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. Our focus of this concern is on two major forces: trade frictions and capital accumulation. The structural 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)) to provide intuitive and revealing counterfactual general equilibrium comparative statics. Our innovation is to bring in capital accumulation in 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. 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.[1] 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

[1] 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.

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 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.[2] 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. In our dynamic structural gravity model, 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 intertemporal consumption smoothing with log-linear utility (implying elasticity of intertemporal substitution equal to one). Im-

[2]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).

portantly, our general equilibrium theory captures the possibility that changes in trade costs between any two trading partners may potentially affect producer prices and consumer prices in any nation in the 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 channel, i.e., capital accumulation in one country will affect trade costs and impact welfare in every other country in the world. Work done on other data (e.g., Anderson and Yotov (2010a) and 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 will lead to additional changes in capital stock.

The benefits of growth in one country are shared with the rest of the world through two channels: (i) increased country size leading to more trade (imports and exports) with all trading partners; and (ii) lower buyers incidence in its trading partners, all else equal. In combination, these dynamic channels 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 increazed 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 welfare effects on non-member countries resulting from small negative terms of trade effects they suffer from trade diversion.

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 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 Previous 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.[3] We extend Frankel and Romer (1999) in two important ways. First, we

[3] 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) and

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.

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.[4] 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.[5]

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 multicountry model. As mentioned in footnote 17 on page 132 in Grossman and Helpman (1991), transitional dynamics naturally arise when allowing for capital accumulation. This is exactly the focus of our study, where we model and quantify the transitional growth effects of trade liberalization. Consistent with Grossman and Helpman's conclusion that "that physical

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Linnemann (1966)) and propose to instrument for trade flows with geographical characteristics and country size.

[4]The work of Eaton and Kortum that is most closely related to our study is nicely and 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).

[5]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. Some counterfactual experiments illustrate.

capital may play only a supporting role in the story of long-run growth." (p. 122), capital accumulation in our setting triggers only transitional growth effects and are no long-run growth effects from capital accumulation.

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% 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. We therefore focus in our dynamic model on the capital accumulation channel, complementing work that focuses on innovation, learning and spill-overs by firms and workers.

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.[6] 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.

[6] There is a literature that explains export dynamics (see for example Das, Roberts, and Tybout (2007) and 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) and Dix-Carneiro (2013)). Both, export dynamics and adjustment and business cycle dynamics, are beyond the scope of this paper.

We also make an empirical contribution to the gravity/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 single most important trade parameter. (See Arkolakis, Costinot, and Rodríguez-Clare (2012).) With values between 5.1 and 9.8 from alternative specifications and robustness experiments, our estimates of the trade elasticity of substitution are comparable to the indexes from the existing literature, which usually vary between 2 and 12.[7]

Finally, we contribute to the literature that studies the effects of Regional Trade Agreements (RTAs). Our contribution to this literature is that we estimate 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. For example, our model predicts that the dynamic effects of NAFTA will still be present 100 years after its formation in 1994, while the NAFTA effects on outsiders have already been exhausted completely less than ten years after its implementation. This result is in sharp contrast with findings from the related static studies who estimate that effects of PTAs for member countries are exhausted within 10 to 15 years after their formation (see Baier and Bergstrand, 2007). Finally, our NAFTA counterfactual experiment reveals the possibility for positive 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.

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

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 Hercowitz and Sampson (1991) and Eckstein et al. (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 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 ensures that capital will not immediately adjust to its new long-run steady-state value. It therefore reflects the costs in adjustments of the volume of capital.[8]

[8]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 investments 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.

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 investments ($\Omega_{j,t}$) to maximize the present discounted value of lifetime utility subject to a sequence of constraints:

$$\begin{aligned}
\max_{C_{j,t},\Omega_{j,t}} \quad & \sum_{t=0}^{\infty} \beta^t \ln(C_{j,t}) \\
K_{j,t+1} &= \Omega_{j,t}^{\delta} K_{j,t}^{1-\delta}, && (3) \\
y_{j,t} &= p_{j,t} A_{j,t} L_{j,t}^{1-\alpha} K_{j,t}^{\alpha}, && (4) \\
y_{j,t} &= P_{j,t} C_{j,t} + P_{j,t} \Omega_{j,t}, && (5) \\
K_0 \quad & \text{given.} && (6)
\end{aligned}$$

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.

The aggregate consumption good and aggregate investments 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 combined according to equations (7)-(8) to an aggregate consumption good and to aggregate investments:

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

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

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 $i \neq j$ ($I_{ij,t}$).

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 $P_{j,t} = \left[\sum_i \left(\gamma_i p_{i,t} t_{ij,t}\right)^{1-\sigma}\right]^{1/(1-\sigma)}$ 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 gravity 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 (MR) terms (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.[9] On the one hand, the MRs translate changes in bilateral trade costs at the upper level into changes in factory gate prices, which stimulate or discourage investment and growth. 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.

[9] The MR terms have been used to perform welfare analysis in a conditional general equilibrium, where output is taken as exogenously given. For example, Anderson and Yotov (2010a,b) use the MR terms to translate changes in the incidence of trade costs (globalization) into changes in real output (acting like TFP changes). Anderson and Yotov (2011) extend further the gravity framework to allow for general equilibrium responses in factory-gate prices under the simplifying assumption of endowment economies.

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 functions of capital and consumption we iterate over the value function (see for details Appendix A) and obtain the following policy function for capital:

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

Policy function (15) is consistent with rational expectations despite the appearance of one period ahead prices only. This is due to the log-linear structure of both preferences and transition, implying that marginal rates of substitution are proportional to the ratio of present to one-period-ahead consumption or capital stocks. In Appendix A we report on confirming that our methods are replicated by the standard dynamic rational expectations solution method DYNARE. 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 capital accumulation and the aggregate consumer price index $P_{j,t}$.[10] 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

[10] 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.

$\alpha p_{j,t} A_{j,t} L_{j,t}^{1-\alpha} K_{j,t}^{\alpha-1}$, consumers will be 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 good as well as investments 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.

Given the policy function for capital, we can easily calculate investments, $\Omega_{j,t}$, consumption, $C_{j,t}$, and income, respectively, as:

$$\begin{aligned}
\Omega_{j,t} &= \left[\frac{p_{j,t} A_{j,t} L_{j,t}^{1-\alpha} \beta \alpha \delta}{P_{j,t} \left(1 - \beta + \delta \beta\right)} \right] K_{j,t}^{\alpha}, \\
C_{j,t} &= \left[\frac{1 - \beta + \delta \beta - \beta \alpha \delta}{1 - \beta + \delta \beta} \right] \frac{p_{j,t} A_{j,t} L_{j,t}^{1-\alpha} K_{j,t}^{\alpha}}{P_{j,t}}, \\
y_{j,t} &= p_{j,t} A_{j,t} L_{j,t}^{1-\alpha} K_{j,t}^{\alpha}.
\end{aligned}$$

Again, investments, consumption and income depend on prices and are therefore linked to the lower level. As we solve only for $P_{j,t}$ and $\Pi_{j,t}$ in the lower level, we note that we can express goods prices $p_{i,t}$ as $\left(y_{i,t}/y_t\right)^{1/(1-\sigma)} / (\gamma_i \Pi_{i,t})$.

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 theoretical growth and trade model:

$$
\begin{aligned}
x_{ij,t} &= \frac{y_{i,t} y_{j,t}}{y_t} \left(\frac{t_{ij,t}}{\Pi_{i,t} P_{j,t}} \right)^{1-\sigma}, && (16) \\
P_{j,t}^{1-\sigma} &= \sum_i \left(\frac{t_{ij,t}}{\Pi_{i,t}} \right)^{1-\sigma} \frac{y_{i,t}}{y_t}, && (17) \\
\Pi_{i,t}^{1-\sigma} &= \sum_j \left(\frac{t_{ij,t}}{P_{j,t}} \right)^{1-\sigma} \frac{y_{j,t}}{y_t}, && (18) \\
p_{j,t} &= \frac{(y_{j,t}/y_t)^{\frac{1}{1-\sigma}}}{\gamma_j \Pi_{j,t}}, && (19) \\
y_{j,t} &= p_{j,t} A_{j,t} L_{j,t}^{1-\alpha} K_{j,t}^{\alpha}, && (20) \\
K_{j,t+1} &= \left[\frac{p_{j,t} A_{j,t} L_{j,t}^{1-\alpha} \beta \alpha \delta}{P_{j,t} \left(1 - \beta + \delta \beta\right)} \right]^{\delta} K_{j,t}^{\alpha\delta + 1 - \delta}, && (21) \\
K_0 & \quad \text{given.}
\end{aligned}
$$

Our strategy in the subsequent sections is to translate system (16)-(21) 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 (16)-(21) to trace the effects of trade liberalization, measured as a reduction of bilateral trade costs t_{ij} at some point in time t. 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 (16) 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 multilateral resistance terms given in Equations (17) and (18).

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 multilateral resistance terms 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.

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 (19)-(20) 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 (19) captures the fact that an increased trade resistance (i.e. a higher outward multilateral resistance) faced by the producers in a given country will translate in lower factory gate prices. The latter will lead to a decrease in the value of domestic production/income via Equation (20). 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, in combination, Equations (19)-(21) capture the effects of trade liberalization on capital accumulation. A change in trade costs will cause a change in factory-gate prices via Equation (19), which will translate into a change in the capital stock via Equation (21). As discussed earlier, the relationship between prices of domestically produced goods and capital accumulation is direct, while the relationship between foreign factory-gate prices and capital accumulation, which is channeled via the inward multilateral resistance $P_{j,t}$ in Equation (21), is inverse. The latter is due to the fact that investments and the aggregate consumption good both are priced at $P_{j,t}$. Hence, an increase of $P_{j,t}$ makes investments and consumption more expensive. Note that trade liberalization will therefore directly change the price of investment. This 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 (16). In addition, changes in output will affect trade flows indirectly via changes in the multilateral resistances that are captured by Equations (17) and (18). In turn, the changes in the MR terms will lead to additional, third-order changes in output and capital accumulation, and so forth.

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 reveals an additional channel through which preferential trade liberalization (e.g. a Regional Trade Agreement, RTA) may benefit non-members. In particular, by making investments more attractive, a regional trade agreement 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.

The long run effects of trade costs on growth are captured by the comparative statics of the steady states. Steady state capital is $K_j = \Omega_j = \alpha\beta\delta y_j/[P_j(1-\beta+\beta\delta)]$, from solving equation (21). Substitute for the factory gate price $p_{j,t}$ in the income equation (20) using the factory gate price equation (19). 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

$$\hat{K}_j = \hat{P}_j^{\frac{-\sigma}{\sigma(1-\alpha)+\alpha}} \hat{\Pi}_j^{\frac{1-\sigma}{\sigma(1-\alpha)+\alpha}} \hat{y}^{\frac{1}{\sigma(1-\alpha)+\alpha}}. \qquad (22)$$

The change in capital expression (22) 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.

In Appendix B we show that the change in capital can directly be related to welfare by deriving an extended ACR formula:

$$\hat{W}_j = \widehat{K}_j^{\alpha} \hat{\lambda}_{jj}^{\frac{1}{1-\sigma}}, \tag{23}$$

where $\hat{\lambda}_{jj}$ denotes the share of domestic expenditure. Equation (23) implies that an increase of steady-state capital will, ceteris paribus, increase welfare.

System (16)-(21) accounts for a series of 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 (16)-(21) translates into a self-sufficient econometric model that is intuitive and straightforward to estimate. We establish that next.

4 Empirical Analysis

This section demonstrates that our model is straightforward to implement empirically, that it is self-sufficient because it delivers almost all parameters needed to perform counterfactuals, and that it readily offers itself to extensions. 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 with 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 multi-country growth-and-trade specification from Frankel and Romer (1999) 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 output 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 (16)-(18). In order to obtain sound econometric estimates of bilateral trade costs and, subsequently, of the multilateral resistances that enter our output and growth 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.[11] 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:

$$ {t_{ij}}^{1-\sigma} = e^{\eta_1 RTA_{ij} + \sum_{m=2}^{5} \eta_m \ln DIST_{ij,m} + \eta_6 BRDR_{ij} + \eta_7 LANG_{ij} + \eta_8 CLNY_{ij} + \eta_9 SMCTRY_{ij}}, \tag{24} $$

where, RTA_{ij} is a dummy variable equal to 1 when i and j have formed a Regional Trade Agreement (RTA) and zero elsewhere.[12] $\ln DIST_{ij,m}$ 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 regional trade agreements. The issue of RTA endogeneity is well-known in the trade literature[13] 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, Baier and Bergstrand (2007) propose two solutions to the endogeneity problem. In order to account for the unobservable linkages

[11] 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 costs 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, which are available upon request.

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

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

between the endogenous RTA covariate and the error term in trade regressions, one should either use first-differenced data or employ bilateral (country-pair) fixed effects. We chose the second option because, as we demonstrate below, it enables us to construct bilateral trade costs from the estimates of the country-pair fixed effects.

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:

$$x_{ij,t} = \exp[\eta_1 RTA_{ij,t} + \chi_{i,t} + \pi_{j,t} + \mu_{ij}] + \epsilon_{ij,t}. \tag{25}$$

Here, $\chi_{i,t}$ denotes the time-varying source-country dummies, which control for the outward 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 $\epsilon_{ij,t}$ in order to control for potential endogeneity of the former. Importantly, μ_{ij} will absorb all time-invariant gravity covariates from (24) along with any other time-invariant determinants of trade costs that are not observable by the researcher. Due to the inclusion of time-varying source-country dummies alongside bilateral dummies, we choose the country-specific internal trade costs as our references. Hence, the estimates of μ_{ij} should be interpreted as relative to they internal trade counterparts μ_{ij}.

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 follow 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 the method obtains estimates of the country-pair fixed effects μ_{ij} from equation (25). Then, in the second stage, the estimates of the bilateral fixed effects are regressed on the set of standard gravity variables from equation

(24):

$$\exp\left(\hat{\mu}_{ij}\right) = \exp[\sum_{m=2}^{5} \tilde{\eta}_m \ln DIST_{ij,m} + \tilde{\eta}_6 BRDR_{ij} + \tilde{\eta}_7 LANG_{ij} + \tilde{\eta}_8 CLNY_{ij}] + \varepsilon_{ij,t}. \quad (26)$$

The estimates from equation (26) 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:

$$\left(\widehat{t}_{ij}^{NORTA}\right)^{1-\sigma} = e^{\sum_{m=2}^{5} \hat{\eta}_m \ln DIST_{ij,m} + \hat{\eta}_6 BRDR_{ij} + \hat{\eta}_7 LANG_{ij} + \hat{\eta}_8 CLNY_{ij}}. \quad (27)$$

The set of bilateral trade costs that account for the presence of RTAs is constructed from (25) and (27):

$$\left(\widehat{t}_{ij,t}^{RTA}\right)^{1-\sigma} = e^{\hat{\eta}_1 RTA_{ij,t}} \left(\widehat{t}_{ij}^{NORTA}\right)^{1-\sigma}. \quad (28)$$

Below, we use (28) to study the dynamic general equilibrium effects of NAFTA and globalization on growth and welfare.

4.1.2 Upper Level Econometric Specification

We now turn to the upper level, where we estimate the equations for output 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.

Output. We start with the estimating equation for output. Transforming the theoretical specification for output into an estimation equation for growth is straight forward. To obtain the estimation equation for output, we substitute equation (19) for prices into equation (20) and we express the resulting equation in natural logarithmic form:

$$\ln y_{j,t} = \frac{1}{\sigma}\ln y_t + \frac{\sigma-1}{\sigma}\ln\frac{A_{j,t}}{\gamma_j} + \frac{(\sigma-1)(1-\alpha)}{\sigma}\ln L_{j,t} + \frac{(\sigma-1)\alpha}{\sigma}K_{j,t} - \frac{1}{\sigma}\ln\left(\frac{1}{\Pi_{j,t}^{1-\sigma}}\right). \quad (29)$$

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 estimates of σ.

Two steps deliver a simple estimation equation for output. First, we experiment with a time trend and with year dummies 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 a set of country-specific fixed effects ϑ_j. Furthermore, we believe that in combination with the time fixed effects, the country fixed effects will absorb most of the variability in $A_{j,t}$. We sum any residual technological the error term $\varepsilon_{j,t}$. (29) becomes

$$\ln y_{j,t} = \kappa_1 \ln L_{j,t} + \kappa_2 K_{j,t} + \kappa_3 \ln\left(\frac{1}{\Pi_{j,t}^{1-\sigma}}\right) + \nu_t + \vartheta_j + \varepsilon_{j,t}. \quad (30)$$

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 multilateral resistance term, $\hat{\kappa}_3$, can be used to recover the trade elasticity of substitution directly as $\hat{\sigma} = -1/\hat{\kappa}_3$.[14] 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 (30), $\kappa_1 + \kappa_2 = 1 + \kappa_3$.

In addition to delivering some key parameters, (30) highlights two of our main contribu-

[14] 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 Arkolakis, Costinot, and Rodríguez-Clare, 2012). Furthermore, we will be able to compare our estimate with existing indexes in order to gauge the success of our methods.

tions to the literature. First, the introduction of $\ln(1/\Pi_{j,t}^{1-\sigma})$ in (30) 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 (30) 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 (25) and (30) deliver a structural foundation for the influential reduced-form specification of the relationship between growth and trade from Frankel and Romer (1999):

$$Trade: \quad x_{ij,t} = \exp[\gamma_1 RTA_{ij} + \gamma_{ij} + \eta_{i,t} + \pi_{j,t}] + \epsilon_{ij,t}, \tag{31}$$

$$Output: \quad \ln y_{j,t} = \kappa_1 \ln L_{j,t} + \kappa_2 K_{j,t} + \kappa_3 \ln\left(\frac{1}{\Pi_{j,t}^{1-\sigma}}\right) + \nu_t + \vartheta_j + \varepsilon_{j,t}. \tag{32}$$

Frankel and Romer (1999) use a version of the gravity equation (31) to instrument for trade, which enters their *Output* equation directly. Instead, in our specification the effects of trade and trade costs are channeled directly via the structural trade term $\ln\left(1/\Pi_{j,t}^{1-\sigma}\right)$.

One final consideration that we address before estimating system (31)-(32) is that the trade term $\ln(1/\Pi_{j,t}^{1-\sigma})$ in equation (32) 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:

$$\tilde{P}_{j,t}^{1-\sigma} = \sum_{\bar{j}} \left(t_{\bar{j}j,t}/\tilde{\Pi}_{\bar{j},t}\right)^{1-\sigma} y_{\bar{j},t}/y_t, \tag{33}$$

$$\tilde{\Pi}_{i,t}^{1-\sigma} = \sum_{\bar{i}} \left(t_{i\bar{i},t}/\tilde{P}_{\bar{i},t}\right)^{1-\sigma} y_{\bar{i},t}/y_t, \tag{34}$$

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 equation that captures the effects of trade (liberalization) on growth/capital accumulation. Equation (21) translates into a simple log-linear econometric specification:

$$Capital: \quad \ln K_{j,t} = \psi_0 + \psi_1 \ln y_{j,t-1} + \psi_2 \ln K_{j,t-1} + \psi_3 \ln P_{j,t-1} + \varsigma_{j,t}, \tag{35}$$

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; $\psi_2 = 1-\delta$ 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. Our model implies the following structural relationships between the coefficients on the three covariates in (35), $\psi_1 = -\psi_3$ and $\psi_1 = 1-\psi_2$. In addition to delivering a single depreciation parameter δ, equation (35) 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 (31), (32), and (35), deliver the econometric version of our structural system of growth and trade:

$$\begin{aligned} &Trade: \quad x_{ij,t} = \exp[\gamma_1 RTA_{ij} + \gamma_{ij} + \eta_{i,t} + \pi_{j,t}] + \epsilon_{ij,t}, &(36)\\ &Output: \quad \ln y_{j,t} = \kappa_1 \ln L_{j,t} + \kappa_2 K_{j,t} + \kappa_3 \ln\left(\frac{1}{\Pi_{j,t}^{1-\sigma}}\right) + \nu_t + \vartheta_j + \varepsilon_{j,t}, &(37)\\ &Capital: \quad \ln K_{j,t} = \psi_0 + \psi_1 \ln y_{j,t-1} + \psi_2 \ln K_{j,t-1} + \psi_3 \ln P_{j,t-1} + \varsigma_{j,t}. &(38) \end{aligned}$$

System (36)-(38) obtains estimates of the key parameters needed to calibrate our model of trade and growth. We demonstrate below. Before that we describe our data.

4.1.3 Data

Our sample covers 82 countries over the period 1990-2011.[15] These countries account for more than 98 percent of world production throughout the period of investigation. In order to perform our analysis, we use data on trade flows, gross domestic product (GDP), employment, capital and regional trade agreements. 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. 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. The

[15] 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).

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 growth regressions. The Penn World Tables 8.0 include data that enables us to measure employment in effective units for all countries in our sample. 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 depreciation past investments 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, 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 5.8 percent of zeroes. Data on regional trade agreements are from the World Trade Organization and are augmented and corrected with information from the RTA secretariat web pages. Finally, data on the standard gravity variables, i.e., distance, common borders, common language, and colonial ties are from the CEPII's Distances Database.

4.1.4 Estimation Results and Analysis

Trade Costs. We start with a brief discussion of our estimate of the effects of regional trade agreements, which is obtained with a PPML estimator from equation (25) with bilateral fixed effects to control for potential RTA endogeneity and exporter-time and importer-time fixed effects to account for the structural multilateral resistance terms and output 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),[16] which is readily comparable to the

[16] Our PTA estimate suggests an increase of 129% ($\exp(0.827) - 1$) in bilateral trade flows among member countries.

corresponding index of 0.76 from Baier and Bergstrand (2007). 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 (26). We start with a brief summary of the estimates of the coefficients on the standard gravity covariates. For brevity, we report the estimates directly in the estimating equation:

$$\begin{aligned}\exp(\hat{\mu}_{ij}) = & \exp[-\underset{(0.014)}{\mathbf{0.842}} \ln DIST_{ij,1} - \underset{(0.013)}{\mathbf{0.825}} \ln DIST_{ij,2} - \underset{(0.008)}{\mathbf{0.747}} \ln DIST_{ij,3} - \underset{(0.012)}{\mathbf{0.744}} \ln DIST_{ij,4}] \\ & \times \exp[\underset{(0.232)}{\mathbf{0.515}}\ BRDR_{ij} + \underset{(0.193)}{\mathbf{0.836}}\ LANG_{ij} + \underset{(0.303)}{\mathbf{0.208}}\ CLNY_{ij} +]. \qquad (39)\end{aligned}$$

As can be seen from equation (39), 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 (standard errors are given in parenthesis below the respective point estimates). 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 (39) to be plausible, and we are comfortable using them to construct bilateral trade costs for our counterfactuals below.

We employ the estimates from equation (39) together with data on the gravity variables to construct a complete set of bilateral trade costs $\{\hat{t}_{ij}\}$ 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 $\hat{t}_{ij} = \widehat{exp(\hat{\mu}_{ij})}^{1/(1-\sigma)}$, where $\widehat{exp(\hat{\mu}_{ij})}$ is the predicted value from (39) 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 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 (in absolute value) estimates of 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 (in absolute values) estimates of t_{ij} for countries that are isolated economically and geographically. The largest (absolute value) estimate is for the pair Singapore-Ecuador (4.352).

Finally, we construct internal trade costs $\{\hat{t}_{ii}\}$ as the product between internal distance and the estimates on the coefficient on $DIST\_1$.[17] 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 t_{ij} as convincing and we are confident in using them to construct the multilateral resistances and to perform counterfactual experiments.

Output. Next, we turn to the upper level and we estimate our output equation

$$\ln y_{j,t} = \kappa_1 \ln L_{j,t} + \kappa_2 \ln K_{j,t} + \kappa_3 \ln \left(\frac{1}{\tilde{\Pi}_{j,t}^{1-\sigma}} \right) + \nu_t + \vartheta_j + \varepsilon_{j,t}. \tag{40}$$

Here, following the discussion in Section 4.1.2, the multilateral resistances are constructed according to system (34)-(33) in order to account for potential endogeneity.

Estimates from various specifications of equation (40) are reported in Table 1. In column (1) of the table, we offer results from a standard unconstrained estimation of the Cobb-Douglas production function with year fixed effects. As can be seen from the table, the sum

[17] $DIST\_1$ 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 with each country. For further details see CEPII's Distances Database.

of the estimates of the labor share and the capital share is close to one (but statistically different from one). In addition, 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 and we are comfortable to proceed with the estimates of our structural model.

Table 1: Trade Costs and Production, 1990-2011

	(1) Cobb-Douglas	(2) Time Trend	(3) Year FE	(4) Constraint	(5) Constraint Country FE
A. Dep. Variable $\ln y_{j,t}$					
$\ln L_{j,t}$	0.181	0.204	0.204	0.189	0.362
	(0.016)**	(0.017)**	(0.017)**	(0.016)**	(0.034)**
$\ln K_{j,t}$	0.717	0.704	0.704	0.709	0.442
	(0.020)**	(0.021)**	(0.021)**	(0.021)**	(0.037)**
$\ln\left(1/\Pi_{j,t}^{1-\sigma}\right)$		-0.193	-0.193	-0.103	-0.196
		(0.023)**	(0.023)**	(0.008)**	(0.026)**
Year FEs	Yes	No	Yes	Yes	Yes
Country FEs	No	No	No	No	Yes
R^2	0.921	0.923	0.923		
B. Structural Parameters					
$\hat{\alpha}$	0.717	0.872	0.872	0.790	0.550
	(0.020)**	(0.025)**	(0.025)**	(0.019)**	(0.041)**
$\hat{\sigma}$		5.182	5.188	9.751	5.100
		(0.606)**	(0.613)**	(0.717)**	(0.684)**

Notes: This table reports results from various specifications of the production function. The number of observations is 1606. Column (1) reports estimates from a standard unconstrained estimation of the Cobb-Douglas production function with year fixed effects. In column (2), we introduce the structural trade term (the multilateral resistance) and we use a time trend. The estimates in column (3) are obtained with year fixed effects. In column (4) we impose the structural constraints of our model. Finally, the estimates in column (5) are obtained with the structural constraints and with year- and country-fixed effects. Standard errors in parentheses. + $p < 0.10$, * $p < .05$, ** $p < .01$. See text for further details.

We introduce trade costs (multilateral resistances) in column (2), where we also use a time trend to control for the world GDP from our theoretical equation. Several properties stand out. First, without any exception, all estimates from column (2) 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 0.872 (std.err. 0.025) for the capital share α. Finally, the estimate on the multilateral resistance term implies a plausible value for the trade elasticity of substitution. In particular, we obtain a value of $\hat{\sigma} = -1/\hat{\kappa}_3 = 5.182$ (std.err. 0.606), 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 3 and 12 (see Footnote **??**).

We proceed with three refinements to the econometric specification, which are presented in columns (3)-(5) of Table 1. First, in column (3) we use year fixed effects instead of a time trend in order to control for world GDP and other time-varying effects that are common across all countries in our sample. The new findings are virtually identical to the results from column (2). Next, we impose the structural restriction $\kappa_1 + \kappa_2 = 1 + \kappa_3$ in order to obtain the estimates in column (4). The new capital share decreases a bit to 0.79 (std.err. 0.019), and the trade elasticity of substitution σ increases to 9.751 (std.err. 0.717), which is in the upper tail of the existing elasticity estimates.

Finally, the indexes in column (5) are obtained from a constrained regression with year fixed effects and country fixed effects. This is our most preferred specification because, in addition to imposing the structural restrictions of our model, the specification with year and country fixed effects is the one that is most likely to account for the effects of technology and preferences that are not explicitly captured in (40). The estimate of the capital share decreases further to 0.55 (std.err. 0.041) and the estimate of σ falls to 5.1 (std.err. 0.684). Once again, both estimates are within their theoretical bounds. Overall, we view the parameter estimates from this section as plausible and we are comfortable using them to perform counterfactual experiments.

Capital. We proceed with estimation of our capital accumulation specification:

$$\ln K_{j,t} = \psi_0 + \psi_1 \ln y_{j,t-1} + \psi_2 \ln K_{j,t-1} + \psi_3 \ln P_{j,t-1} + \varsigma_{j,t}. \qquad (41)$$

(41) will enable us to recover capital depreciation rates (δ's) subject to the following rela-

tionships: $\psi_1 = \delta$; $\psi_2 = 1 - \delta$; and $\psi_3 = -\delta$. Estimation results are presented in Table 2.

We start by estimating (41) directly, without any fixed effects and without imposing any structural constraints. The estimates in column (1) of Table 2 are encouraging. First, the estimates of the three covariates imply reasonable values for δ, which vary between 0.012, as identified from the coefficient on $\ln P_{j,t-1}$, and 0.018, identified directly as the coefficient on $y_{j,t-1}$. These estimates are a bit low, but they are close to our expectations. Second, even though the two estimates of δ are statistically different from each other at the 5% level (this is demonstrated by the formal tests in the bottom panel of Table 2), they are close in magnitude.

Table 2: Capital Accumulation Estimates, 1989-2011

	(1) Unconstr	(2) Year FEs	(3) Constraint	(4) Constraint Country FE
Dep. Variable $\ln K_{j,t}$				
$\ln y_{j,t-1}$	0.018	0.017	0.006	0.052
	(0.003)**	(0.003)**	(0.002)**	(0.006)**
$\ln K_{j,t-1}$	0.984	0.984	0.994	0.948
	(0.003)**	(0.003)**	(0.002)**	(0.006)**
$\ln P_{j,t-1}$	0.012	0.013	-0.006	-0.052
	(0.002)**	(0.002)**	(0.002)**	(0.006)**
Year FEs	No	Yes	Yes	Yes
Country FEs	No	No	Yes	Yes
R^2	.99	.99		
p-value($\psi_1 + \psi_2 = 1$)	0.021	0.183		
p-value($\psi_1 + \psi_3 = 0$)	0.000	0.000		
p-value($\psi_2 - \psi_3 = 1$)	0.000	0.000		

Notes: This table reports results from various specification of the capital accumulation equation. The number of observations is 1722. The estimates in column (1) are obtained without any fixed effects and without imposing any structural constraints. We introduce year-fixed effects in column (2). In column (3), we impose the theoretical constraints of our model. Finally, in column (4), we add country-fixed effects in addition to the year-fixed effects. Rows p-value($\psi_1 + \psi_2 = 1$), p-value($\psi_1 + \psi_3 = 0$) and p-value($\psi_2 - \psi_3 = 1$) report p-values from chi-squared tests of the structural constraints of our model. Standard errors in parentheses. + $p < 0.10$, * $p < .05$, ** $p < .01$. See text for more details.

Next, in column (2) of Table 2, we introduce year fixed effects. As a result, we obtain predicted values of δ that are closer to each other. The new estimates vary between 0.013 and 0.017, and the first formal test $\psi_1 + \psi_2 = 1$, presented in the bottom of the table, cannot reject equality between the capital depreciation estimates from the coefficients on the different covariates. Once again, we obtain relatively low estimates of δ. This is also the case in column (3) of Table 2, where we impose the theoretical constraints of our model to obtain $\delta = 0.006$ (std.err. 0.002). Finally, in the last column of Table 2, we introduce country fixed effects in addition to the year fixed effects from column (2) and we impose the structural constraints of our model. The resulting depreciation rate estimate is $\delta = 0.052$ (std.err. 0.006).

In our last experiment, we use equation (41) to obtain country-specific depreciation rate estimates δ_i's. To do this, we interact each of the three covariates on the right-hand side of (41) with country dummies, and we impose the theoretical constraints of our model. The resulting country-specific estimates are reported in the column (5) of Table 5. 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.

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 3.

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.

Table 3: Parameter Estimates

Parameter	**Min.**	**Max.**
$\hat{\alpha}$	0.550	0.872
	(0.041)**	(0.025)**
$\hat{\sigma}$	5.100	9.751
	(0.684)**	(0.717)**
$\hat{\delta}$	0.006	0.052
	(0.002)**	(0.006)**
$\hat{\delta}_i$	0.030	0.161
	(0.005)**	(0.016)**
$\hat{t}_{ij}$	1.796	4.352

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

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 allow for intermediate goods and we 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 (28); (ii) we recover theory-consistent, steady-state capital stocks according to the capital accumulation equation (21); (iii) we calculate baseline preference-adjusted technology A_j/γ_j according to the market-clearing equation (19) and the production function equation (20).[18] Finally, to obtain the main results, we

[18]Appndix D offers a detailed description of our counterfactual setup and procedures.

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 3. The consumers' discount factor is set equal to $\beta = 0.98$, which is standard in the literature.

As discussed earlier, our parameter estimates are readily comparable with corresponding values from existing studies. 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 correla-

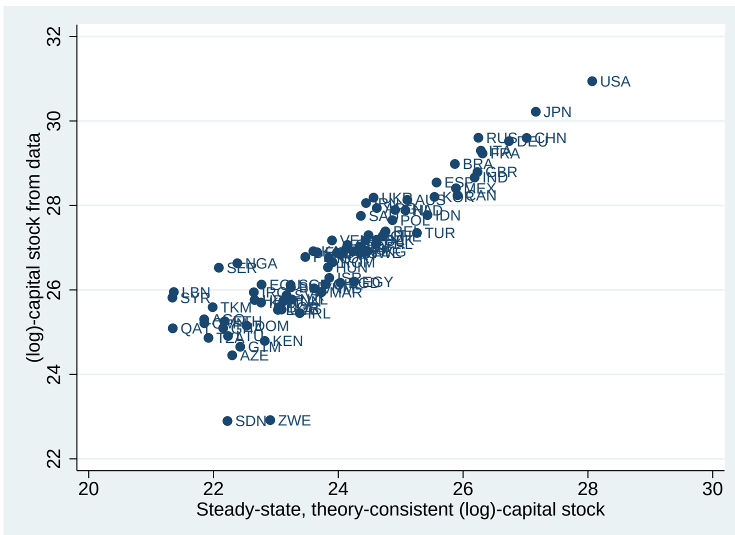

Figure 1: Theory-consistent vs. actual capital stocks.

tion 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. See Appendix D for further details on our counterfactual setup and procedures.

5.1 The Effects of Trade Liberalization and Globalization

In our main counterfactual experiment, we apply our framework to one of the most heavily investigated trade agreements, the North American Free Trade Agreement (NAFTA). 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.[19] In order to demonstrate how our approach builds on previous work, we implement the counterfactual experiments in four steps. First, we discuss the partial equilibrium NAFTA effects. We label this scenario "Direct Effects" and it corresponds to the PTE 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 multilateral resistance terms (16)-(18) at constant GDPs. We label this scenario "Conditional GE" and it corresponds to the 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 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 for each of the four scenarios in Table 4. 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 multilateral resistance terms, however, we take GDPs as exogenous. Several findings stand out. First, we estimate large gains for

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

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 ejoys only modest welfare gains of 0.8%. These numbers are in line with previous studies.[20]

Second, we obtain negative NAFTA effects for all other countries in the world. Trade 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 4, we find that on average non-NAFTA members will suffer -0.22% decrease in welfare. In combination with the 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.[21]

In column (3) of Table 4, 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.[22]

[20] 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.

[21] 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.

[22] In analysis available upon request, we 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.

The large positive welfare effects for NAFTA members in this scenario are comparable to estimates from related studies (see Caliendo and Parro (2012) and 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" 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 4 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.

Real GDP per capita is the standard measure of welfare in the static trade literature, 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.[23] (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 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:

$$\sum_{t=0}^{\infty} \beta^t \ln\left(C_{j,t,c}\right) = \sum_{t=0}^{\infty} \beta^t \ln\left[\left(1+\frac{\lambda}{100}\right) C_{j,t}\right] \Rightarrow$$
$$\lambda = \left(\exp\left[(1-\beta)\left(\sum_{t=0}^{\infty} \beta^t \ln\left(C_{j,t,c}\right) - \sum_{t=0}^{\infty} \beta^t \ln\left(C_{j,t}\right)\right)\right] - 1\right) \times 100. \tag{42}$$

Properly discounted welfare effects are reported in column (5) of Table 4. 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 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 impact of NAFTA. Figure 2 reveals the following. First, we find that the effects on members are large and long-lived. As expected, most of the dynamic gains accrue initially. However, we estimate significant transitional

[23] 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 Equation (16)-(21) 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 Appendix E.

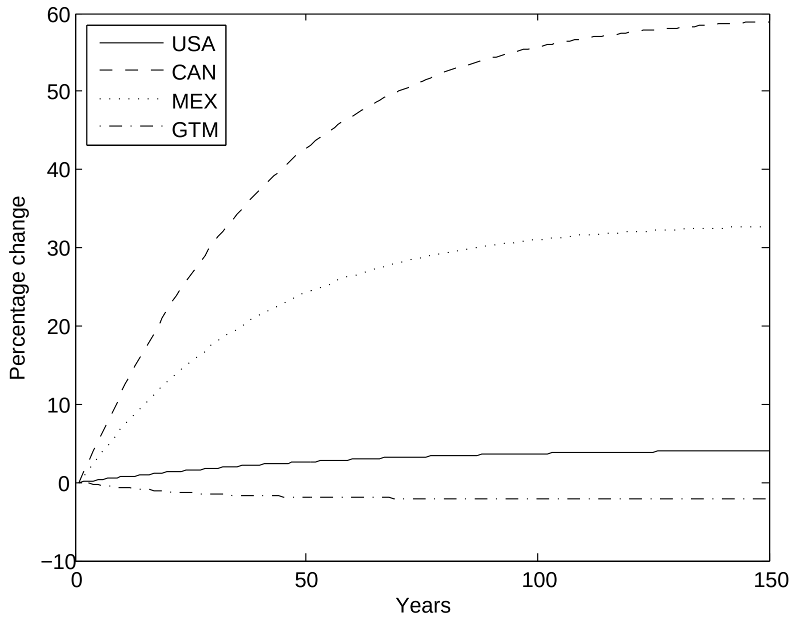

Figure 2: On the transitional effects of NAFTA: Capital stocks.

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. 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 of period of 12 years from Bergstrand, Larch, and Yotov (2013).[24] Results capturing the effects of globalization from the four scenarios in columns (2)-(5) are presented in columns (6)-(9) of Table 4. Several findings stand out. First, without

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

exception, all countries in the world benefit from globalization. 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 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. Specifically, we will first investigate an increase of the capital stock for the USA. Second, we will extend our framework to allow for intermediate goods. We then allow for country-specific depreciation rates, followed by alternative values for the elasticity of substitution, the capital share and the depreciation rate.

5.2.1 Capital Accumulation

The main mechanism that leads to dynamic effects in our framework is through capital accumulation. We therefore want to highlight how a 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.

Table 5 reports the results. In the first column we give the country names, the second column reproduces the welfare results form our base-line "Full Dynamic GE, transition" (column (5) of Table 4). The welfare results for the scenario of the increase of the USA capital stock of 20% are presented in column (3) of Table 5. 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 an 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 clumn (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.

5.2.2 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.[25] 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

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

and capital via the following Cobb-Douglas-production function:[26]

$$y_{j,t} = p_{j,t} A_{j,t} K_{j,t}^{\alpha} L_{j,t}^{\xi} Q_{j,t}^{1-\alpha-\xi} \quad \alpha, \xi \in (0,1), \tag{43}$$

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:[27]

$$\begin{aligned}
x_{ij,t} &= \frac{y_{i,t} y_{j,t}}{y_t} \left(\frac{t_{ij,t}}{\Pi_{i,t} P_{j,t}}\right)^{1-\sigma}, && (44)\\
P_{j,t}^{1-\sigma} &= \sum_i \left(\frac{t_{ij,t}}{\Pi_{i,t}}\right)^{1-\sigma} \frac{y_{i,t}}{y_t}, && (45)\\
\Pi_{i,t}^{1-\sigma} &= \sum_j \left(\frac{t_{ij,t}}{P_{j,t}}\right)^{1-\sigma} \frac{y_{j,t}}{y_t}, && (46)\\
p_{j,t} &= \frac{(y_{j,t}/y_t)^{\frac{1}{1-\sigma}}}{\gamma_j \Pi_{j,t}}, && (47)\\
y_{j,t} &= p_{j,t} A_{j,t} K_{j,t}^{\alpha} L_{j,t}^{\xi} Q_{j,t}^{1-\alpha-\xi}, && (48)\\
K_{j,t+1} &= \left[\frac{(\alpha+\xi) p_{j,t} A_{j,t} L_{j,t}^{\xi} Q_{j,t}^{1-\alpha-\xi} \beta\alpha\delta}{P_{j,t}\left(1-\beta+\delta\beta\right)}\right]^{\delta} K_{j,t}^{\alpha\delta+1-\delta}, && (49)\\
K_0 & \quad \text{given.}
\end{aligned}$$

The introduction of intermediate goods adds a new layer of indirect and general equilibrium linkages that shape the relationship between growth and trade. Equation (48) 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 (48) directly, as before, and indirectly, via the intermediates $Q_{j,t}$. Sec-

[26]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.

[27]Detailed derivations can be found in Appendix F

ond, 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 (49) 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 (49), 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 (43) 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 and the expensive of capital, and we retain the share of labor to 0.45 as in our base-line scenario.[28] Then, we replicate our NAFTA counterfactual experiment to quantify the role of intermediates in our dynamic framework.

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

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

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.

5.2.3 Additional Robustness Checks

IN our first experiment we allow for country-specific capital depreciation rates, which are reported in column (5) of Table 5. The welfare effects of NAFTA in the presence of the country-specific δ's are reported in column (6). 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 (7) of Table 5 we use the largest obtained σ of 9.751. 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 nearly doubling of σ leads to half the size in the welfare effects. 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 (8) of Table 5). The negative effects on non-NAFTA countries are smaller. Finally, we use our lowest estimate of $\delta = 0.006$ (instead of 0.052). This leads to about 20% lower welfare gains as compared to the base-line scenario (see column (9) of Table 5). The mechanism is identical to the one described above for the country-specific δ's. 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. The multi-good model will bring in the important force of specialization. The 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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Table 4: Welfare Effects of NAFTA and Globalization

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)
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

Continued on next page

Table 4 – *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 (28) and recovered theory-consistent, steady-state capital stocks according to the capital accumulation equation (21). We calculate baseline preference-adjusted technology A_j/γ_j according to the market-clearing equation (19) and the production function equation (20). 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 5: Evaluation of NAFTA: Robustness Checks, Welfare Effects for the 'Full Dynamic GE' scenario

Country	Base-line	Capital accum.	Inter-mediates	Ctry-specific δ		$\sigma =$ 9.751	$\alpha =$ 0.872	$\delta =$ 0.006
				δ	Welfare			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
AGO	-0.562	-0.241	-0.608	0.039	-0.541	-0.339	-0.455	-0.454
ARG	-1.177	-0.980	-1.233	0.045	-1.148	-0.774	-0.872	-1.044
AUS	-0.790	-0.255	-0.850	0.044	-0.778	-0.484	-0.626	-0.646
AUT	-0.121	-0.058	-0.136	0.059	-0.123	-0.065	-0.115	-0.088
AZE	-0.280	-0.112	-0.312	0.045	-0.273	-0.153	-0.253	-0.207
BEL	-0.068	-0.041	-0.080	0.065	-0.070	-0.032	-0.074	-0.044
BGD	-0.367	-0.239	-0.401	0.041	-0.352	-0.215	-0.312	-0.292
BGR	-0.307	-0.132	-0.336	0.050	-0.306	-0.179	-0.260	-0.240
BLR	-0.310	-0.135	-0.342	0.047	-0.305	-0.176	-0.270	-0.237
BRA	-0.806	-0.502	-0.858	0.044	-0.786	-0.508	-0.623	-0.683
CAN	44.204	47.557	50.432	0.064	45.679	20.897	65.668	32.843
CHE	-0.048	-0.029	-0.060	0.069	-0.050	-0.017	-0.064	-0.024
CHL	-0.709	-0.467	-0.761	0.042	-0.687	-0.435	-0.566	-0.587
CHN	-0.385	-0.168	-0.419	0.030	-0.354	-0.227	-0.321	-0.305
COL	-1.115	-0.939	-1.170	0.043	-1.080	-0.728	-0.833	-0.984
CZE	-0.163	-0.046	-0.183	0.050	-0.164	-0.087	-0.155	-0.119
DEU	-0.171	-0.046	-0.192	0.057	-0.175	-0.091	-0.161	-0.125
DNK	-0.206	-0.061	-0.229	0.055	-0.210	-0.114	-0.188	-0.155
DOM	-0.974	-0.592	-1.032	0.040	-0.941	-0.622	-0.742	-0.835
ECU	-0.929	-0.801	-0.980	0.044	-0.900	-0.598	-0.706	-0.809
EGY	-0.358	-0.227	-0.390	0.048	-0.353	-0.212	-0.300	-0.287
ESP	-0.522	-0.279	-0.559	0.048	-0.518	-0.321	-0.419	-0.434
ETH	-0.814	-0.264	-0.875	0.045	-0.802	-0.500	-0.642	-0.666
FIN	-0.265	-0.078	-0.294	0.050	-0.266	-0.147	-0.239	-0.200
FRA	-0.287	-0.124	-0.314	0.056	-0.290	-0.170	-0.238	-0.227
GBR	-0.399	-0.153	-0.434	0.059	-0.407	-0.238	-0.326	-0.318
GHA	-0.888	-0.390	-0.949	0.050	-0.886	-0.553	-0.691	-0.740
GRC	-0.272	-0.114	-0.300	0.050	-0.271	-0.155	-0.236	-0.209
GTM	-1.893	-1.611	-1.964	0.052	-1.888	-1.272	-1.370	-1.718
HKG	-0.379	-0.116	-0.415	0.050	-0.374	-0.220	-0.321	-0.294
HRV	-0.450	-0.196	-0.487	0.049	-0.448	-0.273	-0.362	-0.365
HUN	-0.266	-0.117	-0.292	0.054	-0.267	-0.155	-0.226	-0.208
IDN	-0.467	-0.298	-0.503	0.038	-0.444	-0.284	-0.378	-0.383
IND	-0.701	-0.302	-0.753	0.044	-0.687	-0.432	-0.553	-0.577
IRL	-0.181	-0.078	-0.206	0.063	-0.188	-0.094	-0.175	-0.128
IRN	-0.493	-0.303	-0.531	0.045	-0.482	-0.301	-0.397	-0.406
IRQ	-0.421	-0.260	-0.456	0.055	-0.421	-0.252	-0.346	-0.341
ISR	-0.884	-0.159	-0.951	0.053	-0.898	-0.534	-0.715	-0.717
ITA	-0.273	-0.119	-0.300	0.050	-0.273	-0.159	-0.232	-0.214
JPN	-0.334	-0.144	-0.365	0.046	-0.328	-0.196	-0.281	-0.263
KAZ	-0.180	-0.074	-0.209	0.046	-0.174	-0.085	-0.186	-0.117
KEN	-0.819	-0.265	-0.880	0.049	-0.817	-0.503	-0.646	-0.670
KOR	-0.375	-0.242	-0.406	0.039	-0.358	-0.227	-0.308	-0.306
KWT	-0.374	-0.158	-0.410	0.042	-0.362	-0.219	-0.316	-0.294
LBN	-0.454	-0.286	-0.488	0.042	-0.436	-0.285	-0.347	-0.376
LKA	-0.449	-0.283	-0.485	0.042	-0.433	-0.270	-0.368	-0.365
LTU	-0.348	-0.104	-0.383	0.054	-0.352	-0.199	-0.303	-0.269
MAR	-0.435	-0.200	-0.471	0.046	-0.429	-0.264	-0.350	-0.352
MEX	25.015	26.857	28.313	0.055	25.221	12.235	35.986	18.865
MYS	-0.286	-0.188	-0.315	0.038	-0.269	-0.164	-0.251	-0.223
NGA	-0.874	-0.374	-0.935	0.059	-0.890	-0.544	-0.682	-0.727
NLD	-0.143	-0.040	-0.161	0.060	-0.148	-0.075	-0.138	-0.103
NOR	-0.303	-0.092	-0.334	0.055	-0.308	-0.173	-0.265	-0.234
NZL	-0.841	-0.274	-0.904	0.049	-0.838	-0.515	-0.666	-0.688
OMN	-0.495	-0.212	-0.537	0.040	-0.478	-0.297	-0.403	-0.398
PAK	-0.479	-0.207	-0.524	0.053	-0.478	-0.278	-0.404	-0.374
PER	-0.773	-0.676	-0.819	0.041	-0.743	-0.493	-0.596	-0.667
PHL	-0.747	-0.273	-0.803	0.046	-0.739	-0.457	-0.595	-0.612
POL	-0.227	-0.102	-0.250	0.054	-0.228	-0.131	-0.196	-0.176
PRT	-0.298	-0.078	-0.331	0.047	-0.296	-0.163	-0.270	-0.222
QAT	-0.419	-0.177	-0.457	0.034	-0.394	-0.247	-0.349	-0.332

Continued on next page

Country	Base-line	Capital accum.	Inter-mediates	Ctry-specific δ		$\sigma =$ 9.751	$\alpha =$ 0.872	$\delta =$ 0.006
				δ	Welfare			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
ROM	-0.408	-0.260	-0.438	0.051	-0.405	-0.251	-0.326	-0.338
RUS	-0.535	-0.235	-0.577	0.045	-0.525	-0.327	-0.427	-0.438
SAU	-0.470	-0.200	-0.510	0.042	-0.456	-0.282	-0.384	-0.377
SDN	-0.486	-0.301	-0.524	0.043	-0.471	-0.296	-0.392	-0.399
SER	-0.449	-0.194	-0.486	0.050	-0.447	-0.271	-0.364	-0.363
SGP	-0.416	-0.176	-0.454	0.041	-0.401	-0.245	-0.348	-0.329
SVK	-0.243	-0.108	-0.267	0.048	-0.241	-0.141	-0.208	-0.189
SWE	-0.274	-0.082	-0.302	0.057	-0.279	-0.155	-0.242	-0.210
SYR	-0.327	-0.135	-0.359	0.046	-0.321	-0.188	-0.279	-0.253
THA	-0.403	-0.255	-0.436	0.040	-0.385	-0.242	-0.332	-0.327
TKM	-0.399	-0.164	-0.437	0.038	-0.382	-0.233	-0.337	-0.313
TUN	-0.472	-0.357	-0.504	0.049	-0.464	-0.301	-0.356	-0.400
TUR	-0.417	-0.266	-0.449	0.051	-0.415	-0.256	-0.335	-0.345
TZA	-0.653	-0.284	-0.704	0.047	-0.646	-0.396	-0.524	-0.531
UKR	-0.311	-0.135	-0.344	0.046	-0.306	-0.176	-0.272	-0.237
USA	2.748	6.600	3.295	0.048	2.766	1.241	3.813	1.737
UZB	-0.444	-0.187	-0.484	0.048	-0.439	-0.263	-0.368	-0.353
VEN	-0.978	-0.803	-1.032	0.048	-0.962	-0.629	-0.742	-0.850
VNM	-0.405	-0.260	-0.439	0.031	-0.373	-0.244	-0.333	-0.330
ZAF	-0.721	-0.228	-0.778	0.051	-0.724	-0.438	-0.576	-0.585
ZWE	-0.615	-0.270	-0.664	0.161	-0.692	-0.372	-0.497	-0.498
World	1.842	3.018	2.151		1.888	0.827	2.848	1.283
NAFTA	7.671	11.319	8.868		7.813	3.612	11.071	5.466
ROW	-0.423	-0.207	-0.458		-0.414	-0.255	-0.346	-0.342

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 (28) and recovered theory-consistent, steady-state capital stocks according to the capital accumulation equation (21). We calculate baseline preference-adjusted technology A_j/γ_j according to the market-clearing equation (19) and the production function equation (20). 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 GE, dynamic' 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 4. Column (3) assumes a 20% higher capital capital stock in the USA in 1994 when NAFTA was concluded. 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 $\sigma = 9.751$ instead of 5.1. Column (8) reports results based on a capital share of $\alpha = 0.872$, while the last column reports the welfare effects when a common depreciation rate of $\delta = 0.006$ is assumed.

Appendix

A Derivation of the Policy Functions of the Upper Level

Our upper level reads as follows (we omit the country indexes in order to economize on the notational burden):

$$U_t = \sum_{t=0}^{\infty} \beta^t \ln(C_t), \tag{A1}$$

$$K_{t+1} = K_t^{1-\delta} \Omega_t^{\delta}, \tag{A2}$$

$$y_t = p_t A_t L_t^{1-\alpha} K_t^{\alpha}, \tag{A3}$$

$$P_t \Omega_t = y_t - P_t C_t, \tag{A4}$$

$$K_0 \quad \textit{given}. \tag{A5}$$

This is very similar to 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 an analytical solution. To solve for the policy functions of capital and consumption we iterate over the value function. For ease of notation, we skip indices for current periods and denote next period variables by $'$. Further, we define $\phi = 1/\delta$. The value of the value function at step 0, v^0, is equal to 0. In the next step, the value of the value function is given by:

$$v' = \max_{K'} \ln C = \max_{K'} \ln (y/P - \Omega) \tag{A6}$$

$$= \max_{K'} \ln \left(pAL^{1-\alpha} K^{\alpha}/P - (K'^{\phi}/K^{\phi-1}) \right). \tag{A7}$$

The first order condition reads as follows:

$$\frac{1}{pAL^{1-\alpha}K^{\alpha}/P - (K'^{\phi}/K^{\phi-1})}(-\phi)\frac{K'^{\phi-1}}{K^{\phi-1}} = 0. \tag{A8}$$

It follows that $K' = 0$.

Hence, $v' = \ln (pAL^{1-\alpha}K^{\alpha}/P)$. In the next step, we have to solve:

$$v^2 = \max_{K'} \ln \left(pAL^{1-\alpha}K^{\alpha}/P - (K'^{\phi}/K^{\phi-1}) \right) + \beta \ln \left(pAL^{1-\alpha}K'^{\alpha}/P \right). \tag{A9}$$

The first order condition then reads as follows:

$$
\begin{aligned}
&\frac{1}{pAL^{1-\alpha}K^{\alpha}/P-(K'^{\phi}/K^{\phi-1})}(-\phi)\frac{K'^{\phi-1}}{K^{\phi-1}}+\frac{\beta\alpha P}{pAL^{1-\alpha}K'}=0,\\
&\frac{\beta\alpha P}{pAL^{1-\alpha}\phi}\left(pAL^{1-\alpha}K^{\alpha}/P-(K'^{\phi}/K^{\phi-1})\right)=\frac{K'^{\phi}}{K^{\phi-1}},\\
&\frac{\beta\alpha P}{pAL^{1-\alpha}\phi}\left(pAL^{1-\alpha}K^{\alpha}/P\right)=\left(\frac{\beta\alpha P}{pAL^{1-\alpha}\phi}+1\right)\frac{K'^{\phi}}{K^{\phi-1}},\\
&\frac{\beta\alpha}{\phi}K^{\alpha}=\left(\frac{\beta\alpha P}{pAL^{1-\alpha}\phi}+1\right)\frac{K'^{\phi}}{K^{\phi-1}},\\
&\frac{\beta\alpha}{\phi}\frac{pAL^{1-\alpha}\phi}{\beta\alpha P+pAL^{1-\alpha}\phi}K^{\alpha+\phi-1}=K'^{\phi},\\
&\left(\frac{\beta\alpha pAL^{1-\alpha}}{\beta\alpha P+pAL^{1-\alpha}\phi}\right)^{\frac{1}{\phi}}K^{(\alpha+\phi-1)/\phi}=K'. \qquad \text{(A10)}
\end{aligned}
$$

Plugging in the expression for K' given in equation (A10), we end up with:

$$
\begin{aligned}
v^2 &= \ln\left(pAL^{1-\alpha}K^{\alpha}/P-\left(\left(\left(\left(\frac{\beta\alpha pAL^{1-\alpha}}{\beta\alpha P+pAL^{1-\alpha}\phi}\right)^{\frac{1}{\phi}}K^{(\alpha+\phi-1)/\phi}\right)^{\phi}/K^{\phi-1}\right)\right)\right)\\
&\quad+\beta\ln\left(pAL^{1-\alpha}\left(\left(\frac{\beta\alpha pAL^{1-\alpha}}{\beta\alpha P+pAL^{1-\alpha}\phi}\right)^{\frac{1}{\phi}}K^{(\alpha+\phi-1)/\phi}\right)^{\alpha}/P\right),\\
&= \ln\left(\left(pAL^{1-\alpha}/P-\frac{\beta\alpha pAL^{1-\alpha}}{\beta\alpha P+pAL^{1-\alpha}\phi}\right)K^{\alpha}\right)\\
&\quad+\beta\ln\left(pAL^{1-\alpha}\left(\left(\frac{\beta\alpha pAL^{1-\alpha}}{\beta\alpha P+pAL^{1-\alpha}\phi}\right)^{\frac{1}{\phi}}\right)^{\alpha}/PK^{(\alpha+\phi-1)\alpha/\phi}\right),\\
&= \alpha\ln(K)+\beta\theta\alpha\ln(K)+const,
\end{aligned}
$$

where $\theta\equiv(\alpha+\phi-1)/\phi$ and *const* collects all terms not depending on K. The next step is

$$
\begin{aligned}
v^3 &= \max_{K'}\ln\left(pAL^{1-\alpha}K^{\alpha}/P-(K'^{\phi}/K^{\phi-1})\right)+\alpha\beta\ln(K')+\beta^2\theta\alpha\ln(K')\\
&\quad+\beta const. \qquad \text{(A11)}
\end{aligned}
$$

The first order condition is given by:

$$
\begin{aligned}
&\frac{1}{pAL^{1-\alpha}K^{\alpha}/P-(K'^{\phi}/K^{\phi-1})}(-\phi)\frac{K'^{\phi-1}}{K^{\phi-1}}+\frac{\beta\alpha}{K'}+\frac{\alpha\theta\beta^2}{K'}=0,\\
&\frac{\beta\alpha}{\phi}(1+\beta\theta)\left(pAL^{1-\alpha}K^{\alpha}/P-(K'^{\phi}/K^{\phi-1})\right)=\frac{K'^{\phi}}{K^{\phi-1}},\\
&\frac{\beta\alpha}{\phi}(1+\beta\theta)pAL^{1-\alpha}K^{\alpha}/P=\left(\frac{\beta\alpha}{\phi}(1+\beta\theta)+1\right)\frac{K'^{\phi}}{K^{\phi-1}},\\
&K'=\left(\frac{\frac{\beta\alpha}{\phi}(1+\beta\theta)pAL^{1-\alpha}/P}{\frac{\beta\alpha}{\phi}(1+\beta\theta)+1}\right)^{\frac{1}{\phi}}K^{\theta}. \qquad \text{(A12)}
\end{aligned}
$$

Plugging in the solution of K' given in equation (A12) leads to

$$
v^3=\alpha\ln(K)+\alpha\beta\theta\ln(K)+\beta^2\theta^2\alpha\ln(K)+\beta const.
$$

In the next step we therefore have

$$
\begin{aligned}
v^4 \quad = \quad & \max_{K'}\ln\left(pAL^{1-\alpha}K^{\alpha}/P-(K'^{\phi}/K^{\phi-1})\right)+\alpha\beta\ln(K')\left[1+\beta\theta+\beta^2\theta^2\right]\\
&+\beta const, \qquad \text{(A13)}
\end{aligned}
$$

with the following first order condition:

$$
\begin{aligned}
&\frac{1}{pAL^{1-\alpha}K^{\alpha}/P-(K'^{\phi}/K^{\phi-1})}(-\phi)\frac{K'^{\phi-1}}{K^{\phi-1}}+\frac{\beta\alpha\left[1+\beta\theta+\beta^2\theta^2\right]}{K'}=0,\\
&\frac{\beta\alpha}{\phi}\left(1+\beta\theta+\beta^2\theta^2\right)\left(pAL^{1-\alpha}K^{\alpha}/P-(K'^{\phi}/K^{\phi-1})\right)=\frac{K'^{\phi}}{K^{\phi-1}},\\
&\frac{\beta\alpha}{\phi}\left(1+\beta\theta+\beta^2\theta^2\right)pAL^{1-\alpha}K^{\alpha}/P=\left(\frac{\beta\alpha}{\phi}\left(1+\beta\theta+\beta^2\theta^2\right)+1\right)\frac{K'^{\phi}}{K^{\phi-1}},\\
&K'=\left(\frac{\frac{\beta\alpha}{\phi}\left(1+\beta\theta+\beta^2\theta^2\right)pAL^{1-\alpha}/P}{\frac{\beta\alpha}{\phi}\left(1+\beta\theta+\beta^2\theta^2\right)+1}\right)^{\frac{1}{\phi}}K^{\theta}. \qquad \text{(A14)}
\end{aligned}
$$

Now we see the general pattern, which can be described as

$$
v^n \Rightarrow K'=\left[\frac{\frac{\beta\alpha}{\phi}pAL^{1-\alpha}/P\sum_{i=0}^{m}(\beta\theta)^i}{1+\frac{\beta\alpha}{\phi}\sum_{i=0}^{m}(\beta\theta)^i}\right]^{\frac{1}{\phi}}K^{\theta}, \qquad \text{(A15)}
$$

where n denotes the nth-step. When $m\to\infty$, we end up with

$$
\left[\frac{\frac{\beta\alpha}{\phi}pAL^{1-\alpha}/P\sum_{i=0}^{m}(\beta\theta)^i}{1+\frac{\beta\alpha}{\phi}\sum_{i=0}^{m}(\beta\theta)^i}\right]^{\frac{1}{\phi}}=\left[\frac{\frac{\beta\alpha}{\phi}pAL^{1-\alpha}/P\frac{1}{1-\beta\theta}}{1+\frac{\beta\alpha}{\phi}\frac{1}{1-\beta\theta}}\right]^{\frac{1}{\phi}}. \qquad \text{(A16)}
$$

Replacing $\theta \equiv (\alpha + \phi - 1)/\phi$ leads to:

$$
\begin{aligned}
\left[\frac{\frac{\beta\alpha}{\phi} pAL^{1-\alpha}/P \frac{1}{1-\beta(\alpha+\phi-1)/\phi}}{1 + \frac{\beta\alpha}{\phi}\frac{1}{1-\beta(\alpha+\phi-1)/\phi}}\right]^{\frac{1}{\phi}} &= \left[\frac{pAL^{1-\alpha}/P \frac{\beta\alpha}{\phi-\beta(\alpha+\phi-1)}}{1 + \frac{\beta\alpha}{\phi-\beta(\alpha+\phi-1)}}\right]^{\frac{1}{\phi}} = \\
\left[\frac{pAL^{1-\alpha}/P \frac{\beta\alpha}{\phi-\beta(\alpha+\phi-1)}}{\frac{\phi-\beta\phi+\beta}{\phi-\beta(\alpha+\phi-1)}}\right]^{\frac{1}{\phi}} &= \left[\frac{pAL^{1-\alpha}/P\beta\alpha}{\phi - \beta\phi + \beta}\right]^{\frac{1}{\phi}}.
\end{aligned}
$$

Now apply $\phi = 1/\delta$:

$$
\left[\frac{pAL^{1-\alpha}/P\beta\alpha}{1/\delta - \beta/\delta + \beta}\right]^{\delta} = \left[\frac{pAL^{1-\alpha}/P\beta\alpha\delta}{1 - \beta + \delta\beta}\right]^{\delta}. \tag{A17}
$$

Hence,

$$
K' = \left[\frac{pAL^{1-\alpha}\beta\alpha\delta}{P\,(1 - \beta + \delta\beta)}\right]^{\delta} K^{\alpha\delta+1-\delta}. \tag{A18}
$$

This is our policy function for the capital stock in the next period, K'. It depends alongside parameters on goods prices, labor endowments, the price index and the current capital stock. A higher labor endowment, a higher current capital stock and a higher goods price lead to higher next period capital stocks, while a higher current price index decrease capital stocks in the next period. A higher current goods price or a higher current endowment with labor means that output today is more valuable or that more output can be produced today. Hence, consumers are willing to transfer part of their wealth to the next period by capital accumulation. On the other hand, if the current price index is high, consumption is expensive today. Therefore, a higher share of income will be spend on consumption today and less will be saved and transferred for future consumption via capital accumulation.

Note that as soon as we have K' and K, we can determine the level of investment by

$$
\begin{aligned}
\Omega &= \left(\frac{K'}{K^{1-\delta}}\right)^{\frac{1}{\delta}} = \left(\frac{\left[\frac{pAL^{1-\alpha}\beta\alpha\delta}{P(1-\beta+\delta\beta)}\right]^{\delta} K^{\alpha\delta+1-\delta}}{K^{1-\delta}}\right)^{\frac{1}{\delta}} \\
&= \left[\frac{pAL^{1-\alpha}\beta\alpha\delta}{P\,(1 - \beta + \delta\beta)}\right] K^{\alpha}.
\end{aligned} \tag{A19}
$$

The optimal level of current consumption is found by using the policy function for capital and reformulating $P\Omega = y - PC$, i.e.,

$$
\begin{aligned}
C &= \frac{y}{P} - \Omega = \frac{pAL^{1-\alpha}K^{\alpha}}{P} - \left[\frac{pAL^{1-\alpha}\beta\alpha\delta}{P\,(1 - \beta + \delta\beta)}\right] K^{\alpha} \\
&= \left[1 - \frac{\beta\alpha\delta}{1 - \beta + \delta\beta}\right] \frac{pAL^{1-\alpha}K^{\alpha}}{P} \\
&= \left[\frac{1 - \beta + \delta\beta - \beta\alpha\delta}{1 - \beta + \delta\beta}\right] \frac{pAL^{1-\alpha}K^{\alpha}}{P}.
\end{aligned} \tag{A20}
$$

B ACR formula

In ACR, the formula is based on real income. This is used because it is also welfare. However, in our framework this is no longer the case. The reason is that not all of the income is used for consumption. Rather, part of it is used to build up capital. Hence, our welfare measure should be consumption. We therefor start with consumption given by $C_j = y_j/P_j - K_j$ and replace capital K_j by the steady-state expression $K_j = \Omega_j = \alpha\beta\delta y_j/[P_j(1-\beta+\beta\delta)]$:

$$W_j \equiv C_j = \frac{y_j}{P_j} - K_j = \frac{y_j}{P_j} - \frac{\alpha\beta\delta y_j}{(1-\beta+\beta\delta)\,P_j} = \left(\frac{1-\beta+\beta\delta-\alpha\beta\delta}{1-\beta+\beta\delta}\right)\frac{y_j}{P_j}.$$

Taking the log-derivative leads to:

$$d\ln W_j = d\ln y_j - d\ln P_j.$$

y_j is given by Equation (20), i.e., $y_j = p_j A_j L_j^{1-\alpha} K_j^{\alpha}$. Note that with perfect factor markets, this is also the sum of factor payments. To see this, calculate wages and capital rents as value marginal products:

$$\begin{aligned} w_j &= \frac{\partial y_j}{\partial L_j} = (1-\alpha)\,p_j A_j L_j^{-\alpha} K_j^{\alpha}, \\ r_j &= \frac{\partial y_j}{\partial K_j} = \alpha p_j A_j L_j^{1-\alpha} K_j^{\alpha-1}. \end{aligned}$$

Hence,

$$y_j = w_j L_j + r_j K_j = (1-\alpha)\,p_j A_j L_j^{-\alpha} K_j^{\alpha} L_j + \alpha p_j A_j L_j^{1-\alpha} K_j^{\alpha-1} K_j = p_j A_j L_j^{1-\alpha} K_j^{\alpha}.$$

Taking A_j and L_j as constant, we can write $d\ln y_j$ as:

$$d\ln y_j = d\ln p_j + \alpha d\ln K_j.$$

Note that P_j is given by:

$$P_j = \left[\sum_{i=1}^{N} (\gamma_i p_i t_{ij})^{1-\sigma}\right]^{\frac{1}{1-\sigma}}.$$

Then:

$$
\begin{aligned}
d\ln P_j &= \frac{1}{P_j} dP_j, \\
&= \frac{1}{P_j}\frac{1}{1-\sigma}\left[\sum_{i=1}^{N}(\gamma_i p_i t_{ij})^{1-\sigma}\right]^{\frac{1}{1-\sigma}-1} \\
&\quad \times \sum_{i=1}^{N}\left((1-\sigma)\gamma_i^{1-\sigma}p_i^{-\sigma}t_{ij}^{1-\sigma}dp_i + (1-\sigma)\gamma_i^{1-\sigma}p_i^{1-\sigma}t_{ij}^{-\sigma}dt_{ij}\right) \\
&= \left[\sum_{i=1}^{N}(\gamma_i p_i t_{ij})^{1-\sigma}\right]^{-\frac{1}{1-\sigma}}\left[\sum_{i=1}^{N}(\gamma_i p_i t_{ij})^{1-\sigma}\right]^{\frac{1}{1-\sigma}-1} \\
&\quad \times \sum_{i=1}^{N}\left(\gamma_i^{1-\sigma}p_i^{-\sigma}t_{ij}^{1-\sigma}dp_i + \gamma_i^{1-\sigma}p_i^{1-\sigma}t_{ij}^{-\sigma}dt_{ij}\right) \\
&= P_j^{-(1-\sigma)}\sum_{i=1}^{N}\left(\gamma_i^{1-\sigma}p_i^{-\sigma}t_{ij}^{1-\sigma}dp_i + \gamma_i^{1-\sigma}p_i^{1-\sigma}t_{ij}^{-\sigma}dt_{ij}\right) \\
&= \sum_{i=1}^{N}\left(\left(\frac{\gamma_i p_i t_{ij}}{P_j}\right)^{1-\sigma} d\ln p_i + \left(\frac{\gamma_i p_i t_{ij}}{P_j}\right)^{1-\sigma} d\ln t_{ij}\right).
\end{aligned}
$$

Using $x_{ij} = \left(\frac{\gamma_i p_i t_{ij}}{P_j}\right)^{1-\sigma} y_j$ and defining $\lambda_{ij} = x_{ij}/y_j = \left(\frac{\gamma_i p_i t_{ij}}{P_j}\right)^{1-\sigma}$, we can simplify to:

$$
d\ln P_j = \sum_{i=1}^{N}\lambda_{ij}\left(d\ln p_i + d\ln t_{ij}\right). \tag{A21}
$$

Combining terms leads to:

$$
d\ln W_j = d\ln y_j - d\ln P_j = d\ln p_j + \alpha d\ln K_j - \sum_{i=1}^{N}\lambda_{ij}\left(d\ln p_i + d\ln t_{ij}\right).
$$

We next define λ_{ij} as:

$$
\lambda_{ij} = \frac{x_{ij}}{y_j} = \left(\frac{\gamma_i p_i t_{ij}}{P_j}\right)^{1-\sigma}.
$$

Then take the ratio of λ_{ij} and λ_{jj}:

$$
\frac{\lambda_{ij}}{\lambda_{jj}} = \left(\frac{\gamma_i p_i t_{ij}}{\gamma_j p_j t_{jj}}\right)^{1-\sigma}.
$$

Considering a foreign shock that leaves the ability to serve the own market, τ_{jj}, unchanged as in ACR, the change of this ratio is given by:

$$\begin{aligned} d\left(\frac{\lambda_{ij}}{\lambda_{jj}}\right) &= \frac{1-\sigma}{(\gamma_j p_j t_{jj})^{1-\sigma}} (\gamma_i p_i t_{ij})^{-\sigma} (\gamma_i p_i dt_{ij} + \gamma_i t_{ij} dp_i) \\ & -\frac{1-\sigma}{(\gamma_j p_j t_{jj})^{2-\sigma}} (\gamma_i p_i t_{ij})^{1-\sigma} \gamma_j t_{jj} dp_j. \end{aligned}$$

Expressing as log-change leads to:

$$\frac{d\left(\frac{\lambda_{ij}}{\lambda_{jj}}\right)}{\frac{\lambda_{ij}}{\lambda_{jj}}} = d\ln\left(\frac{\lambda_{ij}}{\lambda_{jj}}\right) = d\ln\lambda_{ij} - d\ln\lambda_{jj} = (1-\sigma)\left(d\ln t_{ij} + d\ln p_i - d\ln p_j\right).$$

Combining this with Equation (A21) leads to:

$$\begin{aligned} d\ln P_j &= \sum_{i=1}^{N} \lambda_{ij} \left(d\ln p_i + d\ln t_{ij}\right) \\ &= \sum_{i=1}^{N} \lambda_{ij} \left(\frac{1}{1-\sigma}\left(d\ln\lambda_{ij} - d\ln\lambda_{jj}\right) + d\ln p_j\right) \\ &= \frac{1}{1-\sigma}\left(\sum_{i=1}^{N} \lambda_{ij} d\ln\lambda_{ij} - d\ln\lambda_{jj} \sum_{i=1}^{N} \lambda_{ij}\right) + d\ln p_j \sum_{i=1}^{N} \lambda_{ij}. \end{aligned}$$

Assuming balanced trade as in ACR implies $y_j = \sum_{i=1}^{N} x_{ij}$. Hence, $\sum_{i=1}^{N} \lambda_{ij} = 1$ and $d\sum_{i=1}^{N} \lambda_{ij} = \sum_{i=1}^{N} d\lambda_{ij} = 0$. Further, $\sum_{i=1}^{N} \lambda_{ij} d\ln\lambda_{ij} = \sum_{i=1}^{N} d\lambda_{ij} = 0$.Using these facts, the above expression simplifies to:

$$\begin{aligned} d\ln P_j &= \frac{1}{1-\sigma}\left(\sum_{i=1}^{N} \lambda_{ij} d\ln\lambda_{ij} - d\ln\lambda_{jj} \sum_{i=1}^{N} \lambda_{ij}\right) + d\ln p_j \\ &= -\frac{1}{1-\sigma} d\ln\lambda_{jj} + d\ln p_j. \end{aligned}$$

Using this relationship in the welfare change expression leads to:

$$\begin{aligned} d\ln W_j &= d\ln y_j - d\ln P_j = d\ln p_j + \alpha d\ln K_j + \frac{1}{1-\sigma} d\ln\lambda_{jj} - d\ln p_j \\ &= \alpha d\ln K_j + \frac{1}{1-\sigma} d\ln\lambda_{jj}. \end{aligned}$$

We now integrate between an initial situation (base case) and a counterfactual situation (counterfactual):

$$\begin{aligned}
\int_{W^b}^{W^c} d\ln W_j &= \int_{K_j^b}^{K_j^c} \alpha d\ln K_j + \int_{\lambda_{jj}^b}^{\lambda_{jj}^c} \frac{1}{1-\sigma} d\ln \lambda_{jj}, \\
\ln W_j + C_1 \Big|_{W^b}^{W^c} &= \alpha \ln K_j + C_2 \Big|_{K_j^b}^{K_j^c} + \frac{1}{1-\sigma} \ln \lambda_{jj} + C_3 \Bigg|_{\lambda_{jj}^b}^{\lambda_{jj}^c}, \\
\ln W_j^c + C_1 - \ln W_j^b - C_1 &= \alpha \ln K_j + C_2 - \alpha \ln K_j - C_2 + \frac{1}{1-\sigma} \ln \lambda_{jj}^c + C_3 \\
&\quad - \frac{1}{1-\sigma} \ln \lambda_{jj}^b - C_3.
\end{aligned}$$

Now define the ratio of any counterfactual and base case variable with a hat, i.e. $\hat{v} = v^c/v^b$, to end up with:

$$\ln \hat{W}_j = \alpha \ln \widehat{K}_j + \frac{1}{1-\sigma} \ln \hat{\lambda}_{jj}.$$

Taking the exponent on the left- and right-hand side leads to:

$$\hat{W}_j = \widehat{K}_j^{\alpha} \hat{\lambda}_{jj}^{\frac{1}{1-\sigma}}. \tag{A22}$$

If we now plug in $\hat{K}_j$ from Equation (22), we end up with:

$$\hat{W}_j = \hat{P}_j^{\frac{-\alpha\sigma}{\sigma(1-\alpha)+\alpha}} \hat{\Pi}_j^{\frac{\alpha(1-\sigma)}{\sigma(1-\alpha)+\alpha}} \hat{y}^{\frac{\alpha}{\sigma(1-\alpha)+\alpha}} \hat{\lambda}_{jj}^{\frac{1}{1-\sigma}}.$$

Replacing Equation (20) into Equation (A33), we end up with:

$$K_j = \frac{\alpha\beta\delta p_j A_j L_j^{1-\alpha} K_j^{\alpha}}{(1-\beta+\delta\beta) P_j}.$$

Solving for K_j leads to:

$$K_j = \left[\frac{\alpha\beta\delta p_j A_j L_j^{1-\alpha}}{(1-\beta+\delta\beta) P_j}\right]^{\frac{1}{(1-\alpha)}}.$$

We next calculate the change of K_j. To do so, we first calculate the log-derivative of the left- and right-hand side:

$$d\ln K_j = \frac{1}{1-\alpha} \left(d\ln p_j - d\ln P_j\right).$$

Replacing $d\ln P_j$ by $-\frac{1}{1-\sigma}d\ln\lambda_{jj}+d\ln p_j$ leads to

$$d\ln K_j=\frac{1}{(1-\alpha)}\frac{1}{(1-\sigma)}d\ln\lambda_{jj}.$$

Note, that again $d\ln p_j$ cancels. Hence, the change of the capital stock, a real variable, is not affected by the choice of the numeraire. Integrating the left- and right-hand side between the baseline and the counterfactual and denoting K'/K with hats, where K' denotes the change from the baseline to the counterfactual, leads to:

$$\ln\hat{K}_j=\frac{1}{(1-\alpha)}\frac{1}{(1-\sigma)}\ln\hat{\lambda}_{jj}.$$

Taking the exponent on the left- and right-hand, we end up with:

$$\hat{K}_j=\hat{\lambda}_{jj}^{\frac{1}{(1-\alpha)(1-\sigma)}}. \tag{A23}$$

Plugging in into Equation (A22) leads to:

$$\hat{W}_j=\hat{\lambda}_{jj}^{\frac{\alpha}{(1-\alpha)(1-\sigma)}}\hat{\lambda}_{jj}^{\frac{1}{1-\sigma}}=\hat{\lambda}_{jj}^{\frac{1}{(1-\alpha)(1-\sigma)}}.$$

Note that this shows the link to the interpretation as intermediates. The formula of ACR for intermediates with perfect competition also just adds the share of intermediates in production to the exponent (see page 115 in ACR). Hence, in steady-state, capital accumulation acts pretty much as adding intermediates. This holds for the numeraire and all non-numeraire countries, in short, for all countries.

C Normalization

In order to achieve convergence, we scaled all data (GDP, labor endowments, capital in the initial period) by GDP of USA in 2009. However, this scaling does not affect any of our results. Let us call GDP of USA in 2009 by $\tilde{y}$.

$$
\begin{aligned}
x_{ij,t} &= \frac{y_{i,t}/\tilde{y} y_{j,t}/\tilde{y}}{y_t/\tilde{y}} \left(\frac{t_{ij,t}}{\Pi_{i,t} P_{j,t}}\right)^{(1-\sigma)}, && \text{(A24)}\\
P_{j,t}^{1-\sigma} &= \sum_i \left(\frac{t_{ij,t}}{\Pi_{i,t}}\right)^{1-\sigma} \frac{y_{i,t}/\tilde{y}}{y_t/\tilde{y}}, && \text{(A25)}\\
\Pi_{i,t}^{1-\sigma} &= \sum_j \left(\frac{t_{ij,t}}{P_{j,t}}\right)^{1-\sigma} \frac{y_{j,t}/\tilde{y}}{y_t/\tilde{y}}, && \text{(A26)}\\
p_{j,t} &= \frac{\left(\left(y_{j,t}/\tilde{y}\right)/\left(y_t/\tilde{y}\right)\right)^{\frac{1}{1-\sigma}}}{\gamma_j \Pi_{j,t}}, && \text{(A27)}\\
y_{j,t} &= p_{j,t} A_{j,t} \left(\frac{L_{j,t}}{\tilde{y}}\right)^{1-\alpha} \left(\frac{K_{j,t}}{\tilde{y}}\right)^{\alpha}, && \text{(A28)}\\
K_{j,t+1} &= \left[\frac{p_{j,t} A_{j,t} \left(L_{j,t}/\tilde{y}\right)^{1-\alpha} \beta\alpha\delta}{P_{j,t}\left(1-\beta+\delta\beta\right)}\right]^{\delta} \left(\frac{K_{j,t}}{\tilde{y}}\right)^{\alpha\delta+1-\delta}, && \text{(A29)}\\
K_0/\tilde{y} & \quad \text{given.}
\end{aligned}
$$

From that we observe the following: $P_{j,t}$ and $\Pi_{j,t}$ are not affected by the normalization. Hence, $x_{ij,t}$ also changes by $1/\tilde{y}$. $p_{j,t}$ is also not affected by the normalization.

With data for L, y, t and K_0 we can recover A/γ by noting that the lower level can be solved without knowledge of A/γ and then using P and combining (19) and (20), leading to:

$$
\frac{A_{j,t}}{\gamma_j} = \frac{y_{j,t} P_{j,t}}{\left(y_{j,t}/y_t\right)^{\frac{1}{1-\sigma}} L_{j,t}^{1-\alpha} K_{j,t}^{\alpha}}. \tag{A30}
$$

The normalization leads to:

$$
\frac{A_{j,t}}{\gamma_j} = \frac{y_{j,t}/\tilde{y} P_{j,t}}{\left(\left(y_{j,t}/\tilde{y}\right)/\left(y_t/\tilde{y}\right)\right)^{\frac{1}{1-\sigma}} \left(\frac{L_{j,t}}{\tilde{y}}\right)^{1-\alpha} \left(\frac{K_{j,t}}{\tilde{y}}\right)^{\alpha}}. \tag{A31}
$$

Hence, A/γ is also not affected by the normalization.

Hence, y and K change by $1/\tilde{y}$.

This means that our normalization works through our equations as they should. It changes y and K, but does not change any other variables besides trade flows, which are now also normalized.

D Counterfactual Procedure

In this Appendix we describe our counterfactual procedure in four steps.

Step 1: Obtain trade cost estimates by estimating equations (25) and (26). Then calculate for the baseline:

$$\left(\hat{t}_{ij,t}^{RTA}\right)^{1-\sigma} = e^{\hat{\eta}_1 RTA_{ij,t}+\sum_{m=2}^{5}\hat{\eta}_m \ln DIST_{ij,m}+\hat{\eta}_6 BRDR_{ij}+\hat{\eta}_7 LANG_{ij}+\hat{\eta}_8 CLNY_{ij}+\hat{\eta}_9 SMCTRY_{ij}}. \quad \text{(A32)}$$

For the counterfactual, additional trade costs may have to be calculated. For example, in the case of our NAFTA counterfactual, we set $RTA_{ij,t}$ to zero for the NAFTA countries after 1994, resulting in $RTA_{ij,t}^c$. Then we recalculate $\left(\hat{t}_{ij,t}^{RTA}\right)^{1-\sigma}$ by replacing $RTA_{ij,t}$ with $RTA_{ij,t}^c$ in equation (A32).

Step 2: Using the estimates for trade costs described in Step 1, and estimates for the capital share α, the elasticity of substitution σ, and the capital depreciation rate δ obtained from equations (30) and (35), a value for β taken from the literature, and data for $L_{j,t}$ and $y_{j,t}$, and assuming that we are in a steady-state, i.e., $K_{j,t+1} = K_{j,t}$, we can recover from equation (21) country-specific, theory-consistent steady-state capital stocks as follows:

$$K_j^{SS} = \frac{\alpha\beta\delta y_j}{P_j\left(1-\beta+\beta\delta\right)}. \quad \text{(A33)}$$

We will use K_j^{SS} as our capital stock in period zero, i.e., $K_0 = K_j^{SS}$.

Further, we can recover preference-adjusted technology A_t/γ_j in the baseline scenario by noting that the lower level can be solved without knowledge of A_j/γ_j and then using Π_j and combining (19) and (20), leading to:

$$\frac{A_j}{\gamma_j} = \frac{y_j\Pi_j}{\left(y_j/y\right)^{\frac{1}{1-\sigma}} L_j^{1-\alpha}\left(K_j^{SS}\right)^{\alpha}}. \quad \text{(A34)}$$

As we recover K_j^{SS} and A_j/γ_j from data and estimated parameters, we ensure that our baseline scenario is perfectly consistent with the observed data. However, as a plausibility check, we correlate our theory-consistent steady-state capital stocks and observed capital stocks as reported in the Penn World Tables 8.0. The correlation coefficient is 0.98. Figure 1 plots the log of the two series against each other, showing the strong linear correlation.

Step 3: Using the values obtained in Steps 1 and 2, we can solve our system given by Equations (16)-(21) in the baseline and in the counterfactual starting from year 0 until convergence to the new steady-state.

Step 4: After having solved our model, we calculate the trade, the multilateral resistance (MRT), the welfare, and the capital effects.

Trade effects: The trade effects are calculated as percentage change between the baseline and the counterfactual of overall exports of a country. Specifically, we calculate:

$$\Delta x_i\% = \frac{\left(\sum_{j\neq i} x_{ij}^c - \sum_{j\neq i} x_{ij}\right)}{\sum_{j\neq i} x_{ij}} \times 100. \quad \text{(A35)}$$

where x_{ij} is calculated according to Equation (16), and x_{ij}^c are the counterfactual trade flows in the new steady-state.

Note that in the case of NAFTA, we calculate the change of trade from the case without to the case with NAFTA in place, as a share of trade from the case without NAFTA, even though we have to counterfactually solve for the case without NAFTA.

MRT effects: The MRT effects are also calculated as the percentage change between the baseline and the counterfactual of P_i and Π_i for all i. Note that with symmetric trade costs $P_i = \Pi_i$, hence we only have to report one effect for every country in this case.

$$\Delta P_i\% = \frac{(P_i^c - P_i)}{P_i} \times 100, \tag{A36}$$

where P_i is given by Equation (17), and P_i^c are the counterfactual MRT-terms in the new steady-state.

Welfare effects: In the 'conditional GE' and the 'full GE, static' cases, welfare is given by the real GDP per capita.[29] Using equation (20), $y_j = p_j A_j L_j^{1-\alpha} K_j^{\alpha}$, and equation (19), $(\gamma_j p_j \Pi_j)^{1-\sigma} = y_j / y_t$, to replace p_j, we may write real GDP per capita as:

$$\tilde{y}_j = \frac{y_j}{P_j L_j} = \frac{p_j A_j L_j^{1-\alpha} K_j^{\alpha}}{P_j L_j} = \frac{(y_j/y)^{1/(1-\sigma)} A_j L_j^{-\alpha} K_j^{\alpha}}{\gamma_j \Pi_j P_j}. \tag{A37}$$

The counterfactual real GDP per capita is similarly calculated as:

$$\tilde{y}_{j,c} = \frac{y_{j,c}}{P_{j,c} L_{j,c}} = \frac{p_{j,c} A_{j,c} L_{j,c}^{1-\alpha} K_{j,c}^{\alpha}}{P_{j,c} L_{j,c}} = \frac{(y_{j,c}/y_{t,c})^{1/(1-\sigma)} A_{j,c} L_{j,c}^{-\alpha} K_{j,c}^{\alpha}}{\gamma_j \Pi_{j,c} P_{j,c}}. \tag{A38}$$

The reported change in welfare effects is then given by

$$\Delta \tilde{y}_{j,c}\% = \frac{(\tilde{y}_{j,c} - \tilde{y}_j)}{\tilde{y}_j} \times 100. \tag{A39}$$

In the 'full GE, dynamic' scenario, welfare is calculated according to equation (42).

Capital effects: The capital effects are also calculated as the percentage change between the baseline and the counterfactual of K_i for all j.

$$\Delta K_i\% = \frac{(K_i^c - K_i)}{K_i} \times 100, \tag{A40}$$

where K_i is given by Equation (21), and K_i^c are the counterfactual capital stocks in the new steady-state.

[29] As we assume single sector, single factor economies with CES preferences, P is the ideal price index. C/P therefore corresponds to indirect utility.

E Transition

One contribution of our paper is that we do not only focus on the steady-state, but also consider the transition path. Actually, all our growth effects are transitional. There is no steady-state growth in our framework.

So far we calculate the policy function for capital by value function iteration as described in Appendix A. Thereby, consumers take the variety price p_t and the consumer price P_t as given. Note that in P_t all decisions of the trading partner countries are reflected. If a trading partner country changes its capital accumulation decision, the effect for the country under consideration will be transmitted via prices. In our special case with an intertemporal log-utility function and the chosen transition function for capital, we end up with a closed form solution for our policy function for capital. This policy function gives the optimal decision of consumers for the capital stock tomorrow as a function of prices and the capital stock today.

The question is whether this is consistent with rational expectations and an equilibrium over all N-countries. Given the policy function, the decision of the consumer is consistent with rational expectations as long as we can determine current prices and have an initial capital stock. How do we get an initial capital stock? We calculate the steady-state. In steady-state, we solve our equation system given by equations (16)-(21) simultaneously for all N-countries. Hence, the steady-state is consistent with all prices and steady-state capital stocks for all countries.

We then take this steady-state as our baseline values at time 0. Then we consider a change, like the conclusion of NAFTA, which we assume to be non-anticipated and permanent. Given the current capital stock (which was decided yesterday and therefore is pre-determined) and the current GDP, we can use the new trade costs to calculate new current prices by using Equations (17)-(19). As soon as we have these prices, we can calculate the optimal decision how much to consume and invest by using the policy function (21). With a new capital stock in the next period, we can calculate the new income by using Equation (20), and then re-calculate prices. Note that we simultaneously solve for prices and income by solving the Equations (17)-(20) all simultaneously for all N-countries. We iterate until we end up in the new steady-state, which we also can calculate by just assuming that we are in steady-state and using the new trade costs.

In order to check whether this is really a proper transition, we alternatively set-up a system of first-order conditions which we then solved using dynare. Specifically, we used our utility function (we skip country indices without loss of generality)

$$U_t = \sum_{t=0}^{\infty} \beta^t \ln(C_t),$$

and combined the budget constraint with the production function:

$$P_t C_t + P_t \Omega_t = p_t A_t L_t^{1-\alpha} K_{t-1}^{\alpha}.$$

Note that we changed the timing a little bit: it is no longer K_t but K_{t-1} that appears in the production function. The reason is that we wanted to make clear that it is the capital stock decided in the past that is available for use in production today. However, this change is only expositional, it does not change our results or system in any way. In order to end up with only one constraint, we also replaced Ω_t by using our transition function:

$$\Omega_t = \left(\frac{K_t}{K_{t-1}^{1-\delta}}\right)^{\frac{1}{\delta}}.$$

Note that in order to be consistent, also the timing of this equation had to be changed. So investments today build up capital stock today which is ready to use tomorrow. The capital stock that is available today is again denoted by K_{t-1}. Replacing Ω_t, we end up with the following constraint:

$$P_t C_t + P_t \left(\frac{K_t}{K_{t-1}^{1-\delta}}\right)^{\frac{1}{\delta}} = p_t A_t L_t^{1-\alpha} K_{t-1}^{\alpha}.$$

Setting up the Lagrangian leads to:

$$\mathcal{L} = \sum_{t=0}^{\infty} \beta^t \left[\ln(C_t) + \lambda_t \left(p_t A_t L_t^{1-\alpha} K_{t-1}^{\alpha} - P_t C_t - P_t \left(\frac{K_t}{K_{t-1}^{1-\delta}}\right)^{\frac{1}{\delta}}\right)\right].$$

Taking derivatives with respect to C_t, K_t and λ_t leads to the following set of first-order conditions:

$$\begin{aligned}
\frac{\partial \mathcal{L}}{\partial C_t} &= \frac{\beta^t}{C_t} - \beta^t \lambda_t P_t \overset{!}{=} 0 \quad \text{for all } t. \\
\frac{\partial \mathcal{L}}{\partial K_t} &= \beta^{t+1} \lambda_{t+1} p_{t+1} A_{t+1} L_{t+1}^{1-\alpha} \alpha K_t^{\alpha-1} - \beta^t \lambda_t P_t \left(\frac{1}{K_{t-1}^{1-\delta}}\right)^{\frac{1}{\delta}} \frac{1}{\delta} K_t^{\frac{1}{\delta}-1} \\
&\quad -\beta^{t+1} \lambda_{t+1} P_{t+1} K_{t+1}^{\frac{1}{\delta}} \frac{\delta-1}{\delta} K_t^{-\frac{1}{\delta}} \overset{!}{=} 0 \quad \text{for all } t. \\
\frac{\partial \mathcal{L}}{\partial \lambda_t} &= p_t A_t L_t^{1-\alpha} K_{t-1}^{\alpha} - P_t C_t - P_t \left(\frac{K_t}{K_{t-1}^{1-\delta}}\right)^{\frac{1}{\delta}} \overset{!}{=} 0 \quad \text{for all } t.
\end{aligned}$$

Using the first-order condition for consumption, we can express λ_t as:

$$\lambda_t = \frac{1}{C_t P_t}.$$

Replacing this in the first-order condition for capital leads to:

$$\begin{aligned}
\frac{\partial \mathcal{L}}{\partial K_t} &= \beta^{t+1} \frac{1}{C_{t+1} P_{t+1}} p_{t+1} A_{t+1} L_{t+1}^{1-\alpha} \alpha K_t^{\alpha-1} - \beta^t \frac{1}{C_t} \left(\frac{1}{K_{t-1}^{1-\delta}}\right)^{\frac{1}{\delta}} \frac{1}{\delta} K_t^{\frac{1}{\delta}-1} \\
&\quad -\beta^{t+1} \frac{1}{C_{t+1}} K_{t+1}^{\frac{1}{\delta}} \frac{\delta-1}{\delta} K_t^{-\frac{1}{\delta}} \overset{!}{=} 0 \quad \text{for all } t.
\end{aligned}$$

Simplifying a bit and re-arranging leads to:

$$\frac{\beta p_{t+1}A_{t+1}L_{t+1}^{1-\alpha}\alpha K_t^{\alpha-1}}{C_{t+1}P_{t+1}} = \frac{1}{C_t}\left(\frac{1}{K_{t-1}^{1-\delta}}\right)^{\frac{1}{\delta}}\frac{1}{\delta}K_t^{\frac{1}{\delta}-1} + \frac{(\delta-1)\beta}{\delta C_{t+1}}K_{t+1}^{\frac{1}{\delta}}K_t^{-\frac{1}{\delta}} \quad \text{for all } t.$$

Using our definition of y_t, we can further re-write the left-hand side of this expression as:

$$\frac{\alpha\beta y_{t+1}}{K_t C_{t+1}P_{t+1}} = \frac{1}{\delta C_t}\frac{K_t^{\frac{1}{\delta}-1}}{K_{t-1}^{\frac{1-\delta}{\delta}}} + \frac{\beta(\delta-1)}{\delta C_{t+1}}\left(\frac{K_{t+1}}{K_t}\right)^{\frac{1}{\delta}} \quad \text{for all } t.$$

This is the standard consumption Euler-equation. Note that we have four forward-looking variables for each country: y_t, K_t, C_t, and P_t. Hence, overall we have $4N$ forward-looking variables in our system here. These are also the endogenous variables we have to solve for. So in dynare, we use the following set of equations:

$$\begin{aligned}
y_{j,t} &= \frac{(y_{j,t}/y_t)^{\frac{1}{1-\sigma}}}{\gamma_j P_{j,t}}A_{j,t}L_{j,t}^{1-\alpha}K_{j,t-1}^{\alpha} \quad \text{for all } j \text{ and } t,\\
y_t &= \sum_j y_{j,t} \quad \text{for all } t,\\
y_{j,t} &= P_{j,t}C_{j,t} + P_{j,t}\left(\frac{K_t}{K_{t-1}^{1-\delta}}\right)^{\frac{1}{\delta}} \quad \text{for all } j \text{ and } t,\\
P_t &= \left[\sum_i\left(\frac{t_{ij,t}}{P_{i,t}}\right)^{1-\sigma}\frac{y_{i,t}}{y_t}\right]^{\frac{1}{1-\sigma}} \quad \text{for all } j \text{ and } t,\\
\frac{\alpha\beta y_{t+1}}{K_t C_{t+1}P_{t+1}} &= \frac{1}{\delta C_t}\frac{K_t^{\frac{1}{\delta}-1}}{K_{t-1}^{\frac{1-\delta}{\delta}}} + \frac{\beta(\delta-1)}{\delta C_{t+1}}\left(\frac{K_{t+1}}{K_t}\right)^{\frac{1}{\delta}} \quad \text{for all } j \text{ and } t.
\end{aligned}$$

We then take as initial and end values the baseline and the counterfactual steady-state and solve the transition of our deterministic model assuming perfect foresight. The algorithm for our case is described in the dynare-manuel (dynare.pdf) on page 42, Section 4.12. When looking at the transition resulting from dynare and comparing it with the transition resulting from our policy function, we see that we end up with exactly the same transition path.

F Derivation of the Policy Functions of the Upper Level when Accounting for Intermediates

Our upper level reads as follows (we omit the country indexes in order to economize on the notational burden):

$$U_t = \sum_{t=0}^{\infty} \beta^t \ln(C_t), \tag{A41}$$

$$K_{t+1} = K_t^{1-\delta}\Omega_t^{\delta}, \tag{A42}$$

$$y_t = p_t A_t K_t^{\alpha} L_t^{\xi} Q_t^{1-\alpha-\xi}, \tag{A43}$$

$$P_t C_t = y_t - P_t Q_t - P_t \Omega_t, \tag{A44}$$

$$K_0 \quad \textit{given}. \tag{A45}$$

This is very similar to 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 an analytical solution. To solve for the policy functions of capital and consumption we iterate over the value function. For ease of notation, we skip indices for current periods and denote next period variables by $'$. Further, we define $\phi = 1/\delta$. Due to the Cobb-Douglas production function, the cost shares for all three inputs are given by the respective Cobb-Douglas coefficients. Specifically, $P_{j,t}Q_{j,t}$ is equal to $(1-\alpha-\xi)y_t$. Hence, we can rewrite (A44) as $P_t C_t = (\alpha+\xi)y_t - P_t\Omega_t$.

The value of the value function at step 0, v^0, is equal to 0. In the next step, the value of the value function is given by:

$$v' = \max_{K'} \ln C = \max_{K'} \ln\left((\alpha+\xi)y/P - \Omega\right) \tag{A46}$$

$$= \max_{K'} \ln\left((\alpha+\xi)y_{j,t}/P - \Omega\right) \tag{A47}$$

$$= \max_{K'} \ln\left((\alpha+\xi)pAK^{\alpha}L^{\xi}Q^{1-\alpha-\xi}/P - (K'^{\phi}/K^{\phi-1})\right). \tag{A48}$$

The first order condition reads as follows:

$$\frac{1}{(\alpha+\xi)pAK^{\alpha}L^{\xi}Q^{1-\alpha-\xi}/P - (K'^{\phi}/K^{\phi-1})}(-\phi)\frac{K'^{\phi-1}}{K^{\phi-1}} = 0. \tag{A49}$$

It follows that $K' = 0$.

Hence, $v' = \ln\left((\alpha+\xi)pAK^{\alpha}L^{\xi}Q^{1-\alpha-\xi}/P\right)$. In the next step, we have to solve:

$$v^2 = \max_{K'} \ln\left((\alpha+\xi)pAK^{\alpha}L^{\xi}Q^{1-\alpha-\xi}/P - (K'^{\phi}/K^{\phi-1})\right) \tag{A50}$$

$$+\beta\ln\left((\alpha+\xi)pAK'^{\alpha}L^{\xi}Q^{1-\alpha-\xi}/P\right). \tag{A51}$$

The first order condition then reads as follows:

$$\frac{1}{(\alpha+\xi)pAK^{\alpha}L^{\xi}Q^{1-\alpha-\xi}/P-(K'^{\phi}/K^{\phi-1})}(-\phi)\frac{K'^{\phi-1}}{K^{\phi-1}}+\frac{\beta\alpha}{K'}=0, \tag{A52}$$

$$\frac{\beta\alpha}{\phi}\left((\alpha+\xi)pAK^{\alpha}L^{\xi}Q^{1-\alpha-\xi}/P-(K'^{\phi}/K^{\phi-1})\right)=\frac{K'^{\phi}}{K^{\phi-1}}, \tag{A53}$$

$$\frac{\beta\alpha}{\phi}\left((\alpha+\xi)pAK^{\alpha}L^{\xi}Q^{1-\alpha-\xi}/P\right)=\left(\frac{\beta\alpha}{\phi}+1\right)\frac{K'^{\phi}}{K^{\phi-1}}, \tag{A54}$$

$$\frac{\beta\alpha}{\phi+\beta\alpha}\frac{(\alpha+\xi)pAL^{\xi}Q^{1-\alpha-\xi}}{P}K^{\alpha+\phi-1}=K'^{\phi}, \tag{A55}$$

$$\left(\frac{\beta\alpha}{\phi+\beta\alpha}\frac{(\alpha+\xi)pAL^{\xi}Q^{1-\alpha-\xi}}{P}\right)^{\frac{1}{\phi}}K^{(\alpha+\phi-1)/\phi}=K'. \tag{A56}$$

Plugging in the expression for K' given in equation (A56), we end up with:

$$\begin{aligned}
v^2 &= \ln\Bigg((\alpha+\xi)pAK^{\alpha}L^{\xi}Q^{1-\alpha-\xi}/P \\
&\quad -\left(\left(\left(\left(\frac{\beta\alpha}{\phi+\beta\alpha}\frac{(\alpha+\xi)pAL^{\xi}Q^{1-\alpha-\xi}}{P}\right)^{\frac{1}{\phi}}K^{(\alpha+\phi-1)/\phi}\right)^{\phi}/K^{\phi-1}\right)\right)\Bigg) \\
&\quad +\beta\ln\Bigg((\alpha+\xi)pAL^{\xi}Q^{1-\alpha-\xi} \\
&\quad \left(\left(\frac{\beta\alpha}{\phi+\beta\alpha}\frac{(\alpha+\xi)pAL^{\xi}Q^{1-\alpha-\xi}}{P}\right)^{\frac{1}{\phi}}K^{(\alpha+\phi-1)/\phi}\right)^{\alpha}/P\Bigg), \\
&= \ln\left(\left((\alpha+\xi)pAL^{\xi}Q^{1-\alpha-\xi}/P-\frac{\beta\alpha}{\phi+\beta\alpha}\frac{(\alpha+\xi)pAL^{\xi}Q^{1-\alpha-\xi}}{P}\right)K^{\alpha}\right) \\
&\quad +\beta\ln\Bigg((\alpha+\xi)pAL^{\xi}Q^{1-\alpha-\xi}\left(\left(\frac{\beta\alpha}{\phi+\beta\alpha}\frac{(\alpha+\xi)pAL^{\xi}Q^{1-\alpha-\xi}}{P}\right)^{\frac{1}{\phi}}\right)^{\alpha} \\
&\quad /PK^{(\alpha+\phi-1)\alpha/\phi}\Bigg), \\
&= \alpha\ln(K)+\beta\theta\alpha\ln(K)+const,
\end{aligned}$$

where $\theta\equiv(\alpha+\phi-1)/\phi$ and $const$ collects all terms not depending on K. The next step is

$$v^3 = \max_{K'}\ln\left((\alpha+\xi)pAK^{\alpha}L^{\xi}Q^{1-\alpha-\xi}/P-(K'^{\phi}/K^{\phi-1})\right) \tag{A57}$$

$$+\alpha\beta\ln(K')+\beta^2\theta\alpha\ln(K')+\beta const. \tag{A58}$$

The first order condition is given by:

$$\frac{1}{(\alpha+\xi)pAK^{\alpha}L^{\xi}Q^{1-\alpha-\xi}/P-(K'^{\phi}/K^{\phi-1})}(-\phi)\frac{K'^{\phi-1}}{K^{\phi-1}}$$
$$+\frac{\beta\alpha}{K'}+\frac{\alpha\theta\beta^2}{K'}=0, \tag{A59}$$
$$\frac{\beta\alpha}{\phi}(1+\beta\theta)\left((\alpha+\xi)pAK^{\alpha}L^{\xi}Q^{1-\alpha-\xi}/P-(K'^{\phi}/K^{\phi-1})\right)=\frac{K'^{\phi}}{K^{\phi-1}}, \tag{A60}$$
$$\frac{\beta\alpha}{\phi}(1+\beta\theta)(\alpha+\xi)pAK^{\alpha}L^{\xi}Q^{1-\alpha-\xi}/P=\left(\frac{\beta\alpha}{\phi}(1+\beta\theta)+1\right)\frac{K'^{\phi}}{K^{\phi-1}}, \tag{A61}$$
$$K'=\left(\frac{\frac{\beta\alpha}{\phi}(1+\beta\theta)(\alpha+\xi)pAL^{\xi}Q^{1-\alpha-\xi}/P}{\frac{\beta\alpha}{\phi}(1+\beta\theta)+1}\right)^{\frac{1}{\phi}}K^{\theta}. \tag{A62}$$

Plugging in the solution of K' given in equation (A62) leads to

$$v^3=\alpha\ln(K)+\alpha\beta\theta\ln(K)+\beta^2\theta^2\alpha\ln(K)+\beta const.$$

In the next step we therefore have

$$v^4 = \max_{K'}\ln\left((\alpha+\xi)pAK^{\alpha}L^{\xi}Q^{1-\alpha-\xi}/P-(K'^{\phi}/K^{\phi-1})\right) \tag{A63}$$
$$+\alpha\beta\ln(K')\left[1+\beta\theta+\beta^2\theta^2\right]+\beta const, \tag{A64}$$

with the following first order condition:

$$\frac{1}{(\alpha+\xi)pAK^{\alpha}L^{\xi}Q^{1-\alpha-\xi}/P-(K'^{\phi}/K^{\phi-1})}(-\phi)\frac{K'^{\phi-1}}{K^{\phi-1}}$$
$$+\frac{\beta\alpha\left[1+\beta\theta+\beta^2\theta^2\right]}{K'}=0, \tag{A65}$$
$$\frac{\beta\alpha}{\phi}\left(1+\beta\theta+\beta^2\theta^2\right)\left((\alpha+\xi)pAK^{\alpha}L^{\xi}Q^{1-\alpha-\xi}/P-(K'^{\phi}/K^{\phi-1})\right)$$
$$=\frac{K'^{\phi}}{K^{\phi-1}}, \tag{A66}$$
$$\frac{\beta\alpha}{\phi}\left(1+\beta\theta+\beta^2\theta^2\right)(\alpha+\xi)pAK^{\alpha}L^{\xi}Q^{1-\alpha-\xi}/P$$
$$=\left(\frac{\beta\alpha}{\phi}\left(1+\beta\theta+\beta^2\theta^2\right)+1\right)\frac{K'^{\phi}}{K^{\phi-1}}, \tag{A67}$$
$$K'=\left(\frac{\frac{\beta\alpha}{\phi}\left(1+\beta\theta+\beta^2\theta^2\right)(\alpha+\xi)pAL^{\xi}Q^{1-\alpha-\xi}/P}{\frac{\beta\alpha}{\phi}\left(1+\beta\theta+\beta^2\theta^2\right)+1}\right)^{\frac{1}{\phi}}K^{\theta}. \tag{A68}$$

Now we see the general pattern, which can be described as

$$v^n \Rightarrow K' = \left[\frac{\frac{\beta\alpha}{\phi}(\alpha+\xi)pAL^{\xi}Q^{1-\alpha-\xi}/P\sum_{i=0}^{n-2}(\beta\theta)^i}{1+\frac{\beta\alpha}{\phi}\sum_{i=0}^{n-2}(\beta\theta)^i}\right]^{\frac{1}{\phi}} K^{\theta}, \tag{A69}$$

where n denotes the nth-step. When $n \to \infty$, we end up with

$$\left[\frac{\frac{\beta\alpha}{\phi}(\alpha+\xi)pAL^{\xi}Q^{1-\alpha-\xi}/P\sum_{i=0}^{n-2}(\beta\theta)^i}{1+\frac{\beta\alpha}{\phi}\sum_{i=0}^{n-2}(\beta\theta)^i}\right]^{\frac{1}{\phi}} = \left[\frac{\frac{\beta\alpha}{\phi}(\alpha+\xi)pAL^{\xi}Q^{1-\alpha-\xi}/P\frac{1}{1-\beta\theta}}{1+\frac{\beta\alpha}{\phi}\frac{1}{1-\beta\theta}}\right]^{\frac{1}{\phi}}. \tag{A70}$$

Replacing $\theta \equiv (\alpha+\phi-1)/\phi$ leads to:

$$\left[\frac{\frac{\beta\alpha}{\phi}(\alpha+\xi)pAL^{\xi}Q^{1-\alpha-\xi}/P\frac{1}{1-\beta(\alpha+\phi-1)/\phi}}{1+\frac{\beta\alpha}{\phi}\frac{1}{1-\beta(\alpha+\phi-1)/\phi}}\right]^{\frac{1}{\phi}} = \left[\frac{(\alpha+\xi)pAL^{\xi}Q^{1-\alpha-\xi}/P\frac{\beta\alpha}{\phi-\beta(\alpha+\phi-1)}}{1+\frac{\beta\alpha}{\phi-\beta(\alpha+\phi-1)}}\right]^{\frac{1}{\phi}} = \left[\frac{(\alpha+\xi)pAL^{\xi}Q^{1-\alpha-\xi}/P\frac{\beta\alpha}{\phi-\beta(\alpha+\phi-1)}}{\frac{\phi-\beta\phi+\beta}{\phi-\beta(\alpha+\phi-1)}}\right]^{\frac{1}{\phi}} = \left[\frac{(\alpha+\xi)pAL^{\xi}Q^{1-\alpha-\xi}/P\beta\alpha}{\phi-\beta\phi+\beta}\right]^{\frac{1}{\phi}}.$$

Now apply $\phi = 1/\delta$:

$$\left[\frac{(\alpha+\xi)pAL^{\xi}Q^{1-\alpha-\xi}/P\beta\alpha}{1/\delta-\beta/\delta+\beta}\right]^{\delta} = \left[\frac{(\alpha+\xi)pAL^{\xi}Q^{1-\alpha-\xi}/P\beta\alpha\delta}{1-\beta+\delta\beta}\right]^{\delta}. \tag{A71}$$

Hence,

$$K' = \left[\frac{(\alpha+\xi)pAL^{\xi}Q^{1-\alpha-\xi}\beta\alpha\delta}{P\left(1-\beta+\delta\beta\right)}\right]^{\delta} K^{\alpha\delta+1-\delta}. \tag{A72}$$

This is our policy function for the capital stock in the next period, K'. It depends alongside parameters on goods prices, labor endowments, the price index, the current capital stock and intermediate input use. A higher labor endowment, a higher current capital stock, a higher intermediate input use and a higher goods price lead to higher next period capital stocks, while a higher current price index decrease capital stocks in the next period. A higher current goods price or a higher current endowment with labor means that output today is more valuable or that more output can be produced today. Hence, consumers are willing to transfer part of their wealth to the next period by capital accumulation. On the other hand, if the current price index is high, consumption is expensive today. Therefore, a higher share of income will be spend on consumption today and less will be saved and transferred for future consumption via capital accumulation.

Note that as soon as we have K' and K, we can determine the level of investment by

$$\Omega = \left(\frac{K'}{K^{1-\delta}}\right)^{\frac{1}{\delta}} = \left(\frac{\left[\frac{(\alpha+\xi)pAL^{\xi}Q^{1-\alpha-\xi}\beta\alpha\delta}{P(1-\beta+\delta\beta)}\right]^{\delta} K^{\alpha\delta+1-\delta}}{K^{1-\delta}}\right)^{\frac{1}{\delta}} \tag{A73}$$

$$= \left[\frac{(\alpha+\xi)pAL^{\xi}Q^{1-\alpha-\xi}\beta\alpha\delta}{P\,(1-\beta+\delta\beta)}\right] K^{\alpha}. \tag{A74}$$

The optimal level of current consumption is found by using the policy function for capital and reformulating $P\Omega = y - PC - PQ$, i.e.,

$$C = \frac{y}{P} - \Omega - Q \tag{A75}$$

$$= \frac{pAK^{\alpha}L^{\xi}Q^{1-\alpha-\xi}}{P} - \left[\frac{(\alpha+\xi)pAL^{\xi}Q^{1-\alpha-\xi}\beta\alpha\delta}{P\,(1-\beta+\delta\beta)}\right] K^{\alpha}$$

$$-(1-\alpha-\xi)\frac{pAK^{\alpha}L^{\xi}Q^{1-\alpha-\xi}}{P} \tag{A76}$$

$$= (\alpha+\xi)\frac{pAK^{\alpha}L^{\xi}Q^{1-\alpha-\xi}}{P} - \left[\frac{(\alpha+\xi)pAL^{\xi}Q^{1-\alpha-\xi}\beta\alpha\delta}{P\,(1-\beta+\delta\beta)}\right] K^{\alpha} \tag{A77}$$

$$= \left[1 - \frac{\beta\alpha\delta}{1-\beta+\delta\beta}\right] \frac{(\alpha+\xi)pAK^{\alpha}L^{\xi}Q^{1-\alpha-\xi}}{P} \tag{A78}$$

$$= \left[\frac{(1-\beta+\delta\beta)-\beta\alpha\delta}{1-\beta+\delta\beta}\right] \frac{(\alpha+\xi)pAK^{\alpha}L^{\xi}Q^{1-\alpha-\xi}}{P}. \tag{A79}$$

Note again, that

$$Q = (1-\alpha-\xi)\frac{pAK^{\alpha}L^{\xi}Q^{1-\alpha-\xi}}{P} \Rightarrow$$

$$Q = \left[(1-\alpha-\xi)\frac{pAK^{\alpha}L^{\xi}}{P}\right]^{\frac{1}{\alpha+\xi}}.$$