Growth and Trade: A Structural Estimation Framework*

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Abstract

We build and quantify a structural general equilibrium model of growth and trade. Trade affects growth through changes in consumer and producer prices that in turn stimulate or impede physical capital accumulation. At the same time, growth affects trade, directly through changes in country size and indirectly through altering the incidence of trade costs. The model combines structural gravity with a simple capital accumulation specification of the transition between steady states. An intuitive, self-sufficient econometric system results. Counterfactual experiments based on the estimated model give evidence for strong causal relationships between growth and trade.

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1 Introduction

The relationship of trade and growth has been a central concern of economists since Adam Smith. This subject is ever more relevant nowadays in the eve of the formation of trade mega deals such as the Transatlantic Trade and Investment Partnership (TTIP) between the United States and the European Union. Policy analysts and negotiating parties on both sides expect that "TTIP will result in more jobs and growth."[1] President Obama of U.S. and Minister Rajoy of Spain also agreed that "there is enormous potential for TTIP to increase trade and growth between two of the largest economic actors in the world."[2] However, while such views and expectations are consistent with early economic ideas,[3] more recent studies question our ability to characterize the relationship between trade and growth.[4] Head and Mayer (2014) point to an important deficiency in the available methods to capture the dynamic effects of trade. Specifically, in their recent review of the state of the empirical trade literature, they conclude that all existing microfoundations of empirical models of trade flows (e.g. gravity) are static. "This raises the econometric problem of how to handle the evolution of trade over time in response to changes in trade costs." (Head and Mayer, 2014, p. 189).

Motivated by these concerns, we combine an N-country Armington trade model with a dynamic capital accumulation model that delivers an attractive (simple and tractable) general equilibrium framework that characterizes the relationship between trade and growth. Our focus is on two major forces: trade frictions and capital accumulation. The structural

[1] Press release, Brussels, 28 January 2014, EU-USA Trade Talks: EU and USA announce 4th round of TTIP negotiations in March; stocktaking meeting in Washington D.C. to precede next set of talks; available at http://trade.ec.europa.eu/doclib/press/index.cfm?id=1020.

[2] "Remarks by president Obama and president Mariano Rajoy of Spain after bilateral meeting", Office of the Press Secretary, White House, January, 2014, http://iipdigital.usembassy.gov/st/english/texttrans/2014/01/20140114290784.html#axzz2u59pirmD.

[3] According to Smith (1776) "[t]he opening to a more extensive market encourages [a country] to improve its productive powers and to augment its annual produce to the utmost, and thereby to increase the real revenue of wealth and society." (Smith, 1776, p. 280) Similarly, Marshall (1890) assures that "[t]he causes which determine the economic progress of nations belong to the study of international trade." (Marshall, 1890, p. 255).

[4] In order to motivate their famous paper, Frankel and Romer (1999) note that "[d]espite the great effort that has been devoted to studying the issue, there is little persuasive evidence concerning the effect of trade on income." Similarly, Baldwin (2000) confirms that "[t]he relationships between trade and growth have long been a subject of [study and] controversy among economists. This situation continues today."

gravity model easily handles costly trade in a many country world, and connects trade costs to productivity via multilateral resistance. Small scale simulation models based on structural gravity combine trade cost estimates with simple general equilibrium superstructure (e.g. Eaton and Kortum, 2002; Anderson and van Wincoop, 2003) to provide intuitive and revealing counterfactual general equilibrium comparative statics. Our innovation is to bring in capital accumulation and the transition between steady states. A tractable accumulation model embedding structural gravity is based on Lucas and Prescott (1971), Hercowitz and Sampson (1991) and Eckstein, Foulides, and Kollintzas (1996). The resulting dynamic structural gravity model translates into a simple and intuitive econometric system that is easy to estimate and delivers the key structural parameters needed to calibrate the model.[5] Counterfactual comparative static exercises with the estimated model decompose and quantify the various channels through which trade affects growth and through which growth impacts trade. We offer evidence for strong causal relationships between growth and trade.

The structural gravity setup of Anderson and van Wincoop (2003) based on CES preferences differentiated by place of origin (Armington, 1969) forms the trade module of the static model.[6] Recent work by Arkolakis, Costinot, and Rodríguez-Clare (2012, henceforth also ACR) shows that gains from trade are invariant to the introduction of monopolistic competition, entry of firms and selection into markets. The simple Armington/CES version of structural gravity thus retains more generality than previously understood, its information demands boil down to a single trade elasticity, and it is easy to integrate with a model of capital accumulation. Capital itself is an alternative use of the consumable bundle, with its steady state flow that offsets depreciation equivalent to a composite intermediate good. In

[5] Our system delivers estimates of the trade elasticity of substitution, of the capital (labor) share in production, of the capital depreciation rate, and of bilateral trade costs which are all comparable to corresponding values from the existing literature.

[6] The gravity model is the workhorse in international trade. Anderson (1979) is the first to build a gravity theory of trade based on CES preferences with products differentiated by place of origin. Bergstrand (1985) embeds this setup in a monopolistic competition framework. More recently, Eaton and Kortum (2002), Helpman, Melitz, and Rubinstein (2008), and Chaney (2008) derived structural gravity based on selection (hence substitution on the extensive margin) in a Ricardian framework. Thus, as noted by Eaton and Kortum (2002) and Arkolakis, Costinot, and Rodríguez-Clare (2012), a large class of models generate isomorphic gravity equations. Anderson (2011) summarizes the alternative theoretical foundations of economic gravity.

this sense the model is isomorphic to Eaton and Kortum (2002) but with substitution on the intensive margin. An extension to incorporate intermediate goods of the standard type following Eaton and Kortum (2002) confirms that qualitative properties remain the same while quantitative results shift significantly.

Growth through capital accumulation on the transition path is modeled in the spirit of the dynamic general equilibrium models developed by Lucas and Prescott (1971), Hercowitz and Sampson (1991) and Eckstein, Foulides, and Kollintzas (1996). Their log-linear utility and log-linear capital transition function structure yields a closed-form solution for optimal accumulation by infinitely lived representative agents with perfect foresight. The closed-form accumulation solution is the bridge to empirical implementation and our exploration of the complex relationship between growth and trade.[7] We abstract from non-zero steady state growth for simplicity. While we also abstract from endogenous technological change, note that changes of multilateral resistance (also interpreted as input buyers' and sellers' incidence of trade costs) due to capital accumulation is effectively another type of endogenous technological change.

Trade's effect on growth acts in the model through a relative price channel. Trade volume shifts producer prices relative to consumer prices when trade is costly. Shifts in relative prices affect accumulation, and accumulation affects next period trade. Higher producer prices increase accumulation because they imply higher returns to investment, hence agents lower current consumption in return for expected increased future consumption. Higher investment and consumer prices, in contrast, reduce accumulation due to higher costs of investment and due to higher opportunity costs of consumption. Importantly, due to the general equilibrium forces in our model, changes in trade costs between any two trading partners may potentially affect producer prices and consumer prices in any nation in the

[7] In contrast, no closed-form solution is available for models in the spirit of the dynamic, stochastic, general equilibrium (DSGE) open economy macroeconomics literature, such as Backus, Kehoe, and Kydland (1992, 1994). In our robustness analysis we experiment with alternative specifications for capital accumulation. While these do not lead to the convenient and tractable closed-form solution from our main analysis, they do generate qualitatively identical and quantitatively similar results.

world, regardless of whether this nation takes part in integration and trade liberalization or not. In the empirical results, such third-party effects are significant.

Growth affects trade via two channels, direct and indirect. The direct effect of growth on trade is strictly positive, acting through country size. Growth in one economy results in more exports and in more imports between the growing country and all of its trading partners. The indirect effect of growth on trade arises because changes in country size translate into changes in the multilateral resistance for all countries, with knock on changes in trade flows. Importantly, the indirect channel through which growth affects trade is a general equilibrium one, i.e., capital accumulation in one country affects trade costs and impact welfare in every other country in the world. Work done on other data (e.g. Anderson and Yotov, 2010; Anderson and van Wincoop, 2003) reveals that a higher income is strongly associated with lower sellers' incidence of trade costs and thus a real income increase, a correlation replicated here. Closing the loop, growth-led changes in the incidence of trade costs leads to additional changes in capital stock.

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 simple econometric system that offers a theoretical foundation to the famous reduced-form specification of Frankel and Romer (1999). Our theory allows us to go a step further, and we complement the trade-and-income system of Frankel and Romer with an additional structural equation that captures the effects of trade on capital accumulation. The estimation of our structural econometric system yields estimates of trade costs, multilateral resistance terms as well as of all besides one model parameters. Then, we combine the newly constructed trade costs with data on the rest of the variables in our model and we perform a series of counterfactual experiments in order to capture and to decompose the relationships between growth and trade. These exercises indicate substantial dynamic effects of trade liberalization. The dynamic channels in our framework (increased country size and changes in the multilateral resistances) imply that preferential trade liberalization (e.g. a Regional Trade Agreement, RTA) may benefit non-members eventually, despite the initial negative effect of trade diversion. RTAs that are statically beneficial to members stimulate growth by making investment more attractive. This will normally lead to lower sellers' incidence for these countries, but also to lower buyers' incidence in non-members. Furthermore, the increased income in member countries will translate into an increase of imports from all trading partners, including non-members. Consistent with that logic, our simulation of NAFTA shows that its formation had small and non-monotonic negative trade effects on non-member countries and even some small net trade-creation effects for several non-members such as Switzerland, Belgium and Austria. A battery of sensitivity checks confirms the robustness of our results.

The rest of the paper is organized as follows. In section 2 we present our contributions in relation to existing studies. Section 3 develops the theoretical foundation and discusses the structural links between growth and trade in our model. In Section 4, we translate our theoretical framework into an econometric model. Section 5 offers counterfactual experiments. Section 6 concludes with some suggestions for future research.

2 Relation to Literature

Our work contributes to several influential strands of the literature. First, our paper builds a bridge between the empirical and theoretical literature that studies the links between growth and trade. On the empirical side, most closely related is the seminal work of Frankel and Romer (1999), who offer a reduced-form framework to study the relationships between income and trade.[8] We extend Frankel and Romer (1999) in two important ways. First, we offer a structural estimation system that corresponds directly to their reduced-form specification. Second, we introduce an additional, theoretically-motivated equation that captures the effects of trade on capital accumulation and, therefore, growth.

[8] In order to account for the endogeneity problems that plague the relationships between growth and trade, Frankel and Romer (1999) draw from the early, a-theoretical gravity literature (see Tinbergen, 1962; Linnemann, 1966) and propose to instrument for trade flows with geographical characteristics and country size.

On the structural trade-and-growth side, our paper is related to a series of influential papers by Jonathan Eaton and Samuel Kortum (see Eaton and Kortum, 2001, 2002, 2005), who study the links between trade, production and growth via technological spill-overs.[9] While the relationships between growth and trade are of central interest in this paper and in Eaton and Kortum's work, we view our study as complementary to Eaton and Kortum's agenda because the dynamic relationships between trade and production in our model are generated via capital accumulation.[10]

Our choice is consistent with the theoretical developments of Grossman and Helpman (1991) and is motivated by the empirical findings of Wacziarg (2001), Cuñat and Maffezzoli (2007), Baldwin and Seghezza (2008) and Wacziarg and Welch (2008). On the theoretical side, Grossman and Helpman (1991) develop a series of growth and trade models, where they endogenize the creation of new products and allow for technology diffusion in a dynamic multi-country model. As mentioned in footnote 17 on page 132 in Grossman and Helpman (1991), transitional dynamics naturally arise when allowing for capital accumulation and "that physical capital may play only a supporting role in the story of long-run growth." (p. 122). This is exactly the focus of our study, where we model and quantify the transitional growth effects of trade liberalization.

On the empirical side, Wacziarg (2001) investigates the links between trade policy and economic growth employing a panel of 57 countries for the period of 1970 to 1989. One of the main findings of this study is that physical capital accumulation accounts for about 60%

[9]The work of Eaton and Kortum that is most closely related to our study is thoroughly summarized in their manuscript Eaton and Kortum (2005). In chapter ten, based on Eaton and Kortum (2001), they study how trade in capital goods possibly transmits technological advances. The analysis is based on a model with two goods, a capital good and a consumption good, in an environment of perfect competition in the output market, the labor market, and the rental market for capital. The main finding is that differences in equipment prices can be related to differences in productivity and barriers to trade in equipment. In chapter eleven, they investigate the geographical scope of technological progress in a multi-country (semi)endogenous growth framework. The main empirical finding is that an innovation abroad is two-thirds as potent as a domestic innovation. For a thorough review of the theoretical literature on trade and (endogenous) technology up to the 1990s, we refer the reader to Grossman and Helpman (1995).

[10]Even though technology is exogenous in our model, our framework has implications for TFP calculations and estimations. In particular, the introduction of a structural trade costs term in the production function reveals potential biases in the existing estimates of technology. In addition, our model can be used to simulate the effects of exogenous technological changes.

of the total positive impact of openness on economic growth. Baldwin and Seghezza (2008) and Wacziarg and Welch (2008) confirm these findings for up to 39 countries for two years (1965 and 1989) and a set of 118 countries over the period 1950 to 1998, respectively. Cuñat and Maffezzoli (2007) demonstrate the role of factor accumulation to reproduce the large observed increases in trade shares after modest tariff reductions. These studies motivate the focus on capital accumulation as the source of growth in our model. In line with these empirical findings and without any implications for causality, we note that the correlation between changes in trade openness (measured as exports plus imports as share of gross domestic product) and changes in capital accumulation in our sample is about 0.38 (p-value 0.002).

Second, we contribute to the theoretical and to the empirical gravity literature of international trade. Using the gravity model as a vehicle to study the empirical relationships between growth and trade is pointed as an important direction for future research by Head and Mayer (2014). On the theoretical side, we extend the static gravity models of Anderson (1979) and Anderson and van Wincoop (2003), where output is exogenous, into a structural dynamic model of trade, production and growth. To the best of our knowledge, Olivero and Yotov (2012) and Campbell (2010) are the only two contemporary attempts to build a dynamic gravity equation.[11] In both cases, the focus is on the implications of dynamics for gravity estimations. In addition to relying on a different underlying theoretical structure, here we focus on the production and growth implications of our model and we offer empirical implications for the estimation of production functions.

We also make an empirical contribution to the trade literature. Specifically, the introduction of a structural trade term in the production function enables us to obtain a direct estimate of the trade elasticity of substitution, which has gained recent popularity as the

[11] There is a literature that explains export dynamics (see for example Das, Roberts, and Tybout, 2007; Morales, Sheu, and Zahler, 2014) and one that focuses on adjustment dynamics and business cycle effects of trade liberalization (see for example Artuç, Chaudhuri, and McLaren, 2010; Cacciatore, 2014; Dix-Carneiro, 2013). Both, export dynamics and adjustment and business cycle dynamics, are beyond the scope of this paper.

single most important trade parameter (see ACR). With values between 5.1 and 8.0 from alternative specifications and robustness experiments, our estimates of the trade elasticity of substitution are comparable to the ones from the existing literature, which usually vary between 2 and 12.[12]

Finally, we contribute to the literature that studies the effects of RTAs. Our contribution to this literature is that we provide a framework to study the *dynamic* effects of RTAs. Three important results stand out. First, we find that the dynamic effects of RTAs are strong for member countries and relatively week for outsiders. Second, in terms of duration, we find that the dynamic effects of RTAs on members are long-lasting, while the dynamic effects on outsiders are short-lived. Finally, our NAFTA counterfactual experiment reveals the possibility for non-monotonic effects of preferential trade liberalization on non-member countries. As discussed earlier, the reason is a combination of the trade-driven growth of member countries and the fact that the falling incidence of trade costs for the producers in the growing member economies is shared with buyers in outside countries. These findings offer encouraging support in favor of ongoing trade liberalization and integration efforts.

3 Theoretical Foundation

The theoretical foundation used here to quantify the relationships between growth and trade combines the static structural trade gravity setup of Anderson and van Wincoop (2003) with dynamically endogenous production and capital accumulation in the spirit of the dynamic general equilibrium models developed by Lucas and Prescott (1971), Hercowitz and Sampson (1991) and Eckstein, Foulides, and Kollintzas (1996). Goods are differentiated by place of origin and each of the N countries in the world is specialized in the production of a single good j. Total nominal output in country j at time t ($y_{j,t}$) is produced subject to the following

[12] See Eaton and Kortum (2002), Anderson and van Wincoop (2003), Broda, Greenfield, and Weinstein (2006) and Simonovska and Waugh (2011).

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

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

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. $L_{j,t}$ 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 a Cobb-Douglas transition function following Lucas and Prescott (1971), Hercowitz and Sampson (1991) and Eckstein, Foulides, and Kollintzas (1996):

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

where $\Omega_{j,t}$ denotes the flow of investment in country j at time t and δ is the depreciation rate. This transition function reflects the costs in adjustments of the volume of capital.[13]

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 $\beta < 1$. 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

[13] Alternatively, one could view it as incorporating diminishing returns in research activity or as quality differences between old capital as compared to new investment goods. Note that this formulation does not allow for zero investment Ω in any period, as this would render the capital stock and output to be zero. Further, in the long-run steady-state, $K = \Omega$, i.e., the specific transition function implies full depreciation. Despite these limitations, we prefer this capital accumulation function over the more standard linear capital accumulation function for our main analysis. The benefits of that are: (i) a tractable closed-form solution of our theoretical model; and (ii) a self-sufficient structural econometric system that is straightforward to estimate. In the robustness section we experiment with the linear capital accumulation function. Even though this function no longer allows for a closed-form solution and requires the use of external calibrated parameters, we do find qualitatively identical and quantitatively similar results.

utility subject to a sequence of constraints:

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

$$K_{j,t+1} = \Omega_{j,t}^{\delta} K_{j,t}^{1-\delta}, \tag{3}$$

$$y_{j,t} = p_{j,t} A_{j,t} L_{j,t}^{1-\alpha} K_{j,t}^{\alpha}, \tag{4}$$

$$y_{j,t} = P_{j,t} C_{j,t} + P_{j,t} \Omega_{j,t}, \tag{5}$$

$$K_0 \quad \text{given.} \tag{6}$$

Equations (3) and (4) define the law of motion for the capital stock and the value of production, respectively. Finally, the budget constraint (5) states that aggregate spending in country j has to equal the sum of spending on both consumption and investment goods.

Aggregate consumption and aggregate investment are both comprised by domestic and foreign goods. Consumption and investment goods from different countries i, i.e., $c_{ij,t}$ and $I_{ij,t}$, respectively, are aggregated as follows:

$$C_{j,t} = \left(\sum_i \gamma_i^{\frac{1-\sigma}{\sigma}} c_{ij,t}^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}, \tag{7}$$

$$\Omega_{j,t} = \left(\sum_i \gamma_i^{\frac{1-\sigma}{\sigma}} I_{ij,t}^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}. \tag{8}$$

Equation (7) defines the consumption aggregate ($C_{j,t}$) as a function of consumption from each region i ($c_{ij,t}$), where γ_i is a positive distribution parameter, and $\sigma > 1$ is the elasticity of substitution across goods varieties from different countries. Equation (8) 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 $i \neq j$ ($I_{ij,t}$).[14]

[14] 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. We discuss possible implications and directions for future research in the concluding section.

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. Technologically, a unit of distribution services required to ship goods uses resources in the same proportions as does production. The units of distribution services required on each link vary bilaterally. Trade costs thus can be interpreted by the standard iceberg melting metaphor; it is as if goods melt away in distribution so that 1 unit shipped becomes $1/t_{ij,t} < 1$ units on arrival.

We solve the consumers' optimization problem in two steps. First, we solve the optimal demand of $c_{ij,t}$ and $I_{ij,t}$ given $y_{j,t}$. We label this stage the 'lower level'. Then, we solve the dynamic optimization problem for $C_{j,t}$ and $\Omega_{j,t}$. This is what we call the 'upper level'. Consider the 'lower level' first. Using $x_{ij,t}$ to denote country j's total nominal spending on goods from country i at time t, i.e., $x_{ij,t} = p_{ij,t}(c_{ij,t} + I_{ij,t})$, agents' optimization of (7)-(8), subject to (5) taking $C_{j,t}$ and $\Omega_{j,t}$ as given, yields:

$$x_{ij,t} = \left(\frac{\gamma_i p_{i,t} t_{ij,t}}{P_{j,t}}\right)^{1-\sigma} y_{j,t}, \tag{9}$$

where $P_{j,t} = \left[\sum_i (\gamma_i p_{i,t} t_{ij,t})^{1-\sigma}\right]^{1/(1-\sigma)}$ is the CES price aggregator index for country j at time t.

Market clearance, $y_{i,t} = \sum_j x_{ij,t}$, implies:

$$y_{i,t} = \sum_j (\gamma_i p_{i,t})^{1-\sigma} (t_{ij,t}/P_{j,t})^{1-\sigma} y_{j,t}. \tag{10}$$

(10) simply tells us that, at delivered prices, the output in each country should equal total expenditures on this nation's goods in the world, including i itself. Define $y_t \equiv \sum_i y_{i,t}$ and divide the preceding equation by y_t to obtain:

$$(\gamma_i p_{i,t} \Pi_{i,t})^{1-\sigma} = y_{i,t}/y_t, \tag{11}$$

where $\Pi_{i,t}^{1-\sigma} \equiv \sum_j \left(\frac{t_{ij,t}}{P_{j,t}}\right)^{1-\sigma} \frac{y_{j,t}}{y_t}$. Using (11) to substitute for the power transform of factory-gate prices, $(\gamma_i p_{i,t})^{1-\sigma}$ in equation (9) above and in the CES consumer price aggregator following (9), delivers the familiar structural system of Anderson and van Wincoop (2003):

$$x_{ij,t} = \frac{y_{i,t} y_{j,t}}{y_t} \left(\frac{t_{ij,t}}{\Pi_{i,t} P_{j,t}}\right)^{1-\sigma}, \tag{12}$$

$$P_{j,t}^{1-\sigma} = \sum_i \left(\frac{t_{ij,t}}{\Pi_{i,t}}\right)^{1-\sigma} \frac{y_{i,t}}{y_t}, \tag{13}$$

$$\Pi_{i,t}^{1-\sigma} = \sum_j \left(\frac{t_{ij,t}}{P_{j,t}}\right)^{1-\sigma} \frac{y_{j,t}}{y_t}. \tag{14}$$

Equation (12) links intuitively bilateral exports to market size (the first term on the right-hand side) and trade frictions (the second term on the right-hand side). Coined by Anderson and van Wincoop (2003), $\Pi_{i,t}^{1-\sigma}$ and $P_{j,t}^{1-\sigma}$ are the multilateral resistance terms (MRTs, outward and inward, respectively), which consistently aggregate bilateral trade costs and decompose their incidence on the producers and the consumers in each region. 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.[15] On the one hand, the MRTs 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'. On the other hand, by changing output shares in the multilateral resistances, capital accumulation and growth alter the incidence of trade costs in the world.

To solve the 'upper level' dynamic optimization problem for $C_{j,t}$ and $\Omega_{j,t}$, we adapt the methods of Hercowitz and Sampson (1991). As discussed in detail in Heer and Maußner (2009, chapter 1), this specific set-up with logarithmic utility and log-linear adjustment costs has the advantage of delivering a tractable analytical solution. To solve for the policy

[15] The MRTs have been used to perform welfare analysis in a conditional general equilibrium, where output is taken as exogenously given. For example, Anderson and Yotov (2010) use the MRTs to translate changes in the incidence of trade costs (globalization) into changes in real output (acting like TFP changes).

functions of capital we iterate over the value function to obtain (see for details Supplementary Appendix A):

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

Policy function (15) is consistent with rational expectations 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.[16] Alongside parameters, capital stock in period $t+1$ is determined as a function of the prices of domestically produced goods $p_{j,t}$, technology $A_{j,t}$, labor endowments $L_{j,t}$, the current capital stock $K_{j,t}$, and the aggregate consumer price index across all products in the world $P_{j,t}$. Policy function (15) is consistent with rational expectations 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.[17] Alongside parameters, capital stock in period $t+1$ is determined as a function of the prices of domestically produced goods $p_{j,t}$, technology $A_{j,t}$, labor endowments $L_{j,t}$, the current capital stock $K_{j,t}$, and the aggregate consumer price index across all products in the world $P_{j,t}$.

As expected, (15) depicts the direct relationship between capital accumulation and the levels of technology, labor endowment, and current capital stock. More importantly for the purposes of this paper, (15) suggests a direct relationship between capital accumulation and the prices of domestically produced goods and an inverse relationship between capi-

[16] In Supplementary Appendix B we confirm that our results are replicated by the standard dynamic rational expectations solution method Dynare ((Adjemian, Bastani, Juillard, Karamé, Maih, Mihoubi, Perendia, Pfeifer, Ratto, and Villemot, 2011), http://www.dynare.org/). We also use Dynare to solve our model when we allow for the standard linear capital accumulation function in order to demonstrate the robustness of our findings. This analysis is presented in Section 5.2.1, "Linear Capital Accumulation".

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tal accumulation and the aggregate consumer price index $P_{j,t}$.[18] The intuition behind the positive relationship between the prices of domestic goods and capital accumulation is that when faced with higher returns to investment given by the value marginal product of capital $\alpha p_{j,t} A_{j,t} L_{j,t}^{1-\alpha} K_{j,t}^{\alpha-1}$, consumers are willing to give up more of their current income in order to increase future consumption. 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. Hence, a higher share of income will be spent on consumption today and less will be saved and transferred for future consumption via capital accumulation.

The relationships between prices and capital accumulation are crucial for understanding the relationships between growth and trade because changes in trade costs will result in changes in international prices, which will affect capital accumulation. Specifically, the inward multilateral resistance defined in equation (13) consistently aggregates the changes in bilateral trade costs between any possibly pair of countries in the world for a given economy. Thus, intuitively, if a country liberalizes its inward MRT falls and this triggers investment. However, if liberalization takes place in the rest of the world this will result in an increase in the MRTs for outsiders, and therefore lower investment. Equation (15) reveals a direct relationship between factory-gate prices and investment. Similar to the inward MRTs, factory-gate prices consistently aggregate the effects of changes in bilateral trade costs in the world on investment decisions in a given country. The intuition is that when a country opens up to trade producers from this country enjoy lower outward MRT, which, according to equation (11), translates into higher factory-gate prices. Outsiders face higher outward MRT, their factory-gate prices fall, and investment decreases.

Given the policy function for capital, we can easily calculate investment, $\Omega_{j,t}$, consump-

[18] It should be noted that 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.

tion, $C_{j,t}$, and income, respectively, as:

$$\Omega_{j,t} = \left[\frac{p_{j,t}A_{j,t}L_{j,t}^{1-\alpha}\beta\alpha\delta}{P_{j,t}\left(1-\beta+\delta\beta\right)}\right]K_{j,t}^{\alpha} = \left[\frac{\beta\alpha\delta}{1-\beta+\delta\beta}\right]\frac{y_{j,t}}{P_{j,t}}, \tag{16}$$

$$C_{j,t} = \left[\frac{1-\beta+\delta\beta-\beta\alpha\delta}{1-\beta+\delta\beta}\right]\frac{p_{j,t}A_{j,t}L_{j,t}^{1-\alpha}K_{j,t}^{\alpha}}{P_{j,t}} = \left[\frac{1-\beta+\delta\beta-\beta\alpha\delta}{1-\beta+\delta\beta}\right]\frac{y_{j,t}}{P_{j,t}}, \tag{17}$$

$$y_{j,t} = p_{j,t}A_{j,t}L_{j,t}^{1-\alpha}K_{j,t}^{\alpha}. \tag{18}$$

System (16)-(18) reveals that aggregate consumptions and aggregate investment at the 'upper level' are linked to the 'lower level' via the producer and consumer price indexes (MRTs) which consistently aggregate all bilateral trade and trade costs. In addition, the right-hand side expressions in the first two equations reveal that investment and consumption in each period are always a constant fraction of real gross domestic product (GDP). This is due to the log-linear functional form of capital accumulation which enables us to obtain an analytical solution for the policy function of capital.[19]

The combination of the 'lower level' gravity system given in equations (12)-(14), the market clearing conditions given in equation (11), the policy function for capital as given in equation (15), as well as the definition of income as given in equation (1) delivers our

[19] The intuition is that given real GDP at point t, the optimal distribution of income on investment and consumption in t is a constant share, irrespective of what will happen in the future.

theoretical growth and trade model:

$$
\begin{aligned}
x_{ij,t} &= \frac{y_{i,t}y_{j,t}}{y_t}\left(\frac{t_{ij,t}}{\Pi_{i,t}P_{j,t}}\right)^{1-\sigma}, && (19)\\
P_{j,t}^{1-\sigma} &= \sum_i \left(\frac{t_{ij,t}}{\Pi_{i,t}}\right)^{1-\sigma}\frac{y_{i,t}}{y_t}, && (20)\\
\Pi_{i,t}^{1-\sigma} &= \sum_j \left(\frac{t_{ij,t}}{P_{j,t}}\right)^{1-\sigma}\frac{y_{j,t}}{y_t}, && (21)\\
p_{j,t} &= \frac{(y_{j,t}/y_t)^{\frac{1}{1-\sigma}}}{\gamma_j \Pi_{j,t}}, && (22)\\
y_{j,t} &= p_{j,t}A_{j,t}L_{j,t}^{1-\alpha}K_{j,t}^{\alpha}, && (23)\\
K_{j,t+1} &= \left[\frac{p_{j,t}A_{j,t}L_{j,t}^{1-\alpha}\beta\alpha\delta}{P_{j,t}\left(1-\beta+\delta\beta\right)}\right]^{\delta}K_{j,t}^{\alpha\delta+1-\delta}, && (24)\\
K_0 & \quad \text{given.}
\end{aligned}
$$

The beauty of system (19)-(24) is that the universe of bilateral trade linkages are consistently aggregated for each country and they are nested in the 'upper level' capital accumulation framework via the MRTs. Our strategy in the subsequent sections is to translate system (19)-(24) into an econometric model, which we estimate in order to recover the structural parameters of the model (as well as some data), which are needed to perform our counterfactual experiments. Before that, however, we discuss the structural relationships of trade liberalization on growth that our model offers.

3.1 Growth and Trade: A Discussion

To shed light on the relationships between growth and trade, we use system (19)-(24) to trace the effects of a hypothetical trade liberalization scenario, measured as a reduction of bilateral trade costs t_{ij} at some point in time t, e.g. a bilateral free trade agreement between partners i and j. First, the direct (partial-equilibrium) effect of a fall in $t_{ij,t}$ is an immediate increase in bilateral trade between partners i and j at time t without any implications for the rest of the countries. This effect is captured by equation (19) for given output and multilateral resistances.

Second, trade liberalization between countries i and j at time t has an indirect effect on trade flows through the MRTs given in equations (20) and (21). This effect is emphasized by Anderson and van Wincoop (2003). Importantly, a reduction in trade costs between any two countries will affect trade flows between all other country pairs in time t as the MRTs are general equilibrium constructs, which aggregate consistently all bilateral trade costs faced by the producers in a given country as if they ship to a unified world market and all bilateral trade costs faced by the consumer in a given country as if they buy from a unified world market. Hence, those terms capture the third-country effects through trade creation and trade diversion. In particular, opening to trade between countries i and j will translate into lower MRTs (lower resistance for producers and lower prices for consumers) in the liberalizing countries, while producers and consumers in the rest of the world will suffer higher trade resistance.

Third, and most important for the purposes of this paper, trade liberalizations acts on output and capital accumulation via changes in prices in the world. In combination, equations (22)-(23) depict the contemporaneous effects of changes in trade costs on factory-gate prices $p_{j,t}$, and on the value of domestic production/income $y_{j,t}$. Intuitively, equation (22) captures the fact that a lower trade resistance (i.e. a lower outward multilateral resistance) faced by the producers in a liberalizing country translates into higher factory gate prices. The latter will lead to an increase in the value of domestic production/income via equation (23). The opposite happens in outside countries, which now face higher trade resistance. Importantly, these effects are channeled through the outward multilateral resistance, which, as discussed above, means that a change in trade costs between any two countries may affect prices and output in any other country in the world.

Fourth, equation (24) captures the effects of trade liberalization on capital accumulation. These effects are channeled through the factory-gate prices $p_{j,t}$ and through the inward MRTs. A change in trade costs will cause a change in factory-gate prices via equation (22), which will translate into a change in the capital stock via equation (24). As discussed earlier, the relationship between prices of domestically produced goods and capital accumulation is direct. We demonstrate that trade liberalization will result in higher factory-gate prices leading to more investment for the liberalizing countries, and in lower factory-gate prices leading to less investment for outsiders. The relationship between capital accumulation and the inward multilateral resistance $P_{j,t}$ is inverse (see equation (24)). Trade liberalization will lead to lower MRTs followed by more investment in the liberalizing countries, and to higher MRTs followed by lower investment in outside countries. The changes in the MRTs can be viewed as an embedded capital accumulation effect of trade liberalization. In combination, accumulation has elasticity with respect to the terms of trade $p_{j,t}/P_{j,t}$ equal to δ, the depreciation rate.

Finally, we note that the changes in the value of output will have additional (direct and indirect) effects on trade and world prices. The direct, positive effects of output on trade are captured by equation (19). In addition, changes in output will affect trade flows indirectly via changes in the multilateral resistances that are captured by equations (20) and (21). In turn, the changes in the MRTs will lead to additional, third-order changes in output and capital accumulation, and so forth. These effects are essentially identical to the effects of growth on trade in our model, and we discuss those next.

In our model, growth affects trade via two channels, directly and indirectly. The direct effect of growth on trade is strictly positive and it is channeled through changes in country size. An increase in the size of an economy results in more exports and in more imports between this country and all its trading partners. It should be emphasized that the increase in size in member countries may actually stimulate exports from non-members to the extent that these effects dominate the standard trade diversion forces triggered by preferential trade liberalization. We find evidence of that in our counterfactual experiments.

The indirect effect of growth on trade is channeled trough changes in trade costs. In particular, changes in country size translate into changes in the multilateral resistance for a given country, which lead to changes in trade flows. Importantly, the indirect channel through which growth affects trade is a general equilibrium channel, i.e. capital accumulation in one country may affect trade costs and impact welfare in any other country in the world. Our theory reveals that growth in a given country translates into lower sellers' incidence on the producers in this country. In addition, all else equal, the benefits of growth in one country are shared with the rest of the world through lower buyers' incidence in its trading partners.

The finding that growth in one country may affect trade costs and welfare in other countries is an important dynamic result because it unveils a channel through which preferential trade liberalization (e.g. RTA) may benefit non-members. In particular, by making investment more attractive, a RTA will stimulate growth in the member countries. This will lead to lower sellers' incidence for these countries, but also to lower buyers' incidence in non-members. The latter complements the direct positive size effect of member countries on non-member exports that we described above.[20]

3.2 Growth and Trade in the Long-Run

The long-run effects of trade costs on growth are captured by the comparative statics of the steady states. Steady state capital is:

$$K_j = \Omega_j = \frac{\alpha\beta\delta y_j}{P_j(1-\beta+\beta\delta)}, \tag{25}$$

[20] Theory reveals that, in principle, growth due to regional trade liberalization can lead to benefits for outside countries that do not participate in the integration effort. Such effects can not be observed in an aggregate setting such as ours, but are more likely to arise within a multi-sector framework where growth leads to specialization. It should be noted however, that even though we do not observe positive welfare effects in our sample, we do find non-monotonic trade diversion effects and even sum trade creation effects for outside countries, such as Switzerland, Belgium, and Austria, that are magnified by the dynamic forces in our model.

from solving equation (24). Substitute for the factory gate price $p_{j,t}$ in the *Income equation* (23) using the factory gate price equation (22). This yields:

$$y_j = \frac{(y_j/y)^{\frac{1}{1-\sigma}}}{\gamma_j \Pi_j} A_j L_j^{1-\alpha} K_j^{\alpha}.$$

Then solve for y_j:

$$y_j = \left(\frac{A_j L_j^{1-\alpha} K_j^{\alpha}}{y^{\frac{1}{1-\sigma}} \gamma_j \Pi_j} \right)^{\frac{\sigma-1}{\sigma}}.$$

Use this expression to replace y_j in the steady-state capital expression given above. This yields:

$$K_j = \frac{\alpha\beta\delta}{(1-\beta+\delta\beta)\, P_j} \left(\frac{A_j L_j^{1-\alpha} K_j^{\alpha}}{y^{\frac{1}{1-\sigma}} \gamma_j \Pi_j} \right)^{\frac{\sigma-1}{\sigma}}.$$

Solving for K_j leads to:

$$\begin{aligned} K_j &= \left[\frac{\alpha\beta\delta}{(1-\beta+\delta\beta)\, P_j} \left(\frac{A_j L_j^{1-\alpha}}{y^{\frac{1}{1-\sigma}} \gamma_j \Pi_j} \right)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma(1-\alpha)+\alpha}} \\ &= \left(\frac{\alpha\beta\delta}{(1-\beta+\delta\beta)\, P_j} \right)^{\frac{\sigma}{\sigma(1-\alpha)+\alpha}} \left(\frac{A_j L_j^{1-\alpha}}{y^{\frac{1}{1-\sigma}} \gamma_j \Pi_j} \right)^{\frac{\sigma-1}{\sigma(1-\alpha)+\alpha}}. \end{aligned}$$

Define the relative change in variable x as $\hat{x} \equiv x'/x$ where x' is evaluated at some other point on the real line than x. The ratio of steady state capital stocks is

$$\hat{K}_j = \hat{P}_j^{\frac{-\sigma}{\sigma(1-\alpha)+\alpha}} \hat{\Pi}_j^{\frac{1-\sigma}{\sigma(1-\alpha)+\alpha}} \hat{y}^{\frac{1}{\sigma(1-\alpha)+\alpha}}. \tag{26}$$

The change in capital expression (26) is quite intuitive. First, if P_j increases, capital accumulation becomes more expensive and decreases capital because P_j captures the price of investment as well as consumption. Second, increases in sellers' incidence Π_j reduce capital stock K_j. Π_j affects p_j inversely, so the value marginal product of capital falls with Π_j, decreasing the incentive to accumulate capital. Third, as the world gets richer, measured by an increase of world GDP ($\hat{y}$), capital accumulation in j increases to efficiently serve the larger world market.

3.3 Growth and Trade: Sufficient Statistics

In a recent influential paper ACR demonstrate that the welfare effects of trade liberalization in a wide range of trade models can be summarized by the following sufficient statistics: $\hat{W}_j = \hat{\lambda}_{jj}^{\frac{1}{1-\sigma}}$, where $\hat{\lambda}_{jj}$ denotes the share of domestic expenditure.

Stimulated by ACR, we show in Supplementary Appendix C that the change in capital can directly be related to welfare by deriving an extended ACR formula:

$$\hat{W}_j = \widehat{K}_j^{\alpha} \hat{\lambda}_{jj}^{\frac{1}{1-\sigma}}. \tag{27}$$

Equation (27) implies that an increase of steady-state capital will, ceteris paribus, increase welfare. The extended ACR formula given in (27) holds in and out-of steady-state. Furthermore, as demonstrated in Supplementary Appendix C, we can express $\hat{K}_j$ in terms of $\hat{\lambda}$ in steady-state, leading to $\hat{W}_j = \hat{\lambda}_{jj}^{\frac{1}{(1-\alpha)(1-\sigma)}}$. This expression nicely highlights the similarity of introducing capital or intermediates in the steady state (compare with the formulas given in ACR, p. 115). However, in our dynamic framework capital accumulation is the result of an optimized intertemporal choice of consumers and we can trace the resulting transition between two steady-states. Accounting for this transition has important welfare consequences, as (i) the transition takes time and the welfare gains and losses therefore have to be discounted, and (ii) the gains and looses are non-uniformly distributed over time. While it is no longer possible to derive an ACR-like formula when taking into account the transition (see Supplementary Appendix C.2), we will calculate the appropriate welfare effects taking into account the transition in our counterfactual analysis.

To sum up, system (19)-(24) accounts for some important relationships between growth and trade in a particularly simple way. A series of counterfactual experiments demonstrates that our structural approach can disentangle and decompose these relationships. More importantly, system (19)-(24) translates into a self-sufficient econometric model that is intuitive and straightforward to estimate. We illustrate that next.

4 Empirical Analysis

This section demonstrates that our model is straightforward to implement empirically and that it is self-sufficient because it delivers all key parameters needed to perform counterfactuals. We start by translating our structural growth-and-trade model into a very simple and intuitive estimation system that we employ to obtain our own estimates of all key parameters in our framework. Our parameter estimates are compared to standard values from the existing literature to establish the credibility of our methods. An additional advantage of our econometric framework is that it includes as a special case the famous reduced-form growth-and-trade specification from Frankel and Romer (1999), but also expands on it by introducing an additional estimating equation for capital accumulation while highlighting important contributions of our structural approach. Next, we present our estimation strategy and we discuss some econometric challenges. Then, we describe the data and we offer a discussion of our estimates.

4.1 Econometric Specification

Following the expositional development from the theory section, we translate our structural model into an econometric specification in two steps. First, we discuss the estimation of the 'lower level', which governs the evolution of trade flows. Then, we describe the estimation strategy for the 'upper level', where we estimate the equations for income and for capital accumulation.

4.1.1 'Lower Level' Econometric Specification: Trade

We capitalize on the latest developments in the trade literature in the specification and estimation of our 'lower level' trade system (19)-(21). In order to obtain sound econometric estimates of bilateral trade costs and, subsequently, of the multilateral resistances that enter our income and capital equations, we need to address several econometric challenges. First, we follow Santos Silva and Tenreyro (2006) who advocate the use of the Poisson Pseudo-Maximum-Likelihood (PPML) estimator to account for the presence of heteroskedasticity in trade data. Additionally, it allows for zero trade flows. Second, we use time-varying, directional (exporter and importer), country-specific fixed effects to account for the unobservable multilateral resistances. Importantly, in addition to controlling for the multilateral resistances, the fixed effects in our econometric specification also absorb national output and expenditures and, therefore, control for all dynamic forces from our theory. Third, to avoid the critique from Cheng and Wall (2005) that '[f]ixed-effects estimation is sometimes criticized when applied to data pooled over consecutive years on the grounds that dependent and independent variables cannot fully adjust in a single year's time.' (footnote 8, p. 52), we use 3-year intervals.[21] The final step, which completes the econometric specification of our trade system, is to provide structure behind the unobservable bilateral trade costs. To do this, we employ the standard set of gravity variables from the existing literature and we define the power transforms of bilateral trade costs as:

$$
\begin{aligned}
{t_{ij}}^{1-\sigma} \;=\;& \exp\Big[\eta_1 RTA_{ij} + \sum_{m=2}^{5} \eta_m \ln DIST_{ij,m} + \eta_6 BRDR_{ij} + \eta_7 LANG_{ij} + \eta_8 CLNY_{ij} \\
& + \eta_9 SMCTRY_{ij}\Big], \qquad (28)
\end{aligned}
$$

[21] Trefler (2004) also criticizes trade estimations pooled over consecutive years. He uses three-year intervals. Baier and Bergstrand (2007) use 5-year intervals. Olivero and Yotov (2012) provide empirical evidence that gravity estimates obtained with 3-year and 5-year lags are very similar, but the yearly estimates produce suspicious trade cost parameters. Here, we use 3-year intervals in order to improve efficiency, but we also experiment with 4- and 5-year lags to obtain qualitatively identical and quantitatively very similar results.

where, RTA_{ij} is a dummy variable equal to 1 when i and j have formed a RTA and zero elsewhere.[22] The presence or absence of RTAs, and more specifically NAFTA, will be the basis for our counterfactual experiments. While we recognize that trade liberalization is associated with loss of tariff revenues and other economic rents, in order to isolate and focus on the key, dynamic channels in our framework, we abstract from modeling tariff revenues and rents. $\ln DIST_{ij,m}$ is the logarithm of bilateral distance between trading partners i and j. We follow Eaton and Kortum (2002) to decompose the distance effects into four intervals, $m \in \{2, 3, 4, 5\}$. The distance intervals, in kilometers, are: [0, 3000); [3000, 7000); [7000, 10000); [10000, maximum]. $BRDR_{ij}$ captures the presence of a contiguous border between partners i and j. $LANG_{ij}$ and $CLNY_{ij}$ account for common language and colonial ties, respectively. Finally, $SMCTRY_{ij}$ is a dummy variable equal to 1 when $i = j$ and zero elsewhere. $SMCTRY_{ij}$ picks up all relevant forces that discriminate between internal and international trade.

One final econometric consideration that we address is the potential endogeneity of RTAs. The issue of RTA endogeneity is well-known in the trade literature[23] and to address it, we resort to the average treatment effect methods (see for example Wooldridge, 2010) that have proven to be successful in the treatment of RTA endogeneity by Baier and Bergstrand (2007). In particular, we adopt the method from Baier and Bergstrand (2007) and use country-pair fixed effects in order to account for the unobservable linkages between the endogenous RTA covariate and the error term in trade regressions.

Taking all of the above considerations into account, we use PPML to estimate the following econometric specification of the *Trade equation* in our structural system:

$$x_{ij,t} = \exp[\eta_1 RTA_{ij,t} + \chi_{i,t} + \pi_{j,t} + \mu_{ij}] + \epsilon_{ij,t}. \quad (29)$$

Here, $\chi_{i,t}$ denotes the time-varying source-country dummies, which control for the outward

[22] We use all RTAs as notified to the World Trade Organization. The data were augmented and corrected by using information from the RTA secretariat web pages.

[23] See for example Trefler (1993), Magee (2003) and Baier and Bergstrand (2002, 2004).

multilateral resistances and countries' output shares. $\pi_{j,t}$ encompasses the time varying destination country dummy variables that account for the inward multilateral resistances and total expenditure. μ_{ij} denotes the set of country-pair fixed effects that should absorb the linkages between RTA_{ij} and the remainder error term $\epsilon_{ij,t}$ in order to control for potential endogeneity of the former. Importantly, μ_{ij} will absorb all time-invariant gravity covariates from (29) along with any other time-invariant determinants of trade costs that are not observable by the researcher.

In principle, one can use the estimates of the pair fixed effects $\hat{\mu}_{ij}$ to measure international trade costs. However, due to missing (or zero) trade flows, we cannot identify the complete set of bilateral fixed effects. Therefore, in order to construct bilateral trade costs, we adopt a procedure similar to the one from Anderson and Yotov (2011) who propose a two-step method to construct bilateral trade costs, while accounting for FTA endogeneity with pair fixed effects. Applied to our setting, the first step of this method obtains estimates of the country-pair fixed effects μ_{ij} from equation (29). Then, in the second stage, the estimates of the bilateral fixed effects are regressed on the set of standard gravity variables from equation (28):

$$\exp\left(\hat{\mu}_{ij}\right) = \exp\left[\sum_{m=2}^{5}\tilde{\eta}_m \ln DIST_{ij,m} + \tilde{\eta}_6 BRDR_{ij} + \tilde{\eta}_7 LANG_{ij} + \tilde{\eta}_8 CLNY_{ij}\right] + \varepsilon_{ij,t}, \quad (30)$$

where $\varepsilon_{ij,t}$ is a standard remainder error. The estimates from equation (30) are used in combination with actual data on the gravity variables to construct a complete set of power transforms of bilateral trade costs in the absence of RTAs:

$$\left(\widehat{t}_{ij}^{NORTA}\right)^{1-\sigma} = \exp\left[\sum_{m=2}^{5}\hat{\eta}_m \ln DIST_{ij,m} + \hat{\eta}_6 BRDR_{ij} + \hat{\eta}_7 LANG_{ij} + \hat{\eta}_8 CLNY_{ij}\right]. \quad (31)$$

The set of bilateral trade costs that account for the presence of RTAs is constructed from

(29) and (31):

$$\left(\hat{t}_{ij,t}^{RTA}\right)^{1-\sigma} = \exp\left[\hat{\eta}_1 RTA_{ij,t}\right]\left(\hat{t}_{ij}^{NORTA}\right)^{1-\sigma}. \quad (32)$$

Below, we use (32) to study the dynamic general equilibrium effects of NAFTA and globalization on growth and welfare.

4.1.2 'Upper Level' Econometric Specification: Income and Capital

We now turn to the 'upper level', where we estimate the equations for income and for capital accumulation. The former will enable us to obtain estimates of the trade elasticity of substitution and of the labor and capital shares in production. The latter will deliver country-specific estimates of the capital depreciation rates.

Income. We start with the estimating equation for income. Transforming the theoretical specification for income into an estimation equation for growth is straight forward: We substitute equation (22) for prices into equation (23) and we express the resulting equation in natural logarithmic form:

$$\ln y_{j,t} = \frac{1}{\sigma}\ln y_t + \frac{\sigma-1}{\sigma}\ln\frac{A_{j,t}}{\gamma_j} + \frac{(\sigma-1)(1-\alpha)}{\sigma}\ln L_{j,t} + \frac{(\sigma-1)\alpha}{\sigma}K_{j,t} - \frac{1}{\sigma}\ln\left(\frac{1}{\Pi_{j,t}^{1-\sigma}}\right). \quad (33)$$

We keep the expression for the outward multilateral resistance as a power transform, $\ln(1/\Pi_{j,t}^{1-\sigma})$, because we can recover this power term directly from the 'lower level' estimation procedures without the need to assume any value for the trade elasticity of substitution σ. As demonstrated below, our methods also enable us to obtain our own estimate of σ.

Two steps deliver a simple estimation equation for income. First, we introduce year fixed effects ν_t to control for $\frac{1}{\sigma}\ln y_t$, which may be measured with error, and also to control for any other time-varying variables that may affect output in addition to the industry-time varying covariates that enter our specification explicitly. Second, we do not observe $A_{j,t}$ and data on γ_j is not available. To account for the latter, we introduce country fixed effects ϑ_j. The idea is that, in combination with the year fixed effects, the country fixed effects will absorb most of the variability in $A_{j,t}$ in our sample. We sum any residual effects of technology in the error term $\varepsilon_{j,t}$. Hence, equation (33) becomes:

$$\ln y_{j,t} = \kappa_1 \ln L_{j,t} + \kappa_2 K_{j,t} + \kappa_3 \ln\left(\frac{1}{\Pi_{j,t}^{1-\sigma}}\right) + \nu_t + \vartheta_j + \varepsilon_{j,t}. \tag{34}$$

Here, $\kappa_1 = (\sigma - 1)(1 - \alpha)/\sigma$, $\kappa_2 = (\sigma - 1)\alpha/\sigma$, and $\kappa_3 = -1/\sigma$. The estimate of the coefficient on the MRT, $\hat{\kappa}_3$, can be used to recover the trade elasticity of substitution directly as $\hat{\sigma} = -1/\hat{\kappa}_3$.[24] With σ at hand, we can also obtain the capital share of production as $\alpha = \hat{\kappa}_2\sigma/(\sigma - 1) = \hat{\kappa}_2/(1 + \hat{\kappa}_3)$. Finally, our model implies the following structural relationship between the coefficients on the three covariates in (34), $\kappa_1 + \kappa_2 = 1 + \kappa_3$.

In addition to delivering some key parameters, equation (34) highlights two of our main contributions to the literature. First, the introduction of $\ln(1/\Pi_{j,t}^{1-\sigma})$ in equation (34) has implications for the calculations and the analysis of total factor productivity. As discussed in Anderson (2011), a change in the outward multilateral resistance, which measures the incidence of trade costs on producers, can be interpreted as a productivity shock. For example, lower multilateral resistance has positive effects on producers and can be viewed as an increase in productivity. Equation (34) accounts for these effects explicitly and implies that the TFP estimates from empirical specifications that do not control for the influence of trade costs might be biased.

Second, in combination, equations (29) and (34) deliver a structural foundation for the influential reduced-form specification of the relationship between income and trade from Frankel and Romer (1999):

[24] The ability to estimate σ is a nice feature of our model, especially because this parameter is viewed in the literature as the single most important parameter in international trade (see ACR). Furthermore, we will be able to compare our estimates with existing estimates in order to gauge the success of our methods.

$$Trade: \quad x_{ij,t} = \exp[\gamma_1 RTA_{ij} + \gamma_{ij} + \eta_{i,t} + \pi_{j,t}] + \epsilon_{ij,t}, \tag{35}$$

$$Income: \quad \ln y_{j,t} = \kappa_1 \ln L_{j,t} + \kappa_2 K_{j,t} + \kappa_3 \ln\left(\frac{1}{\Pi_{j,t}^{1-\sigma}}\right) + \nu_t + \vartheta_j + \varepsilon_{j,t}. \tag{36}$$

Frankel and Romer (1999) use a version of the *Trade equation* (35) to instrument for international trade, which enters their *Income equation* corresponding to equation (36) directly, to replace our structural term $\ln\left(1/\Pi_{j,t}^{1-\sigma}\right)$. Instead, in our specification the effects of trade and trade costs are channeled via the structural trade term $\ln\left(1/\Pi_{j,t}^{1-\sigma}\right)$. In the empirical analysis below we estimate system (35)-(36) with the original Frankel and Romer methods and with our structural approach.

One final consideration concerning the estimation of system (35)-(36) is that the trade term $\ln(1/\Pi_{j,t}^{1-\sigma})$ in equation (36) is endogenous by construction, because it includes own national income. We eliminate this endogeneity concern mechanically by calculating the multilateral resistances based on international trade linkages only. Specifically, to obtain the incidence that domestic producers face when shipping to foreign markets ($\tilde{\Pi}_{j,t}^{1-\sigma}$), we solve:

$$\tilde{P}_{j,t}^{1-\sigma} = \sum_{\bar{j}} \left(t_{\bar{j}j,t}/\tilde{\Pi}_{\bar{j},t}\right)^{1-\sigma} y_{\bar{j},t}/y_t, \tag{37}$$

$$\tilde{\Pi}_{i,t}^{1-\sigma} = \sum_{\bar{i}} \left(t_{i\bar{i},t}/\tilde{P}_{\bar{i},t}\right)^{1-\sigma} y_{\bar{i},t}/y_t, \tag{38}$$

where $\bar{i}$ and $\bar{j}$ denote all foreign countries, i.e. all countries besides i and j, respectively. This procedure is akin to the methods from Anderson and Yotov (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, aggregating over foreign partners only, $CFB_i = \tilde{\Pi}_{i,t}^{1-\sigma}/\Pi_{i,t}^{1-\sigma}$, where $\Pi_{i,t}^{1-\sigma}$ is the standard, all-inclusive outward multilateral resistance.

Capital. Our theory allows us to go a step further in the econometric modeling of the relationship between trade and growth. Specifically, in addition to offering a structural foundation for the empirical trade-and-income system from Frankel and Romer (1999), we complement it with an additional estimating equation that captures the effects of trade (liberalization) on growth/capital accumulation. Equation (24) translates into a simple log-linear econometric model:

$$Capital: \quad \ln K_{j,t} = \psi_0 + \psi_1 \ln y_{j,t-1} + \psi_2 \ln K_{j,t-1} + \psi_3 \ln P_{j,t-1} + \varsigma_{j,t}, \tag{39}$$

where: $\psi_0 = \delta \ln[(\beta\alpha\delta)/(1-\beta+\delta\beta)]$; $\psi_1 = \delta$ captures the positive relationship between investment and the value of marginal product of capital. As discussed in our theory section, this relationship is driven by the general-equilibrium impact of changes in trade costs on factory-gate prices. $\psi_2 = 1-\delta$ captures the dependence of current on past capital stock; Finally, $\psi_3 = -\delta$ captures the intuitive inverse relationship between capital accumulation and the prices of consumption and investment goods, which also capture the indirect, general-equilibrium effects of changes in trade costs on capital accumulation. Our model implies the following structural relationships between the coefficients on the three covariates in equation (39), $\psi_1 = -\psi_3$ and $\psi_1 = 1-\psi_2$. In addition to delivering a single depreciation parameter δ, equation (39) can be used to estimate country-specific depreciation parameters by interacting each of the terms of the right-hand side with country dummies. We experiment with such specifications in our empirical analysis.

In combination, equations (35), (36), and (39), deliver the econometric version of our structural system of growth and trade:

$$Trade: \quad x_{ij,t} = \exp[\gamma_1 RTA_{ij} + \gamma_{ij} + \eta_{i,t} + \pi_{j,t}] + \epsilon_{ij,t}, \tag{40}$$

$$Income: \quad \ln y_{j,t} = \kappa_1 \ln L_{j,t} + \kappa_2 K_{j,t} + \kappa_3 \ln\left(\frac{1}{\Pi_{j,t}^{1-\sigma}}\right) + \nu_t + \vartheta_j + \varepsilon_{j,t}, \tag{41}$$

$$Capital: \quad \ln K_{j,t} = \psi_0 + \psi_1 \ln y_{j,t-1} + \psi_2 \ln K_{j,t-1} + \psi_3 \ln P_{j,t-1} + \varsigma_{j,t}. \tag{42}$$

System (40)-(42) obtains estimates of the key parameters needed to calibrate our model of trade and growth. We demonstrate below. Before that we describe our data.

4.2 Data

Our sample covers 82 countries over the period 1990-2011.[25] These countries account for more than 98 percent of world production throughout the period of investigation. In order to perform the analysis, we use data on trade flows, GDP, employment, capital and RTAs. In addition, we construct a set of bilateral trade costs with data on the standard gravity variables including distance, common language, contiguity and colonial ties.

Data on GDP, employment, and capital stocks are from the latest edition of the Penn World Tables 8.0.[26] 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* ($CGDP^o$), 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* ($CGDP^{na}$) 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. To do this we multiply the *Number of persons engaged in the labor force* with the *Human capital index*, which is based on average years of schooling. Capital stocks in the Penn World Tables 8.0 are constructed based on cumulating and depreciating past investment using the perpetual inventory method (PIM). For more detailed information on the construction and the original sources for the Penn World Tables 8.0 series see Feenstra,

[25] The list of countries and their respective labels in parentheses includes Angola (AGO), Argentina (ARG), Australia (AUS), Austria (AUT), Azerbaijan (AZE), Bangladesh (BGD), Belarus (BLR), Belgium (BEL), Brazil (BRA), Bulgaria (BGR), Canada (CAN), Chile (CHL), China (CHN), Colombia (COL), Croatia (HRV), Czech Republic (CZE), Denmark (DNK), Dominican Republic (DOM), Ecuador (ECU), Egypt (EGY), Ethiopia (ETH), Finland (FIN), France (FRA), Germany (DEU), Ghana (GHA), Greece (GRC), Guatemala (GTM), Hong Kong (HKG), Hungary (HUN), India (IND), Indonesia (IDN), Iran (IRN), Iraq (IRQ), Ireland (IRL), Israel (ISR), Italy (ITA), Japan (JPN), Kazakhstan (KAZ), Kenya (KEN), Korea, Republic of (KOR), Kuwait (KWT), Lebanon (LBN), Lithuania (LTU), Malaysia (MYS), Mexico (MEX), Morocco (MAR), Netherlands (NLD), New Zealand (NZL), Nigeria (NGA), Norway (NOR), Oman (OMN), Pakistan (PAK), Peru (PER), Philippines (PHL), Poland (POL), Portugal (PRT), Qatar (QAT), Romania (ROU), Russia (RUS), Saudi Arabia (SAU), Serbia (SRB), Singapore (SGP), Slovak Republic (SVK), South Africa (ZAF), Spain (ESP), Sri Lanka (LKA), Sudan (SDN), Sweden (SWE), Switzerland (CHE), Syria (SYR), Tanzania (TZA), Thailand (THA), Tunisia (TUN), Turkey (TUR), Turkmenistan (TKM), Ukraine (UKR), United Kingdom (GBR), United States (USA), Uzbekistan (UZB), Venezuela (VEN), Vietnam (VNM), Zimbabwe (ZWE).

[26] These series are now maintained by the Groningen Growth and Development Centre and reside at http://www.rug.nl/research/ggdc/data/penn-world-table.

Inklaar, and Timmer (2013).

Aggregate trade data are readily available and come from the United Nations Statistical Division (UNSD) Commodity Trade Statistics Database (COMTRADE). The trade data in our sample includes only 5.8 percent of zeroes due to its aggregate nature. Data on RTAs are from the World Trade Organization. Finally, data on the standard gravity variables, i.e., distance, common borders, common language, and colonial ties are from the CEPII's Distances Database.

4.3 Estimation Results and Analysis

4.3.1 Trade Costs

We start with a brief discussion of our estimate of the effects of RTAs, which is obtained from equation (29) with a PPML estimator to account for heteroskedasticity and zero trade, with bilateral fixed effects to control for potential RTA endogeneity, and with exporter-time and importer-time fixed effects to account for the structural MRTs, income, and expenditure shares. Based on this specification, we obtain an estimate of the average treatment effect of RTAs that is equal to 0.827 (std.err. 0.083), which is readily comparable to the corresponding index of 0.76 from Baier and Bergstrand (2007).[27] This gives us confidence to use our estimate of the RTA effects to proxy for the effects of trade liberalization in the counterfactual experiments below.

Next, we discuss the estimates of bilateral trade costs that we obtain from equation (30). We start with a summary of the estimates of the coefficients on the standard gravity covariates. For brevity, we report the estimates directly in the estimating equation:

$$\begin{aligned}\exp(\hat{\mu}_{ij}) = & \exp[-\underset{(0.014)}{\mathbf{0.842}}\ln DIST_{ij,1} - \underset{(0.013)}{\mathbf{0.826}}\ln DIST_{ij,2} - \underset{(0.008)}{\mathbf{0.747}}\ln DIST_{ij,3} - \underset{(0.012)}{\mathbf{0.744}}\ln DIST_{ij,4}] \\ & \times \exp[\underset{(0.232)}{\mathbf{0.515}}\ BRDR_{ij} + \underset{(0.193)}{\mathbf{0.836}}\ LANG_{ij} + \underset{(0.202)}{\mathbf{0.208}}\ CLNY_{ij}], \qquad (43)\end{aligned}$$

[27] Our PTA estimate suggest a partial equilibrium increase of 129% $(\exp(0.827)-1)$ in bilateral trade flows among member countries.

where the coefficient estimates are reported in bold-face in front of the variables, and the corresponding robust standard errors are in parentheses below them. As can be seen from equation (43), all coefficient estimates have the expected signs and reasonable magnitudes. We find that distance is a strong impediment to trade. All distance estimates are significant at any conventional level. In addition, we find that the largest estimate (in absolute value) is for the shortest distance interval. This is in accordance with the results from Eaton and Kortum (2002). Contiguous borders and common language promote international trade. The estimates on $BRDR$ and $LANG$ are positive, large, statistically significant and comparable to estimates from the existing literature. The estimate of the coefficient on $CLNY$ is positive but it is not statistically significant. This result is consistent with the sectoral findings from Anderson and Yotov (2011) and suggests that colonial ties no longer play such an important role in promoting international trade. Overall, we find the gravity estimates from equation (43) to be plausible, and we are comfortable using them to construct bilateral trade costs for our counterfactuals below.

We employ the estimates from equation (43) together with data on the gravity variables to construct a complete set of bilateral trade costs $\{\hat{t}_{ij}^{1-\sigma}\} = \widehat{exp(\hat{\mu}_{ij})}$, where $\widehat{exp(\hat{\mu}_{ij})}$ is the predicted value from equation (43), which are used in our counterfactual experiments. Without going into details, we briefly discuss several properties of the bilateral trade costs, which are constructed as $\hat{t}_{ij} = \widehat{exp(\hat{\mu}_{ij})}^{1/(1-\sigma)}$ and we use a conventional value of the trade elasticity of substitution, $\sigma = 6$. First, without any exception and in accordance with theory, all estimates of $\hat{t}_{ij}$ are positive and greater than one. Second, we find that the estimates of the bilateral fixed effects vary widely but intuitively across the country pairs in our sample. For example, we obtain the lowest estimates of $\hat{t}_{ij}$ for countries that are geographically and culturally close and economically integrated. The smallest estimate of bilateral trade costs is for the pair Belgium-Netherlands (1.796). On the other extreme of the spectrum, we obtain very large estimates of $\hat{t}_{ij}$ for countries that are isolated economically and geographically. The largest estimate is for the pair Singapore-Ecuador (4.352).

Finally, we construct internal trade costs as the product between internal distance and the estimates on the coefficient on $\ln DIST_{ij,1}$.[28] While not central for our dynamic analysis and main results, our treatment of internal trade costs improves on the standard approach in the literature, where countries are point masses. Specifically, (i) we allow for *positive* internal trade costs, and (ii) we allow for *country-specific* internal trade costs. Overall, we view our estimates of bilateral trade costs as convincing and we are confident in using them to construct the multilateral resistances and to perform counterfactual experiments.

4.3.2 Income

Next, we turn to the 'upper level' and we estimate our *Income equation*:

$$\ln y_{j,t} = \kappa_1 \ln L_{j,t} + \kappa_2 \ln K_{j,t} + \kappa_3 \ln \left(\frac{1}{\tilde{\Pi}_{j,t}^{1-\sigma}} \right) + \nu_t + \vartheta_j + \varepsilon_{j,t}. \tag{44}$$

Here, following the discussion in Section 4.1.2, the multilateral resistances are constructed according to system (37)-(38) in order to account for potential endogeneity.

Estimates from various specifications of equation (44) are reported in Table 1. All specifications include year fixed effects and country fixed effects and we report robust, bootstrapped standard-errors where generated regressors are included in our specifications, i.e. in columns (2) and (3) of Table 1. In column (1) of the table, we offer results from a standard constrained estimation of the Cobb-Douglas production function.[29] As can be seen from the table, both the labor and the capital shares have reasonable magnitudes and are within the theoretical bound [0; 1]. This suggests that our sample is representative.

In column (2) of Table 1 we introduce as an additional regressor the original Frankel and Romer variable $\ln \sum_{j \neq i} \hat{x}_{ij}$, which is the predicted value of total exports for each coun-

[28] $\ln DIST_{ij,1}$ is based on the smallest distance interval in our sample and all internal distances fall within this interval. Consistent with the measure of international distance, internal distance is constructed as a population weighted average of the bilateral distances between the cities within each country. For further details see CEPII's Distances Database.

[29] In Supplementary Appendix D in Table A1 we report unconstrained results from all specifications that we present in this section. Our sensitivity estimates are qualitatively identical and quantitatively very similar to the main, constrained results from Table 1.

try. Following Frankel and Romer (1999), we obtain $\ln \sum_{j \neq i} \hat{x}_{ij}$ from a first-stage gravity regression as given in equation (40). In accordance with the results from Frankel and Romer (1999), the estimates from column (2) suggest that the effect of trade on income/growth is positive and statistically significant.

In column (3), we replace the reduced-form Frankel and Romer specification with our structural model. Several properties stand out. First, without any exception, all estimates from column (3) of Table 1 have expected signs and are statistically significant at any conventional level. Second, using these estimates and applying the structural restrictions of our model, in the bottom panel of the table we recover an estimate of 0.550 (std.err. 0.041) for the capital share α. Third, similar to Frankel and Romer (1999), we find that trade openness leads to higher income/growth. This is captured by the negative and significant estimate of the coefficient of our inverse theoretical measure of trade openness $\ln\left(1/\widehat{\tilde{\Pi}_{j,t}^{1-\sigma}}\right)$. Finally, we capitalize on the structural properties of our model to recover the a plausible estimate of the trade elasticity of substitution. In particular, we obtain a value of $\hat{\sigma} = -1/\hat{\kappa}_3 = 5.100$ (std.err. 0.804), which satisfies the theoretical restriction that the trade elasticity should be greater than one and falls comfortably within the distribution of the existing (Armington) elasticity numbers from the trade literature, which usually vary between 2 and 12 (see the references in footnote 12).

We proceed with two sensitivity experiments. For brevity, we report the estimation results from these experiments in Supplementary Appendix D, and here we just discuss our findings. First, in column (1) of Table A2 we allow capital shares to vary over time. The intuition is that capital shares have increased steadily over the past quarter century and our data should reflect that. In accordance with that, we find that the average capital shares in our sample have increased from 0.391 (std.err. 0.114) during the 1990s to 0.603 (std.err. 0.061) during the 2000s. Next, in column (2) of Table A2 we distinguish between capital shares in poor versus rich countries. We define rich countries as those with income above the median income in each year of our sample. In accordance with our expectations, we find that production in rich countries is more capital intensive than in poor countries. Specifically, we estimate a statistically significant difference of 16 percentage points between the capital shares of the two groups of countries.

Overall, we view the parameter estimates of the capital share α and of the elasticity of substitution σ that we obtain in this section as plausible and we are comfortable using them to perform counterfactual experiments.

4.3.3 Capital

We proceed with estimation of our capital accumulation specification:

$$\ln K_{j,t} = \psi_0 + \psi_1 \ln y_{j,t-1} + \psi_2 \ln K_{j,t-1} + \psi_3 \ln P_{j,t-1} + \varsigma_{j,t}. \tag{45}$$

Equation (45) will enable us to recover capital depreciation rates (δ's) subject to the following relationships: $\psi_1 = \delta$; $\psi_2 = 1 - \delta$; and $\psi_3 = -\delta$. Our main estimation results are encouraging:[30]

$$\ln K_{j,t} = \underset{(0.006)}{\mathbf{0.052}} \ln y_{j,t-1} + \underset{(0.006)}{\mathbf{0.948}} \ln K_{j,t-1} - \underset{(0.006)}{\mathbf{0.052}} \ln P_{j,t-1}. \tag{46}$$

First, the estimates of the three covariates are all significant and with expected signs. In addition, they imply a reasonable value for $\delta = 0.052$ (std.err. 0.006). Importantly, the estimate of the coefficient on the trade term $\ln P_{j,t-1}$ is negative and statistically significant, which, in accordance with our theory, implies a negative relationship between investment and the change in investment costs due to trade. Finally, we obtain a positive and significant estimate of the coefficient on the value of output which, as suggested by our model, captures the positive relationship between the value of marginal product of capital and investment.

In our next experiment, we use equation (45) to obtain country-specific depreciation

[30] Coefficient estimates are reported in bold-face in front of the variables, and the corresponding robust, bootstrapped standard errors are in parentheses below them.

rate estimates δ_i's. To do this, we interact each of the three covariates on the right-hand side of equation (45) with country dummies, and we impose the theoretical constraints of our model. The resulting country-specific estimates are reported in column (6) of Table 4. Two properties stand out. First, without any exception and in accordance with theory, all estimates of δ are positive but smaller than one. Second, the estimates vary significantly but within reasonable bounds, ranging between 0.03 (std.err. 0.005), for China, and 0.161 (std.err. 0.016), for Zimbabwe.

According to our theory, the change in the value of marginal product of capital is driven by changes in factory-gate prices in response to trade liberalization. Since consistent international data on factory-gate prices are not available, in our next experiment we attempt to draw inference for their effects as a residual impact after we control for all other factors that affect investment in our model. Specification (46) already controls for the effects of capital and trade via the multilateral resistances. In addition, we use year and country fixed effects in order to capture differences in technology and other country and time specific unobservables. Thus, we may identify the effects of prices by isolating the impact of labor on capital accumulation from the value of output in specification (46). Results from a constrained and an unconstrained version of specification (46), where labor is added as an additional covariate, are reported in Table A3 of Supplementary Appendix D. The estimates of all variables are highly statistically significant and with expected signs in both specifications. We obtain positive and significant estimates of the effects of labor, which are expected. More importantly, we find that the estimate of the coefficient on $\ln y_{j,t-1}$ remains positive and statistically significant, which is consistent with our theory.

In summary, this section demonstrated that our theoretical model translates into a very simple and intuitive estimation system that is straightforward to implement empirically. Importantly, we were able to obtain plausible estimates for all but one of the parameters that we need for our counterfactual experiments and analysis. The single parameter for which we did not obtain our own indexes, and which we have to borrow from the literature, is the consumer depreciation rate. Minimum values, maximum values, and (when appropriate) standard errors for each of the parameters in our model are reported in Table 2.

Overall, we are encouraged by our empirical results and we are comfortable using the estimated parameters to perform the counterfactual experiments that we present next.

5 Counterfactual Experiments

In order to highlight our contributions in relation to the existing literature and to demonstrate the usefulness of our methods, we perform a series of counterfactual experiments. First, we study the effects of trade liberalization on growth. To do this, we estimate the effects of the North American Free Trade Agreement (NAFTA) and we investigate the effects of a fall in international trade costs for all countries, i.e., a globalization scenario. Next, we study the effects of growth on trade by simulating the effects of a 20% change of the capital stock in the United States. Finally, we perform a series of sensitivity experiments where we employ a different functional form for capital accumulation, allow for intermediate goods, and use alternative values for the parameters in our model.

To perform the counterfactual experiments, we use observed data on labor endowments ($L_{j,t}$) and GDPs ($y_{j,t}$) for our sample of 82 countries. In addition: (i) we construct trade costs $t_{ij,t}$ from our estimates according to equation (32); (ii) we recover theory-consistent, steady-state capital stocks according to the capital accumulation equation (25); (iii) we calculate baseline preference-adjusted technology A_j/γ_j according to the market-clearing equation (22) and the production function equation (23).[31] Finally, to obtain the main results, we use our own estimates of the elasticity of substitution $\hat{\sigma} = 5.1$, the share of capital in the Cobb-Douglas production function $\hat{\alpha} = 0.55$, and the capital depreciation rate $\hat{\delta} = 0.052$ as summarized in Table 2. The consumers' discount factor is set equal to $\beta = 0.98$, which is standard in the literature. See Supplementary Appendix E for further details on our counterfactual setup and procedures.

[31] Supplementary Appendix E offers a detailed description of our counterfactual setup and procedures.

As discussed earlier, our parameter estimates are readily comparable with corresponding values from existing studies. This is already an improvement beyond the standard approach of borrowing key parameters from the literature. However, in addition, our framework offers a unique opportunity to validate the performance of our model before using it for policy evaluation counterfactuals.[32] To further validate our procedures, we compare our calculated theory-consistent, steady-state capital stocks with the observed capital stocks from the Penn World Tables 8.0. Figure 1 reports our findings. The figure depicts a strong linear correlation between the theory-consistent stock of capital and the actual capital stock data. The correlation coefficient is 0.98. This is encouraging evidence in support of our model.

5.1 The Effects of Trade Liberalization and Globalization

In our main counterfactual experiment, we apply our framework to NAFTA, which is one of the most heavily investigated trade agreements. The effects of NAFTA have been the focus of numerous studies but, to our best knowledge, we are the first to offer structural estimates of the dynamic effects of NAFTA.[33] In order to demonstrate how our approach

[32] Ottaviano (2014) notes that "validation of calibrated models before simulating them has increasingly gone missing as recent works tend to favor the implementation of 'exactly identified' [New Quantitative Trade Models]...Validation requires the calibrated model to be able to match other moments of the data different from those used for calibrating. Simulation of counterfactual scenarios can be reasonably performed only if the calibrated model passes the validation checks." (pp. 3-4).

[33] For instance Krueger (1999), Lederman, Maloney, and Servén (2005), Romalis (2007), Trefler (2004, 2006), Anderson and Yotov (2011) and Caliendo and Parro (2012). Krueger (1999) finds in here gravity analysis an increase of trade among NAFTA members of 46%. Lederman, Maloney, and Servén (2005) provide a detailed summary of many studies and find in their own gravity based estimates effects on trade flows of NAFTA of about 40%. They also conclude that the bulk of the rise in trade as a consequence of NAFTA is due to income effects, both static and dynamic through capital accumulation. Romalis (2007) finds trade effects within NAFTA of up to nearly 30%, while the resulting welfare effects are small. Trefler (2004, 2006) highlights the short- and long-run effects of the Canada-United States Free Trade Agreement, showing that low-productivity plants reduced employment by 12% while industry level labor productivity was increased by 15%. Overall, the Canada-United States Free Trade Agreement was welfare-enhancing according to a simple welfare analysis undertaken. Anderson and Yotov (2011) offer static general equilibrium analysis of the effects of NAFTA. They find a 6% increase in the real GDP for Mexico and small (less than 1%) positive welfare effects for Canada and USA. Caliendo and Parro (2012) find the largest increase in exports and imports for Mexico (up to 14%), followed by the United States and Canada. The welfare effects, measured by real wages, were positive in all NAFTA countries, with Mexico having the largest gains of up to 1.5%. There is also a related evaluation of the effects of NAFTA in the computational general equilibrium literature,

builds on previous work, we implement the counterfactual experiments in four steps. First, we obtain the partial equilibrium NAFTA effects. We label this scenario "Direct Effects" and it corresponds to the Partial Trade Impact (PTI) effects from Head and Mayer (2014). Next, we estimate General Equilibrium (GE) NAFTA effects on members and non-member countries via changes in trade costs, which are channeled through the MRTs (19)-(21) at constant GDPs. We label this scenario "Conditional GE" and it corresponds to the Modular Trade Impact (MTI) effects from Head and Mayer (2014). Third, we allow for static GDP changes in response to formation in NAFTA. We label this scenario "Full Static GE" and it corresponds to the General Equilibrium Trade Impact (GETI) effects from Head and Mayer (2014). Finally, we turn on the capital accumulation channel developed in this study to estimate the effects of NAFTA in a "Full Dynamic GE" scenario.

We report estimates of the NAFTA effects on welfare in Table 3.[34] In each case, the indexes measure percentage changes due to the implementation of NAFTA. The first column lists country names. The next three columns report the NAFTA effects on welfare. Column (2) reports "Conditional GE" effects, where we account for trade diversion via price changes due to changes in the MRTs, however, we take GDPs as exogenous. Several findings stand out. First, we estimate large gains for NAFTA members. Canada experiences the largest gains, with an increase of real GDP per capita of about 15%. Mexico's welfare increases by about 9%, while USA enjoys only modest welfare gains of 0.8%. These numbers are in line with previous studies.[35]

Second, we obtain negative NAFTA effects for all other countries in the world. Trade

see for example McCleery (1992), Klein and Salvatore (1995), Brown, Deardorff, and Stern (1992a,b), Fox (1999), Kehoe (2003), Rolleigh (2013) and Shikher (2012).

[34] Further details of the effects of NAFTA on trade flows, the multilateral resistances, and the capital effects can be found in Table A4 in Supplementary Appendix F. Since the direct effects of NAFTA on bilateral trade are confined to members only, we note that according to our estimates NAFTA will increase members' trade by 129% and we devote the analysis in this section to the GE effects of NAFTA.

[35] One would expect smaller effects for Canada as compared to Mexico because many of the gains from trade between Canada and the US have 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, where we can estimate differential partial equilibrium effects of NAFTA across member countries. However, we chose to use a common estimate of the direct NAFTA effect in order to emphasize the methodological contribution of our framework by comparing results across alternative scenarios.

diversion is the natural explanation for this result. The negative effects on non-member countries are small (less than 1%, except for Guatemala with -1.2%). The largest losses are predicted for Latin American countries that are in close geographic proximity and large economic interdependence with the NAFTA members. As demonstrated in the bottom panel of Table 3, we find that on average non-NAFTA members will suffer a -0.22% decrease in welfare. In combination with the relatively strong effects for members (about 2.6% on average), this offers encouraging evidence in support of trade liberalization. Finally, we estimate a net-effect of 0.56% for the world as a whole. Given our assumption of exogenous output in this scenario, the positive effects for the world measure the efficiency gains due to the decrease in the overall trade cost bill.[36]

In column (3) of Table 3, we report estimates from the "Full Static GE" scenario, which allows for responses of factory-gate prices due to the formation of NAFTA. Moving from the "Conditional GE" to the "Full Static GE" scenario, we see a doubling of the positive welfare effects for all NAFTA members. Most of these additional gains are for the 'producers' in NAFTA members. The intuition is that changes in factory-gate prices due to NAFTA enter directly in our calculation of real GDP in the "Full Static GE" scenario, while the effects on consumers are constructed as a weighted average among all delivered prices in the world.[37] The large positive welfare effects for NAFTA members in this scenario are comparable to estimates from related studies (see Caliendo and Parro, 2012; Anderson and Yotov, 2011).

Turning to the effects on non-member countries, we find that the additional general equilibrium forces in this scenario lead to larger losses for non-members, however, the losses are still very small. The only three countries for which we obtain losses that are larger than one percent are Argentina, Guatemala, and Venezuela. Overall, our results indicate significant additional general equilibrium effects when moving from the "Conditional GE"

[36]In a similar setting, Anderson and Yotov (2011) provide a theoretical foundation for the interpretation of the effects of trade agreements as efficiency gains by extending the iceberg trade cost metaphor to the multilateral level.

[37]We can demonstrate that the real GDP changes are mostly driven by factory-gate price changes, while the changes in the multilateral resistances are in the expected direction but are relatively small.

to the "Full Static GE" scenario. However, similar to the conditional effects, we find that the additional effects in the "Full Static GE" are large and positive for members (about 2.5 percentage points on average) and negative, but small for non-members (about 0.15 percentage points on average).

Column (4) of Table 3 reports estimates from our "Full Dynamic GE, SS" scenario, which captures the additional NAFTA effects on trade via capital accumulation by comparing the initial steady-state with the new steady-state, where all capital is fully adjusted to take into account the introduction of NAFTA. Focusing on the NAFTA countries, we see doubling of the NAFTA effects on welfare via the dynamic capital accumulation forces in our framework. The additional dynamic gains are on average almost 6 percentage points. The dynamic effects on non-members are negative, but small in absolute value and also small as a percentage change of the static effects. Overall, the estimates from column (4) reveal significant additional benefits for members on average (about 5.7 percentage points), small additional negative effects for non-members (1.3 percentage points), and an overall efficiency gain for the world of 2.7 percentage points.

Thus far, we follow the standard in the trade literature to measure welfare as real GDP (see ACR for example). However, our dynamic capital-accumulation framework requires an alternative approach to measure welfare effects for the following reasons: (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.[38] (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 of aggregate consumption in each year λ

[38] Given our closed-form solution of the policy function for capital and an initial capital stock K_0, this boils down to solving our system given by equations (19)-(24) for all countries at each point of time. Alternatively, we used Dynare (http://www.dynare.org/) and the implied first-order conditions of our dynamic system to solve the transition path. Both lead to identical results. For further details on the calculation of the transition see Supplementary Appendix 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. Specifically, we calculate:

$$\sum_{t=0}^{\infty} \beta^t \ln(C_{j,t,c}) = \sum_{t=0}^{\infty} \beta^t \ln\left[\left(1+\frac{\lambda}{100}\right) C_{j,t}\right] \Rightarrow$$
$$\lambda = \left(\exp\left[(1-\beta)\left(\sum_{t=0}^{\infty} \beta^t \ln(C_{j,t,c}) - \sum_{t=0}^{\infty} \beta^t \ln(C_{j,t})\right)\right] - 1\right) \times 100. \qquad (47)$$

Properly discounted welfare effects are reported in column (5) labeled "Full Dynamic GE, trans." of Table 3. As expected, the dynamic welfare effects on member and non-member countries are smaller as compared to the welfare changes from column (4). Importantly, they are still significantly larger as compared to the "Full Static GE" effects from column (3). Specifically, the discounted dynamic effects increase the welfare for NAFTA members by more than 2.6 percentage points. The negative effects of non-members increase by only 0.06 percentage points.

An important feature of our work is the ability to characterize the effects of trade liberalization on capital accumulation and the transition between steady states. We capitalize on that in Figure 2. The figure depicts the transition path for capital stocks in four countries from our sample. These countries include all NAFTA members plus Guatemala. The latter is chosen because, according to our model, this is the outside country that experiences the strongest negative impact of NAFTA.

Figure 2 reveals the following. First, we find that the effects on members are large and long-lived. The largest effect of 60 percent increase in capital stock is for Canada, followed by 33 percent for Mexico and 4 percent for US.[39] As expected, most of the dynamic gains accrue initially. However, we estimate significant transitional dynamic gains more than a 100 years after the formation of NAFTA. Second, our results suggest that the transitional effects on non-members are small and relatively short-lived. On average we find that capital stock

[39]The large increase in the capital stock for Canada is explained similarly as the large welfare gain for that country (see footnote 35).

in the non-member countries would have been about 0.5 percent lower without NAFTA, ranging between -1.99 percent for Guatemala to -0.08 percent for Switzerland.[40] According to Figure 2, the negative effects on Guatemala vanish about 50 years after the implementation of NAFTA. However, we estimate that on average non-members reach a new steady-state after about 10 years after the formation of NAFTA. In combination, the large and long-lived dynamic effects of NAFTA for members and the small and relatively short-lived effects for on-members constitute encouraging evidence in support of trade liberalization and integration efforts.

In order to shed further light on the effects of trade on growth, we supplement our NAFTA estimates with estimates of a number of the growth effects of globalization. We therefore increase our estimates of $\widehat{t_{ij}^{1-\sigma}}$ for all $i \neq j$ by 38%, which is the estimate of the effects of globalization over a period of 12 years from Bergstrand, Larch, and Yotov (2013).[41] Results capturing the effects of globalization from the four scenarios in columns (2)-(5) are presented in columns (6)-(9) of Table 3. Several findings stand out. First, without exception, all countries in the world benefit from globalization. Intuitively, through lowering trade costs globalization improves efficiency in the world, and since bilateral trade costs decrease for every country, the efficiency gains are shared among all countries too. Second, the benefits vary across countries. We find that the biggest will be relatively small countries in close proximity to large markets. For example, we find that Canada and Mexico are always among the big winners in each of the scenarios. Third, comparison between the "Full

[40] The net negative effect on non-members is the result of three forces: i) Trade diversion due to NAFTA leads to increased trade resistance which translates into higher producer and consumer prices in the non-member countries; ii) At the same time, improved efficiency in NAFTA members would lead to trade creation between NAFTA and non-NAFTA members and lower the consumer prices in the latter; iii) Finally, larger income in NAFTA members will lead to more imports for those countries from all other countries in the world. The fact that we obtain negative net effects of capital accumulation in all our non-member countries reveals that the first, trade diversion, effect dominates the latter two, trade creation, effects. In principle, it is possible for the trade creation effect to dominate the negative impact of trade liberalization. For example, using sectoral-level data in an endowment setting Anderson and Yotov (2011) offer evidence of decreasing consumer prices in outside countries due to trade liberalization and specialization. The dynamic channels in our framework could magnify these specialization effects which points to the benefits of extending our framework to the sectoral-level. We leave this valuable extension for future work.

[41] With our estimated σ of 5.1, this corresponds to a decrease of t_{ij} by 7.56% for all $i \neq j$.

Static GE" scenario and the "Conditional GE" scenario reveal that the additional general equilibrium forces in the "Full Static GE" case lead on average to doubling of the gains. Finally, we estimate strong dynamic effects of globalization. The "Full Static GE" gains double in the "Full Dynamic GE, SS" scenario, and they increase by more than 50% in the dynamic scenario which takes the transition into account and discounts.

5.2 Alternative Specifications and Robustness Analysis

In this subsection we provide various robustness checks to our dynamic welfare effects presented for NAFTA. In our first experiment, we replace the convenient log-linear capital accumulation function by the more standard linear counterpart. Then, we investigate an exogenous increase of the capital stock for the USA. Third, we extend our framework to allow for intermediate goods. Finally, we experiment with different values for the key parameters in our model including country-specific depreciation rates, followed by alternative values for the elasticity of substitution, and the capital share.

5.2.1 Linear Capital Transition Function

The nice tractability feature of obtaining a closed-form solution for the effects of trade (openness) on capital accumulation in our framework depends crucially on the assumption of a log-linear transition function for capital. In this section, we study the limitations of this assumption by replacing the log-linear capital transition function with the standard linear capital transition function:

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

We retain all other assumptions in our model to derive the following trade and growth system:[42]

$$
\begin{aligned}
x_{ij,t} &= \frac{y_{i,t} y_{j,t}}{y_t} \left(\frac{t_{ij,t}}{\Pi_{i,t} P_{j,t}} \right)^{1-\sigma}, && (48)\\
P_{j,t}^{1-\sigma} &= \sum_i \left(\frac{t_{ij,t}}{\Pi_{i,t}} \right)^{1-\sigma} \frac{y_{i,t}}{y_t}, && (49)\\
\Pi_{i,t}^{1-\sigma} &= \sum_j \left(\frac{t_{ij,t}}{P_{j,t}} \right)^{1-\sigma} \frac{y_{j,t}}{y_t}, && (50)\\
p_{j,t} &= \frac{(y_{j,t}/y_t)^{\frac{1}{1-\sigma}}}{\gamma_j \Pi_{j,t}}, && (51)\\
y_{j,t} &= p_{j,t} A_{j,t} L_{j,t}^{1-\alpha} K_{j,t}^{\alpha}, && (52)\\
\frac{1}{C_t} &= \frac{\beta}{C_{t+1}} \left(\frac{\alpha y_{t+1}}{K_{t+1} P_{t+1}} + 1 - \delta \right), && (53)\\
K_0 & \quad \text{given.}
\end{aligned}
$$

Two main features of the new system stand out. First, the only difference between systems (48)-(53) and (19)-(24) is equation (53), which replaces the closed-form solution (24) for the link between trade and capital accumulation in the original system. Second, as expected, equation (53) no longer represents an analytical expression for next period capital stocks, but rather an implicit relationship that determines consumption. In fact, (53) is the standard consumption Euler-equation, where we have a set of three forward-looking endogenous variables for each country $\{y_t$, C_t, and $P_t\}$.[43]

System (48)-(53) no longer lends itself to the iterative method that we used to perform the counterfactuals of interest. Therefore, we rely on Dynare, which is a standard tool to solve dynamic stochastic general equilibrium (DSGE) and overlapping generations (OLG) models.[44] For consistency with the main analysis, we employ the same data and parameters to simulate the effects of NAFTA once again.[45] To demonstrate the changes due to the new

[42]Detailed derivation steps appear in Supplementary Appendix G.
[43]K_{t+1} is determined in t and therefore not a forward-looking variable.
[44]For further details see http://www.dynare.org/.
[45]Note that (48)-(53) implies that the estimating equations for trade and output remain unchanged.

capital accumulation function, we first focus on the transition of capital stocks. Figure 3 contrasts the transition paths for the four countries that we presented in Figure 2, obtained with the log-linear transition functions, against the corresponding transitions functions for the same countries but this time obtained with the linear capital transition function.

Figure 3 reveals the following. Overall, the effects are similar. Two differences stand out. First, the capital accumulation effects generated with the linear transition function are more pronounced immediately after the implementation of NAFTA both for member and for non-member countries. Second, the linear capital accumulation function implies that the dynamic effects of NAFTA are exhausted a bit faster. For example, we see that for Canada the system with the linear capital transition function converges about 115 years after NAFTA, while the system with the log-linear capital accumulation converges in about 150 years.

While the quantitative effects on transition of capital seem different, we hardly find any difference between the welfare effects obtained with the linear versus the log-linear capital transition function. The welfare effects from both cases are reported in Table 4. In the first column we give the country names, the second column reproduces the welfare results from our base-line "Full Dynamic GE, transition" scenario (column (5) of Table 3). The welfare results for the case with the linear capital accumulation function are reported in column (3). Comparing columns (2) and (3) reveals that the welfare effects are qualitatively identical and quantitatively very similar for the case with our analytical tractable log-linear capital transition function and the more standard linear one. For example, the predicted welfare increases for NAFTA members change from 7.671% in the log-linear case to 7.669% in the linear case, while the ones for the non-members change from -0.423% to -0.403%, respectively.

Therefore, our estimates of the RTA effects, of trade costs, t_{ij}, of the capital share α, and of the elasticity of substitution σ can be estimated as before and remain unchanged. The only parameter that we can no-longer estimate is the capital depreciation rate δ. However, since our estimate of $\delta = 0.05$ is plausible, we retain it in the robustness experiment.

5.2.2 Exogenous Growth

The main mechanism that leads to dynamic effects in our framework is through capital accumulation. We therefore want to highlight how an exogenous change in the initial stock of capital influences trade and welfare of countries in our framework. In order to demonstrate the capital accumulation channel, we investigate how the effects of NAFTA will change if in the presence of NAFTA the capital stock in the USA would be 20% larger.

The welfare results for the scenario of the increase of the USA capital stock of 20% are presented in column (4) of Table 4. First, as we would have expected, the largest increase in welfare is seen in the USA: if the conclusion of NAFTA would be accompanied by a 20% increase of the capital stock in the USA, welfare in the USA would increase by about 6.6%. The difference between the base-line given in column (2) is about 4 percentage points. All other countries gain as well. In particular, the positive effects of NAFTA on Canada and Mexico are magnified, while the negative effects on all other countries in the world are diminished. Note that these large effects for the USA itself and the relatively small positive effects for the other countries fade only slowly over time.

In sum, we see that the capital accumulation is important for the level, but even more so for the persistence of welfare effects over time. The spill-over effects are relatively small, but the persistence of the spill-over effects is large.

5.2.3 Intermediate Goods

Intermediate inputs represent more than half of the goods imported by the developed economies and close to three-quarters of the imports of some large developing countries, such as China and Brazil (Ali and Dadush, 2011). International production fragmentation and international value chains are less pronounced in some sectors, such as agriculture (Johnson and Noguera, 2012), but extreme in others, e.g. high tech products such as computers (Kraemer and Dedrick, 2002), iPods (Varian, 2007) and aircrafts (Grossman and Rossi-Hansberg, 2012). Trade models recognize the important role of intermediate goods for production and trade and introduce intermediates within static settings.[46] In this section we contribute to the related literature by studying the implications of intermediate goods for the relationship between growth and trade within our dynamic framework.

To introduce intermediates within our aggregate framework, we follow the approach of Eaton and Kortum (2002) and we assume that intermediate inputs are combined with labor and capital via the following Cobb-Douglas-production function:[47]

$$y_{j,t} = p_{j,t} A_{j,t} K_{j,t}^{\alpha} L_{j,t}^{\xi} Q_{j,t}^{1-\alpha-\xi} \quad \alpha, \xi \in (0,1), \tag{54}$$

where, $Q_{j,t} = \left(\sum_i \gamma_i^{\frac{1-\sigma}{\sigma}} q_{ij,t}^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}}$ is the amount of intermediates used in country j at time t defined as a CES aggregator of domestic components ($q_{jj,t}$) and imported components from all other regions $i \neq j$ ($q_{ij,t}$).

Following the steps from our theoretical analysis in Section 3, we obtain the following system that describes the relationship between growth and trade in the presence of intermediate inputs:[48]

$$\begin{aligned}
x_{ij,t} &= \frac{y_{i,t} y_{j,t}}{y_t} \left(\frac{t_{ij,t}}{\Pi_{i,t} P_{j,t}}\right)^{1-\sigma}, && (55)\\
P_{j,t}^{1-\sigma} &= \sum_i \left(\frac{t_{ij,t}}{\Pi_{i,t}}\right)^{1-\sigma} \frac{y_{i,t}}{y_t}, && (56)\\
\Pi_{i,t}^{1-\sigma} &= \sum_j \left(\frac{t_{ij,t}}{P_{j,t}}\right)^{1-\sigma} \frac{y_{j,t}}{y_t}, && (57)\\
p_{j,t} &= \frac{(y_{j,t}/y_t)^{\frac{1}{1-\sigma}}}{\gamma_j \Pi_{j,t}}, && (58)\\
y_{j,t} &= p_{j,t} A_{j,t} K_{j,t}^{\alpha} L_{j,t}^{\xi} Q_{j,t}^{1-\alpha-\xi}, && (59)\\
K_{j,t+1} &= \left[\frac{(\alpha+\xi) p_{j,t} A_{j,t} L_{j,t}^{\xi} Q_{j,t}^{1-\alpha-\xi} \beta\alpha\delta}{P_{j,t}(1-\beta+\delta\beta)}\right]^{\delta} K_{j,t}^{\alpha\delta+1-\delta}, && (60)\\
K_0 & \quad \text{given.}
\end{aligned}$$

[46]See for example Eaton and Kortum (2002) and Caliendo and Parro (2012).

[47]We recognize that the use of intermediates vary significantly at the sectoral level as well as across domestic and international inputs, but we leave the dynamic sectoral analysis for future work.

[48]Detailed derivations can be found in Supplementary Appendix H.

The introduction of intermediate goods adds a new layer of indirect and general equilibrium linkages that shape the relationship between growth and trade. Equation (59) captures two additional effects of growth on trade, which are channeled through intermediate inputs. First, the effect of own capital accumulation on trade is magnified because $K_{j,t}$ enters the production function (59) directly, as before, and indirectly, via the intermediates $Q_{j,t}$. Second, and more important, the introduction of intermediates opens a new channel through which foreign capital and foreign capital accumulation enter domestic production (via $Q_{j,t}$). This is an important new link because a change in domestic production will lead to changes in the demand for intermediates from all countries, and therefore, more trade.

Equation (60) captures three new channels through which trade affects growth in the case of intermediates. First, the effect of a change in the price of own capital on capital accumulation is magnified because own capital enters the policy function for capital directly, as before, and indirectly, via the intermediate inputs. Second, foreign capital and foreign capital accumulation now enter the policy function for domestic capital via the intermediate inputs. Finally, since foreign goods are used as intermediates and enter equation (60), any change in their prices will have further effect on domestic capital accumulation.

We are not aware of the existence of international data on the use of intermediate goods at the aggregate level. This makes it impossible to disentangle the shares of labor, capital and intermediates in our Cobb-Douglas production function (54) empirically. Therefore, we adopt Eaton and Kortum's (2002) approach and assume a share for intermediates, which we combine with our data for $L_{j,t}$, $y_{j,t}$, and $t_{ij,t}$ as well as the estimated parameters, to recover the country-specific technological components $A_{j,t}/\gamma_j$. Specifically, we assign a share of intermediates equal to 0.25 at the expensive of capital, and we retain the share of labor to 0.45 as in our base-line scenario.[49] Then, we replicate our NAFTA counterfactual experiment to quantify the role of intermediates in our dynamic framework.

Column (5) of Table 4 presents the results allowing for intermediates. Several properties

[49]Introducing intermediates at the expensive of capital will enable us to demonstrate the difference between capital goods and intermediates in our dynamic framework.

stand out in comparison with the base-line scenario from column (2). First, accounting for intermediates in production increases the welfare effects for NAFTA members by 1.2 percentage points on average. For example, Canada's welfare increases by about 6 percentage points. This increase is exclusively due to the interaction between intermediate inputs and the dynamic forces in our framework. Very similar additional quantitative implications are found for Mexico and the US, even though the US welfare gains are smaller, which is in accordance with the smaller base-line scenario gains for the largest member of NAFTA. Second, we also see very similar effects for welfare of the non-NAFTA countries.

In sum, the analysis of the framework with intermediates demonstrates that the introduction of intermediate goods leads to significant changes in the quantitative predictions of our model. The aggregate nature of our study and lack of appropriate data are limiting our analysis. However, our findings point to clear potential benefits from a more detailed analysis of the dynamic effects of intermediate inputs and to additional insights and knowledge to be gained from an extension of our model to the sectoral level.

5.2.4 Additional Robustness Checks

In our first experiment we allow for country-specific capital depreciation rates, which are reported in column (6) of Table 4. The welfare effects of NAFTA in the presence of the country-specific δ's are reported in column (7). As some δ's are lower and some are higher, an overall statement is difficult. In general, a higher δ implies that more capital has to be replaced in every period. This is a burden for an economy. However, the price for the replacement depends on the price for the final good. Lowering trade costs, as is done by the conclusion of NAFTA, leads to a lower price for the composite final good. This decrease in the final goods price is driven by the direct effect of lower trade costs, leading to lower prices for foreign goods, and due to the larger share of foreign goods used in production. Hence, trade liberalization makes capital replacement cheaper. All else equal, a higher depreciation rate implies that international trade increases, as more foreign goods are demanded for capital replacement and consumption due to the lower price. Also welfare increases as compared to the base-line, as the higher depreciation rate implies a larger role for the capital accumulation channel inducing income growth. The effects are exactly in the opposite direction for a lower depreciation rate. Take for example Zimbabwe, which is the country with the highest capital depreciation rate, $\delta = 0.161$. In our base-line we assume a $\delta = 0.052$. Hence, we would expect higher welfare losses for Zimbabwe, which is indeed the case. The opposite happens for China, which is the country with the smallest capital depreciation rate, $\delta = 0.03$.

Next, we employ extreme values for the key parameters in our model. In column (8) of Table 4 we use the largest obtained σ of 7.998. As expected, a higher σ leads to lower welfare effects. This is the case because σ directly governs the willingness of consumers to substitute products. A higher σ therefore leads to lower gains from trade, as consumers do not value the availability of foreign goods a lot. On average, the increase of σ from 5.1 to 7.998 leads to a decrease of the welfare effects of about 40%. Next, we set $\alpha = 0.872$ (instead of 0.55). The increase of the capital share reinforces the dynamic effects in our model. This leads to about 60% higher welfare gains for the NAFTA countries as compared to the base-line scenario (compare column (2) and column (9) of Table 4). The negative effects on non-NAFTA countries are smaller. In sum, we find that our results are sensitive to the specification of the key parameters, but the model generates intuitive responses to parameter changes.

6 Conclusions

The simplicity of the dynamic structural 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 inter-temporal 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. Success in the extension can quantify how important these forces are.

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Tables

Table 1: Trade Costs and Production, 1990-2011

	Cobb-Douglas (1)	Frankel-Romer (2)	Structural Estimates (3)
A. Dep. Variable $\ln y_{j,t}$			
$\ln L_{j,t}$	0.495	0.493	0.362
	$(0.034)^{**}$	$(0.033)^{**}$	$(0.038)^{**}$
$\ln K_{j,t}$	0.505	0.507	0.442
	$(0.034)^{**}$	$(0.033)^{**}$	$(0.039)^{**}$
$\ln \sum_{j\neq i} \hat{x}_{ij}$		0.028	
		$(0.006)^{**}$	
$\ln\left(1/\widehat{\tilde{\Pi}_{j,t}^{1-\sigma}}\right)$			-0.196
			$(0.031)^{**}$
R^2	0.848	0.858	0.855
B. Structural Parameters			
$\hat{\alpha}$	0.505	0.507	0.550
	(0.034)**	(0.033)**	(0.044)**
$\hat{\sigma}$			5.100
			(0.804)**

Notes: This table reports results from three specifications of the production function. The number of observations is 1606 and all specifications include country and year fixed effects whose estimates are omitted for brevity. Column (1) reports estimates from a standard constrained estimation of the Cobb-Douglas production function. In column (2), we estimate a Frankel-and-Romer-type income regression. Finally, in column (3) we estimate our structural model. Robust (in column (1)) and robust, bootstrapped (in columns (2) and (3)) standard errors in parentheses. + $p < 0.10$, * $p < .05$, ** $p < .01$. See text for further details.

Table 2: Parameter Estimates

From	**Parameter**	**Min.**	**Max.**
Trade	$\hat{\gamma}$	0.827	
		(0.083)**	
	$\hat{t}_{ij}$	1.796	4.352
Income	$\hat{\alpha}$	0.448	0.550
		(0.034)**	(0.044)**
	$\hat{\sigma}$	5.100	7.998
		(0.804)**	(2.204)**
Capital	$\hat{\delta}$	0.052	
		(0.006)**	
	$\hat{\delta}_i$	0.030	0.161
		(0.005)**	(0.016)**
Cons. Discount	$\hat{\beta}$	0.98	

Notes: This table reports the minimum and the maximum values for the key parameters in our model. Standard errors in parentheses. + $p < 0.10$, * $p < .05$, ** $p < .01$.

Table 3: Welfare Effects of NAFTA and Globalization

	NAFTA				Globalization			
Country	Cond. GE	Full Static GE	Full Dynamic GE, SS	Full Dynamic GE, trans.	Cond. GE	Full Static GE	Full Dynamic GE, SS	Full Dynamic GE, trans.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
AGO	-0.292	-0.490	-0.655	-0.562	4.593	9.128	20.316	14.362
ARG	-0.741	-1.121	-1.268	-1.177	4.176	8.442	19.299	13.501
AUS	-0.423	-0.702	-0.907	-0.790	4.638	9.131	20.038	14.242
AUT	-0.051	-0.093	-0.156	-0.121	4.288	8.633	19.665	13.768
AZE	-0.115	-0.218	-0.351	-0.280	4.403	8.842	19.996	14.047
BEL	-0.021	-0.045	-0.097	-0.068	4.199	8.492	19.483	13.604
BGD	-0.180	-0.309	-0.439	-0.367	4.056	8.213	18.826	13.156
BGR	-0.149	-0.258	-0.369	-0.307	4.381	8.791	19.887	13.966
BLR	-0.140	-0.252	-0.380	-0.310	4.380	8.798	19.910	13.983
BRA	-0.463	-0.736	-0.902	-0.806	4.023	8.094	18.424	12.906
CAN	15.424	29.608	60.021	44.204	5.500	10.478	21.820	15.830
CHE	-0.004	-0.022	-0.078	-0.048	4.233	8.556	19.604	13.695
CHL	-0.382	-0.628	-0.811	-0.709	4.325	8.696	19.737	13.843
CHN	-0.190	-0.327	-0.458	-0.385	3.123	6.360	14.807	10.278
COL	-0.692	-1.054	-1.207	-1.115	4.116	8.327	19.068	13.329
CZE	-0.063	-0.123	-0.208	-0.163	4.283	8.619	19.610	13.738
DEU	-0.065	-0.129	-0.218	-0.171	3.618	7.405	17.325	12.004
DNK	-0.087	-0.162	-0.257	-0.206	4.316	8.664	19.633	13.776
DOM	-0.574	-0.901	-1.078	-0.974	4.451	8.852	19.753	13.948
ECU	-0.560	-0.866	-1.018	-0.929	4.238	8.578	19.645	13.732
EGY	-0.181	-0.306	-0.424	-0.358	4.137	8.366	19.152	13.390
ESP	-0.282	-0.462	-0.595	-0.522	4.195	8.430	19.141	13.421
ETH	-0.438	-0.725	-0.934	-0.814	4.770	9.399	20.640	14.667
FIN	-0.112	-0.209	-0.328	-0.265	4.325	8.698	19.740	13.846
FRA	-0.145	-0.246	-0.343	-0.287	4.080	8.232	18.823	13.160
GBR	-0.203	-0.345	-0.471	-0.399	3.827	7.739	17.781	12.408
GHA	-0.495	-0.802	-1.005	-0.888	4.667	9.244	20.478	14.501
GRC	-0.124	-0.223	-0.333	-0.272	4.176	8.420	19.209	13.445
GTM	-1.244	-1.842	-1.989	-1.893	4.314	8.649	19.504	13.719
HKG	-0.180	-0.316	-0.457	-0.379	3.842	7.688	17.342	12.193
HRV	-0.237	-0.395	-0.524	-0.450	4.475	8.932	20.036	14.118
HUN	-0.129	-0.223	-0.321	-0.266	4.263	8.585	19.547	13.692
IDN	-0.250	-0.410	-0.540	-0.467	3.875	7.852	18.051	12.598
IND	-0.382	-0.625	-0.803	-0.701	4.211	8.408	18.908	13.309
IRL	-0.065	-0.133	-0.238	-0.181	4.343	8.745	19.877	13.934
IRN	-0.265	-0.435	-0.569	-0.493	4.269	8.586	19.476	13.665
IRQ	-0.217	-0.363	-0.493	-0.421	4.345	8.756	19.910	13.957
ISR	-0.453	-0.770	-1.017	-0.884	4.778	9.360	20.421	14.543
ITA	-0.132	-0.229	-0.330	-0.273	3.814	7.744	17.893	12.459
JPN	-0.163	-0.282	-0.399	-0.334	2.139	4.447	10.788	7.361
KAZ	-0.047	-0.118	-0.247	-0.180	4.401	8.854	20.057	14.083
KEN	-0.440	-0.729	-0.939	-0.819	4.738	9.335	20.509	14.571
KOR	-0.197	-0.327	-0.438	-0.375	3.884	7.778	17.539	12.337
KWT	-0.181	-0.315	-0.449	-0.374	3.748	7.589	17.450	12.176
LBN	-0.262	-0.416	-0.522	-0.454	4.388	8.816	19.961	14.015
LKA	-0.234	-0.390	-0.524	-0.449	4.223	8.517	19.402	13.591
LTU	-0.157	-0.284	-0.422	-0.348	4.499	8.982	20.140	14.195
MAR	-0.229	-0.382	-0.508	-0.435	4.366	8.750	19.762	13.887
MEX	9.070	17.071	33.309	25.015	4.909	9.538	20.543	14.704
MYS	-0.133	-0.234	-0.348	-0.286	4.369	8.775	19.854	13.946
NGA	-0.485	-0.788	-0.991	-0.874	4.680	9.266	20.517	14.531
NLD	-0.053	-0.106	-0.185	-0.143	4.081	8.242	18.880	13.190
NOR	-0.137	-0.247	-0.368	-0.303	4.406	8.822	19.892	13.987
NZL	-0.450	-0.746	-0.964	-0.841	4.753	9.362	20.543	14.603
OMN	-0.255	-0.430	-0.580	-0.495	4.572	9.099	20.286	14.332
PAK	-0.228	-0.400	-0.574	-0.479	4.378	8.800	19.925	13.992
PER	-0.456	-0.712	-0.856	-0.773	4.214	8.543	19.606	13.695
PHL	-0.399	-0.661	-0.858	-0.747	4.548	9.009	19.974	14.139
POL	-0.109	-0.189	-0.277	-0.227	4.263	8.572	19.478	13.652
PRT	-0.121	-0.232	-0.371	-0.298	4.317	8.667	19.628	13.777

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Table 3 – *Continued from previous page*

Country	NAFTA				Globalization			
	Cond. GE	Full Static GE	Full Dynamic GE, SS	Full Dynamic GE, trans.	Cond. GE	Full Static GE	Full Dynamic GE, SS	Full Dynamic GE, trans.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
QAT	-0.207	-0.356	-0.499	-0.419	4.373	8.759	19.739	13.886
ROM	-0.224	-0.363	-0.469	-0.408	4.309	8.673	19.706	13.816
RUS	-0.288	-0.474	-0.619	-0.535	3.900	7.848	17.881	12.520
SAU	-0.240	-0.407	-0.552	-0.470	4.384	8.741	19.561	13.798
SDN	-0.260	-0.428	-0.562	-0.486	4.430	8.892	20.093	14.121
SER	-0.234	-0.392	-0.525	-0.449	4.500	8.982	20.143	14.195
SGP	-0.204	-0.353	-0.496	-0.416	3.925	7.933	18.173	12.699
SVK	-0.117	-0.203	-0.295	-0.243	4.304	8.675	19.770	13.843
SWE	-0.122	-0.221	-0.335	-0.274	4.321	8.676	19.652	13.793
SYR	-0.153	-0.271	-0.395	-0.327	4.464	8.942	20.153	14.175
THA	-0.209	-0.349	-0.472	-0.403	3.703	7.531	17.422	12.128
TKM	-0.192	-0.335	-0.478	-0.399	4.436	8.894	20.080	14.115
TUN	-0.283	-0.440	-0.534	-0.472	4.290	8.661	19.768	13.836
TUR	-0.227	-0.370	-0.481	-0.417	4.131	8.338	19.040	13.323
TZA	-0.344	-0.573	-0.756	-0.653	4.564	9.100	20.355	14.362
UKR	-0.138	-0.252	-0.383	-0.311	4.293	8.629	19.552	13.724
USA	0.780	1.731	4.213	2.748	2.209	4.775	12.097	8.134
UZB	-0.221	-0.379	-0.526	-0.444	4.424	8.851	19.915	14.017
VEN	-0.588	-0.911	-1.072	-0.978	4.244	8.562	19.520	13.669
VNM	-0.212	-0.352	-0.474	-0.405	4.447	8.903	20.035	14.104
ZAF	-0.379	-0.635	-0.834	-0.721	4.577	9.060	20.066	14.209
ZWE	-0.321	-0.537	-0.715	-0.615	4.479	8.955	20.122	14.172
World	0.556	1.155	2.657	1.842	3.419	6.961	16.165	11.233
NAFTA	2.554	5.073	10.768	7.671				
ROW	-0.220	-0.368	-0.494	-0.423				

Notes: This table reports results from our NAFTA and globalization counterfactual. It is based on observed data on labor endowments and GDPs for our sample of 82 countries. Further, it uses our estimated trade costs based on equation (32) and recovered theory-consistent, steady-state capital stocks according to equation (25). We calculate baseline preference-adjusted technology A_j/γ_j according to the market-clearing equation (22) and the production function equation (23). Finally, the counterfactual is based on our own estimates of the elasticity of substitution $\hat{\sigma} = 5.1$, the share of capital in the Cobb-Douglas production function $\hat{\alpha} = 0.55$, and the capital depreciation rate $\hat{\delta} = 0.052$. The consumers' discount factor β is set equal to 0.98. Column (1) gives the country abbreviations. Columns (2) to (5) report the percentage change in welfare for each country for three different scenarios, for the world as a whole, the NAFTA and the non-NAFTA countries (summarized as rest of the world (ROW)). The "Conditional GE" scenario taking into account the direct and indirect trade cost changes but holding GDPs constant, the "Full Static GE" scenario, which in addition takes general equilibrium income effects into account, and the "Full Dynamic GE" scenario, which adds the capital accumulation effects. For the latter, we report the results from the steady-state not taking into account that gains take time to materialize (column (4)), and the welfare gains taking into account the transition (column (5)). Columns (6) to (9) report the percentage change in welfare for each country for the same three scenarios for our globalization scenario, where we assume that international trade costs for all countries decrease by 38%.

Table 4: Evaluation of NAFTA: Robustness Checks, Welfare Effects for the 'Full Dynamic GE, trans.' scenario

Country	Base-line	Linear trans.	Capital accum.	Inter-mediates	Ctry-specific δ		$\sigma =$ 7.998	$\alpha =$ 0.872
					δ	Welfare		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
AGO	-0.562	-0.536	-0.241	-0.608	0.039	-0.541	-0.401	-0.455
ARG	-1.177	-1.086	-0.980	-1.233	0.045	-1.148	-0.894	-0.872
AUS	-0.790	-0.751	-0.255	-0.850	0.044	-0.778	-0.570	-0.626
AUT	-0.121	-0.119	-0.058	-0.136	0.059	-0.123	-0.079	-0.115
AZE	-0.280	-0.274	-0.112	-0.312	0.045	-0.273	-0.185	-0.253
BEL	-0.068	-0.069	-0.041	-0.080	0.065	-0.070	-0.040	-0.074
BGD	-0.367	-0.352	-0.239	-0.401	0.041	-0.352	-0.256	-0.312
BGR	-0.307	-0.296	-0.132	-0.336	0.050	-0.306	-0.213	-0.260
BLR	-0.310	-0.300	-0.135	-0.342	0.047	-0.305	-0.211	-0.270
BRA	-0.806	-0.756	-0.502	-0.858	0.044	-0.786	-0.593	-0.623
CAN	44.204	43.565	47.557	50.432	0.064	45.679	26.058	65.668
CHE	-0.048	-0.052	-0.029	-0.060	0.069	-0.050	-0.023	-0.064
CHL	-0.709	-0.670	-0.467	-0.761	0.042	-0.687	-0.512	-0.566
CHN	-0.385	-0.369	-0.168	-0.419	0.030	-0.354	-0.269	-0.321
COL	-1.115	-1.030	-0.939	-1.170	0.043	-1.080	-0.843	-0.833
CZE	-0.163	-0.161	-0.046	-0.183	0.050	-0.164	-0.106	-0.155
DEU	-0.171	-0.168	-0.046	-0.192	0.057	-0.175	-0.111	-0.161
DNK	-0.206	-0.202	-0.061	-0.229	0.055	-0.210	-0.137	-0.188
DOM	-0.974	-0.910	-0.592	-1.032	0.040	-0.941	-0.724	-0.742
ECU	-0.929	-0.862	-0.801	-0.980	0.044	-0.900	-0.695	-0.706
EGY	-0.358	-0.342	-0.227	-0.390	0.048	-0.353	-0.252	-0.300
ESP	-0.522	-0.493	-0.279	-0.559	0.048	-0.518	-0.377	-0.419
ETH	-0.814	-0.773	-0.264	-0.875	0.045	-0.802	-0.588	-0.642
FIN	-0.265	-0.259	-0.078	-0.294	0.050	-0.266	-0.177	-0.239
FRA	-0.287	-0.276	-0.124	-0.314	0.056	-0.290	-0.201	-0.238
GBR	-0.399	-0.382	-0.153	-0.434	0.059	-0.407	-0.282	-0.326
GHA	-0.888	-0.838	-0.390	-0.949	0.050	-0.886	-0.648	-0.691
GRC	-0.272	-0.264	-0.114	-0.300	0.050	-0.271	-0.186	-0.236
GTM	-1.893	-1.731	-1.611	-1.964	0.052	-1.888	-1.462	-1.370
HKG	-0.379	-0.366	-0.116	-0.415	0.050	-0.374	-0.262	-0.321
HRV	-0.450	-0.429	-0.196	-0.487	0.049	-0.448	-0.322	-0.362
HUN	-0.266	-0.256	-0.117	-0.292	0.054	-0.267	-0.184	-0.226
IDN	-0.467	-0.442	-0.298	-0.503	0.038	-0.444	-0.335	-0.378
IND	-0.701	-0.664	-0.302	-0.753	0.044	-0.687	-0.507	-0.553
IRL	-0.181	-0.180	-0.078	-0.206	0.063	-0.188	-0.115	-0.175
IRN	-0.493	-0.467	-0.303	-0.531	0.045	-0.482	-0.354	-0.397
IRQ	-0.421	-0.400	-0.260	-0.456	0.055	-0.421	-0.298	-0.346
ISR	-0.884	-0.843	-0.159	-0.951	0.053	-0.898	-0.631	-0.715
ITA	-0.273	-0.263	-0.119	-0.300	0.050	-0.273	-0.189	-0.232
JPN	-0.334	-0.321	-0.144	-0.365	0.046	-0.328	-0.232	-0.281
KAZ	-0.180	-0.182	-0.074	-0.209	0.046	-0.174	-0.107	-0.186
KEN	-0.819	-0.778	-0.265	-0.880	0.049	-0.817	-0.591	-0.646
KOR	-0.375	-0.357	-0.242	-0.406	0.039	-0.358	-0.267	-0.308
KWT	-0.374	-0.360	-0.158	-0.410	0.042	-0.362	-0.260	-0.316
LBN	-0.454	-0.428	-0.286	-0.488	0.042	-0.436	-0.332	-0.347
LKA	-0.449	-0.427	-0.283	-0.485	0.042	-0.433	-0.319	-0.368
LTU	-0.348	-0.337	-0.104	-0.383	0.054	-0.352	-0.238	-0.303
MAR	-0.435	-0.415	-0.200	-0.471	0.046	-0.429	-0.311	-0.350
MEX	25.015	24.533	26.857	28.313	0.055	25.221	15.138	35.986
MYS	-0.286	-0.276	-0.188	-0.315	0.038	-0.269	-0.196	-0.251
NGA	-0.874	-0.826	-0.374	-0.935	0.059	-0.890	-0.637	-0.682
NLD	-0.143	-0.141	-0.040	-0.161	0.060	-0.148	-0.092	-0.138
NOR	-0.303	-0.294	-0.092	-0.334	0.055	-0.308	-0.207	-0.265
NZL	-0.841	-0.798	-0.274	-0.904	0.049	-0.838	-0.606	-0.666
OMN	-0.495	-0.473	-0.212	-0.537	0.040	-0.478	-0.352	-0.403
PAK	-0.479	-0.461	-0.207	-0.524	0.053	-0.478	-0.332	-0.404
PER	-0.773	-0.720	-0.676	-0.819	0.041	-0.743	-0.573	-0.596
PHL	-0.747	-0.709	-0.273	-0.803	0.046	-0.739	-0.538	-0.595
POL	-0.227	-0.220	-0.102	-0.250	0.054	-0.228	-0.156	-0.196
PRT	-0.298	-0.292	-0.078	-0.331	0.047	-0.296	-0.198	-0.270
QAT	-0.419	-0.402	-0.177	-0.457	0.034	-0.394	-0.294	-0.349

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Country	Base-line	Linear trans.	Capital accum.	Inter-mediates	Ctry-specific δ		$\sigma =$ 7.998	$\alpha =$ 0.872
					δ	Welfare		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
ROM	-0.408	-0.385	-0.260	-0.438	0.051	-0.405	-0.295	-0.326
RUS	-0.535	-0.508	-0.235	-0.577	0.045	-0.525	-0.385	-0.427
SAU	-0.470	-0.449	-0.200	-0.510	0.042	-0.456	-0.333	-0.384
SDN	-0.486	-0.461	-0.301	-0.524	0.043	-0.471	-0.349	-0.392
SER	-0.449	-0.428	-0.194	-0.486	0.050	-0.447	-0.320	-0.364
SGP	-0.416	-0.400	-0.176	-0.454	0.041	-0.401	-0.291	-0.348
SVK	-0.243	-0.235	-0.108	-0.267	0.048	-0.241	-0.168	-0.208
SWE	-0.274	-0.266	-0.082	-0.302	0.057	-0.279	-0.186	-0.242
SYR	-0.327	-0.315	-0.135	-0.359	0.046	-0.321	-0.225	-0.279
THA	-0.403	-0.383	-0.255	-0.436	0.040	-0.385	-0.286	-0.332
TKM	-0.399	-0.384	-0.164	-0.437	0.038	-0.382	-0.277	-0.337
TUN	-0.472	-0.443	-0.357	-0.504	0.049	-0.464	-0.350	-0.356
TUR	-0.417	-0.395	-0.266	-0.449	0.051	-0.415	-0.301	-0.335
TZA	-0.653	-0.621	-0.284	-0.704	0.047	-0.646	-0.467	-0.524
UKR	-0.311	-0.302	-0.135	-0.344	0.046	-0.306	-0.211	-0.272
USA	2.748	2.849	6.600	3.295	0.048	2.766	1.569	3.813
UZB	-0.444	-0.426	-0.187	-0.484	0.048	-0.439	-0.312	-0.368
VEN	-0.978	-0.908	-0.803	-1.032	0.048	-0.962	-0.731	-0.742
VNM	-0.405	-0.385	-0.260	-0.439	0.031	-0.373	-0.288	-0.333
ZAF	-0.721	-0.687	-0.228	-0.778	0.051	-0.724	-0.517	-0.576
ZWE	-0.615	-0.586	-0.270	-0.664	0.161	-0.692	-0.439	-0.497
World	1.842	1.855	3.018	2.151		1.888	1.046	2.848
NAFTA	7.671	7.669	11.319	8.868		7.813	4.512	11.071
ROW	-0.423	-0.403	-0.207	-0.458		-0.414	-0.301	-0.346

Notes: This table reports robustness results for our NAFTA counterfactual. It is based on observed data on labor endowments and GDPs for our sample of 82 countries. Further, it uses our estimated trade costs based on equation (32) and recovered theory-consistent, steady-state capital stocks according to equation (25). We calculate baseline preference-adjusted technology A_j/γ_j according to the market-clearing equation (22) and the production function equation (23). Finally, the counterfactual is based on our own estimates of the elasticity of substitution $\hat{\sigma} = 5.1$, the share of capital in the Cobb-Douglas production function $\hat{\alpha} = 0.55$, and the capital depreciation rate $\hat{\delta} = 0.052$. The consumers' discount factor β is set equal to 0.98. Only welfare effects for the 'Full Dynamic GE, trans.' scenario are reported. Column (1) gives the country abbreviations. Columns (2) reports for reasons of comparison the results from our baseline scenario reported in column (5) in Table 3. Column (3) assumes a 20% higher capital stock in the USA in 1994 when NAFTA was concluded. Column (5) is based on the linear instead of the log-linear capital transition function. Column (4) gives the results when allowing for intermediate inputs. Column (5) gives the estimated country-specific depreciation rates δ_i, while Column (6) reports the corresponding welfare effects of NAFTA based on these depreciation rates. Column (7) is based on an elasticity of substitution of $\sigma = 7.998$ instead of 5.1, while the last column reports results based on a capital share of $\alpha = 0.872$.

Figures

Figure 1: Theory-consistent vs. actual capital stocks.

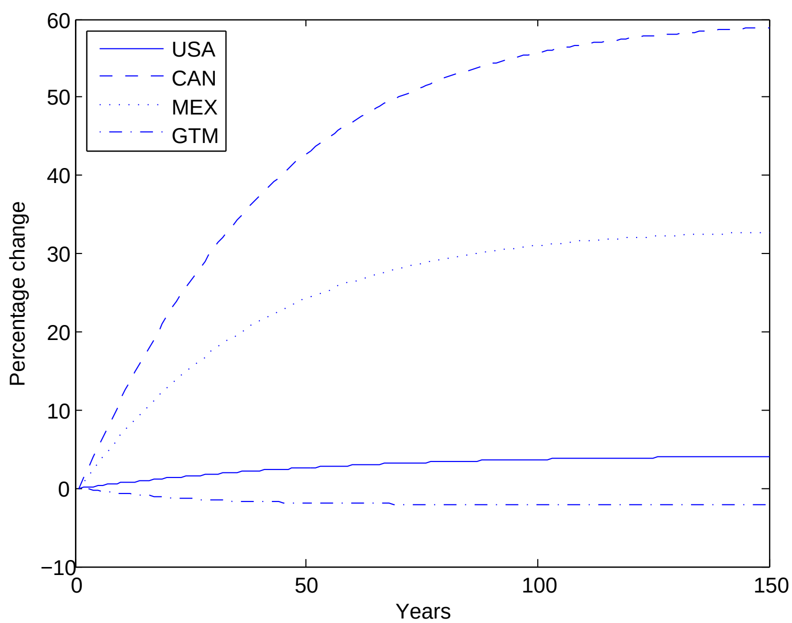

Figure 2: On the transitional effects of NAFTA: Capital stocks.

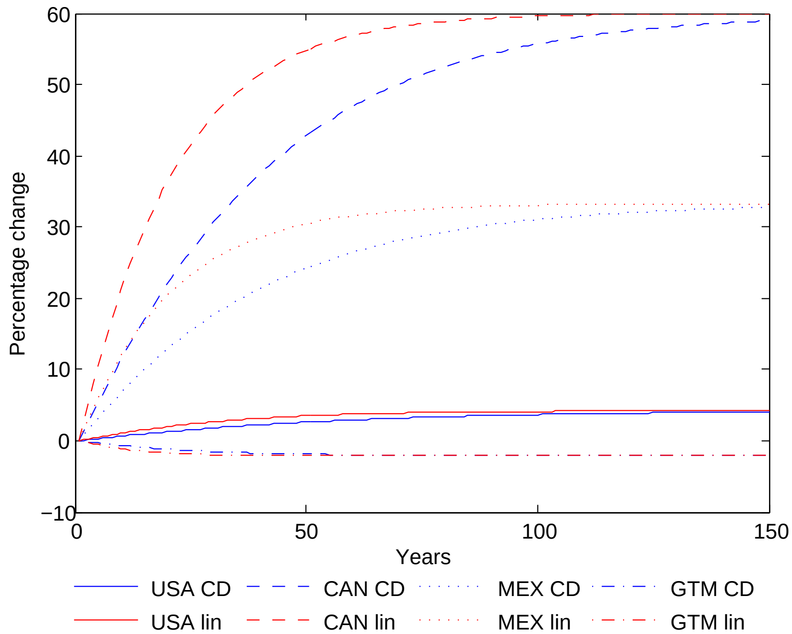

Figure 3: Linear vs. Log-linear Capital Accumulation.