

# Transitional Growth and Trade with Frictions: A Structural Estimation Framework\*

Short Title: "Growth and Trade with Frictions"

James E. Anderson Mario Larch  
Boston College and NBER University of Bayreuth  
CEPII, ifo, CESifo, GEP  
Yoto V. Yotov<sup>†</sup>  
Drexel University  
ifo, CESifo, ERI-BAS

April 23, 2019

### Abstract

We build and estimate a structural model of transitional growth and trade in a many-country world. The gravity model of trade is combined with a capital accumulation mechanism driving transition between steady states. Trade affects growth through changes in consumer and producer prices. Simultaneously, capital accumulation affects trade directly through changes in country size and indirectly through changes in the incidence of trade costs. Theory maps to an econometric system that identifies the parameters of the model and establishes causal links between trade, capital accumulation, and income. Counterfactual trade liberalization magnifies static gains by a *dynamic path* multiplier of 1.8.

**JEL Classification Codes:** F14, F43, O40

**Keywords:** Trade, Transitional Growth, Income, Trade Liberalization, Capital Accumulation.

---

\*Corresponding Author: Yotov–School of Economics, LeBow College of Business, Drexel University, CESifo, ifo Institute, and Economic Research Institute, Bulgarian Academy of Sciences, 3200 Market Street, Philadelphia, PA 19104, USA. Phone: (215) 895-2572. Email: yotov@drexel.edu.

<sup>†</sup>We thank editor Morten Ravn for the excellent handling of our manuscript and for his useful comments and guidance. We also thank the anonymous referees who reviewed our paper and the many colleagues who offered a series of great suggestions.

The relationship of trade and growth has been a central concern of economists since Adam Smith. More than two centuries later debate continues about an empirically strong relationship between trade and growth, c.f., Frankel and Romer (1999) and Baldwin (2000). Better models could help, but Head and Mayer (2014) note that the best fitting trade models are static, and “[t]his raises the econometric problem of how to handle the evolution of trade over time in response to changes in trade costs.” (p. 189). However, introducing dynamics to static multi-country trade models “typically makes spatial dynamic models intractable, both analytically and numerically.” (Desmet and Rossi-Hansberg, 2014, p. 1212). Despite academic doubts, policy analysts and negotiating parties in recent trade deals, such as the new United States-Mexico-Canada Agreement (USMCA), expect that “USMCA will support mutually beneficial trade leading to [...] robust economic growth in North America.”<sup>1</sup>

These observations motivate our development and estimation of a structural dynamic model of trade and capital accumulation.<sup>2</sup> The model features many countries that are asymmetric in size, in bilateral trade frictions and in capital accumulation frictions. The CES-Armington trade gravity model of Anderson and van Wincoop (2003) is combined with a Lucas and Prescott (1971) capital accumulation model of transition between steady states.<sup>3</sup> To end up with a simple framework with closed-form solutions, we assume perfect foresight and our model is based on price taking agents well-behaved intertemporal optimizations. Also, labor, trade imbalances and technologies are taken as exogenous. Hence, our framework is effectively an Arrow-Debreu general equilibrium model.<sup>4</sup> Two frictions interact on

---

<sup>1</sup>Office of the United States Trade Representative, October, 2018, <https://ustr.gov/about-us/policy-offices/press-office/fact-sheets/2018/october/united-states%20%93mexico%20%93canada-trade-fa-1>.

<sup>2</sup>Our focus on capital accumulation as a source of transitional growth is motivated by Wacziarg (2001), who finds that physical capital accumulation accounts for about 60% of the total impact of openness on growth. Baldwin and Seghezza (2008) and Wacziarg and Welch (2008) confirm this result with alternative samples. We abstract from non-zero steady-state growth for simplicity. Thus, if not mentioned explicitly otherwise, when we use the term “growth” we have in mind transitional growth between steady states.

<sup>3</sup>Recent work by Arkolakis et al. (2012, henceforth also ACR) argues that gains from trade measures in such models represent a general class of models for which the key parameter is a single trade elasticity. We demonstrate that this class of models readily integrates with our model of capital accumulation. We refer the reader to Anderson (2011), Head and Mayer (2014), Costinot and Rodríguez-Clare (2014), and Yotov et al. (2016) for reviews of the alternative theoretical foundations of economic gravity.

<sup>4</sup>Relaxing some of these restrictive assumptions, such as modeling stochastics, allowing for mobility of labor, endogenizing trade imbalances or/and technology, are all interesting avenues for future research. See

stage: costly trade and costly capital adjustment. Capital stock adjustment in each country is subject to iceberg trade costs because capital requires imports, but in addition costly adjustment and depreciation act essentially like iceberg frictions on the intertemporal margin. At each point in time bilaterally varying iceberg trade frictions are consistently aggregated into productivity shifters in the form of national multilateral resistances. Over time, the log-linear utility and log-linear capital transition function setup of Lucas and Prescott (1971) applied here yields a closed-form solution for optimal accumulation by infinitely lived representative agents with perfect foresight.

The closed-form solution for accumulation is the bridge to structural estimation of an econometric system of growth and trade. The estimated model allows quantification of the causal effect of openness on income and growth. It also provides all the key structural parameters needed to simulate counterfactuals with the model.<sup>5</sup> We implement the dynamic structural gravity model on a sample of 82 countries over the period 1990–2011. First, we translate the model into a structural econometric system that offers a theoretical foundation to and expands the famous reduced-form specification of Frankel and Romer (1999). In addition, we complement Frankel and Romer (1999) and a series of other studies by proposing a novel instrument derived from structural gravity to identify the effects of trade openness on income.<sup>6</sup> We identify a significant causal effect of trade on income. Importantly, we complement the trade-and-income system of Frankel and Romer with a structural equation that captures the effects of trade openness on capital accumulation. The estimation of our structural system yields estimates of all but one of the model parameters.

A counterfactual experiment quantifies the relationships between growth and trade based

---

for an extension of the static structural gravity framework with labor mobility the recent contribution by Caliendo et al. (2017) and for a gravity framework with knowledge transfers Keller and Yeaple (2013).

<sup>5</sup>The internal consistency of parameter estimates with the data basis of counterfactual exercises is a key advantage of our approach: we test for the hypothesized link's significance and use reasonably precise point estimates to quantify the links in simulations. Our system delivers estimates of the trade elasticity, of the capital (labor) share in production, of the capital stock transition parameter, and of bilateral trade costs. The estimates are all comparable to corresponding values from the literature.

<sup>6</sup>Other studies that propose alternative instruments for trade openness in Frankel-Romer settings include Redding and Venables (2004), Lin and Sim (2013), Felbermayr and Gröschl (2013), and Feyrer (2019).

on the newly constructed trade costs combined with data on the rest of the variables in our model.<sup>7</sup> We find that the average welfare for the North American Free Trade Agreement (NAFTA) members increases from 1.17% to 2.15%, implying a *dynamic path multiplier* of around 1.8 for all member countries despite the big differences in size, in contrast to the static gains that are larger in smaller economies.<sup>8</sup>

Our work is related to several prominent strands of the literature. First, we add dynamics to the family of new quantitative static trade models, such as Eaton and Kortum (2002) and Anderson and van Wincoop (2003) (as summarized in Costinot and Rodríguez-Clare, 2014). In doing so, we extend an earlier literature (e.g., Solow, 1956; Acemoglu and Ventura, 2002; Alvarez, 2017), and we complement some new influential papers (e.g., Sampson, 2016; Eaton et al., 2016) that study the dynamics of trade. These studies calibrate their models in arguably more complex environments. In contrast, we deliver a structural econometric system that allows us to test and establish causal relationships between trade, income, and growth and delivers the key parameters for our counterfactual analysis.

The literature has suggested two prominent ways to make spatial dynamic models tractable. First, Krusell and Smith, Jr. (1998) show that in stochastic, macroeconomic models with heterogeneity features, aggregate variables (e.g., capital stock) can be approximated very well as a function of the mean of the wealth distribution and an aggregate productivity shock. Second, Desmet and Rossi-Hansberg (2014) deliver a tractable, stochastic dynamic framework, where the firm's dynamic decision to innovate reduces to a sequence of static profit-maximization problems, by imposing structure that disciplines the mobility of labor, land-ownership by the firm, and the diffusion of technology. The tractability of our deterministic framework comes from gravity structure that consistently aggregates bilateral trade frictions for each country into multilateral resistance exact indexes, reducing the  $N \times N \times T$

---

<sup>7</sup>To compare dynamic gains from liberalization with a static alternative, we follow Lucas (1987) to calculate the constant fraction of aggregate consumption in each year that consumers would need to be paid in the baseline case to give them the same utility they obtain from the consumption stream in the counterfactual.

<sup>8</sup>As our model does not feature steady-state growth, after full adjustment, i.e., when reaching the new steady-state, there are no additional growth effects from NAFTA.

trade links into  $2N \times T$  multilateral resistance terms, with  $N$  denoting the number of countries and  $T$  the number of years.

We view the simplicity, tractability, ability to test for key causal relationships and to estimate all structural parameters within the same model as important advantages of our dynamic structural estimating gravity framework. These benefits come at the cost of some important abstractions. In robustness analysis, we devoted significant effort to accommodate and discuss the implications of a series of potential improvements and generalizations that have been proposed in the related literature, e.g., alternative specifications for capital accumulation; allowing for intermediate goods; deriving the model with an iso-elastic utility function; solving our dynamic system in changes; and checking the robustness of our results to alternative values for all structural parameters.<sup>9</sup>

Other difficult but important extensions include the development of a dynamic multi-sector framework (with non-traded goods) in the spirit of Costinot et al. (2012); allowing for international lending or borrowing, following Eaton et al. (2016); modeling frictional labor markets, e.g., Caliendo et al. (2019); allowing for endogenous technological change and spillovers *à la* Eaton and Kortum (2005); and modeling stochastics following the macroeconomic literature. Extending our framework to accommodate these forces while preserving the closed-form solution for accumulation may be challenging but feasible because either relaxation implies a contemporaneous allocation of investment across sectors and/or countries with an equilibrium that can nest in the intertemporal allocation of the dynamic model. We leave these theoretical extensions for future research, while we pay close attention to properly control for the possible presence of such forces in our econometric analysis.

## 1 Theoretical Foundation

Goods are differentiated by place of origin and each of the  $N$  countries in the world specializes in production of a single good  $j$ . Total nominal output in country  $j$  at time  $t$  ( $Y_{j,t}$ ) is produced

---

<sup>9</sup>We refer the reader to the extended working paper version Anderson et al. (2015) for robustness analysis.

subject to the following constant returns to scale (CRS) Cobb-Douglas production function:

$$Y_{j,t} = p_{j,t} A_{j,t} L_{j,t}^{1-\alpha} K_{j,t}^\alpha \quad \alpha \in (0, 1), \quad (1)$$

where  $p_{j,t}$  denotes the factory-gate price of good (country)  $j$  at time  $t$  and  $A_{j,t}$  denotes technology in country  $j$  at time  $t$ .<sup>10</sup>  $L_{j,t}$  is the inelastically supplied amount of labor in country  $j$  at time  $t$  and  $K_{j,t}$  is the stock of capital in  $j$  at  $t$ . Capital and labor are country-specific (internationally immobile), and capital accumulates according to:

$$K_{j,t+1} = \Omega_{j,t}^\delta K_{j,t}^{1-\delta}, \quad (2)$$

where  $\Omega_{j,t}$  denotes the flow of investment in  $j$  at time  $t$  and  $\delta \in (0, 1]$  is the *capital stock transition parameter*.<sup>11</sup> Transition function (2) combines depreciation of old capital with costs of adjustment in embodying investment into new capital.

Representative agents in each country work, invest and consume. Consumer preferences are identical and represented by a logarithmic utility function with a subjective discount factor  $\beta \in (0, 1)$ . At every point in time consumers in country  $j$  choose aggregate consumption ( $C_{j,t}$ ) and aggregate investment ( $\Omega_{j,t}$ ) to maximize the present discounted value of lifetime utility subject to a sequence of constraints for given initial level of capital  $K_{j,0}$ :

$$\max_{\{C_{j,t}, \Omega_{j,t}\}} \sum_{t=0}^{\infty} \beta^t \ln(C_{j,t}) \quad (3)$$

$$K_{j,t+1} = \Omega_{j,t}^\delta K_{j,t}^{1-\delta}, \quad \forall t \quad (4)$$

$$Y_{j,t} = p_{j,t} A_{j,t} L_{j,t}^{1-\alpha} K_{j,t}^\alpha, \quad \forall t \quad (5)$$

$$E_{j,t} = P_{j,t} C_{j,t} + P_{j,t} \Omega_{j,t}, \quad \forall t \quad (6)$$

$$E_{j,t} = \phi_{j,t} Y_{j,t}. \quad \forall t \quad (7)$$

---

<sup>10</sup>We formulate our model in terms of nominal output rather than in quantities following the convention in the trade literature and because we use nominal values rather than quantities in the empirical implementation.

<sup>11</sup>This term is apt, but there appears to be no standard term for  $\delta$  in the literature. We prefer the log-linear capital accumulation function over the more standard linear function for our main analysis. The benefits are: (i) a tractable closed-form solution of our model; (ii) a self-sufficient structural system that can be estimated; and (iii) a system with an exact analytical solution that is suitable for counterfactual analysis of major trade policy changes, e.g., the formation of NAFTA, which may be captured with a large error if the analysis were performed with a log-linear approximation. In robustness analysis (please see Anderson et al., 2015), we re-derive our model with a linear capital accumulation function. Even though this function no longer allows for a closed-form solution and requires the use of external parameters, we do find qualitatively identical and quantitatively similar results in our simulation of the impact of NAFTA.

Equations (4) and (5) define the law of motion for the capital stock and the value of production, respectively. The budget constraint (6) states that aggregate spending in country  $j$ ,  $E_{j,t}$ , has to equal the sum of spending on both consumption and investment goods. Equation (7) relates aggregate spending to the value of production by allowing for exogenous trade imbalances, expressed as a factor of the value of production  $\phi_{j,t} > 0$ . Aggregate consumption and investment are both comprised by domestic and foreign goods,  $c_{ij,t}$  and  $I_{ij,t}$ :

$$C_{j,t} = \left( \sum_i \gamma_i^{\frac{1-\sigma}{\sigma}} c_{ij,t}^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}, \quad (8)$$

$$\Omega_{j,t} = \left( \sum_i \gamma_i^{\frac{1-\sigma}{\sigma}} I_{ij,t}^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}. \quad (9)$$

Equation (8) defines the consumption aggregate ( $C_{j,t}$ ) as a function of consumption from each region  $i$  ( $c_{ij,t}$ ), where  $\gamma_i$  is a positive distribution parameter, and  $\sigma > 1$  is the elasticity of substitution across goods varieties from different countries. Equation (9) presents a CES investment aggregator ( $\Omega_{j,t}$ ) that describes investment in each country  $j$  as a function of domestic components ( $I_{jj,t}$ ) and imported components from all other regions  $i \neq j$  ( $I_{ij,t}$ ).<sup>12</sup> Finally, let  $p_{ij,t} = p_{i,t} t_{ij,t}$  denote the price of country  $i$  goods for country  $j$  consumers, where  $t_{ij,t}$  is the variable bilateral trade cost factor on shipment of commodities from  $i$  to  $j$  at time  $t$ . Trade costs can be interpreted by the standard iceberg melting metaphor; it is as if goods melt away so that 1 unit shipped becomes  $1/t_{ij,t} < 1$  units on arrival.

System (3)-(7) decomposes into a nested two-level optimization problem. The ‘lower level’ problem obtains the optimal demand of  $c_{ij,t}$  and  $I_{ij,t}$ , for given  $C_{j,t}$ ,  $\Omega_{j,t}$ , and  $Y_{j,t}$ . The ‘upper level’ dynamic optimization problem solves for the optimal sequence of  $C_{j,t}$  and  $\Omega_{j,t}$ . The combination of the solutions to the lower and to the upper levels delivers our theoretical model of growth and trade:

---

<sup>12</sup>The assumption that consumption and investment goods are both a combination of all world varieties subject to the same CES aggregation is very convenient analytically. In addition, it is also consistent with our aggregate approach in this paper. Allowing for heterogeneity in preferences and prices between and within consumption and investment goods will open additional channels for the interaction between trade and growth which require sectoral treatment. This is beyond the scope of this paper, and we refer the reader to Osang and Turnovsky (2000), Mutreja et al. (2018), and Eaton et al. (2016) for efforts in that direction.

$$X_{ij,t} = \frac{Y_{i,t}\phi_{j,t}Y_{j,t}}{Y_t} \left( \frac{t_{ij,t}}{\Pi_{i,t}P_{j,t}} \right)^{1-\sigma}, \quad (10)$$

$$P_{j,t} = \left[ \sum_i \left( \frac{t_{ij,t}}{\Pi_{i,t}} \right)^{1-\sigma} \frac{Y_{i,t}}{Y_t} \right]^{\frac{1}{1-\sigma}}, \quad (11)$$

$$\Pi_{i,t} = \left[ \sum_j \left( \frac{t_{ij,t}}{P_{j,t}} \right)^{1-\sigma} \frac{\phi_{j,t}Y_{j,t}}{Y_t} \right]^{\frac{1}{1-\sigma}}, \quad (12)$$

$$p_{j,t} = \frac{(Y_{j,t}/Y_t)^{\frac{1}{1-\sigma}}}{\gamma_j \Pi_{j,t}}, \quad (13)$$

$$Y_{j,t} = p_{j,t} A_{j,t} L_{j,t}^{1-\alpha} K_{j,t}^\alpha, \quad (14)$$

$$K_{j,t+1} = \left[ \frac{\alpha \beta \delta \phi_{j,t} p_{j,t} A_{j,t} L_{j,t}^{1-\alpha}}{(1 - \beta + \beta \delta) P_{j,t}} \right]^\delta K_{j,t}^{\alpha \delta + 1 - \delta}. \quad (15)$$

Equations (10)-(13) are standard in the trade literature as they represent the structural gravity system of Anderson and van Wincoop (2003). Equation (10) intuitively links bilateral exports to market size (the first term on the right-hand side) and trade frictions (the second term on the right-hand side). The numerator of the trade cost term includes bilateral trade frictions ( $t_{ij,t}$ ), which we model explicitly below.  $P_{j,t}$  and  $\Pi_{i,t}$  defined in Equations (11)-(12) are the multilateral resistance terms (MRs, inward and outward, respectively). They are consistent aggregates of bilateral trade costs for each country and are interpreted as buyers' and sellers' incidence of the global system of trade costs respectively (Anderson and Yotov, 2010). The multilateral resistances are key to our analysis because they represent the endogenous structural link between the lower level trade analysis and the upper level production and growth equilibrium. The MRs translate changes in bilateral trade costs at the lower level into changes in factory-gate prices, which stimulate or discourage investment and growth at the upper level. At the same time, by changing output shares in the multilateral resistances, capital accumulation and growth alter the incidence of trade costs in the world.

The link between trade and national income (through the multilateral resistances) is channeled through Equations (13) and (14). Equation (13) is a restatement of the market-

clearing condition ( $Y_{i,t} = \sum_j X_{ij,t}$ ), and it unveils an inverse relationship between the outward multilateral resistance, which captures the incidence of trade costs on the producers in  $j$ , and the factory-gate price in  $j$ . The intuition for this result is that when a country opens to trade, producers in this country enjoy lower outward MRs, which, according to Equation (13), translates into higher factory-gate prices. Similarly, producers in outside countries that have been left out of integration will suffer increases in their outward MRs that lead to lower factory gate-prices. The changes in factory-gate prices translate into changes in nominal income via Equation (14), which defines the value of production in country  $j$ .

Most novel and important, Equation (15) is the analytical solution for the policy function of capital. The closed form is possible due to our assumptions of logarithmic utility and log-linear adjustment costs Heer and Maußner (2009, chapter 1). Policy function (15) is consistent with infinitely forward looking agents despite the appearance of one period ahead prices only. This is due to the log-linear functional form of both preferences and capital accumulation, implying that marginal rates of substitution are proportional to the ratio of present to one-period-ahead consumption or capital stocks.<sup>13</sup>

As expected, (15) depicts the direct relationship between capital stock in period  $t + 1$  and the levels of technology  $A_{j,t}$ , labor endowment  $L_{j,t}$ , and current capital stock  $K_{j,t}$ . More important for our purposes, (15) suggests a direct relationship between capital accumulation and the prices of domestically produced goods ( $p_{j,t}$ ), and an inverse relationship between capital accumulation and the aggregate consumer price index ( $P_{j,t}$ ).<sup>14</sup> Thus, due to the direct mapping between domestic factory-gate prices and the outward MRs and due to the dual theoretical interpretation of the aggregate consumer prices as inward MRs, Equation

---

<sup>13</sup>We confirm that our results are replicated by the standard dynamic solution method using Dynare Adjemian et al. (2011). Thus, we solve our model in two completely different ways leading to exactly the same results: i) we use our analytically derived policy function and solve the transition by starting from the baseline steady state and solving for subsequent periods until convergence to the counterfactual steady state. ii) we use the first-order conditions and solve our non-linear equation system using Dynare. We also use Dynare to solve our model when we employ the linear capital accumulation function as a robustness check.

<sup>14</sup>The price of domestic goods enters the aggregate price index and, via this channel, it has a negative effect on capital accumulation. However, as long as country  $j$  consumes at least some foreign goods, this negative effect will be dominated by the direct positive effect of domestic prices on capital accumulation.

(15) structurally links capital accumulation to trade openness via the multilateral resistances.

The intuition behind the positive relationship between the prices of domestic goods and capital accumulation is that, all else equal, when faced with higher returns to investment given by the value marginal product of capital, agents invest more. Extending this relationship to trade, lower outward MRs will result in higher factory-gate prices, which increase accumulation because they imply higher returns to investment. The intuition behind the negative relationship between capital accumulation and aggregate consumer prices is that an increase in  $P_{j,t}$  means that consumption as well as investment become more expensive, i.e., the opportunity costs and the direct costs of investment are higher. This reduces the incentive to build up capital. Importantly, due to the general equilibrium nature of the multilateral resistances, changes in trade costs or trade volumes between any two trading partners potentially affect producer prices and consumer prices in any nation in the world.

The relationship between trade and welfare differs from the familiar static gains from trade due to the dynamic capital-accumulation framework. (i) Transition between steady states is not immediate due to the gradual adjustment of capital stocks. Given our upper level equilibrium, we are able to solve the transition path for capital accumulation simultaneously in each of the  $N$ -countries in our sample. (ii) Consumers in our setting divide their income between consumption and investment. Thus, only part of GDP is used to derive utility. In order to account for these features of our model, we follow Lucas (1987) and calculate the constant fraction  $\zeta$  of aggregate baseline consumption in each year ( $C_{j,t}^b$ ) that consumers would need to be paid in the baseline case to give them the same utility they obtain from the consumption stream in the counterfactual ( $C_{j,t}^c$ ). Specifically, we calculate:

$$\sum_{t=0}^{\infty} \beta^t \ln(C_{j,t}^c) = \sum_{t=0}^{\infty} \beta^t \ln \left[ \left( 1 + \frac{\zeta}{100} \right) C_{j,t}^b \right] \Rightarrow \\ \zeta = \left( \exp \left[ (1 - \beta) \left( \sum_{t=0}^{\infty} \beta^t \ln(C_{j,t}^c) - \sum_{t=0}^{\infty} \beta^t \ln(C_{j,t}^b) \right) \right] - 1 \right) \times 100. \quad (16)$$

In a recent influential paper, ACR demonstrate that the welfare effects of trade liberal-

ization in a wide range of static trade models can be summarized by the following sufficient statistics:  $\widehat{W}_j = \widehat{\lambda}_{jj}^{\frac{1}{1-\sigma}}$ , where  $\lambda_{jj}$  denotes the share of domestic expenditure and “hat” denotes the ratio of the counterfactual and baseline value. We extend ACR to our transition dynamic model in a formula to capture how the change in capital can directly affect welfare:

$$\widehat{W}_j = \widehat{K}_j^\alpha \widehat{\lambda}_{jj}^{\frac{1}{1-\sigma}}. \quad (17)$$

Equation (17), which holds in and out-of steady state, implies that an increase of steady-state capital will, ceteris paribus, increase welfare. Furthermore, we can express  $\widehat{K}_j$  in terms of  $\widehat{\lambda}_{jj}$  in steady state, leading to  $\widehat{W}_j = \widehat{\lambda}_{jj}^{\frac{1}{(1-\alpha)(1-\sigma)}}$ . This expression nicely highlights the similarity of introducing capital or intermediates in the steady state (compare with ACR, p. 115). In steady-state, the new level of capital stocks can be equally thought of as different amounts of intermediate goods in production. However, intermediate goods are not able to explain dynamic adjustments to trade liberalization, as highlighted by Baier et al. (2014) and Anderson and Yotov (2016), and which is at the heart of our structural, dynamic model.<sup>15</sup>

## 2 From Theory to Empirics

System (10)-(15) readily lends itself to calibration. However, our model can also be implemented econometrically, which offers a unique opportunity to capitalize on the advantages of the estimation approach while making some contributions to the literature. Specifically, we will test and establish causal relationships between trade, income, and growth, and we will obtain all key parameters needed to perform counterfactuals. To achieve these goals, we start by translating our theoretical model into the following econometric system:

$$Trade : \quad X_{ij,t} = \exp[GRAV_{ij,t}\gamma + \beta NAFTA_{ij,t} + \mu_{ij,t} + \chi_{i,t} + \pi_{j,t}] + \epsilon_{ij,t}, \quad (18)$$

$$Income : \quad \ln Y_{j,t} = \kappa_1 \ln L_{j,t} + \kappa_2 \ln K_{j,t} + \kappa_3 \ln (\Pi_{j,t}^{\sigma-1}) + \nu_t + \vartheta_j + \varepsilon_{j,t}, \quad (19)$$

$$Capital : \quad \ln K_{j,t} = \psi_1 \ln E_{j,t-1} + \psi_2 \ln K_{j,t-1} + \psi_3 \ln (P_{j,t-1}^{\sigma-1}) + \nu_t + \vartheta_j + \varsigma_{j,t}. \quad (20)$$

---

<sup>15</sup>Besides the derivations of the just-described extended ACR formula, we also derive an ACR-like welfare formula, which only depends on  $\widehat{\lambda}_{jj,t}$  and parameters when taking into account the transition. However, we will typically not observe changes in  $\lambda_{jj,t}$  over time solely driven by the counterfactual under consideration. Please see Anderson et al. (2015) for details.

The following three subsections offer further details on the three estimating equations. The presentation in each subsection follows the same structure. First, we describe how the estimating equation was obtained from our theoretical model. Second, we summarize the objectives of estimating each equation, and what structural parameters will be obtained from it. Third, we discuss the identification challenges and we describe the solutions that we employ in order to obtain sound econometric estimates.

## 2.1 Trade: Estimating Structural Gravity

Equation (18) is the econometric version of gravity equation (10), and its purpose is three-fold. First, comparison of the gravity estimates that we obtain from Equation (18) with corresponding estimates from the voluminous existing literature will establish the representativeness of our sample and our estimation methods. Second, Equation (18) will deliver estimates of bilateral trade costs  $t_{ij,t}^{1-\sigma}$ . Third, Equation (18) will also deliver estimates for the impact of NAFTA, which will be used to obtain the results in our counterfactual experiment.

Our theory does not have implications for structural gravity estimations because, as will become clear shortly, the dynamic forces in our model will be controlled fully by the country-time fixed effects. Nevertheless, in order to obtain sound estimates of bilateral trade costs and of the key NAFTA effects, we implement the latest developments in the related literature. Specifically, first, we follow Santos Silva and Tenreyro (2006) in the use of the Poisson Pseudo-Maximum-Likelihood (PPML) estimator to account for the presence of heteroskedasticity and zeros in trade data. Second, we use time-varying directional (i.e., exporter-time and importer-time) fixed effects ( $\chi_{i,t}$  and  $\pi_{j,t}$ , respectively) to account for the unobservable multilateral resistances. These fixed effects also will absorb national output and expenditure and, therefore, they will control for all dynamic forces from our theory.

Third, we employ a flexible country-pair fixed effects approach to control for all (observable and unobservable) time-invariant bilateral trade costs in the vector  $t_{ij,t}$ . As demonstrated by Baier and Bergstrand (2007), the use of pair fixed effects is an effective method to address endogeneity of regional trade agreements (RTAs), which, as described below, also

enter our econometric model. In addition to the pair fixed effects, we also allow for linear trends in bilateral trade costs. In combination, the pair fixed effects and the linear bilateral trends are captured by vector  $\mu_{ij,t}$  in Equation (18).

Fourth, we include a series of additional time-varying bilateral covariates, which are captured by vector  $GRAV_{ij,t}$  in specification (18). Specifically,  $RTA_{ij,t}$  is a dummy variable equal to 1 when  $i$  and  $j$  have a RTA in place at time  $t$ , and zero elsewhere. Following Baier and Bergstrand (2007) and Anderson and Yotov (2016), we allow for non-linear phasing-in effects of RTAs by introducing 3-, 6-, and 9-year RTA lags.  $WTO_{ij,t}$  and  $EU_{ij,t}$  are dummy variables equal to 1 when  $i$  and  $j$  are both members of WTO and EU, respectively, at time  $t$ , and zero elsewhere. Following Bergstrand et al. (2015), we include a series of time-varying bilateral border dummies,  $\sum_t BRDR_{ij,t}$ , which control for common globalization forces.

Finally, in addition to controlling for the presence of all other RTAs, we use  $NAFTA_{ij,t}$  to explicitly isolate the impact of NAFTA. The motivation for this modeling choice is twofold. First, we will use the estimate of NAFTA, as one of the most widely studied free trade agreement,<sup>16</sup> to perform counterfactual analysis. Second, as demonstrated by Baier et al. (2019), the impact of trade liberalization varies significantly across RTAs. Thus, since NAFTA is a deep RTA, we expect that its impact will be larger as compared to the average effects of other agreements. Baier et al. (2019) also demonstrate that the effects of RTAs vary within agreements and across pairs too. However, we choose to abstract from modeling pair-specific NAFTA effects and we do not allow for phasing-in effects of NAFTA in order to clearly isolate the pure dynamic effects of a single one-time trade shock, i.e., the introduction of NAFTA, which will enable us to focus on and emphasize our methodological contributions.<sup>17</sup>

The rich fixed effects structure of specification (18) (including bilateral fixed effects,

---

<sup>16</sup>For recent examples, see Romalis (2007), Caliendo and Parro (2015), and Anderson and Yotov (2016).

<sup>17</sup>In principle, we may also introduce tariffs in the estimating equation. However, bringing tariff revenues fully into the model opens Pandora's Box, because much of their distortionary effect (and much of the difficulty of negotiating regional trade agreements) is due to dispersion of rates across sectors within countries. Moreover, a proper treatment of effects of trade agreements via government revenue should in principle include effects on *domestic* distortionary tax collections, effects likely to be much larger (because tax rates are higher) than those from trade tax revenues. We refer the reader to Anderson and van Wincoop (2001) and to Egger et al. (2011) for modeling and empirical investigation of the role of tariffs in gravity models.

bilateral trends, time-varying bilateral borders, exporter-time fixed effects, and importer-time fixed effects) supports the assumption of a stochastic error term,  $\epsilon_{ij,t}$ . However, it is still possible that  $\epsilon_{ij,t}$  carries some systematic trade cost information. Anderson et al. (2018) propose a hybrid approach, which uses a model similar to (18) to estimate the effects of trade policy, and then adds the error to the trade cost function in order to match the trade flows data perfectly. In the empirical analysis, we show that our estimated trade costs are very close to the trade costs that match the data perfectly. This gives us confidence to proceed with our analysis while treating  $\epsilon_{ij,t}$  as a stochastic error term.

## 2.2 Income: A Structural Foundation for Frankel and Romer (1999)

Equation (19) is obtained by substituting Equation (13) for prices into Equation (14), then solving the resulting equation for  $Y_{j,t}$  and expressing it in logarithmic form. The objective of estimating Equation (19) is twofold. First, it offers a theoretical foundation for the famous reduced-form equation of Frankel and Romer (1999) and, therefore, it will enable us to test for a causal relationship between trade openness and income. Second, capitalizing on the structural nature of our approach, (19) also obtains estimates of the trade elasticity as well as of the labor and capital shares in production. These parameters can be recovered from the estimates of the coefficients in Equation (19) subject to the following structural relationships:

$$\hat{\sigma} = -1/\hat{\kappa}_3, \hat{\alpha} = \hat{\kappa}_2/(1 + \hat{\kappa}_3), \text{ and } \kappa_1 + \kappa_2 = 1 + \kappa_3.$$

We address several important econometric challenges in order to obtain sound estimates from Equation (19). First, we do not observe  $A_{j,t}$  and  $\gamma_j$ . To account for the latter, we introduce country-specific fixed effects  $\vartheta_j$ , which also will absorb any time-invariant country differences in technology  $A_{j,t}$ . To control for time-varying effects that affect technology globally, we also introduce time fixed effects  $\nu_t$ . The year fixed effects will absorb the structural world output term,  $\frac{1}{\sigma} \ln Y_t$ , and also will control for any other common time-varying variables that may affect output.<sup>18</sup>

---

<sup>18</sup>We are aware of estimations of productivity with firm-level data, cf. Olley and Pakes (1996) and Levinsohn and Petrin (2003). The aggregate nature of our study does not allow us to implement those approaches. The plausible estimates of the production function parameters that we obtain in the empirical analysis are encouraging evidence that our treatment of technology with controls and fixed effects is effective. We are

The next challenge to estimating Equation (19) is that our measure of trade openness,  $\ln(\Pi_{j,t}^{\sigma-1})$ , is endogenous by construction, because it includes own national income.<sup>19</sup> The issue is similar to the endogeneity concern in Frankel and Romer (1999), but we complement their work in two ways. First, our theory delivers a structural trade-openness term that replaces the reduced-form trade variable from Frankel and Romer (1999) and enables us to recover an estimate for the elasticity of substitution  $\hat{\sigma} = -1/\hat{\kappa}_3$ . Second, we propose a new, structural instrument for trade openness by capitalizing on our theory to eliminate the endogeneity resulting from own GDP. Specifically, we calculate the multilateral resistances based on international trade linkages only, i.e., without the endogenous intra-national components that include national income:<sup>20</sup>

$$\tilde{\Pi}_{i,t}^{1-\sigma} = \sum_{j \neq i} \left( \frac{t_{ij,t}}{P_{j,t}} \right)^{1-\sigma} \frac{Y_{j,t}}{Y_t}. \quad (21)$$

Despite removing the endogeneity of own GDP,  $\tilde{\Pi}_{i,t}^{1-\sigma}$  may still be subject to higher-order endogeneity due to the indirect relationship between own national income and (i) the national incomes of all other countries and (ii) the inward multilateral resistances of all other countries. To address this concern, we use population shares for the first year of our sample as weights in the multilateral resistance system (21). In effect, we replace  $Y_{j,t}$  with  $L_{j,1990}$ , where the latter denotes the population in country  $j$  in 1990.<sup>21</sup> In addition to our new instrument, following the recommendations of Feyrer (2019), we also construct an instrument that is based on gravity estimates of bilateral trade costs and population but without using exporter and importer fixed effects because the directional fixed effects will

---

also aware of the productivity measures from Feenstra et al. (2015). However, since these indexes are constructed as residuals from income/production regressions, we cannot include them directly in our income equation. Therefore, we only rely on longer lags of the productivity estimates from Feenstra et al. (2015) as instruments in our regressions.

<sup>19</sup>We keep the expression for the outward multilateral resistance as a power transform,  $\Pi_{j,t}^{\sigma-1}$ , because we can recover this power term directly from the exporter-fixed effects from the lower level trade gravity estimation procedures without the need to assume any value for the elasticity of substitution  $\sigma$ .

<sup>20</sup>This procedure is akin to the methods from Anderson et al. (2014), who use  $\tilde{\Pi}_{i,t}^{1-\sigma}$  to calculate Constructed Foreign Bias, defined as the ratio of predicted to hypothetical frictionless foreign trade.

<sup>21</sup>Thus, the equations for the multilateral resistances become  $\tilde{\Pi}_{i,t}^{1-\sigma} = \sum_{j \neq i} \left( \frac{t_{ij,t}}{P_{j,t}} \right)^{1-\sigma} \frac{L_{j,1990}}{L_{1990}}$ . We thank an anonymous referee for suggesting improvements to our initial instrument.

contaminate the IV estimation since they implicitly account for income and expenditure.

The final challenge with the estimation of Equation (19) is that labor and capital are potentially endogenous as well. To address this concern we employ an IV strategy with the following instruments. We use 2-period lagged capital stocks and occurrence of natural disasters to instrument for current capital stock. To this set of instruments we add the log of population to instrument for labor as well as 4-period lagged TFP measure, which comes from the Penn World Tables. We offer further details on the instruments and their performance in Section 3.

### 2.3 Capital: On the Impact of Trade on Transitional Growth

Equation (20) captures the effects of trade (liberalization) on capital accumulation, and estimating it will deliver three outcomes: (i) it will enable us to test for a causal relationship between trade openness and transitional growth; (ii) it will deliver an estimate of the elasticity of substitution; and (iii) it will deliver estimates of the capital depreciation rates. Equation (20) is obtained by multiplying and dividing the term in the square brackets of Equation (15) by  $K_{j,t}^\alpha$  in order to define expenditure  $E_{j,t}$  in the numerator, then log-linearizing the resulting equation. (20) imposes the following structural relationships:  $\psi_1 = \delta$  captures the positive relationship between investment and the value of marginal product of capital;  $\psi_2 = 1 - \delta$  captures the dependence of current on past capital stock; finally,  $\psi_3 = -\delta/(\sigma - 1)$  captures the intuitive inverse relationship between capital accumulation and the inward multilateral resistances. Thus, to the extent that the inward multilateral resistance is a general equilibrium trade cost index, a significant estimate of  $\psi_3$  will support a causal relationship of trade on capital accumulation. Finally, our model implies that  $\psi_1 = 1 - \psi_2$ .

Several econometric challenges must be met to estimate Equation (20). Equation (20) describes a dynamic process where capital stock in the current period is a function of capital stock in past periods, i.e., the dependent variable is determined by its past realizations. As discussed in detail in Roodman (2009), this gives rise to *dynamic panel bias* since the dependent variable is clearly correlated with country-specific effects in the error term. A

straightforward approach to mitigate the dynamic panel bias is to explicitly control for the country fixed effects ( $\vartheta_j$ ) in our panel with the Least Squares Dummy Variables (LSDV) estimator. The country fixed effects also will control for any time-invariant country-specific characteristics that may affect capital accumulation but are omitted from our model, thus further alleviating endogeneity concerns. In addition to the country fixed effects, we add to Equation (20) year fixed effects ( $\nu_t$ ) to control for any unobserved and omitted time-varying global effects that may affect capital accumulation. We also experiment with the dynamic panel-data estimator proposed by Arellano and Bond (1991). Since the expenditure and trade openness regressors in (20) are also functions of capital, we treat those covariates as endogenous as well. As result, our set of instruments includes the 3-period lags of capital, expenditure and the occurrence of natural disasters as well as the 4-period lag of the structural measure of trade openness and the 1-period lag of our structural openness instrument.

## 2.4 Income: Dynamic Reduced Form Equation

The structural implications of our model of income and capital accumulation are fully exploited by using Equation (15) to substitute for capital in the income equation (14), along with the market clearing condition (13) to substitute for factory-gate prices in (14). The resulting dynamic reduced form income equation is our preferred specification to deliver the parameter estimates for the counterfactuals in Section 4:<sup>22</sup>

$$\ln Y_{j,t} = \kappa_1 \ln L_{j,t} + \kappa_2 \ln E_{j,t-1} + \kappa_3 \ln K_{j,t-1} + \kappa_4 \ln P_{j,t-1}^{\sigma-1} + \kappa_5 \ln \Pi_{j,t}^{\sigma-1} + \nu_t + \vartheta_j + \varepsilon_{j,t}. \quad (22)$$

Here  $\kappa_1 = (1 - \alpha)(\sigma - 1)/\sigma$ ,  $\kappa_2 = \alpha\delta(\sigma - 1)/\sigma$ ,  $\kappa_3 = \alpha(1 - \delta)(\sigma - 1)/\sigma$ ,  $\kappa_4 = -\alpha\delta/\sigma$ , and  $\kappa_5 = -1/\sigma$ . Equation (22) enables us to identify the direct impact of trade on income, via the trade openness term  $\ln \Pi_{j,t}^{\sigma-1}$ , and also the indirect impact of trade on income via capital accumulation, as captured by the structural term  $\ln P_{j,t}^{\sigma-1}$ . Equation (22) simultaneously implies the trade elasticity,  $\hat{\sigma} = -1/\hat{\kappa}_5$ , the capital share,  $\hat{\alpha} = 1 - \hat{\kappa}_1/(1 + \hat{\kappa}_5)$ , and the capital stock transition rate,  $\hat{\delta} = \hat{\kappa}_2/(\hat{\kappa}_2 + \hat{\kappa}_3)$ , subject to the structural constraints  $\hat{\kappa}_2 = (1/\hat{\kappa}_5 + 1)\hat{\kappa}_4$ .

---

<sup>22</sup>We thank an anonymous referee for this good suggestion.

and  $\hat{\kappa}_1 = 1 + \hat{\kappa}_5 - \hat{\kappa}_2 - \hat{\kappa}_3$ . All covariates in (22) are treated as endogenous in estimation. Instruments used are lags of the multilateral resistances, our new structural MR instruments, expenditure, population, occurrence of natural disasters and TFP. To reflect the non-linear nature of capital accumulation, we also employ as instruments the squared and the cubed 2-period lag of capital.

## 2.5 Data

Our sample covers 82 countries, which account for more than 98 percent of world GDP over the period 1990-2011.<sup>23</sup> The data include trade flows, GDP, employment, capital and RTAs. Bilateral trade cost proxies are data on standard gravity variables including distance, common language, contiguity and colonial ties along with regional trade agreements in effect.

Data on GDP, employment, capital stocks, and total factor productivity (TFP) are from the Penn World Tables 8.0.<sup>24</sup> The Penn World Tables 8.0 offer several GDP variables. Following the recommendation of the data developers, we employ *Output-side real GDP at current PPPs (CGDP<sup>o</sup>)*, which compares relative productive capacity across countries at a single point in time, as the initial level in our counterfactual experiments, and we use *Real GDP using national-accounts growth rates (CGDP<sup>na</sup>)* for our output-based cross-country income regressions. The Penn World Tables 8.0 include data that enables us to measure employment in effective units, as the product of *Number of persons engaged in the labor force* and the *Human capital index*, which is based on average years of schooling. Capital stocks (at constant 2005 national prices in mil. 2005USD) in the Penn World Tables 8.0 are constructed based on cumulating and depreciating past investment using the perpetual inventory method. As an instrument we employ TFP levels at current PPPs. In addition, we experiment with an instrument for occurrence of natural disasters, which comes from The International Disaster Database.<sup>25</sup>

Aggregate trade data come from the United Nations Statistical Division (UNSD) Com-

---

<sup>23</sup>The list of countries using their respective labels can be found in Table 2.

<sup>24</sup>For information on the new version of the Penn World Tables 8.0 series see Feenstra et al. (2015).

<sup>25</sup><http://www.emdat.be/database>.

modity Trade Statistics Database (COMTRADE). The trade data in our sample include only 5.8 percent of zeroes due to their aggregate nature. The RTA variables come from Egger and Larch (2008) and are based on information from the World Trade Organization.<sup>26</sup> Finally, data on the standard gravity variables, i.e., distance, common language, colonial ties, etc., are from the CEPII's Distances Database.

### 3 Estimation Results and Analysis

Following the structure of Section 2, this section presents our estimation results.

#### 3.1 Trade

The trade equation estimation results are based on a version of specification (18). The estimates on each of the key covariates are reported in bold in front of each variable. The corresponding standard errors appear in parentheses under the estimates.<sup>27</sup>

$$X_{ij,t} = \exp[0.110 \underset{(0.031)}{RTA}_{ij,t} + 0.084 \underset{(0.026)}{RTA\_LAG3} - 0.008 \underset{(0.027)}{RTA\_LAG6} - 0.012 \underset{(0.025)}{RTA\_LAG9}] \\ \times \exp[0.543 \underset{(0.067)}{NAFTA}_{ij,t} + 0.066 \underset{(0.021)}{WTO}_{ij,t} - 0.035 \underset{(0.044)}{EU}_{ij,t}]. \quad (23)$$

The gravity coefficient estimates are comparable to those in the related literature.<sup>28</sup> For the current effects of RTAs, we report a statistically significant estimate of 0.110 (std.err. 0.031), comparable to that of Baier et al. (2019). We find relatively fast phasing-in effects implied by the positive and significant estimate  $RTA\_LAG3$ . Phasing-in is exhausted within 5 years of RTA entry into force.<sup>29</sup>

Turning to the estimates of the rest of the variables in (23), we obtain a large, positive and highly statistically significant estimate of the impact of NAFTA, (0.543, std.err. 0.067), which implies that, all else equal, NAFTA promoted trade between its members by 72 percent ( $100 \times [\exp(0.543) - 1]$ ), more than the average RTA and consistent with NAFTA's design as

---

<sup>26</sup>A detailed description of the RTA data and the data set itself can be found at Mario Larch's RTA Database website at <http://www.ewf.uni-bayreuth.de/en/re-search/RTA-data/index.html>.

<sup>27</sup>Estimates of the fixed effects and of the border variables are omitted but are available upon request.

<sup>28</sup>See Head and Mayer (2014) for a thorough meta analysis of gravity estimates.

<sup>29</sup>Phasing-in effects faster than in the previous literature may be explained by our use of the PPML estimator, the use of bilateral border dummies, and the use of trends.

a deep agreement. The estimate of the effect of WTO is positive and statistically significant but small in magnitude. The estimate of the impact of EU is not statistically significant; i.e., EU effects on trade are not different from the average RTA effect. The impact of border-time fixed effects (not reported) is consistent with Bergstrand et al. (2015); i.e., the estimates on  $\sum_t BRDR_{ij,t}$  capture the impact of globalization.

The estimated trade equation implies total bilateral trade costs  $\hat{t}_{ij}^{1-\sigma}$ , which will be used in the counterfactual analysis of Section 4. Therefore, we focus on the  $\hat{t}_{ij}^{1-\sigma}$ 's for 2011, which is the baseline year in the counterfactuals (though our conclusions hold for each year in the sample). We are able to obtain bilateral trade costs for all but four pairs of countries in the sample: AGO-IRQ, AGO-TKM, AGO-UZB, and QAT-UZB. Trade costs in levels,  $\hat{t}_{ij}$ , are obtained using a conventional value of the elasticity of substitution  $\hat{\sigma} = 6$ , c.f., Head and Mayer (2014), and they are all greater than one, as suggested by theory.<sup>30</sup> The estimates of  $\hat{t}_{ij}$  vary widely but intuitively across the country pairs. The lowest estimates are for countries that are geographically and culturally close and economically integrated, e.g., Malaysia-Singapore and Belgium-Netherlands, while the largest are for the Ghana-Uzbekistan and Dominican Republic-Turkmenistan. Most other pairs with very large trade costs include former Soviet republics.

For comparison purposes, we also infer an alternative measure of trade costs to match the trade flows data perfectly. The correlation between the estimated and the exact-match trade costs is larger than 0.95 for each year in our sample. Figure 1 illustrates the close fit between the trade costs for Canada, Mexico and US used in the NAFTA counterfactual experiment. The correlations are 0.98, 0.96 and 0.94, respectively. A partial exception to the close fit is Mexico in the last quarter of the sample when estimated trade costs are lower.<sup>31</sup> We use the vector of estimated trade costs for the counterfactual analysis below based on

---

<sup>30</sup>The structural gravity model can only identify relative trade costs and, with the pair-fixed effects in our estimations, we have to impose N (82) normalizations. A natural choice is to set all intra-national trade costs to one ( $t_{ii} = 1, \forall i$ ). Thus, we estimate international trade costs relative to intra-national trade costs.

<sup>31</sup>Investigation of the composition of Mexico's trade partners reveals that the countries in the last quarter of the sample are less developed, and trade with them accounts for only 0.065 percent of Mexico's trade.

(i) the good overall fit between the two sets of trade costs, (ii) the tiny fraction of trade for which estimated trade costs do not closely resemble exact-match counterparts well, and (iii) the fact that trade data with less developed countries are more noisy.

### 3.2 Trade and Income

Estimation results from static income Equation (19) are presented in Panel A of Table 1. The results in column (1) of Table 1 are from an IV estimation that treats all regressors as endogenous and employs the instruments that we described in Section 2. Three findings stand out. First, our instruments pass the ‘underidentification’ test, with Kleibergen-Paap LM statistic  $\chi^2 = 162.40$ , the ‘weak identification’ test, with a Kleibergen-Paap Wald F statistic  $\chi^2 = 82.18$ ,<sup>32</sup> and the ‘overidentification’ test, with a Hansen’s J statistic  $\chi^2 = 1.06$ . Second, all estimates have expected signs and are statistically significant. Third, in the bottom of Table 1, we recover estimates of the elasticity of substitution and of the capital share in production, which are comparable to established values in the literature.<sup>33</sup>

In column (2) of Table 1 we control for endogeneity of all covariates with the same instruments as in column (1) and, in addition, we impose the structural model constraints. As before, the estimates of all coefficients have expected signs, reasonable magnitudes, and are significant at any conventional level. Turning to the estimates of the structural parameters in the bottom of Panel A, we note that the estimate of the trade elasticity is comparable to values from the related trade literature, while the estimate of the capital share is larger than standard values from the literature but still well within the theoretical bounds.<sup>34</sup> In sum,

---

<sup>32</sup>The Kleibergen-Paap Wald test is appropriate when the standard error i.i.d. assumption is not met and the usual Cragg-Donald Wald statistic, along with the corresponding critical values proposed by Stock and Yogo (2005), are no longer valid. This is true in our case, where the standard errors are bootstrapped.

<sup>33</sup>Our estimate of the trade elasticity is comparable to the meta-analysis indexes from Head and Mayer (2014). Our estimate of  $\alpha$  implies an estimate of the labor share of production  $1 - \hat{\alpha} = 0.57$ , which is a bit larger but still comparable to the average labor share of 0.52 obtained by Feenstra et al. (2015).

<sup>34</sup>For a benchmark comparison, we note that our estimate of  $\alpha$  implies an estimate of the labor share of production  $1 - \hat{\alpha} = 0.31$ , which is lower than the labor share of 0.52 from Feenstra et al. (2015). Consistent with our theory, a possible explanation for a potential bias in our estimate of the capital share is that the error term in Equation (19) may contain an accumulation element that affects income. This explanation is in line with the general understanding that income processes are autoregressive. As demonstrated below, our dynamic income Equation (19) addresses this deficiency, at least partially, and delivers a more plausible value for  $\alpha$ , which is readily comparable with the corresponding estimate from Feenstra et al. (2015).

consistent with the reduced-form findings of Frankel and Romer (1999), the structural analysis in this section establishes a causal relationship between trade and income. In addition, our methods deliver estimates for two of the key structural parameters in the model.

### 3.3 Trade and Capital Accumulation

Estimation results from capital accumulation Equation (20) are presented in Panel B of Table 1. In column (3) we treat all covariates as endogenous and we employ an IV estimator with the instruments from Section 2. In column (4) we impose the structural constraints of the model and use the same instruments.

Column (3) reveals that the estimates of all coefficients are statistically significant and have signs as predicted by theory. The instruments pass the IV tests of ‘underidentification’ (Kleibergen-Paap LM  $\chi^2 = 32.243$ ), ‘weak identification’ (Kleibergen-Paap Wald F  $\chi^2 = 6.604$ ), and ‘overidentification’ (Hansen’s J  $\chi^2 = 4.190$ ). The trade elasticity estimate  $\hat{\sigma} = 1.344$  (std.err. 0.319) recovered in the bottom of the table is comparable to values from the international real business cycle (IRBC) literature but on the low end of estimates from the trade literature.<sup>35</sup> Inference of  $\sigma$  from a macroeconomic estimating equation here complements the usual calibration of the trade elasticity in the IRBC literature. Statistical tests reject (by a small margin) the theoretical constraint  $\psi_1 = 1 - \psi_2$ , but the two alternative values of  $\hat{\delta} = \psi_2 = 0.017$  and  $\hat{\delta} = 1 - \psi_1 = 0.047$  that we obtain in column (3) remain plausible in an economic sense. Finally, the constrained-IV estimates in column (4) are similar to the corresponding IV indexes in column (3). As a consequence, they deliver a similar estimate of the trade elasticity  $\hat{\sigma} = 1.831$  and a unique (due to the constraint) estimate of the capital stock transition parameter  $\hat{\delta} = 0.028$ .<sup>36</sup>

---

<sup>35</sup>The elasticity estimates from the trade literature usually vary between 2 and 12. See Eaton and Kortum (2002), Anderson and van Wincoop (2003), Broda et al. (2006). The corresponding indexes from the IRBC literature are usually between 1 and 2. See Backus et al. (1994), Zimmermann (1997), Heathcote and Perri (2002). Ruhl (2008) offers a discussion of the nature of the differences between the trade and the IRBC literature in an attempt to reconcile the estimates from the trade and from the macro side.

<sup>36</sup>This estimate of  $\delta$  is low relative to standard depreciation rate estimates from the literature. A possible explanation could be that capital stocks are constructed with methods that are inherently more prone to measurement error, which may not be orthogonal to the right hand side variables in Equation (20).

### 3.4 Income: Dynamic Reduced Form Equation

The dynamic reduced form income Equation (22) simultaneously identifies the direct and the indirect (via capital accumulation/decumulation) effects of trade on income. Panel C of Table 1 offers results from an IV estimation that uses the instruments described in Section 2, and from a theory constrained IV estimation that employs the same set of instruments.

The main conclusion from the IV regression in column (5) is that the estimates of the coefficients on the key trade terms,  $\ln(\widehat{\Pi}_{j,t-1}^{\sigma-1})$  and  $\ln(\widehat{P}_{j,t-1}^{\sigma-1})$ , are statistically significant and with expected signs. In addition, the instruments pass the IV tests of ‘underidentification’ (Kleibergen-Paap LM  $\chi^2 = 96.068$ ), ‘weak identification’ (Kleibergen-Paap Wald F  $\chi^2 = 11.870$ ), and ‘overidentification’ (Hansen’s J  $\chi^2 = 10.618$ ). The constrained-IV estimation delivers similar results in column (6). All estimates are statistically significant and with expected signs. The structural estimate of the trade elasticity,  $\widehat{\sigma} = 3.502$ , is on the intersection of the values from the related trade and macro literature. The structural estimate of  $\alpha$  implies a labor share of production  $1 - \widehat{\alpha} = 0.46$ , which is close to the average labor share of 0.52 from Feenstra et al. (2015). The estimated  $\widehat{\delta} = 0.141$  is interpreted in our model as a capital stock transition parameter that combines depreciation of old capital with costs of adjustment in embodying investment into new capital. Thus its magnitude unsurprisingly exceeds estimates of the depreciation rate alone in the literature. The reduced form dynamic income equation estimator thus gives plausible values for the three key structural parameters in our model.<sup>37</sup> We use these in our main counterfactual exercise.

## 4 On the Dynamic GE Effects of NAFTA

From a practical perspective, the dynamic general equilibrium (GE) analysis of the effects of NAFTA in this section extends the literature on the static impact of NAFTA<sup>38</sup> by quantifying

---

<sup>37</sup>While the estimates of all structural parameters that we obtain from the dynamic income Equation (22) are within the theoretical bounds and seem plausible to us, we also acknowledge the possibility for potential biases due to our specification of dynamics in a perfect foresight environment. Deviations of the data process from this assumed structure likely leaves some systematic variation outside our model.

<sup>38</sup>Some recent examples are Romalis (2007), Caliendo and Parro (2015), and Anderson and Yotov (2016).

NAFTA's transitional dynamic effects. From a methodological perspective, we want to emphasize the dynamic implications of our approach relative to the standardly used static techniques.

We set the latest year in our sample (i.e., 2011) as a baseline. To describe the world economy in the baseline year, we use observed data on labor endowments ( $L_{j,2011}$ ) and GDPs ( $Y_{j,2011}$ ), and we employ the parameters that we estimated in the previous section, including the vector of trade costs ( $\widehat{t_{ij,2011}^{1-\sigma}}$ ) based on equation (23), and the elasticity of substitution ( $\widehat{\sigma} = 3.5$ ), the capital share ( $\widehat{\alpha} = 0.54$ ), and the capital stock transition parameter ( $\widehat{\delta} = 0.14$ ) from column (6) of Table 1. The only external parameter that we borrow from the literature is the consumers' discount factor ( $\widehat{\beta} = 0.98$ ), which is based on the survey of Yao et al. (2012). With these data and parameters at hand, we construct theory-consistent initial level of capital stock ( $K_{j,2011}$ ), as well as preference-adjusted technology ( $A_{j,2011}/\gamma_j$ ).<sup>39</sup> To simulate the impact of NAFTA, we use our estimate of the partial NAFTA effect ( $\widehat{\gamma}_{NAFTA} = 0.543$ ) to change the trade costs vector, and we calculate the corresponding changes in all endogenous variables, including trade, GDP, capital stock, consumer prices, and producer prices. For brevity and for clarity of exposition, we follow the standard approach in the trade literature and we focus exclusively on the welfare implications of NAFTA. In order to highlight the transitional dynamics contribution of our model, we present three sets of welfare effects, which all appear in Panel A of Table 2.

The estimates in column (1), labeled 'Static', correspond to existing static evaluations of NAFTA, and to obtain them we assume that the stock of capital is exogenous. Without going into details, we note that our static results are in line with findings from previous studies. Specifically, the three members of NAFTA enjoy welfare gains. Canada and Mexico gain more, while the gains for US are significantly smaller in percentage terms.<sup>40</sup> The impact

---

<sup>39</sup>Trade imbalances are consistent with the data and the model. To obtain counterfactual effects uncontaminated by trade imbalances, we first calculate baseline values of all endogenous variables using the data and parameters described above with the fitted model constrained to multilateral trade balance:  $\phi_{j,t} = 1$  for all  $j$  and  $t$  (in the spirit of Dekle et al., 2007; Ossa, 2014). These baseline values are then compared with the counterfactual values from the scenario of interest, where we also assume multilateral trade balance.

<sup>40</sup>The large effect for Canada may seem odd, since the gains from trade between Canada and the US have

of NAFTA on non-member countries is negative and relatively small. These effects are due to the general equilibrium relationships that we described in detail in Section 1. The main impact on non-member countries is due to two GE forces that work in opposite directions. On the one hand, there are GE trade diversion effects that act through the multilateral resistances leading to decreased trade between the NAFTA members and third countries. At the same time, due to the larger size of the NAFTA members, they trade more with all trading partners, including other NAFTA members and non-member countries. The two GE effects work in opposite directions and the negative estimates that we obtain suggest that the negative ‘multilateral resistance’ effect dominates the positive ‘size’ effect. As expected, our results also capture the fact that the net negative impact is stronger for non-member countries that are more integrated with the large US market. Finally, we note that the results in column (1) can be obtained directly with the ACR formula  $\widehat{W}_j = \widehat{\lambda}_{jj}^{\frac{1}{1-\sigma}}$ .

The estimates in column (2) of Table 2 are obtained after allowing for capital accumulation to be endogenous with respect to trade liberalization. Thus, in the new steady state, labeled ‘Dynamic SS’, all capital is fully adjusted to take into account the introduction of NAFTA. Comparison between the static gains from column (1) and the dynamic gains from column (2) reveals that the dynamic effects of NAFTA are significant. Specifically, focusing on the NAFTA countries, we see that the steady state welfare is more than doubled by the dynamic capital accumulation forces in our framework. The negative impact on non-member countries increases as well, but at a lower rate. Trade diversion effects on non-members are magnified, however, they are mitigated by the effects on the size of the NAFTA members. Similar to the static case, the estimates in column (2) can be obtained directly with our augmented dynamic version of the ACR formula  $\widehat{W}_j = \widehat{\lambda}_{jj}^{\frac{1}{(1-\alpha)(1-\sigma)}}$ .<sup>41</sup>

---

already been exploited due to the Canada-US FTA from 1989. This could be captured in our framework with a gravity specification that allows for pair-specific NAFTA effects. However, we chose to use a common estimate of the direct NAFTA effect in order to emphasize the methodological contribution of our framework.

<sup>41</sup>It should be noted, however, since the  $\lambda$  values from the ACR formula are endogenous, they are not identical across columns. Thus, the dynamic estimates in column (2) cannot be obtained directly from their static estimates in column (1) by transforming them to the power of  $1/(1-\alpha)$ . Note, however, that for the NAFTA members it is a good approximation, suggesting an amplification of  $1/(1-\alpha) = 1/(1-0.54) = 2.17$ , but it overstates for most non-member countries (for which effects are small and small general equilibrium

The estimates in column (3) of Table 2 are obtained with the dynamic capital accumulation in place, taking into account the full transition and properly discounting the real GDP changes using the Lucas (1987) formula that we presented in the theory section. We draw three main conclusions based on these estimates. First, the discounted dynamic welfare effects on members are still quite substantial. The welfare estimates for the NAFTA members in column (3) are about 80% larger as compared to the static gains from column (1). Second, the welfare effects in column (3) are smaller than the corresponding welfare changes from column (2). This result emphasizes the importance of proper discounting and proper account for the transitional dynamics in our model. Finally, we note that the additional dynamic gains in column (3) do not vary much across the three NAFTA members. This is in contrast to the static NAFTA gains, which were quite heterogeneous across members. We believe that this is a notable regularity and we label the magnifying effect of the dynamic channel the *dynamic path multiplier*. In the current calibration of the impact of NAFTA the *dynamic path multiplier* takes a value of around 1.8.

To further emphasize the importance of proper discounting and the transitional dynamics in our framework, we plot in Figure 2 the transition path for capital stocks in four countries, the NAFTA members plus Ireland, as the outside country with the strongest negative impact of NAFTA. Figure 2 reveals that the effects on NAFTA members are large and long-lived. The largest gains in capital stock are for Canada, followed by Mexico and then U.S. Most of the dynamic gains accrue initially, and after about 50 years the new steady-state due to the formation of NAFTA is reached. Because it takes time until the new steady-state is reached, proper discounting is required. This, in turn, is the reason why welfare effects in column (3) of Table 2 are smaller as the welfare effects from column (2) of the same table, which were calculated from the steady-state comparison. Turning to the impact on outside countries, represented by Ireland as the country with the largest impact, Figure 2 suggests that the impact on non-member countries is small and relatively short-lived. The impact on capital effects matter more).

accumulation in Ireland is -0.09 percent, with an average impact of -0.02 percent across all outsiders. In addition, according to Figure 2, the negative NAFTA impact on Ireland is exhausted after about 20 years after its implementation.<sup>42</sup>

We conclude this section with three robustness experiments that test the sensitivity of our results with respect to the key structural parameters in the model, namely  $\sigma$ ,  $\alpha$ , and  $\delta$ . Our findings appear in Panel B of Table 2, where we report properly discounted welfare effects with alternative values for the trade elasticity  $\sigma$ , in column (4), the capital share  $\alpha$ , in column (5), and the capital stock transition parameter  $\delta$ , in column (6). In each case, we compare the resulting welfare indexes against our main results from column (3) of Table 2, which are obtained with the estimates of the structural parameters from the constrained-IV specification from column (6) of Table 1, i.e.,  $\sigma = 3.5$ ,  $\alpha = 0.54$ , and  $\delta = 0.14$ .

To obtain robustness results with respect to the trade elasticity, we set  $\sigma = 6$ , which is standard in the trade literature, c.f., Head and Mayer (2014). The estimates from column (4) of Table 2 reveal that a higher  $\sigma$  leads to lower welfare effects for all countries. The reason is that a higher  $\sigma$  implies a lower degree of love-of-variety, mitigating the welfare effects of additional cheaper foreign varieties. To check robustness with respect to the capital share, we follow Acemoglu (2009) to set  $\alpha = 0.3$ . The estimates from column (5) of Table 2 reveal that a lower capital share in production leads to lower welfare gains. This result is intuitive because the dynamic gains in our model are due to capital accumulation, and if capital is less important in production, i.e., when  $\alpha$  is smaller, then the dynamic welfare gains would be smaller as well. Finally, the results in column (6) of Table 2 are obtained by setting the capital stock transition parameter  $\delta = 0.03$ , which is the smallest value based on our own estimates from column (4) of Table 1. Our estimates reveal that, all else equal, a lower depreciation rate implies lower welfare effects. The reason is that lower depreciation rates imply a smaller role for the capital accumulation channel because less foreign goods are

---

<sup>42</sup>In fact, after the initial negative shock on outsiders, we actually observe a slight decrease (in absolute value) of the negative effect on Ireland, resulting from the larger exports of Ireland to the NAFTA member countries due to their increased income.

demanded for capital replacement and consumption due to the lower price. Overall, we view the response of the welfare effects to changes in the structural parameters as intuitive in terms of direction and as plausible in terms of economic magnitude.

## 5 Conclusions

The simplicity of our dynamic structural estimating gravity model derives from severe abstraction: each country produces one good only and there is no international lending or borrowing. Difficult but important extensions of the model entail relaxing each restriction while preserving the closed-form solution for accumulation. This may be feasible because either relaxation implies a contemporaneous allocation of investment across sectors and/or countries with an equilibrium that can nest in the intertemporal allocation of the dynamic model. A multi-good model will bring in the important force of specialization. An international borrowing model will bring in another dynamic channel magnifying differential growth rates. Modeling stochastics will allow for capturing the impact of unexpected short term shocks. Considering foreign direct investments will lead to additional spill-over effects from liberalizing countries to non-liberalizing countries. Allowing for international labor mobility will lead to reallocation of labor across countries and, thereby, change the relative sizes of countries. Allowing for success in the extension can quantify how important these forces are.

Contact Information All Authors: Anderson—Department of Economics, Boston College, and NBER. Chestnut Hill, MA 02467, USA. Phone: 617-552-3691. E-mail: james.anderson@bc.edu; Larch—Department of Law and Economics, University of Bayreuth, CEPII, CESifo, GEP, and ifo Institute. Universitätsstraße 30, 95447 Bayreuth, Germany. Phone: +49 (0) 921 55 6240. E-mail: mario.larch@uni-bayreuth.de; Yotov—School of Economics, LeBow College of Business, Drexel University, CESifo, ifo Institute, and Economic Research Institute, Bulgarian Academy of Sciences, 3200 Market Street, Philadelphia, PA 19104, USA. Phone: (215) 895-2572. Email: yotov@drexel.edu.

## References

- Acemoglu, Daron**, *Introduction to Modern Economic Growth*, Princeton, New Jersey: Princeton University Press, 2009.
- Acemoglu, Daron and Jaume Ventura**, “The World Income Distribution,” *Quarterly Journal of Economics*, 2002, 117 (2), 659–694.
- Adjemian, Stéphane, Houtan Bastani, Michel Juillard, Frédéric Karamé, Junior Maih, Ferhat Mihoubi, George Perendia, Johannes Pfeifer, Marco Ratto, and Sébastien Villemot**, “Dynare: Reference Manual, Version 4,” *Dynare Working Papers*, 1, CEPREMAP, available for download at <http://www.dynare.org/> wp-repo/dynarewp001.pdf, 2011.
- Alvarez, Fernando**, “Capital Accumulation and International Trade,” *Journal of Monetary Economics*, 2017, 91, 1–18.
- Anderson, James E.**, “The Gravity Model,” *Annual Review of Economics*, 2011, 3, 133–160.
- and **Eric van Wincoop**, “Borders, Trade and Welfare,” *Brookings Trade Forum*, 2001, pp. 207–230.
- and —, “Gravity with Gravitas: A Solution to the Border Puzzle,” *American Economic Review*, 2003, 93 (1), 170–192.
- and **Yoto V. Yotov**, “The Changing Incidence of Geography,” *American Economic Review*, 2010, 100 (5), 2157–2186.
- and **Yoto V. Yotov**, “Terms of Trade and Global Efficiency Effects of Free Trade Agreements, 1990–2002,” *Journal of International Economics*, 2016, 99 (C), 279–298.
- , **Catherine A. Milot, and Yoto V. Yotov**, “How Much Does Geography Deflect Services Trade,” *International Economic Review*, 2014, 55 (3), 791–818.
- , **Mario Larch, and Yoto V. Yotov**, “Growth and Trade with Frictions: A Structural Estimation Framework,” *NBER Working Paper No. 21377*, 2015.
- Anderson, James E., Mario Larch, and Yoto V. Yotov**, “GEPPML: General Equilibrium Analysis with PPML,” *The World Economy*, 2018, 41 (10), 2750–2782.
- Arellano, Manuel and Stephen Bond**, “Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations,” *Review of Economic Studies*, 1991, 58 (2), 277–297.
- Arkolakis, Costas, Arnaud Costinot, and Andrés Rodriguez-Clare**, “New Trade Models, Same Old Gains?,” *American Economic Review*, 2012, 102 (1), 94–130.
- Backus, David K., Patrick J. Kehoe, and Finn E. Kydland**, “Dynamics of the Trade Balance and the Terms of Trade: the J-curve,” *American Economic Review*, 1994, 84 (1), 84–103.
- Baier, Scott L. and Jeffrey H. Bergstrand**, “Do Free Trade Agreements Actually Increase Members’ International Trade?,” *Journal of International Economics*, 2007, 71 (1), 72–95.

— , — , and Michael Feng, “Economic Integration Agreements and the Margins of International Trade,” *Journal of International Economics*, 2014, 93 (2), 339–350.

Baier, Scott L., Yoto V. Yotov, and Thomas Zylkin, “On the Widely Differing Effects of Free Trade Agreements: Lessons from Twenty Years of Trade Integration,” *Journal of International Economics*, 2019, 116, 206–226.

Baldwin, Richard, “Trade and Growth: Still Disagreement about the Relationships,” *OECD Economics Department Working Papers No. 264*, 2000.

Baldwin, Richard E. and Elena Seghezza, “Testing for Trade-Induced Investment-Led Growth,” *International Economics*, 2008, 61 (2-3), 507–537.

Bergstrand, Jeffrey H., Mario Larch, and Yoto V. Yotov, “Economic Integration Agreements, Border Effects, and Distance Elasticities in the Gravity Equation,” *European Economic Review*, 2015, 78, 307–327.

Broda, Christian, Joshua Greenfield, and David E. Weinstein, “From Groundnuts to Globalization: A Structural Estimate of Trade and Growth,” *NBER Working Paper No. 12512*, 2006.

Caliendo, Lorenzo and Fernando Parro, “Estimates of the Trade and Welfare Effects of NAFTA,” *Review of Economic Studies*, 2015, 82 (1), 1–44.

— , Luca D. Opronmolla, Fernando Parro, and Alessandro Sforza, “Goods and Factor Market Integration: A Quantitative Assessment of the EU Enlargement,” *NBER Working Paper No. 23695*, 2017.

— , Maximiliano Dvorkin, and Fernando Parro, “Trade and Labor Market Dynamics: General Equilibrium Analysis of the China Trade Shock,” *Econometrica*, forthcoming, 2019.

Costinot, Arnaud and Andrés Rodríguez-Clare, “Trade Theory with Numbers: Quantifying the Consequences of Globalization,” Chapter 4 in the Handbook of International Economics Vol. 4, eds. Gita Gopinath, Elhanan Helpman, and Kenneth S. Rogoff, Elsevier Ltd., Oxford, 2014, pp. 197–261.

— , Dave Donaldson, and Ivana Komunjer, “What Goods Do Countries Trade? A Quantitative Exploration of Ricardo’s Ideas,” *Review of Economic Studies*, 2012, 79 (2), 581–608.

Dekle, Robert, Jonathan Eaton, and Samuel Kortum, “Unbalanced Trade,” *American Economic Review: Papers and Proceedings*, 2007, 97 (2), 351–355.

Desmet, Klaus and Esteban Rossi-Hansberg, “Spatial Development,” *American Economic Review*, 2014, 104 (4), 1211–1243.

Eaton, Jonathan and Samuel Kortum, “Technology, Geography and Trade,” *Econometrica*, 2002, 70 (5), 1741–1779.

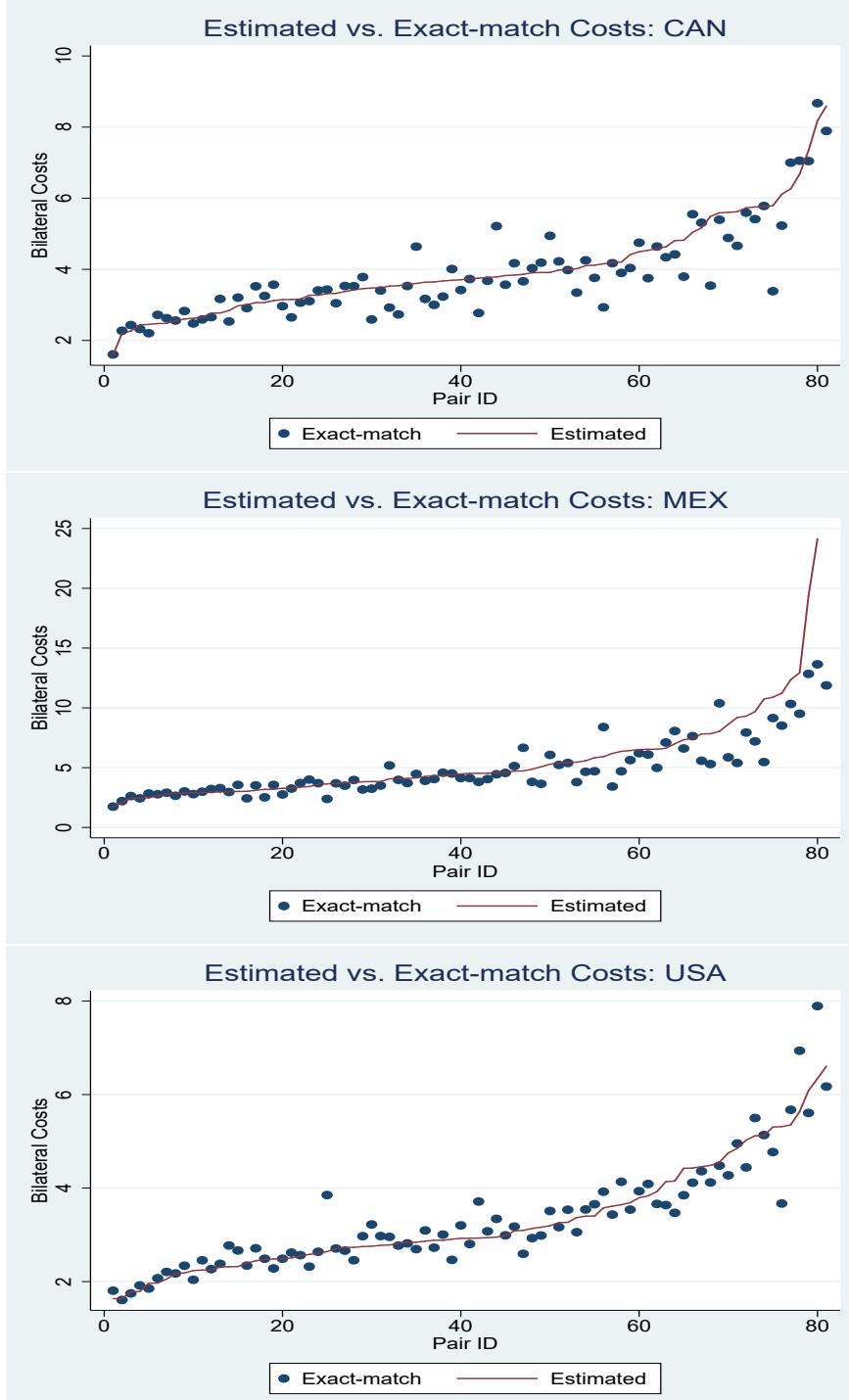
— and — , *Technology and the Global Economy: A Framework for Quantitative Analysis*, Princeton, New Jersey: manuscript in progress for Princeton University Press, 2005.

— , — , Brent Neiman, and John Romalis, “Trade and the Global Recession,” *American Economic Review*, 2016, 106 (11), 3401–3438.

- Egger, Peter and Mario Larch**, “Interdependent Preferential Trade Agreement Memberships: An Empirical Analysis,” *Journal of International Economics*, 2008, 76 (2), 384–399.
- , — , **Kevin E. Staub, and Rainer Winkelmann**, “The Trade Effects of Endogenous Preferential Trade Agreements,” *American Economic Journal: Economic Policy*, 2011, 3 (3), 113–143.
- Feenstra, Robert C., Robert Inklaar, and Marcel P. Timmer**, “The Next Generation of the Penn World Table,” *American Economic Review*, 2015, 105 (10), 3150–3182.
- Felbermayr, Gabriel and Jasmin Gröschl**, “Natural Disasters and the Effect of Trade on Income: A New Panel IV Approach,” *European Economic Review*, 2013, 58 (C), 18–30.
- Feyrer, James**, “Trade and Income – Exploiting Time Series in Geography,” *American Economic Journal: Applied Economics*, forthcoming, 2019.
- Frankel, Jeffrey A. and David H. Romer**, “Does Trade Cause Growth?,” *American Economic Review*, 1999, 89 (3), 379–399.
- Head, Keith and Thierry Mayer**, “Gravity Equations: Workhorse, Toolkit, and Cookbook,” Chapter 3 in the Handbook of International Economics Vol. 4, eds. Gita Gopinath, Elhanan Helpman, and Kenneth S. Rogoff, Elsevier Ltd., Oxford, 2014, pp. 131–195.
- Heathcote, J.H. and F. Perri**, “Financial Autarky and International Business Cycles,” *Journal of Monetary Economics*, 2002, 49 (3), 601–627.
- Heer, Burkhard and Alfred Mausner**, *Dynamic General Equilibrium Modeling: Computational Methods and Applications*, 2 ed., Berlin: Springer, 2009.
- Keller, Wolfgang and Stephen Ross Yeaple**, “The Gravity of Knowledge,” *American Economic Review*, 2013, 103 (4), 1414–1444.
- Krusell, Per and Anthony A. Smith, Jr.**, “Income and Wealth Heterogeneity in the Macroeconomy,” *Journal of Political Economy*, 1998, 106 (5), 867–896.
- Levinsohn, James and Amil Petrin**, “Estimating Production Functions Using Inputs to Control for Unobservables,” *Review of Economic Studies*, 2003, 70 (2), 317–341.
- Lin, Faqin and Nicholas C.S. Sim**, “Trade, Income and the Baltic Dry Index,” *European Economic Review*, 2013, 59 (C), 1–18.
- Lucas, Robert E. and Edward C. Prescott**, “Investment Under Uncertainty,” *Econometrica*, 1971, 39 (5), 659–681.
- Lucas, Robert E. Jr.**, *Models of Business Cycles*, New York: Basil Blackwell, 1987.
- Mutreja, Piyusha, B. Ravikumar, and Michael Sposi**, “Capital Goods Trade, Relative Prices, and Economic Development,” *Review of Economic Dynamics*, 2018, 27, 101–122.
- Olley, G. Steven and Ariel Pakes**, “The Dynamics of Productivity in the Telecommunications Equipment Industry,” *Econometrica*, 1996, 64 (6), 1263–1297.
- Osang, Thomas and Stephen J. Turnovsky**, “Differential Tariffs, Growth, and Welfare in a Small Open Economy,” *Journal of Development Economics*, 2000, 62 (2), 315–342.

- Ossa, Ralph**, "Trade Wars and Trade Talks with Data," *American Economic Review*, 2014, 104 (12), 4104–4146.
- Redding, Stephen J. and Anthony J. Venables**, "Economic Geography and International Inequality," *Journal of International Economic*, 2004, 62 (1), 53–82.
- Romalis, John**, "NAFTA's and CUSTFA's Impact on International Trade," *Review of Economics and Statistics*, 2007, 89 (3), 416–435.
- Roodman, David**, "How To Do xtabond2: An Introduction to Difference and System GMM in Stata," *Stata Journal*, 2009, 9 (1), 86–136.
- Ruhl, Kim J.**, "The International Elasticity Puzzle," unpublished manuscript, available for download at <http://www.kimjruhl.com/>, 2008.
- Sampson, Thomas**, "Dynamic Selection: An Idea Flows Theory of Entry, Trade, and Growth," *The Quarterly Journal of Economics*, 2016, 131 (1), 315–380.
- Santos Silva, João M.C. and Silvana Tenreyro**, "The Log of Gravity," *Review of Economics and Statistics*, 2006, 88 (4), 641–658.
- Solow, Robert M.**, "A Contribution to the Theory of Economic Growth," *Quarterly Journal of Economics*, 1956, 70 (1), 65–94.
- Stock, James H. and Motohiro Yogo**, "Testing for Weak Instruments in Linear IV Regression," in Donald W. K. Andrews and James H. Stock, eds., *Identification and Inference for Econometric Models: Essays in Honor of Thomas Rothenberg*, Cambridge: Cambridge University Press, 2005, pp. 80–108.
- Wacziarg, Romain**, "Measuring the Dynamic Gains from Trade," *World Bank Economic Review*, 2001, 15 (3), 393–425.
- and Karen Horn Welch, "Trade Liberalization and Growth: New Evidence," *World Bank Economic Review*, 2008, 22 (2), 187–231.
- Yao, S., C. F. Mela, J. Chiang, and Y. Chen**, "Determining Consumers' Discount Rates with Field Studies," *Journal of Marketing Research*, 2012, 49 (6), 822–841.
- Yotov, Yoto V., Roberta Piermartini, José-Antonio Monteiro, and Mario Larch**, *An Advanced Guide to Trade Policy Analysis: The Structural Gravity Model*, Geneva, Switzerland, available for download at <http://vi.unctad.org/tpa/index.html>: United Nations and World Trade Organization, 2016.
- Zimmermann, C.**, "International Real Business Cycles among Heterogeneous Countries," *European Economic Review*, 1997, 41 (2), 319–356.

Figure 1: Estimated vs. Exact-match Trade Costs



**Notes:** This figure plots ‘estimated’ vs. ‘exact-match’ trade costs for 2011, which are obtained from gravity specification (23), for Canada, Mexico and US. See main text for further details.

Table 1: Trade (Openness), Income, and Capital Accumulation, 1990-2011

|                                       | Panel A: Income Static |                      | Panel B: Capital    |                      | Panel C: Income Dynamic |                      |
|---------------------------------------|------------------------|----------------------|---------------------|----------------------|-------------------------|----------------------|
|                                       | IV<br>(1)              | Constr.-IV<br>(2)    | IV<br>(3)           | Constr.-IV<br>(4)    | IV<br>(5)               | Constr.-IV<br>(6)    |
| $\ln L_{j,t}$                         | 0.278<br>(0.086)***    | 0.514<br>(0.036)***  |                     |                      | 0.224<br>(0.069)***     | 0.329<br>(0.031)***  |
| $\ln K_{j,t}$                         | 0.349<br>(0.065)***    | 0.559<br>(0.027)***  |                     |                      |                         |                      |
| $\ln(\widehat{\Pi}_{j,t}^{\sigma-1})$ | -0.189<br>(0.031)***   | -0.294<br>(0.026)*** |                     |                      | -0.160<br>(0.076)**     | -0.286<br>(0.027)*** |
| $\ln K_{j,t-1}$                       |                        |                      | 0.953<br>(0.006)*** | 0.972<br>(0.002)***  | 0.314<br>(0.064)***     | 0.331<br>(0.025)***  |
| $\ln E_{j,t-1}$                       |                        |                      | 0.017<br>(0.009)*   | 0.028<br>(0.002)***  | 0.062<br>(0.067)        | 0.054<br>(0.022)**   |
| $\ln(P_{j,t-1}^{\sigma-1})$           |                        |                      | -0.049<br>(0.020)** | -0.034<br>(0.003)*** | -0.150<br>(0.075)**     | -0.022<br>(0.009)**  |
| $\hat{\sigma}$                        | 5.305<br>(0.863)***    | 3.406<br>(0.297)***  | 1.344<br>(0.319)*** | 1.831<br>(0.056)***  | 6.260<br>(2.984)**      | 3.502<br>(0.335)***  |
| $\hat{\alpha}$                        | 0.431<br>(0.083)***    | 0.791<br>(0.040)***  |                     |                      | 0.733<br>(0.092 )***    | 0.539<br>(0.040)***  |
| $\hat{\delta}$                        |                        |                      |                     | 0.028<br>(0.002)***  | 0.165<br>(0.143 )       | 0.141<br>(0.051)**   |
| $N$                                   | 1200                   | 1200                 | 1438                | 1438                 | 1179                    | 1179                 |

**Notes:** Panel A reports estimates of Equation (19). The dependent variable is the logarithm of GDP. Results in column (1) are obtained with country and time fixed effects and an IV estimator that treats all covariates as endogenous. Standard errors are bootstrapped. All IV test statistics are reported in the main text. Column (2) replicates the IV specification from column (2) with the same instruments but under the structural constraints of our theory. The results in columns (1) and (2) deliver estimates of the elasticity of substitution  $\sigma$  and of the capital share  $\alpha$ , which are reported in the bottom of the table. Panel B reports estimates of Equation (20). The dependent variable is the logarithm of capital stock. Results in column (3) are obtained with country and time fixed effects and an IV estimator that treats all covariates as endogenous. Standard errors are bootstrapped. All IV test statistics are reported in the main text. Column (4) replicates the IV specification from column (3) with the same instruments but under the structural constraints of our theory. The results in column (4) deliver an estimate of the depreciation parameter  $\delta$  and of the elasticity of substitution  $\sigma$ , which are reported in the bottom of the table. Panel C offers estimates of Equation (22). The dependent variable is the logarithm of GDP. Results in column (5) are obtained with an IV estimator that treats all covariates as endogenous. Standard errors are robust and all IV test statistics are reported in the main text. Column (6) replicates the IV specification from column (5) with the same instruments and imposes the structural constraints of our theory. The results in columns (5) and (6) deliver estimates of all three key structural parameters in the model, namely the elasticity of substitution  $\sigma$ , of the capital share  $\alpha$ , and of the depreciation parameter  $\delta$ , which are reported in the bottom of the table. Standard errors are robust. \*  $p < 0.10$ , \*\*  $p < .05$ , \*\*\*  $p < .01$ . See text for further details.

Table 2: Welfare Effects of NAFTA

| Country         | Panel A |               |                   | Panel B         |                   |                    |
|-----------------|---------|---------------|-------------------|-----------------|-------------------|--------------------|
|                 | Static  | Dynamic<br>SS | Dynamic<br>trans. | $\sigma =$<br>6 | $\alpha =$<br>0.3 | $\delta =$<br>0.03 |
|                 | (1)     | (2)           | (3)               | (4)             | (5)               | (6)                |
| NAFTA countries |         |               |                   |                 |                   |                    |
| CAN             | 5.038   | 10.617        | 9.147             | 4.610           | 6.628             | 7.250              |
| MEX             | 3.071   | 6.567         | 5.631             | 2.825           | 4.058             | 4.428              |
| USA             | 0.618   | 1.357         | 1.150             | 0.572           | 0.822             | 0.886              |
| Average         | 1.167   | 2.515         | 2.147             | 1.075           | 1.545             | 1.678              |
| Other countries |         |               |                   |                 |                   |                    |
| AGO             | -0.073  | -0.073        | -0.077            | -0.058          | -0.079            | -0.079             |
| ARG             | -0.010  | -0.011        | -0.012            | -0.008          | -0.011            | -0.012             |
| AUS             | -0.011  | -0.013        | -0.013            | -0.009          | -0.013            | -0.013             |
| AUT             | -0.015  | -0.017        | -0.018            | -0.013          | -0.017            | -0.018             |
| AZE             | -0.018  | -0.020        | -0.021            | -0.015          | -0.020            | -0.021             |
| BEL             | -0.034  | -0.034        | -0.036            | -0.027          | -0.037            | -0.037             |
| BGD             | -0.011  | -0.013        | -0.013            | -0.009          | -0.013            | -0.013             |
| BGR             | -0.003  | -0.004        | -0.004            | -0.003          | -0.004            | -0.004             |
| BLR             | -0.002  | -0.002        | -0.002            | -0.001          | -0.002            | -0.002             |
| BRA             | -0.012  | -0.013        | -0.014            | -0.010          | -0.013            | -0.013             |
| CHE             | -0.034  | -0.035        | -0.037            | -0.027          | -0.037            | -0.037             |
| CHL             | -0.041  | -0.043        | -0.045            | -0.033          | -0.045            | -0.046             |
| CHN             | -0.019  | -0.021        | -0.022            | -0.016          | -0.021            | -0.022             |
| COL             | -0.027  | -0.030        | -0.031            | -0.022          | -0.031            | -0.031             |
| CZE             | -0.006  | -0.009        | -0.009            | -0.005          | -0.008            | -0.008             |
| DEU             | -0.020  | -0.022        | -0.023            | -0.016          | -0.022            | -0.023             |
| DNK             | -0.023  | -0.024        | -0.026            | -0.018          | -0.025            | -0.026             |
| DOM             | -0.026  | -0.029        | -0.030            | -0.021          | -0.029            | -0.029             |
| ECU             | -0.031  | -0.034        | -0.036            | -0.025          | -0.035            | -0.035             |
| EGY             | -0.005  | -0.005        | -0.005            | -0.004          | -0.005            | -0.005             |
| ESP             | -0.009  | -0.010        | -0.010            | -0.007          | -0.010            | -0.010             |
| ETH             | -0.001  | -0.002        | -0.002            | -0.001          | -0.001            | -0.001             |
| FIN             | -0.021  | -0.022        | -0.024            | -0.017          | -0.023            | -0.024             |
| FRA             | -0.011  | -0.013        | -0.013            | -0.009          | -0.013            | -0.013             |
| GBR             | -0.021  | -0.023        | -0.024            | -0.017          | -0.024            | -0.024             |
| GHA             | -0.008  | -0.009        | -0.009            | -0.007          | -0.009            | -0.009             |
| GRC             | -0.002  | -0.003        | -0.003            | -0.002          | -0.003            | -0.003             |
| GTM             | -0.058  | -0.063        | -0.066            | -0.047          | -0.065            | -0.066             |
| HKG             | -0.015  | -0.018        | -0.018            | -0.012          | -0.017            | -0.017             |
| HRV             | -0.003  | -0.004        | -0.004            | -0.002          | -0.003            | -0.003             |
| HUN             | -0.011  | -0.013        | -0.013            | -0.009          | -0.012            | -0.013             |
| IDN             | -0.006  | -0.007        | -0.007            | -0.005          | -0.007            | -0.007             |
| IND             | -0.003  | -0.004        | -0.004            | -0.003          | -0.004            | -0.004             |
| IRL             | -0.087  | -0.083        | -0.089            | -0.069          | -0.093            | -0.093             |
| IRN             | 0.000   | 0.000         | 0.000             | 0.000           | 0.000             | 0.000              |
| IRQ             | -0.049  | -0.051        | -0.054            | -0.040          | -0.054            | -0.054             |
| ISR             | -0.042  | -0.046        | -0.048            | -0.035          | -0.047            | -0.048             |
| ITA             | -0.010  | -0.012        | -0.012            | -0.008          | -0.012            | -0.012             |
| JPN             | -0.017  | -0.019        | -0.020            | -0.014          | -0.019            | -0.019             |
| KAZ             | -0.019  | -0.020        | -0.021            | -0.015          | -0.021            | -0.021             |
| KEN             | -0.004  | -0.004        | -0.005            | -0.003          | -0.004            | -0.004             |
| KOR             | -0.028  | -0.030        | -0.031            | -0.023          | -0.031            | -0.031             |
| KWT             | -0.005  | -0.007        | -0.007            | -0.004          | -0.006            | -0.006             |
| LBN             | -0.005  | -0.005        | -0.006            | -0.004          | -0.005            | -0.005             |
| LKA             | -0.010  | -0.011        | -0.011            | -0.008          | -0.011            | -0.011             |
| LTU             | -0.016  | -0.017        | -0.018            | -0.013          | -0.018            | -0.018             |
| MAR             | -0.010  | -0.011        | -0.011            | -0.008          | -0.011            | -0.011             |
| MYS             | -0.060  | -0.060        | -0.064            | -0.048          | -0.066            | -0.066             |
| NGA             | -0.018  | -0.020        | -0.021            | -0.015          | -0.020            | -0.021             |
| NLD             | -0.025  | -0.028        | -0.029            | -0.021          | -0.028            | -0.029             |
| NOR             | -0.040  | -0.041        | -0.043            | -0.032          | -0.044            | -0.044             |

*Continued on next page*

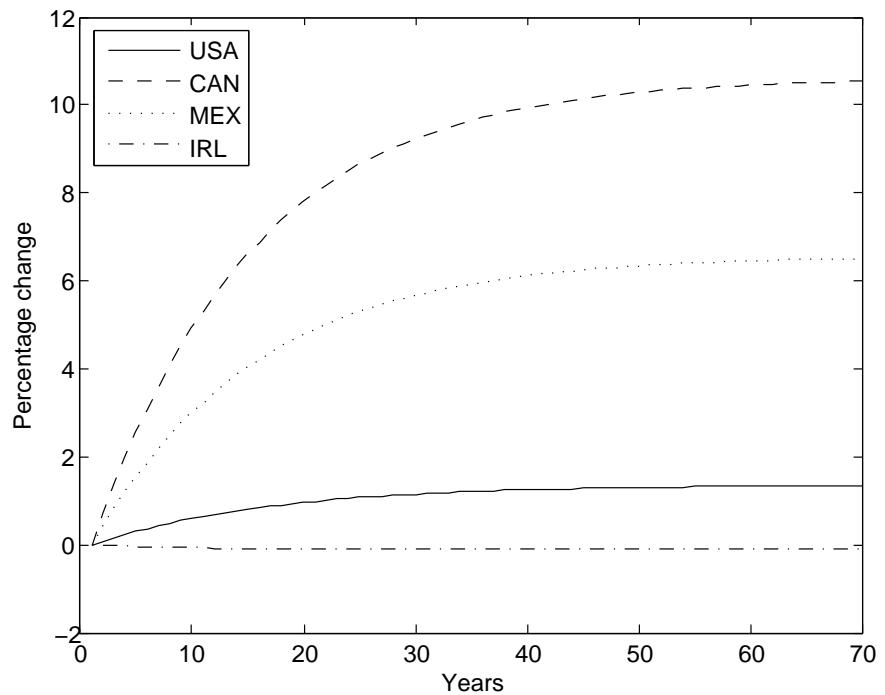
| Country | Panel A |               |                   | Panel B         |                   |                    |
|---------|---------|---------------|-------------------|-----------------|-------------------|--------------------|
|         | Static  | Dynamic<br>SS | Dynamic<br>trans. | $\sigma =$<br>6 | $\alpha =$<br>0.3 | $\delta =$<br>0.03 |
|         | (1)     | (2)           | (3)               | (4)             | (5)               | (6)                |
| NZL     | -0.022  | -0.024        | -0.025            | -0.018          | -0.024            | -0.024             |
| OMN     | -0.003  | -0.005        | -0.005            | -0.003          | -0.004            | -0.004             |
| PAK     | -0.004  | -0.005        | -0.005            | -0.003          | -0.005            | -0.005             |
| PER     | -0.035  | -0.038        | -0.039            | -0.028          | -0.039            | -0.039             |
| PHL     | -0.017  | -0.019        | -0.020            | -0.014          | -0.019            | -0.019             |
| POL     | -0.003  | -0.005        | -0.005            | -0.003          | -0.004            | -0.004             |
| PRT     | -0.006  | -0.007        | -0.007            | -0.005          | -0.007            | -0.007             |
| QAT     | -0.002  | -0.004        | -0.004            | -0.002          | -0.003            | -0.003             |
| ROM     | -0.003  | -0.003        | -0.003            | -0.002          | -0.003            | -0.003             |
| RUS     | -0.003  | -0.004        | -0.004            | -0.003          | -0.004            | -0.004             |
| SAU     | -0.017  | -0.020        | -0.020            | -0.014          | -0.020            | -0.020             |
| SDN     | -0.004  | -0.004        | -0.005            | -0.003          | -0.004            | -0.004             |
| SER     | -0.001  | -0.001        | -0.001            | -0.001          | -0.001            | -0.001             |
| SGP     | -0.055  | -0.054        | -0.057            | -0.044          | -0.059            | -0.059             |
| SVK     | -0.004  | -0.006        | -0.006            | -0.004          | -0.005            | -0.006             |
| SWE     | -0.018  | -0.021        | -0.021            | -0.015          | -0.021            | -0.021             |
| SYR     | -0.002  | -0.002        | -0.002            | -0.001          | -0.002            | -0.002             |
| THA     | -0.019  | -0.022        | -0.023            | -0.016          | -0.022            | -0.022             |
| TKM     | -0.001  | -0.001        | -0.001            | 0.000           | -0.001            | -0.001             |
| TUN     | -0.005  | -0.006        | -0.006            | -0.004          | -0.006            | -0.006             |
| TUR     | -0.004  | -0.005        | -0.005            | -0.004          | -0.005            | -0.005             |
| TZA     | -0.002  | -0.002        | -0.002            | -0.001          | -0.002            | -0.002             |
| UKR     | -0.003  | -0.003        | -0.004            | -0.002          | -0.003            | -0.003             |
| UZB     | 0.000   | 0.000         | 0.000             | 0.000           | 0.000             | 0.000              |
| VEN     | -0.038  | -0.042        | -0.044            | -0.032          | -0.043            | -0.044             |
| VNM     | -0.020  | -0.022        | -0.023            | -0.016          | -0.022            | -0.022             |
| ZAF     | -0.011  | -0.013        | -0.013            | -0.009          | -0.012            | -0.013             |
| ZWE     | 0.000   | -0.001        | -0.001            | 0.000           | 0.000             | 0.000              |
| Average | -0.015  | -0.017        | -0.017            | -0.012          | -0.017            | -0.017             |

World average

|       |       |       |       |       |       |       |
|-------|-------|-------|-------|-------|-------|-------|
| World | 0.258 | 0.568 | 0.482 | 0.239 | 0.344 | 0.374 |
|-------|-------|-------|-------|-------|-------|-------|

**Notes:** This table reports percentage changes in welfare. Panel A, i.e., the first three columns, report the results from three different scenarios from our NAFTA counterfactual with our base calibration from Column (6) of Table 1 ( $\sigma = 3.5$ ,  $\alpha = 0.54$ ,  $\delta = 0.14$ ). The “Static” scenario (column (1)) takes direct and indirect trade cost changes and static general equilibrium income effects into account. The “Dynamic” scenarios add the capital accumulation effects. For the latter, we report results that do not take transition into account (in column (2)) and welfare gains that take transition into account (in column (3)). Panel B, i.e., columns (4) to (6), provide robustness with respect to  $\sigma$ ,  $\alpha$ , and  $\delta$ . See text for further details.

Figure 2: On the Transitional Effects of NAFTA: Capital Stocks



**Notes:** This figure plots the transition of capital stocks due to the introduction of NAFTA for the three member countries and for Ireland, as the outside country that experienced the largest impact of NAFTA. See main text for further details.