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Abstract

We build and estimate a structural dynamic 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 capital accumulation specification of the transition between steady states. Theory translates into an intuitive econometric system that identifies the causal impact of trade on income and growth, and also delivers estimates of the key structural parameters in our model. Counterfactual experiments based on the estimated model give evidence for strong dynamic relationships between growth and trade, resulting in doubling of the static gains from trade liberalization.

JEL-Code: F100, F430, O400.

Keywords: trade, growth, income, trade liberalization, capital accumulation.

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1 Introduction

The relationship of trade and growth has been a central concern of economists since Adam Smith. Recent research raises doubts about an empirically strong relationship between trade and growth.[1] One solution is better models, but Head and Mayer (2014) review the theoretical foundations of the best fitting trade model (gravity) and note that the models are static. "This raises the econometric problem of how to handle the evolution of trade over time in response to changes in trade costs." (Head and Mayer, 2014, p. 189). Similarly, Desmet and Rossi-Hansberg (2014b) note that introducing dynamics to static multi-country trade models adds considerable complexity because: (i) consumers care about the distribution of their economic activities not only over countries, but also over time; and (ii) the clearance of goods and factor markets is difficult, as prices depend on international trade. "These two difficulties typically make spatial dynamic models intractable, both analytically and numerically." (Desmet and Rossi-Hansberg, 2014b, p. 1212). In contrast policy analysts and negotiating parties on both sides of trade mega deals such as the Transatlantic Trade and Investment Partnership (TTIP) between the United States and the European Union expect that "TTIP will result in more jobs and growth".[2] Dissatisfaction with the gap between researchers findings and policymakers' expectations, the lack of strong empirical support for a relationship between trade and growth, and the limitations of static gravity models motivates our development of a dynamic model of trade and growth that allows structural estimation.

We embed an N-country Armington trade gravity model with its well-established good

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

[2] Press release, Brussels, 28 January 2014, EU-US Trade Talks: EU and U.S. announce 4th round of TTIP negotiations in March; stocktaking meeting in Washington D.C. to precede next set of talks; available at http://trade.ec.europa.eu/doclib/press/index.cfm?id=1020. President Obama of U.S. and Minister Rajoy of Spain also agreed that "there is enormous potential for TTIP to increase trade and growth between two of the largest economic actors in the world." ("Remarks by president Obama and president Mariano Rajoy of Spain after bilateral meeting", Office of the Press Secretary, White House, January, 2014, http://iipdigital.usembassy.gov/st/english/texttrans/ 2014/01/20140114290784.html#axzz2u59pirmD.)

fit properties into a dynamic capital accumulation model. The combination quantifies the relationship between trade policy (or other) changes and growth effects in a trading world of many countries, asymmetric in size, bilateral trade frictions and capital accumulation. Our dynamic structural growth-and-trade model is a member of the family of new quantitative trade models, such as Eaton and Kortum (2002) and Anderson and van Wincoop (2003) (as summarized in Costinot and Rodríguez-Clare, 2014), to which we add dynamics.[3]

We also contribute to two notable efforts to introduce dynamics within a heterogeneous spatial framework. First, Krusell and Smith, Jr. (1998) show that in macroeconomic models with heterogeneity features, aggregate variables (i.e. consumption, capital stock, and relative prices) can be approximated very well as a function of the mean of the wealth distribution and an aggregate productivity shock. Second, Desmet and Rossi-Hansberg (2014b) deliver a tractable dynamic framework, where the firm's dynamic decision to innovate reduces to a sequence of static profit-maximization problems, by imposing structure that disciplines the mobility of labor, land-ownership by the firm, and the diffusion of technology.[4] Similar to Desmet and Rossi-Hansberg (2014b), we offer an analytical solution to the consumer's dynamic decision to invest by imposing structure on the accumulation of capital in our model. Added tractability comes from gravity structure that consistently aggregates bilateral trade frictions for each country into multilateral resistance indexes. This second feature is similar to Krusell and Smith, Jr. (1998), but replaces an approximation with an ideal index based on the structure of the system.

Two frictions take center stage in our model: costly trade and costly capital adjustment.

[3] In doing so, we extend on an earlier literature (i.e. Acemoglu and Zilibotti, 2001; Acemoglu and Ventura, 2002; Alvarez and Lucas, Jr., 2007), and we complement some new influential papers (i.e. Sampson, 2014; Eaton, Kortum, Neiman, and Romalis, 2015) that study the dynamics of trade. These studies calibrate their models in arguably more complex environments. In contrast, we deliver a structural econometric system that allows us to test and establish causal relationships between trade, income, and growth and delivers the key parameters that we employ in our counterfactual analysis. The price of this estimatability is a focus on capital accumulation as the single channel for transmitting dynamic effects along with convenient functional form assumptions,

[4] The usefulness of this approach is shown by Desmet and Rossi-Hansberg (2014a) who apply it to study the geographic impact of climate change, and Desmet, Nagy, and Rossi-Hansberg (2015) who develop a dynamic spatial growth theory with realistic geography to study the effects of relaxing migration restrictions and the effects of a rise in the sea level.

The structural gravity model features bilaterally varying iceberg trade frictions and aggregates their effect on productivity into multilateral resistance measures. Small scale simulation models based on structural gravity combine trade cost estimates with simple general equilibrium superstructure (e.g. Eaton and Kortum, 2002; Anderson and van Wincoop, 2003) to provide intuitive and revealing counterfactual general equilibrium comparative statics. We introduce capital accumulation on the transition between steady states to this setting. A tractable accumulation model embedding structural gravity is based on Lucas and Prescott (1971). The costs in adjustment of the capital stock acts essentially like iceberg trade frictions (home bias) but on the inter-temporal rather than international margin. This similarity translates the dynamic structural gravity model into a log-linear econometric system that is easy to estimate. The estimating equations test and our results establish the causal impact of trade on income and growth and deliver all the key structural parameters needed to calibrate the model.[5] Counterfactual comparative static exercises with the estimated model decompose and quantify the various channels through which trade affects growth and through which growth impacts trade. The results are evidence for strong dynamic links between growth and trade.

The structural gravity setup of Anderson and van Wincoop (2003) based on constant elasticity of substitution (CES) preferences differentiated by place of origin (Armington, 1969) forms the trade module of the static model.[6] Recent work by Arkolakis, Costinot, and Rodríguez-Clare (2012, henceforth also ACR) shows that gains from trade are invariant to the introduction of monopolistic competition, entry of firms and selection into markets.

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

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

The simple Armington/CES version of structural gravity exposited here thus stands in for a more general class of models for which the information demands boil down to a single trade elasticity. This class of models readily integrates with our model of capital accumulation. Capital itself is an alternative use of the consumable bundle. In the steady state, the accumulation flow offsets depreciation, essentially 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) and Hercowitz and Sampson (1991). 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.[7] The closed-form accumulation solution is the bridge to structural estimation and our exploration of the complex relationship between growth and trade.[8] We abstract from non-zero steady state growth for simplicity. While we also abstract from endogenous technological change, note that changes in multilateral resistance (also interpreted as input buyers' and sellers' incidence of trade costs) are effectively a type of endogenous technological change.

Trade's effect on growth acts in the model through a relative price channel. Trade cost changes shift producer prices relative to consumer prices. More subtly, when trade is costly, trade volume changes also induce shifts in producer relative to consumer prices. Shifts

[7]More recently, the log-linear capital transition function was for example used by Eckstein, Foulides, and Kollintzas (1996) to synthesize exogenous and endogenous sources of economic growth, by Kocherlakota and Yi (1997) to investigate whether permanent changes in government policies have permanent effects on growth rates, and by Abel (2003) to investigate the effects of a baby boom on stock prices and capital accumulation.

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

in relative prices affect accumulation, and accumulation affects next period trade. Higher producer prices increase accumulation because they imply higher returns to investment, hence agents lower current consumption in return for expected increased future consumption. Higher investment and consumer prices, in contrast, reduce accumulation due to higher costs of investment and due to higher opportunity costs of consumption. Importantly, due to the general equilibrium forces in our model, changes in trade costs or trade volumes between any two trading partners potentially affect producer prices and consumer prices in any nation in the world. 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 also a general equilibrium one, i.e., growth in one country affects trade costs and impacts welfare in every other country in the world. Work done on other data (e.g. Anderson and Yotov, 2010; Anderson and van Wincoop, 2003) reveals that a higher income is strongly associated with lower sellers' incidence of trade costs and thus a real income increase, a correlation replicated here. Closing the loop, growth-led changes in the incidence of trade costs leads to additional changes in capital stock.

We implement the dynamic structural gravity model on a sample of 82 countries over the period 1990–2011. First, we translate the model into a structural econometric system that offers a theoretical foundation to and expands the famous reduced-form specification of Frankel and Romer (1999). Similar to Frankel and Romer (1999), we identify a significant causal effect of trade on income. In addition, we complement the trade-and-income system of Frankel and Romer with a structural equation that captures the effects of trade on capital accumulation. The estimation of our structural system yields estimates of trade costs, multilateral resistance terms as well as of all besides one model parameters.

We then combine the newly constructed trade costs with data on the rest of the variables in our model to perform a series of counterfactual experiments to quantify and decompose the relationships between growth and trade. These experiments reveal that the dynamic effects of trade liberalization lead to doubling in the corresponding static effects.[9] The dynamic channels in our framework (increased country size and changes in the multilateral resistances) imply that preferential trade liberalization (e.g. a Regional Trade Agreement, RTA) may benefit non-members eventually, despite the initial negative effect of trade diversion. RTAs that are statically beneficial to members stimulate growth by making investment more attractive. This will normally lead to lower sellers' incidence for these countries, but also to lower buyers' incidence in non-members. Furthermore, the increased income in member countries will translate into an increase of imports from all trading partners, including non-members. Consistent with that logic, our simulation of the North American Free Trade Agreement (NAFTA) shows that its formation had small and non-monotonic negative trade effects on non-member countries and even some small net trade-creation effects for several non-members (e.g. the Netherlands). A battery of sensitivity checks confirms the robustness of our results.

The rest of the paper is organized as follows. In section 2 we present our contributions in relation to existing studies. Section 3 develops the theoretical foundation and discusses the structural links between growth and trade in our model. In Section 4, we translate our theoretical framework into an econometric model. Section 5 offers counterfactual experiments and a summary of the results from a series of sensitivity analysis. Detailed description of the robustness experiments can be found in the Appendix. Section 6 concludes with some suggestions for future research. All derivations and technical discussions are included in an Online Appendix.

[9] Similarly, in a dynamic setting with heterogeneous firms, Sampson (2014) finds that the effects of trade liberalization triple as compared to the static counterpart.

2 Relation to Literature

Our work contributes to several influential strands of the literature. First, our paper builds a bridge between the empirical and theoretical literatures on the links between growth and trade. The seminal work of Frankel and Romer (1999) uses a reduced-form framework to study the relationships between income and trade.[10] Wacziarg (2001) investigates the links between trade policy and economic growth employing a panel of 57 countries for the period of 1970 to 1989. A key finding 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. These studies motivate our focus on capital accumulation as the source of growth in our model.[11] We extend this reduced form literature in two ways. First, we offer structural equations that corresponds directly to the reduced-form specification of Frankel and Romer (1999). Second, we introduce a theoretically-motivated equation that captures the effects of trade on capital accumulation and hence growth.

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. We abstract from the random productivity draws setup of Eaton and Kortum (EK) for simplicity, since the EK model is observationally equivalent to the structural gravity model we estimate. This simplicity allows our addition of capital accumulation in transition. The steady state

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

[11]The correlation in our sample between changes in trade openness (measured as exports plus imports as share of gross domestic product) and changes in capital accumulation is about 0.38 (p-value 0.002).

of our model is equivalent to EK if we add a flow use of intermediate goods to the flow of capital to offset depreciation.[12]

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.[13]

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

[12]The work of Eaton and Kortum that is most closely related to our study is thoroughly summarized in their manuscript Eaton and Kortum (2005). In chapter ten, based on Eaton and Kortum (2001), they study how trade in capital goods possibly transmits technological advances. The analysis is based on a model with two goods, a capital good and a consumption good, in an environment of perfect competition in the output market, the labor market, and the rental market for capital. The main finding is that differences in equipment prices can be related to differences in productivity and barriers to trade in equipment. In chapter eleven, they investigate the geographical scope of technological progress in a multi-country (semi)endogenous growth framework. The main empirical finding is that an innovation abroad is two-thirds as potent as a domestic innovation. For a thorough review of the theoretical literature on trade and (endogenous) technology up to the 1990s, we refer the reader to Grossman and Helpman (1995). For more recent developments in the related literature, we refer the reader to Acemoglu and Zilibotti (2001), Acemoglu and Ventura (2002), Alvarez and Lucas, Jr. (2007), Sampson (2014), and Eaton, Kortum, Neiman, and Romalis (2015).

[13]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.

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

offer encouraging support in favor of ongoing trade liberalization and integration efforts.

A useful by-product of our model is a direct estimate of the trade elasticity of substitution, which has gained recent popularity as the single most important trade parameter (see ACR). The estimator is due to a structural trade term in the production function of our model. With values between 5.1 and 8.0 from alternative specifications and robustness experiments, our estimates of the trade elasticity of substitution are comparable to the ones from the existing literature, which usually vary between 2 and 12.[14]

In broader context, 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 family of static gravity models that were stimulated by Eaton and Kortum (2002) and Anderson and van Wincoop (2003) by a structural dynamic model of trade, production and growth.[15] On the empirical side, we complement Olivero and Yotov (2012) and Campbell (2010), who build estimating dynamic gravity equations, by testing and establishing the causal relationships between trade, income, and growth.[16]

3 Theoretical Foundation

The theoretical foundation used here to quantify the relationships between growth and trade combines the static structural trade gravity setup of Anderson and van Wincoop (2003) with dynamically endogenous production and capital accumulation in the spirit of the dynamic general equilibrium models developed by Lucas and Prescott (1971) and Hercowitz and Sampson (1991). Goods are differentiated by place of origin and each of the N countries

[14] See Eaton and Kortum (2002), Anderson and van Wincoop (2003), Broda, Greenfield, and Weinstein (2006) and Simonovska and Waugh (2011). Costinot and Rodríguez-Clare (2014) and Head and Mayer (2014) each offer a summary and discussion of the available estimates of the trade elasticity parameter.

[15] See Costinot and Rodríguez-Clare (2014) for an excellent review of related recent developments.

[16] There is a literature that explains export dynamics (see for example Das, Roberts, and Tybout, 2007; Morales, Sheu, and Zahler, 2015) and one that focuses on adjustment dynamics and business cycle effects of trade liberalization (see for example Artuç, Chaudhuri, and McLaren, 2010; Cacciatore, 2014; Dix-Carneiro, 2014). Export dynamics and adjustment and business cycle dynamics are beyond the scope of this paper.

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) and Hercowitz and Sampson (1991):

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

where $\Omega_{j,t}$ denotes the flow of investment in country j at time t and $\delta \in (0,1]$ is the depreciation rate. This transition function reflects the costs in adjustments of the volume of capital.[17]

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

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

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

Equations (3) and (4) define the law of motion for the capital stock and the value of production, respectively. The budget constraint (5) states that aggregate spending in country j has to equal the sum of spending on both consumption and investment goods. Aggregate consumption and investment are both comprised by domestic and foreign goods, $c_{ij,t}$ and $I_{ij,t}$, which are aggregated as follows:

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

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

Equation (7) defines the consumption aggregate ($C_{j,t}$) as a function of consumption from each region i ($c_{ij,t}$), where γ_i is a positive distribution parameter, and $\sigma > 1$ is the elasticity of substitution across goods varieties from different countries. Equation (8) presents a CES investment aggregator ($\Omega_{j,t}$) that describes investment in each country j as a function of domestic components ($I_{jj,t}$) and imported components from all other regions $i \neq j$ ($I_{ij,t}$).[18]

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

[18] The assumption that consumption and investment goods are both a combination of all world varieties subject to the same CES aggregation is very convenient analytically. In addition, it is also consistent with our aggregate approach in this paper. Allowing for heterogeneity in preferences and prices between and within consumption and investment goods will open additional channels for the interaction between trade and growth which require sectoral treatment. This is beyond the scope of this paper, and we refer the reader to Osang and Turnovsky (2000), Mutreja, Ravikumar, and Sposi (2014), and Eaton, Kortum, Neiman, and Romalis (2015) for efforts in that direction.

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 obtain the optimal demand of $c_{ij,t}$ and $I_{ij,t}$, for given $C_{j,t}$, $\Omega_{j,t}$, and $y_{j,t}$. 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 $y_{j,t} = \sum_i x_{ij,t} = \sum_i p_{ij,t}(c_{ij,t} + I_{ij,t})$, taking $C_{j,t}$ and $\Omega_{j,t}$ as given, and using (5) 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 system of Anderson and van Wincoop (2003):

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

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

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

Equation (12) links intuitively bilateral exports to market size (the first term on the right-hand side) and trade frictions (the second term on the right-hand side). Coined by Anderson and van Wincoop (2003), $\Pi_{i,t}^{1-\sigma}$ and $P_{j,t}^{1-\sigma}$ are the multilateral resistance terms (MRs, outward and inward, respectively), which consistently aggregate bilateral trade costs and decompose their incidence on the producers and the consumers in each region (Anderson and Yotov, 2010). The multilateral resistances are key to our analysis because they represent the endogenous structural link between the 'lower level' trade analysis and the 'upper level' production and growth equilibrium. The MRs translate changes in bilateral trade costs at the 'lower level' into changes in factory-gate prices, which stimulate or discourage investment and growth at the 'upper level'. At the same time, by changing output shares in the multilateral resistances, capital accumulation and growth alter the incidence of trade costs in the world.

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 an analytical solution. To solve for the policy functions of capital we iterate over the value function to obtain (see for details Online Appendix B):

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

Policy function (15) is consistent with rational expectations despite the appearance of one period ahead prices only. This is due to the log-linear functional form of both preferences and capital accumulation, implying that marginal rates of substitution are proportional to the ratio of present to one-period-ahead consumption or capital stocks.[19] 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 important 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 $P_{j,t}$.[20] The intuition behind the positive relationship between the prices of domestic goods and capital accumulation is that, all else equal, when faced with higher returns to investment given by the value marginal product of capital $\alpha p_{j,t} A_{j,t} L_{j,t}^{1-\alpha} K_{j,t}^{\alpha-1}$, consumers are willing to give up more of their current income in order to increase future consumption. The intuition behind the negative relationship between capital accumulation and aggregate consumer prices is that an increase in $P_{j,t}$ means that consumption as well as investment become more expensive. Hence, a higher share of income will be spent on consumption today and less will be saved and transferred for future consumption via capital accumulation.

The relationships between prices and capital accumulation are crucial for understanding the relationships between growth and trade because changes in trade costs will result in changes in international prices, which will affect capital accumulation. Specifically, the inward multilateral resistance defined in equation (13) consistently aggregates the changes in bilateral trade costs between any possibly pair of countries in the world for a given

[19] In Online Appendix C we confirm that our results are replicated by the standard dynamic rational expectations solution method Dynare (Adjemian, Bastani, Juillard, Karamé, Maih, Mihoubi, Perendia, Pfeifer, Ratto, and Villemot, 2011, http://www.dynare.org/). We also use Dynare to solve our model when we allow for the standard linear capital accumulation function in order to demonstrate the robustness of our findings. This analysis is presented in Appendix A.2, "Linear Capital Accumulation".

[20] 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.

economy. Thus, intuitively, if a country liberalizes its inward MR falls and this triggers investment. However, if liberalization takes place in the rest of the world this will result in an increase in the MRs for outsiders, and therefore lower investment. Equation (15) reveals a direct relationship between factory-gate prices and investment. Similar to the inward MRs, factory-gate prices consistently aggregate the effects of changes in bilateral trade costs in the world on investment decisions in a given country. The intuition is that when a country opens up to trade producers from this country enjoy lower outward MR, which, according to equation (11), translates into higher factory-gate prices. Outsiders face higher outward MR, their factory-gate prices fall, and investment decreases.

Given the policy function for capital, we can easily calculate investment, $\Omega_{j,t}$, consumption, $C_{j,t}$, and income, respectively, as (see for details Online Appendix B):

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

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

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

System (16)-(18) reveals that aggregate consumption and aggregate investment at the 'upper level' are linked to the 'lower level' via the consumer price indexes and factory-gate prices, which consistently aggregate all bilateral trade links for consumers and investors, respectively. In addition, the right-hand side expressions in the first two equations reveal that investment and consumption in each period are always a constant fraction of real gross domestic product (GDP). This is due to the log-linear functional form of capital accumulation which enables us to obtain an analytical solution for the policy function of capital.[21] Note that when there are no costs in adjustment of the volume of capital, i.e. $\delta = 1$, (15)-(18) implies that adjustment to the steady state is instantaneous. Thus adjustment costs for capital play much the same role in capital adjustment (16) as iceberg trade costs play

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

in gravity equation (12). (In the special case where the trade costs reflect home bias in preferences only, the similarity is even closer.)

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:

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

The beauty of system (19)-(24) is that the universe of bilateral trade linkages are consistently aggregated for each country and they are nested in the 'upper level' capital accumulation framework via the MRs.[22] Our strategy in the subsequent sections is to translate system (19)-(24) into an econometric model, which we estimate in order test and establish the causal relationships between trade, income and growth and 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.

[22] With the given parameter restrictions on α, β, and δ, the solution for the endogenous variables of system (19)-(24) can be shown to be unique.

3.1 Growth and Trade: A Discussion

The relationships between growth/capital accumulation and trade are illustrated by a hypothetical trade liberalization scenario acting on system (19)-(24). Consider a reduction of bilateral trade costs t_{ij} at some point in time t, e.g. a bilateral free trade agreement between partners i and j. First, the direct (partial-equilibrium) effect of a fall in $t_{ij,t}$ is an immediate increase in bilateral trade between partners i and j at time t without any implications for the rest of the countries. This effect is captured by equation (19) for given output and multilateral resistances.

Second, trade liberalization between countries i and j at time t has an indirect effect on trade flows through the MRs given in equations (20) and (21). Anderson and van Wincoop (2004) emphasize that MRs are general equilibrium constructs that aggregate consistently all bilateral trade costs. For producers in a given country, the outward MR effectively acts as the friction faced if they ship to a unified world market. Inward MR aggregates all bilateral trade costs faced by the consumer in a given country as if they buy from a unified world market. A reduction in trade costs between any two countries affects trade flows between all other country pairs in time t through their MRs. Hence, those terms capture the third-country effects through trade creation and trade diversion. In particular, opening to trade between countries i and j will translate into lower MRs (lower resistance for producers and lower prices for consumers) in the liberalizing countries, while producers and consumers in the rest of the world will suffer higher trade resistance.

Third, and most important for the purposes of this paper, trade liberalization acts on output and capital accumulation via changes in prices in the world. In combination, equations (22)-(23) depict the contemporaneous effects of changes in trade costs on factory-gate prices $p_{j,t}$, and on the value of domestic production/income $y_{j,t}$. Intuitively, equation (22) captures the fact that a lower trade resistance (i.e. a lower outward multilateral resistance) faced by the producers in a liberalizing country translates into higher factory-gate prices. The latter will lead to an increase in the value of domestic production/income via equation

(23). The opposite happens in outside countries, which now face higher trade resistance. Importantly, these effects are channeled through the outward multilateral resistance, which, as discussed above, means that a change in trade costs between any two countries may affect prices and output in any other country in the world.

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

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

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 any country size translate into changes in the multilateral resistances for all countries, which lead to changes in trade flows. Thus the MR channel is a general equilibrium system: i.e. growth in one country will affect trade costs and impact welfare in every other country in the world. The model 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 growth-led changes in the sellers' and buyers' incidence of trade costs lead to additional changes in capital stocks activating further changes in GDP, multilateral resistances, and factory-gate prices.

The dynamic feature of our model allows quantification of the intuition that preferential trade liberalization (e.g. a RTA) may benefit non-members through the growth of members and the resultant terms of trade improvement of non-members. By making investment more attractive, a RTA will stimulate growth in the member countries. This will lead to lower sellers' incidence for these countries, but also to lower buyers' incidence in non-members. The latter complements the direct positive size effect of member countries on non-member exports that we described above.[23]

[23] Theory reveals that, in principle, growth due to regional trade liberalization can lead to benefits for outside countries that do not participate in the integration effort. Such effects can not be observed in an aggregate setting such as ours, but are more likely to arise within a multi-sector framework where growth leads to specialization. It should also be noted, however, that even though we do not observe positive welfare effects for outside countries in our sample, we do find non-monotonic trade diversion effects. In some cases (e.g. the Czech Republic, Ireland, and the Netherlands) the dynamic forces in our framework lead to trade creation effects that are stronger than the initial static trade diversion effects. Details are available in Table A1 of Online Appendix G.

3.2 Growth and Trade in the Long-Run

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

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

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

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

Solving for K_j leads to:

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

Define the relative change in variable x as $\widehat{x} \equiv x'/x$ where x' is evaluated at some other point on the real line than x. Taking A_j, L_j and parameters as given, the ratio of steady state capital stocks is

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

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

3.3 Growth and Trade: Sufficient Statistics

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

Stimulated by ACR, we show (see Online Appendix D for details) that the change in capital can directly be related to welfare by deriving an extended ACR formula:

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

Equation (27) implies that an increase of steady-state capital will, ceteris paribus, increase welfare. The extended ACR formula given in (27) holds in and out-of steady-state. Furthermore, as demonstrated in Online Appendix D, we can express $\widehat{K}_j$ in terms of $\widehat{\lambda}$ in steady-state, leading to $\widehat{W}_j = \widehat{\lambda}_{jj}^{\frac{1}{(1-\alpha)(1-\sigma)}}$. This expression nicely highlights the similarity of introducing capital or intermediates in the steady state (compare with the formulas given in ACR, p. 115). However, in our dynamic framework capital accumulation is the result of an optimized intertemporal choice of consumers and we can trace the resulting transition between two steady-states. Accounting for this transition has important welfare consequences, as (i) the transition takes time and the welfare gains and losses therefore have to be discounted, and (ii) the gains and losses are non-uniformly distributed over time. While we are able to derive an ACR-like welfare formula, which only depends on $\widehat{\lambda}$ and parameters when taking into account the transition (see Online Appendix D.2), we will typically not observe changes in λ_{jj} over time solely driven by the counterfactual under consideration. However, by using our system, we can calculate the transition in our welfare counterfactual analysis.

4 Empirical Analysis

Our model is straightforward to implement empirically. It simultaneously enables us to test and establish the causal relationships between trade, income and growth and delivers all the key parameters needed to perform counterfactuals. The parameter estimates are compared to standard values from the existing literature to establish the credibility of our methods. The econometric framework includes as a special case the reduced-form growth-and-trade specification from Frankel and Romer (1999), but also expands on it by introducing an additional estimating equation for capital accumulation while highlighting important contributions of our structural approach. Section 4.1 presents the estimation strategy and some econometric challenges. Section 4.2 describes the data and Section 4.3 presents the estimates.

4.1 Econometric Specification

We translate our theoretical model into estimating equations in two steps. We begin with the estimation strategy for the 'lower level', the gravity model of trade flows. Then we describe the estimation strategy for the 'upper level', i.e. for income and for capital.

4.1.1 'Lower Level' Econometric Specification: Trade

To obtain sound econometric estimates of bilateral trade costs and, subsequently, of the multilateral resistances that enter the income and capital equations, several econometric challenges must be met. First, we follow Santos Silva and Tenreyro (2006) in the use of the Poisson Pseudo-Maximum-Likelihood (PPML) estimator to account for the presence of heteroskedasticity 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.[24] 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:

$$t_{ij,t}^{1-\sigma} = \exp\left[\eta_1 RTA_{ij,t} + \sum_{m=2}^{5} \eta_m \ln DIST_{ij,m-1} + \eta_6 BRDR_{ij} + \eta_7 LANG_{ij} + \eta_8 CLNY_{ij}\right], \quad (28)$$

where, $RTA_{ij,t}$ is a dummy variable equal to 1 when i and j have a RTA in place at time t, and zero elsewhere.[25] The presence or absence of RTAs, and more specifically NAFTA, will be the basis for our counterfactual experiments. $\ln DIST_{ij,m-1}$ 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.

One final econometric consideration that we address is the potential endogeneity of RTAs. The issue of RTA endogeneity is well-known in the trade literature[26] and to address it, we adopt the method from Baier and Bergstrand (2007) and use country-pair fixed effects in order to account for the unobservable linkages between the endogenous RTA covariate and the error term in trade regressions.

Taking all of the above considerations into account and using equation (28) for the specification of trade costs $t_{ij,t}^{1-\sigma}$, we use PPML to estimate the following econometric specification of the *Trade equation* (19) of our structural system:

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

[25] The original source for data on regional trade agreements is the World Trade Organization. A detailed description of the RTA data used and the data set itself can be found at http://www.ewf.uni-bayreuth.de/en/research/RTA-data/index.html.

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

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

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 $RTA_{ij,t}$ and the remainder error term $\epsilon_{ij,t}$ in order to control for potential endogeneity of the former. Importantly, μ_{ij} will absorb all time-invariant gravity covariates from (28) along with any other time-invariant determinants of trade costs that are not observable by the researcher.

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

$$\exp\left(\widehat{\mu}_{ij}\right) = \exp\left[\sum_{m=2}^{5} \tilde{\eta}_m \ln DIST_{ij,m-1} + \tilde{\eta}_6 BRDR_{ij} + \tilde{\eta}_7 LANG_{ij} + \tilde{\eta}_8 CLNY_{ij}\right] + \varepsilon_{ij,t}, \tag{30}$$

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

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

The set of bilateral trade costs that account for the presence of RTAs is constructed from (29) and (31):

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

Below, we use (32) to study the dynamic general equilibrium effects of NAFTA and globalization on growth and welfare. (For the NAFTA exercise, we abstract from modeling tariff revenues and rents in order to isolate and focus on the key dynamic channels in our framework.)

4.1.2 'Upper Level' Econometric Specification: Income and Capital

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

Income. We start with the estimating equation for income. Transforming the theoretical specification for income into an estimating equation for growth is straight forward: We substitute equation (22) for prices into equation (23), solve for $y_{j,t}$ and express the resulting equation in natural logarithmic form:

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

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

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

$\varepsilon_{j,t}$.[27] Hence, equation (33) becomes:

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

Here, $\kappa_1 = (\sigma - 1)(1 - \alpha)/\sigma$, $\kappa_2 = (\sigma - 1)\alpha/\sigma$, and $\kappa_3 = -1/\sigma$. Importantly, a significant estimate of the coefficient on the MR term, $\widehat{\kappa}_3$, will support a causal relationship of trade on income. In addition, $\widehat{\kappa}_3$ can be used to recover the trade elasticity of substitution directly as $\widehat{\sigma} = -1/\widehat{\kappa}_3$.[28] With $\widehat{\sigma}$ at hand, we can also obtain the capital share of production as $\widehat{\alpha} = \widehat{\kappa}_2\widehat{\sigma}/(\widehat{\sigma} - 1) = \widehat{\kappa}_2/(1 + \widehat{\kappa}_3)$. Finally, our model implies the following structural relationship between the coefficients on the three covariates in (34), $\kappa_1 + \kappa_2 = 1 + \kappa_3$.

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

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

[27] We are aware of the successful efforts to estimate productivity with available firm-level data, cf. Olley and Pakes (1996) and Levinsohn and Petrin (2003). However, the aggregate nature of our study does not allow us to implement those estimation approaches. The plausible estimates of the production function parameters that we obtain in the empirical analysis are encouraging evidence that our treatment of technology with country and time fixed effects is effective.

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

$$Trade: \qquad x_{ij,t} = \exp[\eta_1 RTA_{ij} + \chi_{i,t} + \pi_{j,t} + \mu_{ij}] + \epsilon_{ij,t}, \tag{35}$$

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

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

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

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

$$\tilde{\Pi}_{i,t}^{1-\sigma} = \sum_{j \neq i} \left(\frac{t_{ij,t}}{\tilde{P}_{j,t}}\right)^{1-\sigma} \frac{y_{j,t}}{y_t}. \tag{38}$$

This procedure is akin to the methods from Anderson, Milot, and Yotov (2014), who use $\tilde{\Pi}_{i,t}^{1-\sigma}$ to calculate Constructed Foreign Bias, defined as the ratio of predicted to hypothetical frictionless foreign trade, aggregating over foreign partners only, $CFB_i = \tilde{\Pi}_{i,t}^{1-\sigma}/\Pi_{i,t}^{1-\sigma}$, where $\Pi_{i,t}^{1-\sigma}$ is the standard, all-inclusive outward multilateral resistance.

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

$$\ln K_{j,t} = \psi_1 \ln y_{j,t-1} + \psi_2 \ln K_{j,t-1} + \psi_3 \ln P_{j,t-1} + \nu_t + \vartheta_j + \varsigma_{j,t}, \tag{39}$$

where: $\psi_1 = \delta$ captures the positive relationship between investment and the value of marginal product of capital. As discussed in our theory section, this relationship is driven by the general-equilibrium impact of changes in trade costs on factory-gate prices. $\psi_2 = 1 - \delta$ captures the dependence of current on past capital stock. Finally, $\psi_3 = -\delta$ captures the intuitive inverse relationship between capital accumulation and the prices of consumption and investment goods, which also capture the indirect, general-equilibrium effects of changes in trade costs on capital accumulation. Thus, a significant estimate of ψ_3 will support a causal relationship of trade on capital accumulation. Additionally, ν_t and ϑ_j are year and country fixed effects that control for parameters $\delta \ln [(\alpha\beta\delta)/(1-\beta+\beta\delta)]$ and any other time-varying and country-varying variables that may affect capital accumulation. Our model implies the following structural relationships between the coefficients on the three covariates in equation (39), $\psi_1 = -\psi_3$ and $\psi_1 = 1 - \psi_2$. In addition to delivering a single depreciation parameter δ, equation (39) can be used to estimate country-specific depreciation parameters by interacting each of the terms of the right-hand side with country dummies. We experiment with such specifications in our empirical analysis.

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

$$Trade: \qquad x_{ij,t} = \exp[\gamma_1 RTA_{ij} + \chi_{i,t} + \pi_{j,t} + \mu_{ij}] + \epsilon_{ij,t}] + \epsilon_{ij,t}, \tag{40}$$

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

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

System (40)-(42) obtains estimates of the key parameters needed to calibrate our model of trade and growth. In addition, the system will enable us to isolate and identify the causal effect of trade on income and growth via the estimates of κ_3 and ψ_3 on the trade terms

$\ln\left(\frac{1}{\tilde{\Pi}_{j,t}^{1-\sigma}}\right)$ and $\ln P_{j,t-1}$ in our *Income* and *Capital* equations, respectively. We demonstrate below. Before that we describe our data.

4.2 Data

Our sample covers 82 countries over the period 1990-2011.[29] These countries account for more than 98 percent of world GDP throughout the period of investigation. In order to perform the analysis, we use data on trade flows, GDP, employment, capital and RTAs. In addition, we construct a set of bilateral trade costs with data on the standard gravity variables including distance, common language, contiguity and colonial ties.

Data on GDP, employment, and capital stocks are from the latest edition of the Penn World Tables 8.0.[30] The Penn World Tables 8.0 offer several GDP variables. Following the recommendation of the data developers, we employ *Output-side real GDP at current PPPs* ($CGDP^o$), which compares relative productive capacity across countries at a single point in time, as the initial level in our counterfactual experiments, and we use *Real GDP using national-accounts growth rates* ($CGDP^{na}$) for our output-based cross-country income regressions. The Penn World Tables 8.0 include data that enables us to measure employment in effective units. To do this we multiply the *Number of persons engaged in the labor force* with the *Human capital index*, which is based on average years of schooling. Capital stocks (at constant 2005 national prices in mil. 2005USD) in the Penn World Tables 8.0 are constructed

[29] 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), and Zimbabwe (ZWE).

[30] These series are now maintained by the Groningen Growth and Development Centre and reside at http://www.rug.nl/research/ggdc/data/pwt/.

based on cumulating and depreciating past investment using the perpetual inventory method. 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 only 5.8 percent of zeroes due to its aggregate nature. The RTA-dummy is constructed based on information from the World Trade Organization. A detailed description of the RTA data used and the data set itself can be found at http://www.ewf.uni-bayreuth.de/en/research/RTA-data/index.html. Finally, data on the standard gravity variables, i.e., distance, common language, colonial ties, etc., are from the CEPII's Distances Database, available for download at http://www.cepii.fr/cepii/en/bdd_modele/bdd.asp.

4.3 Estimation Results and Analysis

4.3.1 Trade Costs

We start with a brief discussion of our estimate of the effects of RTAs, which is obtained from equation (29) with a PPML estimator to account for heteroskedasticity and zero trade, with bilateral fixed effects to control for potential RTA endogeneity, and with exporter-time and importer-time fixed effects to account for the structural MRs, income, and expenditure shares. Based on this specification, we obtain an estimate of the average treatment effect of RTAs that is equal to 0.827 (std.err. 0.083), which is readily comparable to the corresponding index of 0.76 from Baier and Bergstrand (2007).[31] This gives us confidence to use our estimate of the RTA effects to proxy for the effects of trade liberalization in the counterfactual experiments below.

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

[31] Our RTA estimate suggest a partial equilibrium increase of 129% ($100 \times [\exp(0.827) - 1]$) in bilateral trade flows among member countries.

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

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

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

Finally, we construct internal trade costs as the product between internal distance and the estimates on the coefficient on $\ln DIST_{ij,1}$.[32] While not central for our dynamic analysis and main results, our treatment of internal trade costs improves on the standard approach in the literature, where countries are point masses. Specifically, (i) we allow for *positive* internal trade costs, and (ii) we allow for *country-specific* internal trade costs. Overall, we view our estimates of bilateral trade costs as convincing and we are confident in using them to construct the multilateral resistances and to perform counterfactual experiments.

4.3.2 Income

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

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

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

Estimates from various specifications of equation (44) are reported in Table 1. All specifications include year fixed effects and country fixed effects and we report robust, bootstrapped standard-errors where generated regressors are included in our specifications, i.e. in columns (2) and (3) of Table 1. In column (1) of the table, we offer results from a standard constrained estimation of the Cobb-Douglas production function.[33] As can be seen from the table, both the labor and the capital shares have reasonable magnitudes and are within the theoretical bound [0; 1]. This suggests that our sample is representative.

In column (2) of Table 1 we introduce as an additional regressor the original Frankel

[32] $\ln DIST_{ij,1}$ is based on the smallest distance interval in our sample and all internal distances fall within this interval. Consistent with the measure of international distance, internal distance is constructed as a population weighted average of the bilateral distances between the cities within each country. For further details see CEPII's Distances Database, available for download at http://www.cepii.fr/cepii/en/bdd_modele/bdd.asp.

[33] In Table 4 of Appendix A.1 we report unconstrained results from all specifications that we present in this section. Our sensitivity estimates are qualitatively identical and quantitatively very similar to the main, constrained results from Table 1.

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

In column (3), we replace the reduced-form Frankel and Romer specification with our structural model. Several properties stand out. First, all estimates from column (3) of Table 1 have expected signs and are statistically significant at any conventional level. Importantly, and similar to Frankel and Romer (1999), we find that trade openness leads to higher income. Thus, we offer evidence for a causal relationship between trade and income/growth. This is captured by the negative and significant estimate of the coefficient of our inverse theoretical measure of trade openness $\ln\left(1/\widehat{\tilde{\Pi}_{j,t}^{1-\sigma}}\right)$. Next, we capitalize on the structural properties of our model to recover a plausible estimate of the trade elasticity of substitution. In particular, we obtain a value of $\widehat{\sigma} = -1/\widehat{\kappa}_3 = 5.100$ (std.err. 0.804), which satisfies the theoretical restriction that the trade elasticity should be greater than one and falls comfortably within the distribution of the existing (Armington) elasticity numbers from the trade literature, which usually vary between 2 and 12 (see the references in footnote 14). Finally, using these estimates and applying the structural restrictions of our model, in the bottom panel of the table we recover an estimate of 0.550 (std.err. 0.041) for the capital share α.

We proceed with two sensitivity experiments. For brevity, we report the estimation results from these experiments in Appendix A.1, and here we just discuss our findings. First, we allow capital shares to vary over time. The intuition is that capital shares have increased steadily over the past quarter century and our data should reflect that. In accordance with that, we find that the average capital shares in our sample have increased from 0.391 (std.err. 0.114) during the 1990s to 0.603 (std.err. 0.061) during the 2000s. Next, we distinguish between capital shares in poor versus rich countries. We define rich countries as those with income above the median income in each year of our sample. In accordance with our expectations, we find that production in rich countries is more capital intensive than in poor countries. Specifically, we estimate a statistically significant difference of 8.3 percentage points between the capital shares of the two groups of countries. Overall, the parameter estimates of the capital share α and of the elasticity of substitution σ that we obtain in this section are within the bounds established in the literature and we view them as plausible.

4.3.3 Capital

We proceed with estimation of our capital accumulation specification:

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

Equation (45) will enable us to recover capital depreciation rates (δ's) subject to the following relationships: $\psi_1 = \delta$; $\psi_2 = 1 - \delta$; and $\psi_3 = -\delta$. Our results are encouraging:[34]

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

First, the estimates of the three covariates are all significant and with expected signs. In addition, they imply a reasonable value for $\delta = 0.052$ (std.err. 0.006). Importantly, the estimate of the coefficient on the trade term $\ln P_{j,t-1}$ is statistically significant, which implies a causal relationship between trade and capital accumulation. In accordance with our theory, the estimate of ψ_3 captures the inverse relationship between investment and investment costs. Finally, we obtain a positive and significant estimate of the coefficient on the value of output which, as suggested by our model, captures the positive relationship between the value of marginal product of capital and investment.

In our next experiment, we use equation (45) to obtain country-specific depreciation rate estimates δ_i's. To do this, we interact each of the three covariates on the right-hand side of equation (45) with country dummies, and we impose the theoretical constraints of our model. The resulting country-specific estimates are reported in column (6) of Table 7 in

[34]Coefficient estimates are reported in bold-face in front of the variables, and the corresponding robust, bootstrapped standard errors are in parentheses below them. The regression includes year and country fixed effects whose estimates are omitted for brevity.

Appendix A.1. Two properties stand out. First, without any exception and in accordance with theory, all estimates of δ are positive but smaller than one. Second, the estimates vary significantly but within reasonable bounds, ranging between 0.03 (std.err. 0.005) for China, and 0.161 (std.err. 0.016) for Zimbabwe.

According to our theory, the change in the value of marginal product of capital is driven by changes in factory-gate prices in response to trade liberalization. Since consistent international data on factory-gate prices are not available, in our next experiment we attempt to draw inference for their effects as a residual impact after we control for all other factors that affect investment in our model. Specification (46) already controls for the effects of capital and trade via the multilateral resistances. In addition, we use year and country fixed effects in order to capture differences in technology and other country and time specific unobservables. Thus, we may identify the effects of prices by isolating the impact of labor on capital accumulation from the value of output in specification (46). Results from a constrained and an unconstrained version of specification (46), where labor is added as an additional covariate, are reported in Table 6 of Appendix A.1. The estimates of all variables are highly statistically significant and with expected signs in both specifications. We obtain positive and significant estimates of the effects of labor, which are expected. More importantly, we find that the estimate of the coefficient on $\ln y_{j,t-1}$ remains positive and statistically significant, which is consistent with our theory.

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

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

5 Counterfactual Experiments

Counterfactual experiments reveal the implications of our estimated model for, respectively, the effect of trade liberalization on growth and the effect of growth on trade. For the effects of trade liberalization on growth, we estimate the effects of the North American Free Trade Agreement (NAFTA), and the effects of a fall in international trade costs for all countries (globalization). The effects of growth on trade are illustrated by simulation of the effects of a 20% change of the capital stock in the United States. We also perform a series of sensitivity experiments using a different functional form for capital accumulation, allowance for intermediate goods, and alternative values for the parameters of our model.

The basis for the counterfactual experiments includes the 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 $t_{ij,t}^{1-\sigma}$ from our estimates according to equation (32); (ii) we recover theory-consistent, steady-state capital stocks according to the capital accumulation equation (25); (iii) we calculate baseline preference-adjusted technology A_j/γ_j according to the market-clearing equation (22) and the production function equation (23).[35] For parameter estimates in the baseline case we use our own estimates of the elasticity of substitution $\widehat{\sigma} = 5.1$ and the share of capital in the Cobb-Douglas production function $\widehat{\alpha} = 0.55$ from column (3) of Table 1, and the capital depreciation rate $\widehat{\delta} = 0.052$ obtained from equation (46). The consumers' discount factor is set equal to $\beta = 0.98$, which is standard in the literature.[36]

Our framework provides a "smell test" of our capital accumulation model prior to its use for policy evaluation counterfactuals.[37] Our parameter estimates are comparable to

[35] Online Appendix E offers a detailed description of our counterfactual setup and procedures.

[36] Alternatively, we could solve our system in changes following Dekle, Eaton, and Kortum (2007, 2008). The results are identical to the results from the system in levels. For details please see Online Appendix F.

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

corresponding values from existing studies. The smell test compares our calculated theory-consistent, steady-state capital stocks with the observed capital stocks from the Penn World Tables 8.0. Figure 1 plots the calculated stock of capital with the Penn capital stock data. The correlation coefficient is 0.98. This is strong supporting evidence for the capital accumulation implications of our model.

5.1 The Effects of Trade Liberalization and Globalization

Our main counterfactual experiment evaluates the welfare effects of NAFTA and we complement the existing literature by offering estimates of the dynamic effects of NAFTA on member and non-member countries.[38] Results reported in Table 3 are decomposed into three stages of increasing general equilibrium adjustment. The first column of Table 3 lists country names. The next three columns present the NAFTA effects on welfare, where reported numbers are percentage changes in welfare due to the implementation of NAFTA. Column (2) reports the "Conditional General Equilibrium" (Conditional GE) effects of NAFTA, which include the direct effects of the bilateral changes in trade costs with resulting changes in the MRs (19)-(21) at constant GDPs. These indexes correspond to the the Modular Trade Impact (MTI) effects from Head and Mayer (2014). Column (3) presents the static GDP changes in response to formation of NAFTA. We label this scenario "Full Static GE" and it

the calibrated model passes the validation checks." (pp. 3-4).

[38]For instance Krueger (1999), Lederman, Maloney, and Servén (2005), Romalis (2007), Trefler (2004, 2006), Anderson and Yotov (2011) and Caliendo and Parro (2015). 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 U.S. Caliendo and Parro (2015) 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).

corresponds to the General Equilibrium Trade Impact (GETI) effects from Head and Mayer (2014). Finally, in column (4), we turn on the capital accumulation channel to estimate the effects of NAFTA in "Full Dynamic GE" scenarios, one for the steady state and one for the transition.[39]

The "Conditional GE" estimates from column (2) of Table 3 reveal large gains for NAFTA members. Canada experiences the largest gains, with an increase of real GDP per capita of about 15%. Mexico's welfare increases by about 9%, while U.S. enjoys only modest welfare gains of 0.8%. These numbers are in line with previous studies.[40] In contrast, there are negative NAFTA effects for all other countries in the world due to trade diversion. Notably, 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. The bottom panel of Table 3 reports that on average non-NAFTA members will suffer a -0.22% decrease in welfare.

In column (3) of Table 3, we report estimates from the "Full Static GE" scenario that allows for responses of factory-gate prices due to the formation of NAFTA. Compared to the "Conditional GE" scenario, the positive welfare effects double 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.[41] The large positive welfare effects

[39] Further details of the effects of NAFTA on trade flows, the multilateral resistances, and the capital effects can be found in Table A1 in Online Appendix G. Since the direct effects of NAFTA on bilateral trade are confined to members only, we devote the analysis in this section to the GE effects of NAFTA. According to our estimates NAFTA will increase members' trade by 129%.

[40] One would expect smaller effects for Canada as compared to Mexico because many of the gains from trade between Canada and the U.S. 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.

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

for NAFTA members in this scenario are comparable to estimates from related studies (see Anderson and Yotov, 2011; Caliendo and Parro, 2015).

Turning to the effects on non-member countries, the additional general equilibrium forces in this scenario lead to larger losses for non-members, but the losses are still very small. The only three countries for which we obtain losses that are larger than one percent are Argentina, Colombia, and Guatemala. 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 3 reports estimates from our "Full Dynamic GE, SS" scenario, which captures the capital accumulation effects of NAFTA by comparing the initial steady-state (SS) with the new steady-state, where all capital is fully adjusted to take into account the introduction of NAFTA. Focusing on the NAFTA countries, we see doubling of the NAFTA effects on welfare via the dynamic capital accumulation forces in our framework. The additional dynamic gains are on average almost 6 percentage points. The dynamic effects on non-members are negative, but small in absolute value and also small as a percentage change of the static effects. Overall, the estimates from column (4) reveal significant additional benefits for members on average (about 5.7 percentage points), small additional negative effects for non-members (1.3 percentage points), and an overall efficiency gain for the world of 2.7 percentage points.

Thus far, we follow the standard in the trade literature to measure welfare as real GDP (see ACR for example). However, our dynamic capital-accumulation framework requires an alternative approach to measure welfare effects for the following reasons: (i) Transition between steady states is not immediate due to the gradual adjustment of capital stocks. Given our 'upper level' equilibrium, we are able to solve the transition path for capital accumulation simultaneously in each of the N-countries in our sample.[42] (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 λ of aggregate consumption in each year that consumers would need to be paid in the baseline case to give them the same utility they obtain from the consumption stream in the counterfactual. Specifically, we calculate:

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

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

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

Figure 2 reveals that the effects on NAFTA members are large and long-lived. The largest effect of 60 percent increase in capital stock is for Canada, followed by 33 percent

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

for Mexico and 4 percent for U.S.[43] Most of the dynamic gains accrue initially, but there remain significant transitional dynamic gains more than 100 years after the formation of NAFTA. In contrast, our results suggest that the transitional effects on non-members are small and relatively short-lived. On average we find that capital stock in the non-member countries would have been about 0.5 percent lower without NAFTA, ranging between -1.99 percent for Guatemala to -0.08 percent for Switzerland.[44] 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 non-members constitute encouraging evidence in support of trade liberalization and integration efforts.

A second counterfactual experiment sheds more light on the effects of trade on growth in our model. A globalization experiment increases $\widehat{t_{ij}^{1-\sigma}}$ for all $i \neq j$ by 38% (the estimate of the effects of globalization over a period of 12 years from Bergstrand, Larch, and Yotov, 2013).[45] The globalization effects in the four scenarios of columns (2)-(5) are presented in columns (6)-(9) of Table 3. All countries in the world benefit from globalization. Intuitively, through lowering trade costs globalization improves efficiency in the world, and since bilateral trade costs decrease for every country, the efficiency gains are shared among all countries too. Second, the benefits vary across countries with the biggest gains to relatively small

[43]The large increase in the capital stock for Canada is explained similarly as the large welfare gain for that country (see footnote 40).

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

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

countries in close proximity to large markets. For example, Canada and Mexico are among the big winners in all 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 section we offer a brief summary of a series of robustness experiments that we performed in order to gauge the sensitivity of the results from our NAFTA counterfactual to relaxing some important theoretical assumptions and to employing alternative values for the key structural parameters in our model. We offer a detailed description and results for each experiment in Appendix A.

In our first experiment, we replace the log-linear (Cobb-Douglas) capital transition function with the standard linear form: $K_{j,t+1} = \Omega_{j,t} + (1-\delta)K_{j,t}$. The main (and only) implication for our theory is that the equation for capital accumulation in system (19)-(24) is replaced by a standard consumption Euler-equation. Thus, our growth-and-trade system no longer has a closed-form solution and it does not lend itself to the iterative methods that we used for our main counterfactual. Therefore, in order to simulate the effects of NAFTA in the new setting, we now rely on Dynare, which is a standard tool to solve dynamic general equilibrium and overlapping generations models. For consistency with the main analysis, we employ the same data and parameters. Figure 3 summarizes our findings by comparing the transition paths for capital accumulation with the linear and with the log-linear transition function for the four countries that we presented in Figure 2. Overall, the effects are similar. Three findings stand out. First, the capital accumulation effects generated with the linear transition function are more pronounced immediately after the implementation of NAFTA both for member and for non-member countries. Second, the dynamic NAFTA effects are exhausted a bit faster with the linear capital accumulation function. Third, we find that the welfare effects obtained with the linear versus the log-linear capital transition function are very similar. Thus, we conclude that replacing the standard linear capital accumulation function with its analytically convenient log-linear counterpart has little implications for the level of welfare. However, the linear capital accumulation function increases the speed of convergence. Estimation results and more detailed analysis of this experiment are presented in Appendix A.2.

In order to highlight the importance of the capital accumulation channel, which is the vehicle for the dynamic effects in our model, we investigate how the effects of NAFTA will change if capital stock in the U.S. were 20% larger. Estimates that we present in Table 7 of Appendix A.3 reveal the following. First, the largest increase in welfare is seen in the U.S. (about 6.6%). Second, we find that 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. Finally, we find that effects of increased U.S. capital base for the United States and for all other countries are more persistent and fade only slowly over time. In sum, this experiment demonstrates that capital accumulation is an important channel for the level of welfare, but even more so for the persistence of welfare effects for members and non-members over time.

The important role of intermediate goods[46] is well-documented in the static trade literature.[47] In our next experiment, we study the dynamic implications of intermediate goods. We model intermediates in the spirit of Eaton and Kortum (2002) while retaining all other theoretical assumptions in our model. (See Appendix A.4 for details.) The introduction of

[46]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).

[47]See for example Eaton and Kortum (2002) and Caliendo and Parro (2015).

intermediate goods adds a new layer of general equilibrium linkages that shape the relationship between growth and trade. First, the effect of changes in the price of own capital on capital accumulation and the effect of own capital accumulation on trade and welfare are magnified because, via the intermediates, own capital enters the production function also indirectly. Second, the introduction of intermediates opens a new channel through which foreign capital enters domestic production and the policy function for domestic capital. This new channel is important because it may transmit positive capital accumulation effects in liberalizing countries to non-members. Third, since foreign goods are used as intermediates, any change in their prices will have further effect on domestic capital accumulation. We find support for our theoretical predictions in Table 7 of Appendix A.4, where we see that the introduction of intermediates magnifies disproportionately the effects of NAFTA for member countries relative to non-members.

We finish with five experiments that document the sensitivity of our results to changes in the key model parameters. First, we allow for country-specific capital depreciation rates, which are obtained as discussed in Section 4.3.3. Our findings, presented in Appendix A.5, reveal that, all else equal, higher depreciation rates lead to more trade and higher welfare. The intuition is that, due to lower prices resulting from trade liberalization, more foreign goods are demanded for capital replacement and consumption, which leads to more trade and higher welfare. The opposite happens for lower depreciation rates. Next, we experiment with values for the trade elasticity of substitution. As expected, we find that a higher σ leads to lower welfare effects. This is intuitive because a higher σ means that consumers do not value the availability of foreign goods a lot. Third, we increase the share of capital in production. This reinforces the dynamic effects in our model by magnifying the positive effects for NAFTA members and by mitigating the negative impact on non-members. Fourth, we set the value of the consumer discount factor to $\beta = 0.95$, which is the value used in Eaton, Kortum, Neiman, and Romalis (2015). The lower consumer discount factor results in smaller, but still relatively large, dynamic effects on welfare. This result is expected and is a reflection of the fact that a smaller β means that consumers value the future stream of consumption less. Finally, we lower the intertemporal elasticity of substitution of one (implied by our logarithmic utility function) to 0.5 using an iso-elastic utility function for instantaneous utility. A lower willingness to change the consumption-investment-decision to changes in prices over time leads to slower adjustment to the new steady-state with higher levels of consumption in the first years after the shock. This leads to slightly higher dynamic welfare gains. In sum, we find that our results are sensitive to the specification of the key parameters, but the model generates intuitive responses to parameter changes.

6 Conclusions

The simplicity of the dynamic structural gravity model derives from severe abstraction: each country produces one good only and there is no international lending or borrowing. Difficult but important extensions of the model entail relaxing each restriction while preserving the closed-form solution for accumulation. This may be feasible because either relaxation implies a contemporaneous allocation of investment across sectors and/or countries with an equilibrium that can nest in the inter-temporal allocation of the dynamic model. A multi-good model will bring in the important force of specialization. An international borrowing model will bring in another dynamic channel magnifying differential growth rates. Success in the extension can quantify how important these forces are.

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Tables

Table 1: Trade Costs and Production, 1990-2011

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

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

Table 2: Parameter Estimates

From	**Parameter**	**Min.**	**Max.**
Trade	$\widehat{\eta}_1$	0.827	
		(0.083)**	
	$\widehat{t}_{ij}$	1.796	4.352
Income	$\widehat{\alpha}$	0.448	0.550
		(0.034)**	(0.044)**
	$\widehat{\sigma}$	5.100	7.998
		(0.804)**	(2.204)**
Capital	$\widehat{\delta}$	0.052	
		(0.006)**	
	$\widehat{\delta}_i$	0.030	0.161
		(0.005)**	(0.016)**
Cons. Discount	$\widehat{\beta}$	0.98	

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

Table 3: Welfare Effects of NAFTA and Globalization

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 3 – *Continued from previous page*

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

Notes: This table reports results from our NAFTA and globalization counterfactual. It is based on observed data on labor endowments and GDPs for our sample of 82 countries. Further, it uses our estimated trade costs based on equation (32) and recovered theory-consistent, steady-state capital stocks according to equation (25). We calculate baseline preference-adjusted technology A_j/γ_j according to the market-clearing equation (22) and the production function equation (23). Finally, the counterfactual is based on our own estimates of the elasticity of substitution $\widehat{\sigma} = 5.1$, the share of capital in the Cobb-Douglas production function $\widehat{\alpha} = 0.55$, and the capital depreciation rate $\widehat{\delta} = 0.052$. 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 our NAFTA counterfactual for each country, for the world as a whole, the NAFTA and the non-NAFTA countries (summarized as Rest Of the World, ROW) for three different scenarios. The "Conditional GE" scenario takes the direct and indirect trade cost changes into account but holds GDPs constant, the "Full Static GE" scenario additionally takes general equilibrium income effects into account, and the "Full Dynamic GE" scenario 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 counterfactual, where we assume that international trade costs for all countries decrease by 38%.

Figures

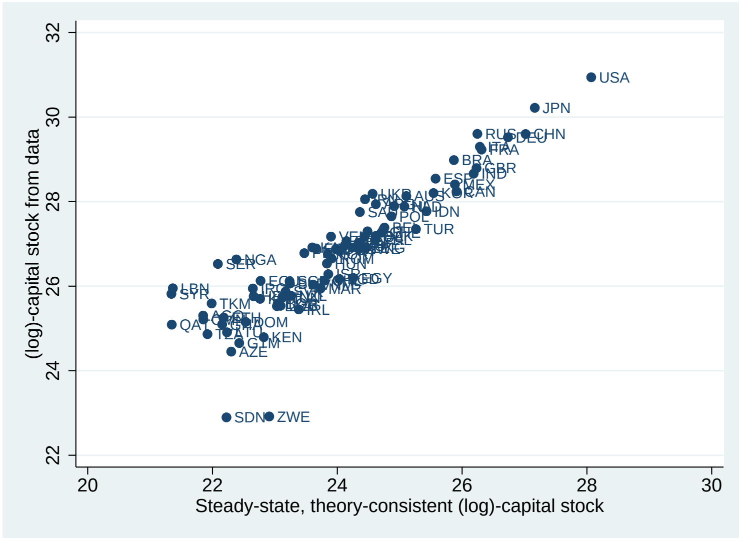

Figure 1: Theory-Consistent vs. Actual Capital Stocks

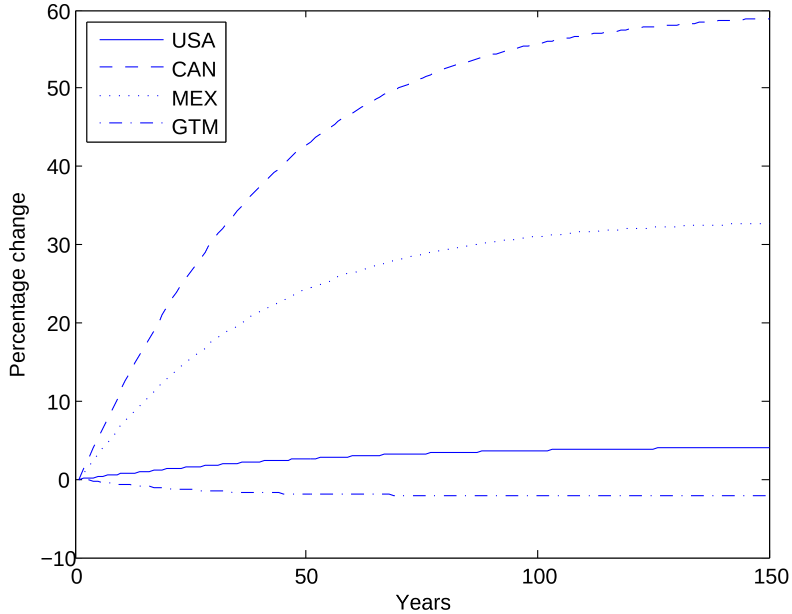

Figure 2: On the Transitional Effects of NAFTA: Capital Stocks

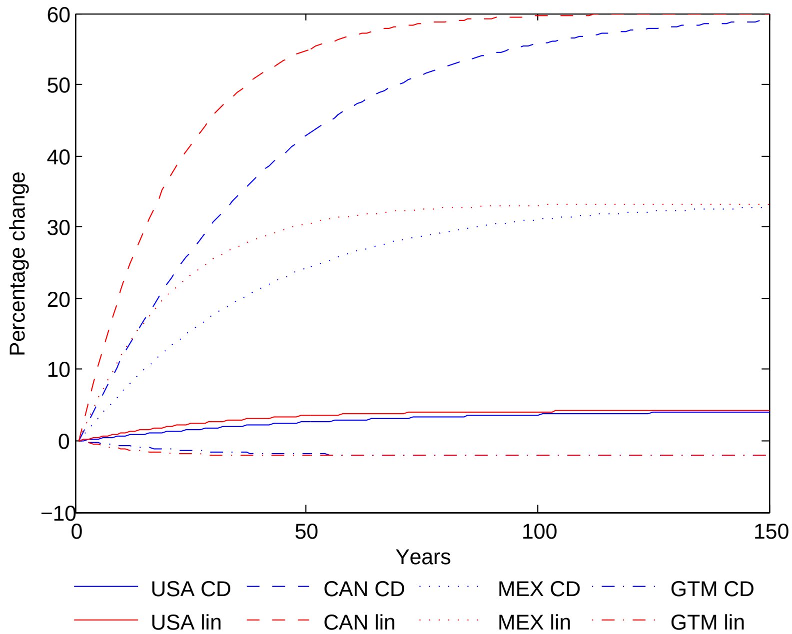

Figure 3: Linear vs. Log-Linear (Cobb-Douglas, CD) Capital Accumulation

A Appendix: Robustness Checks and Sensitivity Experiments

This Appendix offers a series of sensitivity experiments that gauge the robustness of our results. First, we report alternative specifications of the *Income equation* and the *Capital equation*, which identify causal relationships between trade, income and capital accumulation and also deliver some of the key parameters in our model. Then, we offer details for the robustness checks that we summarized in Section 5.2 of the main text. We start by replacing the convenient log-linear capital accumulation function with a more standard linear counterpart. Then, we investigate the effect on NAFTA dynamics of an exogenous increase of the capital stock for the U.S. Third, we repeat the NAFTA counterfactual in the model extended to allow for intermediate goods. Finally, we experiment with different values for the key parameters in our model including country-specific depreciation rates, followed by alternative values for the elasticity of substitution, and for the capital share.

A.1 Estimating Equations for Income and Capital

This section provides the additional tables for our sensitivity experiments for the *Income equation* and the *Capital equation* that we discuss in the corresponding sections from the main text. Table 4 provides additional results for the *Income equation* when estimating it without imposing the theoretical restrictions on the coefficients. As noted in the main text, our findings are qualitatively identical and quantitatively very similar. Table 5 allows for heterogeneous effects of capital shares over time and across country-groups. In accordance with our expectations, the estimates from Table 5 reveal that, on average, capital shares have increased over time and also that production in rich countries is more capital intensive. Table 6 introduces employment as an additional variable in our *Capital equation* in order to isolate the effects of factory-gate prices on capital accumulation. The main finding is that the estimate on the value of output, which now proxies exclusively for the effects of factory-gate prices, is still positive and statistically significant as predicted by our theory.

A.2 Linear Capital Transition Function

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

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

We retain all other assumptions in our model to derive the following trade and growth system:[48]

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

Two main features of the new system stand out. First, the only difference between systems (48)-(53) and (19)-(24) is equation (53), which replaces the closed-form solution (24) for the link between trade and capital accumulation in the original system. Second, as expected, equation (53) no longer represents an analytical expression for next period capital stocks, but rather an implicit relationship that determines consumption. In fact, (53) is the standard consumption Euler-equation, where we have a set of three forward-looking endogenous variables for each country $\{y_t$, C_t, and $P_t\}$.[49]

System (48)-(53) no longer lends itself to the iterative method that we used to perform the counterfactuals of interest. Therefore, we rely on Dynare, which is a standard tool to solve dynamic general equilibrium and overlapping generations models.[50] For consistency with the main analysis, we employ the same data and parameters to simulate the effects of NAFTA once again.[51] To demonstrate the changes due to the new capital accumulation function, we first focus on the transition of capital stocks. As introduced in Section 5.2, Figure 3 contrasts the transition paths for the four countries that we presented in Figure 2, obtained with the log-linear transition functions, against the corresponding transitions functions for the same countries but this time obtained with the linear capital transition function.

Figure 3 reveals the following. Overall, the effects are similar. Two differences stand

[48] Detailed derivation steps appear in Online Appendix H.

[49] K_{t+1} is determined in t and therefore not a forward-looking variable.

[50] For further details see http://www.dynare.org/.

[51] Note that (48)-(53) implies that the estimating equations for trade and output remain unchanged. Therefore, our estimates of the RTA effects, of trade costs, t_{ij}, of the capital share α, and of the elasticity of substitution σ can be estimated as before and remain unchanged. The only parameter that we can no longer estimate is the capital depreciation rate δ. However, since our estimate of $\delta = 0.05$ is plausible, we retain it in the robustness experiment. Note also that, without the closed-form solution for capital accumulation, we can no longer test for causal effects of trade on capital accumulation.

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

While the quantitative effects on transition of capital seem different, we hardly find any difference between the welfare effects obtained with the linear versus the log-linear capital transition function. The welfare effects from both cases are reported in Table 7. In the first column we give the country names, the second column reproduces the welfare results from our baseline "Full Dynamic GE, transition" scenario (column (5) of Table 3). The welfare results for the case with the linear capital accumulation function are reported in column (3). Comparing columns (2) and (3) reveals that the welfare effects are qualitatively identical and quantitatively very similar for the case with our analytical tractable log-linear capital transition function and the more standard linear one. For example, the predicted welfare increases for NAFTA members change from 7.671% in the log-linear case to 7.669% in the linear case, while the ones for the non-members change from -0.423% to -0.403%, respectively. Thus, we conclude that replacing the standard linear capital accumulation function with its analytically convenient log-linear counterpart has little implications for the level of welfare. However, the linear capital accumulation function increases the speed of convergence.

A.3 Exogenous Growth

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

The welfare results for the counterfactual of an increase of the U.S. capital stock of 20% are presented in column (4) of Table 7. First, as we would have expected, the largest increase in welfare is seen in the U.S.: if the formation of NAFTA was accompanied by a 20% increase of the capital stock in the U.S., welfare in the U.S. would increase by about 6.6%. The difference between the baseline given in column (2) is about 4 percentage points. All other countries gain as well. In particular, the positive effects of NAFTA on Canada and Mexico are magnified, while the negative effects on all other countries in the world are diminished. Note that these large effects for the U.S. itself and the relatively small positive effects for the other countries fade only slowly over time.

In sum, we see that capitU.S.al accumulation is very important for the level of welfare in our framework, but even more important for the persistence of the welfare effects over time. The spill-over effects for non-member countries are relatively small, but the persistence of the spill-over effects is large.

A.4 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.[52] In this section we contribute to the related literature by studying the implications of intermediate goods for the dynamic relationships between growth and trade.

To introduce intermediates within our aggregate framework, we follow the approach of Eaton and Kortum (2002) and we assume that intermediate inputs are combined with labor and capital via the following Cobb-Douglas-production function:[53]

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

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

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

[52] See for example Eaton and Kortum (2002) and Caliendo and Parro (2015).

[53] 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.

inputs:[54]

$$
\begin{aligned}
x_{ij,t} &= \frac{y_{i,t}y_{j,t}}{y_t}\left(\frac{t_{ij,t}}{\Pi_{i,t}P_{j,t}}\right)^{1-\sigma}, & (55)\\
P_{j,t}^{1-\sigma} &= \sum_i \left(\frac{t_{ij,t}}{\Pi_{i,t}}\right)^{1-\sigma}\frac{y_{i,t}}{y_t}, & (56)\\
\Pi_{i,t}^{1-\sigma} &= \sum_j \left(\frac{t_{ij,t}}{P_{j,t}}\right)^{1-\sigma}\frac{y_{j,t}}{y_t}, & (57)\\
p_{j,t} &= \frac{(y_{j,t}/y_t)^{\frac{1}{1-\sigma}}}{\gamma_j\Pi_{j,t}}, & (58)\\
y_{j,t} &= p_{j,t}A_{j,t}K_{j,t}^{\alpha}L_{j,t}^{\xi}Q_{j,t}^{1-\alpha-\xi}, & (59)\\
Q_{j,t} &= (1-\alpha-\xi)\frac{y_{j,t}}{P_{j,t}}, & (60)\\
K_{j,t+1} &= \left[\frac{(\alpha+\xi)\alpha\beta\delta p_{j,t}A_{j,t}L_{j,t}^{\xi}Q_{j,t}^{1-\alpha-\xi}}{(1-\beta+\beta\delta)\,P_{j,t}}\right]^{\delta}K_{j,t}^{\alpha\delta+1-\delta}, & (61)\\
K_0 & \text{ given.}
\end{aligned}
$$

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

Equation (61) 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 (61), any change in their prices will have further effects on domestic capital accumulation.

We are not aware of the existence of international data on the use of intermediate goods at the aggregate level. This makes it impossible to disentangle the shares of labor, capital and intermediates in our Cobb-Douglas production function (54) empirically. Therefore, we adopt Eaton and Kortum's (2002) approach and assume a share for intermediates, which we combine with our data for $L_{j,t}$, $y_{j,t}$, and $t_{ij,t}^{1-\sigma}$ as well as the estimated parameters, to recover the country-specific technological components A_j/γ_j. Specifically, we assign a share of intermediates equal to 0.25 at the expensive of capital, and we retain the share of labor to

[54] Detailed derivations can be found in Online Appendix I.

0.45 as in our baseline setting.[55] Then, we replicate our NAFTA counterfactual experiment to quantify the role of intermediates in our dynamic framework.

Column (5) of Table 7 presents the results after allowing for intermediates. Several properties stand out in comparison with the baseline setting from column (2). First, accounting for intermediates in production increases the welfare effects for NAFTA members by 1.2 percentage points on average. For example, Canada's welfare increases by about 6 percentage points. This increase is exclusively due to the interaction between intermediate inputs and the dynamic forces in our framework. Very similar additional quantitative implications are found for Mexico and the U.S. even though the U.S. welfare gains are smaller, which is in accordance with the smaller baseline setting gains for the largest member of NAFTA. Second, we find that the negative effects on non-member countries are also larger. The negative impact of NAFTA on non-members increases by 0.035 percentage points on average. Importantly, we note that the additional negative effect on non-members is not only smaller as compared to the additional gain for members in absolute value, but also as percent (8.3 percent vs. 15.6 percent). The intuition for this result is that the positive spill-over effects of capital accumulation in member countries that are channeled via the intermediate goods in non-member countries partly offset the negative trade diversion effect in the latter.

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.

A.5 Sensitivity to Structural Parameter Values

In this section we investigate the sensitivity of our results with respect to key parameters of our model. In our first experiment we allow for country-specific capital depreciation rates, which are reported in column (6) of Table 7. The welfare effects of NAFTA in the presence of the country-specific δ's are reported in column (7). As some δ's are lower and some are higher, an overall statement is difficult. In general, a higher δ implies that more capital has to be replaced in every period. This is a burden for an economy. However, the price for the replacement depends on the price for the final good. Lowering trade costs, as is done by the conclusion of NAFTA, leads to a lower price for the composite final good. This decrease in the final goods price is driven by the direct effect of lower trade costs, leading to lower prices for foreign goods, and due to the larger share of foreign goods used in production. Hence, trade liberalization makes capital replacement cheaper. All else equal, a higher depreciation rate implies that international trade increases, as more foreign goods are demanded for capital replacement and consumption due to the lower price. Also welfare increases as compared to the baseline, as the higher depreciation rate implies a larger role for the capital accumulation channel inducing income growth. The effects of trade liberalization are exactly in the opposite direction for a lower depreciation rate. For non-liberalizing

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

countries, the negative effects will become stronger for higher δ's and weaker for lower δ's due to the same logic. Take for example Zimbabwe, which is the country with the highest capital depreciation rate, $\delta = 0.161$. In our baseline we assume a $\delta = 0.052$. Hence, we would expect higher welfare losses for Zimbabwe, which is indeed the case. The opposite happens for China, which is the country with the smallest capital depreciation rate, $\delta = 0.03$.

Next, we employ extreme values for the key parameters in our model. In column (8) of Table 7 we use our largest estimate of $\sigma = 7.998$. As expected, a higher σ leads to lower welfare effects. This is the case because σ directly governs the willingness of consumers to substitute products. A higher σ therefore leads to lower gains from trade, as consumers do not value the availability of foreign goods a lot. On average, the increase of σ from 5.1 to 7.998 leads to a decrease of the welfare effects of about 40%. Next, we set $\alpha = 0.391$, which is the lowest of our capital shares estimates. As expected, the decrease of the capital share mitigates the dynamic effects in our model. This leads to about 15% lower welfare gains for the NAFTA countries as compared to the baseline setting (compare column (2) and column (9) of Table 7). The negative effects on non-NAFTA countries are smaller but disproportionately so. This suggests that, combined with trade liberalization, more intensive use of capital will lead to relatively more gains for member countries.

We finish with two experiments involving the external parameters β (the subjective discount factor) and the intertemporal elasticity of substitution, respectively.[56] Specifically, we set the value of the consumer discount factor to $\beta = 0.95$, which is the value used in Eaton, Kortum, Neiman, and Romalis (2015). The lower consumer discount factor results in smaller, but still relatively large, dynamic effects on welfare. The estimates from column (10) of Table 7 reveal that the dynamic welfare gains for NAFTA members decrease by about 22%, while the negative effects on non-members are 15% smaller. The overall smaller dynamic effects that correspond to a smaller discount factor are expected because they reflect the fact that a smaller β means that consumers value the future stream of consumption less. Concerning the intertemporal elasticity of substitution, we change it from one to 0.5, a value supported by empirical findings (see Sampson, 2014). A lower willingness to change the consumption-investment-decision when relative prices over time changes leads to slightly larger additional dynamic welfare gains. The reason is that a lower intertemporal elasticity of substitution leads to a slower adjustment to the new steady-state, implying that there is a higher level of consumption in early years. In combination with discounting of future consumption, this leads to a slightly higher overall dynamic welfare gain.

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.

[56]Note that our logarithmic utility function implies an intertemporal elasticity of substitution of 1. In Appendix J we generalize our logarithmic intertemporal utility function to an iso-elastic utility function.

Table 4: Trade Costs and Production, 1990-2011

	Cobb-Douglas		Frankel-Romer		Structural Estimates	
	Unconstr.	Constr.	Unconstr.	Constr.	Unconstr.	Constr.
	(1)	(2)	(3)	(4)	(5)	(6)
A. Dep. Variable $\ln y_{j,t}$						
$\ln L_{j,t}$	0.332	0.495	0.272	0.493	0.331	0.362
	(0.041)**	(0.034)**	(0.040)**	(0.033)**	(0.049)**	(0.038)**
$\ln K_{j,t}$	0.460	0.505	0.448	0.507	0.443	0.442
	(0.035)**	(0.034)**	(0.034)**	(0.033)**	(0.041)**	(0.039)**
$\ln \sum_{j \neq i} \widehat{x}_{ij}$			0.056	0.028		
			(0.009)**	(0.006)**		
$\ln\left(1/\widehat{\tilde{\Pi}_{j,t}^{1-\sigma}}\right)$					-0.125	-0.196
					(0.034)**	(0.031)**
R^2	0.854	0.848	0.856	0.858	0.856	0.855
B. Structural Parameters						
$\widehat{\alpha}$	0.460	0.505	0.448	0.507	0.506	0.550
	(0.035)**	(0.034)**	(0.034)**	(0.033)**	(0.037)**	(0.044)**
$\widehat{\sigma}$					7.998	5.100
					(2.204)**	(0.804)**

Notes: This table reports results from various specifications of the production function. The number of observations is 1606 and all specifications include country and year fixed effects whose estimates are omitted for brevity. Column (1) reports estimates from a standard unconstrained estimation of the Cobb-Douglas production function. In column (2), we impose the theoretical constraint that the coefficients of $\ln L_{j,t}$ and $\ln K_{j,t}$ should add up to one. In column (3), we re-estimate the Frankel and Romer (1999) specifications by introducing the variable $\ln \sum_{j \neq i} \widehat{x}_{ij}$, which is the predicted value of total national exports that we obtain from a first-stage gravity regression as given in equation (40). In column (4), we again impose the theoretical constraint that the coefficients of $\ln L_{j,t}$ and $\ln K_{j,t}$ should add up to one. In column (5), we introduce the structural trade term (the multilateral resistance term). In the last column, we impose the theoretical constraint that $\kappa_1 + \kappa_2 = 1 + \kappa_3$. Robust (in columns (1) and (2)) and robust, bootstrapped (in columns (3)-(6)) standard errors in parentheses. + $p < 0.10$, * $p < .05$, ** $p < .01$. See text for further details.

Table 5: Heterogeneous Capital Shares

	Time (1)	Development (2)
A. Dep. Variable $\ln y_{j,t}$		
$\ln L_{j,1990s}$	0.490	
	(0.092)**	
$\ln L_{j,2000s}$	0.319	
	(0.049)**	
$\ln K_{j,1990s}$	0.314	
	(0.092)**	
$\ln K_{j,2000s}$	0.484	
	(0.049)**	
$\ln L_{poor,t}$		0.390
		(0.037)**
$\ln L_{rich,t}$		0.323
		(0.037)**
$\ln K_{poor,t}$		0.414
		(0.037)**
$\ln K_{rich,t}$		0.481
		(0.037)**
$\ln\left(1/\widehat{\tilde{\Pi}_{j,t}^{1-\sigma}}\right)$	-0.196	-0.196
	(0.031)**	(0.031)**
B. Structural Parameters		
$\widehat{\alpha}_{1990s}$	0.391	
	(0.114)**	
$\widehat{\alpha}_{2000s}$	0.603	
	(0.061)**	
$\widehat{\alpha}_{poor}$		0.515
		(0.046)**
$\widehat{\alpha}_{rich}$		0.598
		(0.046)**

Notes: This table reports results from two alternative specifications of the production function from our structural model. The number of observations is 1606 and all specifications include country and year fixed effects whose estimates are omitted for brevity. Column (1) reports estimates where we allow for heterogeneous capital shares in the 1990s and the 2000s. In column (2) we allow for heterogeneous capital shares for poor and rich countries. Rich countries are defined as those with income above the median income in each year of our sample. Robust, bootstrapped standard errors in parentheses. + $p < 0.10$, * $p < .05$, ** $p < .01$. See text for further details.

Table 6: Trade and Capital Accumulation

	Unconstr. (1)	Constr. (2)
$\ln y_{j,t-1}$	0.051	0.057
	$(0.007)^{**}$	$(0.006)^{**}$
$\ln K_{j,t-1}$	0.949	0.943
	$(0.007)^{**}$	$(0.006)^{**}$
$\ln P_{j,t-1}$	-0.051	-0.057
	$(0.007)^{**}$	$(0.006)^{**}$
$\ln L_{j,t-1}$	0.045	0.026
	$(0.007)^{**}$	$(0.003)^{**}$

Notes: This table reports results from two alternative specifications of the capital accumulation equation. The number of observations is 1533 and all specifications include country and year fixed effects whose estimates are omitted for brevity. Column (1) reports results as in the specification in the main text but including employment $\ln L_{j,t-1}$. Column (2) imposes the additional constraint that the coefficient of $\ln L_{j,t-1}$ is equal to $(1-\widehat{\alpha})\delta$, where $\widehat{\alpha} = 0.55$, which is the estimate for α from column (6) of Table 4. Robust, bootstrapped standard errors in parentheses. $+\ p < 0.10$, * $p < .05$, ** $p < .01$. See text for more details.

Table 7: Evaluation of NAFTA: Robustness Checks, Welfare Effects for the 'Full Dynamic GE, trans.' scenario

Country	Base-line	Linear trans.	Capital accum.	Inter-mediates	Ctry-specific δ δ	Ctry-specific δ Welfare	$\sigma =$ 7.998	$\alpha =$ 0.391	$\beta =$ 0.95	$\rho =$ 2
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
AGO	-0.562	-0.536	-0.241	-0.608	0.039	-0.541	-0.401	-0.544	-0.476	-0.588
ARG	-1.177	-1.086	-0.980	-1.233	0.045	-1.148	-0.894	-1.175	-1.045	-1.231
AUS	-0.790	-0.751	-0.255	-0.850	0.044	-0.778	-0.570	-0.770	-0.673	-0.827
AUT	-0.121	-0.119	-0.058	-0.136	0.059	-0.123	-0.079	-0.111	-0.097	-0.125
AZE	-0.280	-0.274	-0.112	-0.312	0.045	-0.273	-0.185	-0.260	-0.226	-0.292
BEL	-0.068	-0.069	-0.041	-0.080	0.065	-0.070	-0.040	-0.059	-0.051	-0.070
BGD	-0.367	-0.352	-0.239	-0.401	0.041	-0.352	-0.256	-0.350	-0.308	-0.383
BGR	-0.307	-0.296	-0.132	-0.336	0.050	-0.306	-0.213	-0.293	-0.256	-0.320
BLR	-0.310	-0.300	-0.135	-0.342	0.047	-0.305	-0.211	-0.292	-0.255	-0.323
BRA	-0.806	-0.756	-0.502	-0.858	0.044	-0.786	-0.593	-0.792	-0.699	-0.843
CAN	44.204	43.565	47.557	50.432	0.064	45.679	26.058	37.977	35.161	45.344
CHE	-0.048	-0.052	-0.029	-0.060	0.069	-0.050	-0.023	-0.038	-0.032	-0.049
CHL	-0.709	-0.670	-0.467	-0.761	0.042	-0.687	-0.512	-0.690	-0.607	-0.742
CHN	-0.385	-0.369	-0.168	-0.419	0.030	-0.354	-0.269	-0.368	-0.322	-0.401
COL	-1.115	-1.030	-0.939	-1.170	0.043	-1.080	-0.843	-1.110	-0.987	-1.166
CZE	-0.163	-0.161	-0.046	-0.183	0.050	-0.164	-0.106	-0.149	-0.131	-0.169
DEU	-0.171	-0.168	-0.046	-0.192	0.057	-0.175	-0.111	-0.157	-0.137	-0.178
DNK	-0.206	-0.202	-0.061	-0.229	0.055	-0.210	-0.137	-0.192	-0.168	-0.215
DOM	-0.974	-0.910	-0.592	-1.032	0.040	-0.941	-0.724	-0.962	-0.850	-1.019
ECU	-0.929	-0.862	-0.801	-0.980	0.044	-0.900	-0.695	-0.920	-0.817	-0.971
EGY	-0.358	-0.342	-0.227	-0.390	0.048	-0.353	-0.252	-0.343	-0.302	-0.373
ESP	-0.522	-0.493	-0.279	-0.559	0.048	-0.518	-0.377	-0.507	-0.448	-0.545
ETH	-0.814	-0.773	-0.264	-0.875	0.045	-0.802	-0.588	-0.794	-0.694	-0.852
FIN	-0.265	-0.259	-0.078	-0.294	0.050	-0.266	-0.177	-0.247	-0.216	-0.277
FRA	-0.287	-0.276	-0.124	-0.314	0.056	-0.290	-0.201	-0.276	-0.240	-0.300
GBR	-0.399	-0.382	-0.153	-0.434	0.059	-0.407	-0.282	-0.384	-0.335	-0.417
GHA	-0.888	-0.838	-0.390	-0.949	0.050	-0.886	-0.648	-0.870	-0.763	-0.929
GRC	-0.272	-0.264	-0.114	-0.300	0.050	-0.271	-0.186	-0.257	-0.224	-0.284
GTM	-1.893	-1.731	-1.611	-1.964	0.052	-1.888	-1.462	-1.904	-1.702	-1.980
HKG	-0.379	-0.366	-0.116	-0.415	0.050	-0.374	-0.262	-0.361	-0.314	-0.395
HRV	-0.450	-0.429	-0.196	-0.487	0.049	-0.448	-0.322	-0.436	-0.382	-0.470
HUN	-0.266	-0.256	-0.117	-0.292	0.054	-0.267	-0.184	-0.253	-0.221	-0.277
IDN	-0.467	-0.442	-0.298	-0.503	0.038	-0.444	-0.335	-0.452	-0.398	-0.487
IND	-0.701	-0.664	-0.302	-0.753	0.044	-0.687	-0.507	-0.683	-0.599	-0.733
IRL	-0.181	-0.180	-0.078	-0.206	0.063	-0.188	-0.115	-0.165	-0.143	-0.188
IRN	-0.493	-0.467	-0.303	-0.531	0.045	-0.482	-0.354	-0.478	-0.421	-0.515
IRQ	-0.421	-0.400	-0.260	-0.456	0.055	-0.421	-0.298	-0.405	-0.356	-0.439
ISR	-0.884	-0.843	-0.159	-0.951	0.053	-0.898	-0.631	-0.855	-0.750	-0.926
ITA	-0.273	-0.263	-0.119	-0.300	0.050	-0.273	-0.189	-0.260	-0.227	-0.285
JPN	-0.334	-0.321	-0.144	-0.365	0.046	-0.328	-0.232	-0.319	-0.279	-0.348
KAZ	-0.180	-0.182	-0.074	-0.209	0.046	-0.174	-0.107	-0.158	-0.137	-0.187
KEN	-0.819	-0.778	-0.265	-0.880	0.049	-0.817	-0.591	-0.798	-0.698	-0.857
KOR	-0.375	-0.357	-0.242	-0.406	0.039	-0.358	-0.267	-0.362	-0.319	-0.391
KWT	-0.374	-0.360	-0.158	-0.410	0.042	-0.362	-0.260	-0.357	-0.312	-0.391
LBN	-0.454	-0.428	-0.286	-0.488	0.042	-0.436	-0.332	-0.447	-0.388	-0.473
LKA	-0.449	-0.427	-0.283	-0.485	0.042	-0.433	-0.319	-0.433	-0.381	-0.468
LTU	-0.348	-0.337	-0.104	-0.383	0.054	-0.352	-0.238	-0.329	-0.288	-0.364
MAR	-0.435	-0.415	-0.200	-0.471	0.046	-0.429	-0.311	-0.422	-0.368	-0.455
MEX	25.015	24.533	26.857	28.313	0.055	25.221	15.138	21.668	20.146	25.714
MYS	-0.286	-0.276	-0.188	-0.315	0.038	-0.269	-0.196	-0.270	-0.237	-0.298
NGA	-0.874	-0.826	-0.374	-0.935	0.059	-0.890	-0.637	-0.856	-0.751	-0.915
NLD	-0.143	-0.141	-0.040	-0.161	0.060	-0.148	-0.092	-0.130	-0.114	-0.149
NOR	-0.303	-0.294	-0.092	-0.334	0.055	-0.308	-0.207	-0.286	-0.251	-0.317
NZL	-0.841	-0.798	-0.274	-0.904	0.049	-0.838	-0.606	-0.819	-0.716	-0.880
OMN	-0.495	-0.473	-0.212	-0.537	0.040	-0.478	-0.352	-0.478	-0.418	-0.518
PAK	-0.479	-0.461	-0.207	-0.524	0.053	-0.478	-0.332	-0.456	-0.398	-0.500
PER	-0.773	-0.720	-0.676	-0.819	0.041	-0.743	-0.573	-0.762	-0.676	-0.808
PHL	-0.747	-0.709	-0.273	-0.803	0.046	-0.739	-0.538	-0.727	-0.637	-0.782
POL	-0.227	-0.220	-0.102	-0.250	0.054	-0.228	-0.156	-0.216	-0.188	-0.237
PRT	-0.298	-0.292	-0.078	-0.331	0.047	-0.296	-0.198	-0.277	-0.242	-0.311
QAT	-0.419	-0.402	-0.177	-0.457	0.034	-0.394	-0.294	-0.402	-0.351	-0.438

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Table 7 – *Continued from previous page*

Country	Base-line	Linear trans.	Capital accum.	Inter-mediates	Ctry-specific δ		$\sigma =$ 7.998	$\alpha =$ 0.391	$\beta =$ 0.95	$\rho =$ 2
					δ	Welfare				
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
ROM	-0.408	-0.385	-0.260	-0.438	0.051	-0.405	-0.295	-0.397	-0.349	-0.425
RUS	-0.535	-0.508	-0.235	-0.577	0.045	-0.525	-0.385	-0.521	-0.456	-0.560
SAU	-0.470	-0.449	-0.200	-0.510	0.042	-0.456	-0.333	-0.453	-0.396	-0.491
SDN	-0.486	-0.461	-0.301	-0.524	0.043	-0.471	-0.349	-0.471	-0.414	-0.507
SER	-0.449	-0.428	-0.194	-0.486	0.050	-0.447	-0.320	-0.435	-0.380	-0.470
SGP	-0.416	-0.400	-0.176	-0.454	0.041	-0.401	-0.291	-0.398	-0.348	-0.435
SVK	-0.243	-0.235	-0.108	-0.267	0.048	-0.241	-0.168	-0.231	-0.202	-0.253
SWE	-0.274	-0.266	-0.082	-0.302	0.057	-0.279	-0.186	-0.257	-0.225	-0.286
SYR	-0.327	-0.315	-0.135	-0.359	0.046	-0.321	-0.225	-0.310	-0.271	-0.341
THA	-0.403	-0.383	-0.255	-0.436	0.040	-0.385	-0.286	-0.388	-0.341	-0.420
TKM	-0.399	-0.384	-0.164	-0.437	0.038	-0.382	-0.277	-0.381	-0.332	-0.417
TUN	-0.472	-0.443	-0.357	-0.504	0.049	-0.464	-0.350	-0.468	-0.409	-0.493
TUR	-0.417	-0.395	-0.266	-0.449	0.051	-0.415	-0.301	-0.405	-0.357	-0.435
TZA	-0.653	-0.621	-0.284	-0.704	0.047	-0.646	-0.467	-0.633	-0.554	-0.682
UKR	-0.311	-0.302	-0.135	-0.344	0.046	-0.306	-0.211	-0.293	-0.255	-0.324
USA	2.748	2.849	6.600	3.295	0.048	2.766	1.569	2.335	2.036	2.792
UZB	-0.444	-0.426	-0.187	-0.484	0.048	-0.439	-0.312	-0.426	-0.373	-0.464
VEN	-0.978	-0.908	-0.803	-1.032	0.048	-0.962	-0.731	-0.968	-0.859	-1.022
VNM	-0.405	-0.385	-0.260	-0.439	0.031	-0.373	-0.288	-0.391	-0.344	-0.423
ZAF	-0.721	-0.687	-0.228	-0.778	0.051	-0.724	-0.517	-0.700	-0.612	-0.755
ZWE	-0.615	-0.586	-0.270	-0.664	0.161	-0.692	-0.439	-0.595	-0.521	-0.643
World	1.842	1.855	3.018	2.151		1.888	1.046	1.548	1.420	1.878
NAFTA	7.671	7.669	11.319	8.868		7.813	4.512	6.583	5.997	7.851
ROW	-0.423	-0.403	-0.207	-0.458		-0.414	-0.301	-0.408	-0.358	-0.442

Notes: This table reports robustness results for our NAFTA counterfactual. It is based on observed data on labor endowments and GDPs for our sample of 82 countries. Further, it uses our estimated trade costs based on equation (32) and recovered theory-consistent, steady-state capital stocks according to equation (25). We calculate baseline preference-adjusted technology A_j/γ_j according to the market-clearing equation (22) and the production function equation (23). Finally, the counterfactual is based on our own estimates of the elasticity of substitution $\widehat{\sigma} = 5.1$, the share of capital in the Cobb-Douglas production function $\widehat{\alpha} = 0.55$, and the capital depreciation rate $\widehat{\delta} = 0.052$. The consumers' discount factor β is set equal to 0.98. Only welfare effects for the 'Full Dynamic GE, trans.' scenario are reported. Column (1) gives the country abbreviations. Columns (2) reports for reasons of comparison the results from our baseline setting reported in column (5) in Table 3. Column (3) is based on the linear instead of the log-linear capital transition function. Column (4) assumes a 20% higher capital stock in U.S. in 1994 when NAFTA was concluded. Column (5) gives the results when allowing for intermediate inputs. Column (6) gives the estimated country-specific depreciation rates δ_i, while Column (7) reports the corresponding welfare effects of NAFTA based on these depreciation rates. Column (8) is based on an elasticity of substitution of $\widehat{\sigma} = 7.998$ instead of 5.1, column (9) reports results based on a capital share of $\widehat{\alpha} = 0.391$, the lowest value obtained in our estimates, instead of 0.55. Column (10) changes the subjective discount factor from 0.98 to 0.95, while the last column changes the intertemporal elasticity of substitution from one (implied by our logarithmic utility function for instantaneous utility) to 0.5 ($=1/\rho$) using an iso-elastic utility function for instantaneous utility.

Online Appendix for "Growth and Trade with Frictions: A Structural Estimation Framework"

by James E. Anderson, Mario Larch, and Yoto V. Yotov

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B Derivation of the Policy Functions of the 'Upper Level'

Our 'upper level' specification is very similar to Hercowitz and Sampson (1991) (we omit the country indexes in order to economize on the notational burden):

$$
\begin{aligned}
U_t &= \sum_{t=0}^{\infty} \beta^t \ln(C_t), && \text{(A1)}\\
K_{t+1} &= K_t^{1-\delta} \Omega_t^{\delta}, && \text{(A2)}\\
y_t &= p_t A_t L_t^{1-\alpha} K_t^{\alpha}, && \text{(A3)}\\
y_t &= P_t C_t + P_t \Omega_t, && \text{(A4)}\\
K_0 & \quad \textit{given}. && \text{(A5)}
\end{aligned}
$$

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 obtaining 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. The value of the value function at step 1, v^1, is given by:

$$
\begin{aligned}
v' &= \max_{K'} \ln C = \max_{K'} \ln\left(y/P - \Omega\right)\\
&= \max_{K'} \ln\left(pAL^{1-\alpha}K^{\alpha}/P - (K'^{\phi}/K^{\phi-1})\right).
\end{aligned}
$$

The associated first order condition is:

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

It follows that $K' = 0$. Hence, $v' = \ln\left(pAL^{1-\alpha}K^{\alpha}/P\right)$ and, in the next step, we have to solve:

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

The first order condition becomes:

$$
\begin{aligned}
&\frac{1}{pAL^{1-\alpha}K^{\alpha}/P - (K'^{\phi}/K^{\phi-1})}(-\phi)\frac{K'^{\phi-1}}{K^{\phi-1}} + \frac{\alpha\beta}{K'} = 0,\\
&\frac{\alpha\beta}{\phi}\left(pAL^{1-\alpha}K^{\alpha}/P - (K'^{\phi}/K^{\phi-1})\right) = \frac{K'^{\phi}}{K^{\phi-1}},\\
&\frac{\alpha\beta}{\phi}\left(pAL^{1-\alpha}K^{\alpha}/P\right) = \left(\frac{\alpha\beta}{\phi}+1\right)\frac{K'^{\phi}}{K^{\phi-1}},\\
&\frac{\alpha\beta}{\alpha\beta+\phi} pAL^{1-\alpha}K^{\alpha+\phi-1}/P = K'^{\phi},\\
&\left(\frac{\alpha\beta}{\alpha\beta+\phi} pAL^{1-\alpha}/P\right)^{\frac{1}{\phi}} K^{(\alpha+\phi-1)/\phi} = K'. && \text{(A6)}
\end{aligned}
$$

Plugging in the expression for K' given in equation (A6), we end up with:

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

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

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

The first order condition is given by:

$$\begin{aligned}
&\frac{1}{pAL^{1-\alpha}K^{\alpha}/P - (K'^{\phi}/K^{\phi-1})}(-\phi)\frac{K'^{\phi-1}}{K^{\phi-1}} + \frac{\alpha\beta}{K'} + \frac{\alpha\theta\beta^2}{K'} = 0, \\
&\frac{\alpha\beta}{\phi}(1+\beta\theta)\left(pAL^{1-\alpha}K^{\alpha}/P - (K'^{\phi}/K^{\phi-1})\right) = \frac{K'^{\phi}}{K^{\phi-1}}, \\
&\frac{\alpha\beta}{\phi}(1+\beta\theta)pAL^{1-\alpha}K^{\alpha}/P = \left(\frac{\alpha\beta}{\phi}(1+\beta\theta)+1\right)\frac{K'^{\phi}}{K^{\phi-1}}, \\
&K' = \left(\frac{\frac{\alpha\beta}{\phi}(1+\beta\theta)pAL^{1-\alpha}/P}{\frac{\alpha\beta}{\phi}(1+\beta\theta)+1}\right)^{\frac{1}{\phi}} K^{\theta}. \qquad \text{(A7)}
\end{aligned}$$

Plug in the solution of K' given in equation (A7) to obtain:

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

The resulting value of the value function is:

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

and the accompanying first order condition becomes:

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

Note now that the general pattern can be described as:

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

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

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

Replace $\theta\equiv(\alpha+\phi-1)/\phi$ in the above expression to obtain:

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

Apply the definition of $\phi=1/\delta$:

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

The resulting expression is our policy function for the capital stock in the next period, K':

$$K'=\left[\frac{\alpha\beta\delta pAL^{1-\alpha}}{(1-\beta+\beta\delta)P}\right]^{\delta}K^{\alpha\delta+1-\delta}. \tag{A8}$$

Intuitively, (A8) reveals that, alongside parameters, capital accumulation depends on current capital stock, labor endowments, technology, factory-gate prices, and the aggregate price index. A higher labor endowment, a higher current capital stock and a higher technology level translate into higher next-period capital stocks. The relationship between capital stock and factory-gate prices is also positive. As noted in the main text, the intuition is that an increase in the factory-gate price leads to an increase in the value of marginal product of capital and, therefore, investment. The relationship between investment and the aggregate price index is inverse. The intuition is that a higher price of investment and a higher price of consumption increase the direct cost and the opportunity cost of investment. A higher current goods price 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 with K' and K at hand, one can determine the level of investment as:

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

In addition, the optimal level of current consumption can be obtained by using the policy function for capital and reformulating $y = PC + P\Omega$, i.e.,

$$\begin{aligned} C &= \frac{y}{P} - \Omega = \frac{pAL^{1-\alpha}K^{\alpha}}{P} - \left[\frac{\alpha\beta\delta pAL^{1-\alpha}}{(1-\beta+\beta\delta)\,P}\right] K^{\alpha} \\ &= \left[1 - \frac{\alpha\beta\delta}{1-\beta+\beta\delta}\right] \frac{pAL^{1-\alpha}K^{\alpha}}{P} \\ &= \left[\frac{1-\beta+\beta\delta-\alpha\beta\delta}{1-\beta+\beta\delta}\right] \frac{pAL^{1-\alpha}K^{\alpha}}{P}. \end{aligned} \tag{A9}$$

C Transition

An important contribution of our paper is that we do not only focus on the steady-state, but we also characterize the transition path. In fact, as emphasized in the main text, all growth effects in our framework are transitional, and there is no steady-state growth. A nice feature of the theoretical framework is that the assumptions of an intertemporal log-utility function and the log-linear transition function for capital enable us to obtain a closed-form solution for the transition path in the model. In order to do that, we first calculate the policy function for capital by value function iteration as described in Online Appendix B, where consumers take the variety price p_t and the consumer price P_t as given. It should be noted that p_t and P_t are both general equilibrium indexes that consistently aggregate the decisions of all countries in the world, which are transmitted through changes in trade costs. See discussion in main text for further details. Thus, our policy function gives the optimal decision of consumers for the capital stock tomorrow as a function of prices and the capital stock today, and it is consistent with rational expectations as long as we can determine current prices and have an initial capital stock.

We take the following steps in order to characterize the transition path analytically.

First, we calculate the initial capital stock by assuming that we are in a steady-state. In particular, we solve our equation system given by equations (19)-(24) simultaneously for all N-countries at steady-state. By construction, the steady-state is consistent with all prices and steady-state capital stocks for all countries. We take this steady-state as our baseline values at time 0. Then, we consider a non-anticipated and permanent change, e.g. a change in bilateral trade costs among Canada, Mexico and the United States due to the formation of NAFTA. Given the current capital stock (which was determined yesterday), we use equations (20)-(23) to solve for new current prices and current GDPs for the new vector of bilateral trade costs. As soon as we have these prices and GDPs, we can calculate the optimal choice of consumption and investment by using the policy function (24). With a new capital stock in the next period, we can again use equations (20)-(23) to solve for next periods prices and GDPs. We then iterate until convergence, i.e. until we reach the new steady-state.

It is important to note that equations (20)-(23) solve for prices and income simultaneously for all N-countries in our model. In order to ensure that our calculations are correct, we take two steps. First, we compare the steady-state from the iterative procedure with a new steady-state that we obtain in one shot, ignoring transition, by simply solving our theoretical system directly with the new vector of trade costs. The two steady-states are identical. This is encouraging, but tells us nothing about the transition path. In order to validate the correctness of the transition path calculations, we set-up a system of first-order conditions which we then solve using Dynare. Specifically, we use our utility function (we skip country indices without loss of generality):

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

and combine the budget constraint with the production function:

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

In order to end up with only one constraint, we also use the definition of Ω_t:

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

leading to the following budget constraint:

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

The corresponding expression for the Lagrangian is:

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

Take derivatives with respect to C_t, K_{t+1} and λ_t to obtain the following set of first-order conditions:

$$\begin{aligned}
\frac{\partial \mathcal{L}}{\partial C_t} &= \frac{\beta^t}{C_t} - \beta^t \lambda_t P_t \overset{!}{=} 0 \quad \text{for all } t. \\
\frac{\partial \mathcal{L}}{\partial K_{t+1}} &= \beta^{t+1} \lambda_{t+1} p_{t+1} A_{t+1} L_{t+1}^{1-\alpha} \alpha K_{t+1}^{\alpha-1} - \beta^t \lambda_t P_t \left(\frac{1}{K_t^{1-\delta}} \right)^{\frac{1}{\delta}} \frac{1}{\delta} K_{t+1}^{\frac{1}{\delta}-1} \\
&\quad - \beta^{t+1} \lambda_{t+1} P_{t+1} K_{t+2}^{\frac{1}{\delta}} \frac{\delta - 1}{\delta} K_{t+1}^{-\frac{1}{\delta}} \overset{!}{=} 0 \quad \text{for all } t. \\
\frac{\partial \mathcal{L}}{\partial \lambda_t} &= p_t A_t L_t^{1-\alpha} K_t^{\alpha} - P_t C_t - P_t \left(\frac{K_{t+1}}{K_t^{1-\delta}} \right)^{\frac{1}{\delta}} \overset{!}{=} 0 \quad \text{for all } t.
\end{aligned}$$

Use the first-order condition for consumption to express λ_t as:

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

Replace this in the first-order condition for capital:

$$\begin{aligned}
\frac{\partial \mathcal{L}}{\partial K_{t+1}} &= \beta^{t+1} \frac{1}{C_{t+1} P_{t+1}} p_{t+1} A_{t+1} L_{t+1}^{1-\alpha} \alpha K_{t+1}^{\alpha-1} - \beta^t \frac{1}{C_t} \left(\frac{1}{K_t^{1-\delta}} \right)^{\frac{1}{\delta}} \frac{1}{\delta} K_{t+1}^{\frac{1}{\delta}-1} \\
&\quad - \beta^{t+1} \frac{1}{C_{t+1}} K_{t+2}^{\frac{1}{\delta}} \frac{\delta - 1}{\delta} K_{t+1}^{-\frac{1}{\delta}} \overset{!}{=} 0 \quad \text{for all } t.
\end{aligned}$$

Simplify and re-arrange to obtain:

$$\frac{\beta p_{t+1} A_{t+1} L_{t+1}^{1-\alpha} \alpha K_{t+1}^{\alpha-1}}{C_{t+1} P_{t+1}} = \frac{1}{C_t} \left(\frac{1}{K_t^{1-\delta}} \right)^{\frac{1}{\delta}} \frac{1}{\delta} K_{t+1}^{\frac{1}{\delta}-1} + \frac{(\delta - 1)\beta}{\delta C_{t+1}} K_{t+2}^{\frac{1}{\delta}} K_{t+1}^{-\frac{1}{\delta}} \quad \text{for all } t.$$

Use the definition of y_t to re-write the left-hand side of the above expression as:

$$\frac{\alpha \beta y_{t+1}}{K_{t+1} C_{t+1} P_{t+1}} = \frac{1}{\delta C_t} \frac{K_{t+1}^{\frac{1}{\delta}-1}}{K_t^{\frac{1-\delta}{\delta}}} + \frac{\beta (\delta - 1)}{\delta C_{t+1}} \left(\frac{K_{t+2}}{K_{t+1}} \right)^{\frac{1}{\delta}} \quad \text{for all } t.$$

As expected, we end up with 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, i.e. we have $4N$ forward-looking variables in our system. These are the endogenous variables we have to solve for. In order to do that, we feed the following set of equations into Dynare:

$$\begin{aligned}
y_{j,t} &= \frac{(y_{j,t}/y_t)^{\frac{1}{1-\sigma}}}{\gamma_j P_{j,t}} A_{j,t} L_{j,t}^{1-\alpha} K_{j,t}^{\alpha} \quad \text{for all } j \text{ and } t, && \text{(A10)} \\
y_t &= \sum_j y_{j,t} \quad \text{for all } t, && \text{(A11)} \\
y_{j,t} &= P_{j,t} C_{j,t} + P_{j,t} \left(\frac{K_{t+1}}{K_t^{1-\delta}} \right)^{\frac{1}{\delta}} \quad \text{for all } j \text{ and } t, && \text{(A12)} \\
P_{j,t} &= \left[\sum_i \left(\frac{t_{ij,t}}{P_{i,t}} \right)^{1-\sigma} \frac{y_{i,t}}{y_t} \right]^{\frac{1}{1-\sigma}} \quad \text{for all } j \text{ and } t, && \text{(A13)} \\
\frac{\alpha \beta y_{j,t+1}}{K_{j,t+1} C_{j,t+1} P_{j,t+1}} &= \frac{1}{\delta C_{j,t}} \frac{K_{j,t+1}^{\frac{1}{\delta}-1}}{K_{j,t}^{\frac{1-\delta}{\delta}}} + \frac{\beta(\delta-1)}{\delta C_{j,t+1}} \left(\frac{K_{j,t+2}}{K_{j,t+1}} \right)^{\frac{1}{\delta}} \quad \text{for all } j \text{ and } t. && \text{(A14)}
\end{aligned}$$

We then take as initial and end values the baseline and the counterfactual steady-state and we let Dynare solve for the transition of our deterministic model assuming perfect foresight. The algorithm for our case is described in Adjemian, Bastani, Juillard, Karamé, Maih, Mihoubi, Perendia, Pfeifer, Ratto, and Villemot (2011) in Section 4.12. Comparison between the transition path from Dynare and the transition path that we solved for analytically reveals that those are identical.

D ACR formula

This section obtains the ACR-equivalent formula in our dynamic setting. Before we start, we note that in ACR the formula is based on real income, which is equivalent to welfare in their setting. However, this is no-longer the case in our framework as not all of the income is used for consumption because part of it is used to build up capital. Accordingly, our welfare measure should be based on consumption. In order to derive the ACR equivalent, we start with consumption as given by equation (A9) and use the production function $y_j = p_j A_j L_j^{1-\alpha} K_j^{\alpha}$ as given in equation (A3) to express welfare as (we skip time indices without loss of generality):

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

Taking the log-derivative leads to:

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

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

$$d \ln y_j = d \ln p_j + \alpha d \ln K_j. \tag{A15}$$

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:

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

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

$$d\ln P_j = \sum_{i=1}^{N} \lambda_{ij}\left(d\ln p_i + d\ln t_{ij}\right). \tag{A16}$$

Combine terms:

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

Take the ratio of λ_{ij} and λ_{jj}:

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

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

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

Express as log-change:

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

Use this expression with equation (A16):

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

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:

$$
\begin{aligned}
d\ln P_j &= \frac{1}{1-\sigma}\left(\sum_{i=1}^{N} \lambda_{ij} d\ln\lambda_{ij} - d\ln\lambda_{jj}\sum_{i=1}^{N}\lambda_{ij}\right) + d\ln p_j \\
&= -\frac{1}{1-\sigma} d\ln\lambda_{jj} + d\ln p_j. \qquad \text{(A17)}
\end{aligned}
$$

Using this relationship in the welfare change expression leads to:

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

Integrate between an initial situation (base case) and a counterfactual situation (counterfactual):

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

Use 'hat' to denote the ratio of any counterfactual and base case variable, i.e. $\widehat{v} = v^c/v^b$:

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

Take the exponent on the left- and right-hand side:

$$
\widehat{W}_j = \widehat{K}_j^{\alpha} \widehat{\lambda}_{jj}^{\frac{1}{1-\sigma}}. \tag{A18}
$$

Note that this expression for welfare holds in and out-of steady-state.

D.1 ACR Formula In Steady-State

In steady-state, we can use the expression for K_j as given in equation (25) as starting point. First, we replace y_j by the expression given in equation (23):

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

Solve for K_j:

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

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

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

Replace $d\ln P_j$ by $-\frac{1}{1-\sigma} d\ln \lambda_{jj} + d\ln p_j$:

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

Note that $d \ln p_j$ cancels out. 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:

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

Take the exponent on the left- and right-hand to obtain:

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

Plug this expression into equation (A18):

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

Note that this expression is very similar to the ACR formula for intermediates with perfect competition, which 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. The key difference between our setting and a model with intermediates is the dynamics and the transition path. We characterize in Section C the transition path, and discuss the extension to allow for intermediates in Section A.4.

D.2 ACR Formula Out-of Steady-State

In Subsection D.1 we assume that we are in a steady-state. In this section, we investigate the properties of our model with respect to ACR out of steady-state. To do this, we go back and depart from equation (A18), which holds in and out-of steady-state:

$$\widehat{W_{j,t}} = \widehat{K}_{j,t}^{\alpha} \widehat{\lambda}_{jj,t}^{\frac{1}{1-\sigma}}.$$

Starting with this expression, we have to determine $\widehat{K}_{j,t}$. Take the capital equation as given by equation (24) and replace $p_{j,t}A_{j,t}$ using equation (22):

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

Let us next write this equation in log-derivatives:

$$d \ln K_{j,t+1} = \delta(d \ln y_{j,t} - d \ln P_{j,t}) + (1-\delta) d \ln K_{j,t}.$$

Using equation (A15)

$$d \ln y_{j,t} = d \ln p_{j,t} + \alpha d \ln K_{j,t},$$

and (A17)

$$d \ln P_{j,t} = -\frac{1}{1-\sigma} d \ln \lambda_{jj,t} + d \ln p_{j,t},$$

we end up with:

$$\begin{aligned}
d\ln K_{j,t+1} &= \delta(\alpha d\ln K_{j,t} + \frac{1}{1-\sigma}d\ln\lambda_{jj,t}) + (1-\delta)d\ln K_{j,t} \Rightarrow \\
d\ln K_{j,t+1} &= \frac{1}{1-\sigma}d\ln\lambda_{jj,t} + (1-\delta(1+\alpha))d\ln K_{j,t}.
\end{aligned}$$

Integrate between an initial situation (base case) and a counterfactual situation (counterfactual):

$$\begin{aligned}
\int_{K^b_{j,t+1}}^{K^c_{j,t+1}} d\ln K_{j,t+1} &= \int_{\lambda^b_{jj}}^{\lambda^c_{jj}} \frac{1}{1-\sigma}d\ln\lambda_{jj,t} + \int_{K^b_{j,t}}^{K^c_{j,t}} (1-\delta(1+\alpha))d\ln K_{j,t}, \\
(\ln K_{j,t+1} + C_1)\,\Big|_{K^b_{j,t+1}}^{K^c_{j,t+1}} &= \left(\frac{1}{1-\sigma}\ln\lambda_{jj,t} + C_2\right)\Big|_{\lambda^b_{jj}}^{\lambda^c_{jj}} \\
&\quad + ((1-\delta(1+\alpha))\ln K_{j,t} + C_3)\,\Big|_{K^b_{j,t}}^{K^c_{j,t}}, \\
\big(\ln K^c_{j,t+1} + C_1 - \ln K^b_{j,t+1} - C_1\big) &= \left(\frac{1}{1-\sigma}\ln\lambda^c_{jj,t} + C_2 - \frac{1}{1-\sigma}\ln\lambda^b_{jj,t} - C_2\right) \\
&\quad +\big((1-\delta(1+\alpha))\ln K^c_{j,t} + C_3 \\
&\quad -(1-\delta(1+\alpha))\ln K^b_{j,t} - C_3\big).
\end{aligned}$$

Use 'hat' to denote the ratio of any counterfactual and base case variable, i.e. $\widehat{v} = v^c/v^b$:

$$\ln\widehat{K}_{j,t+1} = \frac{1}{1-\sigma}\ln\widehat{\lambda}_{jj,t} + (1-\delta(1+\alpha))\ln\widehat{K}_{j,t}.$$

Take the exponent on the left- and right-hand side:

$$\widehat{K}_{j,t+1} = \widehat{K}_{j,t}^{1-\delta(1+\alpha)}\widehat{\lambda}_{jj,t}^{\frac{1}{1-\sigma}}.$$

In combination with $\widehat{W}_j = \widehat{K}_j^{\alpha}\widehat{\lambda}_{jj}^{\frac{1}{1-\sigma}}$ and noting that in period zero $\widehat{K}_{j,0} = 1$, we can express welfare as an iterative formula which only depends on $\widehat{\lambda}_{jj,t}$ and changes of the capital stock:

$$\begin{aligned}
\widehat{W}_{j,t} &= \widehat{K}_{j,t}^{\alpha}\widehat{\lambda}_{jj,t}^{\frac{1}{1-\sigma}}, \\
\widehat{K}_{j,t+1} &= \widehat{K}_{j,t}^{1-\delta(1+\alpha)}\widehat{\lambda}_{jj,t}^{\frac{1}{1-\sigma}}, \\
\widehat{K}_{j,0} &= 1.
\end{aligned}$$

To show that welfare can be expressed as function of $\widehat{\lambda}_{jj}$ and parameters alone, we iteratively plug in $\widehat{K}_{j,t+1}$. In period 0 we have:

$$\begin{aligned}
\widehat{W}_{j,0} &= \widehat{\lambda}_{jj,0}^{\frac{1}{1-\sigma}}, \\
\widehat{K}_{j,1} &= \widehat{\lambda}_{jj,0}^{\frac{1}{1-\sigma}}.
\end{aligned}$$

In period 1 we have:

$$\widehat{W}_{j,1} = \widehat{\lambda}_{jj,0}^{\frac{1}{1-\sigma}} \widehat{\lambda}_{jj,1}^{\frac{1}{1-\sigma}},$$
$$\widehat{K}_{j,2} = \widehat{\lambda}_{jj,0}^{\frac{1-\delta(1+\alpha)}{1-\sigma}} \widehat{\lambda}_{jj,1}^{\frac{1}{1-\sigma}}.$$

In period 2 we have:

$$\widehat{W}_{j,2} = \widehat{\lambda}_{jj,0}^{\frac{1-\delta(1+\alpha)}{1-\sigma}} \widehat{\lambda}_{jj,1}^{\frac{1}{1-\sigma}} \widehat{\lambda}_{jj,2}^{\frac{1}{1-\sigma}},$$
$$\widehat{K}_{j,3} = \widehat{\lambda}_{jj,0}^{\frac{(1-\delta(1+\alpha))^2}{1-\sigma}} \widehat{\lambda}_{jj,1}^{\frac{1-\delta(1+\alpha)}{1-\sigma}} \widehat{\lambda}_{jj,2}^{\frac{1}{1-\sigma}}.$$

Hence, in period n we have:

$$\widehat{W}_{j,n} = \widehat{\lambda}_{jj,n}^{\frac{1}{1-\sigma}} \prod_{i=0}^{n-1} \widehat{\lambda}_{jj,i}^{\frac{(1-\delta(1+\alpha))^{n-1-i}}{1-\sigma}},$$
$$\widehat{K}_{j,n+1} = \prod_{i=0}^{n} \widehat{\lambda}_{jj,i}^{\frac{(1-\delta(1+\alpha))^{n-i}}{1-\sigma}},$$

which are both functions of $\widehat{\lambda}_{jj}$ and parameters only.

So far the out-of steady-state formulae give welfare when not taking into account the discounting. Note that $\widehat{W}_{j,t} = \widehat{C}_{j,t}$. Hence, we can calculate welfare with discounting by using equation (47):

$$\begin{aligned}
\lambda &= \left(\exp\left[(1-\beta)\left(\sum_{t=0}^{\infty}\beta^t \ln\left(C_{j,t,c}\right) - \sum_{t=0}^{\infty}\beta^t \ln\left(C_{j,t}\right)\right)\right] - 1\right) \times 100 \\
&= \left(\exp\left[(1-\beta)\left(\sum_{t=0}^{\infty}\beta^t \ln\left(\widehat{C}_{j,t}\right)\right)\right] - 1\right) \times 100 \\
&= \left(\exp\left[(1-\beta)\left(\sum_{t=0}^{\infty}\beta^t \ln\left(\widehat{K}_{j,t}^{\alpha} \widehat{\lambda}_{jj,t}^{\frac{1}{1-\sigma}}\right)\right)\right] - 1\right) \times 100 \qquad \text{(A19)}
\end{aligned}$$

Hence, out-of steady-state, welfare can also be expressed as a function of the changes in $\lambda_{jj,t}$. However, we have to trace the change of λ_{jj} only driven by the counterfactual change over the transition. As we will typically not be able to observe these changes, this expression is more for gaining theoretical insights into the working of the system than for practical use.

E Counterfactual Procedure

The counterfactuals are performed in four steps.

Step 1: Obtain trade cost estimates by estimating equations (29) and (30). Then calculate bilateral trade costs for the baseline setting:

$$\left(\widehat{t}_{ij,t}^{RTA}\right)^{1-\sigma} = \exp\left[\widehat{\eta}_1 RTA_{ij,t} + \sum_{m=2}^{5} \widehat{\eta}_m \ln DIST_{ij,m-1} + \widehat{\eta}_6 BRDR_{ij} + \widehat{\eta}_7 LANG_{ij} + \widehat{\eta}_8 CLNY_{ij}\right]. \tag{A20}$$

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 $\left(\widehat{t}_{ij,t}^{RTA}\right)^{1-\sigma}$ by replacing $RTA_{ij,t}$ with $RTA_{ij,t}^c$ in equation (A20). The differences between the values for the key variables of interest are obtained as a response to the change in the trade costs vector from $RTA_{ij,t}$ to $RTA_{ij,t}^c$.

Step 2: Using the estimates for trade costs described in Step 1, and estimates for the capital share $\widehat{\alpha}$, the elasticity of substitution $\widehat{\sigma}$, and the capital depreciation rate $\widehat{\delta}$ obtained from equations (34) and (39), 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 calculate P_j using equations (20) and (21) and recover (from equation (24)) country-specific, theory-consistent steady-state capital stocks as follows:

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

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

We also recover preference-adjusted technology A_j/γ_j in the baseline setting by noting that the 'lower level' can be solved without knowledge of A_j/γ_j and then using Π_j and combining (22) and (23), leading to:

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

As we recover K_j^{SS} and A_j/γ_j from data and estimated parameters, we ensure that our baseline setting is perfectly consistent with our GDP and employment data. However, our model allows us to perform one validation check. Specifically, 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 of the main text offers a visual representation of this relationship by plotting the log of the two series against each other, showing the strong log-linear correlation, which validates our estimates and gives us confidence to proceed with the policy counterfactual analysis as described in the next steps.

Step 3: Using the values obtained in Steps 1 and 2, we solve our system given by equations (19)-(24) in the baseline and in the counterfactual starting from year 0 until convergence to the new steady-state.

Step 4: After solving the model, we calculate the effects on trade, on the MRs, on welfare, and on capital accumulation. We report the results for all countries individually, as well as aggregates for the world, NAFTA, and the non-NAFTA countries (labeled "Rest Of the World", ROW).

Trade effects: Trade effects are calculated as percentage changes in overall exports for each country between the baseline and the counterfactual values:

$$\Delta x_{i,t}\% = \frac{\left(\sum_{j\neq i} x^c_{ij,t} - \sum_{j\neq i} x_{ij,t}\right)}{\sum_{j\neq i} x_{ij,t}} \times 100,$$

where $x_{ij,t}$ is calculated according to equation (19), and $x^c_{ij,t}$ are the counterfactual trade flows. Note that, in the case of NAFTA, we calculate the change of trade from the case without NAFTA to the case with NAFTA in place, as a share of trade in the case without NAFTA, even though we have to counterfactually solve for the case without NAFTA. The effects for the world as a whole are calculated by summing over all countries, i.e. $\Delta x_{\text{World},t}\% = \left(\sum_i \sum_{j\neq i} x^c_{ij,t} - \sum_i \sum_{j\neq i} x_{ij,t}\right) / \left(\sum_i \sum_{j\neq i} x_{ij,t}\right) \times 100$. For the trade effects within NAFTA, we only sum over the six within-NAFTA trade relationships (CAN-USA, CAN-MEX, MEX-CAN, MEX-USA, USA-CAN, USA-MEX). For ROW, we sum all remaining bilateral trade relationships.

MR effects: The MR effects are also calculated as the percentage change of $P_{i,t}$ and $\Pi_{i,t}$ for each country i and year t between the baseline and the counterfactual values. Note that with balanced trade and with symmetric trade costs $P_{i,t} = \Pi_{i,t}$, hence we only have to report one effect for every country in this case:

$$\Delta P_{i,t}\% = \frac{\left(P^c_{i,t} - P_{i,t}\right)}{P_{i,t}} \times 100,$$

where P_i is given by equation (20), and $P^c_{i,t}$ are the counterfactual MRs. The effects for the world are calculated as simple means over the changes for all countries, i.e. $\Delta P_{\text{World},t} = 1/N \sum_i \Delta P_{i,t}\%$. For NAFTA, we only take the mean over the three NAFTA members, while the results for ROW are calculated as the mean over the remaining 79 countries.

Welfare effects: In the 'Conditional GE' and in the 'Full Static GE' cases, welfare is given by real GDP per capita.[57] Using equation (23), $y_i = p_i A_i L_i^{1-\alpha} K_i^{\alpha}$, and equation (22), $(\gamma_i p_i \Pi_i)^{1-\sigma} = y_i/y$, to replace p_i, we can express real GDP per capita as:

$$\tilde{y}_i = \frac{y_i}{P_i L_i} = \frac{p_i A_i L_i^{1-\alpha} K_i^{\alpha}}{P_i L_i} = \frac{(y_i/y)^{1/(1-\sigma)} A_i L_i^{-\alpha} K_i^{\alpha}}{\gamma_i \Pi_i P_i},$$

[57]Note that in our setting P can also be interpreted as an ideal price index. C/P therefore corresponds to indirect utility.

and, similarly, the counterfactual real GDP per capita as:

$$\tilde{y}_i^c = \frac{y_i^c}{P_i^c L_i^c} = \frac{p_i^c A_i \left(L_i\right)^{1-\alpha} \left(K_i^c\right)^{\alpha}}{P_i^c L_i} = \frac{\left(y_i^c/y^c\right)^{1/(1-\sigma)} A_i \left(L_i\right)^{-\alpha} \left(K_i^c\right)^{\alpha}}{\gamma_i \Pi_i^c P_i^c}.$$

The change in welfare effects is then given by:

$$\Delta\tilde{y}_i\% = \frac{\left(\tilde{y}_i^c - \tilde{y}_i\right)}{\tilde{y}_i} \times 100.$$

In the 'Full Dynamic GE, SS' and 'Full Dynamic GE, trans.' scenarios, welfare is calculated according to equation (47). The results for the world are calculated as weighted sums of the welfare effects over all countries. We use GDPs as weights. Hence, the reported world welfare effects are calculated as: $\Delta\tilde{y}_{\text{World}}\% = \sum_i \left(\Delta\tilde{y}_i\% \times \frac{y_i}{\sum_j y_j}\right)$. For NAFTA, we only take the GPD weighted sum over the three NAFTA members, while the results for ROW are calculated as the GDP weighted sums over the remaining 79 countries.

Capital effects: The effects on capital are also calculated as the percentage changes between the baseline and the counterfactual values:

$$\Delta K_{i,t}\% = \frac{\left(K_{i,t}^c - K_{i,t}\right)}{K_{i,t}} \times 100,$$

where $K_{i,t}$ is given by equation (24), and $K_{i,t}^c$ are the counterfactual capital stocks in the new steady-state. The results for the world are calculated by summing over all countries, i.e. $\Delta K_{\text{World},t}\% = \left(\sum_i K_{i,t}^c - \sum_i K_{i,t}\right) / \left(\sum_i K_{i,t}\right) \times 100$. For NAFTA, we only sum capital stocks over the three NAFTA members in the baseline and counterfactual and calculate the change of this sum, while the results for ROW are calculated as the change of the sum of capital stocks for the remaining 79 countries.

F Our System in Changes

In this appendix, we derive our system in changes using the exact hat algebra as introduced by Dekle, Eaton, and Kortum (2007, 2008). We first derive the system in changes out-of steady-state followed by the system in changes in steady-state.

Denote counterfactual values with a prime ($'$), and define the change for variable z, as $\widehat{z} = z'/z$. Start with the capital equation as given by equation (24) and replace $p_{j,t}A_{j,t}$ using equation (22):

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

This relationship holds in the baseline and counterfactual, so that we can write the change as:

$$\widehat{K}_{j,t+1} = \left[\frac{\widehat{y}_{j,t}}{\widehat{P}_{j,t}}\right]^{\delta} \widehat{K}_{j,t}^{1-\delta}.$$

To derive an expression for the changes of prices we use equation (22) to write:

$$\widehat{p}_{j,t} = \frac{(\widehat{y}_{j,t}/\widehat{y}_t)^{\frac{1}{1-\sigma}}}{\widehat{\Pi}_{j,t}},$$

with

$$\widehat{y}_t = \frac{\sum_i y'_{i,t}}{\sum_i y_{i,t}} \Rightarrow y_t\widehat{y}_t = \sum_i y_{i,t}\widehat{y}_{it}.$$

Next we derive an equation for $\widehat{\Pi}_{j,t}$. We use equation (21) to write:

$$\Pi_{i,t}^{1-\sigma}\widehat{\Pi}_{i,t}^{1-\sigma} = \sum_j \left(\frac{t_{ij,t}\widehat{t}_{ij,t}}{P_{j,t}\widehat{P}_{j,t}}\right)^{1-\sigma} \frac{y_{j,t}\widehat{y}_{j,t}}{y_t\widehat{y}_t}.$$

Similarly, we can write the change for $P_{j,t}$ using equation (20):

$$P_{j,t}^{1-\sigma}\widehat{P}_{j,t}^{1-\sigma} = \sum_i \left(\frac{t_{ij,t}\widehat{t}_{ij,t}}{\Pi_{i,t}\widehat{\Pi}_{i,t}}\right)^{1-\sigma} \frac{y_{i,t}\widehat{y}_{i,t}}{y_t\widehat{y}_t}.$$

The change in GDP is derived by using equation (23), and assuming that technology and labor stay constant:

$$\widehat{y}_{j,t} = \widehat{p}_{j,t}\widehat{K}_{j,t}^{\alpha}.$$

This completes our system in changes:

$$\begin{aligned}
\widehat{x}_{ij,t} &= \frac{\widehat{y}_{i,t}\widehat{y}_{j,t}}{\widehat{y}_t}\left(\frac{\widehat{t}_{ij,t}}{\widehat{\Pi}_{i,t}\widehat{P}_{j,t}}\right)^{1-\sigma}, \\
\Pi_{i,t}^{1-\sigma}\widehat{\Pi}_{i,t}^{1-\sigma} &= \sum_j \left(\frac{t_{ij,t}\widehat{t}_{ij,t}}{P_{j,t}\widehat{P}_{j,t}}\right)^{1-\sigma} \frac{y_{j,t}\widehat{y}_{j,t}}{y_t\widehat{y}_t}, \\
P_{j,t}^{1-\sigma}\widehat{P}_{j,t}^{1-\sigma} &= \sum_i \left(\frac{t_{ij,t}\widehat{t}_{ij,t}}{\Pi_{i,t}\widehat{\Pi}_{i,t}}\right)^{1-\sigma} \frac{y_{i,t}\widehat{y}_{i,t}}{y_t\widehat{y}_t}, \\
\widehat{p}_{j,t} &= \frac{(\widehat{y}_{j,t}/\widehat{y}_t)^{\frac{1}{1-\sigma}}}{\widehat{\Pi}_{j,t}}, \\
y_t\widehat{y}_t &= \sum_i y_{i,t}\widehat{y}_{it}, \\
\widehat{y}_{j,t} &= \widehat{p}_{j,t}\widehat{K}_{j,t}^{\alpha}, \\
\widehat{K}_{j,t+1} &= \left[\frac{\widehat{y}_{j,t}}{\widehat{P}_{j,t}}\right]^{\delta}\widehat{K}_{j,t}^{1-\delta}.
\end{aligned}$$

This system needs only data on GDPs ($y_{i,t}$) and trade costs ($t_{ij,t}$), and knowledge about α,

σ and δ. In other words, knowledge about $A_{j,t}$, γ_j, and β is not necessary. The change in $t_{ij,t}$, $\widehat{t}_{ij,t}$, are exogenous, i.e. they form the basis of our counterfactual NAFTA experiment. Further, with given GDPs and trade costs, we can solve for the $\Pi_{i,t}$'s and $P_{j,t}$'s. Hence, we are left with seven equations for each t in the seven unknown changes $\widehat{x}_{ij,t}$, $\widehat{y}_{i,t}$, $\widehat{y}_t$, $\widehat{\Pi}_{i,t}$, $\widehat{P}_{j,t}$, $\widehat{p}_{j,t}$, $\widehat{K}_{j,t}$.

Note that the capital equation in changes does not determine the level of capital. However, this is also not necessary. We merely have to note that $\widehat{K}_{j,0} = 1$, i.e. that there are no capital adjustments in the first iteration. Hence, we can write and solve our system in changes and solve for all counterfactual values of all endogenous variables with given K_0. The solutions are identical to the solutions of our system in levels. This shows that our reported changes from the system in levels are also invariant to the values of $A_{j,t}$, γ_j, and β. The reason is that they all enter multiplicative and are assumed to be constant between baseline and counterfactual.

In steady-state, the capital equation in changes simplifies to:

$$\widehat{K}_j = \left[\frac{\widehat{y}_j}{\widehat{P}_j}\right]^{\delta} \widehat{K}_j^{1-\delta} \Rightarrow \widehat{K}_j = \frac{\widehat{y}_j}{\widehat{P}_j}.$$

All other equations stay the same without time index.

G Additional Results for the NAFTA Counterfactual

In this appendix we provide detailed results for our NAFTA counterfactual. Specifically, we report the changes in trade, MR, welfare, and capital stocks for all countries, as well as summary statistics for the NAFTA members, the non-NAFTA members and the world as a whole. All changes are calculated as described in Online Appendix E, Step 4.

Table A1: Evaluation of NAFTA

Country	Trade effects			MR effects			Welfare effects			Capital
	Cond. GE	Full Static GE	Full Dynamic GE, trans.	Cond. GE	Full Static GE	Full Dynamic GE, trans.	Cond. GE	Full Static GE	Full Dynamic GE, trans.	Full Dynamic GE, trans.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
AGO	-0.018	-0.180	-0.290	0.293	0.327	0.377	-0.292	-0.490	-0.562	-0.655
ARG	-0.176	-0.581	-0.775	0.746	0.682	0.569	-0.741	-1.121	-1.177	-1.268
AUS	-0.115	-0.354	-0.511	0.425	0.446	0.456	-0.423	-0.702	-0.790	-0.907
AUT	-0.004	0.009	0.062	0.051	0.106	0.222	-0.051	-0.093	-0.121	-0.156
AZE	-0.007	-0.049	-0.074	0.115	0.176	0.282	-0.115	-0.218	-0.280	-0.351
BEL	-0.002	0.032	0.104	0.021	0.079	0.203	-0.021	-0.045	-0.068	-0.097
BGD	-0.076	-0.148	-0.172	0.181	0.226	0.310	-0.180	-0.309	-0.367	-0.439
BGR	-0.011	-0.070	-0.089	0.149	0.198	0.288	-0.149	-0.258	-0.307	-0.369
BLR	-0.011	-0.068	-0.096	0.140	0.195	0.291	-0.140	-0.252	-0.310	-0.380
BRA	-0.285	-0.501	-0.578	0.465	0.465	0.454	-0.463	-0.736	-0.806	-0.902
CAN	0.780	13.053	39.278	-13.363	-13.344	-13.377	15.424	29.608	44.204	60.021
CHE	-0.000	0.044	0.118	0.004	0.067	0.198	-0.004	-0.022	-0.048	-0.078
CHL	-0.043	-0.261	-0.409	0.383	0.404	0.426	-0.382	-0.628	-0.709	-0.811
CHN	-0.444	-0.473	-0.385	0.191	0.236	0.315	-0.190	-0.327	-0.385	-0.458
COL	-0.216	-0.582	-0.749	0.697	0.644	0.550	-0.692	-1.054	-1.115	-1.207
CZE	-0.007	-0.008	0.024	0.063	0.123	0.238	-0.063	-0.123	-0.163	-0.208
DEU	-0.058	-0.060	-0.021	0.066	0.126	0.241	-0.065	-0.129	-0.171	-0.218

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Table A1 – *Continued from previous page*

Country	Trade effects: Cond. GE	Trade effects: Full Static GE	Trade effects: Full Dynamic GE, trans.	MR effects: Cond. GE	MR effects: Full Static GE	MR effects: Full Dynamic GE, trans.	Welfare effects: Cond. GE	Welfare effects: Full Static GE	Welfare effects: Full Dynamic GE, trans.	Capital: Full Dynamic GE, trans.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
DNK	-0.012	-0.029	-0.013	0.087	0.144	0.253	-0.087	-0.162	-0.206	-0.257
DOM	-0.138	-0.457	-0.633	0.577	0.558	0.509	-0.574	-0.901	-0.974	-1.078
ECU	-0.050	-0.371	-0.553	0.563	0.538	0.491	-0.560	-0.866	-0.929	-1.018
EGY	-0.051	-0.126	-0.147	0.181	0.224	0.305	-0.181	-0.306	-0.358	-0.424
ESP	-0.093	-0.228	-0.283	0.283	0.312	0.358	-0.282	-0.462	-0.522	-0.595
ETH	-0.020	-0.286	-0.483	0.440	0.459	0.464	-0.438	-0.725	-0.814	-0.934
FIN	-0.012	-0.050	-0.062	0.112	0.171	0.275	-0.112	-0.209	-0.265	-0.328
FRA	-0.057	-0.103	-0.095	0.145	0.191	0.280	-0.145	-0.246	-0.287	-0.343
GBR	-0.165	-0.240	-0.240	0.204	0.246	0.320	-0.203	-0.345	-0.399	-0.471
GHA	-0.015	-0.316	-0.530	0.497	0.502	0.487	-0.495	-0.802	-0.888	-1.005
GRC	-0.034	-0.075	-0.078	0.125	0.178	0.277	-0.124	-0.223	-0.272	-0.333
GTM	-0.335	-1.021	-1.331	1.259	1.091	0.797	-1.244	-1.842	-1.893	-1.989
HKG	-0.220	-0.280	-0.269	0.180	0.230	0.315	-0.180	-0.316	-0.379	-0.457
HRV	-0.021	-0.139	-0.200	0.238	0.274	0.336	-0.237	-0.395	-0.450	-0.524
HUN	-0.019	-0.062	-0.060	0.129	0.179	0.273	-0.129	-0.223	-0.266	-0.321
IDN	-0.179	-0.276	-0.288	0.250	0.283	0.341	-0.250	-0.410	-0.467	-0.540
IND	-0.195	-0.385	-0.476	0.383	0.403	0.423	-0.382	-0.625	-0.701	-0.803
IRL	-0.003	-0.008	0.006	0.065	0.128	0.247	-0.065	-0.133	-0.181	-0.238
IRN	-0.061	-0.190	-0.251	0.266	0.296	0.350	-0.265	-0.435	-0.493	-0.569
IRQ	-0.011	-0.117	-0.173	0.218	0.257	0.326	-0.217	-0.363	-0.421	-0.493
ISR	-0.066	-0.346	-0.565	0.455	0.484	0.490	-0.453	-0.770	-0.884	-1.017
ITA	-0.095	-0.130	-0.109	0.132	0.182	0.276	-0.132	-0.229	-0.273	-0.330
JPN	-0.856	-0.812	-0.578	0.163	0.211	0.297	-0.163	-0.282	-0.334	-0.399
KAZ	-0.001	0.000	0.000	0.047	0.120	0.250	-0.047	-0.118	-0.180	-0.247
KEN	-0.038	-0.303	-0.496	0.442	0.461	0.466	-0.440	-0.729	-0.819	-0.939
KOR	-0.227	-0.279	-0.244	0.198	0.236	0.309	-0.197	-0.327	-0.375	-0.438
KWT	-0.179	-0.242	-0.238	0.181	0.229	0.313	-0.181	-0.315	-0.374	-0.449
LBN	-0.014	-0.142	-0.194	0.263	0.286	0.335	-0.262	-0.416	-0.454	-0.522
LKA	-0.054	-0.164	-0.217	0.235	0.271	0.336	-0.234	-0.390	-0.449	-0.524
LTU	-0.009	-0.081	-0.124	0.157	0.212	0.304	-0.157	-0.284	-0.348	-0.422
MAR	-0.031	-0.142	-0.194	0.230	0.267	0.331	-0.229	-0.382	-0.435	-0.508
MEX	2.646	9.812	24.343	-8.316	-8.317	-8.346	9.070	17.071	25.015	33.309
MYS	-0.015	-0.063	-0.077	0.133	0.185	0.281	-0.133	-0.234	-0.286	-0.348
NGA	-0.009	-0.305	-0.518	0.488	0.494	0.482	-0.485	-0.788	-0.874	-0.991
NLD	-0.019	-0.011	0.031	0.053	0.113	0.231	-0.053	-0.106	-0.143	-0.185
NOR	-0.013	-0.068	-0.090	0.137	0.192	0.288	-0.137	-0.247	-0.303	-0.368
NZL	-0.041	-0.313	-0.515	0.452	0.471	0.474	-0.450	-0.746	-0.841	-0.964
OMN	-0.017	-0.152	-0.237	0.256	0.294	0.354	-0.255	-0.430	-0.495	-0.580
PAK	-0.019	-0.141	-0.235	0.228	0.277	0.352	-0.228	-0.400	-0.479	-0.574
PER	-0.042	-0.297	-0.438	0.458	0.451	0.440	-0.456	-0.712	-0.773	-0.856
PHL	-0.084	-0.310	-0.462	0.400	0.423	0.440	-0.399	-0.661	-0.747	-0.858
POL	-0.020	-0.047	-0.030	0.109	0.159	0.259	-0.109	-0.189	-0.227	-0.277
PRT	-0.020	-0.068	-0.097	0.121	0.183	0.288	-0.121	-0.232	-0.298	-0.371
QAT	-0.039	-0.138	-0.193	0.207	0.253	0.328	-0.207	-0.356	-0.419	-0.499
ROM	-0.026	-0.128	-0.164	0.225	0.256	0.319	-0.224	-0.363	-0.408	-0.469
RUS	-0.244	-0.358	-0.374	0.288	0.318	0.366	-0.288	-0.474	-0.535	-0.619
SAU	-0.073	-0.189	-0.247	0.241	0.281	0.345	-0.240	-0.407	-0.470	-0.552
SDN	-0.008	-0.143	-0.220	0.261	0.293	0.348	-0.260	-0.428	-0.486	-0.562
SER	-0.013	-0.131	-0.197	0.235	0.273	0.336	-0.234	-0.392	-0.449	-0.525
SGP	-0.140	-0.224	-0.247	0.205	0.251	0.327	-0.204	-0.353	-0.416	-0.496
SVK	-0.007	-0.042	-0.035	0.117	0.167	0.265	-0.117	-0.203	-0.243	-0.295
SWE	-0.018	-0.061	-0.070	0.122	0.177	0.277	-0.122	-0.221	-0.274	-0.335
SYR	-0.003	-0.069	-0.102	0.154	0.205	0.296	-0.153	-0.271	-0.327	-0.395
THA	-0.200	-0.268	-0.255	0.210	0.248	0.320	-0.209	-0.349	-0.403	-0.472
TKM	-0.006	-0.100	-0.162	0.192	0.241	0.322	-0.192	-0.335	-0.399	-0.478
TUN	-0.016	-0.154	-0.203	0.284	0.299	0.339	-0.283	-0.440	-0.472	-0.534
TUR	-0.078	-0.174	-0.197	0.228	0.260	0.323	-0.227	-0.370	-0.417	-0.481
TZA	-0.004	-0.205	-0.352	0.345	0.374	0.409	-0.344	-0.573	-0.653	-0.756
UKR	-0.029	-0.084	-0.110	0.138	0.194	0.292	-0.138	-0.252	-0.311	-0.383
USA	3.047	4.240	6.870	-0.774	-0.893	-1.097	0.780	1.731	2.748	4.213
UZB	-0.027	-0.138	-0.206	0.222	0.265	0.337	-0.221	-0.379	-0.444	-0.526

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Table A1 – *Continued from previous page*

Country	Trade effects			MR effects			Welfare effects			Capital
	Cond. GE	Full Static GE	Full Dynamic GE, trans.	Cond. GE	Full Static GE	Full Dynamic GE, trans.	Cond. GE	Full Static GE	Full Dynamic GE, trans.	Full Dynamic GE, trans.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
VEN	-0.099	-0.430	-0.611	0.591	0.563	0.508	-0.588	-0.911	-0.978	-1.072
VNM	-0.019	-0.118	-0.164	0.212	0.250	0.320	-0.212	-0.352	-0.405	-0.474
ZAF	-0.068	-0.286	-0.439	0.381	0.408	0.433	-0.379	-0.635	-0.721	-0.834
ZWE	-0.019	-0.201	-0.332	0.322	0.354	0.396	-0.321	-0.537	-0.615	-0.715
World	0.503	1.105	2.306	-0.021	0.009	0.059	0.556	1.155	1.842	2.213
NAFTA	34.848	48.764	78.183	-7.484	-7.518	-7.607	2.554	5.073	7.671	10.024
ROW	-1.413	-1.308	-0.914	0.262	0.295	0.350	-0.220	-0.368	-0.423	-0.485

Notes: This table reports results from our NAFTA counterfactual. It is based on observed data on labor endowments and GDPs for our sample of 82 countries. Further, it uses our estimated trade costs based on equation (32) and recovered theory-consistent, steady-state capital stocks according to the capital accumulation equation (24). We calculate baseline preference-adjusted technology A_j/γ_j according to the market-clearing equation (22) and the production function equation (23). Finally, the counterfactual is based on our own estimates of the elasticity of substitution $\widehat{\sigma} = 5.1$, the share of capital in the Cobb-Douglas production function $\widehat{\alpha} = 0.55$, and the capital depreciation rate $\widehat{\delta} = 0.052$. The consumers' discount factor β is set equal to 0.98. Column (1) gives the country abbreviations. Columns (2) to (4) report the percentage change in exports for the NAFTA counterfactual for each country, for the world as a whole, the NAFTA and the non-NAFTA countries (summarized as Rest Of the World, ROW) for three different scenarios. The "Conditional GE" scenario takes into account the direct and indirect trade cost changes but holds GDPs constant, the "Full Static GE" scenario additionally takes general equilibrium income effects into account, and the "Full Dynamic GE, trans." scenario adds the capital accumulation effects. For the latter, we report the results from the steady-state taking into account that gains take time to materialize. Columns (5) to (7) report the percentage change in the multilateral resistance terms for each country for the same three scenarios. Similarly, columns (8) to (10) give the welfare effects. The last column shows the percentage change in capital stocks for each country for the "Full Dynamic GE, trans." scenario. Further details to the counterfactuals can be found in Section 5 and Online Appendix E.

H Linear Capital Accumulation Function

In this appendix we investigate the consequences of the convenient log-linear capital accumulation function by deriving our system under the assumption that capital accumulation is subject to the more standard linear transition function (we skip country indices without loss of generality):

$$K_{t+1} = \Omega_t + (1-\delta)K_t.$$

The utility function is:

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

Combine the budget constraint with the production function:

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

Use the linear transition function for capital to express Ω_t as:

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

Set up the Lagrangian:

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

Take derivatives with respect to C_t, K_{t+1} and λ_t:

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

Use the first-order condition for consumption to express λ_t as:

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

Replace this in the first-order condition for capital:

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

Simplify and re-arrange:

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

Use the definition of y_t to re-write the left-hand side of the above expression:

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

Rearrange to obtain:

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

which is the familiar and standard consumption Euler-equation. Note that there are three forward-looking variables for each country in this system: y_t, C_t, and P_t (K_{t+1} is determined in t and therefore it is not a forward-looking variable). Thus, overall, we have $3N$ forward-looking variables in this system. These are also the endogenous variables we have to solve for.

Since there exists no analytical solution for this system, we feed the following set of equations into Dynare:

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

As noted in the main text, the Euler-equation is the only difference between our main system and the corresponding system obtained under linear capital accumulation (compare these equations to the ones we used in Dynare for our original system given in equations (A10)-(A14)). We also can formulate the original system for the case of a linear capital accumulation function:

$$
\begin{aligned}
x_{ij,t} &= \frac{y_{i,t} y_{j,t}}{y_t} \left(\frac{t_{ij,t}}{\Pi_{i,t} P_{j,t}} \right)^{1-\sigma}, && \text{(A21)} \\
P_{j,t}^{1-\sigma} &= \sum_i \left(\frac{t_{ij,t}}{\Pi_{i,t}} \right)^{1-\sigma} \frac{y_{i,t}}{y_t}, && \text{(A22)} \\
\Pi_{i,t}^{1-\sigma} &= \sum_j \left(\frac{t_{ij,t}}{P_{j,t}} \right)^{1-\sigma} \frac{y_{j,t}}{y_t}, && \text{(A23)} \\
p_{j,t} &= \frac{(y_{j,t}/y_t)^{\frac{1}{1-\sigma}}}{\gamma_j \Pi_{j,t}}, && \text{(A24)} \\
y_{j,t} &= p_{j,t} A_{j,t} L_{j,t}^{1-\alpha} K_{j,t}^{\alpha}, && \text{(A25)} \\
\frac{1}{C_t} &= \frac{\beta}{C_{t+1}} \left(\frac{\alpha y_{t+1}}{K_{t+1} P_{t+1}} + 1 - \delta \right), && \text{(A26)} \\
K_0 & \quad \text{given.}
\end{aligned}
$$

When we compare the above equations with our original system given by equations (19)-(24), we see that the only differing equation is again the expression for capital accumulation. As noted above, equation (A26) is the consumption Euler equation, which gives an expression for the relationship that determines investment and, hence, capital stocks, but it no longer offers an analytical expression for next period capital stocks.

What does this new system imply for our results?

1. Concerning the empirical specification, we see that the trade cost estimates and the output equation estimates do not change at all. Therefore, trade costs $t_{ij}^{1-\sigma}$, the capital share α, and the elasticity of substitution σ can be estimated as in the case with the Cobb-Douglas transition function. However, as we no longer have a closed-form

solution for our policy function, we can not derive an estimable *Capital equation* and, therefore, we are no longer able to back out the depreciation rate δ and test for causal effects of trade on growth.

2. The steady-state version of equation (A26) is:

$$\begin{aligned} \frac{1}{C} &= \frac{\beta}{C}\left(\frac{\alpha y}{KP}+1-\delta\right) \Rightarrow \\ K &= \frac{\alpha y}{\left(\frac{1}{\beta}-1+\delta\right)P} = \frac{\alpha\beta y}{(1-\beta+\beta\delta)\,P}. \end{aligned}$$

Given this solution for the steady-state capital stock, which is again a function of parameters and y/P, all our analytical insights from Section 3.1 go through. Actually, the only difference is the missing δ in the numerator for the steady-state capital stock. However, when plugging in $y = PC + P\left(K_{t+1} - (1-\delta)K_t\right) = PC + \delta PK$, we see that δ reappears. From this equation we also can calculate steady-state consumption:

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

This demonstrates that consumption is given by exactly the same function as in the case of our Cobb-Douglas transition function for capital in steady-state. Similarly, the level of investment δK is identical. With our estimated parameters of $\alpha = 0.55$, $\beta = 0.98$, $\delta = 0.05$, we end up with $\Omega P/y = 0.3943$ and $CP/y = 0.6057$. Note, however, that the capital stock as a share of GDP is now given by $\Omega P/(y\delta) = 7.886$.

3. Finally, for our counterfactuals, we have to back out A/γ. This can be done in the exact same fashion, given that we can determine the steady-state capital stock.

I Derivation of the Policy Functions of the 'Upper Level' when Accounting for Intermediates

In this appendix we extend our model to allow for intermediates. Intermediates in country j at time t, Q_{jt}, are assumed as an additional production factor in our Cobb-Dougals production function following Eaton and Kortum (2002) and Caliendo and Parro (2015). While α still denotes the capital share of production, we now introduce ξ as the labor share of produciton. The share of intermediates is then given by $1-\alpha-\xi$. We assume that intermediates are CES composites of domestic components ($q_{jj,t}$) and imported components from all other countries $i \neq j$ ($q_{ij,t}$), i.e. $Q_{j,t} = \left(\sum_i \gamma_i^{(1-\sigma)/\sigma} q_{ij,t}^{(\sigma-1)/\sigma}\right)^{\sigma/(\sigma-1)}$. With intermediates, the corresponding 'upper level' setting becomes (we omit the country indexes in order to economize on the notational burden):

$$\begin{aligned}
U_t &= \sum_{t=0}^{\infty} \beta^t \ln(C_t), && \text{(A27)}\\
K_{t+1} &= K_t^{1-\delta}\Omega_t^{\delta}, && \text{(A28)}\\
y_t &= p_t A_t K_t^{\alpha} L_t^{\xi} Q_t^{1-\alpha-\xi}, && \text{(A29)}\\
y_t &= P_t C_t + P_t Q_t + P_t \Omega_t, && \text{(A30)}\\
K_0 & \quad \textit{given}. && \text{(A31)}
\end{aligned}$$

As in Online Appendix B, we skip indices for current periods and denote next period variables by $'$. Further, we again define $\phi = 1/\delta$. Due to the Cobb-Douglas production function, the cost shares for all three inputs are given by their respective Cobb-Douglas coefficients. Specifically, $P_t Q_t$ is equal to $(1-\alpha-\xi)y_t$. Thus, we can rewrite (A30) 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:

$$\begin{aligned}
v' &= \max_{K'} \ln C = \max_{K'} \ln\left((\alpha+\xi)y/P - \Omega\right)\\
&= \max_{K'} \ln\left((\alpha+\xi)y/P - \Omega\right)\\
&= \max_{K'} \ln\left((\alpha+\xi)pAK^{\alpha}L^{\xi}Q^{1-\alpha-\xi}/P - (K'^{\phi}/K^{\phi-1})\right).
\end{aligned}$$

The corresponding first order condition is:

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

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 solve:

$$\begin{aligned}
v^2 &= \max_{K'} \ln\left((\alpha+\xi)pAK^{\alpha}L^{\xi}Q^{1-\alpha-\xi}/P - (K'^{\phi}/K^{\phi-1})\right)\\
&\quad +\beta \ln\left((\alpha+\xi)pAK'^{\alpha}L^{\xi}Q^{1-\alpha-\xi}/P\right).
\end{aligned}$$

The first order condition is:

$$\begin{aligned}
&\frac{1}{(\alpha+\xi)pAK^{\alpha}L^{\xi}Q^{1-\alpha-\xi}/P-(K'^{\phi}/K^{\phi-1})}(-\phi)\frac{K'^{\phi-1}}{K^{\phi-1}}+\frac{\alpha\beta}{K'}=0,\\
&\frac{\alpha\beta}{\phi}\left((\alpha+\xi)pAK^{\alpha}L^{\xi}Q^{1-\alpha-\xi}/P-(K'^{\phi}/K^{\phi-1})\right)=\frac{K'^{\phi}}{K^{\phi-1}},\\
&\frac{\alpha\beta}{\phi}\left((\alpha+\xi)pAK^{\alpha}L^{\xi}Q^{1-\alpha-\xi}/P\right)=\left(\frac{\alpha\beta}{\phi}+1\right)\frac{K'^{\phi}}{K^{\phi-1}},\\
&\frac{\alpha\beta}{\phi+\alpha\beta}\frac{(\alpha+\xi)pAL^{\xi}Q^{1-\alpha-\xi}}{P}K^{\alpha+\phi-1}=K'^{\phi},\\
&\left(\frac{\alpha\beta}{\phi+\alpha\beta}\frac{(\alpha+\xi)pAL^{\xi}Q^{1-\alpha-\xi}}{P}\right)^{\frac{1}{\phi}}K^{(\alpha+\phi-1)/\phi}=K'.
\end{aligned} \tag{A32}$$

Plug in the expression for K' given in equation (A32):

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

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

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

The first order condition is given by:

$$
\begin{aligned}
&\frac{1}{(\alpha+\xi)pAK^{\alpha}L^{\xi}Q^{1-\alpha-\xi}/P-(K'^{\phi}/K^{\phi-1})}(-\phi)\frac{K'^{\phi-1}}{K^{\phi-1}}\\
&+\frac{\alpha\beta}{K'}+\frac{\alpha\theta\beta^{2}}{K'}=0,\\
&\frac{\alpha\beta}{\phi}(1+\beta\theta)\left((\alpha+\xi)pAK^{\alpha}L^{\xi}Q^{1-\alpha-\xi}/P-(K'^{\phi}/K^{\phi-1})\right)=\frac{K'^{\phi}}{K^{\phi-1}},\\
&\frac{\alpha\beta}{\phi}(1+\beta\theta)(\alpha+\xi)pAK^{\alpha}L^{\xi}Q^{1-\alpha-\xi}/P=\left(\frac{\alpha\beta}{\phi}(1+\beta\theta)+1\right)\frac{K'^{\phi}}{K^{\phi-1}},\\
&K'=\left(\frac{\frac{\alpha\beta}{\phi}(1+\beta\theta)(\alpha+\xi)pAL^{\xi}Q^{1-\alpha-\xi}/P}{\frac{\alpha\beta}{\phi}(1+\beta\theta)+1}\right)^{\frac{1}{\phi}}K^{\theta}.
\end{aligned}
\tag{A33}
$$

Plug in the solution of K' given in equation (A33):

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

The next value of the value function takes the form:

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

with the following first order condition:

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

Now we see the general pattern that can be described as:

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

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

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

Replace $\theta \equiv (\alpha+\phi-1)/\phi$:

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

Apply $\phi = 1/\delta$:

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

Obtain the investment equation in the case with intermediates:

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

The main difference between this policy function for the capital stock in the next period, K', and the one in our main system is the appearance of the term for intermediates. If $(\alpha+\xi)=1$, i.e. if there are no intermediates, we end up with equation (15). As discussed in the main text, the main implications are that the effects of domestic investment in our model are magnified through this term, and that foreign capital now has an indirect impact on domestic output and investment that is also channeled through the new term for intermediates.

Finally, once we have pinned down the values for K' and K, we can determine the level of investment:

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

In addition, we can obtain the optimal level of current consumption by using the policy function for capital and reformulating $y = PC + P\Omega + PQ$, i.e.,

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

Note again, that:

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

J Iso-Elastic Utility Function

Our log-linear utility function implies an intertemporal elasticity of substitution of 1. The macro-literature often uses a value of 0.5. Empirical studies seem to support values between 0.25 and 1, cf. Sampson (2014). In order to investigate the sensitivity of our results concerning the log-linear utility function, we generalize our utility function to an iso-elastic one (we skip country indices without loss of generality):

$$U_t = \sum_{t=0}^{\infty} \beta^t \frac{C_t^{1-\rho} - 1}{1-\rho}, \quad \rho > 0,$$

where $1/\rho$ denotes the intertemporal elasticity of substitution. Note that this utility function approaches $\ln(C_t)$ for $\rho \to 1$. We retain all other assumptions of our baseline model.

Combining the budget constraint with the production function leads to:

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

In order to end up with only one constraint, we replace Ω_t by using our capital transition function:

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

Replacing Ω_t, we end up with the following constraint:

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

Setting up the Lagrangian leads to:

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

Taking derivatives with respect to C_t, K_{t+1} and λ_t leads to the following set of first-order conditions:

$$\begin{aligned}
\frac{\partial \mathcal{L}}{\partial C_t} &= \beta^t C_t^{-\rho} - \beta^t \lambda_t P_t \stackrel{!}{=} 0 \quad \text{for all } t. \\
\frac{\partial \mathcal{L}}{\partial K_{t+1}} &= \beta^{t+1} \lambda_{t+1} p_{t+1} A_{t+1} L_{t+1}^{1-\alpha} \alpha K_{t+1}^{\alpha-1} - \beta^t \lambda_t P_t \left(\frac{1}{K_t^{1-\delta}} \right)^{\frac{1}{\delta}} \frac{1}{\delta} K_{t+1}^{\frac{1}{\delta}-1} \\
&\quad - \beta^{t+1} \lambda_{t+1} P_{t+1} K_{t+2}^{\frac{1}{\delta}} \frac{\delta - 1}{\delta} K_{t+1}^{-\frac{1}{\delta}} \stackrel{!}{=} 0 \quad \text{for all } t. \\
\frac{\partial \mathcal{L}}{\partial \lambda_t} &= p_t A_t L_t^{1-\alpha} K_t^{\alpha} - P_t C_t - P_t \left(\frac{K_{t+1}}{K_t^{1-\delta}} \right)^{\frac{1}{\delta}} \stackrel{!}{=} 0 \quad \text{for all } t.
\end{aligned}$$

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

$$\lambda_t = \frac{C_t^{-\rho}}{P_t}.$$

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

$$\begin{aligned}
\frac{\partial \mathcal{L}}{\partial K_{t+1}} &= \beta^{t+1} \frac{C_{t+1}^{-\rho}}{P_{t+1}} p_{t+1} A_{t+1} L_{t+1}^{1-\alpha} \alpha K_{t+1}^{\alpha-1} - \beta^t C_t^{-\rho} \left(\frac{1}{K_t^{1-\delta}} \right)^{\frac{1}{\delta}} \frac{1}{\delta} K_{t+1}^{\frac{1}{\delta}-1} \\
&\quad - \beta^{t+1} C_{t+1}^{-\rho} K_{t+2}^{\frac{1}{\delta}} \frac{\delta - 1}{\delta} K_{t+1}^{-\frac{1}{\delta}} \stackrel{!}{=} 0 \quad \text{for all } t.
\end{aligned}$$

Simplifying a bit and re-arranging leads to:

$$\frac{\beta C_{t+1}^{-\rho} p_{t+1} A_{t+1} L_{t+1}^{1-\alpha} \alpha K_{t+1}^{\alpha-1}}{P_{t+1}} = C_t^{-\rho} \left(\frac{1}{K_t^{1-\delta}}\right)^{\frac{1}{\delta}} \frac{1}{\delta} K_{t+1}^{\frac{1}{\delta}-1} + C_{t+1}^{-\rho} \frac{(\delta-1)\beta}{\delta} K_{t+2}^{\frac{1}{\delta}} K_{t+1}^{-\frac{1}{\delta}} \quad \text{for all } t.$$

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

$$\frac{\alpha\beta C_{t+1}^{-\rho} y_{t+1}}{K_{t+1} P_{t+1}} = \frac{C_t^{-\rho}}{\delta} \frac{K_{t+1}^{\frac{1}{\delta}-1}}{K_t^{\frac{1-\delta}{\delta}}} + \frac{\beta(\delta-1) C_{t+1}^{-\rho}}{\delta} \left(\frac{K_{t+2}}{K_{t+1}}\right)^{\frac{1}{\delta}} \quad \text{for all } t.$$

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:

$$\begin{aligned}
y_{j,t} &= \frac{(y_{j,t}/y_t)^{\frac{1}{1-\sigma}}}{\gamma_j P_{j,t}} A_{j,t} L_{j,t}^{1-\alpha} K_{j,t}^{\alpha} \quad \text{for all } j \text{ and } t, \\
y_t &= \sum_j y_{j,t} \quad \text{for all } t, \\
y_{j,t} &= P_{j,t} C_{j,t} + P_{j,t} \left(\frac{K_{j,t+1}}{K_{j,t}^{1-\delta}}\right)^{\frac{1}{\delta}} \quad \text{for all } j \text{ and } t, \\
P_{j,t} &= \left[\sum_i \left(\frac{t_{ij,t}}{P_{i,t}}\right)^{1-\sigma} \frac{y_{i,t}}{y_t}\right]^{\frac{1}{1-\sigma}} \quad \text{for all } j \text{ and } t, \\
\frac{\alpha\beta C_{j,t+1}^{-\rho} y_{j,t+1}}{K_{j,t+1} P_{j,t+1}} &= \frac{C_{j,t}^{-\rho}}{\delta} \frac{K_{j,t+1}^{\frac{1}{\delta}-1}}{K_{j,t}^{\frac{1-\delta}{\delta}}} + \frac{\beta(\delta-1) C_{j,t+1}^{-\rho}}{\delta} \left(\frac{K_{j,t+2}}{K_{j,t+1}}\right)^{\frac{1}{\delta}} \quad \text{for all } j \text{ and } t. \qquad \text{(A34)}
\end{aligned}$$

Note that Equation (A34) only gives a relationship for determining the capital stocks, it is no longer an analytical expression for next period capital stocks, but rather the consumption Euler-equation.

What does this new system imply for our results:

1. Concerning the empirical specification, we see that the trade cost estimates and the output equation estimates do not change at all. Hence, trade costs, α and σ would be estimated as we did so far. However, we could not estimate a capital equation. Hence, we would not be able to back out δ's and establish a causal relationship between trade liberalization and capital accumulation.

2. Let us next study the implications for the steady-state (SS). In SS, Equation (A34)

reads as:

$$
\begin{aligned}
\frac{\alpha\beta C_j^{-\rho} y_j}{K_j P_j} &= \frac{C_j^{-\rho}}{\delta} \frac{K_j^{\frac{1}{\delta}-1}}{K_j^{\frac{1-\delta}{\delta}}} + \frac{\beta(\delta-1) C_j^{-\rho}}{\delta} \left(\frac{K_j}{K_j}\right)^{\frac{1}{\delta}} \Rightarrow \\
\frac{\alpha\beta y_j}{K_j P_j} &= \frac{1}{\delta} + \frac{\beta(\delta-1)}{\delta} \Rightarrow \\
K_j &= \frac{\delta}{1+\beta(\delta-1)} \frac{\alpha\beta y_j}{P_j} \Rightarrow \\
K_j &= \frac{\alpha\beta\delta y_j}{(1-\beta+\beta\delta) P_j}.
\end{aligned}
$$

Given this solution for the steady-state capital stock, which is again a function of parameters and y/P, all our analytical insights from Sections 2 and 3 of this document go through. Actually, the expression for the steady-state capital stock is identical to our expression for the steady-state capital stock in our baseline setting. Also consumption in steady-state is identical:

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

This shows that consumption is given by exactly the same function as in the case of our log-linear intertemporal utility function.

3. For our counterfactuals, we have to back out A/γ. This can be done in the exact same fashion, given that we can determine the steady-state capital stock.

Concerning welfare, we have to take care to use the iso-elastic utility function. Additionally, for our Lucas formula, we now have:

$$
\begin{aligned}
\sum_{t=0}^{\infty} \beta^t \frac{C_{j,t,c}^{1-\rho} - 1}{1-\rho} &= \sum_{t=0}^{\infty} \beta^t \frac{\left[\left(1+\frac{\lambda}{100}\right) C_{j,t}\right]^{1-\rho} - 1}{1-\rho} \Rightarrow \\
\sum_{t=0}^{\infty} \beta^t C_{j,t,c}^{1-\rho} &= \sum_{t=0}^{\infty} \beta^t \left[\left(1+\frac{\lambda}{100}\right) C_{j,t}\right]^{1-\rho} \Rightarrow \\
\left(1+\frac{\lambda}{100}\right)^{1-\rho} &= \frac{\sum_{t=0}^{\infty} \beta^t C_{j,t,c}^{1-\rho}}{\sum_{t=0}^{\infty} \beta^t C_{j,t}^{1-\rho}} \Rightarrow \\
\lambda &= \left[\left(\frac{\sum_{t=0}^{\infty} \beta^t C_{j,t,c}^{1-\rho}}{\sum_{t=0}^{\infty} \beta^t C_{j,t}^{1-\rho}}\right)^{\frac{1}{1-\rho}} - 1\right] \times 100.
\end{aligned}
$$