The Regional and Sectoral Consequences of Leaving NAFTA*

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Abstract

The Trump administration is renegotiating NAFTA, the free trade agreement between the United States, Mexico, and Canada. Little research has quantified the potential effects of such a renegotiation.

To evaluate these effects, we use a dynamic trade model adapted from Caliendo, Dvorkin, and Parro. The model, which considers both input-output linkages and migration/trade frictions, can estimate how leaving NAFTA will change employment and welfare across 23 sectors and 87 regions.

We find that leaving NAFTA decreases aggregate U.S. welfare by 0.03%, while decreasing aggregate Mexican and Canadian welfare by 0.15%. U.S. non-employment increases by 0.09%, or 45,000 people. For particular U.S. industries, the shock of leaving NAFTA can be large: employment in textiles rises by 0.49%, and employment in transportation equipment manufacturing falls by 0.25%. Trade between NAFTA countries is significantly affected: trade from Canada and Mexico to the U.S. falls by 14%, while trade in the opposite direction falls by 7%.

*Thanks to my advisor, Lorenzo Caliendo, who introduced me to research. He also taught me that no research exists in a vacuum, so to the lives NAFTA has changed: this paper is for you.

†For interactive figures, code, and contact info, visit the online companion at `http://www.tinyurl.com/LeavingNAFTA`.

1 Introduction

Ratified by the United States, Mexico, and Canada in 1994, the North American Free Trade Agreement (NAFTA) covers a combined economy with a GDP of $21 trillion and a population of 490 million.[1] Under NAFTA, annual imports from Mexico and Canada to the U.S. rose from $180 billion in 1994 to $580 billion in 2016; exports from the U.S. to Mexico and Canada rose from $165 billion to $500 billion. Beyond its effect on trade, NAFTA has led to a multitude of changes: it helped the U.S. auto sector (Burfisher et al., 2001), ameliorated Mexican wage inequality (Esquivel and Rodríguez-López, 2003), and even worsened obesity (Hawkes, 2006).

Most of these changes have been small; despite this, free trade agreements have become a politically charged topic. According to a November 2017 poll by the Pew Research Center, 33% of Americans believe that NAFTA is bad for their country. Yet this belief differs sharply across party lines. 54% of Republicans believe that NAFTA is bad for the U.S., while only 18% of Democrats believe similarly. Neither belief is necessarily unfounded: Caliendo, Dvorkin, and Parro (2017; henceforth, CDP) demonstrate that trade shocks can cause a wide distribution of welfare changes across labor markets. In other words, trade shocks can create both "winners" and "losers."

In an effort to help workers hurt by trade shocks, the Trump administration is renegotiating NAFTA with Mexico and Canada. There are growing indications the U.S. may leave NAFTA completely, but we refrain from predicting the outcome of these negotiations. Rather, this paper examines what would happen to labor and welfare should a complete dissolution of NAFTA occur, and the U.S., Mexico, and Canada return to most-favored-nation (MFN) status with one another.[2]

Importantly, we only measure the effect of increasing tariffs between NAFTA countries to their MFN levels. That is, we do not allow non-tariff trade costs to change, nor do we allow any negotiations that lower tariffs for certain industries and raise tariffs for others. (Rerunning our model to estimate the effects of such deals, however, is straightforward.) More broadly, we ignore any political and cultural ramifications associated with NAFTA's dissolution.

2 Existing results

2.1 Literature on *entering* NAFTA

There is little, if any, existing research on the effects of *leaving* NAFTA. Still, a fair number of studies have analyzed the effects of *entering* NAFTA; overall, these effects were small.

Due to the difficulty of measuring certain economic fundamentals (e.g. migration/trade frictions), most of these studies involve reduced-form estimations. Although powerful, these estimations often focus on a single economic variable at the cost of ignoring others. An estimation explaining NAFTA's effects on trade diversion, for instance, is unlikely to uncover its effects on wages.[3] Nevertheless, by surveying a variety of these reduced-form studies, we can obtain a sense of what *entering* NAFTA meant for the economy, and whether our paper's results on *leaving* NAFTA are reasonable.

Trade - perhaps the economic variable most directly affected by NAFTA - provides a nice starting point

[1] 2016 data from the World Bank.

[2] Per World Trade Organization (WTO) rules, should NAFTA dissolve, the three nations are required to give each other tariff rates equal to those given to other WTO nations.

[3] *Trade diversion* occurs when imports move from low-cost countries (experiencing high tariffs) to higher-cost countries (experiencing lower tariffs). *Trade creation* occurs when production is moved to countries with a comparative advantage.

for our survey. At first blush, NAFTA seems to have affected trade significantly: from 1993 (the year before NAFTA's signing) to 1998, Mexico's share of total U.S. imports rose by 50%. Yet as Krueger (1999) observes, NAFTA's effects on Mexican trade, at least over the first three years, may have been modest compared to those of the peso crisis and the country's lowering of MFN tariffs. Two other studies refine Krueger's finding by showing that NAFTA changed prices only in highly-protected sectors. Specifically, Fukao et al. (2003) find that NAFTA was statistically significant in explaining trade diversion for only 15 out of 70 industries; using a different model, Romalis (2007) discovers that NAFTA caused trade diversion only in highly-protected sectors. Romalis also finds no evidence of trade creation.

Based on NAFTA's modest effect on trade, one might infer that NAFTA's effect on aggregate wages was even smaller. Studies support this conclusion, but also indicate the importance of studying the *distributional* (and not just aggregate) effects of trade shocks. Hakobyan and McLaren (2016), for instance, discover that the effect of NAFTA on most U.S. workers was small. Indeed, for college-educated workers, NAFTA had no significant effect on wages. Even for most high school dropouts, NAFTA's effect on wage growth was negligible. However, for an important subset of workers - such as dropouts living in a South Carolina town dependent on textiles - NAFTA may have reduced wage growth during the 1990s by over 8%. According to Hakobyan and McLaren, the fact that location and industry matter for the changes in blue-collar wage growth, but not for the changes in white-collar wage growth, is evidence of heterogeneous mobility frictions.[4] This reduced-form study, then, complements our paper in two ways: first, it shows the importance of having a model with heterogeneous labor markets, and second, it validates the direction and magnitude of our results. (Indeed, our results - based on a general equilibrium model instead of a reduced-form one - also show negligible effects on wages for most Americans and disproportionate effects for textile workers.)

After an analysis of wages, a reasonable next step would be to quantify NAFTA's effect on employment. In a report commissioned by the U.S. Department of Labor, Hinojosa-Ojeda et al. (2000) use a partial equilibrium approach to pinpoint NAFTA's effect on jobs. Even in the most exaggerated analyses where demand and productivity remain fixed, NAFTA's yearly *impact* is no larger than 100,000 jobs. By comparison, the U.S. economy causes the separation of 5,000,000 workers from their jobs yearly.[5] A Congressional Budget Office (1993) analysis, conducted *before* NAFTA's implementation, yields similar results; it estimates that over an entire decade, net job gains from *entering* NAFTA would be anywhere from 35,000 to 170,000. (By comparison, our model predicts that net job losses from *leaving* NAFTA, in the long-run, would be 45,000.)

As Burfisher et al. (2001) observe, studies like these indicate that for the U.S., NAFTA likely had little aggregate effect. Studies looking at Mexico and in particular Canada are less prevalent, but a survey by Kose et al. (2005) suggests that NAFTA benefitted Mexico sizably. Kouparitsas (1997), for instance, employs a dynamic general equilibrium model to conclude that NAFTA increased long-run Mexican welfare by 0.96%; López-Córdova (2003), using plant-level data, estimates that NAFTA increased Mexican total factor productivity (TFP) by 10% from 1993 to 1999. By comparison, we estimate that *leaving* NAFTA will decrease Mexican welfare by 0.15%.[6] Their results are larger than ours. Yet as we emphasize later, these studies cover the effects of *entering*, and not *leaving* NAFTA. Indeed, we estimate Mexican welfare will drop by "only" 0.15% in part because Mexico has reduced MFN rates significantly since NAFTA's implementation.[7]

[4] After all, college-educated workers stuck in a struggling industry are arguably more able to switch to others.

[5] Importantly, impact does not equal job losses, as workers can still relocate to higher-paying sectors. The model in Hinojosa-Ojeda et al. is unable to dissect these migration flows; our model, on the other hand, explicitly forecasts worker relocation.

[6] Although we, like Kouparitsas, measure changes in welfare based on compensating variation, we have a different utility specification than he does. These numbers are, as a result, not directly comparable.

[7] Additionally, Monge-Naranjo critiques López-Córdova's paper for not fully specifying its "without-NAFTA" assumptions.

Most of the studies above depend on reduced-form estimations, and the few based on a general equilibrium model focus on NAFTA's aggregate effects (rather than its distributional ones). There are two papers, however, that demonstrate how one can use a general equilibrium model to estimate NAFTA's distributional effects on any important economic variable. In this sense, they provide both the impetus and methodological framework for our own.

In the first paper, Caliendo and Parro (2012; henceforth, CP) develop a general equilibrium model (without labor dynamics, but with sectoral linkages and heterogeneity) to estimate the trade and welfare effects of entering NAFTA. They find that entering NAFTA led to a 0.08% increase in U.S. welfare, a 1.31% increase in Mexican welfare, and a 0.06% decrease in Canadian welfare.[8] From CP, we obtain the motivation of this paper: flipping their question on its head to find the effects of *leaving* NAFTA.

In the second paper, CDP extend CP to create a *dynamic* general equilibrium model with migration costs. Importantly, CDP measure the effect of the China productivity shock, and not of entering NAFTA. They consequently assume differing productivities across their baseline and counterfactual scenarios, but unchanged tariffs. With some work, though, we can modify CDP's model to allow for tariffs that differ between the baseline scenario of staying in NAFTA and the counterfactual one of leaving it. The payoff for this modest amount of work is sizable - given these modifications, pinpointing how leaving NAFTA will affect the time evolution of employment, wages, welfare, expenditures, and trade is simple.

2.2 Our contribution

A natural question to ask, given the literature review above, is how this paper can contribute to both the academic and policy debate around NAFTA. As alluded to earlier, there are two key aspects that differentiate this paper from others.

First (and perhaps most importantly!), the results above estimate the effects of *joining* NAFTA in 1994, rather than the effects of *leaving* NAFTA in 2017. In the two decades since NAFTA's implementation, the economy has experienced significant structural changes: the share of manufacturing as a portion of U.S. GDP has *dropped* from 16.6% in 1997 to 12.3% in 2015, while the share of manufacturing as a portion of Mexican GDP has *risen* from 17.2% in 1994 to 18.8% in 2015.[9] Looking at trade more specifically, U.S. exports to Mexico in 1994 were 5.5 times greater than U.S. exports to China; U.S. exports to Mexico in 2016 were only double U.S. exports to China.

Even if the economy experienced no *structural* changes from 1994 to 2017, one would be remiss to ignore an important *policy* change between the two years: an across-the-board reduction in MFN tariff rates. Average MFN tariff rates for the U.S. dropped from 6% in 1994 to 3.65% in 2012. For this reason alone, the effects of *leaving* NAFTA are unlikely to equal the effects of *entering* it. (To elucidate this point, we run a second counterfactual where all nations go back to their 1993 tariff rates. The results are significant, with a supermajority of U.S. industries experiencing employment share changes of over 0.3%.)

Because López-Córdova regresses TFP on trade and foreign direct investment (FDI), and not on NAFTA itself, saying that NAFTA *caused* an increase in TFP because it caused an increase in FDI is perilous. After all, most Latin American countries also experienced monumental increases in FDI during the 1990s.

[8] CP's definition of welfare differs from ours. Loosely speaking, they measure welfare as total absorption; we measure welfare as wages plus migration option value.

[9] Data in this subsection from the World Bank; there was no U.S. manufacturing data for 1994.

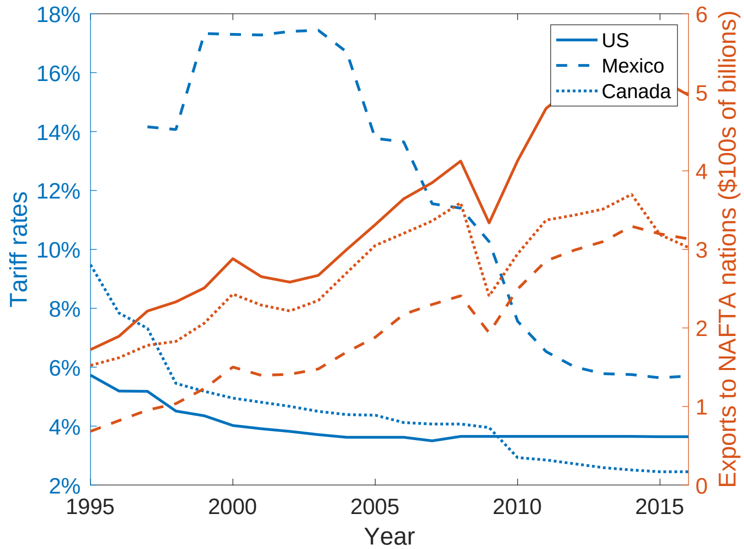

Figure 1: Tariff rates have fallen over the past two decades, while trade has risen
[MFN simple mean, all manufactured products]

Second, most of the results above are based on reduced-form models. As touched on earlier, such models fail to predict labor migration, wages, and trade in a single coherent framework. (Indeed, very few papers quantify NAFTA's effect on labor migration at all.) Yet the true payoff of using a general equilibrium model is not the ability to predict all these variables at once. Rather, the true payoff of using a model such as ours is the ability to highlight the subtle interplays between economic variables - interplays that are not always intuitive and often hidden from reduced-form studies.

Despite any differences our paper may or may not have with others, however, we must stress one important fact. Practically all the papers above indicate that NAFTA had a small positive effect on aggregate U.S. employment and welfare, even if its distributional ones were much more varied. Our discovery that *leaving* NAFTA would have a small negative effect on aggregate U.S. employment and welfare, then, should not come as a huge surprise to readers - despite what news reports might imply.

3 The model

As mentioned in the previous section, the model we adapt from CDP has several advantages over competing ones. Indeed, our model considers not only input-output linkages and international trade, but also time and trade/migration costs. Stated differently, we consider the time evolution of *trade* and *migration* between markets, where a market consists of a sector and region (e.g. chemicals in Florida).

Our adapted model is descended from two others - one which describes the demand side of the labor market, and one which describes the supply side. Starting with the demand side of the labor market, each market in our model has a continuum of heterogeneous firms producing intermediate goods. All firms follow the standard assumptions: they are competitive, have constant returns to scale, and demand (1) labor, (2) local factors of production, and (3) intermediate materials from all other markets. With these assumptions, we can develop a model similar to that in Eaton and Kortum (2002).

Switching to the supply side of the labor market, each household in our model is rational and forward-looking. Specifically, at any given time t, households have the option of moving to some other market at time $t+1$. They make this decision conditional on their current market, migration costs (not unique to any household), and some idiosyncratic shock (unique to each household). Each household receives its local market wage by supplying a unit of labor.[10] Combining these facts allows us to build a discrete choice model similar to that in Artuç, Chaudhuri, and McLaren (2010; henceforth, ACM).

With $N = 87$ regions and $J = 22$ sectors in our model (not including non-employment), we would ordinarily have to estimate productivities, migration/trade frictions, and endowments for over 1,000 different markets. Luckily, by utilizing a technique they call dynamic hat algebra, CDP create a model that permits us to perform counterfactual analyses without having to estimate these fundamentals. Beyond the calibration data needed to pinpoint the model's equilibrium conditions, we require only (1) trade elasticities, (2) migration elasticities, and (3) a discount factor.

Because CDP already provide an excellent exposition of their model, we do not provide any in-depth derivations below.[11] Rather, we summarize the main points of CDP's model, with special emphasis on changes relevant to this paper (e.g. those dealing with tariffs).

3.1 Basic characteristics

The world has N regions (indexed by n, i) and J sectors (indexed by j, k), not including non-employment. The non-employment "sector" is indexed by $j = J + 1$. A labor market consists of a region-sector combo. All labor markets are competitive.

Firms have productivities that are distributed Fréchet, with a sector-specific productivity dispersion parameter θ^j.

Time is discrete, and denoted by $t = 0, 1, 2, \ldots$. This economy can be separated into two problems: a dynamic problem characterizing labor migration conditional on real wages, and a static sub-problem characterizing a period's prices and wages conditional on that period's labor supply.

3.2 Dynamic problem: households

At time $t = 0$, there are L_0^{nj} households in the labor market described by region n and sector j. One "sector" is non-employment: all non-employed workers receive consumption $b^n > 0$, which can be viewed as home production.[12] For all other sectors, households provide a unit of labor inelastically and receive the market wage w_t^{nj}.

Preferences are Cobb-Douglas; specifically, a household's utility at time t is

$$U(C_t^{nj}) = \log(C_t^{nj}), \tag{1}$$

where

$$C_t^{nj} = \prod_{k=1}^{J} (c_t^{nj,k})^{\alpha^k}$$

for employed workers, and $C_t^{nj} = b^n$ for non-employed workers. (We define $c_t^{nj,k}$ as the consumption of sector k goods in market nj at time t, and α^k as the final consumption share, where $\sum_{k=1}^{J} \alpha^k = 1$.)

[10] They may also choose not to work, which can be treated as an "industry" in and of itself. Non-employed households receive consumption through home production. Importantly, non-employment includes those not in the labor force - not just those unemployed.

[11] Readers familiar with CDP can skip the majority of Sections 3 and 4, focusing their attention on the end of Subsections 3.3.1 and 3.3.3.

[12] Note that home production is dependent only on region.

Because preferences are Cobb-Douglas, we let the ideal price index be

$$P_t^n = \prod_{k=1}^{J} (P_t^{nk}/\alpha^k)^{\alpha^k}.$$

Now suppose households face a time-invariant and additive labor reallocation cost $\tau^{nj,ik} \geq 0$, which is the cost of moving from market nj to ik in terms of utility.[13] Also suppose households have additive idiosyncratic shocks ϵ_t^{ik} for each choice. These idiosyncratic shocks are i.i.d. over time and distributed Type-I Extreme Value with zero mean.

If households are rational and forward-looking, we can formulate the household's choice problem recursively. Letting $1/\nu$ represent a migration elasticity parameter, the household's problem becomes

$$v_t^{nj} = U(C_t^{nj}) + \max_{\{i,k\}} \{\beta \mathbb{E}[v_{t+1}^{ik}] - \tau^{nj,ik} + \nu \epsilon_t^{ik}\},$$

such that

$$C_t^{nj} = \begin{cases} b^n & \text{if } j = J+1 \\ \frac{w_t^{nj}}{P_t^n} & \text{otherwise} \end{cases}.$$

Note that v_t^{nj} represents the lifetime utility of a household in market nj at time t, and that this lifetime utility is a function of (1) current utility and (2) tomorrow's expected lifetime utility, adjusted for migration costs. Households move to the market that maximizes tomorrow's lifetime utility, adjusted for migration costs.

Define $V_t^{nj} = \mathbb{E}[v_t^{nj}]$, and let $\mu_t^{nj,ik}$ represent the share of households in market nj relocating to market ik. CDP demonstrate that given our assumptions, the following two equations must hold:

$$V_t^{nj} = U(C_t^{nj}) + \nu \log \left(\sum_{i=1}^{N} \sum_{k=1}^{J+1} \exp(\beta V_{t+1}^{ik} - \tau^{nj,ik})^{1/\nu} \right) \tag{2}$$

$$\mu_t^{nj,ik} = \frac{\exp(\beta V_{t+1}^{ik} - \tau^{nj,ik})^{1/\nu}}{\sum_{m=1}^{N} \sum_{h=1}^{J+1} \exp(\beta V_{t+1}^{mh} - \tau^{nj,mh})^{1/\nu}}. \tag{3}$$

Equation (2), as CDP note, states that the value of being in market nj today is a function of (1) current-period consumption and (2) the option value of moving to any other market tomorrow. (Stated differently, V_t^{nj} is the average utility of households in market nj.) Similarly, Equation (3), which denotes the share of people moving from market nj to ik, suggests that markets with higher lifetime utilities net of migration costs will attract more households.

Of course, given $\mu_t^{nj,ik}$ and L_t^{nj}, we can find L_{t+1}^{nj}:

$$L_{t+1}^{nj} = \sum_{i=1}^{N} \sum_{k=1}^{J+1} \mu_t^{ik,nj} L_t^{ik}. \tag{4}$$

With the dynamics of the model characterized, we now describe the static production sub-problem.

[13] Although we stress this point later, our model has no international migration. That is, $\tau^{nj,ik} = \infty$ for certain market pairs.

3.3 Static sub-problem: production

In each market, firms produce many varieties of intermediate goods (denoted by q) using labor and structures. Beyond these two primary factors of production, they also use materials, which are goods from all sectors. The total factor productivity (TFP) of the production technologies is given by a regional-sectoral component A_t^{nj} and an idiosyncratic variety-specific component z^{nj}.

3.3.1 Intermediate goods production

The production function for intermediate goods is

$$q_t^{nj} = z^{nj}(A_t^{nj}(h_t^{nj})^{\xi^n}(l_t^{nj})^{1-\xi^n})^{\gamma^{nj}} \prod_{k=1}^{J}(M_t^{nj,nk})^{\gamma^{nj,nk}},$$

where l_t^{nj}, h_t^{nj}, and $M_t^{nj,nk}$ are labor, structure, and material inputs from sector k in market nj, respectively.[14] The share of structures in value-added is ξ^n, the share of value-added in production is γ^{nj}, and the share of materials from sector k is $\gamma^{nj,nk}$. Because we assume constant returns to scale, we set $\gamma^{nj} + \sum_{k=1}^{J}\gamma^{nj,nk} = 1$. Importantly, structures are in fixed supply for each market.

Now, define P_t^{nj} to be the price of materials from market nj, and r_t^{nj} to be the rental price of structures. Due to the production function's Cobb-Douglas form, we can solve for the unit price of an input bundle given the firm's budget:

$$x_t^{nj} = B^{nj}((r_t^{nj})^{\xi^n}(w_t^{nj})^{1-\xi^n})^{\gamma^{nj}} \prod_{k=1}^{J}(P_t^{nk})^{\gamma^{nj,nk}}, \tag{5}$$

where B^{nj} is some constant. The unit cost of an intermediate good z_t^{nj} is then $\frac{x_t^{nj}}{z^{nj}(A_t^{nj})^{\gamma^{nj}}}$.

We use iceberg trade costs in this model. In other words, the cost of transporting one unit of intermediate good j from region i to region n requires producing $\kappa_t^{nj,ij} \geq 1$ units of that good in region i. Certain goods (those associated with the services sector) are non-tradable; for these goods, trade costs are infinite. Because of perfect competition, the price paid for a particular variety of good j in region n is equal to the minimum unit cost of that good across different regions, accounting for trade costs and idiosyncratic productivity differences. Formally,

$$p_t^{nj}(z^j) = \min_i \left\{\kappa_t^{nj,ij} x_t^{ij} z^{ij} (A_t^{ij})^{\gamma^{ij}}\right\}.$$

Because CDP do not explicitly model tariffs in their paper, they do not separate trade costs into tariff and non-tariff components. To adapt their model to ours, let $\kappa_t^{nj,ij}$ consist of both tariff $T_t^{nj,ij}$ and non-tariff components $d_t^{nj,ij}$ (e.g. cost, insurance, and freight). Specifically, assume

$$\kappa = (1+T)(1+d).$$

In this paper, non-tariff trade costs are assumed to be constant across both time and scenarios, but not regions. This assumption enables us to drop non-tariff trade costs when solving for the model's equilibrium, as we demonstrate later. We consequently abuse notation for the rest of this paper and treat κ as the gross tariff rate $1 + T$.[15]

[14] Observe how material inputs are goods produced in the same region.

[15] Making this assumption likely understates the impact of leaving NAFTA, as NAFTA also removed non-tariff barriers. The

3.3.2 Local sectoral aggregate goods

Intermediate goods from sector j from all regions are aggregated into a single local sectoral good. Define Q_t^{nj} to be the quantity produced of aggregate sectoral goods j in region n, and $\tilde{q}_t^{nj}(z^j)$ to be the quantity demanded of an intermediate good of a given variety from the lowest cost supplier. The production function aggregating the different varieties of goods is

$$Q_t^{nj} = \left(\int_{\mathbb{R}_+^N} (\tilde{q}_t^{nj}(z^j))^{1-1/\eta^{nj}} d\phi^j(z^j) \right)^{\eta^{nj}/(\eta^{nj}-1)},$$

where we define $\phi^j(z^j) = \exp\left\{ -\sum_{n=1}^N (z^{nj})^{-\theta^j} \right\}$ as the joint distribution over the vector of idiosyncratic productivities z^j. This distribution has marginal $\phi^{nj}(z^{nj}) = \exp\left\{ -(z^{nj})^{-\theta^j} \right\}$.[16] The market for sectoral aggregate goods is competitive, so there are zero profits at all times; along the same vein, there are no fixed costs or barriers to entry/exit in the production of intermediate and sectoral goods.

These local sectoral goods are used both for final consumption and as materials for the production of intermediate varieties. Importantly, these goods are not themselves traded: rather, households and intermediate goods producers are buying the tradable varieties described in Subsection 3.3.1.

As CDP note, under the assumption $1 + \theta^j > \eta^{nj}$, the price of good Q_t^{nj} is

$$P_t^{nj} = \Gamma \left(\sum_{i=1}^N (x_t^{ij} \kappa_t^{nj,ij})^{-\theta^j} (A_t^{ij})^{\theta^j \gamma^{ij}} \right)^{-1/\theta^j}, \tag{6}$$

where Γ is a constant. As a result, the share of total expenditures $\pi_t^{nj,ij}$ in market nj on goods j from region i is

$$\pi_t^{nj,ij} = \frac{(x_t^{ij} \kappa_t^{nj,ij})^{-\theta^j} (A_t^{ij})^{\theta^j \gamma^{ij}}}{\sum_{m=1}^N (x_t^{mj} \kappa_t^{nj,mj})^{-\theta^j} (A_t^{mj})^{\theta^j \gamma^{mj}}}. \tag{7}$$

Economically, the share of total expenditures on goods from region i rises as non-idiosyncratic TFP A_t^{ij} rises, trade costs $\kappa_t^{nj,ij}$ fall, and input bundle costs x_t^{ij} fall.

3.3.3 Market clearing

While most of the above exposition follows CDP closely, we make changes in this subsection to account for the fact that any tariff revenue is rebated back to a country's residents.

Assume there is mass 1 of immobile rentiers in each region. Rentiers own local structures, rent them to local firms, and send any rents to a global portfolio. They then receive some constant share ι^n of dividends from the global portfolio, such that $\sum_{n=1}^N \iota^n = 1$. Rentiers use their income to buy local goods, with preferences for goods equivalent to those of workers, or Equation (1).

Denote X_t^{nj} to be the total expenditures on sector j goods in region n. The goods market clearing condition requires total expenditures to equal the expenditures from intermediate goods production plus the expenditures from final goods consumption. That is,

U.S. food industry, for instance, benefitted from a standardization of labelling requirements after the agreement's implementation.

[16] For non-tradables, we only care about the marginal, as sectoral goods producers use only local intermediate goods.

$$X_t^{nj} = \underbrace{\sum_{k=1}^{J} \gamma^{nk,nj} \sum_{i=1}^{N} \frac{\pi_t^{ik,nk}}{1+\kappa_t^{ik,nk}} X_t^{ik}}_{\text{intermediate materials}} + \alpha^j \underbrace{\left(\overbrace{\sum_{k=1}^{J} w_t^{nk} L_t^{nk}}^{\text{worker income}} + \overbrace{\iota^n \chi_t}^{\text{rentier income}} + \overbrace{\sum_{k=1}^{J} \sum_{i=1}^{N} \frac{\kappa_t^{nk,ik} \pi_t^{nk,ik}}{1+\kappa_t^{nk,ik}} X_t^{nk}}^{\text{tariff revenue}} \right)}_{\text{final consumption}}, \tag{8}$$

where $\chi_t = \sum_{i=1}^{N} \sum_{k=1}^{J} r_t^{ik} H^{ik}$, or the total revenues sent to the global portfolio.[17] Importantly, tariff revenue for a region (which is given to that region's rentiers) is a function of only that region's imports and associated tariffs. In economic terms, then, no region in our model shares tariff revenue with other regions.[18]

Labor market clearing is then given by

$$L_t^{nj} = \frac{\gamma^{nj}(1-\xi^n)}{w_t^{nj}} \sum_{i=1}^{N} \frac{\pi_t^{ij,nj}}{1+\kappa_t^{ij,nj}} X_t^{ij}, \tag{9}$$

and structures market clearing is given by

$$H_t^{nj} = \frac{\gamma^{nj}\xi^n}{r_t^{nj}} \sum_{i=1}^{N} \frac{\pi_t^{ij,nj}}{1+\kappa_t^{ij,nj}} X_t^{ij}. \tag{10}$$

3.4 Equilibrium

The state variable in this model is the labor distribution L_t. As in CDP, we denote exogenous fundamentals as $\Theta_t = (\Theta_{1t}, \Theta_2)$, where Θ_{1t} denotes time-varying fundamentals and Θ_2 denotes constant fundamentals. As a recap, the fundamentals used in this model are: (1) regional-sectoral productivities $A_t = \left\{A_t^{nj}\right\}_{n=1,j=1}^{N,J}$, bilateral trade costs (e.g. tariffs) $\kappa_t = \left\{\kappa_t^{nj,ij}\right\}_{n=1,i=1,j=1}^{N,N,J}$, labor migration costs $\tau = \left\{\tau^{nj,ik}\right\}_{n=1,j=1,i=1,k=1}^{N,J+1,N,J+1}$, structures $H = \left\{H^{nj}\right\}_{n=1,j=1}^{N,J}$, and home production (i.e. non-employed production) $b = \{b^n\}_{n=1}^{N}$.

3.4.1 Definitions

Static equilibrium At each time t, we seek to solve the static sub-problem by finding equilibrium wages $w_t = \left\{w_t^{nj}\right\}_{n=1,j=1}^{N,J}$, bilateral trade flows $\pi_t = \left\{\pi_t^{ij,nj}\right\}_{i=1,j=1,n=1}^{N,J,N}$, and total expenditures $X_t = \left\{X_t^{nj}\right\}_{n=1,j=1}^{N,J}$ given that period's labor L_t and fundamentals Θ_t. That is, given (L_t, Θ_t), a static equilibrium is a set of wages $w_t(L_t, \Theta_t)$ that fulfill Equations (5) to (10).

Sequential competitive equilibrium Assume $w_t(L_t, \Theta_t)$ has a solution for each time t. Define real wages as $\omega^{nj}(L_t, \Theta_t) = w_t^{nj}/P_t^n$. We then seek to solve the dynamic problem by finding a path of migration

[17] For ease of exposition, we abuse notation again: earlier, we let κ equal the *gross* tariff rate. Here, it is the *net* tariff rate.

[18] Because our model looks at both countries and states, this assumption does not hold perfectly. As written, the market clearing condition assumes every region is essentially its own country, with trade between the "country" of Florida and the "country" of New York being subject to zero tariffs.

However, the United States government, not individual states, collects tariff revenue. Hence, tariff revenue collected due to trade between China and Florida may end up in New York rather than Florida. With this fact in mind, there are other ways to distribute tariff revenue across the United States. We could, for instance, distribute tariff revenue based on federal spending by state.

Regardless of how we make this assumption, the model results should remain roughly identical. (An original iteration of this paper ignored the effect of tariffs on market clearing, and obtained similar results.)

shares $\mu_t = \left\{\mu_t^{nj.ik}\right\}_{n=1,j=1,i=1,k=1}^{N,J+1,N,J+1}$ and lifetime utilities $V_t = \left\{V_t^{nj}\right\}_{n=1,j=1}^{N,J+1}$ given a path of fundamentals $\Theta = \{\Theta_t\}_{t=0}^{\infty}$ and an initial labor distribution L_0.

In other words, a sequential competitive equilibrium is a path of $\{L_t, \mu_t, V_t, w(L_t, \Theta_t)\}_{t=0}^{\infty}$ that satisfies Equations (2) to (4) given (L_0, Θ). Note that for each t, the sequential competitive equilibrium satisfies the static equilibrium.

Stationary equilibrium A stationary equilibrium is simply a steady state of the model where labor distributions do not change. Importantly, the immigration into any market must equal the emigration from that market, but individual households can still move from market to market.

Formally, we have reached a stationary equilibrium when $\{L_t, \mu_t, V_t, w(L_t, \Theta_t)\}_{t=0}^{\infty}$ are constant for all t; as a corollary, stationary equilibria imply constant fundamentals.

4 Computation

We briefly restate the propositions and solution methods in CDP. (Interested readers are encouraged to see their paper for detailed derivations.) Their key breakthrough is to utilize a technique called *dynamic hat algebra*. By solving for changes (rather than levels), CDP avoid having to estimate fundamentals such as frictions, endowments, and productivities. There are two types of changes for which we will solve. The first, changes over *time*, allows us to characterize the baseline economy's evolution. Given level data for time $t = 0$, we can convert changes back into levels for all future periods $t = 1, 2, \ldots$.

The second type of change, changes over *economies*, allows us to compare the relative differences between a baseline and counterfactual economy at every point in time. Recall from the previous paragraph that dynamic hat algebra can give us level data for the baseline economy at all times t; hence, we can combine this level data with our newfound change data to obtain level data for the counterfactual economy.

4.1 The baseline economy (i.e. staying in NAFTA)

Define the baseline economy as the allocation $\{L_t, \mu_{t-1}, \pi_t, X_t\}_{t=0}^{\infty}$ corresponding to the set of fundamentals $\{\Theta_t\}_{t=0}^{\infty}$. (In regard to our data, this set of fundamentals contains bilateral trade costs equal to 2012 world tariffs.)

In the spirit of dynamic hat algebra, we find the allocation $\{L_t, \mu_{t-1}, \pi_t, X_t\}_{t=0}^{\infty}$ by solving for time differences. That is, define $\dot{y}_{t+1} \equiv (y_{t+1}^1/y_t^1, y_{t+1}^2/y_t^2, \ldots)$ as the proportional change in *any* vector y between time t and $t+1$. Then, we can solve for (the change in) a static equilibrium of the economy $\dot{w}_{t+1}(\dot{L}_{t+1}, \dot{\Theta}_{t+1})$ without needing the levels of Θ_t.

Proposition 1 (CDP) *Given the static equilibrium at time t, $\{L_t, \pi_t, X_t\}$, we can find the static equilibrium at time $t+1$ for a given change in labor $\dot{L}_{t+1}$ and fundamentals $\dot{\Theta}_{t+1}$ without needing the levels of fundamentals Θ_t. Specifically, $\left\{\dot{L}_{t+1}, \dot{\pi}_{t+1}, X_{t+1}\right\}$ solves the following system:*

$$\dot{x}_{t+1}^{nj} = (\dot{L}_{t+1}^{nj})^{\gamma^{nj}\xi^n} (\dot{w}_{t+1}^{nj})^{\gamma^{nj}} \prod_{k=1}^{J} (\dot{P}_{t+1}^{nk})^{\gamma^{nj,nk}} \tag{11}$$

$$\dot{P}_{t+1}^{nj} = \left(\sum_{i=1}^{N} \pi_t^{nj,ij} (\dot{x}_{t+1}^{ij} \dot{\kappa}_{t+1}^{nj,ij})^{-\theta^j} (\dot{A}_{t+1}^{ij})^{\theta^j \gamma^{ij}} \right)^{-1/\theta^j} \tag{12}$$

$$\pi_{t+1}^{nj,ij} = \pi_t^{nj,ij} \left(\frac{\dot{x}_{t+1}^{ij} \dot{\kappa}_{t+1}^{nj,ij}}{\dot{P}_{t+1}^{nj}} \right)^{-\theta^j} (\dot{A}_{t+1}^{ij})^{\theta^j \gamma^{ij}} \tag{13}$$

$$X_{t+1}^{nj} = \sum_{k=1}^{J} \gamma^{nk,nj} \sum_{i=1}^{N} \frac{\pi_{t+1}^{ik,nk}}{1+\kappa_{t+1}^{ik,nk}} X_{t+1}^{ik} + \alpha^j \left(\sum_{k=1}^{J} w_{t+1}^{nk} L_{t+1}^{nk} + \iota^n \chi_{t+1} + \sum_{k=1}^{J} \sum_{i=1}^{N} \frac{\kappa_{t+1}^{nk,ik} \pi_{t+1}^{nk,ik}}{1+\kappa_{t+1}^{nk,ik}} X_{t+1}^{nk} \right) \tag{14}$$

$$w_{t+1}^{nj} L_{t+1}^{nj} = \gamma^{nj}(1-\xi^n) \sum_{i=1}^{N} \frac{\pi_{t+1}^{ij,nj}}{1+\kappa_{t+1}^{ij,nj}} X_{t+1}^{ij}, \tag{15}$$

where global portfolio income is given by $\chi_{t+1} = \sum_{i=1}^{N} \sum_{k=1}^{J} \frac{\xi^i}{1-\xi^i} w_{t+1}^{ik} L_{t+1}^{ik}$.

The first two equations determine factor and good prices and the third bilateral trade shares. The fourth equation ensures the goods market clears, and the last ensures the labor market clears. Although we include changes in fundamentals such as $\dot{\kappa}$ and $\dot{A}$ in the above equations, this paper calibrates these variables to equal a vector of ones. Stated differently, households and firms do not expect either trade costs or non-idiosyncratic productivities to vary with time.

Now that we can solve for static equilibria without having to estimate large numbers of fundamentals, we do the same for the dynamic problem (i.e. the sequential equilibrium). Suppose our economy approaches a stationary equilibrium (and consequently, has a set of fundamentals such that $\lim_{t\to\infty} \dot{\Theta}_t = 1$). Similar to CDP, simplify notation by letting market nj's transformed expected lifetime utility be $u_t^{nj} \equiv \exp(V_t^{nj})^{\beta/\nu}$.[19] Also define $\dot{\omega}^{nj}(\dot{L}_{t+1}, \dot{\Theta}_{t+1})$ to be the change in equilibrium real wages, as well as the solution to Proposition 1. (Equilibrium real wages were defined above as $\omega^{nj}(L_t, \Theta_t) = w_t^{nj}/P_t^n$.) Then, we can solve for (the change in) the sequential equilibrium of the economy without needing the levels of fundamentals Θ_t.[20]

Proposition 2 (CDP) *Given (1) an initial allocation of the economy* $\{L_0, \mu_{-1}, \pi_0, X_0\}$ *and (2) an anticipated convergent sequence of changes in fundamentals* $\{\dot{\Theta}_t\}_{t=1}^{\infty}$, *we do not need levels of fundamentals to solve for a sequential equilibrium in time differences. Specifically, given the above, the baseline economy* $\{L_{t+1}, \pi_{t+1}, X_{t+1}\}_{t=0}^{\infty}$ *solves the following system:*

$$\mu_{t+1}^{nj,ik} = \frac{\mu_t^{nj,ik} \dot{u}_{t+2}^{ik}}{\sum_{m=1}^{N} \sum_{h=1}^{J+1} \mu_t^{nj,mh} \dot{u}_{t+2}^{mh}} \tag{16}$$

$$\dot{u}_{t+1}^{nj} = \left(\dot{\omega}^{nj}(\dot{L}_{t+1}, \dot{\Theta}_{t+1}) \right)^{\beta/\nu} \left(\sum_{i=1}^{N} \sum_{k=1}^{J+1} \mu_t^{nj,ik} \dot{u}_{t+2}^{ik} \right)^{\beta} \tag{17}$$

$$L_{t+1}^{nj} = \sum_{i=1}^{N} \sum_{k=1}^{J+1} \mu_t^{ik,nj} L_t^{ik}, \tag{18}$$

where $\dot{\omega}(\dot{L}_t, \dot{\Theta}_t)$ *solves Proposition 1.*

The first equation resembles a gravity equation, with migration flows from market nj to ik tomorrow equal to flows today weighted by the transformed utility of being in market ik two periods later. The second equation suggests that the transformed utility of being in market nj is a function of real wages and migration flows out of market nj. The last equation is standard.

[19] The transformation of u_t^{nj} here is slightly different from that in CDP.

[20] Although we say *the* sequential equilibrium, rather than *a* sequential equilibrium, we have not proven that this general equilibrium model yields unique results. As of publication, numerical experiments indicate that there *may* be multiple equilibria in certain cases. (There are other potential explanations for these differences, such as machine precision.) These equilibria, however, return practically identical results when aggregated across industries, and only mildly different results when aggregated across regions.

Importantly, these equations work even when the economy is not initially in a steady state. Yet by assuming the economy will eventually go to a steady state, we can construct an algorithm to pin down the evolution of labor, welfare, real wages, and trade flows. (See Subsection 4.3 for details.)

4.2 The counterfactual economy (i.e. leaving NAFTA)

Earlier, we claimed that there are two types of changes for which we will solve. The first, changes over *time*, enabled us to solve the baseline economy. The second, changes over *economies*, will enable us to solve the counterfactual economy.

Formally, a counterfactual economy is the allocation $\left\{L_t', \mu_{t-1}', \pi_t', X_t'\right\}_{t=0}^{\infty}$ corresponding to the set of fundamentals $\{\Theta_t'\}_{t=0}^{\infty}$. In this paper, Θ and Θ' differ only in tariff rates; in the counterfactual economy, tariffs between NAFTA members equal their MFN rates.

The following equations suppose perfect foresight holds. Specifically, households and firms do not expect an increase in tariffs at $t = 0$, but learn of NAFTA's sudden dissolution at $t = 1$. Like with other MIT shocks, they then assume no further changes. Using an MIT shock serves one key purpose: it enables us to use dynamic hat algebra to solve for changes over *economies*.

Just as we introduced new notation when solving for changes over *time*, we define $\hat{y}_{t+1} \equiv \dot{y}_{t+1}'/\dot{y}_{t+1}$ as the proportional change in time between the counterfactual and baseline equilibria.

Proposition 3 (CDP) *Given (1) a baseline economy $\{L_t, \mu_{t-1}, \pi_t, X_t\}_{t=0}^{\infty}$ and (2) a convergent sequence of changes in counterfactual fundamentals (relative to baseline changes) $\left\{\hat{\Theta}_t\right\}_{t=1}^{\infty}$, we do not need baseline fundamentals to solve for a counterfactual equilibrium. Specifically, the counterfactual economy $\left\{L_{t+1}', \pi_{t+1}', X_{t+1}'\right\}_{t=0}^{\infty}$ solves the following system:*

$$\mu_{t+1}^{'nj,ik} = \frac{\mu_{t-1}^{nj,ik} \dot{\mu}_t^{'nj,ik} \hat{u}_{t+1}^{ik}}{\sum_{m=1}^{N} \sum_{h=1}^{J+1} \mu_{t-1}^{nj,mh} \dot{\mu}_t^{'nj,mh} \hat{u}_{t+1}^{mh}} \tag{19}$$

$$\hat{u}_t^{nj} = \left(\hat{\omega}^{nj}(\hat{L}_t, \hat{\Theta}_t)\right)^{\beta/\nu} \left(\sum_{i=1}^{N} \sum_{k=1}^{J+1} \mu_{t-1}^{'nj,ik} \dot{\mu}_t^{nj,ik} \hat{u}_{t+1}^{ik}\right)^{\beta} \tag{20}$$

$$L_{t+1}^{'nj} = \sum_{i=1}^{N} \sum_{k=1}^{J+1} \mu_t^{'ik,nj} L_t^{'ik}, \tag{21}$$

where $\hat{\omega}(\hat{L}_t, \hat{\Theta}_t)$ solves Proposition 1. The static problem remains similar:

$$\hat{x}_{t+1}^{nj} = (\hat{L}_{t+1}^{nj})^{\gamma^{nj}\xi^n} (\hat{w}_{t+1}^{nj})^{\gamma^{nj}} \prod_{k=1}^{J} (\hat{P}_{t+1}^{nk})^{\gamma^{nj,nk}} \tag{22}$$

$$\hat{P}_{t+1}^{nj} = \left(\sum_{i=1}^{N} \pi_t^{'nj,ij} \dot{\pi}_{t+1}^{nj,ij} (\hat{x}_{t+1}^{ij} \hat{\kappa}_{t+1}^{nj,ij})^{-\theta^j} (\hat{A}_{t+1}^{ij})^{\theta^j \gamma^{ij}}\right)^{-1/\theta^j} \tag{23}$$

$$\pi_{t+1}^{'nj,ij} = \pi_t^{'nj,ij} \dot{\pi}_{t+1}^{nj,ij} \left(\frac{\hat{x}_{t+1}^{ij} \hat{\kappa}_{t+1}^{nj,ij}}{\hat{P}_{t+1}^{nj}}\right)^{-\theta^j} (\hat{A}_{t+1}^{ij})^{\theta^j \gamma^{ij}} \tag{24}$$

$$X_{t+1}^{'nj} = \sum_{k=1}^{J} \gamma^{nk,nj} \sum_{i=1}^{N} \frac{\pi_{t+1}^{'ik,nk}}{1 + \kappa_{t+1}^{'ik,nk}} X_{t+1}^{'ik} + \alpha^j \left(\sum_{k=1}^{J} w_{t+1}^{'nk} L_{t+1}^{'nk} + \iota^n \chi_{t+1}' + \sum_{k=1}^{J} \sum_{i=1}^{N} \frac{\kappa_{t+1}^{'nk,ik} \pi_{t+1}^{'nk,ik}}{1 + \kappa_{t+1}^{'nk,ik}} X_{t+1}^{'nk}\right) \tag{25}$$

$$w_{t+1}^{\prime nj} L_{t+1}^{\prime nj} = \gamma^{nj}(1-\xi^n) \sum_{i=1}^{N} \frac{\pi_{t+1}^{\prime ij,nj}}{1+\kappa_{t+1}^{\prime ij,nj}} X_{t+1}^{\prime ij}, \tag{26}$$

where global portfolio income is given by $\chi_{t+1}^{\prime} = \sum_{i=1}^{N} \sum_{k=1}^{J} \frac{\xi^i}{1-\xi^i} w_{t+1}^{\prime ik} L_{t+1}^{\prime ik}$.

Armed with Propositions 1 to 3, we are ready to code the model.

4.3 Algorithm

To turn the model from a list of equations to a usable set of results, we perform three tasks. First, we *calibrate* the model and obtain the initial allocation of the economy. Second, we find the *baseline* economy using Subsection 4.1. Finally, using the results for our *baseline* economy, we then estimate the *counterfactual* economy using Subsection 4.2.

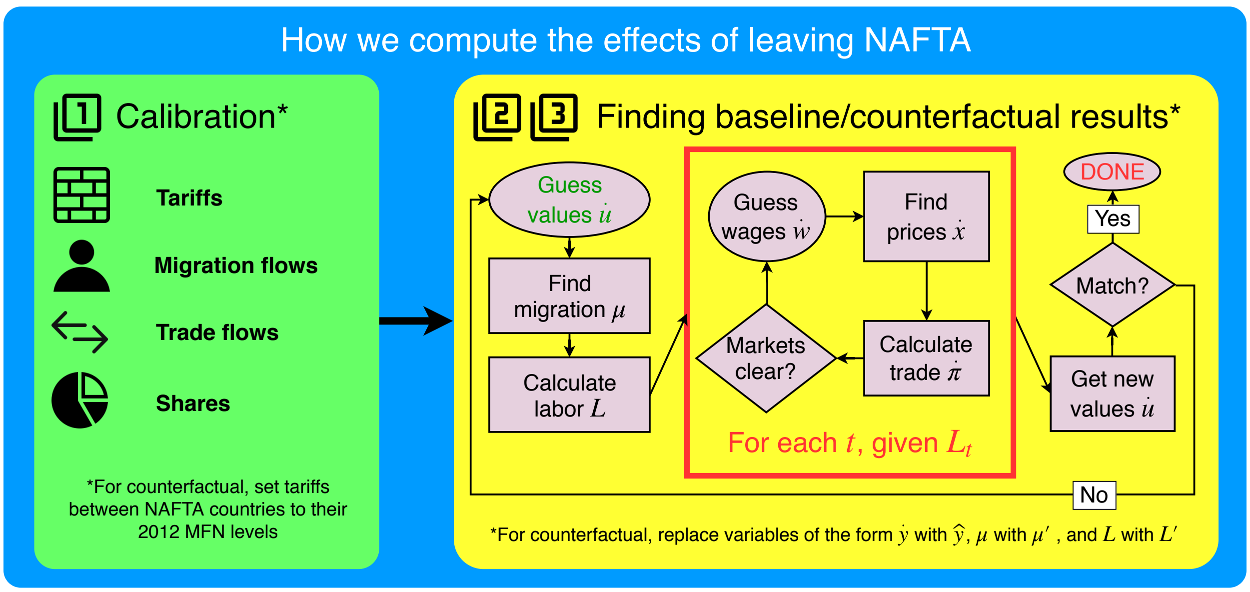

Figure 2: An algorithm based on value function iteration empowers us to solve the model

An algorithm employing value function iteration is sketched both in the above figure and in Appendix B; complete, documented MATLAB code is available at the online companion.

5 Calibration

Roughly speaking, we can divide our data requirements into four categories: (1) tariffs, (2) migration flows, (3) trade flows, and (4) value-adds/elasticities.

Most of the above data is available on a yearly basis; trade flows, unfortunately, are not. As of publication, the latest *nation-level* trade flows were from 2014, and the latest *state-level* flows were from 2012. We hence calibrate all model variables to their 2012 values unless otherwise indicated. Although the data used is roughly five years old, there is little reason to believe that the results would change significantly with updated numbers.

A brief discussion of data sources follows. For an in-depth discussion, see Appendix A. For code and step-by-step replication instructions, visit the online companion.

5.1 Sectors and regions

Like CDP, we include 50 U.S. states, 37 non-U.S. countries, and a constructed "Rest of the World" in our model. As for industries, our model considers 22 sectors (not including non-employment). Of these 22 sectors, twelve are manufacturing-based and ten are services-based.[21]

Importantly, recall that there is no international migration in our model. (That is, $\tau = \infty$ for migration between countries.[22]) We similarly assume that each non-U.S. country has a single labor market shared across its 22 sectors.

Hence, there are a total of $(50)(22 + 1) + 37 = 1{,}187$ modeled labor markets.

5.2 Tariffs

To calculate tariff rates, we exploit data from the World Integrated Trade Solution (WITS). WITS provides data on both MFN and preferential tariff rates (on an ad-valorem equivalent basis) for every country.

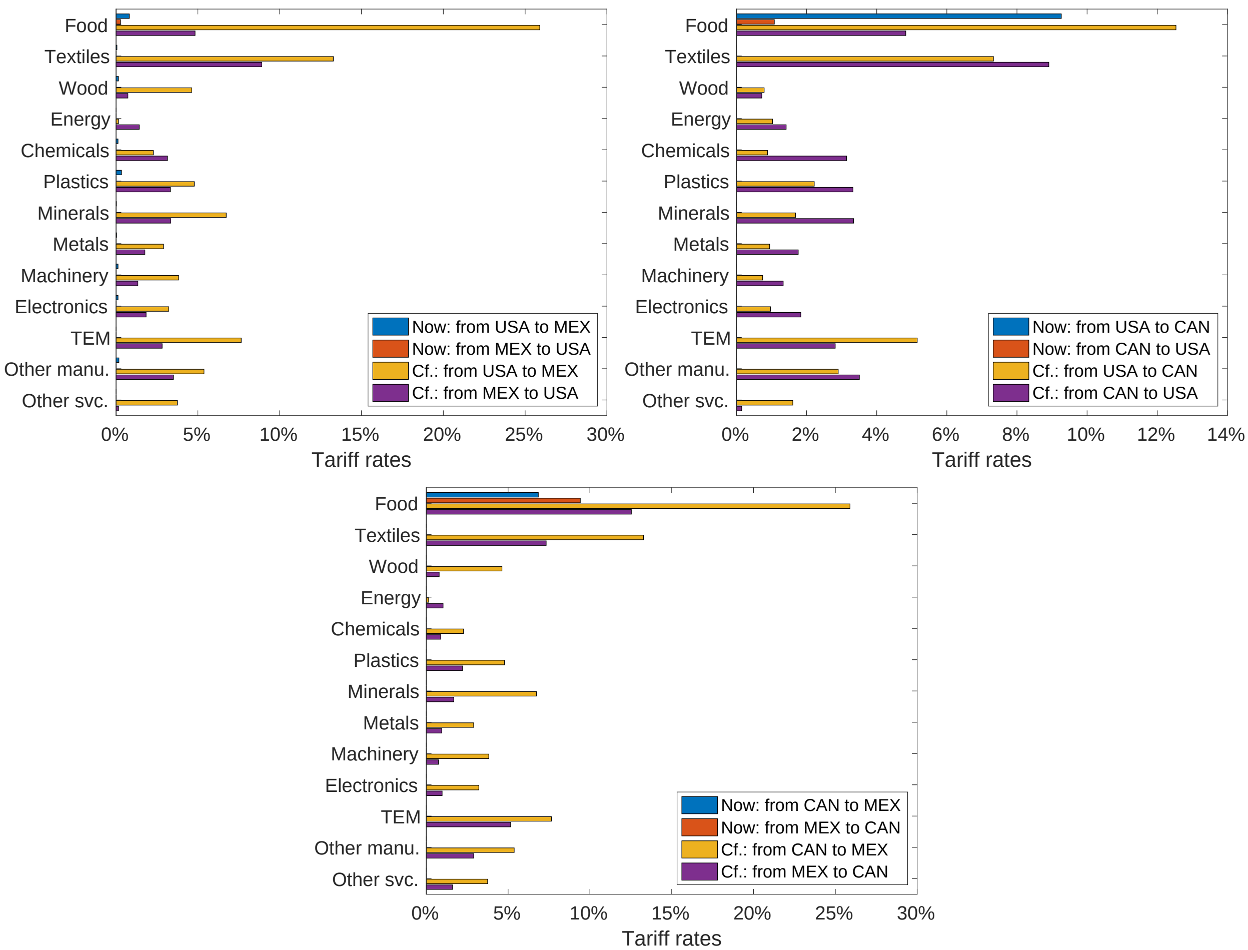

Figure 3: Leaving NAFTA would increase tariffs in all industries

[21]We exclude the following primary and governmental sectors: Agriculture, Forestry, Fishing, Mining, Utilities/Waste Management, and Public Administration/Defense.

[22]This lack of international migration results from data scarcity, not from model limitations. This assumption, however, is not unreasonable: migration costs between, say, Mexico and the U.S. are undoubtedly *many* times greater than the migration costs between any two U.S. states. Moving from Florida to Texas requires only a plane ticket; moving from Mexico to Texas requires either a hard-to-obtain visa or a dangerous trek across international borders.

For the baseline economy, we assume that the tariff rates between any two countries are equal to their preferential rates unless no such rate exists. In that case, we suppose that MFN rates apply.

The tariff rates for the counterfactual economy are identical to those for the baseline economy, except in six instances. In those six instances - tariffs from one NAFTA country to another, we replace any preferential tariffs with their MFN counterparts.

Above are three graphs showing baseline and counterfactual tariff rates for NAFTA countries, broken down by industry. All the tariffs seem reasonable - across the board, baseline tariffs are functionally zero, and counterfactual tariffs are modest but significant. (As a quick sanity check, the World Bank calculates 2012 MFN rates across *all* manufacturing industries to be 6% for Mexico, 3.7% for the U.S., and 2.7% for Canada. By an order of magnitude, then, our numbers match theirs.[23])

5.3 Migration flows

To calculate U.S. migration flows, we exploit the IPUMS-CPS dataset, which is a harmonized version of the U.S. Census Bureau's Current Population Survey (Flood et al., 2017). IPUMS-CPS provides panel data on current/past employment and residence. For 2012, IPUMS-CPS contains 95,609 usable observations.

Migration type	% of total households
Different sector, same state	13.13%
Different state, same sector	1.02%
Different sector, different state	0.47%
Same sector, same state	85.38%

Table 1: Most migration occurs across industries, not states

The CPS selects a weighted sample of 60,000 U.S. households and asks them information about (1) their current occupation, (2) their occupation last year, (3) their current residence, and (4) their residence last year. The CPS also includes information on employment status (e.g. not in labor force). With all this information, creating yearly migration matrices estimating flows by industry and state is theoretically simple. Obtaining the initial labor distribution, of course, is a matter of finding the marginals of the migration matrix.

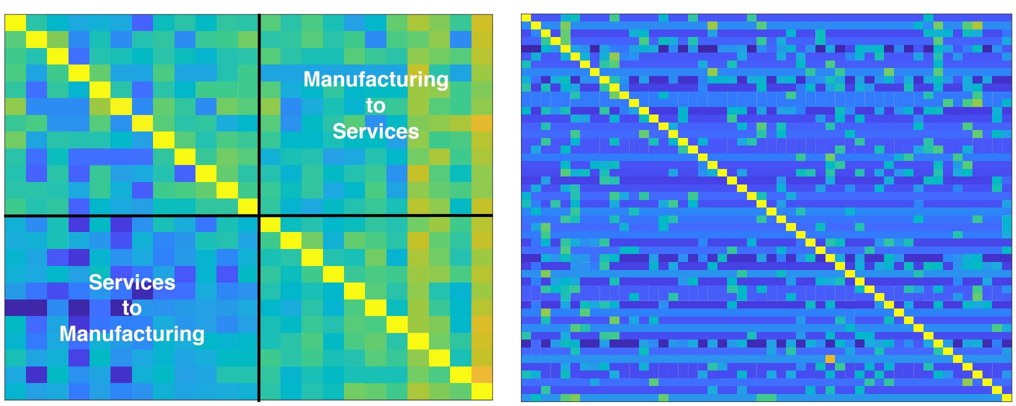

Figure 4: Migration flows are heterogeneous, showing the value of a model like ours
[Aggregated by industry (left) and state (right); more yellow = higher value]

[23]There are two aspects about the tariffs which might prove concerning. The first - non-zero tariff rates for food shipped to/from Canada - occurs as there are certain dairy, poultry, and alcohol products that do *not* fall under NAFTA. (Some of these duties have changed since 2012, however.) The second - non-zero tariff rates for "Other services" - occurs because "Other services" includes the leasing of equipment.

Looking at the migration matrix heatmaps above, note that migration is indeed heterogeneous, which reinforces the need to use a model like ours. As expected, fewer people migrate from services to manufacturing than from manufacturing to services. We also include a tree-map of the initial labor distribution below. Observe how services constitute the vast majority of the U.S. economy.

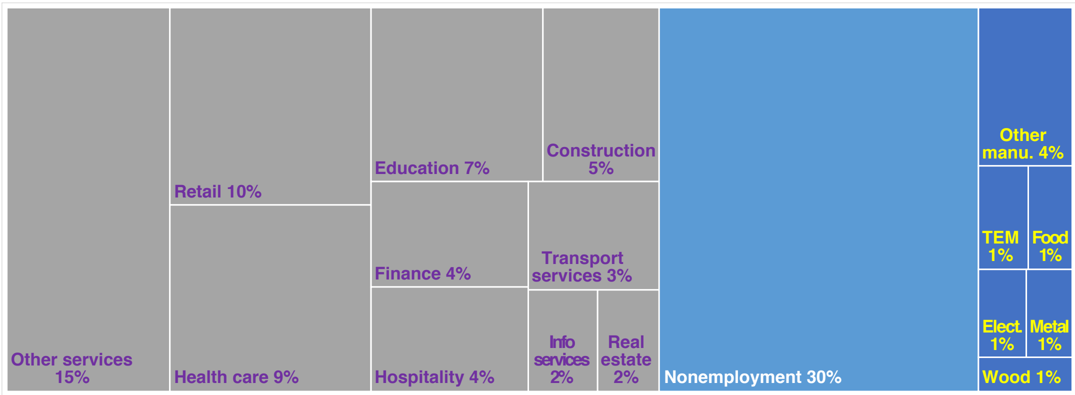

Figure 5: Services constitute an overwhelming amount of the U.S. economy
[Textiles, energy, chemicals, plastics, minerals, and machinery condensed into other manufacturing]

We impart a word of caution before continuing. Earlier, we suggested that creating yearly migration matrices was (theoretically) simple. Yet the IPUMS-CPS is perhaps the most suspect of all the datasets used. As Kambourov and Manovskii (2013) write, using the CPS to study worker mobility is rife with issues. The CPS, for instance, asks not what a worker's occupation was exactly one year ago (as a true migration matrix would require), but rather what a worker's occupation was for most of the past calendar year. By imposing certain assumptions (noted in Appendix A), we can overcome these difficulties and convert raw CPS data into a true migration matrix. Our migration matrix, however, may still underestimate true mobility: while we assume the CPS measures migration on an eight-month scale, Kambourov and Manovskii argue that the CPS may measure migration on a three-month scale.

5.4 Trade flows

To calculate country-to-country trade flows, we utilize the 2012 Input-Output Table (WIOT) from the World Input-Output Database (Timmer et al., 2015). This table provides in-depth information on value-added, production, and final consumption at a regional and sectoral level. Specifically, because the WIOT provides data on (1) input-output linkages (i.e. intermediate material usage by sector), (2) international trade flows, and (3) final consumption, we can match each entry in the WIOT to our model.

For state-level trade flows, we combine the WIOT with the 2012 Commodity Flow Survey (CFS), which provides detailed information on commodity shipments - including their origins, destinations, and industries. (As an example, the CFS tells us the total value of all rubber products traveling from Florida to New York in 2012.) Hence, we can impute bilateral trade flows between the 50 U.S. states by combining U.S. domestic sales data from the WIOT with state-level shipment data from the CFS.[24]

[24] Although relatively minor, one difficulty with using the CFS is accurately mapping its products to model industries. Take grain, for instance. At first blush, one might think that grain products should be classified under food manufacturing. If the grain is intended as animal feed, however, it should instead be classified under the (non-model) industry agriculture.

In general, we lean towards classifying such commodities under model industries, not under non-model industries. Specifics are available at the online companion.

We still have not explained how to find state-to-country trade flows (and vice versa). Like CDP and Autor, Dorn, and Hanson (2013; henceforth, ADH), we assume that the exposure of a local labor market to international trade is proportional to that market's share of national sectoral employment. That is, we use the Bureau of Economic Analysis's regional employment data to estimate a state's share of total national employment for a given industry. Then, we suppose that the share of that state in total U.S. trade for that industry is proportional to its share of national employment for that industry.

5.5 Value-added, shares, and elasticities

The process for finding these values requires only standard assumptions; as a result, we leave most details for Appendix A.

5.5.1 Value-added and shares

We find value-added VA_0, shares of value-added in gross output γ^{nj}, and shares of intermediate materials used in production $\gamma^{nj,nk}$ through the datasets above. Consumption shares α^j and portfolio shares ι^n are calculated through a formula.

To find the share of structures in value-added, ξ^n, we use the 2011 OECD Input-Output Tables. These tables provide information on labor compensation by region.

5.5.2 Discount rates and elasticities

We let the yearly discount rate β equal a conventional 0.96, which corresponds to a yearly risk-free rate of 4%. For sectoral trade elasticities θ^j, we employ the values found in CP. (For service sectors, we assume an elasticity of 4.) Finally, we set the *annual* migration elasticity $1/\nu$ equal to 2.02, as calculated in CDP using a modified version of ACM's model.

6 Results

We now discuss the model's results. As mentioned in Section 4, we first compute the baseline economy by assuming constant fundamentals. We then expose the world to an MIT shock, and calculate the counterfactual economy. That is, in 2012, we assume that people act as if there is zero probability of leaving NAFTA. Then, the following year, NAFTA is unexpectedly dissolved, and people act as if NAFTA will stay permanently dissolved.

Here, we examine not only employment shares, but also worker welfare and trade flows. During this examination, two takeaways should emerge: (1) leaving NAFTA will not affect the vast majority of Americans, although (2) leaving NAFTA will affect a few labor markets disproportionately. We will conclude this section by talking about the model's shortcomings, and why our takeaways should remain correct despite these shortcomings.

Many more results (particularly disaggregated ones) are available at the online companion. We impart a word of caution, however, before continuing: when interpreting disaggregated results (i.e. results at the labor market level), care must be taken when dealing with extremely small markets. For these markets, the model often utilizes imputed values.

6.1 Employment shares

6.1.1 Case study: employment shares over time in transportation equipment manufacturing

While most of this paper focuses on the long-run effects of NAFTA's dissolution, our model can estimate medium- and short-run ones as well. Indeed, because our model is a dynamic one, we can look at the evolution of employment shares, wages, and welfare over time. Since our commentary generalizes to other industries, however, we perform a detailed time-series analysis for only one - transportation equipment manufacturing (henceforth, TEM).[25]

The line plot below demonstrates how leaving NAFTA might affect the employment shares of the TEM industry - which is particularly affected by NAFTA's dissolution, relative to others.[26] To emphasize how leaving NAFTA will not affect employment shares for most sectors, we also include the evolution of employment shares for an aggregated manufacturing industry.

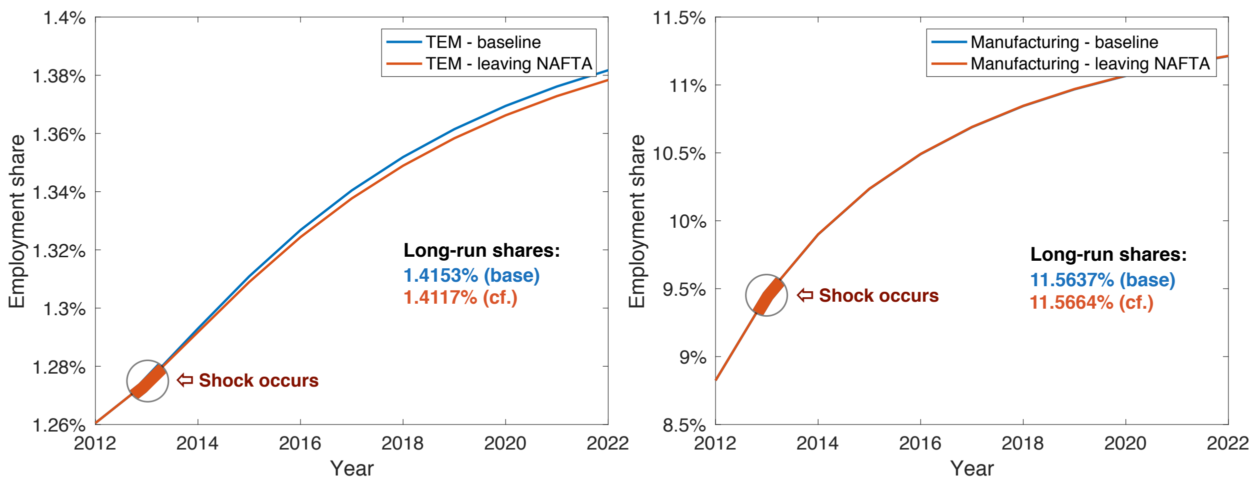

Figure 6: Even in the TEM industry, leaving NAFTA should not cause many job losses

Observe how the employment share of the TEM industry is increasing over time in both the baseline and counterfactual economies. This phenomenon occurs because the economy was out of equilibrium in 2012. Still, NAFTA's dissolution causes the TEM industry's employment share to fall (relative to its baseline value). Loosely speaking, then, we might claim that NAFTA's dissolution will cause 6,000 TEM workers to switch industries or become non-employed in the long-run.[27]

Putting these values into context is essential. In 2012, 1.26% of all Americans worked in the TEM industry. In the long-run, the baseline model has 1.415% of all Americans working in the TEM industry, and the counterfactual model has 1.412% of all Americans working in the TEM industry. NAFTA's dissolution, then, would explain no more than 3% of the long-run secular trend in TEM job gains. Given that the TEM industry is one of the industries most affected by NAFTA (as emphasized below), one takeaway should emerge: leaving NAFTA will not significantly change America's employment landscape.

[25] Additional time-series available at the online companion.

[26] The national *employment share* of an industry is the number of people employed in that industry divided by the total number of U.S. residents ages 25-65. To convert level changes in employment shares to changes in jobs, multiply the level change in employment share by the total number of U.S. residents ages 25-65. (Our model, which depends on 2012 data, places this number at 156 million. In 2016, the number of U.S. residents ages 25-65 rose marginally to 163 million.)

This conversion works because our model assumes a constant number of workers for all times t.

[27] We say loosely speaking because this number could include people not currently in the TEM industry but who would have entered the TEM industry had NAFTA remained intact.

Many policy briefs, when talking about NAFTA, might use language like "U.S. manufacturers added more than 800,000 jobs in the four years after NAFTA came into force."[28] Although these statements are not incorrect, our results demonstrate that they can be very mis-leading - and for two reasons. First, changes in employment over time are immeasurably more likely to be a result of phenomena (technological, structural, etc.) not related to NAFTA. Second, as our line plot demonstrates, shocks such as NAFTA's dissolution can take many years to propagate to employment shares.

Before we focus on the long-run effects of NAFTA's dissolution (rather than on the short- and medium-run ones), a comment on our last point - that shocks may take several years to propagate to employment shares - may prove worthwhile. Labor markets are sticky, and most shocks take time to affect employment levels. As a result, should the Trump administration dissolve NAFTA, any short-term changes in employment numbers - good or bad - are probably not a result of the dissolution.[29]

6.1.2 Changes in employment share: distributional effects

As mentioned earlier, NAFTA's dissolution can cause disparate effects across labor markets - even when those markets share a region or industry. Space considerations, unfortunately, require us to relegate results for most of our model's 1,000+ markets to the online companion. Still, there is significant value in understanding how varied the effects of leaving NAFTA can be; hence, prior to aggregating these effects by industry and state, we first discuss their distribution.

A good first step towards understanding the distributional effects of leaving NAFTA might be to look at the heatmap of changes in long-run employment share below.[30]

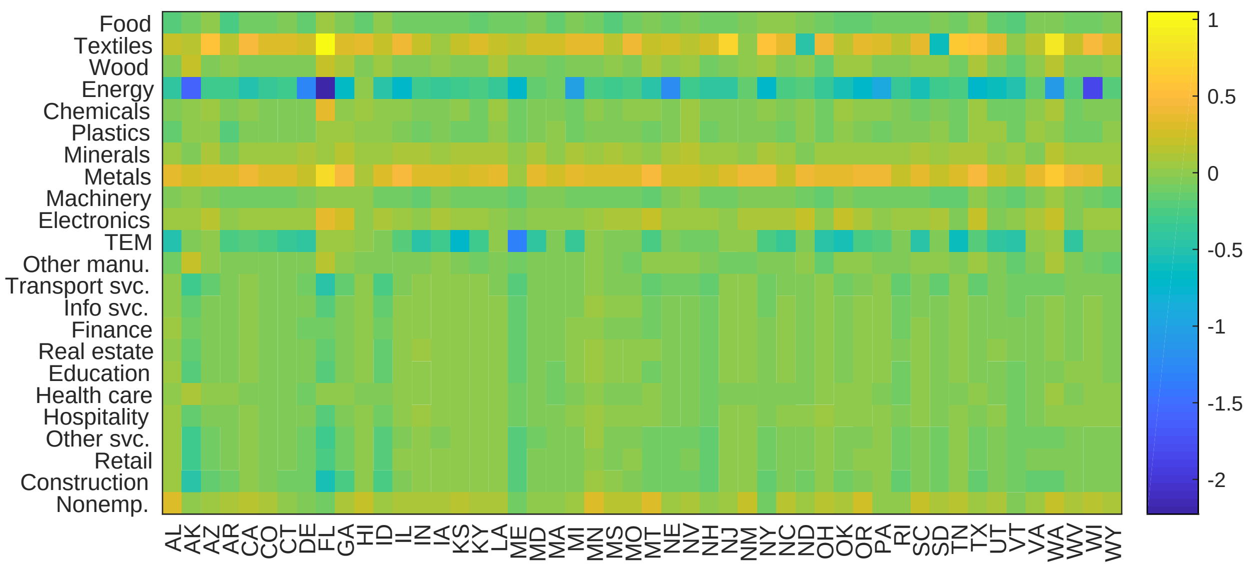

Figure 7: Even among markets that share an industry or state, the effects of leaving NAFTA vary
[Percent changes in long-run employment share; results for small markets imputed]

[28]This particular statement comes from a 2017 brief by the U.S. Chamber of Commerce titled "The Facts on NAFTA."

[29]When we talk about welfare in Subsection 6.2.2, we will see that TEM wage growth quickly falls, and then slowly reverts to baseline. Intuitively, this fact should not be surprising - in real life, wages tend to be less sticky than employment numbers, and in our model, wages adjust instantly to changes in labor supply. Furthermore, the long-run changes in employment ensure wage growth eventually returns to normal.

[30]Specifically, if the long-run employment share under NAFTA is $x\%$ and the long-run employment share without NAFTA is $y\%$, the heatmap (along with all future figures showing percent changes) shows the value $100\% \left(\frac{y-x}{x}\right)$.

Given a particular industry, the effects of NAFTA's dissolution appear to be directionally similar across the 50 states, even if certain states occasionally see a much bigger effect than others. Furthermore, given a service industry, different states will generally see similar effects from leaving NAFTA; given a manufacturing industry, different states will often see disparate effects from leaving NAFTA. The histogram below reinforces this observation, with the variance of employment share changes across service markets smaller than the variance of employment share changes across manufacturing markets.

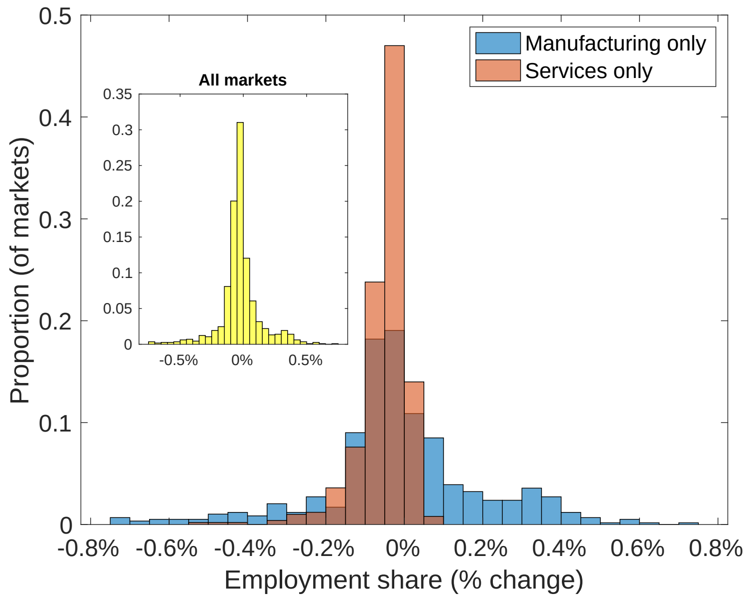

Figure 8: Manufacturing markets see more varied effects than service markets do
[Long-run changes; some outliers hidden]

To explore how our model can highlight the distributional effects of leaving NAFTA, we delve into a case study involving the TEM industry. Before doing so, however, we make one additional observation: the industries seeing the biggest *aggregate* effects from leaving NAFTA (e.g. energy and textiles) often see the biggest *variability* in effects across states.

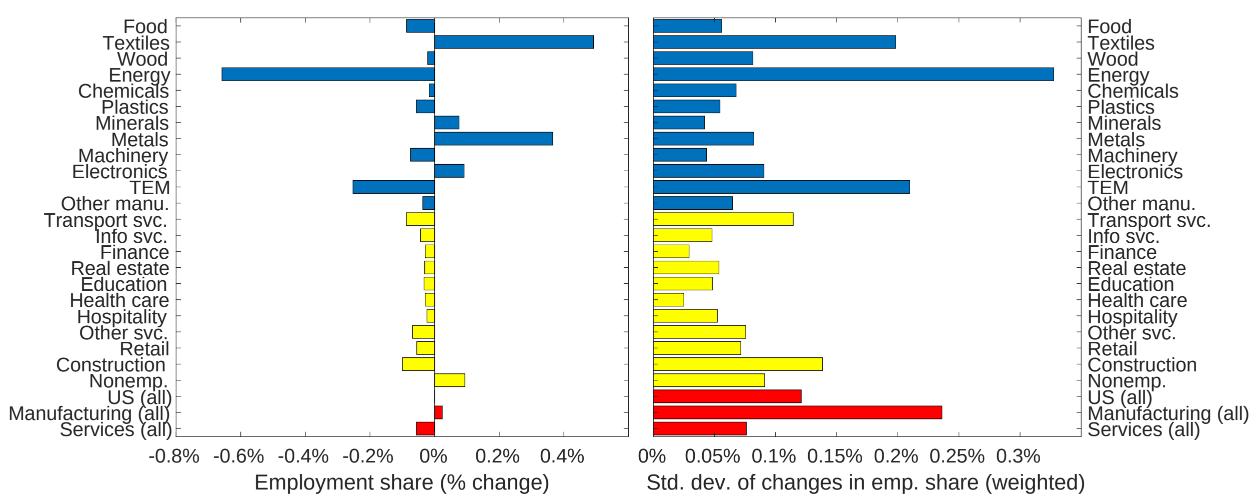

Figure 9: Big *aggregate* changes in employment share (left) often imply big *variability* across states (right)
[Standard deviation weighted by state's share of national industry employment]

Case study: state-level differences in TEM employment share There are two reasons why the TEM industry proves a good case study for studying the distributional effects of leaving NAFTA: first, it is disproportionately affected by NAFTA's dissolution, and second, it is heavily concentrated in a handful of states. Indeed, the leftmost map below reveals heavy concentrations of TEM workers in the Rust Belt and the Southeast. There are also pockets of TEM workers in Maine, Kansas, and Washington.

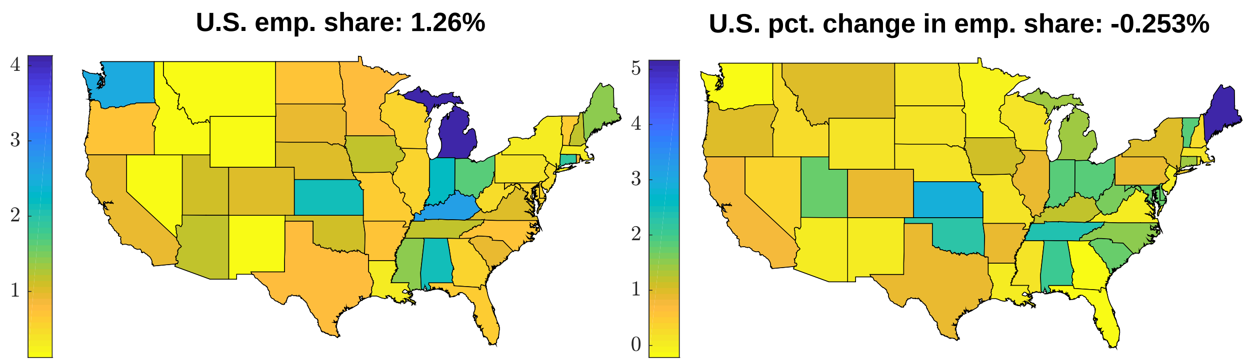

Figure 10: States with more TEM workers (left) see a disproportionate effect from leaving NAFTA (right)
[Left = 2012 state share of TEM workers, relative to U.S. share; right = long-run pct. chg. in TEM share, relative to U.S. pct. chg.; interpretation example: obtain the TEM employment share in MI by multiplying 1.26% by 4.1; results from small markets imputed]

Generally, regions with higher concentrations of TEM workers see bigger drops in TEM employment shares. These regions' TEM markets therefore experience a "double whammy" from NAFTA's dissolution. Not only do more workers lose their jobs by dint of the markets' large size, but the *proportion* of TEM workers who lose their jobs is also higher. Economically, this observation may hint at an agglomeration effect. Smith and Florida (1994) and Head et al. (1995) have shown, for instance, how regions with high concentrations of manufacturing workers often attract even more manufacturing companies. This paper suggests a similar phenomenon, where shocks that harm concentrated TEM sectors get amplified.

This rule, of course, does not hold perfectly. Yet examining some of the rule's exceptions may prove informative. Take, for instance, the state of Washington. Despite its high concentration of TEM workers, it actually sees an *increase* in TEM employment share. A close examination of the *type* of transportation equipment manufacturing occurring in Washington likely explains this phenomenon. Indeed, in 2012, aerospace manufacturer Boeing employed 86,000 of Washington's 108,000 TEM workers. Because aerospace manufacturing is quite different from the automotive manufacturing happening in the Rust Belt, there is a strong possibility our model is capturing the differences between aerospace and automotive manufacturing.

A similar (if more subtle) reason *may* explain why Michigan's TEM sector does not see a bigger effect from NAFTA's dissolution, relative to the rest of the nation. With the exception of a single Mazda plant, almost all the automotive manufacturing in Michigan is done by the "Big Three" American automakers: GM, Ford, and Chrysler.[31] In contrast, automotive manufacturing in other states is done by both foreign (e.g. Toyota and BMW) and domestic companies. The model, hence, may be hinting at a phenomenon where (the often non-unionized) workers employed by foreign automotive companies are more vulnerable to NAFTA's dissolution.[32]

Before moving on to the aggregate changes in employment share that result from leaving NAFTA, we

[31] 2009 data from the New York Times's "For Baffled Buyers, a Guide to Cars Made in North America." Chrysler is technically owned by Italian company Fiat Automobiles, but shares many characteristics with GM and Ford, such as a unionized workforce.

[32] Recall that the model allows for differing migration costs; unionized workers in Michigan likely have different migration costs than non-unionized workers in Alabama do.

stress that our model does not explicitly explain *why* such outliers occur. Hence, the above explanations are merely suggestive, and should be met with skepticism.

6.1.3 Changes in employment share: industry level

Below, two bar plots illustrate the aggregate effects of NAFTA's dissolution, in terms of both employment shares and job numbers.

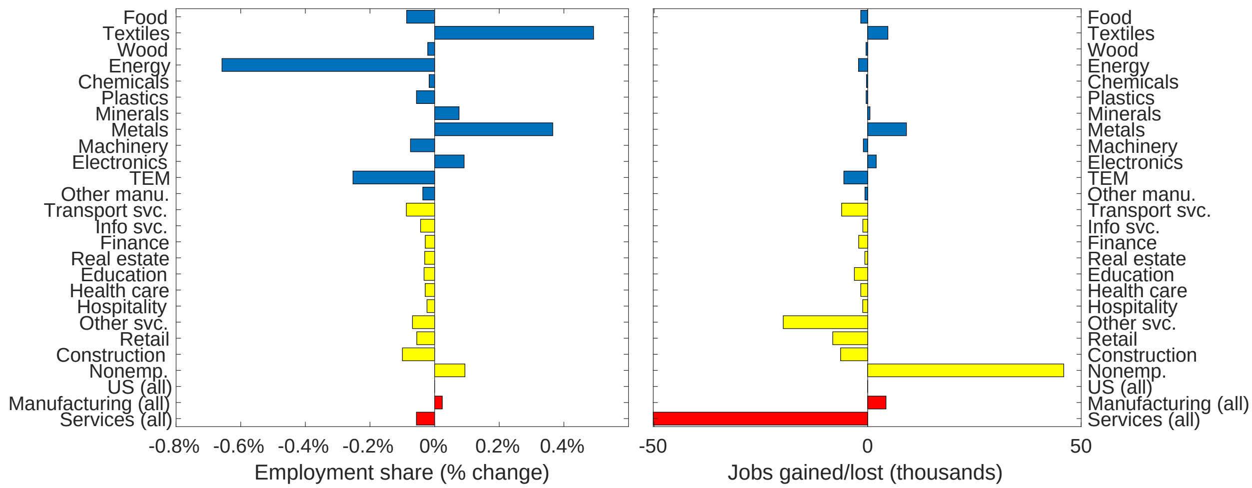

Figure 11: For all but a few industries, NAFTA's employment effect is small

As the first figure demonstrates, leaving NAFTA will disproportionately affect the manufacturing sector, with certain manufacturing industries experiencing relatively large changes in employment share. Notably, a fair number of manufacturing industries barely see any effect.

Of the manufacturing industries disproportionately affected by NAFTA's dissolution, two experience large rises in employment share, and two experience large drops. The two experiencing large rises - textiles and the primary metals industry - are frequented cited in the news as being particularly hurt by free trade deals. In terms of jobs, then, the model validates this anecdotal claim. On the other hand, the TEM industry is particularly hurt by NAFTA's dissolution. Intuitively, this result is attractive. Autos require copious metal, and if the TEM industry gets its metals abroad, tariff increases will make autos more expensive. This expense in turn hurts the TEM industry. Of course, because firms search for the lowest-cost supplier in our model, an increase in steel tariffs will make American steel relatively more attractive, boosting the fortunes of that sector.

Overall, service industries see a universal but very minor drop in employment, and non-employment rises slightly. In fact, looking at the number of jobs gained/lost (rather than changes in employment share), we see that long-run non-employment increases by 45,000 due to NAFTA's dissolution. At first glance, this number may sound significant, but context indicates otherwise. There were, after all, 45 *million* non-employed Americans in 2012. Furthermore, as discussed in Subsection 6.1.1, this number is based on *long-run* equilibria. Due to labor market stickiness, several years must pass before any noticeable differences in employment numbers occur.

6.1.4 Changes in population share: state level

Our model is a *migration* model, so we end this subsection by examining how NAFTA's dissolution might affect *geographic* movement (rather than sectoral movement). There has been copious research on how economic factors affect migration. The pictures below, however, best summarize this research.

Figure 12: Pictures of the same Detroit factory, taken in 1941 (left) and 2013 (right), show migration's effects
[Images from the DetroitUrbex.com project]

Although explaining Detroit's de-industrialization is beyond the scope of this paper, many people point to foreign competition as a reason for the decline of America's industrial cities. Hence, we might hope to use our model to examine a more modest question: will NAFTA's dissolution cause people to move back to states they previously left? The maps below provide an answer.[33]

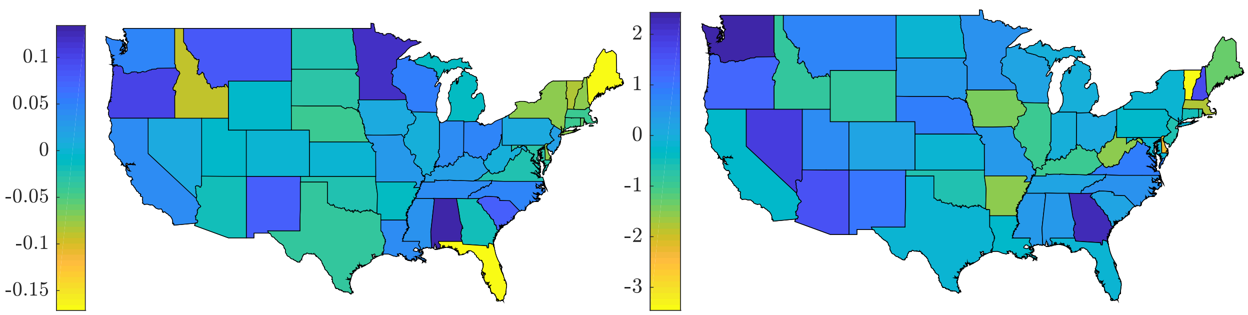

Figure 13: NAFTA's dissolution causes an inflow into the Rust Belt, and an outflow from populous states
[Percent changes in pop.; left = long-run changes from leaving NAFTA; right = changes from 2011 to 2012 from data, not model]

For the example of Michigan, NAFTA's dissolution causes people to move *out* of the state (partly because of its harm to the TEM industry). Yet the Rust Belt as a whole sees an *inflow* of people, and populous states such as New York, Florida, and Texas see an *outflow* of people. As emphasized throughout this paper, however, all these effects are incredibly small. The state experiencing the largest outflow of people is Florida, which sees 16,000 people ultimately leave.[34] In comparison, the state had a 2016 population of 21 million.

[33]Interpreting the leftmost map is similar to interpreting the employment share plots above. If a state shows a value of 1%, for instance, its long-run counterfactual population is 1% higher than its long-run baseline population.

[34]As mentioned before, although we talk about 16,000 people leaving to economize on language, this phrasing is somewhat deceptive. Of these 16,000 people, there may have been people who are not currently living in Florida, but would have moved to its sunny beaches had NAFTA not dissolved.

6.2 Welfare

6.2.1 The components of welfare

Employment shares do not capture the entire story, though. In fact, a worker can experience an increase in wage growth rates and still be worse off due to second-order effects.[35] To better capture changes in well-being for workers, then, we look at the welfare effects of leaving NAFTA - both at a disaggregate and aggregate level.

As CDP show, the change in welfare $\hat{W}^{nj}$ between the baseline and counterfactual economies for workers in market nj is

$$\hat{W}^{nj} = \sum_{s=1}^{\infty} \beta^s \log \left(\frac{\hat{C}_s^{nj}}{(\hat{\mu}_s^{nj,nj})^{\nu}} \right).$$

This equation is a derivation and not a definition, which makes it economically attractive. To see why, rearrange:

$$\hat{W}^{nj} = \underbrace{\sum_{s=1}^{\infty} \beta^s \left[\log \left(\hat{C}_s^{nj} \right) \right]}_{\Delta \text{ in consumption growth}} - \overbrace{\nu \sum_{s=1}^{\infty} \beta^s \left[\log \left(\hat{\mu}_s^{nj,nj} \right) \right]}^{\Delta \text{ in those where } nj \text{ is still a best choice}}.$$

The log-linear approximation suggests how $x \approx \log(1+x)$ for small x; as a result, log changes are often used to approximate percent changes. (The observant reader may notice how $\log \left(\hat{C}_s^{nj} \right) \equiv \log \left(\dot{C}_s'^{nj} \right) - \log \left(\dot{C}_s^{nj} \right)$ is nothing but the difference in consumption growth rates, in terms of percentages, between the two economies at time $t = s$.[36]) Hence, the first term in the above equation is the present discounted difference in consumption growth rates that occurs from leaving NAFTA. As consumption increases (whether through higher nominal wages or lower prices), welfare intuitively increases.

The second term in the above equation, meanwhile, involves those for which market nj is still a best choice, scaled by the inverse of migration elasticity. This term is less intuitive, but is explained by the following. Suppose more people leave market nj after NAFTA's dissolution (i.e. $\hat{\mu}^{nj,nj}$ falls). They are leaving because there are "greener pastures" where they can obtain more utility; hence, the option value of anyone in market nj rises.

Examining this equation explains why a labor market can see an increase in employment share but also a decrease in welfare. As more people flood into a market, two phenomena occur. First, the real wages in that market may not increase as quickly as expected due to the greater supply of workers, moderating any changes in consumption. Second, the increase in $\hat{\mu}^{nj,nj}$ means that other labor markets are less attractive, which then decreases the option value of anyone in market nj.

To better clarify how real wages and migration have differing effects on overall welfare, we define two new terms used for the remainder of the paper. Changes in *industry* welfare are defined as changes in real wages; we use this terminology because people often view rising real wages in an industry as proof of that industry's prosperity. Changes in *worker* welfare, on the other hand, are defined as changes in the overall welfare of a market's workers. Formally,

[35] By definition, real wages in our model equal consumption.

[36] Indeed, $\log \left(\dot{C}_s'^{nj} \right)$ is the percent change in consumption for the counterfactual economy between times $t = s$ and $t = s - 1$.

$$\hat{W}^{nj}_{industry} = \underbrace{\sum_{s=1}^{\infty} \beta^s \left[\log\left(\hat{C}^{nj}_s\right)\right]}_{\Delta \text{ in consumption growth}} \tag{27}$$

and

$$\hat{W}^{nj}_{worker} = \underbrace{\sum_{s=1}^{\infty} \beta^s \left[\log\left(\hat{C}^{nj}_s\right)\right]}_{\Delta \text{ in consumption growth}} - \overbrace{\nu \sum_{s=1}^{\infty} \beta^s \left[\log\left(\hat{\mu}^{nj,nj}_s\right)\right]}^{\Delta \text{ in those where } nj \text{ is still a best choice}} . \tag{28}$$

We will generally distinguish between the two; if not, we are talking about worker, or overall, welfare.[37]

To better grasp this difference, we examine welfare effects for one group especially hurt by NAFTA's dissolution: Alabaman TEM workers.

6.2.2 Case study: welfare for Alabaman TEM workers

We pick transportation equipment manufacturing (TEM) in Alabama as an example of a labor market disproportionately hurt by the dissolution of NAFTA. Alabama's TEM sector is quite robust: Mercedes-Benz, for instance, has its only North American factory in Vance, AL. Like those of many states, Alabama's TEM workers would be disproportionately hurt by NAFTA's dissolution. Yet with a worker welfare drop of -0.09%, TEM workers in Alabama are an anomaly even compared to their out-of-state brethren. (The average TEM worker's welfare drop is 0.06%.) Granted, looking at changes in employment share says a good amount about the overall story: employment share for the labor market decreases by 0.51% in the long-run. (The average employment share for the TEM industry decreases by 0.25%.) We might wonder, though, why Alabama's TEM workers do not see a larger welfare drop relative to the national average, given that its loss in employment share is more than double that of the national average.

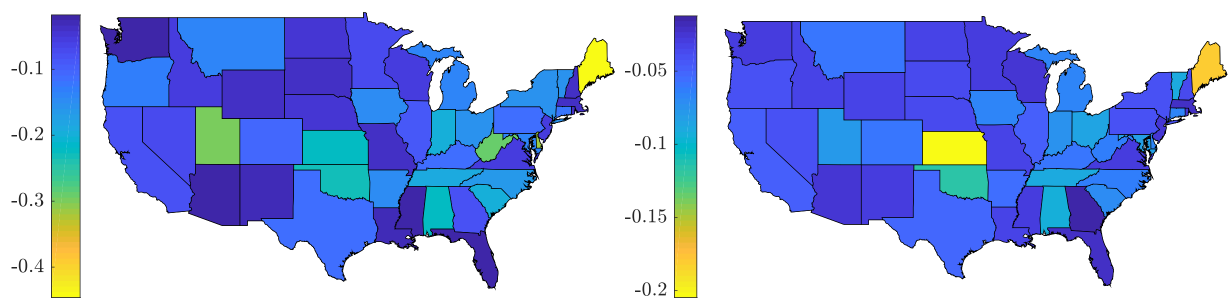

Figure 14: For the TEM sector, both industry (left) and worker (right) welfare fall after NAFTA's dissolution
[Percent changes in industry/worker welfare; results for small markets imputed]

A good way to understand where this worker welfare drop is coming from is to look at the individual terms in the welfare equation, or Equation (28). To assist with this visualization, we provide a line plot below.[38]

[37] The phrase *industry welfare* is imperfect, but clarifies, in our opinion, the difference between working in an industry and the industry itself. An auto worker in Michigan can become an IT expert in New York with training. The auto industry, however, cannot become the IT industry.

[38] In the figure, the value for any particular year is the *discounted* value for that year only. In other words, the value shown for the year 2014 involves a β^2 term, but does not consider the value for the year 2013.

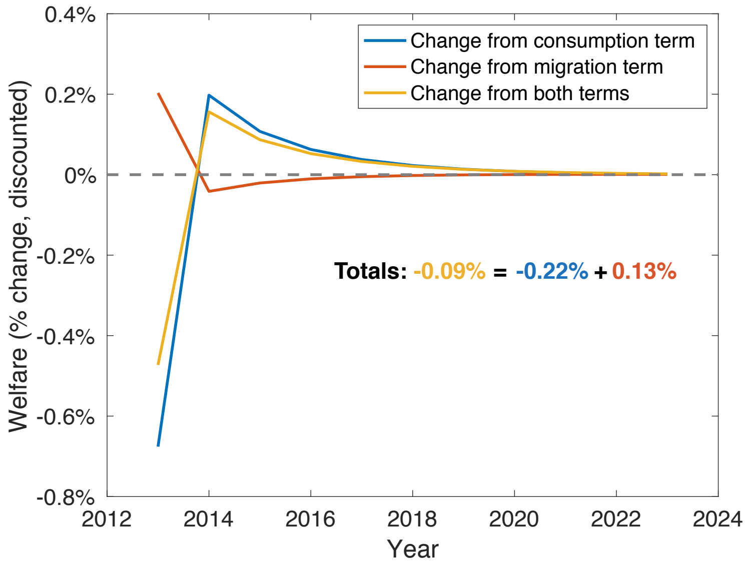

Figure 15: For Alabaman TEM workers, leaving NAFTA lowers wages, but raises the option value of moving

The contribution of changes in wages to changes in worker welfare is at first fairly negative. It then turns mildly positive to correct for the overshoot, and later tends to zero as a result of discounting. Examining the migration term proves similarly informative. The year after NAFTA's dissolution, the contribution of changes in migration to changes in worker welfare is fairly positive, but then tends to zero. Overall, the ability of Alabaman TEM workers to migrate more than halves the blow of leaving NAFTA.

This observation provides a stark reminder that migration can be an important tool for ameliorating economic shocks. In the short-run, migration may feel painful as workers cut ties to their original communities and retool for new industries. In the long-run, however, migration can raise incomes and reinvigorate workers.

Now that we have looked at a market in-depth, we take a step back and examine welfare trends aggregated at the industry and state level.[39] More disaggregated results are available as interactive figures at the online companion.

6.2.3 Changes in welfare: industry level

Overall, most U.S. industries - particularly tertiary ones - are only modestly affected by NAFTA. There are some exceptions: workers in the textiles and metals industries are particularly helped, while workers in the energy and TEM industries are particularly hurt.[40]

[39] We aggregate welfare in a utilitarian manner. That is, a market's welfare is weighted based on its initial mass of workers.

[40] Caution should be taken when analyzing the petroleum/coal sector. With an extremely high sectoral elasticity, this sector may have results sensitive to model error.

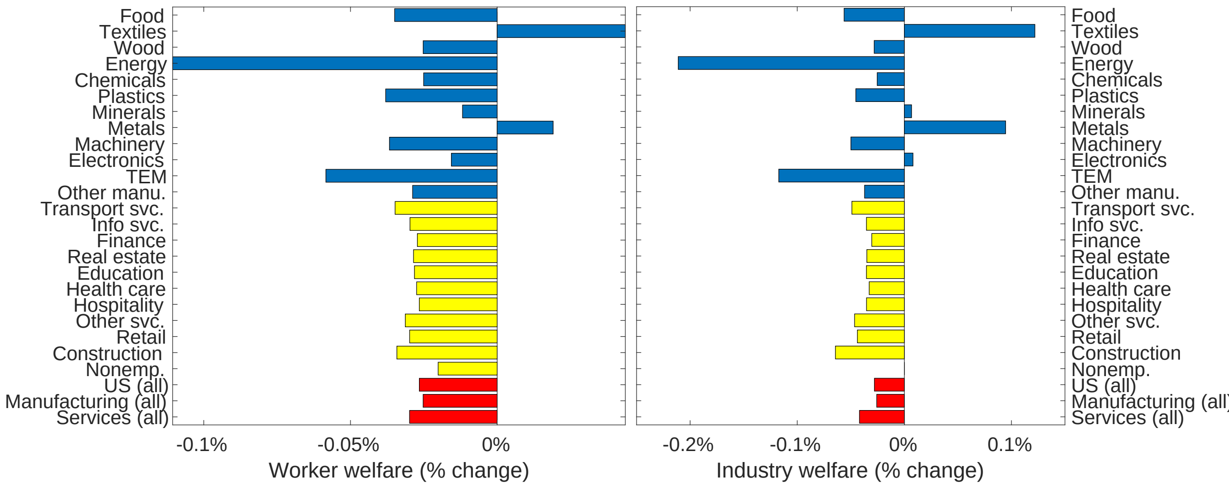

Figure 16: Changes in *worker* welfare (left) sometimes differ from changes in *industry* welfare (right)

Note that changes in *industry* welfare, or changes in real wage growth rates, occasionally differ from changes in *worker* welfare. Indeed, we see the electronics *industry* helped as a result of higher wages, and electronics *workers* hurt as a result of lower migration option values. Still, these results concord well with news reports. The aluminum and steel industries, for instance, have been especially supportive of putting tariffs on their goods; as a result, President Trump has pushed for (and passed) steel tariffs. Based on our model, the industry would likely benefit from such an action. Moreover, the model suggests that the industry arguing *against* steel tariffs - TEM companies - would likely get hurt by President Trump's recent actions.

6.2.4 Changes in welfare: state level

Aggregating results at the state level, we see several noteworthy items. First, the Rust Belt's manufacturing *industries* are hurt the most by NAFTA's dissolution. A closer examination of the distributional data (available at the online companion) suggests that the majority of this effect arises from (1) the high proportion of Rust Belt manufacturing workers in the TEM industry and (2) the large harm the TEM industry experiences from leaving NAFTA.

A keen eye might also note that manufacturing workers from two of the four most populous states - Florida and New York - experience some of the largest gains in wage growth rates. Among the states that suffer losses in manufacturing wage growth rates, another one of these large states - Texas - sees a relatively small level of losses. To be clear, our model does not explicitly indicate *why* such results might happen. Yet the fact that California experiences an average fall in wage growth rates suggests that larger states do not, ipso facto, experience larger relative gains or losses from trade shocks.[41]

[41] We do not formally hypothesize why larger states have manufacturing wages that fare better under NAFTA's dissolution, but we do comment that most large states have (relatively) few manufacturing workers.

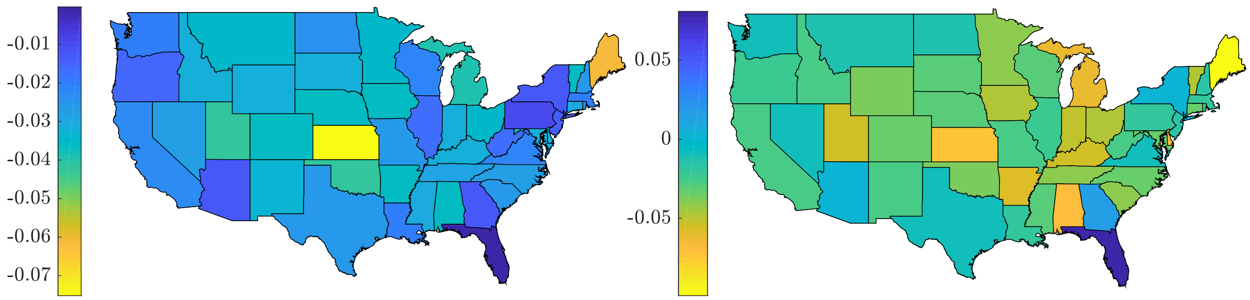

Figure 17: Manufacturing sees both *worker* (left) and *industry* (right) welfare fall by 0.03%
[Percent changes in worker/industry welfare]

Pivoting to the service sectors, we see a somewhat antithetical pattern - especially when looking at *industry* welfare. Recall from Table 1 that workers are about ten times more likely to change sectors than they are to change states. Most input-output linkages also occur within states. Hence, any nationwide shock is arguably more likely to cause changes *within* a state's sectors than *across* states.

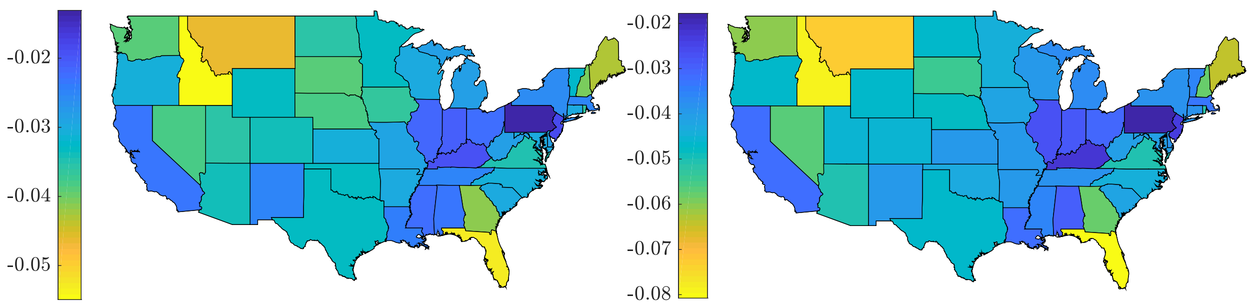

Figure 18: Services see *worker* (left) and *industry* (right) welfare fall by 0.03% and 0.04%, respectively
[Percent changes in worker/industry welfare]

For completeness, we show how dissolving NAFTA might affect aggregated welfare in each state. (Informally, we combine the results from the manufacturing and services maps to indicate how NAFTA's dissolution would affect the average resident of each state.[42]) There is little to say that has not been covered, but observe how no state sees an overall *worker* welfare drop of more than 0.05%. Hence, one takeaway should remain clear: for most Americans, leaving NAFTA will change little.

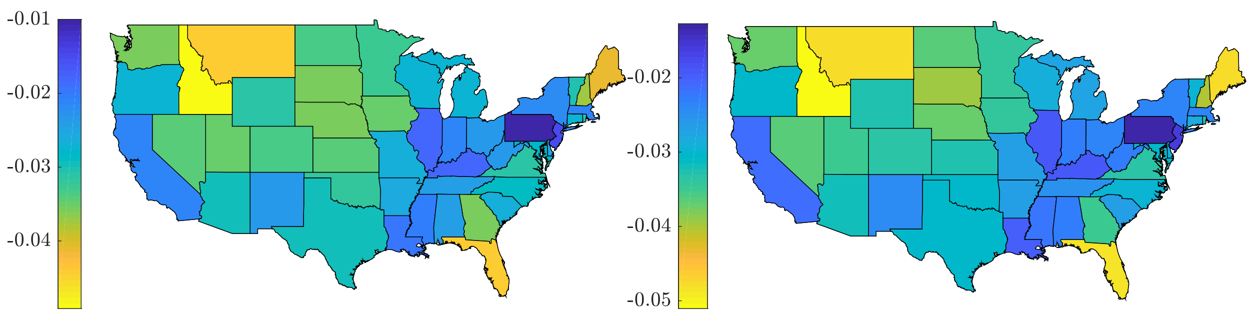

Figure 19: The U.S. sees both *worker* (left) and *industry* (right) welfare fall by 0.03%
[Percent changes in worker/industry welfare]

[42]We also include the non-employment "sector" here.

6.2.5 Non-U.S. countries

Calculating the change in welfare for non-U.S. countries is trickier, as our model has no international migration, along with only one labor market per non-U.S. country. As a result, each non-U.S. country has a single real wage at any given time t.[43]

Yet much of the welfare analysis remains the same as before. Specifically, *worker* welfare

$$\hat{W}^{nj}_{worker} = \underbrace{\sum_{s=1}^{\infty}\beta^s\left[\log\left(\hat{C}^{nj}_s\right)\right]}_{\Delta \text{ in consumption growth}} - \overbrace{\nu\sum_{s=1}^{\infty}\beta^s\left[\log\left(\hat{\mu}^{nj,nj}_s\right)\right]}^{\Delta \text{ in those where } nj \text{ is still a best choice}}$$

simplifies to

$$\hat{W}^{nj}_{worker,non-U.S.} = \underbrace{\sum_{s=1}^{\infty}\beta^s\left[\log\left(\hat{C}^{nj}_s\right)\right]}_{\Delta \text{ in consumption growth}},$$

since $\hat{\mu}^{nj,nj} = 1$ for $nj \neq$ U.S. market. In other words, *worker* and *industry* welfare are equal for non-U.S. markets.

The welfare changes for all non-NAFTA countries are functionally zero.[44] Mexico's and Canada's welfare both change by -0.15%, so their present discounted real wage growth rates decrease by 0.15%. By comparison, the U.S.'s present discounted real wage growth rates decrease by 0.03%.

6.3 Trade flows

6.3.1 Total expenditures

To get an imperfect feel of how NAFTA's dissolution might affect Mexico and Canada on a sectoral level, we show how total expenditures change the period NAFTA's dissolution is announced (i.e. at time $t = 1$).[45]

[43] That said, we can still pinpoint NAFTA's effect on foreign industries by looking at how total expenditures X^{nj}_t change between the baseline and counterfactual economies. We perform this analysis in the next subsection.

[44] The largest such value, in absolute value terms, occurs with Taiwan. With a welfare change of 0.0014%, Taiwan sees no effect from NAFTA's dissolution. Additionally, this number is well within the model's numerical error tolerance.

[45] The effects of NAFTA's dissolution for non-North American countries are an order of magnitude smaller, and are hence not discussed here.

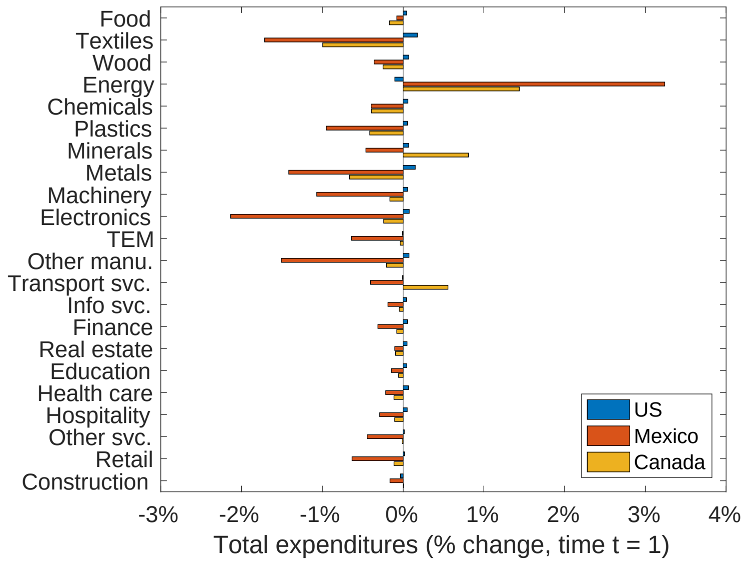

Figure 20: The U.S. sees a small initial rise in total expenditures, but Mexico and Canada see a large drop
[Percent change in total expenditures calculated as $\hat{X}_1^{nj} - 1$]

There are several noteworthy items in the plot above. First, the effect of NAFTA's dissolution on any given industry, in terms of total expenditures at time $t = 1$, is five to twenty times greater for Mexico and Canada than it is for the United States. A glance at the tables below suggests that this multiple of five to twenty is not unreasonable.[46]

Country	All trade (% of GDP)	NAFTA trade (% of GDP)	NAFTA trade, rel. to U.S. prop.
United States	27%	9%	1
Mexico	78%	66%	7.3
Canada	64%	50%	5.6

Table 2: Mexico and Canada are more dependent on NAFTA (as a portion of GDP) than the U.S. is
[Data from WITS]

Country	% change in total expenditures
United States	0.04%
Mexico	-0.27%
Canada	-0.01%

Table 3: Mexico sees a larger drop in total expenditures than its NAFTA partners do
[Time $t = 1$, weighted by industry]

Second, most manufacturing industries in Mexico and Canada experience a sizable drop in total expenditures at time $t = 1$. Service sectors in the two countries see only a modest drop in total expenditures, but the fact that NAFTA's dissolution harms almost every industry in Mexico and Canada is notable. Finally, Mexico sees a much larger effect than Canada does. Even though both Mexico and Canada have a fairly similar proportion of trade to GDP, Mexico is much more hurt from NAFTA's dissolution (in terms of expenditures) than Canada is.

Before examining how NAFTA's dissolution might affect international trade flows, we take a brief look at how changes in total expenditures $\hat{X}_t - 1$ evolve over time.

[46]Both Mexico and Canada trade much more with their immediate neighbor (by an order of magnitude) than with each other.

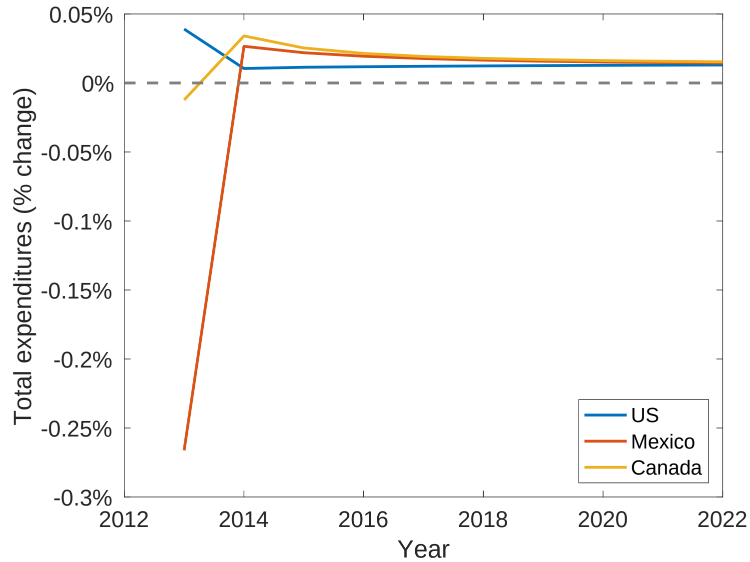

Figure 21: After the shock of leaving NAFTA, total expenditures return to more normal growth rates
[Percent change in total expenditures calculated as $\hat{X}_t^{nj} - 1$; weighted by industry]

The growth rates of total expenditures quickly return to normal as people internalize the initial unexpected shock of leaving NAFTA.

6.3.2 International trade flows

Given trade's importance to NAFTA's renegotiation, we end by discussing the effect of NAFTA's dissolution on international trade flows. We repeat the same analysis as in Subsection 6.3.1, except we graph $\hat{X}_1^{nj,ij} - 1$ instead of $\hat{X}_1^{nj} - 1$, where n and i are NAFTA countries and j is an industry.[47]

[47] We plot trade between Mexico and Canada for completeness; however, as mentioned earlier, trade between the two is fairly insignificant.

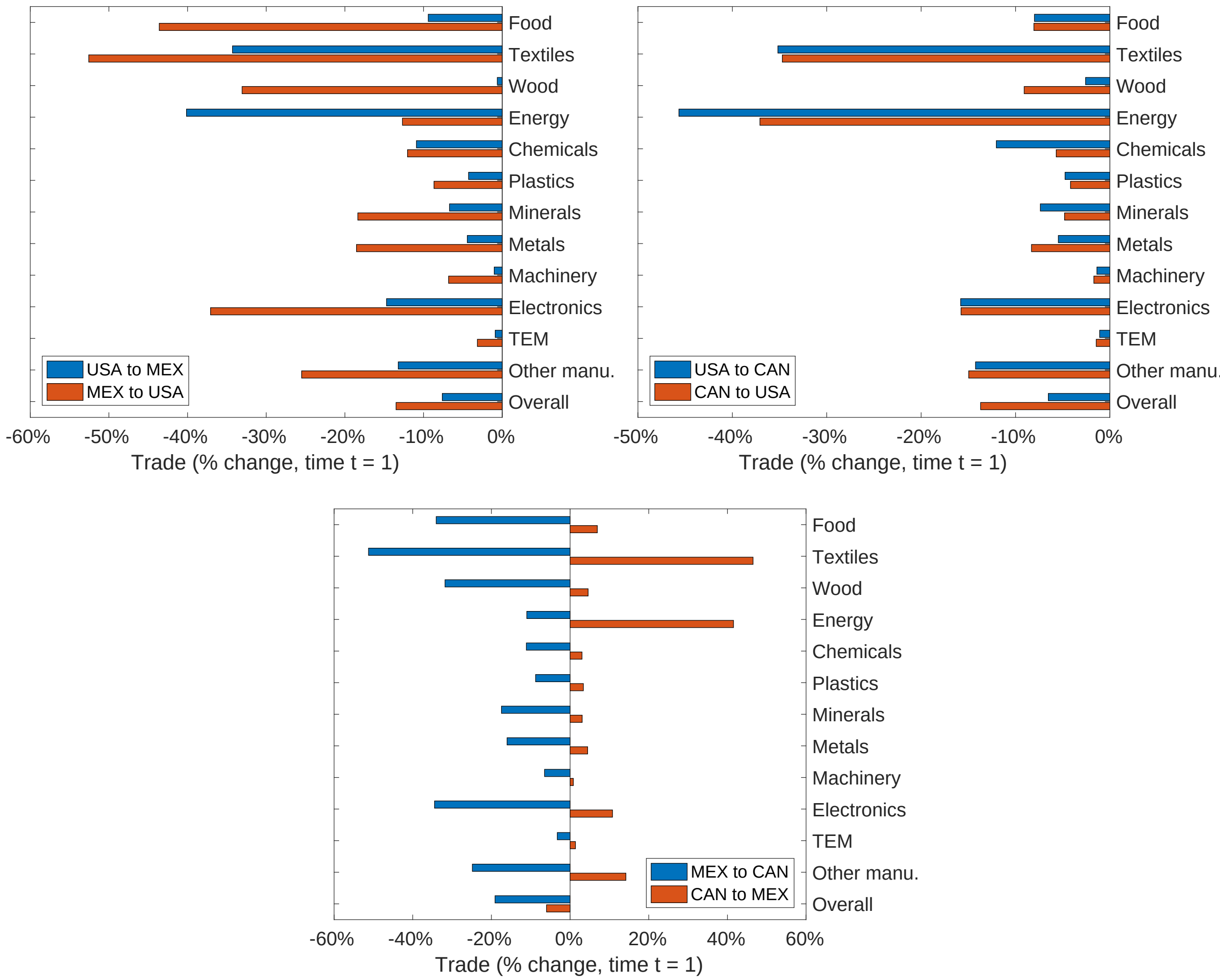

Figure 22: Leaving NAFTA lowers both the imports and exports of some U.S. industries disproportionately

Here, the results are striking. Overall U.S. exports to both Mexico and Canada drop by 7%, while overall U.S. imports from both Mexico and Canada drop by double that number, or 14%. Recall that average MFN tariff rates for the three countries are fairly small: 2.7% for Canada, 3.7% for the U.S., and 6% for Mexico. Hence, international trade is extremely sensitive to tariff differences (and likely price differences more generally).

Before concluding this subsection, we note that once again, there are notable heterogeneous effects caused by NAFTA's dissolution. The trade in electronics from Mexico to the U.S. drops by a stunning 40% the year after NAFTA's dissolution; meanwhile, the trade in TEM goods drops by only a few percent. These results show the importance of using a model with heterogeneous labor markets - a model like the one we adapt from CDP.

6.4 A critical assessment - and a defense of those critiques

Before ending our results section and concluding this paper, we take a moment to perform some self-introspection. First, we examine this paper's potential shortcomings. We then give a brief argument examining why this paper's key takeaways should remain correct *despite* these potential shortcomings.

6.4.1 A critical assessment

There are several potential issues which could skew results. Although we already have covered them, discussing them in one place may prove useful and help inform future research. In order from what we deem most to least serious:

1. *Biased labor mobility estimates:* Our source of migration data - the Census Bureau's Current Population Survey - may prove inaccurate, and arguably underestimates true labor mobility. We assume that the CPS covers an eight-month migration period, but Kambourov and Manovskii argue that mistaken survey responses may cause the CPS to cover a three-month period in reality.

2. *No primary sectors:* We exclude primary and governmental sectors from the model, partly because of issues with using the Commodity Flow Survey to categorize raw materials like grain. That said, raw materials production makes up a relatively small proportion of each NAFTA economy.

Country	% of GDP	% of all exports	% of all imports
United States	1.0%[2015]	9.4%	0.5%
Mexico	3.8%	10.2%	17.1%
Canada	1.8%[2013]	21.2%	2.1%

Table 4: Primary sectors do not make up a large proportion of any NAFTA economy
[2016 data from the World Bank, unless noted]

3. *Non-tariff trade costs:* We do not measure how NAFTA's dissolution might change non-tariff trade costs. For instance, the food manufacturing industry benefited from NAFTA's standardization of labeling requirements. NAFTA's dissolution could also have significant political and cultural ramifications that this paper does not discuss.

4. *Model mis-specifications:* Beyond the utility and production function specifications needed for dynamic hat algebra to work, we also assume infinite international migration costs and constant productivities.

6.4.2 A defense of our takeaways

There are three reasons why we believe our takeaways to be valid despite these potential shortcomings. The first has to do with the intuitiveness of our results. For instance, the industry most vocal about leaving NAFTA - the steel and primary metals industry - sees one of the biggest boosts in industry welfare from its dissolution. Similarly, the industry most vocal about staying in NAFTA - the TEM industry - sees one of the biggest falls in industry welfare from its dissolution.

Second, a back-of-the-envelope Fermi calculation that is not based on any economic model suggests how the magnitude of our results is reasonable. Indeed, leaving NAFTA might increase average tariff rates between the U.S. and Mexico/Canada from 0 to 3%. Trade with all countries accounts for about 25% of U.S. GDP. Of that amount, 33% involves trade between the U.S. and Mexico/Canada. Now, tariffs are not wasted money - the revenue that governments receive from tariffs is rebated back to residents. If we assume a 20% deadweight loss from tariffs, then, total U.S. GDP might change by $(0.03)(0.25)(0.33)(0.2) = 0.04$ percent. GDP is not the same thing as welfare in our model, but the results are similar by an order of magnitude.

Finally, as noted in the beginning of the paper, our results mesh well with estimates of the effects of *entering* NAFTA in 1994. Hinojosa-Ojeda et al. show that the yearly *impact* of entering NAFTA is at most 100,000 jobs; our model suggests that leaving NAFTA will *impact* roughly 45,000 jobs in the *long-run* (rather than yearly).[48] Similarly, our discovery that the textiles industry will see a large increase in real wage growth rates from *leaving* NAFTA is similar to Hakobyan and McLaren's discovery that the textiles industry saw a large decrease in real wage growth rates from *entering* NAFTA.

Our results on *leaving* NAFTA, however, are still somewhat smaller than the aforementioned results on *entering* it. To test whether a general decrease in global tariff rates can help explain this occurrence, we run a second counterfactual where all countries revert to their 1993 tariff rates.

6.4.3 A second counterfactual: traveling back to 1993

Running a second counterfactual serves two purposes. First, it enables us to understand whether a gradual fall in global tariff rates explains why the effects of *entering* NAFTA exceed the effects of *leaving* it. Second, it shows how our model can estimate a multitude of tariff shocks.

For this counterfactual, after 2012, all countries return to their 1993 tariff rates.[49]

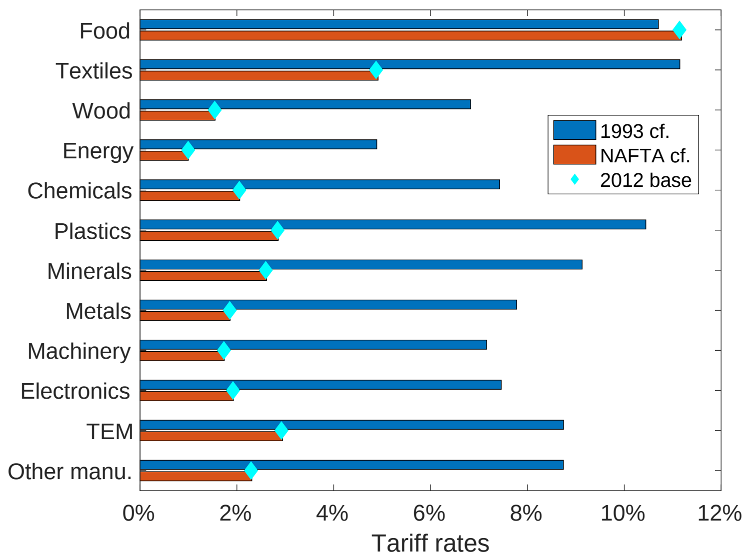

Figure 23: Global tariff rates have fallen dramatically since 1993
[Values computed by taking the simple mean of entries in $\kappa^{nj,ij}$ for each j, excl. diagonals]

Although this counterfactual is unlikely to happen in reality, it provides a good comparison with which to compare our above results. (As a side note, although we have only modeled trade shocks that last a single period, our model can easily handle longer-lasting shocks. A trade shock lasting more than one period, for instance, might occur if two nations enter a cycle of retaliation for raising import duties. We leave these analyses, however, for future research.[50])

To conserve space, complete results are available at the online companion. However, we provide a look

[48] For our purposes, if NAFTA's dissolution causes industry j to employ J_j more/less people in the long-run, NAFTA's impact on the U.S. is equal to $\frac{1}{2}\sum_{j=1}^{J}|J_j|$.

[49] 1993 tariffs from CP. They take a weighted (rather than a simple) average of tariff rates; these differences should not meaningfully change either the numbers or takeaways here.

[50] In engaging in such research, the key is to remember that our model is a *dynamic* one. Hence, we could do something like follows. Suppose the U.S. raises tariffs on the primary metals industry to 20% in a surprise announcement (i.e. at $t = 1$). Then, at time $t = 2$, have every other country implement a "tit for tat" policy of raising their tariff rates for U.S. metals to 20%. Given this scenario, it is then simple to predict the time evolution of wages, employment, and welfare.

at the aggregate differences between this counterfactual and our original one for two economic variables: employment shares and welfare.

Employment shares Moving to 1993 tariff levels causes noticeable changes in employment shares, with a broad-based migration of workers from services and into manufacturing and non-employment. Yet the graphs below clearly show that manufacturing should not be treated as a homogeneous industry when analyzing trade shocks. Indeed, some manufacturing sectors - namely textiles, electronics, and the primary metals industry - see a sizable rise in employment. Others - such as energy, machinery, and the TEM industry - see a notable drop.

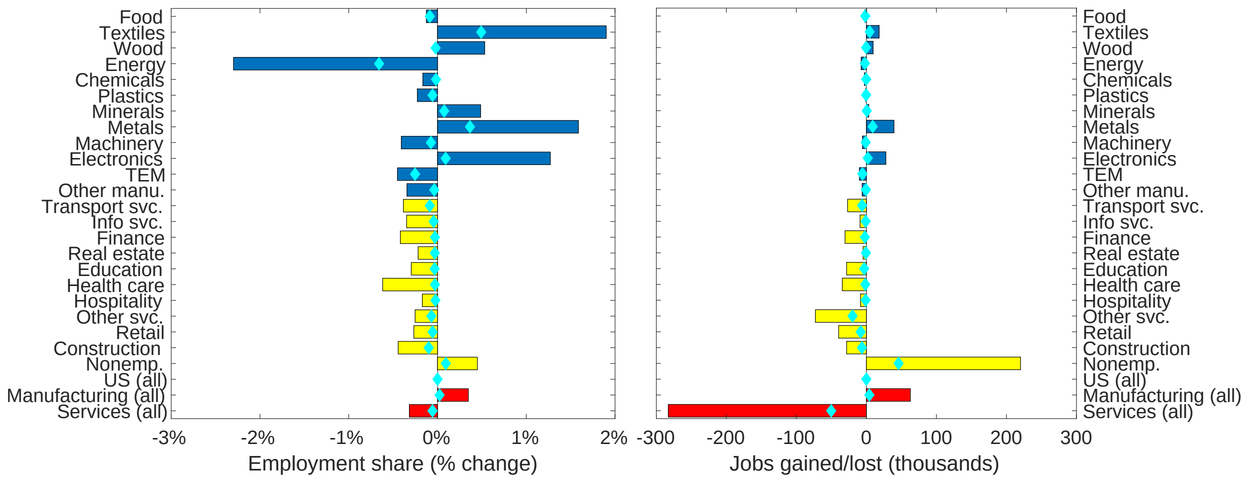

Figure 24: Job changes are bigger under the new scenario (bars) than under the original one (diamonds)

In addition, there is a large employment share drop in the health care industry, at least relative to that of other service industries. We emphasize that our model does not explain *why* such results might happen. Yet in many communities that used to be heavily industrialized, hospital systems have become the biggest employer. Our results may, consequently, be hinting at a phenomenon where manufacturing workers who lose their jobs retrain to enter the healthcare sector. (This connection is highly tenuous - indeed, in the original counterfactual involving NAFTA's dissolution, health care workers saw one of the *smallest* changes in employment shares. Still, it is an interesting avenue for future research.)

Welfare (U.S.) Almost every sector sees *worker* welfare changes of over 0.10%, and *industry* welfare changes of over 0.20%. Interestingly, moving to 1993 tariff rates appears to have the same *directional* effect for most industries as leaving NAFTA does - even if that effect is amplified.

Among manufacturing industries, responses to this new counterfactual are once again quite disparate; among service industries, responses are fairly similar.

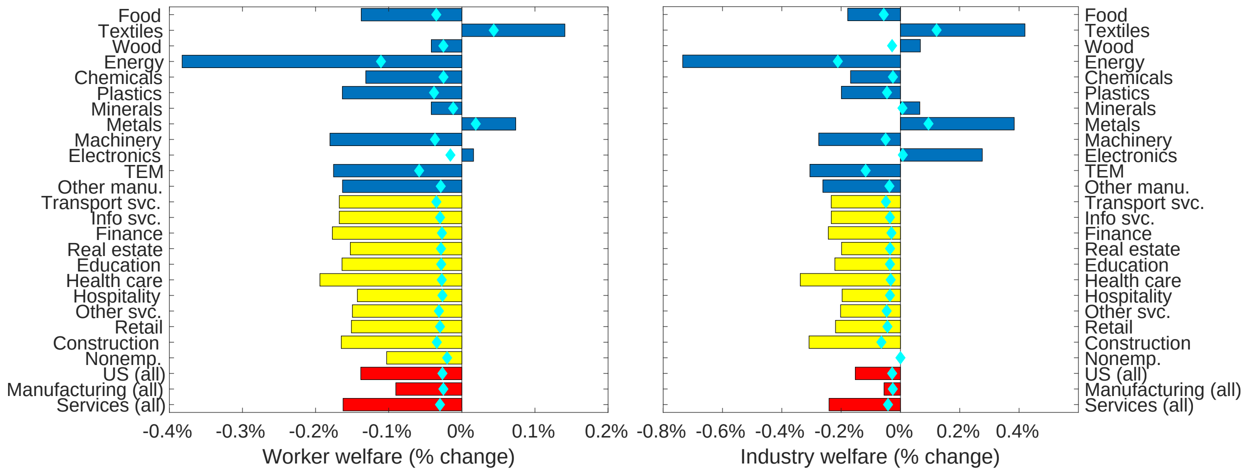

Figure 25: In the new scenario, U.S. *worker* (left) and *industry* (right) welfare *drop* by 0.14% and 0.15%, respectively
[Bars represent the "traveling back to 1993" counterfactual; diamonds represent the "leaving NAFTA" counterfactual]

Welfare (world) We end the analysis of this counterfactual by looking at how welfare changes across the model's 38 countries. Recall, once again, that for non-U.S. countries, *industry* and *worker* welfare are equivalent.

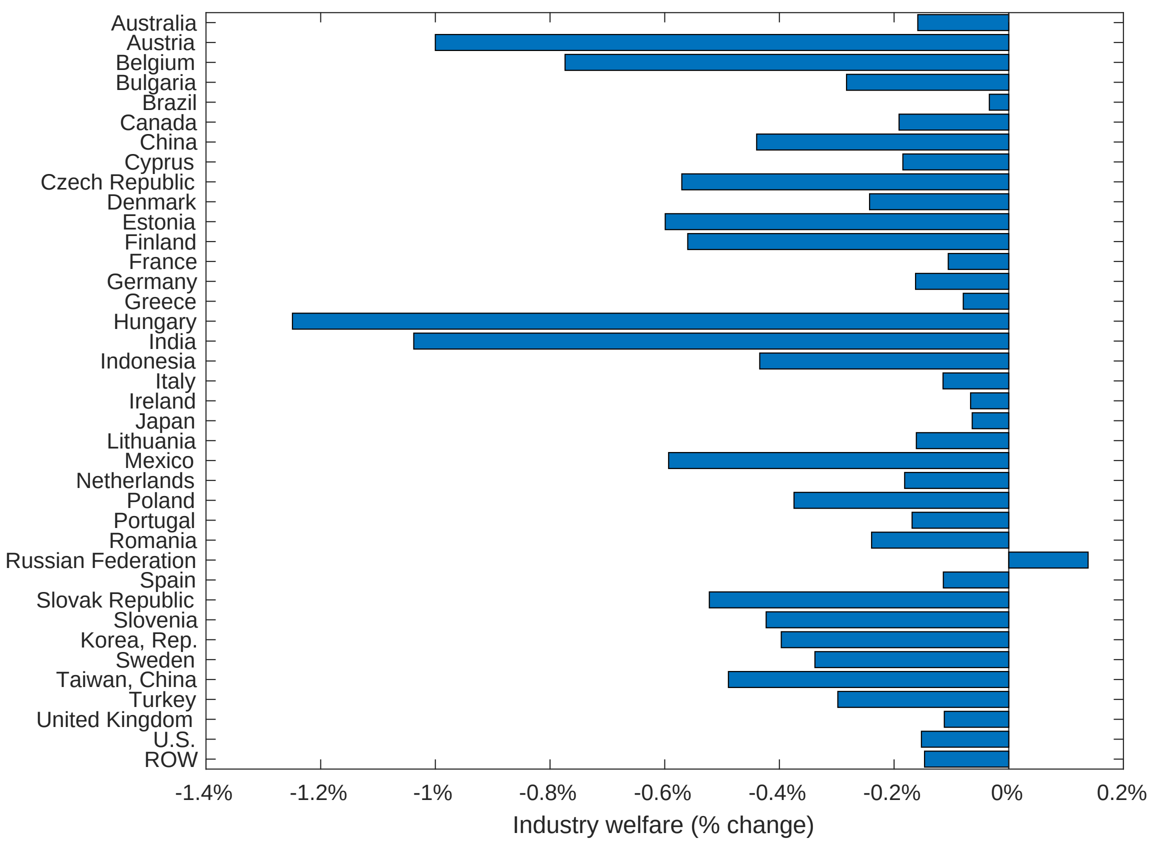

Figure 26: Most countries see a decline in wages from the new counterfactual, but results are heterogeneous

Country	Leaving NAFTA counterfactual		Traveling back to 1993 counterfactual	
	Worker welfare	Industry welfare	Worker welfare	Industry welfare
United States	-0.03%	-0.03%	-0.14%	-0.15%
Mexico	-0.15%	-0.15%	-0.59%	-0.59%
Canada	-0.15%	-0.15%	-0.19%	-0.19%

Table 5: Going to 1993 tariff rates leads to bigger welfare changes than simply dissolving NAFTA does
[Percent change in welfare; worker and industry welfare definitionally equivalent for non-U.S. countries]

Interestingly, every country except Russia sees a sizable decline in wage growth when everyone moves to 1993 tariff rates. That said, certain countries are much more affected than others.

Summary: what happens if everyone goes back to 1993 tariff rates? The results from this second counterfactual hint that while leaving NAFTA or raising a small number of tariffs may not materially affect the economy, a trade war leading to a broad-based increase in tariffs can lower aggregate wage growth and cause sizable sectoral migration. However, just as in the first counterfactual, trade shocks often lead to disparate outcomes for different industries.

7 Conclusion

The Trump administration is renegotiating NAFTA, the free trade agreement between the United States, Mexico, and Canada. Although there is a growing chance the U.S. will sever the agreement completely, there is a dearth of research on what leaving NAFTA might mean for the economy. We attempt to rectify this dearth by quantifying the effects of NAFTA's dissolution on a regional and sectoral level. Indeed, by adapting a model from Caliendo, Dvorkin, and Parro, we can create a rich spatial and temporal framework with which to estimate changes in employment levels, real wages, and worker welfare - all while accounting for input-output linkages and migration/trade frictions.

Our results are clear. While certain industries and workers will be relatively helped or hurt by NAFTA's dissolution, the vast majority of Americans will see little effect. (Indeed, long-run U.S. non-employment increases by 0.09%, while U.S. aggregate welfare falls by 0.03%.) Even within relatively affected industries, the effect of NAFTA's dissolution is limited: the employment shares of one of the most affected industries - the TEM industry - does not drop by more than 0.25%.

The other two participants of NAFTA - Mexico and Canada - are more hurt by NAFTA's dissolution. Indeed, their welfares fall by 0.15%. However, considering the news coverage NAFTA has received, even these numbers might be considered less serious than previously feared. For every other country, the dissolution of NAFTA is unlikely to affect their economies by any measurable amount. If, however, NAFTA's dissolution sparks a broad increase in tariffs across all countries, the world will generally see lower wage growth and increased sectoral migration.

We emphasize, of course, that no *one* number can fully capture NAFTA's effect on the economy. Each metric with which we might measure the effect of NAFTA's dissolution - employment shares, job numbers, industry welfare, worker welfare, trade flows - obscures important information. Studying industry welfare enables us to examine changes in real wages, but blinds us to the second-order effect of changes in option value. Examining changes in long-run job numbers gives us important employment predictions, but conceals how long it may take for these predictions to take effect.

Nor can any *set* of numbers fully capture NAFTA's effect on the economy. There are many non-economic considerations that policymakers may have concerning NAFTA - none of which this paper covers. Dissolving NAFTA, for instance, may help restore feelings of national identity, while also increasing non-tariff trade costs. Furthermore, by reducing NAFTA's effects to a series of numbers, policymakers risk missing the individual effects it has had on the human population - good and bad.

Regardless, we hope this paper will help inform an often contentious debate.

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A Appendix: Data

We set $t = 0$ to correspond to the year 2012, which all data sources describe unless noted. Time is discrete, with one period corresponding to one year.

A.1 Sectors and regions

A.1.1 Sectors

As in CDP, we have $J = 22$ sectors in our model. Our model also includes non-employment.

Manufacturing sectors	Service sectors
Food, Beverage, and Tobacco	Transport Services
Textiles, Apparel, and Leather	Information Services
Wood Products, Paper, and Printing	Finance and Insurance
Petroleum and Coal	Real Estate
Chemicals	Education
Plastics and Rubber	Health Care
Nonmetallic Mineral Products	Accommodation and Food Services
Primary and Fabricated Metal Products	Other Services
Machinery	Wholesale and Retail Trade
Computers, Electronics, and Appliances	Construction
Transportation Equipment	
Furniture and Miscellaneous Manufacturing	

Table 6: Model sectors

A.1.2 Regions

Our model includes 36 non-U.S. countries, a constructed "Rest of the World" (ROW), and all 50 U.S. states (excluding D.C.). Countries not below were a part of ROW. Hence, our model includes $N = 87$ regions.

Australia	Ireland
Austria	Japan
Belgium	Lithuania
Bulgaria	Mexico
Brazil	Netherlands
Canada	Poland
China	Portugal
Cyprus	Romania
Czech Republic	Russia
Denmark	Spain
Estonia	Slovakia
Finland	Slovenia
France	South Korea
Germany	Sweden
Greece	Taiwan
Hungary	Turkey
India	United Kingdom
Indonesia	U.S. (as 50 states)
Italy	Rest of the World (ROW)

Table 7: Model regions

A.2 Tariffs

To calculate tariff rates, we exploit data from the World Integrated Trade Solution (WITS). WITS provides data on both MFN and preferential tariff rates (on an ad-valorem equivalent basis) for every country.

A.2.1 Baseline tariffs

Because WITS provides tariff data at the product level, obtaining industry-wide tariff rates can prove tricky. That said, our process for doing so is as follows:

1. For each of our 37 countries, download both 2012 "MFN applied rates w/ ad-valorem equivalents" data and 2012 "Preferential rates w/ ad-valorem equivalents" data.[51] (Note that all countries in the European Union use the same set of tariffs.)

2. Match every product in each table to a model industry. In WITS, products are described by HS2007 and HS2012 (Harmonized Commodity Description and Coding Systems) codes; the United Nations has tables mapping these codes to ISIC Rev. 3 (International Standard Industrial Classification) codes. We then manually map all two-digit ISIC categories to model industries.[52]

3. For each importing country n, exporting country i, and manufacturing industry j, retrieve the MFN data for country n, focusing only on products associated with industry j. For each such product in the MFN data, see if a preferential rate exists whenever country i is the exporter.[53] If not, the rate to send the product from country i to country n is the MFN rate.[54]

4. Take the simple average of all the product rates in Step 3. This is $\kappa^{nj,ij}$.[55] (The only exception occurs whenever $n = i$ or $n, i \in \{European\,Union\}$; then, $\kappa^{nj,ij} = 0$.)

5. Calculate $\kappa^{ROWj,ij}$ for all i and j by assuming the Rest of the World adopts a "tit for tat" policy of symmetric trade costs. Specifically, let $\kappa^{ROWj,ij} = \kappa^{ij,ROWj}$.

A.2.2 Counterfactual tariffs

Should the United States dissolve NAFTA, we assume that the United States, Mexico, and Canada return to MFN status with one another, as required by World Trade Organization (WTO) rules. Our model assumes no other changes. (For instance, we do not suppose that the current U.S. administration will withdraw from the WTO altogether.)

Recall from the above section that we treat the Rest of the World (ROW) as if it were a real country receiving MFN rates from all other countries. Then, for all sectors j, our counterfactual tariff matrix κ' is described by

[51] Due to data availability issues, some substitutions were made: (1) MFN rates w/ AVE data for China and Turkey came from the year 2011, (2) preferred rates w/ AVE data for India came from the year 2010, and (3) preferred rates w/ AVE data for Mexico came from the year 2009. The last substitution has the largest cause for concern, but the only Mexican trade agreement signed from 2009 to 2012 involved Latin American countries not in our model.

[52] Using the correct version of the HS and ISIC codes is crucial to accurate mapping.

[53] In the data, preferential rates are given by partners (which describe blocs of countries) rather than by individual countries; WITS provides mappings, however, linking partners to countries.

[54] For $i = ROW$, we always assume no preferential rate exists.

[55] Here, $\kappa^{nj,ij}$ does not include non-tariff trade costs. We discuss this assumption in the text.

$$\kappa'^{nj,ij} = \kappa^{nj,ROWj}$$

for any $n \in \{Canada,\ Mexico,\ U.S.\}$, $i \in \{Canada,\ Mexico,\ U.S.\}$, and $n \neq i$.

Otherwise,

$$\kappa'^{nj,ij} = \kappa^{nj,ij}$$

holds.

A.3 Migration flows and initial employment distribution

A.3.1 Migration flows

Recall that there is no international migration in our model.

To calculate U.S. migration flows, we exploit the 2012 Annual Social and Economic Supplement (ASEC) to the Current Population Survey (CPS). Specifically, we use the harmonized IPUMS-CPS dataset released by the University of Minnesota. IPUMS-CPS provides panel data on current/past employment and residence. For the year 2012, IPUMS-CPS contains 95,609 usable observations.[56] Of these observations, 13,008 people switched industries and 1,426 people moved states.[57]

The steps to convert the IPUMS-CPS data to an *unnormalized* migration matrix $\tilde{\mu}^{ik,nj}$ are as follows:

1. Obtain the IPUMS-CPS (ASEC 2012) dataset, selecting the following variables: STATEFIP (current state of residence), MIGSTA1 (state of residence last year), EMPSTAT (employment status), IND (industry at time of survey), INDLY (industry last year), and WKSWORK1 (weeks worked last year). Subset the data into those ages 25-65 not in the armed forces.[58]

2. Map all CPS industries to model industries. Remove anyone associated with a non-model industry (e.g. if IND or INDLY is public administration). Also remove anyone associated with a non-model region (e.g. if MIGSTA1 is D.C. or abroad).

3. Start with a migration matrix filled with zeros. For each person in the dataset, we have information on their origin state i, origin industry k, destination state n, and destination industry j.

    (a) Finding the origin state and destination state is straight-forward.

    (b) Finding the destination industry is also straight-forward, although we place persons currently non-employed into a separate "Non-employment" sector regardless of their usual industry.

    (c) Finding the origin industry requires a few assumptions, since INDLY reports the industry the respondent worked the longest during the last calendar year. For our purposes, we assume the following: (1) survey subjects can switch industries no more than once from March 1, 2011 to March 1, 2012, (2) switches, if they occur, are equally likely to occur on any given day, and (3) the probability of being non-employed on March 1, 2011 is equal to (52 - WKSWORK1)/52, and the probability of working in industry INDLY is equal to WKSWORK1/52.

[56] Out of 106,141 total observations, 10,532 were removed for reasons described in the procedure.

[57] Although the model describes the actions of *households*, our migration matrix captures the actions of *workers*. Unfortunately, resolving this tension is challenging. While the CPS does group responses by households, workers within households are obviously heterogeneous.

[58] We assume most people have finished their educations by age 25, and have retired after age 65.

4. Hence, we can populate the migration matrix by looking at each person in the dataset and incrementing $\tilde{\mu}^{ik,nj}$ as necessary.[59]

5. Finally, we replace any zero entries with a functionally zero value of 0.1.

A.3.2 Initial employment distribution

Given the unnormalized migration matrix $\tilde{\mu}$ above, we calculate the *unnormalized* initial employment distribution $\tilde{L}_0^{nj}$ by noting how for all states n and sectors j,

$$\tilde{L}_0^{nj} = \sum_{k=1}^{J+1} \sum_{i=1}^{N} \tilde{\mu}^{ik,nj}.$$

Because our model does not have international migration, we simply set $\tilde{L}_0^{nj} = 1$ for all non-U.S. regions n.

A.4 Bilateral trade flows

To calculate country-to-country trade flows, we utilize the 2012 Input-Output Table (WIOT) from the World Input-Output Database. This table provides in-depth information on value-added, production, and final consumption at a regional and sectoral level. For state-level trade flows, we combine WIOT data with the 2012 Commodity Flow Survey (CFS), which provides detailed information on commodity shipments - including their origins, destinations, and industries.

A.4.1 Country-to-country trade flows

We calculate period 0's total output Y_0^{nj} of all goods from country n and sector j by selecting all the WIOT rows corresponding to that country and sector. We then sum all the entries in those rows, less inventory changes.[60]

We calculate $X_0^{nj,ij}$, the total expenditures in market nj on good j from country i, by defining $M_0^{nj,ij}$ to be the amount of intermediate good j from country i used in the production of good j in country n. Specifically, $M_0^{nj,ij}$ is the summed value of any WIOT cells with rows corresponding to market ij and columns corresponding to market nj.[61] For $n = i$, define domestic sales as $M_0^{nj,nj} = Y_0^{nj} - \sum_{m \neq n} M_0^{mj,nj}$.

Then,

$$X_0^{nj,ij} = (1 + \kappa^{nj,ij}) M_0^{nj,ij}.$$

A.4.2 State-to-state trade flows

State-to-state trade flows are calculated by combining WIOT data with CFS data. CFS data provides information on shipments by Standard Classification of Transported Goods (SCTG) industry, origin geography, and destination geography. Our process is as follows:

[59] To correct for sampling issues, increments should be adjusted by the person-level weights (WTSUPP) supplied by the CPS. Additionally, anyone switching sectors (not coming from or going to the "Non-employment" sector) must have their weights adjusted by a factor of 3/2, given the nature of INDLY.

[60] The WIOT had no data on Mexico's real estate industry, and yielded slightly negative total expenditures for Slovenia's petroleum industry. Hence, for both markets, we impute Y_0^{nj} to equal 1 - a functionally zero value.

[61] We assume that Mexico's real estate industry spends nothing on real estate from other regions.

1. Map the SCTG industry associated with each shipment in the CFS data to a model sector.

2. Calculate λ^{nj}, the proportion of sector j goods (by value) going to state n. Note that $\sum_n \lambda^{nj} = 1$ for all j.[62]

3. Find $\lambda^{nj,ij}$, the proportion of sector j goods arriving in state n coming from state i. Note that $\sum_i \lambda^{nj,ij} = 1$ for all n, j.

4. Define U.S. domestic sales for sector j as $X_0^{USAj,USAj}$ - values found from WIOT in the above subsection. Then, let $X_0^{nj,ij}$ be the total expenditures on goods j from state i in market nj. Hence, for any manufacturing sector j,
$$X_0^{nj,ij} = X_0^{USAj,USAj} \lambda^{nj} \lambda^{nj,ij}.$$

5. For any non-manufacturing sector j, let $X_0^{nj,ij} = 0$ for $n \neq i$. Otherwise, let
$$X_0^{nj,nj} = X_0^{USAj,USAj} \rho^{nj},$$
where the calculation of ρ^{nj} is described below.

We calculate $M_0^{nj,ij}$ analogously.

A.4.3 Country-to-state and state-to-country trade flows

Every year, the Bureau of Economic Analysis (BEA) breaks down the number of workers employed in each state and industry. Hence, similar to ADH, we suppose that the share of each state in total U.S. trade for an industry is proportional to its share of workers in national employment for that industry. Suppose ρ^{nj} is the proportion of workers from state n in the national employment of sector j (i.e. $\sum_n \rho^{nj} = 1$ for all j). Then,
$$X_0^{nj,ij} = \rho^{ij} X_0^{nj,USAj}$$
for $n = country$, $i = US\,state$, and
$$X_0^{nj,ij} = \rho^{nj} X_0^{USAj,ij}$$
for $n = US\,state$, $i = country$.

We calculate $M_0^{nj,ij}$ analogously.

Note that we now can calculate $\pi_0^{nj,ij}$ when either n or i is a state; indeed,
$$\pi_0^{nj,ij} = \frac{X_0^{nj,ij}}{\sum_{i \in all\,regions} X_0^{nj,ij}}.$$

A.5 Value-added

Value-added for each country and sector is taken directly from the value-added entries in WIOT.[63]

Value-added for each state and sector is taken from 2012 regional data on GDP from the BEA. For each state and sector, we let VA_0^{nj} equal GDP minus TOPILS (taxes on production and imports less subsidies).

[62] Several values were fuzzed to protect confidentiality; in any dataset where this phenomenon occurs, such values were assumed to be zero.

[63] Brazil's petroleum industry had negative value-added, and Mexico's real estate industry had no value-added. Both were imputed to be functionally zero.

In 43 cases, VA_0^{nj} exceeded gross output $Y_0^{nj} = \sum_m M_0^{mj,nj}$. (The CFS may have missing shipments, and imprecise industry mappings.) In these cases, we set VA_0^{nj} equal to gross output.

A.6 Shares

A.6.1 Shares of value-added in gross output

At both the country and state level, shares of value-added in gross output γ^{nj} are equivalent to value-added VA_0^{nj} divided by total output Y_0^{nj}.[64] For states, we set total output Y_0^{nj} to the sum of domestic sales and total exports, or $M_0^{nj,nj} + \sum_{m \neq n} M_0^{mj,nj}$.

A.6.2 Shares of structures

At the country level, we calculate $1 - \xi^n$ using the 2011 OECD Input-Output Tables (OIOT). Specifically, for each country, we sum labor compensation across all industries, and divide this value by the sum of value-added at basic prices across all industries (as suggested by OIOT, and not WIOT).[65]

At the state level, we calculate $1 - \xi^n$ using 2012 regional data on GDP from the BEA. Specifically, for each state, we sum employee compensation across all model industries, and divide this value by the sum of value-added across all model industries (defined earlier as GDP less TOPILS).

A.6.3 Shares of intermediate materials

We calculate $\gamma^{nj,nk}$, the share of materials from sector k used in the production of good j from country n, by defining $M_0^{nj,nk}$ to be the amount of intermediate good k from country n used in the production of intermediate good j in country n. Specifically, $M_0^{nj,nk}$ is the summed value of any WIOT cells with rows corresponding to market nk and columns corresponding to market nj.[66] Then,

$$\gamma^{nj,nk} = \frac{M_0^{nj,nk}}{\sum_{m \in industry} M_0^{nj,nm}}.$$

For $n = US\, state$, we assume $\gamma^{nj,nk}$ is equivalent to the national U.S. value.

A.6.4 Final consumption

Observe how the share of income spent on goods from sector j is

$$\alpha^j = \frac{\sum_{n=1}^{N} \sum_{k=1}^{J} \gamma^{nk,nj} \sum_{i=1}^{N} \frac{\pi^{ik,nk}}{1+\kappa^{ik,nk}} X^{ik}}{\sum_{n=1}^{N} \sum_{k=1}^{J} w^{nk} L^{nk} + \sum_{n=1}^{N} \iota^n \chi + \sum_{n=1}^{N} \sum_{k=1}^{J} \sum_{i=1}^{N} \frac{\kappa^{nk,ik} \pi^{nk,ik}}{1+\kappa^{nk,ik}} X^{nk}},$$

where the numerator equals total spending in intermediate goods across all regions, and the denominator equals total world income. Hence, we can simply calculate the numerator for any j, and then normalize α such that $\sum_j \alpha^j = 1$.

[64] The share of value-added in gross output for Delaware's (negligible) petroleum industry was imputed to be the simple average of $\gamma^{n,petroleum}$ for all other states.

[65] In these two sums, we include industries not otherwise used in the model, such as agriculture.

[66] We assume that Mexico's real estate industry uses only other real estate services in production. Because we calculate the share of value-added in gross production to be 1 for Mexico's real estate industry, however, this assumption does not matter.

A.6.5 Global portfolio

Define D^{nj} to be the trade deficit of market nj, and D^n to be the trade deficit of region n. That is, $D^{nj} = \sum_i M^{nj,ij} - \sum_i M^{ij,nj}$ (imports less exports), and $D^n = \sum_j D^{nj}$ (sum of all deficits within a region).

Using value-added data and shares of structures, we calculate

$$\iota^n = \frac{\sum_{k=1}^{J} \xi^n VA^{nk} - D^n}{\sum_{i=1}^{N} \sum_{k=1}^{J} \xi^i VA^{ik}}.$$

The world is a closed economy, so $\sum_n D^n = 0$. As a result, we can simply calculate the numerator of the above fraction for any n, and then normalize ι such that $\sum_n \iota^n = 1$.

A.7 Discount rates and elasticities

A.7.1 Discount rate

We set the discount rate β to 0.96, implying a yearly interest rate of 4%.

A.7.2 Trade elasticities

We use the sectoral elasticities calculated by CP. Specifically, we use their estimates of θ^j from the full sample of their dataset.[67]

For service sectors, elasticities are assumed to be $\theta^j = 4$.

A.7.3 Migration elasticity

We use the migration elasticity (at an annual frequency) estimated by CDP of $1/\nu = 1/2.02$.[68]

B Appendix: Algorithm

This algorithm is a shortened one of that from CDP. On a modern workstation, compute time should be under eight hours.

1. Find the model parameters and initial allocations (e.g. labor and migration distributions in 2012), as explained in both Section 5 and Appendix A.

2. Find the baseline economy. Suppose the baseline economy approaches a stationary equilibrium within T periods.

   (a) Guess the values of $\left\{\dot{u}_{t+1}^{nj(0)}\right\}_{t=0}^{T}$ to be all ones. Every time this guess updates, increment the number in the parentheses by one for bookkeeping.

   (b) *Dynamic problem:* Calculate the path of employment and migration flows given the path of values in time differences.

      i. Solve for the path of migration flows using Equation (16) and initial migration flows.

[67] CP use slightly different sectors than we do in this paper. We remap their manufacturing sectors to match ours, but otherwise reuse their code.

[68] CDP use a *quarterly* migration elasticity of $1/\nu = 0.2$, which leads to an implied annual migration elasticity of $1/\nu = 1/2.02$.

ii. Compute the path of employment using Equation (18), the path of migration flows, and the initial labor distribution.

(c) *Static problem:* Calculate the path of real wages given the path of employment. For each *t:*

i. Given $\dot{L}_{t+1}$, guess the values of $\dot{w}_{t+1}$.

ii. Use fixed point iteration on the factor price equations - Equations (11) and (12) - to find $\dot{x}_{t+1}$ and $\dot{P}_{t+1}$.

iii. Employ the trade flows equation - Equation (13) - and factor prices to find $\dot{\pi}_{t+1}$.

iv. Calculate total expenditures X_{t+1} with the goods market clearing condition, Equation (14).[69]

v. Find wages $\dot{w}_{t+1}$ using Equation (15) and total expenditures. If these wages are sufficiently close to our original one, stop. If not, update $\dot{w}_{t+1}$ and go back to step 2(c-ii).

(d) *Recursive problem:* Find $\left\{\dot{u}_{t+1}^{nj(1)}\right\}_{t=0}^{T}$ using Equation (17), the path of real wages, the path of migration flows, and our initial guess $\left\{\dot{u}_{t+1}^{nj(0)}\right\}$.

(e) Check if our new guess $\left\{\dot{u}_{t+1}^{nj(1)}\right\}_{t=0}^{T}$ is sufficiently close to our original one. If yes, stop. If not, go back to step 2(b).

3. Find the counterfactual economy. Once again, suppose the counterfactual economy approaches a stationary equilibrium within T periods.

(a) Guess the values of $\left\{\hat{u}_{t+1}^{nj(0)}\right\}_{t=0}^{T}$ to be all ones. Every time this guess updates, increment the number in the parentheses by one for bookkeeping. Load the results obtained from step 2.

(b) *Dynamic problem:* Calculate the path of employment and migration flows given the path of values in time differences.

i. Solve for the path of migration flows using Equation (19) and initial migration flows.

A. Time 0: Because we assume an MIT shock, everyone in time 0 acts the same in the counterfactual and baseline economies. That is, set

$$\hat{u}_0^{nj} = 1$$

$$\mu_0^{'nj,ik} = \mu_0^{nj,ik}.$$

B. Time 1: Now, people suddenly see the new sequence of tariffs κ and adjust their behaviors to account for this surprise. Following CDP, let

$$\mu_1^{'nj,ik} = \frac{\vartheta_0^{nj,ik} \hat{u}_2^{ik}}{\sum_{m=1}^{N} \sum_{h=1}^{J+1} \vartheta_0^{nj,mh} \hat{u}_2^{mh}}$$

$$\vartheta_0^{nj,ik} = \mu_1^{nj,ik} \hat{u}_1^{ik}.$$

C. Time 2 to T:

$$\mu_t^{'nj,ik} = \frac{\mu_{t-1}^{'nj,ik} \dot{\mu}_t^{nj,ik} \hat{u}_{t+1}^{ik}}{\sum_{m=1}^{N} \sum_{h=1}^{J+1} \mu_{t-1}^{'nj,mh} \dot{\mu}_t^{nj,mh} \hat{u}_{t+1}^{mh}}.$$

[69]In practice, this step causes the biggest bottleneck. (Solving the goods market clearing condition takes over 50% of the model's total runtime.) For a system with many unknowns (> 5,000), using a GPU may be desirable; our model code allows for this option.

ii. Compute the path of employment using Equation (21), the path of migration flows, and the initial labor distribution.

(c) *Static problem:* Calculate the path of real wages given the path of employment. (The procedure here is the same as the procedure in step 2(c).)

(d) *Recursive problem:* Find $\left\{\hat{u}_{t+1}^{nj(1)}\right\}$ using the path of real wages, the path of migration flows, and our initial guess $\left\{\dot{u}_{t+1}^{nj(0)}\right\}$. We again follow CDP, letting

$$\hat{u}_t^{nj(1)} = \begin{cases} \left(\hat{\omega}^{nj}(\hat{L}_1, \hat{\Theta}_1)\right)^{\beta/\nu} \left(\sum_{i=1}^{N} \sum_{k=1}^{J+1} \vartheta_0^{nj,ik(0)} \hat{u}_2^{ik}\right)^{\beta} & \text{for time } t = 1 \\ \left(\hat{\omega}^{nj}(\hat{L}_t, \hat{\Theta}_t)\right)^{\beta/\nu} \left(\sum_{i=1}^{N} \sum_{k=1}^{J+1} \mu_{t-1}^{\prime nj,ik} \dot{\mu}_t^{nj,ik} \hat{u}_{t+1}^{ik}\right)^{\beta} & \text{otherwise} \end{cases}.$$

(e) Check if our new guess $\left\{\hat{u}_{t+1}^{nj(1)}\right\}_{t=0}^{T}$ is sufficiently close to our original one. If yes, stop. If not, go back to step 3(b).

C Appendix: Additional results

Additional results - such as interactive figures denoting employment and welfare changes - are available at the online companion. Visit `http://www.tinyurl.com/LeavingNAFTA` for more info.