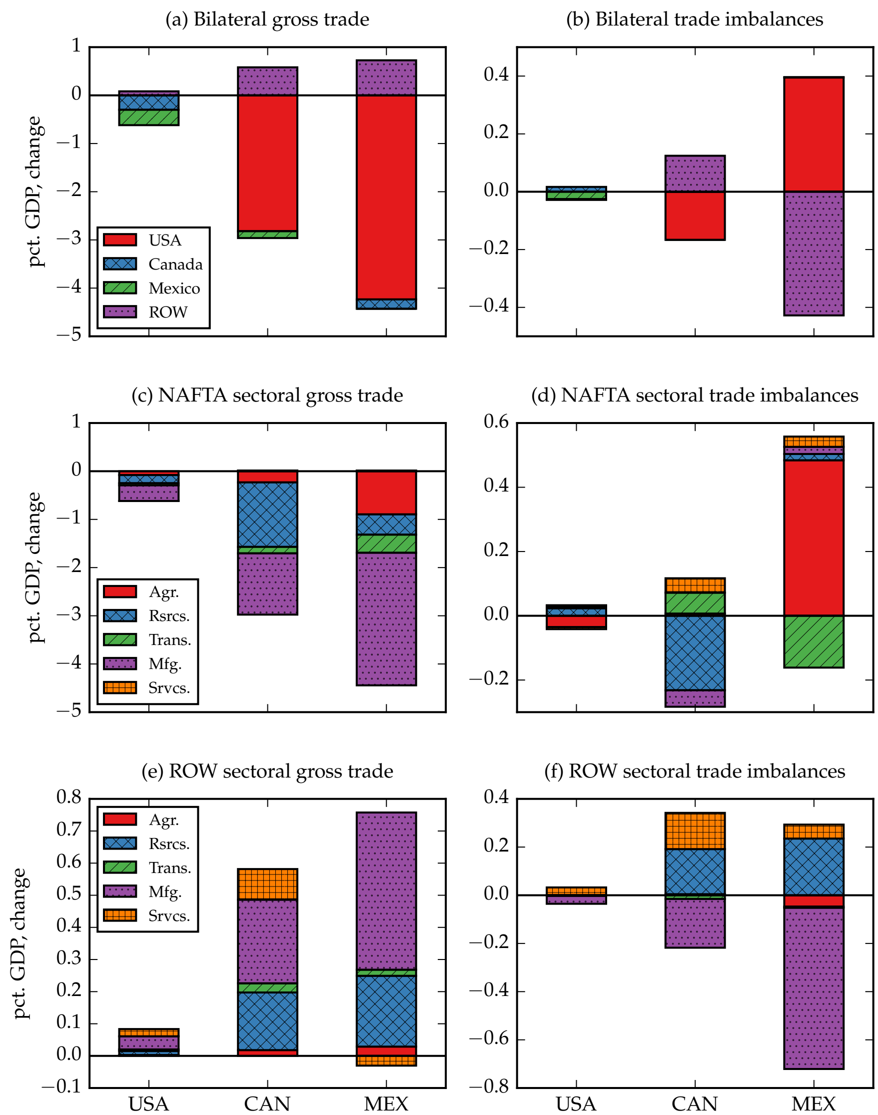

FIGURE 5 Long-run effects of NAFTA termination on sectoral reallocation

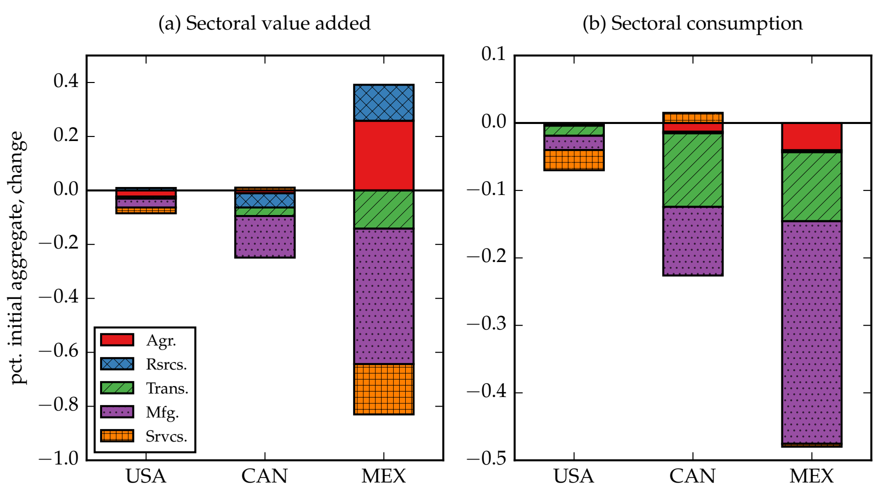

FIGURE 6 Dynamic effects of NAFTA termination

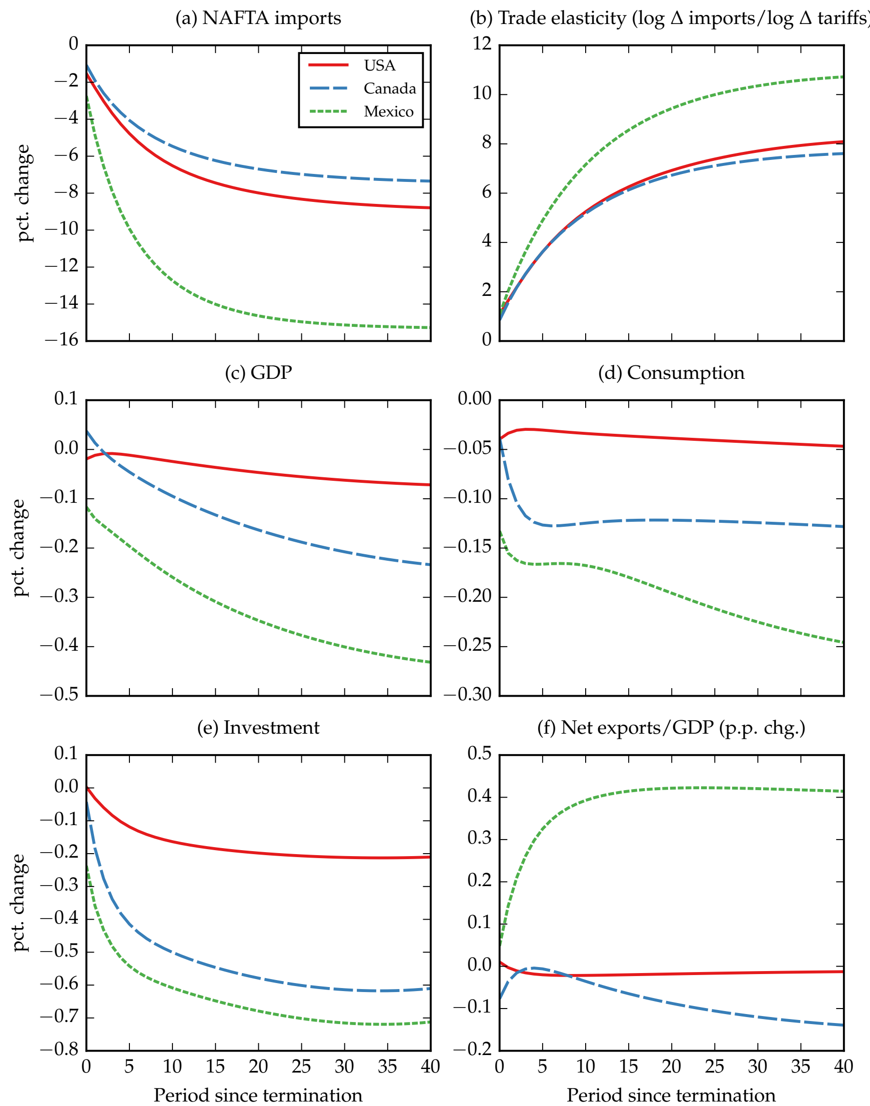

FIGURE 7 Dynamic effects of NAFTA termination (no trade adj. costs)