Growth and Trade with Frictions: A Structural Estimation Framework*

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Abstract

We build and estimate a structural dynamic general equilibrium model of growth and trade. Gravity is combined with a capital accumulation mechanism driving transition between steady states. Trade affects growth through changes in consumer and producer prices that stimulate or impede physical capital accumulation. Simultaneously, growth affects trade, directly through changes in country size and indirectly through changes in the incidence of trade costs. Theory maps to an econometric system that identifies the structural parameters of the model. Counterfactual trade liberalization magnifies static gains on the discounted path to the steady state by a *dynamic path multiplier* of around 1.6.

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1 Introduction

The relationship of trade and growth has been a central concern of economists since Adam Smith. More than two centuries later debate continues about an empirically strong relationship between trade and growth.[1] Despite academic doubts, 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] These observations motivate our development and estimation of a structural dynamic model of trade and transitional capital accumulation. Accumulation effects are big. Counterfactual simulations of two different trade liberalization experiments with the fitted model yield discounted dynamic gains over the path to the steady state that are more than 60% larger than static gains, a *dynamic path multiplier* around 1.6. Multipliers do not vary much with economy size, in contrast to the static gains that are larger in smaller economies.

The model features many countries that are asymmetric in size, in bilateral trade frictions and in capital accumulation frictions. The CES Armington trade gravity model is combined with a Lucas and Prescott (1971) capital accumulation model of transition between steady states. Two frictions interact on stage: costly trade and costly capital adjustment. Capital stock adjustment in each country is subject to iceberg trade costs because capital requires

[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."

Better models could help, but Head and Mayer (2014) note that the best fitting trade model (gravity) is static, and "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 (2014) 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, 2014, p. 1212).

[2] Press release, Brussels, 28 January 2014, 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." (Office of the Press Secretary, White House, January, 2014, http://iipdigital.usembassy.gov/st/english/texttrans/2014/01/20140114290784.html#axzz2u59pirmD.)

imports, but in addition costly adjustment and depreciation act essentially like iceberg frictions on the intertemporal margin. At each point in time bilaterally varying iceberg trade frictions are consistently aggregated into productivity shifters in the form of national multilateral resistances. Over time, the log-linear utility and log-linear capital transition function setup of Lucas and Prescott (1971) and Hercowitz and Sampson (1991) applied here yields a closed-form solution for optimal accumulation by infinitely lived representative agents with perfect foresight.[3] The closed-form solution for accumulation is the bridge to structural estimation of an econometric system of growth and trade.[4]

The estimated model allows quantification of the causal effect of openness on income and growth. It also provides all the key structural parameters needed to simulate counterfactuals with the model.[5] Counterfactual liberalization experiments with the estimated model decompose and quantify the various channels through which trade affects growth and through which growth impacts trade. To compare dynamic gains from liberalization with a static alternative, we follow Lucas (1987) to calculate the constant fraction of aggregate consumption in each year that consumers would need to be paid in the baseline case to give them the same utility they obtain from the consumption stream in the counterfactual.

Our model adds dynamics to the family of new quantitative static trade models, such as Eaton and Kortum (2002) and Anderson and van Wincoop (2003) (as summarized in Costinot and Rodríguez-Clare, 2014). In doing so, we extend an earlier literature (i.e., Solow, 1956; Acemoglu and Zilibotti, 2001; Acemoglu and Ventura, 2002; Alvarez and Lucas, Jr.,

[3] More recently, the log-linear capital transition function was, for example, used by Eckstein et al. (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.

[4] 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 et al. (1992, 1994). In our robustness analysis (see online Appendix C.3) 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.

[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 the capital (labor) share in production, of the capital stock transition parameter, and of bilateral trade costs. The estimates are all comparable to corresponding values from the literature.

2007), and we complement some new influential papers (i.e., Sampson, 2016; Eaton et al., 2016) that study the dynamics of trade. These studies calibrate their models in arguably more complex environments. In contrast, we deliver a structural econometric system that allows us to test and establish causal relationships between trade, income, and growth and delivers the key parameters 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.

The macroeconomic literature has suggested two prominent ways to make spatial dynamic models tractable. First, Krusell and Smith, Jr. (1998) show that in stochastic, macroeconomic models with heterogeneity features, aggregate variables (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 (2014) deliver a tractable, stochastic dynamic framework, where the firm's dynamic decision to innovate reduces to a sequence of static profit-maximization problems, by imposing structure that disciplines the mobility of labor, land-ownership by the firm, and the diffusion of technology.[6] The tractability of our deterministic framework comes from gravity structure that consistently aggregates bilateral trade frictions for each country into multilateral resistance exact indexes, reducing the $N \times N \times T$ trade links into $2N \times T$ multilateral resistance terms, with N denoting the number of countries and T the number of years.

We abstract from non-zero steady-state growth for simplicity.[7] We also abstract from endogenous technological change, but changes in multilateral resistance are effectively a type of endogenous technological change.

The structural gravity setup of Anderson and van Wincoop (2003) based on constant

[6] The usefulness of this approach is shown by Desmet and Rossi-Hansberg (2015) who apply it to study the geographic impact of climate change, and Desmet et al. (2016) who develop a dynamic spatial growth theory with realistic geography to study the effects of migration and of a rise in the sea level.

[7] Growth in our framework is exclusively driven by capital accumulation. Please see the literature review Section 2 for motivation of this choice. Further, consistent with the description of the role of capital accumulation in transitional dynamics in Grossman and Helpman (1991), our framework generates transitional but not steady-state growth. Thus, if not mentioned explicitly otherwise, when we use the term "growth" we have in mind capital accumulation between steady states.

elasticity of substitution (CES) preferences over products differentiated by place of origin (Armington, 1969) forms the trade module of the model.[8] Recent work by Arkolakis et al. (2012, henceforth also ACR) argues that gains from trade measures in such models represent a general class of models for which the key parameter is a single trade elasticity. 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 following Eaton and Kortum (2002) confirms that qualitative properties are the same while quantitative results shift significantly.

We implement the dynamic structural gravity model on a sample of 82 countries over the period 1990–2011. First, we translate the model into a structural econometric system that offers a theoretical foundation to and expands the famous reduced-form specification of Frankel and Romer (1999). In addition, we complement Frankel and Romer (1999) and a series of other studies by proposing three novel instruments derived from structural gravity to identify the effects of trade openness on income.[9] Similar to Frankel and Romer (1999) and other related studies, 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

[8]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 et al. (2008), and Chaney (2008) derived structural gravity based on selection (hence substitution on the extensive margin) in a Ricardian framework. Costinot et al. (2012) and Caliendo and Parro (2015) build on Eaton and Kortum (2002) to offer solid theoretical foundations for empirical gravity analysis in a multi-sector Ricardian setting and a multi-sector setting with intermediates, respectively. As noted by Eaton and Kortum (2002) and Arkolakis et al. (2012), a large class of models generate isomorphic gravity equations. Anderson (2011) and Costinot and Rodríguez-Clare (2014) summarize the alternative theoretical foundations of economic gravity.

[9]Notable studies that propose alternative instruments for trade/trade openness in Frankel-Romer settings include Redding and Venables (2004), that uses a version of their market access index, Feyrer (2009b), that proposes a new time-varying geographic instrument which capitalizes on the fact that country pairs with relatively short air routes have benefited more from improvements in technology, Feyrer (2009a), that exploits the closing of the Suez canal as a natural experiment, Lin and Sim (2013), that constructs a new measure of trade cost based on the Baltic Dry Index, and Felbermayr and Gröschl (2013), that uses natural disasters as an instrument. See Sections 4.1.2 and 4.3.2 for further details and performance of our instrument.

that captures the effects of trade openness on capital accumulation. The estimation of our structural system yields estimates of all but one of the model parameters.

Two counterfactual liberalization experiments quantify and decompose the relationships between growth and trade, each based on the newly constructed trade costs combined with data on the rest of the variables in our model. These experiments reveal that the dynamic effects of trade liberalization lead to an over 60 percent increase in the corresponding static effects, implying a *dynamic path multiplier* of around 1.6.

In the first experiment we find that the average welfare for the North American Free Trade Agreement (NAFTA) members increases from 1.27% to 2.06%. Following Estevadeordal and Taylor (2013), we calculate a yearly growth rate effect of NAFTA for the first 15 years of adjustment of about 0.116%, while for the non-NAFTA countries we find a small negative effect of -0.001%. Hence, our framework implies an acceleration in growth rates of real gross domestic product (GDP) in NAFTA countries compared to non-NAFTA countries of about 0.117% per year for the first 15 years after the implementation of NAFTA.[10] The second, *'globalization'*, experiment examines the effect of a *uniform* fall in international trade costs of 6.4%. All countries gain, smaller ones gain more, and the *dynamic path multiplier* is around 1.6 for all countries despite the big differences in size.

We view the simplicity, tractability, ability to test for key causal relationships and to estimate all structural parameters within the same model as important advantages of our dynamic structural estimating gravity framework. These benefits come at the cost of some important abstractions. We devoted significant effort to accommodate and discuss the implications of a series of potential improvements and generalizations that have been proposed in the related literature including: alternative specifications for capital accumulation (in online

[10] Estevadeordal and Taylor (2013) use a small open developing economy model to motivate their empirical difference equation. They use a treatment-and-control approach to compare the acceleration in growth rates of real GDP in liberalizing countries compared to non-liberalizing countries. The main finding is a difference in the two groups' trends of about 1% per year. Our comparable finding of 0.12% is based on a structural model taking care of all general equilibrium effects which is not possible with a treatment-and-control approach and potentially biasing the results substantially (see Heckman and Taber, 1998). Sampson (2016) finds in a setting with heterogeneous firms that the dynamic effects of trade liberalization triple.

Appendix K); allowing for intermediate goods (in online Appendix L); deriving the model with an iso-elastic utility function (in online Appendix M); deriving an ACR-type formula in steady state (in online Appendix E.1) and out-of steady state (in online Appendix E.2); solving our dynamic system of growth-and-trade in changes (in online Appendix H); and checking the robustness of our results to alternative values for all structural parameters (in online Appendix C).

Other difficult but important extensions include the development of a dynamic multi-sector framework (with no-traded goods) in the spirit of Costinot et al. (2012); allowing for international lending or borrowing, following Eaton et al. (2016); incorporating foreign direct investment, and modeling labor markets.[11] We leave these extensions for future research.

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

2 Relation to Literature

Our work contributes to several influential strands of the literature. First, we build a bridge between the empirical and theoretical literature 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.[12] 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

[11]Extending our framework to accommodate these forces while preserving the closed-form solution for accumulation may be challenging but feasible because either relaxation implies a contemporaneous allocation of investment across sectors and/or countries with an equilibrium that can nest in the intertemporal allocation of the dynamic model.

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

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.

More recently, Eaton et al. (2016) find that "[...] a decline in the efficiency of investment in durable manufacturing capital stocks drove the stunning collapse in trade and in manufacturing production that accompanied the global recession." (p. 32). Egger and Nigai (2016) undertook a trade-growth accounting exercise and found that "[o]verall, the preferable dynamic, endogenous-endowments-and-technology model suggested that (shocks to) endowment accumulation, trade costs, and productivity—in that order—were the most important drivers of world trade between 1988 and 2007." (p. 29).

These studies motivate our focus on capital accumulation as the source of growth in our model.[13] We extend this literature in three ways. First, we offer a theoretical equation that corresponds directly to the reduced-form specification of Frankel and Romer (1999). Second, we propose three novel instruments for trade openness derived from estimated structural gravity. Third, 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),[14] 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

[13] 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).

[14] The work of Eaton and Kortum that is most closely related to our study is thoroughly summarized in their manuscript Eaton and Kortum (2005). Most relevant to our work are their chapters ten and eleven, which study how trade in capital goods possibly transmits technological advances and investigate the geographical scope of technological progress in a multi-country (semi)endogenous growth framework, respectively. For a thorough review of the earlier theoretical literature on trade and (endogenous) technology, we refer the reader to Grossman and Helpman (1995). More recent developments include Acemoglu and Zilibotti (2001), Acemoglu and Ventura (2002), Alvarez and Lucas, Jr. (2007), Sampson (2016), and Eaton et al. (2016).

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 of our model is equivalent to EK if we add a flow use of intermediate goods to the flow of capital to offset depreciation. 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.[15]

Our approach is related to recent influential work by Eaton et al. (2016), EKNR hereafter. We share with EKNR the common elements of a gravity structure and capital accumulation specified as a perfect foresight Cobb-Douglas adjustment process as in Lucas and Prescott (1971). We differ in imposing the polar case of financial autarky in contrast to the complete markets polar case of EKNR and, less essentially, in assuming one good in contrast to the four goods of EKNR. Our strategy of simplification attains an estimatable system focused on the contribution of transitional growth on a trend line of trade policy. EKNR focus on a real business cycle decomposition of the sources of the Great Recession trade collapse, where key parameter values are assumed and trade friction and investment efficiency shocks are inferred using the "wedges" technique of Chari et al. (2007). Another difference is that EKNR's sectoral setting allows for the capturing of structural changes in response to trade liberalization while our framework is aggregate. Our approach is suited to thinking about the impact of a trade policy shift such as a big regional trade agreement starting in the neighborhood of an economy-wide steady state, using estimated parameters that best fit the model to the panel data of that steady state for the countries and years chosen.

Our model is also related to Acemoglu and Ventura (2002), who develop an AK-model with trade in intermediates and without capital depreciation in continuous time to show that even without diminishing returns in production of capital, international trade leads to a

[15]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.

stable world income distribution due to terms-of-trade adjustments. Note that in Acemoglu and Ventura (2002) the optimal policy is "...to consume a fixed fraction of wealth." (p. 667). This is similar to our optimal policy rule in the case of a log-linear intertemporal utility function and a log-linear capital transition function. Besides the differences in the model structure (continuous time, trade in intermediates, no capital depreciation, and no diminishing returns to capital), the focus of Acemoglu and Ventura (2002) is to provide a framework with a stable world income distribution in an AK-setting. Our goal is to develop an estimable dynamic gravity framework suitable for ex-post and ex-ante policy evaluation.

From a modeling perspective, the model in the main part of our paper (with Cobb-Douglas capital accumulation) can be viewed as a Solow model because, as in Solow, consumption and investment are constant shares of real GDP in our setting with the log-linear capital accumulation function. However, there are two important differences. The first difference is that, in our case, the investment/consumption share is not just a single exogenously given parameter, but it rather consists of a combination of several structural parameters in the model. The second difference is that once we use linear capital accumulation (in our robustness analysis), we depart further from Solow as consumption and expenditure are no longer constant shares of real GDP, even with a log-linear intertemporal utility function.

We also contribute to the literature on the effects of RTAs with a framework to study their *dynamic* effects. Two results stand out. First, we find that the dynamic effects of RTAs are strong for member countries and relatively week for outsiders. Second, our NAFTA counterfactual experiment reveals the possibility for non-monotonic effects of preferential trade liberalization on non-member countries. As discussed earlier, the reason is a combination of the trade-driven growth of member countries and the fact that the falling incidence of trade costs for the producers in the growing member economies is shared with buyers in outside countries. These findings offer encouraging support in favor of ongoing trade liberalization and integration efforts.

A useful by-product of our model is a direct estimate of the trade elasticity, 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 and the fact that the trade elasticity is related to the elasticity of substitution σ by $1-\sigma$. With values of the elasticity of substitution between 4.1 and 11.3 (implying trade elasticities between -10.3 and -3.1) from alternative specifications and robustness experiments, our estimates of the elasticity of substitution are comparable to the ones from the existing literature, which usually vary between 2 and 12.[16] In the sensitivity experiments, we checked the robustness of our results using different values for the elasticity of substitution.

Finally, 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 (see footnote 8) by a structural dynamic model of trade, production and growth. On the empirical side, we build on leading static empirical gravity frameworks, e.g. Waugh (2010), that investigates the role of asymmetric trade costs for differences in standards of living and total factor productivity across countries, and Redding and Venables (2004), who structurally estimate a new economic geography model to evaluate the cross-country differences in income per capita and manufacturing wages, and 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.[17]

[16] See Eaton and Kortum (2002), Anderson and van Wincoop (2003), Broda et al. (2006) and Simonovska and Waugh (2014). Costinot and Rodríguez-Clare (2014) and Head and Mayer (2014) each offer a summary and discussion of the available methods to obtain estimates of the elasticity of substitution and trade elasticity parameters. For example, a value for the elasticity of substitution can be obtained by employing bilateral tariff data. Our structural model is compatible with and can incorporate (conditional on data availability) these methods to recover the elasticity of substitution.

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

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 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 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:

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

where $\Omega_{j,t}$ denotes the flow of investment in j at time t and $\delta \in (0,1]$ is the *capital stock transition parameter*.[18] Transition function (2) combines depreciation of old capital with costs of adjustment in embodying investment into new capital.[19]

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

[18]This term is apt, but there appears to be no standard term for δ in the literature.

[19]Alternatively, one could view (2) 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 $\Omega_{j,t}$ in any period. Further, in the long-run steady-state, the transition function implies full depreciation. Despite these limitations, we prefer this function over the more standard linear capital accumulation function for our main analysis. The benefits are: (i) a tractable closed-form solution of our model; and (ii) a self-sufficient structural system that can be estimated. In online Appendices K and C.3, respectively, we re-derive our model and we perform sensitivity experiments with a linear capital accumulation function. Even though this function no longer allows for a closed-form solution and requires the use of external calibrated parameters, we do find qualitatively identical and quantitatively similar results.

utility subject to a sequence of constraints:

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

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

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

$$E_{j,t} = P_{j,t} C_{j,t} + P_{j,t} \Omega_{j,t}, \ \forall t \tag{6}$$

$$E_{j,t} = \phi_{j,t} Y_{j,t}, \ \forall t \tag{7}$$

$$K_{j,0} \quad \text{given.} \tag{8}$$

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

$$C_{j,t} = \left(\sum_i \gamma_i^{\frac{1-\sigma}{\sigma}} c_{ij,t}^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}, \tag{9}$$

$$\Omega_{j,t} = \left(\sum_i \gamma_i^{\frac{1-\sigma}{\sigma}} I_{ij,t}^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}. \tag{10}$$

Equation (9) 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 (10) 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 $i \neq j$ ($I_{ij,t}$).[20]

[20] The assumption that consumption and investment goods are both a combination of all world varieties subject to the same CES aggregation is very convenient analytically. In addition, it is also consistent with our aggregate approach in this paper. Allowing for heterogeneity in preferences and prices between and within consumption and investment goods will open additional channels for the interaction between trade and growth which require sectoral treatment. This is beyond the scope of this paper, and we refer the reader to Osang and Turnovsky (2000), Mutreja et al. (2014), and Eaton et al. (2016) for efforts in that direction.

Let $p_{ij,t} = p_{i,t}t_{ij,t}$ denote the price of country i goods for country j consumers, where $t_{ij,t}$ is the variable bilateral trade cost factor on shipment of commodities from i to j at time t. Technologically, a unit of distribution services required to ship goods uses resources in the same proportions as does production. The units of distribution services required on each link vary bilaterally. Trade costs can be interpreted by the standard iceberg melting metaphor; it is as if goods melt away so that 1 unit shipped becomes $1/t_{ij,t} < 1$ units on arrival.

System (3)-(8) decomposes into a nested two-level optimization problem. The lower level problem obtains the optimal demand of $c_{ij,t}$ and $I_{ij,t}$, for given $C_{j,t}$, $\Omega_{j,t}$, and $Y_{j,t}$. The upper level dynamic optimization problem solves for the optimal sequence of $C_{j,t}$ and $\Omega_{j,t}$. Consider the lower level first. Let $X_{ij,t}$ denote country j's total nominal spending on goods from country i at time t. The agents' optimization of (9)-(10), subject to $E_{j,t} = \phi_{j,t}Y_{j,t} = \sum_i X_{ij,t} = \sum_i p_{ij,t}(c_{ij,t} + I_{ij,t})$, taking $C_{j,t}$ and $\Omega_{j,t}$ as given, and using (6) yields:

$$X_{ij,t} = \left(\frac{\gamma_i p_{i,t} t_{ij,t}}{P_{j,t}}\right)^{1-\sigma} E_{j,t}, \tag{11}$$

where $P_{j,t} = \left[\sum_i (\gamma_i p_{i,t} t_{ij,t})^{1-\sigma}\right]^{1/(1-\sigma)}$ is the CES price aggregator index for country j at time t. Note that equation (11) implies that the partial elasticity of relative imports $(X_{ij,t}/X_{jj,t})$ with respect to variable trade costs, referred to as "trade elasticity" (see Arkolakis et al., 2012), is given by $(1-\sigma)$. Market clearance, $Y_{i,t} = \sum_j X_{ij,t}$, implies:

$$Y_{i,t} = \sum_j (\gamma_i p_{i,t})^{1-\sigma} (t_{ij,t}/P_{j,t})^{1-\sigma} E_{j,t}. \tag{12}$$

(12) 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:

$$(\gamma_i p_{i,t} \Pi_{i,t})^{1-\sigma} = Y_{i,t}/Y_t, \tag{13}$$

where $\Pi_{i,t} \equiv \left[\sum_j \left(\frac{t_{ij,t}}{P_{j,t}}\right)^{1-\sigma} \frac{E_{j,t}}{Y_t}\right]^{1/(1-\sigma)}$. Using (13) to substitute for the power transform of factory-gate prices, $(\gamma_i p_{i,t})^{1-\sigma}$ in equation (11) above and in the CES consumer price aggregator following (11), delivers the gravity system of Anderson and van Wincoop (2003):

$$X_{ij,t} = \frac{Y_{i,t}E_{j,t}}{Y_t}\left(\frac{t_{ij,t}}{\Pi_{i,t}P_{j,t}}\right)^{1-\sigma}, \tag{14}$$

$$P_{j,t} = \left[\sum_i \left(\frac{t_{ij,t}}{\Pi_{i,t}}\right)^{1-\sigma}\frac{Y_{i,t}}{Y_t}\right]^{\frac{1}{1-\sigma}}, \qquad \Pi_{i,t} = \left[\sum_j \left(\frac{t_{ij,t}}{P_{j,t}}\right)^{1-\sigma}\frac{E_{j,t}}{Y_t}\right]^{\frac{1}{1-\sigma}}. \tag{15}$$

Equation (14) intuitively links bilateral exports to market size (the first term on the right-hand side) and trade frictions (the second term on the right-hand side). Coined by Anderson and van Wincoop (2003), $\Pi_{i,t}$ and $P_{j,t}$ 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.

The upper level dynamic optimization problem solves for sequence $\{C_{j,t}, \Omega_{j,t}\}$. As discussed 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. The solution for the policy function of capital is given by (see for details online Appendix A):

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

Policy function (16) is consistent with infinitely forward looking agents despite the appearance of one period ahead prices only. This is due to the log-linear functional form of both preferences and capital accumulation, implying that marginal rates of substitution are proportional to the ratio of present to one-period-ahead consumption or capital stocks.[21]

[21] In online Appendix B we confirm that our results are replicated by the standard dynamic solution method using Dynare (Adjemian et al., 2011, http://www.dynare.org/). Thus, we solve our models in two completely different ways leading to exactly the same results: i) we use our analytically derived policy function and solve the transition by starting from the baseline steady state and solving for subsequent periods until convergence

As expected, (16) depicts the direct relationship between capital stock in period $t+1$ and the levels of technology $A_{j,t}$, labor endowment $L_{j,t}$, and current capital stock $K_{j,t}$. More important for the purposes of this paper, (16) 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 $P_{j,t}$.[22] 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 invest more. 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. This reduces the incentive to build up capital.

The relationships between prices and capital accumulation are crucial for understanding the relationships between growth and trade. Changes in trade costs will result in changes in international prices, which will affect capital accumulation. Specifically, the inward multilateral resistance from equation (15) consistently aggregates the changes in bilateral trade costs between any pair of countries in the world for a given economy. Thus, 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 (16) 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 to trade, producers in this country enjoy lower outward MR, which, according to equation (13), translates into higher factory-gate prices. Outsiders face higher outward MR, their factory-gate prices fall, and investment falls.

to the counterfactual steady state. ii) we use the first-order conditions and solve our non-linear equation system using Dynare. We also use Dynare to solve our model when we employ the linear capital accumulation function as a robustness check in online Appendix C.3.

[22] 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.

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

$$\Omega_{j,t} = \left[\frac{\phi_{j,t}p_{j,t}A_{j,t}L_{j,t}^{1-\alpha}\alpha\beta\delta}{P_{j,t}\left(1-\beta+\beta\delta\right)}\right]K_{j,t}^{\alpha} = \left[\frac{\alpha\beta\delta}{1-\beta+\beta\delta}\right]\frac{E_{j,t}}{P_{j,t}}, \tag{17}$$

$$C_{j,t} = \left[\frac{1-\beta+\beta\delta-\alpha\beta\delta}{1-\beta+\beta\delta}\right]\frac{\phi_{j,t}p_{j,t}A_{j,t}L_{j,t}^{1-\alpha}K_{j,t}^{\alpha}}{P_{j,t}} = \left[\frac{1-\beta+\beta\delta-\alpha\beta\delta}{1-\beta+\beta\delta}\right]\frac{E_{j,t}}{P_{j,t}}, \tag{18}$$

$$E_{j,t} = \phi_{j,t}Y_{j,t} = \phi_{j,t}p_{j,t}A_{j,t}L_{j,t}^{1-\alpha}K_{j,t}^{\alpha}. \tag{19}$$

System (17)-(19) reveals that aggregate consumption and aggregate investment at the upper level are linked to the lower level via the general equilibrium consumer price indexes and factory-gate prices. 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 aggregate spending. This is due to the log-linear functional form of capital accumulation that enables us to obtain an analytical solution for the capital policy function.[23] Note that when there are no costs in adjustment of the volume of capital, i.e., $\delta = 1$, (16)-(19) implies that adjustment to the steady state is instantaneous. Thus adjustment costs for capital play the same role in capital adjustment (17) as iceberg costs play in gravity equation (14).[24]

The combination of the lower level gravity system (14)-(15), the market clearing conditions (13), the policy function for capital (16), as well as the definition of nominal output (1) delivers our theoretical model of growth and trade:

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

[24] In the special case where the trade costs reflect home bias in preferences, the similarity is even closer.

$$
\begin{aligned}
X_{ij,t} &= \frac{Y_{i,t}\phi_{j,t}Y_{j,t}}{Y_t}\left(\frac{t_{ij,t}}{\Pi_{i,t}P_{j,t}}\right)^{1-\sigma}, && (20)\\
P_{j,t} &= \left[\sum_i \left(\frac{t_{ij,t}}{\Pi_{i,t}}\right)^{1-\sigma}\frac{Y_{i,t}}{Y_t}\right]^{\frac{1}{1-\sigma}}, && (21)\\
\Pi_{i,t} &= \left[\sum_j \left(\frac{t_{ij,t}}{P_{j,t}}\right)^{1-\sigma}\frac{\phi_{j,t}Y_{j,t}}{Y_t}\right]^{\frac{1}{1-\sigma}}, && (22)\\
p_{j,t} &= \frac{(Y_{j,t}/Y_t)^{\frac{1}{1-\sigma}}}{\gamma_j\Pi_{j,t}}, && (23)\\
Y_{j,t} &= p_{j,t}A_{j,t}L_{j,t}^{1-\alpha}K_{j,t}^{\alpha}, && (24)\\
K_{j,t+1} &= \left[\frac{\alpha\beta\delta\phi_{j,t}p_{j,t}A_{j,t}L_{j,t}^{1-\alpha}}{(1-\beta+\beta\delta)\,P_{j,t}}\right]^{\delta}K_{j,t}^{\alpha\delta+1-\delta}, && (25)\\
K_{j,0} & \quad \text{given.}
\end{aligned}
$$

The beauty of system (20)-(25) 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.[25] Our strategy in the subsequent sections is to translate system (20)-(25) 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, which are needed to perform our counterfactual experiments. Before that, however, we discuss the structural effects of trade on growth that our model offers.

3.1 Growth and Trade: A Discussion

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 in relative prices affect accumulation, and accumulation affects next period trade. Higher

[25](20)-(25) is a well-behaved dynamic problem. We show in Section A.2 that the following transversality condition always holds: $\lim_{t\to\infty}\beta^t\frac{\partial F(K_{j,t}^*,K_{j,t+1}^*)}{\partial K_{j,t}}K_{j,t}^* = 0$, where $F \equiv \ln\left[\left(\phi_{j,t}p_{j,t}A_{j,t}L_{j,t}^{1-\alpha}K_{j,t}^{\alpha}\right)/P_{j,t} - \left(K_{j,t+1}/K_{j,t}^{1-\delta}\right)^{1/\delta}\right]$, and stars denote the solutions of the dynamic problem. With the given parameter restrictions on α, β, and δ, the solution for the endogenous variables of system (20)-(25) can be shown to be unique. This is demonstrated in Allen et al. (2014), and more specifically in the accompanying note, "Capital Dynamics", which covers our case.

producer prices increase accumulation because they imply higher returns to investment. 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 with 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.

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.[26]

[26]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 cannot 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. Austria), the dynamic forces in our framework lead to trade creation effects that are stronger than the

The long-run effects of trade costs on growth are captured by the comparative statics of the steady states. Steady-state capital is $K_j = (\alpha\beta\delta\phi_j Y_j)/[(1-\beta+\beta\delta)P_j]$. The ratio of steady-state capital stocks between the counterfactual steady state, K_j^c, and the baseline steady state, K_j^b, can be expressed as (see online Appendix D for a detailed derivation): $\widehat{K}_j = K_j^c/K_j^b = \widehat{P}_j^{\frac{-\sigma}{\sigma(1-\alpha)+\alpha}}\widehat{\Pi}_j^{\frac{1-\sigma}{\sigma(1-\alpha)+\alpha}}\widehat{Y}^{\frac{1}{\sigma(1-\alpha)+\alpha}}$. This expression is intuitive. First, if P_j increases, capital accumulation becomes more expensive and investment decreases, because P_j captures the price of investment as well as consumption. Second, increases in sellers' incidence Π_j reduce capital accumulation because Π_j affects p_j inversely, so the value marginal product of capital falls with Π_j, decreasing the incentive to invest. 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.

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 λ_{jj} denotes the share of domestic expenditure and "hat" denotes the ratio of the counterfactual and baseline value. Motivated by ACR, we show (in online Appendix E) that the change in capital can directly affect welfare by deriving an extended ACR formula:

$$\widehat{W}_j = \widehat{K}_j^{\alpha}\widehat{\lambda}_{jj}^{\frac{1}{1-\sigma}}. \tag{26}$$

Equation (26) implies that an increase of steady-state capital will, ceteris paribus, increase welfare. The extended ACR formula given in (26) holds in and out-of steady state. Furthermore, as demonstrated in online Appendix E, we can express $\widehat{K}_j$ in terms of $\widehat{\lambda}_{jj}$ in steady state, leading to $\widehat{W}_j = \widehat{\lambda}_{jj}^{\frac{1}{(1-\alpha)(1-\sigma)}}$. This expression nicely highlights the similarity of introducing capital or intermediates in the steady state (compare with ACR, p. 115). In steady-state, the new level of capital stocks can be equally thought of as different amounts of intermediate goods in production. However, intermediate goods are not able to explain dynamic adjustments to trade liberalization, as highlighted by Baier et al. (2014) and Anderson and Yotov (2016), and which is at the heart of our structural, dynamic model.

initial static trade diversion effects. Details are available in Table A4 of online Appendix J.

We are also able to derive an ACR-like welfare formula, which only depends on $\widehat{\lambda}_{jj,t}$ and parameters when taking into account the transition (see online Appendix E.2). However, we will typically not observe changes in $\lambda_{jj,t}$ over time solely driven by the counterfactual under consideration. While the standard approach in a static setting is to measure welfare in terms of real GDP, our dynamic capital-accumulation framework requires some adjustments to this standard approach 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.[27] (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 ζ 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 ($C^c_{j,t}$). Specifically, we calculate:

$$\sum_{t=0}^{\infty} \beta^t \ln\left(C^c_{j,t}\right) = \sum_{t=0}^{\infty} \beta^t \ln\left[\left(1+\frac{\zeta}{100}\right) C^b_{j,t}\right] \Rightarrow$$

$$\zeta = \left(\exp\left[(1-\beta)\left(\sum_{t=0}^{\infty} \beta^t \ln\left(C^c_{j,t}\right) - \sum_{t=0}^{\infty} \beta^t \ln\left(C^b_{j,t}\right)\right)\right] - 1\right) \times 100. \tag{27}$$

4 Empirical Analysis

There are two possible approaches to take system (20)-(25) to data. The first is a *calibration* approach. It uses the model to recover some parameters and variables, e.g. bilateral trade costs, to match some data moments perfectly, and borrows other parameters, e.g. the trade elasticity, from the literature in order to perform counterfactual simulations. The second is an *estimation* approach. It employs the structural model equations to estimate own structural

[27] Given our closed-form solution of the policy function for capital and an initial capital stock $K_{j,0}$, this boils down to solving system (20)-(25) 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 computational details see online Appendix B.

parameters, which are then used in the counterfactual experiments.

Each approach has advantages and disadvantages, cf. Dawkins et al. (2001). While our framework readily lends itself to the *calibration* approach, our model is straightforward to implement econometrically and, therefore, it offers a unique opportunity to capitalize on the advantages of the *estimation* approach while making some meaningful contributions to the existing literature. Specifically, it simultaneously enables us to test and establish the causal relationships between trade, income, and growth, and it also delivers all the key parameters needed to perform counterfactuals.

The parameter estimates that we obtain are comparable 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 income-and-trade specification from Frankel and Romer (1999), but also expands on it by proposing novel instruments for trade openness and 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 equations 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 and zeros in trade data. 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 expenditure 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.[28]

The final step, which completes the econometric specification of our trade system, is to provide structure behind the unobservable bilateral trade costs $t_{ij,t}$. We employ a flexible country-pair fixed effects approach in order to account for all (observable and unobservable) time-invariant trade costs. In addition, we use RTAs to capture the effects of trade policy.[29] Econometrically, we have to address the potential endogeneity of RTAs. The issue of RTA endogeneity is well-known in the trade literature[30] 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 RTAs and the error term in our trade regressions.

Taking all of the above considerations into account, we employ PPML to estimate the following econometric specification of the *Trade equation* (20) from our structural system:

[28] 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.

[29] We chose to focus exclusively on RTAs in order emphasize the methodological contributions of our work. In principle, we also may introduce tariffs and other time-varying trade costs in the estimating gravity equation (28). However, bringing tariff revenues fully into the model opens Pandora's Box, because much of their distortionary effect (and much of the difficulty of negotiating regional trade agreements) is due to dispersion of rates across sectors within countries. Moreover, a proper treatment of effects of trade agreements via government revenue should in principle include effects on *domestic* distortionary tax collections, effects likely to be much larger (because tax rates are higher) than those from trade tax revenues. We refer the interested reader to Anderson and van Wincoop (2001) and to Egger et al. (2011) for modeling and empirical investigation of the role of heterogeneous tariff revenues in gravity models. Instead, here we choose to abstract from modeling such time-varying trade costs and potential tariff revenues and rents in order to be able to clearly isolate the pure dynamic effects of a single one-time trade shock, such as the introduction or the removal of an RTA, which will enable us to focus on and emphasize our methodological contributions.

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

$$X_{ij,t} = \exp[\eta_1 RTA_{ij,t} + \chi_{i,t} + \pi_{j,t} + \mu_{ij}] + \epsilon_{ij,t}, \tag{28}$$

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. $\chi_{i,t}$ 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. The error term is introduced because the relation between $X_{ij,t}$ and $\exp[\eta_1 RTA_{ij,t} + \chi_{i,t} + \pi_{j,t} + \mu_{ij}]$ holds on average but not for each observation (see Goldberger, 1991; Santos Silva and Tenreyro, 2006).[31] Importantly, μ_{ij} will absorb all time-invariant gravity covariates, such as bilateral distance, contiguous borders, common language and colonial ties, along with any other time-invariant determinants of trade costs that are not observable. We use the estimates of the country-pair fixed effects $\widehat{\mu}_{ij}$ from equation (28) to measure directly international trade costs in the absence of RTAs (for details please see online Appendix F):

$$\left(\widehat{t}_{ij}^{NORTA}\right)^{1-\sigma} = \exp\left[\hat{\mu}_{ij}\right]. \tag{29}$$

Bilateral trade costs that account for the presence of RTAs are constructed as follows:

$$\left(\widehat{t}_{ij,t}^{RTA}\right)^{1-\sigma} = \exp\left[\widehat{\eta}_1 RTA_{ij,t}\right]\left(\widehat{t}_{ij}^{NORTA}\right)^{1-\sigma}. \tag{30}$$

Below, we use (30) to study the dynamic general equilibrium effects of NAFTA and globalization in general on growth and welfare.

[31] The rich fixed effects structure (including bilateral fixed effects, exporter-time fixed effects, and importer-time fixed effects) of specification (28) supports the assumption of a stochastic error term, $\epsilon_{ij,t}$. However, it may still be possible that $\epsilon_{ij,t}$ carries some systematic trade cost information. Anderson et al. (2015) propose a hybrid approach, dubbed *"estibration"*, which uses an empirical gravity model similar to (28) to obtain estimates of the effects of trade policy and then adds the error to the trade cost function in order to match the trade flows data perfectly. We experimented with this method here to obtain virtually identical results, both in the estimations of our *Income* and *Capital* equations as well as in the counterfactual experiments. This gives us confidence to proceed and perform our main analysis while treating $\epsilon_{ij,t}$ as a stochastic error term.

4.1.2 Upper Level Econometric Specification: Income and Capital

Estimation of the equation for income allows a test for a causal relationship between trade openness and the value of production, and also obtains estimates of the trade elasticity and of the labor and capital shares in production. Estimation of the capital accumulation equation allows a test for a causal relationship between trade openness and growth and also delivers estimates of the capital depreciation rates. Begin with the estimating equation for income.

Income. Transforming the theoretical specification for income into an estimating equation is straightforward: substitute equation (23) for prices into equation (24), solve for $Y_{j,t}$ and express the resulting equation in natural logarithmic form:

$$\ln Y_{j,t} = \frac{1}{\sigma}\ln Y_t + \frac{\sigma-1}{\sigma}\ln\frac{A_{j,t}}{\gamma_j} + \frac{(\sigma-1)(1-\alpha)}{\sigma}\ln L_{j,t} + \frac{(\sigma-1)\alpha}{\sigma}K_{j,t} - \frac{1}{\sigma}\ln\left(\frac{1}{\Pi_{j,t}^{1-\sigma}}\right). \quad (31)$$

We keep the expression for the outward multilateral resistance as a power transform, $\Pi_{j,t}^{1-\sigma}$, because we can recover this power term directly from the exporter-fixed effects from the lower level trade gravity estimation procedures without the need to assume any value for the elasticity of substitution σ.[32] As demonstrated below, our methods also enable us to obtain our own estimate of σ.

We address several important econometric challenges in order to obtain sound estimates of the key coefficients in equation (31). First, we do not observe $A_{j,t}$ and data on γ_j are not available. To account for the latter, we introduce country-specific fixed effects ϑ_j. These country fixed effects will also absorb any time-invariant differences and variation in technology $A_{j,t}$ at the country level. In order to control for additional time-varying effects that may have affected technology globally, we also introduce time fixed effects ν_t. The year fixed effects will also control for any other common time-varying variables that may affect output in addition to the time-varying covariates that enter our specification explicitly. In addition, the year dummies will absorb the structural world output term $\frac{1}{\sigma}\ln Y_t$.

While we believe that the country fixed effects and the year fixed effects in our specifica-

[32] In fact, we capitalize on the property of the PPML estimator to be perfectly consistent with structural gravity (see Fally, 2015; Anderson et al., 2015), in order to recover the power transforms of the multilateral resistances directly from the directional gravity fixed effects.

tion will absorb most of the variability in technology $A_{j,t}$, it is still possible that we would miss some high-frequency moves in $A_{j,t}$ at the country-year level. We account for such movements by introducing several additional covariates as proxies for productivity. These include a direct TFP measure, a measure of R&D, and a measure of the occurrence of natural disasters. We label the vector of these additional covariates $TFP_{j,t}$.[33] Taking the above considerations into account, equation (31) becomes:

$$\ln Y_{j,t} = \kappa_1 \ln L_{j,t} + \kappa_2 \ln K_{j,t} + \kappa_3 \ln \left(\frac{1}{\Pi_{j,t}^{1-\sigma}} \right) + TFP_{j,t}\kappa_4 + \nu_t + \vartheta_j + \varepsilon_{j,t}, \tag{32}$$

where $\varepsilon_{j,t}$ is a remainder error term accounting for the fact that the relation between $\ln Y_{j,t}$ and the conditional expectation of $\ln Y_{j,t}$, given by $\kappa_1 \ln L_{j,t} + \kappa_2 \ln K_{j,t} + \kappa_3 \ln \left(\frac{1}{\Pi_{j,t}^{1-\sigma}} \right) + TFP_{j,t}\kappa_4 + \nu_t + \vartheta_j$, holds on average but not for each observation. 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/trade openness term, $\widehat{\kappa}_3$, will support a causal relationship of trade on income. In addition, $\widehat{\kappa}_3$ can be used to recover the elasticity of substitution directly as $\widehat{\sigma} = -1/\widehat{\kappa}_3$.[34] 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 (32), $\kappa_1 + \kappa_2 = 1 + \kappa_3$.

The next challenge to estimating equation (32) is that our measure of trade openness, $\ln \left(\frac{1}{\Pi_{j,t}^{1-\sigma}} \right)$, is endogenous by construction, because it includes own national income. The issue is similar to the endogeneity concern in the famous Frankel and Romer (1999). Our work complements and builds on Frankel and Romer (1999) in two ways. First, in combination, equations (28) and (32) deliver a structural foundation for the reduced-form trade-and-

[33] Further details on these variables and the data used for their construction appear in Section 4.2. 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 controls and country as well as time fixed effects is effective.

[34] The ability to estimate σ and correspondingly the trade elasticity $(1-\sigma)$ 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 and Costinot and Rodríguez-Clare, 2014). Furthermore, we will be able to compare our estimates with existing estimates in order to gauge the success of our methods.

income specification from Frankel and Romer (1999). Frankel and Romer use a version of *Trade equation* (28) to instrument for international trade, which enters their *Income equation* corresponding to equation (32) 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 openness on income are channeled via the structural trade term $\ln\left(1/\Pi_{j,t}^{1-\sigma}\right)$. Importantly, this will enable us not only to test for a causal relationship between trade openness and income, but also to recover an estimate for the elasticity of substitution $\hat{\sigma} = -1/\hat{\kappa}_3$.[35]

Our second contribution in relation to Frankel and Romer (1999) and related studies (see footnote 9) that have estimated trade-and-income regressions is that we propose three new instruments for trade openness. The first instrument eliminates the endogeneity resulting from own GDP by calculating the multilateral resistances based on international trade linkages only, removing the intra-national components that include national income and therefore cause endogeneity:[36]

$$\tilde{\Pi}_{i,t}^{1-\sigma} = \sum_{j \neq i} \left(\frac{t_{ij,t}}{P_{j,t}}\right)^{1-\sigma} \frac{Y_{j,t}}{Y_t}. \tag{33}$$

Despite removing the endogeneity of own GDP, $\tilde{\Pi}_{i,t}^{1-\sigma}$ may still not be completely exogenous. The reason is that higher-order endogeneity may be present based on equation (33) due to the indirect relationship between own national income and (i) the national incomes of all other countries and (ii) the inward multilateral resistances of all other countries. Such effects are indirect and tend to be small. Nevertheless, in theory such effects are present and may affect our estimates. To test for sensitivity to such residual endogeneity, we also employ a version of the original instrument proposed by Frankel and Romer (1999) in addition to the new instrument that we propose here. More specifically, we employ the inverse of the Frankel-Romer instrument since our structural trade openness index technically measures

[35] In the empirical analysis below we estimate system (28)-(32) with the original Frankel-Romer methods and with our structural approach and we compare our results.

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

the inverse of trade openness.

The second instrument that we introduce capitalizes on the structural relationships in our model and on the original intuition from Frankel and Romer (1999) to use labor instead of GDP to proxy for country size.[37] Specifically, we construct our second structural instrument by solving the multilateral resistance system with labor (instead of output) shares used as weights. Finally, our third instrument capitalizes on the panel dimension of our data and, once again, solves the multilateral resistance system, but this time with the initial levels of output used instead of the current output values. We offer further details on the instruments and their performance in Section 4.3.

The final challenge with the estimation of Specification (32) is that the labor and capital covariates are potentially endogenous as well. In Section 4.3 we account for these endogeneity concerns sequentially and we also treat all regressors from specification (32) simultaneously as endogenous by using a series of instruments that pass all relevant econometric IV tests.

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 (25) translates into a simple log-linear econometric model:

$$\ln K_{j,t} = \psi_1 \ln E_{j,t-1} + \psi_2 \ln K_{j,t-1} + \psi_3 \ln P_{j,t-1} + \varsigma_{j,t}. \tag{34}$$

Here, $\psi_1 = \delta$ 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

[37] We thank an anonymous referee for suggesting this instrument.

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. Finally, our model implies the following structural relationships $\psi_1 = -\psi_3$ and $\psi_1 = 1 - \psi_2$.[38]

Several econometric challenges must be met to estimate equation (34). First, each of the three regressors in specification (34) is potentially endogenous. We will address this challenge with an instrumental variable estimator. Second, equation (34) describes a dynamic process where capital stock in the current period is a function of capital stock in past periods, i.e., the dependent variable is determined by its past realizations. As discussed in detail in Roodman (2009), this gives rise to *dynamic panel bias* since the dependent variable is clearly correlated with country-specific effects in the error term. A straightforward approach to mitigate the dynamic panel bias is to explicitly control for the country fixed effects in our panel with the Least Squares Dummy Variables (LSDV) estimator. Specifically, we add to equation (34) country fixed effects (ϑ_j) and year fixed effects (ν_t) in order to control for any unobserved and omitted time-varying global effects that may affect capital accumulation:

$$\ln K_{j,t} = \psi_1 \ln E_{j,t-1} + \psi_2 \ln K_{j,t-1} + \psi_3 \ln P_{j,t-1} + \nu_t + \vartheta_j + \varsigma_{j,t}, \tag{35}$$

where $\varsigma_{j,t}$ is the remainder error term accounting for the fact that $\ln K_{j,t}$ and the conditional expectation of $\ln K_{j,t}$ given by $\psi_1 \ln E_{j,t-1} + \psi_2 \ln K_{j,t-1} + \psi_3 \ln P_{j,t-1} + \vartheta_j + \nu_t$ holds on average but not for each observation. Additionally, ν_t and ϑ_j control for the parameters $\delta \ln [(\alpha\beta\delta)/(1-\beta+\beta\delta)]$. In combination with the year dummies, the country fixed effects will not only mitigate the dynamic bias but also will control for any time-invariant country-specific characteristics that may affect capital accumulation but are omitted from our model, thus alleviating endogeneity concerns.

The rich set of fixed effects may not fully absorb all possible causes for endogeneity. Furthermore, the country fixed effects do not completely absorb the correlation between the

[38] In addition to delivering a single depreciation parameter δ, equation (34) 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.

dependent variable and the dynamic error term and our estimates are still subject to the Nickell (1981) dynamic bias. In order to address these concerns we use a series of instrumental variables and we employ the Arellano and Bond (1991) linear generalized method of moments (GMM) estimator. Further details on our empirical strategy are presented in Section 4.3.

4.1.3 A Structural Estimating System of Trade, Income, and Growth

In combination, equations (28), (32), and (35), deliver the econometric version of our structural system of growth and trade:

$$Trade: \quad X_{ij,t} = \exp[\gamma_1 RTA_{ij,t} + \chi_{i,t} + \pi_{j,t} + \mu_{ij}] + \epsilon_{ij,t}, \tag{36}$$

$$Income: \quad \ln Y_{j,t} = \kappa_1 \ln L_{j,t} + \kappa_2 \ln K_{j,t} + \kappa_3 \ln \left(\frac{1}{\Pi_{j,t}^{1-\sigma}} \right) + TFP_{j,t}\kappa_4 + \nu_t + \vartheta_j + \varepsilon_{j,t}, \tag{37}$$

$$Capital: \quad \ln K_{j,t} = \psi_1 \ln E_{j,t-1} + \psi_2 \ln K_{j,t-1} + \psi_3 \ln P_{j,t-1} + \nu_t + \vartheta_j + \varsigma_{j,t}. \tag{38}$$

With system (36)-(38) we obtain 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 equation* (32) and *Capital equation* (34), respectively. We demonstrate below. Before that we describe our data.

4.2 Data

Our sample covers 82 countries over the period 1990-2011.[39] These countries account for more than 98 percent of world GDP during that period. The data include trade flows, GDP, employment, capital and RTAs. Bilateral trade cost proxies are data on standard gravity variables including distance, common language, contiguity and colonial ties along with regional trade agreements in effect.

Data on GDP, employment, capital stocks, and total factor productivity (TFP) are from the Penn World Tables 8.0.[40] The Penn World Tables 8.0 offer several GDP variables.

[39]The list of countries and their respective labels can be found in online Appendix G.
[40]These series are now maintained by the Groningen Growth and Development Centre and reside at http://www.rug.nl/research/ggdc/data/pwt/.

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 based on cumulating and depreciating past investment using the perpetual inventory method. As a main measure for total factor productivity we use TFP level at current PPPs. For more detailed information on the construction and the original sources for the Penn World Tables 8.0 series see Feenstra et al. (2013). In addition, we also employ a measure for research and development (R&D) spending, which is taken from the World Development Indicators. Finally, we experiment with an instrument for occurrence of natural disasters, which comes from EM-DAT - The International Disaster Database.[41]

Aggregate trade data 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.

[41] http://www.emdat.be/database.

4.3 Estimation Results and Analysis

4.3.1 Trade Costs

Specification (28) delivers an estimate of the average treatment effect of RTAs that is equal to 0.827 (std.err. 0.135), which is readily comparable to the corresponding index of 0.76 from Baier and Bergstrand (2007).[42] This gives us confidence to use our estimate of the RTA effects to proxy for the effects of trade liberalization in the counterfactual experiments.

Without going into details and merely for demonstration purposes of the magnitudes of trade costs implied using country-pair fixed effects to calculate them, we briefly discuss several properties of the bilateral trade costs, which are constructed as $\widehat{t_{ij}} = exp(\hat{\mu}_{ij})^{1/(1-\hat{\sigma})}$, where we use a conventional value of the elasticity of substitution, $\hat{\sigma} = 6$.[43] All estimates of $\widehat{t_{ij}}$ are positive and greater than one. The mean estimate of bilateral trade costs is 5.569 (std.dev. 4.216). 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 Malaysia-Singapore (1.184), followed by Belgium-Netherlands (1.327). While more than 95% of our estimates of bilateral trade costs are smaller than 12, we also obtain some very large estimates of $\widehat{t_{ij}}$ for countries that are isolated economically and geographically. The largest estimate is for the pair Uzbekistan-Dominican Republic (132.7). Most other pairs with very large bilateral trade cost estimates also include as one partner one of the less developed former Soviet republics. This result is consistent with the findings of Waugh (2010) that trade flows in less developed countries are subject to larger trade costs. Another outlier pair is Israel-Iran (30.21). We note that these estimates are obtained directly from the pair fixed effects as a very flexible proxy for trade

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

[43] Head and Mayer (2014) survey the related literature and report average values and standard deviations of 744 elasticity estimates obtained from a sample of 32 papers. The mean estimate of σ from Head and Mayer (2014) when the selection criteria is "structural gravity" estimation, as in our analysis, is $\hat{\sigma} = 6.13$. Importantly, below we obtain our own structural estimate of $\hat{\sigma} = 5.847$ (std.err. 0.620), which is remarkably close to (and, in fact, not statistically different from) Head and Mayer's index. Here, just for presenting the magnitude of the trade costs, we assume the value of 6. See for details online Appendix F.

costs. This suggests that the standard set of proxies for trade costs that are routinely used in gravity estimations may miss to account for some important obstacles to international trade, especially among less developed pairs.

4.3.2 Income

Estimates from various specifications of *Income equation* (32) are reported in Table 1. All specifications include year fixed effects and country fixed effects, and we report standard errors that are robust or bootstrapped when a generated regressor enters the estimating equation directly. We begin with two benchmark specifications. In columns (1) and (2) of Table 1, respectively, we offer results from an unconstrained and from a constrained estimation of a standard Cobb-Douglas production function. As can be seen from the table, both the labor and the capital shares in each specification are within the theoretical bounds $[0; 1]$ even though the capital share is a bit higher than the standard corresponding value from the literature.[44]

Column (3) of Table 1 reports estimates of a Frankel-Romer type specification, where we introduce the log of international trade/total exports, $\ln \sum_{j \neq i} X_{ij,t}$, as an additional regressor in the unconstrained Cobb-Douglas estimation from column (1). As correctly noted by Frankel and Romer (1999), the trade regressor is endogenous. Therefore, we follow Frankel and Romer's strategy and perform an IV estimation, where bilateral exports are predicted in a first-stage gravity model by the standard gravity regressors (see for details online Appendix F) and by the logarithms of exporter and importer populations. Our first-stage gravity regression follows the recommendation of Feyrer (2009b) not to use exporter and importer fixed effects in a Frankel-Romer setting because the directional fixed effects will contaminate the IV estimation since they implicitly account for income and expenditure.

Results from the IV experiment are presented in column (3) of Table 1. Consistent with the findings of Frankel and Romer (1999), our estimates confirm that the effect of trade on income/growth is positive and statistically significant. In addition, our instruments pass the

[44] Below, we offer some validity checks with respect to the estimated capital share. Moreover, in the sensitivity analysis for our counterfactuals we experiment with alternative values for α.

underidentification and the "weak identification" test that we also report in the bottom of panel A. Overall, the results from the Frankel-Romer experiment are consistent with those from the literature.

In columns (4) and (5) of Table 1, we replace the trade variable from the reduced-form Frankel-Romer specification with our structural trade openness measure. The estimates in column (4) are unconstrained, while the specification in column (5) imposes the structural restrictions of our theory. The constrained and the unconstrained results are very similar, and not statistically different from each other. This is encouraging preliminary evidence in support of our model. It also enables us to focus interpretation on the constrained estimates from column (5), where we see that estimates have expected signs and are statistically significant at any conventional level. Importantly, we find that trade openness leads to higher income. This is captured by the negative and significant estimate of the coefficient of our inverse theoretical measure of trade openness $\ln\left(1/\widehat{\Pi_{j,t}^{1-\sigma}}\right)$. Thus, our model and estimates offer evidence for a causal relationship between trade and income.

The structural properties of the model yield estimates of the elasticity of substitution, $\hat{\sigma}$, and of the capital share, $\hat{\alpha}$, which are reported at the bottom of column (5). The inferred value of $\widehat{\sigma} = -1/\widehat{\kappa}_3 = 4.084$ falls comfortably within the distribution of the existing (Armington) elasticity numbers from the trade literature, which usually vary between 2 and 12. (See footnote 16). The inferred estimate of the capital share $\widehat{\alpha} = 0.572$ is a bit higher than expected but falls within the theoretically required interval [0;1].

The specification in column (6) addresses potential high-frequency (country-year) technology changes not controlled for with the set of country and year fixed effects in the econometric model. We introduce a direct TFP measure as a covariate, taken from the Penn World Tables. We obtain a positive and significant estimate on the coefficient of $TFP_{j,t}$. The addition of the TFP measure does not affect our findings qualitatively, as all estimates are still statistically significant at any level and with signs as expected. However, the magnitudes of the effects of labor, capital, and trade openness are changed. Specifically, controlling for

TFP decreases the effects of effective labor and trade openness and leads to a higher estimate of the effect of capital. The reduction in importance of trade openness is attributable to the fact that multilateral resistance is part of TFP. The structural estimate of the elasticity of substitution increases to $\widehat{\sigma} = -1/\widehat{\kappa}_3 = 10.114$, which is now on the higher end of the distribution of corresponding estimates from the literature. In online Appendix C.1 we also add R&D and the occurrence of natural disasters as possible candidates that may affect productivity and income. None of the effects of these variables is significant and they do not affect the estimates of the effects of the other covariates in our specification. We capitalize on this result below, where we use the occurrence of natural disasters as an instrument in the IV specifications of our *Income equation*.

We account for endogeneity of trade openness in columns (7) and (8) of Table 1. First, in column (7), we use the new structural instrument that we proposed in Section 4.1.2, which is constructed after explicitly removing the endogenous components from the OMR/trade openness index. In addition, we also employ the lag of our openness regressor in order to mitigate simultaneity concerns. The IV results in column (7) are encouraging. All variables retain their signs and statistical significance. In addition, as evident from the test statistics reported at the bottom of panel A, our instruments pass the underidentification, the weak identification, and also the overidentification tests. Inspection of the first stage IV estimates reveals that both of our instruments are highly statistically significant and contribute significantly to explain the variability in the endogenous trade openness regressor. The estimates from panel B reveal that the structural parameters that we recover are also within the theoretical limits and are comparable to the estimates from column (6). In sum, our results suggest that the new instrument proposed here performs well. Nevertheless, in column (8) of Table 1, we also add the inverse of the Frankel-Romer instrument that we used to obtain the results from column (3). As noted earlier, we use the inverse of this instrument because our structural trade term is an inverse measure of trade openness by construction. The estimates in column (8) are virtually identical to those from column (7). In addition, once again, the instruments pass all IV tests. At the end of this section, we also discuss the performance of the other two instruments that we propose.

Next, we control for endogenous capital, endogenous labor, and endogenous TFP in columns (9), (10), and (11), respectively, of Table 1. Our approach is to endogenize one additional variable at a time while still treating all variables that already have been endogenized in previous specifications as endogenous. As a result, the estimates in column (11) are obtained with all covariates from equation (32) being treated as endogenous. In column (9), we use lagged capital stocks and occurrence of natural disasters to instrument for current capital stock. Then, in column (10), we also allow for endogenous labor in addition to endogenous capital and endogenous trade openness, and we add the log of population to instrument for labor in addition to the instruments for capital and those for openness. Finally, in column (11), we add lagged and 2-period lagged TFP as instruments for current TFP. The estimates from column (11), where trade openness, capital, labor, and TFP are all treated as endogenous, are very similar to those from column (8), where only trade openness was treated as endogenous. The values of the structural parameters from column (11) are also similar to the corresponding estimates from column (8). Finally, we note that the instruments that we use in each of specifications (9)-(11) pass all IV tests.

The last column of Table 1 presents our main results, obtained after controlling for endogeneity of all covariates (as in column (11)), while simultaneously imposing the structural constraints of our model (as in column (5)). Estimates of all covariates have expected signs, reasonable magnitudes, and are significant at any conventional level. The structurally estimated capital share is a bit higher than expected, but it is still within the theoretical bounds. With a value of 5.847, our estimate of elasticity of substitution is right in the middle of the standard range from the literature and it is not statistically different from the summary measure of $\sigma = 6.13$ reported in Head and Mayer (2014).[45]

[45] Our estimates reveal that the elasticity of income with respect to the Frankel-Romer measure of openness, which we obtain in column (3), is higher as compared to the elasticity with respect to our structural measure of openness. We offer two possible explanations. First, gravity theory may explain part of the differences. Specifically, we note that our structural measure of trade openness represents only one component of the

Given the importance of proper account for endogeneity in the relationship between trade and income/growth (see Frankel and Romer, 1999), and the interest that this issue has generated and attracted over the years in the profession (see Footnote 9), we devote the end of this section to discuss the performance of the two additional instruments that we proposed earlier. Estimation results are presented in Table 2. For brevity, we only present and discuss findings from the three key specifications for each of the two new instruments, which correspond to columns (7), (8), and (12) from Table 1. In addition, to ease comparison, the first three columns of Table 2 reproduce the corresponding estimates with the first instrument from Table 1. Columns (4)-(6) of Table 2 report estimates with the openness instrument that uses labor shares. Columns (7)-(9) of Table 2 report estimates with the openness instrument that uses initial output shares. Two main findings from Table 2 stand out. First, estimation results across the specifications with the three structural instruments are not statistically different from each other across the corresponding specifications. Second, similar to the first instrument, the two additional instruments pass all IV specification tests. The main implication of the results from Table 2 is that using any of the three instruments that we propose here would not result in any significant changes in our findings. We chose to focus on the first instrument that explicitly removes the direct endogeneity links because this instrument performed best in the first stage analysis and because this is the only instrument that remained significant when all three instruments were included simultaneously in the first-stage regressions.[46]

Overall, the parameter estimates of α and σ that we obtain in this section are plausible.

theoretically predicted trade variable from Frankel and Romer. Second, we add as a control in the income regression a direct TFP measure. Comparison between the results from columns (4) and (5) reveal that, while all of our estimates remain significant and with expected signs, the introduction of TFP affects the magnitude of our results and they become smaller.

[46] The loss in significance for some of the instruments when all three of them are included in the analysis simultaneously is not surprising since the three measures are highly correlated. We also experimented with various combinations of two of the new instruments. The combinations of instruments performed well. They passed the IV tests and delivered results that were virtually identical to those from Tables 1 and 2. However, the instrument that explicitly removes the direct endogeneity links always outperformed each of the other two instruments in the first-stage regressions. This reinforced our decision to use this instrument in the main analysis.

Furthermore, we view the stable and robust performance of our results across all the specifications in Table 1, which range from a very basic unconstrained OLS model (column (4)) to a constrained IV specification that allows for all structural terms to be endogenous (column (12)), as encouraging evidence in support of our model.

4.3.3 Capital

To estimate the capital accumulation equation (34) we use the main estimate of the elasticity of substitution $\hat{\sigma} = 5.847$ from our income regressions to construct $\ln P_{j,t-1}$ from the power transform of the inward multilateral resistance.[47] Equation (34) will enable us to recover capital depreciation rates (δ's) subject to the following relationships: $\psi_1 = \delta$; $\psi_2 = 1 - \delta$; and $\psi_3 = -\delta$. In addition, the estimate of the coefficient ψ_3 on $\ln P_{j,t-1}$ will enable us to test our theory for a positive relationship between trade and capital accumulation.

Begin with a simple OLS regression based on (34). Results are presented in column (1) of Table 3. The estimates of all three covariates are statistically significant at any conventional level and with expected signs. The estimate on the lagged capital stock variable is very close to one and very precisely estimated, capturing strong persistence as expected. Importantly, the estimate of the coefficient on the trade openness term $\ln P_{j,t-1}$ is negative and statistically significant, suggesting a positive causal relationship between trade openness and capital accumulation. The intuition is that, in accordance with our theory, the estimate of ψ_3 captures the inverse relationship between investment and the costs of investment (both direct and opportunity costs). Finally, we obtain a positive and significant estimate of the coefficient on the expenditure term $\ln E_{j,t-1}$, which, as suggested by our model, captures the positive relationship between the value of marginal product of capital and investment.

The estimates in column (2) of Table 3 are obtained from the same specification as in column (1) under the structural constraints of our model. All estimates are statistically significant at any conventional level and have expected signs. The capital depreciation rate

[47] Results are robust to using alternative values for σ. For example, below we will use our structural specification with $\hat{\sigma} = 5.847$ to recover a capital depreciation rate $\hat{\delta} = 0.061$. This estimate varies between 0.054 and 0.063 for corresponding values of $\hat{\sigma}$ equal to 3 and 12.

is relatively low at 1.6 percent. Possible reasons for the downward bias in our estimate of the depreciation include (i) endogenous regressors and (ii) Nickell dynamic panel bias (Nickell, 1981) due to the use of the lagged dependent variable as a regressor in specification (34).

In columns (3), (4), and (5) of Table 3, respectively, we sequentially treat the lags of trade openness, expenditure, and the stock of capital as endogenous. Our approach is to endogenize one additional variable at a time while still treating all variables that have been endogenized in previous specifications as endogenous. In column (3), we use two instruments for trade openness. These instruments include the second lag of the endogenous variable $\ln P_{j,t-1}$ and the second lag of the openness variable but, as discussed in section 4.1.2, constructed without intra-national components. In column (4), we instrument for lagged expenditure with the second lags of this variable and of the variable for occurrence of natural disasters. Finally, in column (5) we also instrument for the lagged capital stock variable with its second lag. The results from columns (3)-(5) are similar and in accordance with our findings from the simple baseline OLS specification from column (1). In addition, our instruments pass the IV tests of underidentification, weak identification, and overidentification.

The estimates in column (6) of Table 3 are obtained with the Least Squares Dummy Variables (LSDV) estimator with country and year fixed effects added to specification (34), while all covariates are still treated as endogenous. As noted in Roodman (2009), this is a natural first step to mitigate (but not to eliminate) the dynamic panel bias by purging the country fixed effects out of the error term. The estimates in column (6) are qualitatively identical and quantitatively similar to those from the previous specifications. The main difference is the increase in the magnitude of the estimate on the lagged value of expenditure. In addition, we see that the estimates on lagged capital stock and on trade openness are a bit smaller, the latter still statistically significant but marginally so. Once again, we note that the instruments from the LSDV specification pass all IV tests. Finally, we find that two of the three structural constrains of our theory are satisfied in this specification.

Our main estimates of the *Capital equation* are presented in column (7) of Table 3. To obtain these results we treat all regressors as endogenous and we use the full set of fixed effects, as in column (6), but under the structural constraints of our model. The effects of all structural terms are highly significant and with expected signs. The estimate of the capital depreciation rate is 6.1 percent, suggesting that the depreciation rate $\hat{\delta} = 0.016$ from column (2) was indeed biased due to endogeneity and dynamic panel biases.

Next, we employ the dynamic panel-data estimator proposed by Arellano and Bond (1991) and refined by Arellano and Bover (1995) and Blundell and Bond (1998) in order to account for the remaining Nickell bias, which may still be present in our sample even after the inclusion of the country fixed effects because the lagged dependent variable may still be correlated with the unobserved panel effects within each country group. Since the expenditure and trade openness regressors are also functions of capital, we treat those covariates as potentially subject to dynamic bias concerns as well. Thus, our set of instruments includes all lags of all three endogenous regressors. In addition, we add as level instruments our structural trade openness instrument, the occurrence of natural disasters and the second lags of the logarithms of capital and expenditure. As in all previous specifications, the estimates in column (8) are obtained with robust standard errors and year and country fixed effects.

The results from column (8) of Table 3 reveal that, as in our main specification from column (7), the estimates of all regressors in the *Capital equation* are statistically significant and have signs as expected. In addition, even though we do not impose any structural constraints, we see that the magnitudes of the estimates are comparable to those from previous specifications. Importantly, the test statistics for first and second order zero autocorrelation in first-differenced errors, which are reported in the bottom of Table 3, suggest that the null hypothesis of no-autocorrelation is not rejected. Finally, we note that while our instruments clearly pass any weak identification test, they do not pass the Sargan overidentification test by a large margin. We offer two explanations for this result. First, it is natural to expect that the Sargan test, which cannot identify separately the contribution of the "good" instruments that we employed in previous specifications, will be weakened by the inclusion of lags and lagged differences of the endogenous regressors.[48] Second, while the estimates in column (8) are obtained with robust errors, the Sargan statistic is obtained without controlling for possible heteroskedasticity, which weakens the test further. Despite the fact that our results do not pass the overidentification test, we find the estimates from column (8) encouraging because (i) they are not subject to the dynamic Nickell bias, and (ii) they are readily comparable to the estimates from all previous specifications, which range from a very basic unconstrained OLS model (column (1)), through an unconstrained IV-LSDV specification with all endogenous regressors (column (6)), through a constrained IV-LSDV specification that allows for all structural terms to be endogenous (column (7)).

In combination with the estimates from our income regressions, our capital regression results demonstrate that the theoretical model and its structural econometric system perform well empirically. The results provide evidence for the substantial causal impact of trade on income and capital accumulation. We obtain plausible estimates for all but one of the parameters needed for counterfactual experiments. The lone parameter that we borrow from the literature is the consumer depreciation rate.[49] Minimum values, maximum values, and (when appropriate) standard errors for each of the parameters in our model are reported in Table 4. The good empirical results validate our parameter estimates for use in the trade liberalization counterfactual experiments that follow. In addition, in the robustness analysis (see online Appendix C), we experiment with alternative values for all structural parameters to obtain qualitatively identical results and intuitive quantitive variations.

5 Counterfactual Experiments

Two counterfactual experiments reveal the implications of the estimated model for the effect of trade liberalization shocks on growth. The trade liberalization 'shocks' that we consider

[48] We experimented by using longer lags as instruments and the Sargan statistic that we report in Table 3 decreased by orders of magnitude. However, no set of lags that we experimented with passed the Sargan test. Therefore, we decided to report the specification that includes all lags.

[49] We note that the consumer discount factor is only relevant for discounting the welfare effects in our setting. This can be seen in online Appendix H, where we solve our system in changes using the methods from Dekle et al. (2008).

are NAFTA and a 6.4% fall in international trade costs for all countries (globalization). We also perform a series of sensitivity experiments using a different functional form for capital accumulation (derived in online Appendix K), allowance for intermediate goods (derived in online Appendix L), using a different functional form for the intertemporal utility function (derived in online Appendix M), and alternative values for the parameters of our model and study the effect of growth shocks on trade, where the growth shock is a 20% change of the capital stock in the United States (discussed in Section C.4 of the online Appendix). Additionally, we perform a validation experiment that compares our calculated theory-consistent, steady-state capital stocks with the observed capital stocks for 1994, showing a correlation coefficient of 0.98 (see for details online Appendix C.2).

The fitted model "data" includes (i) the observed data on labor endowments ($L_{j,t}$) and GDPs ($Y_{j,t}$) for our sample of 82 countries; (ii) constructed trade costs $t_{ij,t}^{1-\sigma}$ from estimates of equation (30); (iii) theory-consistent steady-state capital stocks according to the capital accumulation equation (25); and (iv) baseline preference-adjusted technology A_j/γ_j according to the market-clearing equation (23) and the production function equation (24). Hence, we back out theory-consistent steady-state capital stocks and preference-adjusted technology using our theory and GDP and employment data. We do that for a single point in time, ensuring that for the specific year GDP and employment data are matched perfectly in our baseline case. For the counterfactual analysis, we assume that preference-adjusted technology stays constant, while the capital stocks endogenously adjust according to our transition function. Online Appendix I offers a detailed description of our counterfactual setup and procedures. Parameter estimates in the baseline case include our estimates of the elasticity of substitution $\widehat{\sigma} = 5.847$ and the share of capital in the Cobb-Douglas production function $\widehat{\alpha} = 0.545$ from column (12) of Table 1, and the capital depreciation rate $\widehat{\delta} = 0.061$ from column (7) of Table 3. The consumers' discount factor is set equal to $\beta = 0.98$, a standard in the literature.[50]

[50] Alternatively, we could solve our system in changes following Dekle et al. (2007, 2008). The results are identical to the results from the system in levels using the system in changes derived in online Appendix H.

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

5.1 Dynamic Effects of NAFTA

Our first counterfactual experiment evaluates the welfare effects of NAFTA, extending the static effects literature to include the dynamic effects of NAFTA on member and non-member countries (see for recent examples Trefler, 2004; Romalis, 2007; Caliendo and Parro, 2015; Anderson and Yotov, 2016). Results reported in Table 5 are decomposed into three stages of increasing general equilibrium adjustment. The first column of Table 5 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" ("Cond. GE") effects of NAFTA, which include the direct effects of the bilateral changes in trade costs with resulting changes in the MRs (20)-(22) at constant GDPs. These indexes correspond to the Modular Trade Impact (MTI) effects from Head and Mayer (2014). Column (3) also allows for static GDP changes in response to formation of NAFTA. We label this scenario "Full Static GE" and it corresponds to the General Equilibrium Trade Impact (GETI) effects from Head and Mayer (2014). Finally, in columns (4) and (5), 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.[51]

The main "takeaway" of our paper is that dynamic effects are big. Column (4) of Table 5 reports estimates from the "Full Dynamic GE, SS" scenario, which compares the initial steady

[51] Discussion of findings from related NAFTA studies and estimates of the effects of NAFTA on trade flows, the multilateral resistances, and the capital effects can be found in online Appendix J. 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%.

state (SS) to the new steady state, where all capital is fully adjusted to take into account the introduction of NAFTA. Focusing on the NAFTA countries, steady state welfare is more than doubled by the dynamic capital accumulation forces in our framework. The additional dynamic gains are on average almost 1.5 percentage points. Turning to non-members of NAFTA, the dynamic effects are negative but small.

Properly discounted welfare effects on the transition path[52] are reported in column (5), labeled "Full Dynamic GE, trans." of Table 5. The dynamic gains to NAFTA members increase the static gains by over 60% (63% for Canada and Mexico, 62% for the U.S.). Hence, the additional dynamic gains for Canada, Mexico and the U.S. do not vary much. This is in contrast to the static gains from trade liberalization, which lead to bigger gains for the smaller economies. We label the magnifying effect of the dynamic channel the *dynamic path multiplier*, which takes a value of around 1.6 here. The discounted dynamic welfare effects on members are smaller than the welfare changes from column (4), but still big. As a share of initial welfare, the discounted dynamic effects increase the welfare for NAFTA members by about 2.06 percent. The negative effects of non-members increase by only 0.005 percentage points compared to the static effects.

In terms of income growth effects, we find a growth rate effect of NAFTA for the first 15 years of adjustment of about 0.116% per year. For the non-NAFTA countries we find a slight negative effect of -0.001% per year, resulting in an overall acceleration in growth rates of real GDP in NAFTA countries compared to non-NAFTA countries of about 0.117% per year. This is about a third of the corresponding finding of Estevadeordal and Taylor (2013), which is based on a treatment-and-control approach.

Our approach permits tracing the effects of trade liberalization on capital accumulation. Figure 1 depicts the transition path for capital stocks in four countries, the NAFTA members plus Singapore. Singapore is the outside country with the strongest negative impact of

[52]We follow Lucas (1987) and calculate the constant fraction ζ 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 ($C^c_{j,t}$) as specified in equation (27) from Section 3.1.

NAFTA. Figure 1 reveals that the effects on NAFTA members are large and long-lived. The largest effect of about 13 percent increase in capital stock is for Canada, followed by about 8 percent for Mexico and 1.4 percent for U.S.[53] Most of the dynamic gains accrue initially, but there remain significant transitional dynamic gains more than 50 years after the formation of NAFTA. In contrast, our results suggest that the transitional effects on non-members are small. On average, we find that capital stock in the non-member countries would have been about 0.02 percent lower without NAFTA, ranging between -0.105 percent for Singapore to nearly zero for Uzbekistan, Iran and Turkmenistan.[54] According to Figure 1, there are no additional negative effects on Singapore after about 50 years after the implementation of NAFTA. We estimate that on average non-members reach a new steady state after about 10 years after the formation of NAFTA.

5.2 Dynamic Effects of Globalization

A second counterfactual experiment sheds more light on the effects of trade on growth in our model. Uniform globalization is assumed to increase $\widehat{t_{ij}^{1-\sigma}}$ for all $i \neq j$ by 38% (the estimate of the effects of globalization over a period of 12 years from Bergstrand et al., 2015).[55] The globalization effects in the four scenarios of columns (2)-(5) are presented in columns (6)-(9) of Table 5. 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 countries

[53] The large increase in the capital stock for Canada is explained by the fact that 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. However, we use a common NAFTA estimate in order to emphasize our methodological contributions.

[54] 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. However, in principle, it is possible for the trade creation effect to dominate the negative impact of trade liberalization.

[55] With our estimated σ of 5.847, this corresponds to a decrease of t_{ij} by 6.43% for all $i \neq j$.

in close proximity to large markets. For example, Belgium, Ireland and Singapore are among the big winners in all scenarios. Third, comparison between the "Full Static GE" scenario and the "Cond. 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 increase by more than 60% in the dynamic scenario, implying a *dynamic path multiplier* of 1.6.

6 Conclusions

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

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Table 1: Trade Openness and Income, 1990-2011

	(1) CD	(2) CDCnstr	(3) FR	(4) Base	(5) BaseCnstr	(6) TFP	(7) IV-IMR	(8) IV-IMR1	(9) IV-Cap	(10) IV-Lab	(11) IV-All	(12) IV-All-Cnstr
A. Dep. Variable $\ln y_{j,t}$												
$\ln L_{j,t}$	0.332	0.495	0.264	0.283	0.323	0.236	0.212	0.212	0.231	0.314	0.269	0.377
	(0.041)**	(0.035)**	(0.038)**	(0.044)**	(0.037)**	(0.033)**	(0.045)**	(0.045)**	(0.044)**	(0.066)**	(0.060)**	(0.025)**
$\ln K_{j,t}$	0.460	0.505	0.322	0.425	0.432	0.524	0.507	0.507	0.474	0.442	0.459	0.452
	(0.035)**	(0.035)**	(0.050)**	(0.032)**	(0.039)**	(0.038)**	(0.046)**	(0.046)**	(0.045)**	(0.052)**	(0.050)**	(0.023)**
$\ln \sum_{j\neq i} X_{ij}$			0.264									
			(0.062)**									
$\ln(\widehat{\Pi_{j,t}^{\sigma-1}})$				-0.214	-0.245	-0.099	-0.089	-0.089	-0.099	-0.107	-0.085	-0.171
				(0.026)**	(0.020)**	(0.034)**	(0.029)**	(0.029)**	(0.029)**	(0.029)**	(0.030)**	(0.018)**
$TFP_{j,t}$						0.303	0.307	0.307	0.301	0.296	0.340	0.303
						(0.088)**	(0.097)**	(0.097)**	(0.099)**	(0.101)**	(0.081)**	(0.026)**
N	1606	1606	1579	1579	1579	1447	1380	1380	1380	1380	1322	1322
UnderId			16.519				156.439	156.921	158.530	153.488	147.666	
χ^2 p-val			(0.000)				(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	
Weak Id			14.782				510.75	345.439	213.842	229.508	153.673	
χ^2 p-val			(0.000)				(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	
Over Id							0.351	1.465	1.234	4.782	7.737	
χ^2 p-val							(0.554)	(0.481)	(0.745)	(0.189)	(0.102)	
B. Structural Parameters												
$\widehat{\alpha}$		0.505		0.540	0.572	0.582	0.557	0.557	0.525	0.495	0.501	0.545
		(0.035)**		(0.050)**	(0.046)**	(0.052)**	(0.054)**	(0.054)**	(0.054)**	(0.060)**	(0.053)**	(0.027)**
$\widehat{\sigma}$				4.674	4.084	10.114	11.282	11.180	10.128	9.385	11.812	5.847
				(0.580)**	(0.394)**	(2.817)**	(3.701)**	(3.632)**	(2.929)**	(2.547)**	(4.173)**	(0.620)**

Notes: This table reports estimates of the relationship between trade openness and income. All specifications include country and year fixed effects whose estimates are omitted for brevity. Columns (1) and (2) report estimates from an unconstrained and a constrained specification of the Cobb-Douglas production function. In column (3), we estimate a Frankel-and-Romer type of income regression. Columns (4) and (5), respectively, present unconstrained and constrained baseline estimates of our structural model. Column (6) introduces an additional control variable for technology. In column (7) we instrument for trade openness with our new instrument, and in column (8) we also add a version of the original Frankel-Romer instrument. Columns (9), (10), and (11) sequentially allow for endogeneous capital, labor, and TFP in addition to allowing for endogenous openness. Finally, in column (12) all regressors are treated as endogenous and we impose the structural restrictions of the model. In the bottom of panel A, we report UnderId χ^2 values, "weak identification" (WeakId) Kleibergen-Paap Wald F statistics (Kleibergen and Paap, 2006), and OverId χ^2 values when available. Note that the Kleibergen-Paap Wald test is appropriate when the standard error i.i.d. assumption is not met and the usual Cragg-Donald Wald statistic (Cragg and Donald, 1993), along with the corresponding critical values proposed by Stock and Yogo (2005), are no longer valid. This is true in our case, where the standard errors are either robust or bootstrapped. + $p < 0.10$, * $p < .05$, ** $p < .01$. See text for further details.

Table 2: Trade Openness and Income: Additional Instruments for Openness

	No Direct Internal Links			Labor Shares as Weights			Initial Output Levels as Weights		
	IV-IMR	IV-IMR1	IV-All-Cnstr	IV-IMR	IV-IMR1	IV-All-Cnstr	IV-IMR	IV-IMR1	IV-All-Cnstr
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
A. Dep. Variable $\ln y_{j,t}$									
$\ln L_{j,t}$	0.212	0.212	0.377	0.212	0.213	0.353	0.212	0.213	0.375
	$(0.045)^{**}$	$(0.045)^{**}$	$(0.025)^{**}$	$(0.045)^{**}$	$(0.045)^{**}$	$(0.023)^{**}$	$(0.045)^{**}$	$(0.045)^{**}$	$(0.025)^{**}$
$\ln K_{j,t}$	0.507	0.507	0.452	0.507	0.506	0.465	0.507	0.506	0.448
	$(0.046)^{**}$	$(0.046)^{**}$	$(0.023)^{**}$	$(0.046)^{**}$	$(0.047)^{**}$	$(0.022)^{**}$	$(0.046)^{**}$	$(0.047)^{**}$	$(0.023)^{**}$
$\ln(\widehat{\Pi_{j,t}^{\sigma-1}})$	-0.089	-0.089	-0.171	-0.092	-0.094	-0.182	-0.092	-0.094	-0.177
	$(0.029)^{**}$	$(0.029)^{**}$	$(0.018)^{**}$	$(0.031)^{**}$	$(0.031)^{**}$	$(0.018)^{**}$	$(0.031)^{**}$	$(0.031)^{**}$	$(0.018)^{**}$
$TFP_{j,t}$	0.307	0.307	0.303	0.306	0.305	0.297	0.306	0.305	0.300
	$(0.097)^{**}$	$(0.097)^{**}$	$(0.026)^{**}$	$(0.096)^{**}$	$(0.096)^{**}$	$(0.026)^{**}$	$(0.097)^{**}$	$(0.096)^{**}$	$(0.026)^{**}$
N	1380	1380	1322	1380	1380	1322	1380	1380	1322
UnderId	156.439	156.921		155.457	155.70		155.783	155.789	
χ^2 p-val	(0.000)	(0.000)		(0.000)	(0.000)		(0.000)	(0.000)	
Weak Id	510.75	345.439		337.725	231.167		327.377	227.193	
χ^2 p-val	(0.000)	(0.000)		(0.000)	(0.000)		(0.000)	(0.000)	
Over Id	0.351	1.465		1.542	1.679		3.710	4.001	
χ^2 p-val	(0.554)	(0.481)		(0.214)	(0.432)		(0.054)	(0.135)	
B. Structural Parameters									
$\widehat{\alpha}$	0.557	0.557	0.545	0.558	0.559	0.568	0.559	0.559	0.544
	(0.054)**	(0.054)**	(0.027)**	(0.054)**	(0.054)**	(0.026)**	(0.055)**	(0.054)**	(0.027)**
$\widehat{\sigma}$	11.282	11.180	5.847	10.852	10.610	5.485	10.845	10.583	5.662
	(3.701)**	(3.632)**	(0.620)**	(3.599)**	(3.439)**	(0.541)**	(3.595)**	(3.421)**	(0.585)**

Notes: This table reports estimates of the relationship between trade openness and income with three alternative sets of instruments. All specifications include country and year fixed effects whose estimates are omitted for brevity. Columns (1)-(3) replicate the estimates from columns (7), (8), and (12) of Table 1, which are obtained with an instrument for openness that explicitly removes the direct internal links in the multilateral resistance system. Columns (4)-(6) use an instrument that is constructed by solving the full multilateral resistance system but using labor shares instead of income shares as weights. Finally, the estimates in columns (7)-(9) are obtained with an instrument that is constructed by solving the full multilateral resistance system but using output shares from the initial year in our sample instead of current output shares as weights. In the bottom of panel A, we report UnderId χ^2 values, "weak identification" (WeakId) Kleibergen-Paap Wald F statistics (Kleibergen and Paap, 2006), and OverId χ^2 values when available. Note that the Kleibergen-Paap Wald test is appropriate when the standard error i.i.d. assumption is not met and the usual Cragg-Donald Wald statistic (Cragg and Donald, 1993), along with the corresponding critical values proposed by Stock and Yogo (2005), are no longer valid. This is true in our case, where the standard errors are either robust or bootstrapped. $+$ $p < 0.10$, * $p < .05$, ** $p < .01$. See text for further details.

Table 3: Trade Openness and Capital Accumulation, 1990-2011

	(1) Base	(2) BaseCnstr	(3) IV-IMR	(4) IV-GDP	(5) IV-All	(6) IV-All-LSDV	(7) IV-All-Cnstr	(8) Diff-GMM
$\ln E_{j,t-1}$	0.011	0.016	0.012	0.007	0.010	0.083	0.061	0.047
	(0.003)**	(0.003)**	(0.004)**	(0.004)+	(0.004)**	(0.012)**	(0.004)**	(0.012)**
$\ln K_{j,t-1}$	0.984	0.984	0.983	0.986	0.983	0.948	0.939	0.934
	(0.003)**	(0.003)**	(0.003)**	(0.003)**	(0.003)**	(0.008)**	(0.004)**	(0.009)**
$\ln P_{j,t-1}$	-0.052	-0.016	-0.047	-0.064	-0.065	-0.043	-0.061	-0.164
	(0.012)**	(0.003)**	(0.013)**	(0.013)**	(0.013)**	(0.026)+	(0.004)**	(0.083)*
N	1684	1684	1602	1602	1602	1602	1602	1684
UnderId			197.088	197.406	197.512	255.859		
χ^2 p-val			(0.000)	(0.000)	(0.000)	(0.000)		
Weak Id			6899	4007	3190	243.210		
χ^2 p-val			(0.000)	(0.000)	(0.000)	(0.000)		
OverId			0.388	4.559	2.921	1.553		3919
χ^2 p-val			(0.533)	(0.103)	(0.232)	(0.460)		(0.000)
AR(1)								-1.210
χ^2 p-val								(0.226)
AR(2)								-0.412
χ^2 p-val								(0.680)

Notes: This table reports estimates of the relationship between trade openness and capital accumulation. Column (1) reports results from a baseline OLS estimator. In column (2), we impose the structural constraints of our theory. Columns (3), (4) and (5) report IV estimates, where trade openness (i.e., the inward multilateral resistances), expenditure, and capital are sequentially treated as endogenous. Column (6) reports Least Squares Dummy Variable (LSDV) panel estimates with all regressors being treated as endogenous. In addition to treating all regressors as endogenous and using an LSDV estimator, the specification in column (7) also imposes the structural restrictions of our theory. Finally, the estimates in column (8) implements a dynamic panel-data difference GMM estimator. Robust standard errors in parentheses. + $p < 0.10$, * $p < .05$, ** $p < .01$. See text for further details.

Table 4: Parameter Estimates

Recovered From	**Parameter**	**Min. Value**	**Max. Value**
Trade	$\widehat{\eta}_1$	0.827	
		(0.135)**	
	$\widehat{t}_{ij}$	1.184	132.7
Income	$\widehat{\alpha}$	0.495	0.582
		(0.060)**	(0.052)**
	$\widehat{\sigma}$	4.084	11.282
		(0.394)**	(3.701)**
Capital	$\widehat{\delta}$	0.016	0.061
		(0.003)**	(0.004)**
Cons. Discount	$\widehat{\beta}$	0.98	

Notes: This table reports the values for parameters in our model. Panel "Trade" reports the RTA estimate (top row), and the minimum and maximum values for bilateral trade costs (bottom row). Panel "Income" reports the minimum and the maximum values for the capital shares (top row), and for the trade elasticity (bottom row), from panel B of Table 1. Panel "Capital" reports the minimum and the maximum values of the capital depreciation rates from the constrained structural regressions from Table 3. Finally, in panel "Cons. Discount" we report the estimate of the consumer discount factor, which we borrow from the literature. Robust standard errors, when available, are in parentheses. + $p < 0.10$, * $p < .05$, ** $p < .01$.

Table 5: Welfare Effects of NAFTA and Globalization

	NAFTA				Globalization			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Country	Cond. GE	Full Static GE	Full Dynamic GE, SS	Full Dynamic GE, trans.	Cond. GE	Full Static GE	Full Dynamic GE, SS	Full Dynamic GE, trans.
AGO	-0.034	-0.059	-0.093	-0.079	1.510	2.998	6.489	4.804
ARG	-0.007	-0.012	-0.019	-0.016	0.467	0.939	2.095	1.533
AUS	-0.007	-0.013	-0.021	-0.018	0.632	1.277	2.866	2.091
AUT	-0.005	-0.009	-0.015	-0.013	2.244	4.477	9.804	7.217
AZE	-0.005	-0.010	-0.015	-0.013	0.607	1.222	2.733	1.997
BEL	-0.012	-0.021	-0.032	-0.027	4.140	8.072	16.870	12.639
BGD	-0.003	-0.005	-0.009	-0.008	0.221	0.450	1.029	0.746
BGR	-0.001	-0.002	-0.004	-0.003	0.848	1.715	3.871	2.818
BLR	0.000	-0.001	-0.002	-0.001	1.166	2.316	5.021	3.715
BRA	-0.006	-0.011	-0.019	-0.016	0.298	0.603	1.364	0.992
CAN	2.927	5.859	12.899	9.572	2.050	4.029	8.527	6.368
CHE	-0.017	-0.029	-0.044	-0.038	2.779	5.492	11.787	8.745
CHL	-0.027	-0.048	-0.076	-0.064	1.140	2.276	4.984	3.672
CHN	-0.008	-0.015	-0.024	-0.020	0.427	0.866	1.966	1.428
COL	-0.015	-0.027	-0.043	-0.036	0.318	0.642	1.447	1.055
CZE	-0.002	-0.003	-0.006	-0.005	1.866	3.747	8.313	6.089
DEU	-0.008	-0.014	-0.022	-0.019	1.546	3.126	7.031	5.125
DNK	-0.006	-0.011	-0.019	-0.016	2.077	4.166	9.217	6.758
DOM	-0.023	-0.041	-0.067	-0.056	0.514	1.029	2.272	1.669
ECU	-0.018	-0.032	-0.052	-0.044	0.769	1.542	3.408	2.502
EGY	-0.002	-0.004	-0.007	-0.006	0.339	0.688	1.565	1.136
ESP	-0.005	-0.009	-0.014	-0.012	1.050	2.123	4.789	3.486
ETH	-0.001	-0.002	-0.003	-0.002	0.134	0.271	0.616	0.448
FIN	-0.008	-0.015	-0.024	-0.020	1.994	3.994	8.817	6.471
FRA	-0.005	-0.009	-0.015	-0.013	1.204	2.443	5.541	4.025
GBR	-0.010	-0.017	-0.028	-0.023	1.003	2.049	4.708	3.403
GHA	-0.004	-0.008	-0.013	-0.011	0.375	0.764	1.748	1.266
GRC	-0.001	-0.002	-0.003	-0.003	0.584	1.189	2.719	1.969
GTM	-0.031	-0.056	-0.090	-0.076	0.519	1.042	2.313	1.695
HKG	-0.012	-0.022	-0.035	-0.030	1.780	3.535	7.644	5.661
HRV	-0.001	-0.002	-0.004	-0.003	0.498	1.013	2.315	1.676
HUN	-0.003	-0.005	-0.009	-0.008	1.879	3.769	8.347	6.118
IDN	-0.003	-0.005	-0.009	-0.007	0.477	0.972	2.216	1.607
IND	-0.002	-0.004	-0.006	-0.005	0.185	0.377	0.867	0.626
IRL	-0.032	-0.055	-0.081	-0.071	3.930	7.672	16.060	12.028
IRN	0.000	-0.001	-0.001	-0.001	0.362	0.732	1.651	1.202
IRQ	-0.018	-0.033	-0.052	-0.044	0.990	1.978	4.341	3.196
ISR	-0.033	-0.058	-0.093	-0.078	1.479	2.968	6.568	4.819
ITA	-0.004	-0.007	-0.012	-0.010	0.952	1.935	4.405	3.195
JPN	-0.009	-0.016	-0.025	-0.021	0.400	0.811	1.842	1.338
KAZ	-0.004	-0.007	-0.011	-0.009	0.854	1.709	3.760	2.766
KEN	-0.001	-0.002	-0.004	-0.003	0.184	0.374	0.847	0.616
KOR	-0.017	-0.031	-0.049	-0.041	1.130	2.266	5.011	3.678
KWT	-0.005	-0.010	-0.017	-0.014	0.921	1.850	4.101	3.008
LBN	-0.004	-0.007	-0.011	-0.009	0.801	1.620	3.652	2.660
LKA	-0.004	-0.008	-0.013	-0.011	0.358	0.728	1.659	1.204
LTU	-0.006	-0.010	-0.016	-0.014	0.928	1.879	4.244	3.089
MAR	-0.004	-0.007	-0.011	-0.009	0.648	1.313	2.970	2.160
MEX	1.764	3.532	7.778	5.748	1.303	2.587	5.594	4.143
MYS	-0.032	-0.056	-0.087	-0.074	2.849	5.627	12.007	8.936
NGA	-0.029	-0.051	-0.081	-0.069	1.615	3.203	6.915	5.124
NLD	-0.009	-0.016	-0.026	-0.022	2.937	5.835	12.637	9.343
NOR	-0.037	-0.065	-0.097	-0.084	2.093	4.194	9.266	6.798
NZL	-0.010	-0.018	-0.030	-0.025	0.974	1.954	4.326	3.174
OMN	-0.005	-0.009	-0.015	-0.012	1.305	2.601	5.680	4.190
PAK	-0.002	-0.003	-0.006	-0.005	0.168	0.343	0.783	0.567
PER	-0.026	-0.046	-0.073	-0.062	0.634	1.274	2.835	2.076
PHL	-0.008	-0.014	-0.023	-0.020	0.634	1.285	2.907	2.115
POL	-0.001	-0.002	-0.004	-0.003	0.965	1.962	4.472	3.242
PRT	-0.003	-0.005	-0.008	-0.007	1.204	2.430	5.459	3.980

Continued on next page

Table 5 – *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.
QAT	-0.003	-0.006	-0.011	-0.009	1.930	3.827	8.253	6.118
ROM	-0.001	-0.003	-0.004	-0.004	0.837	1.695	3.838	2.790
RUS	-0.001	-0.002	-0.004	-0.003	0.330	0.671	1.528	1.108
SAU	-0.010	-0.018	-0.030	-0.025	0.890	1.786	3.957	2.903
SDN	-0.002	-0.003	-0.005	-0.005	0.444	0.893	1.988	1.455
SER	-0.001	-0.001	-0.002	-0.002	0.391	0.793	1.806	1.310
SGP	-0.042	-0.072	-0.105	-0.092	5.404	10.359	20.856	15.856
SVK	-0.001	-0.002	-0.004	-0.003	2.244	4.475	9.792	7.211
SWE	-0.008	-0.015	-0.025	-0.021	2.202	4.409	9.720	7.137
SYR	-0.003	-0.005	-0.008	-0.007	1.316	2.636	5.822	4.274
THA	-0.009	-0.016	-0.026	-0.022	0.994	2.004	4.475	3.272
TKM	0.000	-0.001	-0.001	-0.001	0.587	1.178	2.613	1.916
TUN	-0.001	-0.002	-0.004	-0.003	0.975	1.967	4.415	3.220
TUR	-0.002	-0.004	-0.006	-0.005	0.519	1.056	2.409	1.746
TZA	-0.001	-0.002	-0.004	-0.003	0.295	0.597	1.345	0.980
UKR	-0.001	-0.002	-0.003	-0.003	0.607	1.219	2.703	1.982
USA	0.316	0.637	1.428	1.031	0.358	0.736	1.710	1.231
UZB	0.000	-0.001	-0.001	-0.001	0.232	0.468	1.048	0.766
VEN	-0.024	-0.043	-0.070	-0.059	0.637	1.277	2.825	2.074
VNM	-0.006	-0.012	-0.020	-0.016	0.984	1.984	4.438	3.244
ZAF	-0.005	-0.009	-0.015	-0.012	0.575	1.164	2.624	1.911
ZWE	0.000	-0.001	-0.002	-0.001	0.184	0.371	0.835	0.608
World	0.171	0.344	0.770	0.562	0.779	1.568	3.500	2.559
NAFTA	0.630	1.265	2.806	2.056				
ROW	-0.007	-0.013	-0.021	-0.018				

Notes: This table reports results from our NAFTA and globalization counterfactuals. Column (1) lists the country abbreviations. Columns (2) to (5) report percentage changes in welfare for three different scenarios. The "Cond. 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. The "Full Dynamic GE" scenario adds the capital accumulation effects. For the latter, we report results that do not take transition into account (in column (4)) and welfare gains that take transition into account (in column (5)). Columns (6) to (9) report percentage changes in welfare for the same four scenarios for our globalization counterfactual. See text for further details.

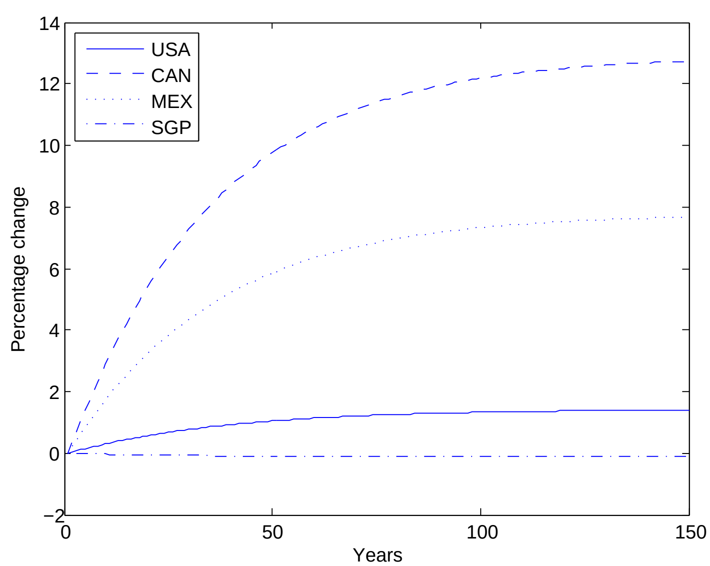

Figure 1: On the Transitional Effects of NAFTA: Capital Stocks

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

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

Appendix A Solution of the Upper Level **A2**
A.1 Derivation of the Policy Functions of the Upper Level A2
A.2 Derivation of the Transversality Condition A8

Appendix B Transition **A10**

Appendix C Robustness & Sensitivity Experiments **A14**
C.1 Sensitivity: TFP Controls & Capital Shares A14
C.2 Capital Stocks: Theory vs. Data. A "Smell Test" A14
C.3 Linear Capital Transition Function A15
C.4 Exogenous Growth A17
C.5 Intermediate Goods A18
C.6 Sensitivity to Structural Parameter Values A21

Appendix D Growth and Trade in the Long-Run **A27**

Appendix E ACR Formula **A28**
E.1 ACR Formula In Steady State A30
E.2 ACR Formula Out-of Steady State A31

Appendix F Details to Trade Cost Estimates **A35**

Appendix G Country List and Country Labels **A37**

Appendix H The Growth-and-Trade System in Changes **A38**

Appendix I Counterfactual Procedure **A40**

Appendix J Additional Results for the NAFTA Counterfactual **A43**

Appendix K Linear Capital Accumulation Function **A47**

Appendix L Solution of the Upper Level with Intermediates **A54**
L.1 Derivation of the Policy Functions of the Upper Level with Intermediates . . A54
L.2 Derivation of the Transversality Condition A63

Appendix M Iso-Elastic Utility Function **A65**

A Solution of the Upper Level

A.1 Derivation of the Policy Functions of the Upper Level

Our upper-level specification is very similar to Hercowitz and Sampson (1991) and given by equations (3)-(8), which we repeat here for the convenience of the reader:

$$
\begin{aligned}
\max_{\{C_{j,t},\Omega_{j,t}\}} & \quad \sum_{t=0}^{\infty} \beta^t \ln(C_{j,t}) && \text{(A1)}\\
K_{j,t+1} &= \Omega_{j,t}^{\delta} K_{j,t}^{1-\delta}, \ \forall t && \text{(A2)}\\
Y_{j,t} &= p_{j,t} A_{j,t} L_{j,t}^{1-\alpha} K_{j,t}^{\alpha}, \ \forall t && \text{(A3)}\\
E_{j,t} &= P_{j,t} C_{j,t} + P_{j,t} \Omega_{j,t}, \ \forall t && \text{(A4)}\\
E_{j,t} &= \phi_{j,t} Y_{j,t}, \ \forall t && \text{(A5)}\\
K_{j,0} & \quad \text{given.} && \text{(A6)}
\end{aligned}
$$

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 function of capital, investment, and consumption, we first solve for $C_{j,t}$ using equation (A4), leading to $C_{j,t} = E_{j,t}/P_{j,t} - \Omega_{j,t}$. Next, use $E_{j,t} = \phi_{j,t} Y_{j,t}$ and plug in $Y_{j,t}$ as given by equation (A3), leading to $C_{j,t} = \left(\phi_{j,t} p_{j,t} A_{j,t} L_{j,t}^{1-\alpha} K_{j,t}^{\alpha}\right)/P_{j,t} - \Omega_{j,t}$. Then, use equation (A2) to replace $\Omega_{j,t}$, leading to $C_{j,t} = \left(\phi_{j,t} p_{j,t} A_{j,t} L_{j,t}^{1-\alpha} K_{j,t}^{\alpha}\right)/P_{j,t} - \left(K_{j,t+1}/K_{j,t}^{1-\delta}\right)^{1/\delta}$ and to the following objective function:

$$
\max_{\{K_{j,t}\}} \sum_{t=0}^{\infty} \beta^t \ln\left[\left(\phi_{j,t} p_{j,t} A_{j,t} L_{j,t}^{1-\alpha} K_{j,t}^{\alpha}\right)/P_{j,t} - \left(K_{j,t+1}/K_{j,t}^{1-\delta}\right)^{1/\delta}\right].
$$

The corresponding first-order conditions are:

$$
\frac{\beta^t}{C_{j,t}} \left(\frac{\alpha \phi_{j,t} Y_{j,t}}{P_{j,t} K_{j,t}} - \frac{(\delta-1)}{\delta} K_{j,t+1}^{1/\delta} K_{j,t}^{-1/\delta} \right) - \frac{1}{\delta} \frac{\beta^{t-1}}{C_{j,t-1}} K_{j,t-1}^{(\delta-1)/\delta} K_{j,t}^{1/\delta-1} \stackrel{!}{=} 0,
$$

which hold for all j's and t's. Simplify:

$$
\frac{\delta \beta C_{j,t-1}}{C_{j,t}} \left(\frac{\alpha \phi_{j,t} Y_{j,t}}{P_{j,t} K_{j,t}} - \frac{(\delta-1)}{\delta} K_{j,t+1}^{1/\delta} K_{j,t}^{-1/\delta} \right) \stackrel{!}{=} K_{j,t-1}^{(\delta-1)/\delta} K_{j,t}^{1/\delta-1}. \tag{A7}
$$

Replace $C_{j,t}$ and $C_{j,t-1}$:

$$
\frac{\delta \beta \left(\phi_{j,t-1} Y_{j,t-1}/P_{j,t-1} - \left(K_{j,t}/K_{j,t-1}^{1-\delta}\right)^{1/\delta}\right)}{\left(\phi_{j,t} Y_{j,t}/P_{j,t} - \left(K_{j,t+1}/K_{j,t}^{1-\delta}\right)^{1/\delta}\right)} \left(\frac{\alpha \phi_{j,t} Y_{j,t}}{P_{j,t} K_{j,t}} - \frac{(\delta-1)}{\delta} K_{j,t+1}^{1/\delta} K_{j,t}^{-1/\delta} \right)
$$

$$
\stackrel{!}{=} K_{j,t-1}^{(\delta-1)/\delta} K_{j,t}^{1/\delta-1} \Rightarrow
$$

$$
\delta\beta\left(\frac{\phi_{j,t-1}Y_{j,t-1}}{P_{j,t-1}}-\left(\frac{K_{j,t}}{K_{j,t-1}^{1-\delta}}\right)^{1/\delta}\right)\left(\frac{\alpha\phi_{j,t}Y_{j,t}}{P_{j,t}K_{j,t}}-\frac{(\delta-1)}{\delta}K_{j,t+1}^{1/\delta}K_{j,t}^{-1/\delta}\right)
$$

$$
\stackrel{!}{=}\frac{K_{j,t-1}^{(\delta-1)/\delta}K_{j,t}^{1/\delta-1}\phi_{j,t}Y_{j,t}}{P_{j,t}}-K_{j,t-1}^{(\delta-1)/\delta}K_{j,t}^{1/\delta-1}\left(\frac{K_{j,t+1}}{K_{j,t}^{1-\delta}}\right)^{1/\delta}\Rightarrow
$$

$$
\delta\beta\left(\frac{\phi_{j,t-1}Y_{j,t-1}}{P_{j,t-1}}-\left(\frac{K_{j,t}}{K_{j,t-1}^{1-\delta}}\right)^{1/\delta}\right)\left(\frac{\alpha\phi_{j,t}Y_{j,t}}{P_{j,t}K_{j,t}}-\frac{(\delta-1)}{\delta}K_{j,t+1}^{1/\delta}K_{j,t}^{-1/\delta}\right)
$$

$$
\stackrel{!}{=}\frac{K_{j,t-1}^{(\delta-1)/\delta}K_{j,t}^{1/\delta-1}\phi_{j,t}Y_{j,t}}{P_{j,t}}-K_{j,t-1}^{(\delta-1)/\delta}K_{j,t+1}^{1/\delta}\Rightarrow
$$

$$
\frac{\alpha\beta\delta\phi_{j,t}Y_{j,t}\phi_{j,t-1}Y_{j,t-1}}{P_{j,t}K_{j,t}P_{j,t-1}}-\frac{(\delta-1)\delta\beta}{\delta}\frac{K_{j,t+1}^{1/\delta}\phi_{j,t-1}Y_{j,t-1}}{K_{j,t}^{1/\delta}P_{j,t-1}}
$$

$$
-\delta\beta\left(\frac{K_{j,t}}{K_{j,t-1}^{1-\delta}}\right)^{1/\delta}\frac{\alpha\phi_{j,t}Y_{j,t}}{P_{j,t}K_{j,t}}+\frac{\delta\beta(\delta-1)}{\delta}\left(\frac{K_{j,t+1}K_{j,t}}{K_{j,t}K_{j,t-1}^{1-\delta}}\right)^{1/\delta}
$$

$$
\stackrel{!}{=}\frac{K_{j,t-1}^{(\delta-1)/\delta}K_{j,t}^{1/\delta-1}\phi_{j,t}Y_{j,t}}{P_{j,t}}-K_{j,t-1}^{(\delta-1)/\delta}K_{j,t+1}^{1/\delta}\Rightarrow
$$

$$
\frac{\alpha\beta\delta\phi_{j,t}Y_{j,t}\phi_{j,t-1}Y_{j,t-1}}{P_{j,t}K_{j,t}P_{j,t-1}}-(\delta-1)\beta\frac{K_{j,t+1}^{1/\delta}\phi_{j,t-1}Y_{j,t-1}}{K_{j,t}^{1/\delta}P_{j,t-1}}
$$

$$
-\left(\frac{K_{j,t}}{K_{j,t-1}^{1-\delta}}\right)^{1/\delta}\frac{\alpha\beta\delta\phi_{j,t}Y_{j,t}}{P_{j,t}K_{j,t}}+\beta(\delta-1)\left(\frac{K_{j,t+1}}{K_{j,t-1}^{1-\delta}}\right)^{1/\delta}
$$

$$
\stackrel{!}{=}K_{j,t-1}^{(\delta-1)/\delta}\left(\frac{K_{j,t}^{1/\delta-1}\phi_{j,t}Y_{j,t}}{P_{j,t}}-K_{j,t+1}^{1/\delta}\right)\Rightarrow
$$

$$
\frac{\alpha\beta\delta\phi_{j,t}Y_{j,t}\phi_{j,t-1}Y_{j,t-1}}{P_{j,t}K_{j,t}P_{j,t-1}}-(\delta-1)\beta\frac{K_{j,t+1}^{1/\delta}\phi_{j,t-1}Y_{j,t-1}}{K_{j,t}^{1/\delta}P_{j,t-1}}+\beta(\delta-1)\left(\frac{K_{j,t+1}}{K_{j,t-1}^{1-\delta}}\right)^{1/\delta}
$$

$$
\stackrel{!}{=}K_{j,t-1}^{(\delta-1)/\delta}\left(\frac{K_{j,t}^{1/\delta-1}\phi_{j,t}Y_{j,t}}{P_{j,t}}-K_{j,t+1}^{1/\delta}+\frac{\alpha\beta\delta\phi_{j,t}Y_{j,t}K_{j,t}^{1/\delta-1}}{P_{j,t}}\right)\Rightarrow
$$

$$\frac{\alpha\beta\delta\phi_{j,t}Y_{j,t}\phi_{j,t-1}Y_{j,t-1}}{P_{j,t}K_{j,t}P_{j,t-1}} - (\delta-1)\beta\frac{K_{j,t+1}^{1/\delta}\phi_{j,t-1}Y_{j,t-1}}{K_{j,t}^{1/\delta}P_{j,t-1}} + \beta(\delta-1)\left(\frac{K_{j,t+1}}{K_{j,t-1}^{1-\delta}}\right)^{1/\delta}$$
$$\stackrel{!}{=} K_{j,t-1}^{(\delta-1)/\delta}\left(\frac{K_{j,t}^{1/\delta-1}\phi_{j,t}Y_{j,t}}{P_{j,t}}(1+\alpha\beta\delta) - K_{j,t+1}^{1/\delta}\right) \Rightarrow$$

$$\frac{\alpha\beta\delta\phi_{j,t}Y_{j,t}\phi_{j,t-1}Y_{j,t-1}}{P_{j,t}P_{j,t-1}} - (\delta-1)\beta\frac{K_{j,t+1}^{1/\delta}\phi_{j,t-1}Y_{j,t-1}}{K_{j,t}^{(1-\delta)/\delta}P_{j,t-1}} + \beta(\delta-1)K_{j,t}\left(\frac{K_{j,t+1}}{K_{j,t-1}^{1-\delta}}\right)^{1/\delta}$$
$$\stackrel{!}{=} K_{j,t-1}^{(\delta-1)/\delta}\left(\frac{K_{j,t}^{1/\delta}\phi_{j,t}Y_{j,t}}{P_{j,t}}(1+\alpha\beta\delta) - K_{j,t}K_{j,t+1}^{1/\delta}\right) \Rightarrow$$

$$\frac{\alpha\beta\delta\phi_{j,t}Y_{j,t}\phi_{j,t-1}Y_{j,t-1}}{P_{j,t}P_{j,t-1}} - (\delta-1)\beta\left(\frac{K_{j,t+1}}{K_{j,t}^{1-\delta}}\right)^{1/\delta}\frac{\phi_{j,t-1}Y_{j,t-1}}{P_{j,t-1}} + \beta(\delta-1)K_{j,t}\left(\frac{K_{j,t+1}}{K_{j,t-1}^{1-\delta}}\right)^{1/\delta}$$
$$\stackrel{!}{=} \left(\frac{K_{j,t}}{K_{j,t-1}^{1-\delta}}\right)^{1/\delta}\frac{\phi_{j,t}Y_{j,t}}{P_{j,t}}(1+\alpha\beta\delta) - K_{j,t}\left(\frac{K_{j,t+1}}{K_{j,t-1}^{1-\delta}}\right)^{1/\delta} \Rightarrow$$

$$\frac{\alpha\beta\delta\phi_{j,t}Y_{j,t}\phi_{j,t-1}Y_{j,t-1}}{P_{j,t}P_{j,t-1}} + (1+\beta(\delta-1))K_{j,t}\left(\frac{K_{j,t+1}}{K_{j,t-1}^{1-\delta}}\right)^{1/\delta}$$
$$\stackrel{!}{=} \left(\frac{K_{j,t}}{K_{j,t-1}^{1-\delta}}\right)^{1/\delta}\frac{\phi_{j,t}Y_{j,t}}{P_{j,t}}(1+\alpha\beta\delta) + (\delta-1)\beta\left(\frac{K_{j,t+1}}{K_{j,t}^{1-\delta}}\right)^{1/\delta}\frac{\phi_{j,t-1}Y_{j,t-1}}{P_{j,t-1}} \Rightarrow$$

$$\frac{\alpha\beta\delta\phi_{j,t}Y_{j,t}\phi_{j,t-1}Y_{j,t-1}}{P_{j,t}P_{j,t-1}} + (1+\beta(\delta-1))K_{j,t}\frac{K_{j,t}^{(1-\delta)/\delta}}{K_{j,t}^{(1-\delta)/\delta}}\left(\frac{K_{j,t+1}}{K_{j,t-1}^{1-\delta}}\right)^{1/\delta}$$
$$\stackrel{!}{=} \left(\frac{K_{j,t}}{K_{j,t-1}^{1-\delta}}\right)^{1/\delta}\frac{\phi_{j,t}Y_{j,t}}{P_{j,t}}(1+\alpha\beta\delta) + (\delta-1)\beta\left(\frac{K_{j,t+1}}{K_{j,t}^{1-\delta}}\right)^{1/\delta}\frac{\phi_{j,t-1}Y_{j,t-1}}{P_{j,t-1}} \Rightarrow$$

$$\frac{\alpha\beta\delta\phi_{j,t}Y_{j,t}\phi_{j,t-1}Y_{j,t-1}}{P_{j,t}P_{j,t-1}} + (1+\beta(\delta-1))\left(\frac{K_{j,t}}{K_{j,t-1}^{1-\delta}}\right)^{1/\delta}\left(\frac{K_{j,t+1}}{K_{j,t}^{1-\delta}}\right)^{1/\delta}$$
$$\stackrel{!}{=} \left(\frac{K_{j,t}}{K_{j,t-1}^{1-\delta}}\right)^{1/\delta}\frac{\phi_{j,t}Y_{j,t}}{P_{j,t}}(1+\alpha\beta\delta) + (\delta-1)\beta\left(\frac{K_{j,t+1}}{K_{j,t}^{1-\delta}}\right)^{1/\delta}\frac{\phi_{j,t-1}Y_{j,t-1}}{P_{j,t-1}} \Rightarrow$$

$$
\begin{aligned}
&\alpha\beta\delta + (1+\beta(\delta-1))\left(\frac{K_{j,t}}{K_{j,t-1}^{1-\delta}}\right)^{1/\delta}\left(\frac{K_{j,t+1}}{K_{j,t}^{1-\delta}}\right)^{1/\delta}\frac{P_{j,t}P_{j,t-1}}{\phi_{j,t}Y_{j,t}\phi_{j,t-1}Y_{j,t-1}} \\
&\stackrel{!}{=}\left(\frac{K_{j,t}}{K_{j,t-1}^{1-\delta}}\right)^{1/\delta}\frac{P_{j,t-1}}{\phi_{j,t-1}Y_{j,t-1}}(1+\alpha\beta\delta) + (\delta-1)\beta\left(\frac{K_{j,t+1}}{K_{j,t}^{1-\delta}}\right)^{1/\delta}\frac{P_{j,t}}{\phi_{j,t}Y_{j,t}}.
\end{aligned}
$$

Define $B_{j,t-1} \equiv \left(\frac{K_{j,t}}{K_{j,t-1}^{1-\delta}}\right)^{1/\delta}\frac{P_{j,t-1}}{\phi_{j,t-1}Y_{j,t-1}}$:

$$
\begin{aligned}
(1+\beta(\delta-1))B_{j,t-1}B_{j,t} - (\delta-1)\beta B_{j,t} &\stackrel{!}{=} B_{j,t-1}(1+\alpha\beta\delta) - \alpha\beta\delta. \\
B_{j,t} &\stackrel{!}{=} \frac{(1+\alpha\beta\delta)B_{j,t-1} - \alpha\beta\delta}{(1+\beta(\delta-1))B_{j,t-1} - (\delta-1)\beta}. \qquad \text{(A8)}
\end{aligned}
$$

Note that $B_{j,t-1} \equiv \left(\frac{K_{j,t}}{K_{j,t-1}^{1-\delta}}\right)^{1/\delta}\frac{P_{j,t-1}}{\phi_{j,t-1}Y_{j,t-1}} = \Omega_{j,t-1}\frac{P_{j,t-1}}{\phi_{j,t-1}Y_{j,t-1}} \Rightarrow \Omega_{j,t-1} = B_{j,t-1}\frac{\phi_{j,t-1}Y_{j,t-1}}{P_{j,t-1}}$. Hence, $B_{j,t-1}$ is the share of real expenditure used for investments in country j in period $t-1$ and $1-B_{j,t-1}$ is the share of real expenditure used for consumption in country j in period $t-1$ (as $\phi_{j,t-1}Y_{j,t-1}/P_{j,t-1} = C_{j,t-1} + \Omega_{j,t-1}$). Since $B_{j,t-1}$ is a share, it is bounded between zero and one. Note also that equation (A8) holds for all t. There are two steady states for (A8) where $B_{j,t} = B_{j,t-1} = B_j$, which are given by:

$$
(1+\beta(\delta-1))B_j^2 - (1+\alpha\beta\delta)B_j - (\delta-1)\beta B_j + \alpha\beta\delta \stackrel{!}{=} 0 \Rightarrow
$$

$$
B_j^2 - \frac{(1+\alpha\beta\delta+\delta\beta-\beta)}{(1-\beta+\beta\delta)}B_j + \frac{\alpha\beta\delta}{1-\beta+\beta\delta} \stackrel{!}{=} 0 \Rightarrow
$$

$$
\begin{aligned}
B_j &= \frac{1+\alpha\beta\delta+\delta\beta-\beta}{2(1-\beta+\beta\delta)} \pm \left(\frac{(1+\delta\beta-\beta+\alpha\beta\delta)^2}{4(1-\beta+\beta\delta)^2} - \frac{\alpha\beta\delta}{1-\beta+\beta\delta}\right)^{1/2} \Rightarrow \\
B_j &= \frac{1+\alpha\beta\delta+\delta\beta-\beta}{2(1-\beta+\beta\delta)} \\
&\quad \pm \left(\frac{(1+\delta\beta-\beta)^2 + 2(1+\delta\beta-\beta)\alpha\beta\delta + (\alpha\beta\delta)^2 - 4(1-\beta+\beta\delta)\alpha\beta\delta}{4(1-\beta+\beta\delta)^2}\right)^{1/2} \Rightarrow \\
B_j &= \frac{1+\alpha\beta\delta+\delta\beta-\beta}{2(1-\beta+\beta\delta)} \pm \left(\frac{(1+\delta\beta-\beta)^2 - 2(1+\delta\beta-\beta)\alpha\beta\delta + (\alpha\beta\delta)^2}{4(1-\beta+\beta\delta)^2}\right)^{1/2} \Rightarrow \\
B_j &= \frac{1+\alpha\beta\delta+\delta\beta-\beta}{2(1-\beta+\beta\delta)} \pm \left(\frac{(1+\delta\beta-\beta-\alpha\beta\delta)^2}{4(1-\beta+\beta\delta)^2}\right)^{1/2} \Rightarrow \\
B_j &= \frac{1+\alpha\beta\delta+\delta\beta-\beta}{2(1-\beta+\beta\delta)} \pm \frac{1+\delta\beta-\beta-\alpha\beta\delta)}{2(1-\beta+\beta\delta)} \Rightarrow \\
B_j &= \frac{(1+\alpha\beta\delta+\delta\beta-\beta) \pm (1+\delta\beta-\beta-\alpha\beta\delta)}{2(1-\beta+\beta\delta)} \Rightarrow
\end{aligned}
$$

$$B_j^- = \frac{(1+\alpha\beta\delta+\delta\beta-\beta)-(1+\delta\beta-\beta-\alpha\beta\delta)}{2(1-\beta+\beta\delta)} = \frac{\alpha\beta\delta}{1-\beta+\beta\delta}.$$
$$B_j^+ = \frac{(1+\alpha\beta\delta+\delta\beta-\beta)+(1+\delta\beta-\beta-\alpha\beta\delta)}{2(1-\beta+\beta\delta)} = 1.$$

Remember that $\Omega_{j,t-1} = B_{j,t-1}\frac{\phi_{j,t-1}Y_{j,t-1}}{P_{j,t-1}}$. Therefore, $B_j^+ = 1$ implies that $\phi_{j,t-1}Y_{j,t-1} = P_{j,t-1}\Omega_{j,t-1}$, which means that the total amount of expenditure is invested and nothing consumed. This cannot be optimal, as $\ln(0) = -\infty$. It also violates the transversality condition (see Section A.2). Alternatively, $B = B_j^- = \frac{\alpha\beta\delta}{(1-\beta+\beta\delta)}$, implies $\Omega_{j,t-1} = \frac{\alpha\beta\delta}{(1-\beta+\beta\delta)}\frac{\phi_{j,t-1}Y_{j,t-1}}{P_{j,t-1}}$, which means that a constant share of real expenditure is invested in all countries. It also satisfies the transversality condition (see again Section A.2). We next show that $B_j^- = \frac{\alpha\beta\delta}{(1-\beta+\beta\delta)}$ is an unstable equilibrium. First, linearize equation (A8) around $B_{j,0}$:

$$\begin{aligned} B_{j,t}(B_{j,t-1}) = & \frac{(1+\alpha\beta\delta)\,B_{j,0}-\alpha\beta\delta}{(1+\beta(\delta-1))B_{j,0}-(\delta-1)\beta} \\ & + \frac{\beta(1-\delta(1-\alpha))}{[(1-\beta(1-\delta))B_{j,0}+(1-\delta)\beta]^2}\left(B_{j,t-1}-B_{j,0}\right), \end{aligned}$$

where we used the following expression for the partial derivative of equation (A8) with respect to $B_{j,t-1}$:

$$\begin{aligned} \frac{\partial B_{j,t}}{\partial B_{j,t-1}} = & \frac{(1+\alpha\beta\delta)\,[(1+\beta(\delta-1))B_{j,t-1}-(\delta-1)\beta]}{[(1+\beta(\delta-1))B_{j,t-1}-(\delta-1)\beta]^2} \\ & - \frac{(1+\beta(\delta-1))\,[(1+\alpha\beta\delta)\,B_{j,t-1}-\alpha\beta\delta]}{[(1+\beta(\delta-1))B_{j,t-1}-(\delta-1)\beta]^2} \\ = & \frac{-(1+\alpha\beta\delta)\,(\delta-1)\beta+(1+\beta(\delta-1))\alpha\beta\delta}{[(1+\beta(\delta-1))B_{j,t-1}-(\delta-1)\beta]^2} \\ = & \frac{-(\delta-1)\beta-\alpha\beta\delta(\delta-1)\beta+\alpha\beta\delta+\beta(\delta-1)\alpha\beta\delta}{[(1+\beta(\delta-1))B_{j,t-1}-(\delta-1)\beta]^2} \\ = & \frac{\beta(1+\delta(\alpha-1))}{[(1+\beta(\delta-1))B_{j,t-1}-(\delta-1)\beta]^2} \\ = & \frac{\beta(1-\delta(1-\alpha))}{[(1-\beta(1-\delta))B_{j,t-1}+(1-\delta)\beta]^2}. \end{aligned}$$

Evaluate at point $B_{j,0} = B_j^- = \frac{\alpha\beta\delta}{(1-\beta+\beta\delta)}$:

$$\begin{aligned} B_{j,t}(B_{j,t-1}) = & \frac{(1+\alpha\beta\delta)\,\frac{\alpha\beta\delta}{(1-\beta+\beta\delta)}-\alpha\beta\delta}{(1+\beta(\delta-1))\frac{\alpha\beta\delta}{(1-\beta+\beta\delta)}-(\delta-1)\beta} \\ & + \frac{\beta(1-\delta(1-\alpha))}{[(1-\beta(1-\delta))\frac{\alpha\beta\delta}{(1-\beta+\beta\delta)}+(1-\delta)\beta]^2}\left(B_{j,t-1}-\frac{\alpha\beta\delta}{(1-\beta+\beta\delta)}\right) \Rightarrow \end{aligned}$$

$$B_{j,t}(B_{j,t-1}) = \frac{\alpha\beta\delta\left(\frac{1+\alpha\beta\delta}{1-\beta+\beta\delta}-1\right)}{\alpha\beta\delta-(\delta-1)\beta} + \frac{\beta(1-\delta(1-\alpha))}{[\alpha\beta\delta+(1-\delta)\beta]^2}\left(B_{j,t-1}-\frac{\alpha\beta\delta}{(1-\beta+\beta\delta)}\right) \Rightarrow$$
$$B_{j,t}(B_{j,t-1}) = \frac{\alpha\beta\delta\left(\frac{\alpha\beta\delta+\beta-\beta\delta}{1-\beta+\beta\delta}\right)}{\alpha\beta\delta-(\delta-1)\beta} + \frac{(1-\delta+\alpha\delta))}{\beta[\alpha\delta+1-\delta)]^2}\left(B_{j,t-1}-\frac{\alpha\beta\delta}{(1-\beta+\beta\delta)}\right) \Rightarrow$$
$$B_{j,t}(B_{j,t-1}) = \frac{\alpha\beta\delta\left(\alpha\beta\delta+\beta-\beta\delta\right)}{\left(\alpha\beta\delta+\beta-\beta\delta)\right)\left(1-\beta+\beta\delta\right)} + \frac{1}{\beta\left(\alpha\delta+1-\delta\right)}\left(B_{j,t-1}-\frac{\alpha\beta\delta}{(1-\beta+\beta\delta)}\right) \Rightarrow$$
$$B_{j,t}(B_{j,t-1}) = \frac{\alpha\beta\delta}{1-\beta+\beta\delta} + \frac{1}{\beta\left[1-\delta\left(1-\alpha\right)\right]}\left(B_{j,t-1}-\frac{\alpha\beta\delta}{(1-\beta+\beta\delta)}\right).$$

The theoretical constraints of the structural parameters $0 < \beta < 1$, $0 < \delta \leq 1$, and $0 < \alpha < 1$ imply $(\alpha\beta\delta)/(1-\beta+\beta\delta) > 0$ and $1/\left\{\beta\left[1-\delta\left(1-\alpha\right)\right]\right\} > 1$. Hence, all values starting above $B^{-}_{j,t-1} = \frac{\alpha\beta\delta}{(1-\beta+\beta\delta)}$ will converge to $B^{+}_{j} = 1$. However, as discussed above, $B^{+}_{j} = 1$ implies that everything is invested and nothing consumed which is not optimal and violates the transversality condition. Alternatively, all values starting below $B^{-}_{j,t-1} = \frac{\alpha\beta\delta}{(1-\beta+\beta\delta)}$, will converge to 0. This implies that nothing is invested, which is not feasible either because in this case the capital stock, output, and income will all be equal to zero (see equations (A2) and (A3)). It follows that $B^{-}_{j} = \frac{\alpha\beta\delta}{(1-\beta+\beta\delta)}$ is *the only* solution of (A8) consistent with the transversality condition and with positive investment and output in each period. Thus, the optimal solution requires $B_{j,t}$ to be constant along the transition path and to be equal to $\frac{\alpha\beta\delta}{(1-\beta+\beta\delta)}$. Together with $K_{j,t+1} = \Omega^{\delta}_{j,t}K^{1-\delta}_{j,t}$ and $Y_{j,t} = p_{j,t}A_{j,t}L^{1-\alpha}_{j,t}K^{\alpha}_{j,t}$, this enables us to express the policy function for capital as:

$$\begin{aligned}
K_{j,t+1} &= \left(\frac{\alpha\beta\delta}{(1-\beta+\beta\delta)}\frac{\phi_{j,t}Y_{j,t}}{P_{j,t}}\right)^{\delta} K^{1-\delta}_{j,t} \\
&= \left(\frac{\alpha\beta\delta}{(1-\beta+\beta\delta)}\frac{\phi_{j,t}p_{j,t}A_{j,t}L^{1-\alpha}_{j,t}K^{\alpha}_{j,t}}{P_{j,t}}\right)^{\delta} K^{1-\delta}_{j,t} \\
&= \left(\frac{\alpha\beta\delta}{(1-\beta+\beta\delta)}\frac{\phi_{j,t}p_{j,t}A_{j,t}L^{1-\alpha}_{j,t}}{P_{j,t}}\right)^{\delta} K^{\alpha\delta+1-\delta}_{j,t}. \qquad \text{(A9)}
\end{aligned}$$

Intuitively, (A9) reveals that, alongside parameters, capital accumulation depends on current capital stock $K_{j,t}$, labor endowment $L_{j,t}$, technology $A_{j,t}$, the factory-gate price $p_{j,t}$, and the aggregate price index $P_{j,t}$. 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 the factory-gate price 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, to an increase in 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 through capital accumulation. On the other hand, if the current price index is high, consumption and investment are expensive today. Therefore, less will be saved via capital accumulation. Finally, note that equation (A9) can be used to determine the level of investment:

$$\begin{aligned}\Omega_{j,t} &= \left(\frac{K_{j,t+1}}{K_{j,t}^{1-\delta}}\right)^{\frac{1}{\delta}} = \left(\frac{\left[\frac{\alpha\beta\delta\phi_{j,t}p_{j,t}A_{j,t}L_{j,t}^{1-\alpha}}{(1-\beta+\beta\delta)P_{j,t}}\right]^{\delta} K_{j,t}^{\alpha\delta+1-\delta}}{K_{j,t}^{1-\delta}}\right)^{\frac{1}{\delta}} \\ &= \left[\frac{\alpha\beta\delta\phi_{j,t}p_{j,t}A_{j,t}L_{j,t}^{1-\alpha}}{(1-\beta+\beta\delta)P_{j,t}}\right]K_{j,t}^{\alpha} = \frac{\alpha\beta\delta}{(1-\beta+\beta\delta)}\frac{\phi_{j,t}Y_{j,t}}{P_{j,t}}. \qquad \text{(A10)}\end{aligned}$$

In addition, the optimal level of current consumption can be obtained by using the policy function for capital and reformulating $E_{j,t} = \phi_{j,t}Y_{j,t} = P_{j,t}C_{j,t} + P_{j,t}\Omega_{j,t}$, i.e.,

$$\begin{aligned}C_{j,t} &= \frac{\phi_{j,t}Y_{j,t}}{P_{j,t}} - \Omega_{j,t} = \frac{\phi_{j,t}Y_{j,t}}{P_{j,t}} - \frac{\alpha\beta\delta}{(1-\beta+\beta\delta)}\frac{\phi_{j,t}Y_{j,t}}{P_{j,t}} \\ &= \left(\frac{1-\beta+\beta\delta-\alpha\beta\delta}{1-\beta+\beta\delta}\right)\frac{\phi_{j,t}Y_{j,t}}{P_{j,t}} = \left(\frac{1-\beta+\beta\delta-\alpha\beta\delta}{1-\beta+\beta\delta}\right)\frac{\phi_{j,t}p_{j,t}A_{j,t}K_{j,t}^{\alpha}L_{j,t}^{1-\alpha}}{P_{j,t}}. \qquad \text{(A11)}\end{aligned}$$

A.2 Derivation of the Transversality Condition

This section demonstrates that system (A1)-(A6) is a well-behaved dynamic problem that satisfies the following transversality condition, which is defined in the spirit of Acemoglu (2009) (see their equation (6.26) on page 283) and Stokey et al. (1989) (see their equation (3) on page 98):

$$\lim_{t\to\infty}\beta^t\frac{\partial F(x_t^*, x_{t+1}^*)}{\partial x_t}x_t^* = 0,$$

where '*' denotes the solution of the dynamic problem. Start with the following objective function:

$$\max_{\{K_{j,t}\}}\sum_{t=0}^{\infty}\beta^t \ln\left[\left(\phi_{j,t}p_{j,t}A_{j,t}L_{j,t}^{1-\alpha}K_{j,t}^{\alpha}\right)/P_{j,t} - \left(K_{j,t+1}/K_{j,t}^{1-\delta}\right)^{1/\delta}\right],$$

which only depends on $K_{j,t}$ and $K_{j,t+1}$ alongside exogenous variables for the consumer (such as $p_{j,t}$ and $P_{j,t}$) and parameters. Define

$$F \equiv \ln\left[\left(\phi_{j,t}p_{j,t}A_{j,t}L_{j,t}^{1-\alpha}K_{j,t}^{\alpha}\right)/P_{j,t} - \left(K_{j,t+1}/K_{j,t}^{1-\delta}\right)^{1/\delta}\right],$$

and express the transversality condition as follows:

$$\lim_{t\to\infty}\beta^t\frac{\partial F(K_{j,t}^*, K_{j,t+1}^*)}{\partial K_{j,t}}K_{j,t}^* = 0.$$

To show that the transversality condition is satisfied, take the derivative of F with respect to $K_{j,t}$ and plug it into the transversality condition:

$$\lim_{t\to\infty} \frac{\beta^t}{C^*_{j,t}} \left(\frac{\alpha\phi_{j,t}Y^*_{j,t}}{P^*_{j,t}K^*_{j,t}} - \frac{(\delta-1)}{\delta} \left(K^*_{j,t+1}\right)^{1/\delta} \left(K^*_{j,t}\right)^{-1/\delta} \right) K^*_{j,t} =$$
$$\lim_{t\to\infty} \frac{\beta^t}{C^*_{j,t}} \left(\frac{\alpha\phi_{j,t}Y^*_{j,t}}{P^*_{j,t}} - \frac{(\delta-1)}{\delta} \left(K^*_{j,t+1}\right)^{1/\delta} \left(K^*_{j,t}\right)^{1-1/\delta} \right) =$$
$$\lim_{t\to\infty} \beta^t \left(\frac{\alpha\phi_{j,t}Y^*_{j,t}}{C^*_{j,t}P^*_{j,t}} - \frac{(\delta-1)\Omega^*_{j,t}}{\delta C^*_{j,t}} \right).$$

Remembering that $\Omega^*_{j,t} = \frac{\alpha\beta\delta}{1-\beta+\beta\delta}\frac{\phi_{j,t}Y^*_{j,t}}{P^*_{j,t}}$, and $C^*_{j,t} = \frac{1-\beta+\beta\delta-\alpha\beta\delta}{1-\beta+\beta\delta}\frac{\phi_{j,t}Y^*_{j,t}}{P^*_{j,t}}$, we can replace $\frac{\phi_{j,t}Y^*_{j,t}}{C^*_{j,t}P^*_{j,t}}$ by $\frac{1-\beta+\beta\delta}{1-\beta+\beta\delta-\alpha\beta\delta}$ and $\frac{\Omega^*_{j,t}}{C^*_{j,t}}$ by $\frac{\alpha\beta\delta}{1-\beta+\beta\delta-\alpha\beta\delta}$ to end up with:

$$\lim_{t\to\infty} \beta^t \left(\frac{\alpha-\alpha\beta+\alpha\beta\delta}{1-\beta+\beta\delta-\alpha\beta\delta} - \frac{(\delta-1)\alpha\beta\delta}{\delta\left(1-\beta+\beta\delta-\alpha\beta\delta\right)} \right) =$$
$$\lim_{t\to\infty} \beta^t \left(\frac{\alpha\delta-\alpha\beta\delta+\alpha\beta\delta^2-\alpha\beta\delta^2+\alpha\beta\delta}{\delta(1-\beta+\beta\delta-\alpha\beta\delta)} \right) =$$
$$\lim_{t\to\infty} \beta^t \left(\frac{\alpha}{1-\beta\left(1-\delta\left(1-\alpha\right)\right)} \right) = 0,$$

where the result that the transversality condition holds follows from the theoretical restrictions on the parameters in our model, $0 < \beta < 1$, $0 < \delta \leq 1$, and $0 < \alpha < 1$.

B Transition

An important contribution of our paper 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 and to characterize the transition path between steady states. In order to do that, we first calculate the policy function for capital as described in online Appendix A, where consumers take the variety price $p_{j,t}$ and the consumer price $P_{j,t}$ as given. It should be noted that $p_{j,t}$ and $P_{j,t}$ 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 infinitely forward-looking agents 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 (20)-(25) 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 (21)-(24) 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 (25). With a new capital stock in the next period, we can again use equations (21)-(24) 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 (21)-(24) 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:

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

and combine the budget constraint with the production function:

$$P_{j,t}C_{j,t} + P_{j,t}\Omega_{j,t} = \phi_{j,t}p_{j,t}A_{j,t}L_{j,t}^{1-\alpha}K_{j,t}^{\alpha}.$$

Apply the definition of $\Omega_{j,t}$:

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

to obtain the following budget constraint:

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

The corresponding expression for the Lagrangian is:

$$\mathcal{L} = \sum_{t=0}^{\infty}\beta^t\left[\ln(C_{j,t}) + \lambda_{j,t}\left(\phi_{j,t}p_{j,t}A_{j,t}L_{j,t}^{1-\alpha}K_{j,t}^{\alpha} - P_{j,t}C_{j,t} - P_{j,t}\left(\frac{K_{j,t+1}}{K_{j,t}^{1-\delta}}\right)^{\frac{1}{\delta}}\right)\right].$$

Obtain the first-order conditions with respect to $C_{j,t}$, $K_{j,t+1}$ and $\lambda_{j,t}$:

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

Use the first-order condition for consumption to express $\lambda_{j,t}$ as:

$$\lambda_{j,t} = \frac{1}{C_{j,t}P_{j,t}}.$$

Replace this solution in the first-order condition for capital:

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

Simplify and re-arrange terms to obtain:

$$\begin{aligned}\frac{\beta\phi_{j,t+1}p_{j,t+1}A_{j,t+1}L_{j,t+1}^{1-\alpha}\alpha K_{j,t+1}^{\alpha-1}}{C_{j,t+1}P_{j,t+1}} &= \frac{1}{C_{j,t}}\left(\frac{1}{K_{j,t}^{1-\delta}}\right)^{\frac{1}{\delta}}\frac{1}{\delta}K_{j,t+1}^{\frac{1}{\delta}-1} \\ &\quad +\frac{(\delta-1)\beta}{\delta C_{j,t+1}}K_{j,t+2}^{\frac{1}{\delta}}K_{j,t+1}^{-\frac{1}{\delta}} \quad \text{for all } j \text{ and } t.\end{aligned}$$

Use the definition of $Y_{j,t}$ to re-write the left-hand side of the above expression as:

$$\frac{\alpha\beta\phi_{j,t+1}Y_{j,t+1}}{K_{j,t+1}C_{j,t+1}P_{j,t+1}} = \frac{1}{\delta C_{j,t}}\frac{K_{j,t+1}^{\frac{1}{\delta}-1}}{K_{j,t}^{\frac{1-\delta}{\delta}}} + \frac{\beta(\delta-1)}{\delta C_{j,t+1}}\left(\frac{K_{j,t+2}}{K_{j,t+1}}\right)^{\frac{1}{\delta}} \quad \text{for all } j \text{ and } t.$$

As expected, we end up with a standard consumption Euler equation. Note that we have four forward-looking variables for each country: $Y_{j,t}$, $K_{j,t}$, $C_{j,t}$ and $P_{j,t}$, i.e., we have $4N$ forward-looking variables in our system. These are, alongside $\Pi_{j,t}$, the endogenous variables we have to solve for. In order to do that, we feed the following set of equations into Dynare:

$$Y_{j,t} = \frac{(Y_{j,t}/Y_t)^{\frac{1}{1-\sigma}}}{\gamma_j P_{j,t}}A_{j,t}L_{j,t}^{1-\alpha}K_{j,t}^{\alpha} \quad \text{for all } j \text{ and } t, \tag{A12}$$

$$Y_t = \sum_j Y_{j,t} \quad \text{for all } t, \tag{A13}$$

$$Y_{j,t} = P_{j,t}C_{j,t} + P_{j,t}\left(\frac{K_{j,t+1}}{K_{j,t}^{1-\delta}}\right)^{\frac{1}{\delta}} \quad \text{for all } j \text{ and } t, \tag{A14}$$

$$P_{j,t} = \left[\sum_i \left(\frac{t_{ij,t}}{\Pi_{i,t}}\right)^{1-\sigma}\frac{Y_{i,t}}{Y_t}\right]^{\frac{1}{1-\sigma}} \quad \text{for all } j \text{ and } t, \tag{A15}$$

$$\Pi_{i,t} = \left[\sum_j \left(\frac{t_{ij,t}}{P_{j,t}}\right)^{1-\sigma}\frac{\phi_{j,t}Y_{j,t}}{Y_t}\right]^{\frac{1}{1-\sigma}} \quad \text{for all } i \text{ and } t, \tag{A16}$$

$$\frac{\alpha\beta\phi_{j,t+1}Y_{j,t+1}}{K_{j,t+1}C_{j,t+1}P_{j,t+1}} = \frac{1}{\delta C_{j,t}}\frac{K_{j,t+1}^{\frac{1}{\delta}-1}}{K_{j,t}^{\frac{1-\delta}{\delta}}} + \frac{\beta(\delta-1)}{\delta C_{j,t+1}}\left(\frac{K_{j,t+2}}{K_{j,t+1}}\right)^{\frac{1}{\delta}} \quad \text{for all } j \text{ and } t. \tag{A17}$$

The first equation is the production function from equation (24), where we have replaced $p_{j,t}$ using equation (23). The second equation is the definition of world GDP. The third equation is the budget constraint, where we use equation (2) to replace $\Omega_{j,t}$. The fourth and fifth equations are the MRs as given by equations (21) and (22), respectively, and the last equation is the Euler equation just derived above. We then take as initial and end values the baseline and the counterfactual steady states and we let Dynare solve for the transition of our deterministic model assuming perfect foresight. The algorithm for our case is described in Adjemian et al. (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.

C Robustness & Sensitivity Experiments

This appendix offers a series of sensitivity experiments that gauge the robustness of our results. First, we report the results from several alternative specifications of the *Income equation*. Next we provide a "smell test" of our capital accumulation model. Then, we offer 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 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.

C.1 Sensitivity: TFP Controls & Capital Shares

Table A1 reports results from three alternative specifications of the production function from our structural model, where we introduce additional regressors that are intended to control for TFP. Column (1) of Table A1 reports estimates where we add R&D spending. The new estimates are very similar to our main findings from Table 1. However the number of observations decreases in half. Furthermore, the estimate of the effects of R&D is not statistically significant. Next, in column (2), we add a control for the occurrence of natural disasters. Once again, the new estimates are very similar to those from Table 1, however the estimate on the new control variable is not statistically significant either. We capitalize on the fact that the occurrence of natural disasters has no direct significant effect in the income equation and we employ this variable as an instrument in some of our IV specifications. See main text for further details. Finally, in column (3) of Table A1, we add the controls for R&D and for natural disasters simultaneously and neither of them is statistically significant.

Table A2 allows for heterogeneous effects of capital shares over time and across country-groups. 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 0.441 (std.err. 0.099) during the 1990s to 0.706 (std.err. 0.077) 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 7.9 percentage points between the capital shares of the two groups of countries. Overall, we view the estimates from Table A2 as encouraging and in support of our econometric specification for income.

C.2 Capital Stocks: Theory vs. Data. A "Smell Test"

Ottaviano (2015) notes that "validation of calibrated models before simulating them has increasingly gone missing as recent works tend to favor the implementation of "exactly identified" [New Quantitative Trade Models]...Validation requires the calibrated model to be able to match other moments of the data different from those used for calibrating. Simulation of counterfactual scenarios can be reasonably performed only if the calibrated model passes the validation checks." (pp. 174-175). As demonstrated in the main text, our parameter estimates are comparable to corresponding values from existing studies. In addition, our framework provides an opportunity for a "smell test" that compares generated steady-state stocks with stocks in the data for a given year. If the two series diverge widely, it would imply that either the model is bad or the data is far from a steady state. A close fit, however, is taken to indicate good model performance in a world where the capital stocks are not far from the steady state.

The smell test compares our calculated theory-consistent, steady-state capital stocks with the observed capital stocks for 1994 from the Penn World Tables 8.0. Note that we do not assume that 1994 is a steady state and this year was chosen as the year when NAFTA entered into force. Figure 2 plots the calculated stock of capital with the Penn capital stock data. The eyeball closeness of the two series is quantified by a correlation coefficient of 0.98. No formal statistical test is proposed here, but the high correlation is intuitive supporting evidence for the capital accumulation implications of our model.

Figure 2: Theory-Consistent vs. Actual Capital Stocks

C.3 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:[56]

$$\begin{aligned}
X_{ij,t} &= \frac{Y_{i,t}\phi_{j,t}Y_{j,t}}{Y_t}\left(\frac{t_{ij,t}}{\Pi_{i,t}P_{j,t}}\right)^{1-\sigma}, && \text{(A18)}\\
P_{j,t} &= \left[\sum_i \left(\frac{t_{ij,t}}{\Pi_{i,t}}\right)^{1-\sigma}\frac{Y_{i,t}}{Y_t}\right]^{\frac{1}{1-\sigma}}, && \text{(A19)}\\
\Pi_{i,t} &= \left[\sum_j \left(\frac{t_{ij,t}}{P_{j,t}}\right)^{1-\sigma}\frac{\phi_{j,t}Y_{j,t}}{Y_t}\right]^{\frac{1}{1-\sigma}}, && \text{(A20)}\\
p_{j,t} &= \frac{(Y_{j,t}/Y_t)^{\frac{1}{1-\sigma}}}{\gamma_j\Pi_{j,t}}, && \text{(A21)}\\
Y_{j,t} &= p_{j,t}A_{j,t}L_{j,t}^{1-\alpha}K_{j,t}^{\alpha}, && \text{(A22)}\\
\frac{1}{C_{j,t}} &= \frac{\beta}{C_{j,t+1}}\left(\frac{\alpha\phi_{j,t+1}Y_{j,t+1}}{K_{j,t+1}P_{j,t+1}} + 1 - \delta\right), && \text{(A23)}\\
K_{j,0} & \quad \text{given.}
\end{aligned}$$

Two main features of the new system stand out. First, the only difference between systems (A18)-(A23) and (20)-(25) is equation (A23), which replaces the closed-form solution (25) for the link between trade and capital accumulation in the original system. Second, as expected, equation (A23) no longer represents an analytical expression for next period capital stocks, but rather an implicit relationship that determines consumption. In fact, (A23) is the standard consumption Euler equation, where we have a set of three forward-looking endogenous variables for each country $\{Y_{j,t}, C_{j,t}, \text{ and } P_{j,t}\}$.[57]

System (A18)-(A23) no longer lends itself to the iterative method that we used to perform the counterfactuals of interest.[58] Therefore, we rely on Dynare as 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 to simulate the effects of NAFTA once again.[59] To demonstrate the changes due to the new capital accumulation function,

[56]Detailed derivation steps appear in online Appendix K.

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

[58]Note also that with the linear capital accumulation we depart further from Solow, as consumption and expenditure are no longer constant shares of expenditure, even when assuming a log-linear intertemporal utility function.

[59]Note that (A18)-(A23) implies that the estimating equations for trade and output remain unchanged. Therefore, our estimates of the RTA effects, of trade costs, $t_{ij,t}$, 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 $\delta = 0.061$ is plausible, we retain it in the robustness experiment. Note also that without the closed-form solution for capital accumulation we

we first focus on the transition of capital stocks. Figure 3 contrasts the transition paths for capital stocks for the four countries that we presented in Figure 1, obtained with the log-linear transition function, against the corresponding transition paths for capital stocks for the same countries but this time obtained with the linear capital transition function, which are reported in red color.

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, 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 A3. In the first column we list the country names. The second column reproduces the welfare results from our baseline "Full Dynamic GE, trans." scenario (column (5) of Table 5). The welfare results for the case with the linear capital accumulation function are reported in column (3). Comparison between 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 increase for NAFTA members changes from 2.056% in the log-linear case to 2.059% in the linear case, while the effect on the non-members changes from -0.018% to -0.017%. Based on these estimates, we conclude that replacing the standard linear capital accumulation function with its analytically convenient log-linear counterpart increases the speed of convergence but it has little implications for our estimates of the welfare changes.

C.4 Exogenous Growth

The main mechanism that leads to dynamic effects in our framework is through capital accumulation. 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

no longer can test for causal effects of trade on capital accumulation.

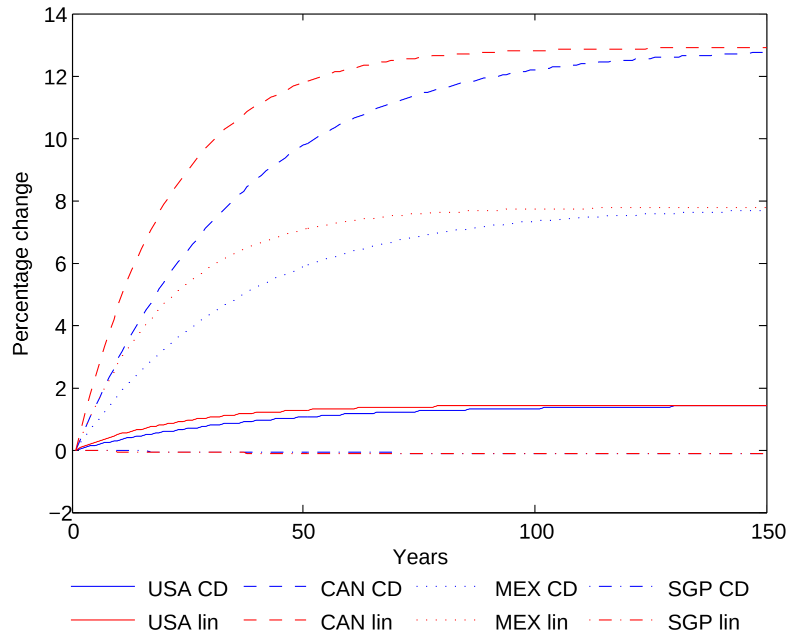

Figure 3: Linear vs. Log-Linear (Cobb-Douglas, CD) Capital Accumulation

lead to additional changes in capital stocks activating further changes in GDP, multilateral resistances, and factory-gate prices.

In order to highlight the growth implications of our model, we study the effects of an exogenous change in the initial stock of capital. In particular, we investigate how the effects of NAFTA will change if, in the presence of NAFTA, the capital stock in the U.S. were 20% larger. The welfare results from this experiment are presented in column (4) of Table A3. Several findings stand out. First, as expected, the largest increase in welfare is seen in the U.S. We find that 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 have increased by about 5.1%. The difference to the baseline, which is reported 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. In some cases, we even obtain small welfare gains for outsiders. See, for example, the calculated effects for the Dominican Republic and for Ireland. Finally, we note that the large positive effects for the U.S. and the relatively small positive effects for the other countries fade only slowly over time. In sum, the analysis in this section demonstrates that capital 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 these effects is strong.

C.5 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 aircraft (Grossman and Rossi-Hansberg, 2012). Trade models recognize the important role of intermediate goods for production and trade and introduce intermediates within static settings.[60] 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 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:[61]

$$Y_{j,t} = p_{j,t} A_{j,t} K_{j,t}^{\alpha} L_{j,t}^{\xi} Q_{j,t}^{1-\alpha-\xi} \quad \alpha, \xi \in (0,1), \tag{A24}$$

where, $Q_{j,t} = \left(\sum_i \gamma_i^{\frac{1-\sigma}{\sigma}} q_{ij,t}^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}$ is the amount of intermediates used in country j at time t defined as a CES aggregator of domestic components ($q_{jj,t}$) and imported components from all other regions $i \neq j$ ($q_{ij,t}$). Following the steps from our theoretical analysis in Section 3, we obtain the following system that describes the relationship between growth and trade in the presence of intermediate inputs:[62]

$$\begin{aligned}
X_{ij,t} &= \frac{Y_{i,t}\phi_{j,t}Y_{j,t}}{Y_t}\left(\frac{t_{ij,t}}{\Pi_{i,t}P_{j,t}}\right)^{1-\sigma}, && \text{(A25)}\\
P_{j,t} &= \left[\sum_i \left(\frac{t_{ij,t}}{\Pi_{i,t}}\right)^{1-\sigma}\frac{Y_{i,t}}{Y_t}\right]^{\frac{1}{1-\sigma}}, && \text{(A26)}\\
\Pi_{i,t} &= \left[\sum_j \left(\frac{t_{ij,t}}{P_{j,t}}\right)^{1-\sigma}\frac{\phi_{j,t}Y_{j,t}}{Y_t}\right]^{\frac{1}{1-\sigma}}, && \text{(A27)}\\
p_{j,t} &= \frac{(Y_{j,t}/Y_t)^{\frac{1}{1-\sigma}}}{\gamma_j\Pi_{j,t}}, && \text{(A28)}\\
Y_{j,t} &= p_{j,t}A_{j,t}K_{j,t}^{\alpha}L_{j,t}^{\xi}Q_{j,t}^{1-\alpha-\xi}, && \text{(A29)}\\
Q_{j,t} &= (1-\alpha-\xi)\frac{\phi_{j,t}Y_{j,t}}{P_{j,t}}, && \text{(A30)}\\
K_{j,t+1} &= \left[\frac{\alpha\beta\delta\phi_{j,t}p_{j,t}A_{j,t}L_{j,t}^{\xi}Q_{j,t}^{1-\alpha-\xi}}{(1-\beta+\beta\delta)P_{j,t}}\right]^{\delta}K_{j,t}^{\alpha\delta+1-\delta}, && \text{(A31)}\\
K_{j,0} & \quad \text{given.}
\end{aligned}$$

The introduction of intermediate goods adds a new layer of indirect and general equilibrium

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

[61] 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.

[62] Detailed derivations can be found in online Appendix L.

linkages that shape the relationship between growth and trade. Equation (A29) 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 (A29) 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 (A31) 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 (A31), 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 (A24) empirically. Therefore, we adopt Eaton and Kortum (2002)'s 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 $A_{j,t}/\gamma_j$. Specifically, we assign a share of intermediates equal to 0.25 at the expense of capital, and we retain the share of labor to 0.455 as in our baseline setting.[63] Then, we replicate our NAFTA counterfactual experiment to quantify the role of intermediates in our dynamic framework.

Column (5) of Table A3 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 0.248 percentage points on average. For example, Canada's welfare increases by about 1.1 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. Second, we find that the negative effects on non-member countries are also a bit larger. The negative impact of NAFTA on non-members increases by 0.001 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 a percent (5.5 percent vs. 12.1 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 in this section 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 limit our analysis. However, our findings point to clear potential benefits from a more detailed analysis of the dynamic effects of

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

intermediate inputs and to additional insights and knowledge to be gained from an extension of our model to the sectoral level.

C.6 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 A3. We use equation (34) 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 (34) with country dummies, and we impose the theoretical constraints of our model. Several properties of our country-specific estimates stand out. With only one exception, all estimates of δ are positive but smaller than one, as assumed in our theory.[64] We also obtain one positive but small and insignificant estimate $\delta_{SDN} = 0.006$ (std.err. 0.012), for Sudan. All other estimates are statistically significant and in the interval (0;1). The mean of the distribution of estimated depreciation rates is $\bar{\delta} = 5.5\%$ (std.dev. 2.3%). We obtain positive and significant, but suspiciously small depreciation estimates (less than 1%) for 2 countries, Vietnam (0.82%) and China (0.99%). The largest estimate that we obtain is $\delta_{GBR} = 10\%$ for Great Britain. Overall, despite the few exceptions, we view the country-specific depreciation estimates as encouraging evidence in support of our model.

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 than the benchmark estimate $\hat{\delta} = 0.061$ from the main analysis, an overall assessment of the effects of the country-specific estimates 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 of the replacement depends on the price for the final good. Lowering trade costs leads to a lower price for the composite final good. This decrease 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 larger changes of international trade due to trade liberalization, as more foreign goods are demanded for capital replacement and consumption due to the lower price. Also welfare increases as compared to an analysis with a lower depreciation rate, as the higher depreciation rate implies a larger role for the capital accumulation channel inducing income growth. The effects of trade liberalization are exactly the opposite for a lower depreciation rate. Specifically, for non-liberalizing countries, the negative effects will become stronger for higher δ's and weaker for lower δ's due to the same logic. Consider the case of Great Britain, which is the country with the highest capital depreciation rate, $\hat{\delta} = 0.1$, which is also higher than the baseline average estimate $\hat{\delta} = 0.061$. According to the above logic, one would expect higher welfare losses for Great Britain, and this is exactly what we find. The opposite happens for Sudan, which is the country with the smallest capital depreciation rate, $\delta = 0.006$.

Next, we employ extreme values for the key parameters in our model. In column (8) of Table A3, we use our largest estimate of $\hat{\sigma} = 11.282$. As expected, a higher σ leads to lower

[64] The single exception is Zimbabwe, for which we obtain a negative estimate $\delta_{ZWE} = -0.087$ (Std.err. 0.005). Since a negative depreciation rate is inconsistent with the theoretical restrictions of our model, in the counterfactual experiment we replace the negative value for Zimbabwe with our average estimate $\hat{\delta} = 0.061$.

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 5.847 to 11.282 leads to a decrease of the welfare effects of about 53%. Next, we set $\alpha = 0.3$, a standard value from the literature (see for example Acemoglu, 2009). As expected, the decrease of the capital share mitigates the dynamic effects in our model. Specifically, this leads to about 24% lower welfare gains for the NAFTA countries as compared to the baseline setting (compare column (2) and column (9) of Table A3). 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.[65] Specifically, we set the value of the consumer discount factor to $\beta = 0.95$, which is the value used in Eaton et al. (2016). The lower consumer discount factor results in smaller, but still relatively large, dynamic effects on welfare. The estimates from column (10) of Table A3 reveal that the dynamic welfare gains for NAFTA members decrease by about 21%, while the negative effects on non-members are 17% 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 (implied by our logarithmic utility function for instantaneous utility) to 0.5 ($= 1/\rho$) using an iso-elastic utility function for instantaneous utility, a value supported by empirical findings (see Sampson, 2016). A lower willingness to change the intertemporal consumption-investment-decision when relative prices change 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, the experiments in this section reveal that our results are sensitive to the specification of the key parameters, but the model generates intuitive responses to parameter changes.

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

Table A1: Trade, R&D, Disasters, and Income, 1990-2011

	(1)	(2)	(3)
	R&D	Disastr.	R&D & Disastr.
$\ln L_{j,t}$	0.190	0.236	0.190
	$(0.041)^{**}$	$(0.046)^{**}$	$(0.050)^{**}$
$\ln K_{j,t}$	0.403	0.524	0.403
	$(0.045)^{**}$	$(0.042)^{**}$	$(0.042)^{**}$
$\ln\left(\widehat{\Pi_{j,t}^{\sigma-1}}\right)$	-0.141	-0.099	-0.140
	$(0.029)^{**}$	$(0.028)^{**}$	$(0.021)^{**}$
$TFP_{j,t}$	0.456	0.303	0.456
	$(0.059)^{**}$	$(0.110)^{**}$	$(0.063)^{**}$
$R\&D_{j,t}$	0.008		0.008
	(0.014)		(0.013)
$Disastr_{j,t}$		0.165	-0.036
		(0.351)	(0.305)
N	787	1447	787

Notes: This table reports results from three alternative specifications of the production function from our structural model. All specifications include country and year fixed effects whose estimates are omitted for brevity. Column (1) reports estimates where we add R&D spending. In column (2) we add a control for the occurrence of natural disasters. Finally, in column (3) we add the controls for R&D and for natural disasters simultaneously. Robust standard errors in parentheses. + $p < 0.10$, * $p < .05$, ** $p < .01$. See text for further details.

Table A2: Heterogeneous Capital Shares

	(1) Time	(2) Development
A. Dep. Variable $\ln Y_{j,t}$		
$\ln L_{j,1990s}$	0.464	
	$(0.082)^{**}$	
$\ln L_{j,2000s}$	0.243	
	$(0.064)^{**}$	
$\ln K_{j,1990s}$	0.365	
	$(0.082)^{**}$	
$\ln K_{j,2000s}$	0.586	
	$(0.064)^{**}$	
$\ln L_{poor,t}$		0.318
		$(0.053)^{**}$
$\ln L_{rich,t}$		0.252
		$(0.036)^{**}$
$\ln K_{poor,t}$		0.511
		$(0.053)^{**}$
$\ln K_{rich,t}$		0.577
		$(0.036)^{**}$
$\ln\left(\widehat{\Pi_{j,t}^{\sigma-1}}\right)$	-0.171	-0.171
	(0.018)	$(0.018)^{**}$
$TFP_{j,t}$	0.303	0.303
	(0.026)	(0.026)
B. Structural Parameters		
$\widehat{\alpha}_{1990s}$	0.441	
	(0.099)**	
$\widehat{\alpha}_{2000s}$	0.706	
	(0.077)**	
$\widehat{\alpha}_{poor}$		0.617
		(0.063)**
$\widehat{\alpha}_{rich}$		0.696
		(0.043)**

Notes: This table reports results from two alternative specifications of the production function from our structural model. The number of observations is 1447 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 standard errors in parentheses. + $p < 0.10$, * $p < .05$, ** $p < .01$. See text for further details.

Table A3: Evaluation of NAFTA: Robustness Checks, Welfare Effects for the "Full Dynamic GE, trans." scenario

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Country	Base-line	Linear trans.	Capital accum.	Inter-mediates	Ctry-specific δ		$\sigma =$ 11.282	$\alpha =$ 0.3	$\beta =$ 0.95	$\rho =$ 2
					δ	Welfare				
AGO	-0.079	-0.076	-0.012	-0.084	0.042	-0.074	-0.044	-0.068	-0.067	-0.082
ARG	-0.016	-0.016	-0.010	-0.017	0.057	-0.016	-0.009	-0.014	-0.014	-0.017
AUS	-0.018	-0.017	-0.001	-0.019	0.058	-0.017	-0.010	-0.015	-0.015	-0.018
AUT	-0.013	-0.012	-0.005	-0.014	0.065	-0.013	-0.007	-0.011	-0.011	-0.013
AZE	-0.013	-0.013	-0.006	-0.014	0.041	-0.012	-0.007	-0.011	-0.011	-0.014
BEL	-0.027	-0.026	-0.006	-0.029	0.071	-0.028	-0.015	-0.023	-0.023	-0.028
BGD	-0.008	-0.007	-0.003	-0.008	0.037	-0.007	-0.004	-0.006	-0.006	-0.008
BGR	-0.003	-0.003	-0.002	-0.003	0.059	-0.003	-0.002	-0.003	-0.003	-0.003
BLR	-0.001	-0.001	0.000	-0.001	0.056	-0.001	-0.001	-0.001	-0.001	-0.001
BRA	-0.016	-0.015	-0.009	-0.017	0.062	-0.016	-0.008	-0.013	-0.013	-0.016
CAN	9.572	9.545	10.143	10.666	0.077	10.153	4.453	7.254	7.570	9.797
CHE	-0.038	-0.037	-0.020	-0.040	0.076	-0.039	-0.022	-0.033	-0.033	-0.040
CHL	-0.064	-0.062	-0.037	-0.068	0.043	-0.061	-0.036	-0.055	-0.055	-0.067
CHN	-0.020	-0.019	-0.007	-0.021	0.010	-0.014	-0.011	-0.017	-0.017	-0.021
COL	-0.036	-0.035	-0.021	-0.039	0.048	-0.035	-0.020	-0.031	-0.031	-0.038
CZE	-0.005	-0.005	-0.002	-0.005	0.054	-0.005	-0.003	-0.004	-0.004	-0.005
DEU	-0.019	-0.018	-0.006	-0.020	0.061	-0.019	-0.010	-0.016	-0.016	-0.019
DNK	-0.016	-0.015	-0.007	-0.017	0.067	-0.016	-0.008	-0.013	-0.013	-0.016
DOM	-0.056	-0.054	0.014	-0.060	0.040	-0.052	-0.031	-0.048	-0.047	-0.058
ECU	-0.044	-0.042	-0.010	-0.047	0.047	-0.042	-0.024	-0.037	-0.037	-0.046
EGY	-0.006	-0.006	-0.001	-0.006	0.061	-0.006	-0.003	-0.005	-0.005	-0.006
ESP	-0.012	-0.011	-0.008	-0.013	0.058	-0.012	-0.006	-0.010	-0.010	-0.012
ETH	-0.002	-0.002	0.000	-0.002	0.045	-0.002	-0.001	-0.002	-0.002	-0.002
FIN	-0.020	-0.019	-0.010	-0.021	0.060	-0.020	-0.011	-0.017	-0.017	-0.021
FRA	-0.013	-0.012	-0.003	-0.014	0.075	-0.013	-0.007	-0.011	-0.011	-0.013
GBR	-0.023	-0.022	-0.009	-0.025	0.100	-0.025	-0.013	-0.020	-0.020	-0.024
GHA	-0.011	-0.010	-0.004	-0.011	0.055	-0.010	-0.006	-0.009	-0.009	-0.011
GRC	-0.003	-0.003	-0.001	-0.003	0.057	-0.003	-0.001	-0.002	-0.002	-0.003
GTM	-0.076	-0.073	-0.015	-0.081	0.086	-0.080	-0.042	-0.064	-0.064	-0.079
HKG	-0.030	-0.029	-0.001	-0.032	0.049	-0.028	-0.016	-0.025	-0.025	-0.031
HRV	-0.003	-0.003	0.000	-0.003	0.052	-0.003	-0.002	-0.003	-0.003	-0.003
HUN	-0.008	-0.007	-0.003	-0.008	0.067	-0.008	-0.004	-0.006	-0.006	-0.008
IDN	-0.007	-0.007	-0.002	-0.008	0.046	-0.007	-0.004	-0.006	-0.006	-0.008
IND	-0.005	-0.005	-0.002	-0.006	0.057	-0.005	-0.003	-0.004	-0.004	-0.005
IRL	-0.071	-0.068	0.003	-0.074	0.095	-0.075	-0.040	-0.062	-0.060	-0.074
IRN	-0.001	-0.001	-0.002	-0.001	0.062	-0.001	-0.001	-0.001	-0.001	-0.001
IRQ	-0.044	-0.043	-0.007	-0.047	0.073	-0.045	-0.024	-0.038	-0.037	-0.046
ISR	-0.078	-0.076	0.025	-0.083	0.052	-0.076	-0.043	-0.067	-0.066	-0.081
ITA	-0.010	-0.010	-0.004	-0.011	0.067	-0.010	-0.006	-0.009	-0.009	-0.011
JPN	-0.021	-0.020	-0.007	-0.023	0.072	-0.022	-0.012	-0.018	-0.018	-0.022
KAZ	-0.009	-0.009	-0.006	-0.010	0.054	-0.009	-0.005	-0.008	-0.008	-0.009
KEN	-0.003	-0.003	0.000	-0.003	0.065	-0.003	-0.002	-0.003	-0.003	-0.003
KOR	-0.041	-0.040	-0.020	-0.044	0.038	-0.038	-0.023	-0.035	-0.035	-0.043
KWT	-0.014	-0.013	0.004	-0.015	0.043	-0.013	-0.007	-0.012	-0.011	-0.014
LBN	-0.009	-0.009	0.002	-0.010	0.034	-0.008	-0.005	-0.008	-0.008	-0.010
LKA	-0.011	-0.011	-0.003	-0.012	0.045	-0.010	-0.006	-0.009	-0.009	-0.011
LTU	-0.014	-0.013	-0.009	-0.015	0.065	-0.014	-0.008	-0.012	-0.012	-0.014
MAR	-0.009	-0.009	-0.002	-0.010	0.045	-0.009	-0.005	-0.008	-0.008	-0.009
MEX	5.748	5.740	6.086	6.418	0.080	6.138	2.687	4.369	4.538	5.880
MYS	-0.074	-0.071	-0.025	-0.078	0.034	-0.067	-0.042	-0.064	-0.063	-0.077
NGA	-0.069	-0.066	0.012	-0.073	0.089	-0.072	-0.038	-0.059	-0.058	-0.071
NLD	-0.022	-0.021	-0.004	-0.023	0.081	-0.022	-0.012	-0.018	-0.018	-0.022
NOR	-0.084	-0.080	-0.077	-0.088	0.086	-0.089	-0.048	-0.073	-0.072	-0.088
NZL	-0.025	-0.024	-0.009	-0.027	0.070	-0.025	-0.014	-0.021	-0.021	-0.026
OMN	-0.012	-0.012	0.007	-0.013	0.042	-0.012	-0.007	-0.010	-0.010	-0.013
PAK	-0.005	-0.004	-0.001	-0.005	0.063	-0.005	-0.002	-0.004	-0.004	-0.005
PER	-0.062	-0.060	-0.037	-0.066	0.043	-0.059	-0.034	-0.053	-0.053	-0.065
PHL	-0.020	-0.019	-0.004	-0.021	0.051	-0.019	-0.011	-0.016	-0.016	-0.020
POL	-0.003	-0.003	-0.002	-0.003	0.068	-0.003	-0.002	-0.003	-0.003	-0.003
PRT	-0.007	-0.006	-0.003	-0.007	0.052	-0.006	-0.003	-0.005	-0.005	-0.007
QAT	-0.009	-0.009	0.000	-0.010	0.016	-0.007	-0.005	-0.007	-0.007	-0.009

Continued on next page

Table A3 – *Continued from previous page*

(1) Country	(2) Base-line	(3) Linear trans.	(4) Capital accum.	(5) Inter-mediates	(6) Ctry-specific δ: δ	(7) Ctry-specific δ: Welfare	(8) $\sigma =$ 11.282	(9) $\alpha =$ 0.3	(10) $\beta =$ 0.95	(11) $\rho =$ 2
ROM	-0.004	-0.004	-0.002	-0.004	0.061	-0.004	-0.002	-0.003	-0.003	-0.004
RUS	-0.003	-0.003	0.000	-0.004	0.072	-0.003	-0.002	-0.003	-0.003	-0.003
SAU	-0.025	-0.024	0.001	-0.027	0.057	-0.025	-0.014	-0.021	-0.021	-0.026
SDN	-0.005	-0.004	-0.005	-0.005	0.006	-0.003	-0.002	-0.004	-0.004	-0.005
SER	-0.002	-0.002	0.000	-0.002	0.057	-0.002	-0.001	-0.002	-0.002	-0.002
SGP	-0.092	-0.088	-0.006	-0.096	0.035	-0.084	-0.053	-0.081	-0.079	-0.096
SVK	-0.003	-0.003	-0.001	-0.003	0.057	-0.003	-0.001	-0.002	-0.002	-0.003
SWE	-0.021	-0.020	-0.006	-0.022	0.097	-0.022	-0.011	-0.017	-0.017	-0.021
SYR	-0.007	-0.007	-0.001	-0.007	0.047	-0.007	-0.004	-0.006	-0.006	-0.007
THA	-0.022	-0.021	-0.007	-0.023	0.046	-0.021	-0.012	-0.019	-0.018	-0.023
TKM	-0.001	-0.001	0.000	-0.001	0.036	-0.001	-0.001	-0.001	-0.001	-0.001
TUN	-0.003	-0.003	-0.001	-0.004	0.048	-0.003	-0.002	-0.003	-0.003	-0.004
TUR	-0.005	-0.005	-0.001	-0.006	0.088	-0.005	-0.003	-0.004	-0.004	-0.005
TZA	-0.003	-0.003	-0.002	-0.003	0.048	-0.003	-0.002	-0.003	-0.003	-0.003
UKR	-0.003	-0.003	-0.001	-0.003	0.054	-0.003	-0.001	-0.002	-0.002	-0.003
USA	1.031	1.037	5.113	1.163	0.091	1.125	0.483	0.789	0.804	1.052
UZB	-0.001	-0.001	0.000	-0.001	0.078	-0.001	0.000	-0.001	-0.001	-0.001
VEN	-0.059	-0.056	-0.008	-0.062	0.067	-0.059	-0.032	-0.050	-0.049	-0.061
VNM	-0.016	-0.016	-0.004	-0.017	0.008	-0.011	-0.009	-0.014	-0.014	-0.017
ZAF	-0.012	-0.012	-0.002	-0.013	0.081	-0.013	-0.007	-0.010	-0.010	-0.013
ZWE	-0.001	-0.001	0.000	-0.001	0.061	-0.001	-0.001	-0.001	-0.001	-0.001
World	0.562	0.564	1.553	0.631		0.606	0.262	0.427	0.441	0.575
NAFTA	2.056	2.059	5.566	2.304		2.211	0.961	1.565	1.616	2.101
ROW	-0.018	-0.017	-0.006	-0.019		-0.017	-0.010	-0.015	-0.015	-0.018

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 (30) and recovered theory-consistent, steady-state capital stocks according to the capital accumulation equation (25). We calculate baseline preference-adjusted technology A_j/γ_j according to the market-clearing equation (23) and the production function equation (24). Finally, the counterfactual is based on our own estimates of the elasticity of substitution $\widehat{\sigma} = 5.847$, the share of capital in the Cobb-Douglas production function $\widehat{\alpha} = 0.545$, and the capital depreciation rate $\widehat{\delta} = 0.061$. 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) lists the country abbreviations. Columns (2) reports for reasons of comparison the results from our baseline setting reported in column (5) in Table 5. 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) reports results that allow for intermediate inputs. Column (6) lists 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 $\widehat{\sigma} = 11.282$ instead of 5.847. Column (9) reports results based on a capital share of $\widehat{\alpha} = 0.3$, a standard value from the literature, instead of 0.545. 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.

D Growth and Trade in the Long-Run

The long-run effects of trade openness on growth are captured by the comparative statics of the steady states. Equation (25) defines steady-state capital:

$$K_j = \Omega_j = \frac{\alpha\beta\delta\phi_j Y_j}{(1-\beta+\beta\delta)P_j}, \tag{A32}$$

Substitute for the factory-gate price $p_{j,t}$ in the *Income equation* (24) using the factory-gate price equation (23) 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 (A32):

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

Solve for K_j:

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

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:

$$\widehat{K}_j = \widehat{P}_j^{\frac{-\sigma}{\sigma(1-\alpha)+\alpha}}\,\widehat{\Pi}_j^{\frac{1-\sigma}{\sigma(1-\alpha)+\alpha}}\,\widehat{Y}^{\frac{1}{\sigma(1-\alpha)+\alpha}}. \tag{A33}$$

Equation (A33) captures several intuitive relationships. 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.

E ACR Formula

This section obtains the ACR-equivalent formula in our dynamic setting. Before we start, we note that real income and welfare coincide in the original ACR formula, however, this is no longer the case in our framework where 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 an ACR equivalent, we start with consumption, as given by equation (A11), and we use the production function $Y_{j,t} = p_{j,t}A_{j,t}L_{j,t}^{1-\alpha}K_{j,t}^{\alpha}$ to express welfare as:

$$W_{j,t} \equiv C_{j,t} = \left(\frac{1-\beta+\beta\delta-\alpha\beta\delta}{1-\beta+\beta\delta}\right)\frac{\phi_{j,t}Y_{j,t}}{P_{j,t}}.$$

Take log-derivative:[66]

$$d\ln W_{j,t} = d\ln Y_{j,t} - d\ln P_{j,t}.$$

Take $A_{j,t}$ and $L_{j,t}$ as given, and express $d\ln Y_{j,t}$ as:

$$d\ln Y_{j,t} = d\ln p_{j,t} + \alpha d\ln K_{j,t}. \tag{A34}$$

Use the definition of $P_{j,t}$:

$$P_{j,t} = \left[\sum_{i=1}^{N}\left(\gamma_i p_{i,t} t_{ij,t}\right)^{1-\sigma}\right]^{\frac{1}{1-\sigma}}.$$

Differentiate:

$$\begin{aligned}
d\ln P_{j,t} &= \frac{1}{P_{j,t}}dP_{j,t}, \\
&= \frac{1}{P_{j,t}}\frac{1}{1-\sigma}\left[\sum_{i=1}^{N}\left(\gamma_i p_{i,t} t_{ij,t}\right)^{1-\sigma}\right]^{\frac{1}{1-\sigma}-1} \\
&\quad \times \sum_{i=1}^{N}\left((1-\sigma)\gamma_i^{1-\sigma}p_{i,t}^{-\sigma}t_{ij,t}^{1-\sigma}dp_{i,t} + (1-\sigma)\gamma_i^{1-\sigma}p_{i,t}^{1-\sigma}t_{ij,t}^{-\sigma}dt_{ij,t}\right) \\
&= \left[\sum_{i=1}^{N}\left(\gamma_i p_{i,t} t_{ij,t}\right)^{1-\sigma}\right]^{-\frac{1}{1-\sigma}}\left[\sum_{i=1}^{N}\left(\gamma_i p_{i,t} t_{ij,t}\right)^{1-\sigma}\right]^{\frac{1}{1-\sigma}-1} \\
&\quad \times \sum_{i=1}^{N}\left(\gamma_i^{1-\sigma}p_{i,t}^{-\sigma}t_{ij,t}^{1-\sigma}dp_{i,t} + \gamma_i^{1-\sigma}p_{i,t}^{1-\sigma}t_{ij,t}^{-\sigma}dt_{ij,t}\right)
\end{aligned}$$

[66] Note that all parameters do not change between baseline and any counterfactual analysis.

$$
\begin{aligned}
&= P_{j,t}^{-(1-\sigma)} \sum_{i=1}^{N} \left(\gamma_i^{1-\sigma} p_{i,t}^{-\sigma} t_{ij,t}^{1-\sigma} dp_{i,t} + \gamma_i^{1-\sigma} p_{i,t}^{1-\sigma} t_{ij,t}^{-\sigma} dt_{ij,t} \right) \\
&= \sum_{i=1}^{N} \left(\left(\frac{\gamma_i p_{i,t} t_{ij,t}}{P_{j,t}} \right)^{1-\sigma} d\ln p_{i,t} + \left(\frac{\gamma_i p_{i,t} t_{ij,t}}{P_{j,t}} \right)^{1-\sigma} d\ln t_{ij,t} \right).
\end{aligned}
$$

Use $X_{ij,t} = \left(\frac{\gamma_i p_{i,t} t_{ij,t}}{P_{j,t}} \right)^{1-\sigma} \phi_{j,t} Y_{j,t}$ and define $\lambda_{ij,t} = X_{ij,t} / \left(\phi_{j,t} Y_{j,t} \right) = \left(\frac{\gamma_i p_{i,t} t_{ij,t}}{P_{j,t}} \right)^{1-\sigma}$:

$$
d\ln P_{j,t} = \sum_{i=1}^{N} \lambda_{ij,t} \left(d\ln p_{i,t} + d\ln t_{ij,t} \right). \tag{A35}
$$

Combine terms:

$$
d\ln W_{j,t} = d\ln Y_{j,t} - d\ln P_{j,t} = d\ln p_{j,t} + \alpha d\ln K_{j,t} - \sum_{i=1}^{N} \lambda_{ij,t} \left(d\ln p_{i,t} + d\ln t_{ij,t} \right).
$$

Take the ratio of $\lambda_{ij,t}$ and $\lambda_{jj,t}$:

$$
\frac{\lambda_{ij,t}}{\lambda_{jj,t}} = \left(\frac{\gamma_i p_{i,t} t_{ij,t}}{\gamma_j p_{j,t} t_{jj,t}} \right)^{1-\sigma}.
$$

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

$$
\begin{aligned}
d\left(\frac{\lambda_{ij,t}}{\lambda_{jj,t}} \right) &= \frac{1-\sigma}{\left(\gamma_j p_{j,t} t_{jj,t} \right)^{1-\sigma}} \left(\gamma_i p_{i,t} t_{ij,t} \right)^{-\sigma} \left(\gamma_i p_{i,t} dt_{ij,t} + \gamma_i t_{ij,t} dp_{i,t} \right) \\
&\quad - \frac{1-\sigma}{\left(\gamma_j p_{j,t} t_{jj,t} \right)^{2-\sigma}} \left(\gamma_i p_{i,t} t_{ij,t} \right)^{1-\sigma} \gamma_j t_{jj,t} dp_{j,t}.
\end{aligned}
$$

Express as log-change:

$$
\frac{d\left(\frac{\lambda_{ij,t}}{\lambda_{jj,t}} \right)}{\frac{\lambda_{ij,t}}{\lambda_{jj,t}}} = d\ln \left(\frac{\lambda_{ij,t}}{\lambda_{jj,t}} \right) = d\ln \lambda_{ij,t} - d\ln \lambda_{jj,t} = (1-\sigma) \left(d\ln t_{ij,t} + d\ln p_{i,t} - d\ln p_{j,t} \right).
$$

Use this expression in equation (A35):

$$
\begin{aligned}
d\ln P_{j,t} &= \sum_{i=1}^{N} \lambda_{ij,t} \left(d\ln p_{i,t} + d\ln t_{ij,t} \right) \\
&= \sum_{i=1}^{N} \lambda_{ij,t} \left(\frac{1}{1-\sigma} \left(d\ln \lambda_{ij,t} - d\ln \lambda_{jj,t} \right) + d\ln p_{j,t} \right) \\
&= \frac{1}{1-\sigma} \left(\sum_{i=1}^{N} \lambda_{ij,t} d\ln \lambda_{ij,t} - d\ln \lambda_{jj,t} \sum_{i=1}^{N} \lambda_{ij,t} \right) + d\ln p_{j,t} \sum_{i=1}^{N} \lambda_{ij,t}.
\end{aligned}
$$

Express total expenditure as $\phi_{j,t}Y_{j,t} = \sum_{i=1}^{N} X_{ij,t}$. Hence, $\sum_{i=1}^{N} \lambda_{ij,t} = 1$ and $d\sum_{i=1}^{N} \lambda_{ij,t} = \sum_{i=1}^{N} d\lambda_{ij,t} = 0$. Further, $\sum_{i=1}^{N} \lambda_{ij,t} d\ln\lambda_{ij,t} = \sum_{i=1}^{N} d\lambda_{ij,t} = 0$. Use these relationships to simplify the above expression:

$$\begin{aligned} d\ln P_{j,t} &= \frac{1}{1-\sigma}\left(\sum_{i=1}^{N} \lambda_{ij,t} d\ln\lambda_{ij,t} - d\ln\lambda_{jj,t}\sum_{i=1}^{N}\lambda_{ij,t}\right) + d\ln p_{j,t} \\ &= -\frac{1}{1-\sigma} d\ln\lambda_{jj,t} + d\ln p_{j,t}. \end{aligned} \tag{A36}$$

Substitute this relationship in the welfare change expression:

$$\begin{aligned} d\ln W_{j,t} &= d\ln Y_{j,t} - d\ln P_{j,t} = d\ln p_{j,t} + \alpha d\ln K_{j,t} + \frac{1}{1-\sigma} d\ln\lambda_{jj,t} - d\ln p_{j,t} \\ &= \alpha d\ln K_{j,t} + \frac{1}{1-\sigma} d\ln\lambda_{jj,t}. \end{aligned}$$

Integrate between a baseline situation and a counterfactual scenario:

$$\begin{aligned} \int_{W_{j,t}^b}^{W_{j,t}^c} d\ln W_{j,t} &= \int_{K_{j,t}^b}^{K_{j,t}^c} \alpha d\ln K_{j,t} + \int_{\lambda_{jj,t}^b}^{\lambda_{jj,t}^c} \frac{1}{1-\sigma} d\ln\lambda_{jj,t}, \\ \left(\ln W_{j,t} + C_1\right)\Big|_{W_{j,t}^b}^{W_{j,t}^c} &= \left(\alpha\ln K_{j,t} + C_2\right)\Big|_{K_{j,t}^b}^{K_{j,t}^c} + \left(\frac{1}{1-\sigma}\ln\lambda_{jj,t} + C_3\right)\Bigg|_{\lambda_{jj,t}^b}^{\lambda_{jj,t}^c}, \\ \ln W_{j,t}^c + C_1 - \ln W_{j,t}^b - C_1 &= \alpha\ln K_{j,t}^c + C_2 - \alpha\ln K_{j,t}^b - C_2 + \frac{1}{1-\sigma}\ln\lambda_{jj,t}^c + C_3 \\ & \quad -\frac{1}{1-\sigma}\ln\lambda_{jj,t}^b - C_3. \end{aligned}$$

Use "hat" to denote the ratio of any counterfactual to baseline value of a variable, i.e., $\widehat{X} = X^c/X^b$:

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

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

$$\widehat{W_{j,t}} = \widehat{K}_{j,t}^{\alpha}\widehat{\lambda}_{jj,t}^{\frac{1}{1-\sigma}}. \tag{A37}$$

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

E.1 ACR Formula in Steady State

Start by recovering theory-consistent, steady-state capital stocks from the capital accumulation equation (25), and use expression (24) to replace Y_j:

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

Solve for K_j:

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

To calculate the change in K_j, first take log-derivatives:

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

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 both sides between the baseline and the counterfactual and denoting K^c/K^b with hats, where K^c and K^b denote the counterfactual and baseline values of K, respectively:

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

Exponentiate:

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

Plug this expression into equation (A37):

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

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). Thus, in steady state, capital accumulation acts pretty much the same as adding intermediates. The key difference between our setting and a model with intermediates is the dynamics and the transition path. We characterize the transition path in Section B, and we discuss the extension to allow for intermediates in Section C.5.

E.2 ACR Formula Out-of Steady State

In Subsection E.1 we assumed that we were 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 to equation (A37), 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 (25) and replace $p_{j,t}A_{j,t}K_{j,t}^{\alpha}L_{j,t}^{1-\alpha}$ by $Y_{j,t}$:

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

Write this equation in log-derivatives:

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

Use equation (A34),

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

and equation (A36),

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

to obtain:

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

Integrate between a <u>b</u>aseline situation and a <u>c</u>ounterfactual situation:

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

Use "hat" to denote the ratio of any counterfactual and baseline value of a given variable, i.e., $\widehat{X} = X^c/X^b$:

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

Exponentiate:

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

Use $\widehat{W}_{j,t} = \widehat{K}_{j,t}^{\alpha} \widehat{\lambda}_{jj,t}^{\frac{1}{1-\sigma}}$ and note that in period zero $\widehat{K}_{j,0} = 1$. 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 a function of $\widehat{\lambda}_{jj,t}$ and parameters alone, we iteratively plug in $\widehat{K}_{j,t+1}$. In period 0:

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

In period 1:

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

In period 2:

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

Finally, in period T:

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

which are both functions of $\widehat{\lambda}_{jj,t}$ and parameters only. So far the out-of steady state formulae give welfare without taking discounting into account. Note that $\widehat{W}_{j,t} = \widehat{C}_{j,t}$. Hence, we can calculate welfare with discounting by using equation (27):

$$\begin{aligned}\zeta &= \left(\exp\left[(1-\beta)\left(\sum_{t=0}^{\infty}\beta^t \ln\left(C_{j,t}^c\right) - \sum_{t=0}^{\infty}\beta^t \ln\left(C_{j,t}^b\right)\right)\right] - 1\right)\times 100 \\ &= \left(\exp\left[(1-\beta)\left(\sum_{t=0}^{\infty}\beta^t \ln\left(\widehat{C}_{j,t}\right)\right)\right] - 1\right)\times 100 \\ &= \left(\exp\left[(1-\beta)\left(\sum_{t=0}^{\infty}\beta^t \ln\left(\widehat{K}_{j,t}^{\alpha}\widehat{\lambda}_{jj,t}^{\frac{1}{1-\sigma}}\right)\right)\right] - 1\right)\times 100. \end{aligned} \tag{A38}$$

Thus, we have demonstrated that, in principle, 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 $\lambda_{jj,t}$ 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.

F Details to Trade Cost Estimates

As discussed in the main text, our strategy to measure bilateral trade costs has been to use the estimates of the country-pair fixed effects $\widehat{\mu}_{ij}$ from equation (28) directly. However, due to missing (or zero) trade flows, we cannot identify the complete set of bilateral fixed effects. Fortunately, our data (due to its aggregate nature) enabled us to obtain estimates of the bilateral fixed effects for all but seven pairs including Angola-Iraq, Angola-Turkmenistan, Angola-Uzbekistan, Iraq-Uzbekistan, Ghana-Turkmenistan, Qatar-Uzbekistan, and Turkmenistan-Venezuela. In robustness analysis we reproduce our results treating trade costs between the pairs as missing, and we find virtually identical results. Nevertheless, to obtain the main results in the paper, we decided to recover the bilateral trade costs for the seven missing pairs. In order to do this, we adopt a procedure similar to the one from Anderson and Yotov (2016) 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 the Anderson-Yotov procedure obtains estimates of the country-pair fixed effects μ_{ij} from equation (28). Then, in the second stage, the estimates of the bilateral fixed effects are regressed on the set of standard gravity variables:

$$\exp\left(\widehat{\mu}_{ij}\right) = \exp\left[\sum_{m=2}^{5} \tilde{\eta}_m \ln DIST_{ij,m-1} + \tilde{\eta}_6 BRDR_{ij} + \tilde{\eta}_7 LANG_{ij} + \tilde{\eta}_8 CLNY_{ij} + \tilde{\chi}_i + \tilde{\pi}_j\right] + \varepsilon_{ij,t}, \tag{A39}$$

where $\ln DIST_{ij,m-1}$ 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]. Unlike Eaton and Kortum (2002) however, we do not only use indicator variables for each distance interval but instead, following Anderson and Yotov (2016), we interact the interval indicator variables with actual distances. This will enable us to account for further variation in trade costs within each distance interval. $BRDR_{ij}$ 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. $\varepsilon_{ij,t}$ is a standard remainder error. As described in Agnosteva et al. (2014), the exporter and importer fixed effects, $\tilde{\chi}_i$ and $\tilde{\pi}_j$, are included in equation (A39) to account for the fact that the bilateral fixed effects from specification (28) are estimated relative to intra-national trade costs.

The estimates of bilateral trade costs that we obtain from equation (A39) are used to complete the matrix of bilateral trade costs where bilateral fixed effects are missing. For brevity, we report the estimates directly in the estimating equation:

$$\begin{aligned}\exp\left(\widehat{\mu}_{ij}\right) = \; & \exp[-\underset{(0.083)}{\mathbf{0.487}} \ln DIST_{ij,1} - \underset{(0.072)}{\mathbf{0.504}} \ln DIST_{ij,2} - \underset{(0.067)}{\mathbf{0.521}} \ln DIST_{ij,3} - \underset{(0.064)}{\mathbf{0.523}} \ln DIST_{ij,4}] \\ & \times \exp[\underset{(0.107)}{\mathbf{0.441}}\, BRDR_{ij} + \underset{(0.097)}{\mathbf{0.102}}\, LANG_{ij} + \underset{(0.125)}{\mathbf{0.487}}\, CLNY_{ij}],\end{aligned} \tag{A40}$$

where the coefficient estimates are reported in bold-face in front of the variables, and the corresponding robust standard errors, clustered by country pair, are in parentheses below them. All coefficient estimates of equation (A40) have the expected signs and reasonable magnitudes. Distance strongly impedes trade with precisely estimated elasticity around -0.5 in all intervals. (Our distance elasticity is about 1/2 the representative value reported by Head and Mayer (2014), due to our different methods.) Contiguous borders promote international trade. The estimate on $BRDR$ is positive, large, statistically significant and comparable to estimates from the existing literature. Our estimate of the effect of language on bilateral trade is positive, as expected, but it is relatively small and not statistically significant. Finally, the estimate of the coefficient on $CLNY$ is large, positive and statistically significant as found in most of the literature.

Overall, we view the gravity estimates from equation (A40) to be plausible, and we are comfortable using them together with data on the gravity variables to construct the missing observations from the set of bilateral trade costs. These in turn are used to construct the multilateral resistance terms for the *Income* and *Capital* regressions that we estimate below, and also to perform our counterfactual experiments. We remind the reader that: (i) We only construct 7 missing values for bilateral trade costs; and (ii) Results obtained with and without recovering the missing seven observations are virtually identical.

G Country List and Country Labels

Our sample consists of the 82 countries. 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).

H The Growth-and-Trade System in Changes

In this section, we derive our system in changes using the 'exact hat' algebra as introduced by Dekle et al. (2007, 2008). In deriving the system in changes, the objective is to stick as close as possible to our original system (20)-(25), and specifically also keep the multilateral resistance terms. Doing so, however, shows that information about baseline trade costs is used when formulating the system in changes. Dekle et al. (2007, 2008) use observed trade flows to formulate the system in changes in terms of trade shares. In this case, only changes of trade costs, but not baseline levels of trade costs for solving the counterfactual values are necessary.

We first derive the system in changes out-of steady state followed by the system in changes in steady state. Denote baseline and counterfactual values with a superscript b and c, respectively, and define the change for variable X, as $\widehat{X} = X^c/X^b$. Start with the capital equation (25) and use the production function $Y_{j,t} = p_{j,t}A_{j,t}K_{j,t}^{\alpha}L_{j,t}^{1-\alpha}$:

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

This relationship holds in the baseline and in the counterfactual scenario. Therefore we can express it as a change:

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

Use equation (23) to derive an expression for the changes of prices:

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

where,

$$\widehat{Y}_t = \frac{\sum_i Y_{i,t}^c}{\sum_i Y_{i,t}^b} \Rightarrow Y_t^b\widehat{Y}_t = \sum_i Y_{i,t}^b\widehat{Y}_{i,t}.$$

Use equation (22) to derive an equation for $\widehat{\Pi}_{j,t}$:

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

Similarly, use equation (21) to describe the change in $P_{j,t}$:

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

Assuming that technology and labor stay constant, use equation (24) to derive the change in GDP:

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

Collect equations to obtain the system of growth-and-trade in changes:

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

This system needs only data on GDPs ($Y_{i,t}^{b}$) and trade costs ($t_{ij,t}^{b}$) in the baseline, and parameter values for α, σ and δ. Note that information on $A_{j,t}$, γ_j, and β is not needed. The changes in $t_{ij,t}$, $\widehat{t}_{ij,t}$, are exogenous, i.e., they form the basis of our counterfactual experiments, e.g., the basis for the evaluation of NAFTA. Further, with given GDPs and trade costs, we can solve for the baseline $\Pi_{i,t}^{b}$'s and $P_{j,t}^{b}$'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 also 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 $K_{j,0}$. We verified that the solutions that we obtain from our system in changes are identical to the solutions of our system in levels. This confirms 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 addition, the equivalence of the results in levels and in changes is reassuring of the validity of our methods.

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.

I Counterfactual Procedure

The counterfactuals are performed in four steps.

Step 1: Obtain trade cost estimates by estimating equations (28) and (A39). Then calculate bilateral trade costs for the baseline setting:

$$\left(\widehat{t}_{ij,t}^{RTA}\right)^{1-\sigma} = \exp\left[\widehat{\eta}_1 RTA_{ij,t} + \hat{\mu}_{ij}\right]. \tag{A41}$$

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 (A41). 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 (32) and (34), 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 in the baseline, i.e., $K_{j,t+1} = K_{j,t}$, we can calculate P_j using equations (21) and (22) and we can recover (from equation (25)) country-specific, theory-consistent steady-state capital stocks as follows:

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

We use K_j^{SS} as our capital stock in period zero, i.e., $K_{j,0} = K_j^{SS}$.

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 (23) and (24), 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.

Step 3: Using the values obtained in Steps 1 and 2, we solve our system given by equations (20)-(25) 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:

$$\Delta X_{i,t}\% = \frac{\left(\sum_{j\neq i} X_{ij,t}^{c} - \sum_{j\neq i} X_{ij,t}^{b}\right)}{\sum_{j\neq i} X_{ij,t}^{b}} \times 100,$$

where $X_{ij,t}$ is calculated according to equation (20), and $X_{ij,t}^{b}$ and $X_{ij,t}^{c}$ are the baseline and counterfactual trade flows, respectively. 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., $\Delta X_{\text{World},t}\% = \left(\sum_i \sum_{j\neq i} X_{ij,t}^{c} - \sum_i \sum_{j\neq i} X_{ij,t}^{b}\right) / \left(\sum_i \sum_{j\neq i} X_{ij,t}^{b}\right) \times 100$. 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, respectively. Note that we calculate the baseline assuming balanced trade (i.e., $\phi_{i,t} = 1$ for all i and t) and together with symmetric trade costs this implies $P_{i,t} = \Pi_{i,t}$. Hence, we only have to report one effect for every country in this case:

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

where $P_{i,t}$ is calculated as given by equation (21), and $P_{i,t}^{b}$ and $P_{i,t}^{c}$ are the baseline and counterfactual values of the 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 "Cond. GE" and in the "Full Static GE" cases, welfare is given by real GDP per capita.[67] Using equation (24), $Y_{i,t} = p_{i,t} A_{i,t} L_{i,t}^{1-\alpha} K_{i,t}^{\alpha}$, and equation (23), $(\gamma_i p_{i,t} \Pi_{i,t})^{1-\sigma} = Y_{i,t}/Y_t$, to replace $p_{i,t}$, we can express real GDP per capita as:

$$\tilde{Y}_{i,t} = \frac{Y_{i,t}}{P_{i,t} L_{i,t}} = \frac{p_{i,t} A_{i,t} L_{i,t}^{1-\alpha} K_{i,t}^{\alpha}}{P_{i,t} L_{i,t}} = \frac{(Y_{i,t}/Y_t)^{1/(1-\sigma)} A_{i,t} L_{i,t}^{-\alpha} K_{i,t}^{\alpha}}{\gamma_i \Pi_{i,t} P_{i,t}}.$$

This expression can be used to calculate baseline and counterfactual values of $\tilde{Y}_{i,t}$, i.e., $\tilde{Y}_{i,t}^{b}$

[67] Note that in our setting $P_{j,t}$ can also be interpreted as an ideal price index. $C_{j,t}/P_{j,t}$ therefore corresponds to indirect utility.

and $\tilde{Y}_{i,t}^c$. The change in welfare effects is then given by:

$$\Delta\tilde{Y}_{i,t}\% = \frac{\left(\tilde{Y}_{i,t}^c - \tilde{Y}_{i,t}^b\right)}{\tilde{Y}_{i,t}^b} \times 100.$$

Note that the change in real expenditure ($\Delta\tilde{E}_{i,t}\%$) is identical to $\Delta\tilde{Y}_{i,t}\%$, as we only consider exogenous trade imbalances.

In the "Full Dynamic GE, SS" and "Full Dynamic GE, trans." scenarios, welfare is calculated according to equation (27). 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: $\Delta\tilde{Y}_{\text{World},t}\% = \sum_i \left(\Delta\tilde{Y}_{i,t}\% \times \frac{Y_{i,t}^b}{\sum_j Y_{j,t}^b}\right)$. 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:

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

where $K_{i,t}$ is calculated as given by equation (25), and $K_{i,t}^b$ and $K_{i,t}^c$ are the baseline and counterfactual capital stocks, respectively. The results for the world are calculated by summing over all countries, i.e., $\Delta K_{\text{World},t}\% = \left(\sum_i K_{i,t}^c - \sum_i K_{i,t}^b\right) / \left(\sum_i K_{i,t}^b\right) \times 100$. 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.

J Additional Results for the NAFTA Counterfactual

In this section we provide a review of findings of related NAFTA studies and we offer more detailed results for our NAFTA counterfactual. We also provide a general discussion of the effects of trade liberalization, such as NAFTA, in our framework.

Arguably, NAFTA is among the most widely studied free trade agreements. Very often the effects of NAFTA have been evaluated with the gravity model. For example, using gravity estimates, Krueger (1999) finds an increase of trade among NAFTA members of 46%. Lederman et al. (2005) provides a detailed summary of many studies and finds, again using gravity based estimates, effects on trade flows of NAFTA of about 40%. These authors 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) 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 increased by 15%. Overall, the Canada-United States Free Trade Agreement was welfare-enhancing according to a simple welfare analysis undertaken. Anderson and Yotov (2016) 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 et al. (1992a,b), Fox (1999), Kehoe (2003), Rolleigh (2013) and Shikher (2012).

We provide further details to our NAFTA counterfactual in Table A4. 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 I, Step 4. The relationships between growth/capital accumulation and trade underlying the NAFTA counterfactual are illustrated by a hypothetical trade liberalization scenario acting on system (20)-(25).

Several findings stand out. 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 (20) 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 (21) and (22). 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 (23)-(24) depict the contemporaneous effects of changes in trade costs on factory-gate prices $p_{j,t}$, and on the values of domestic production/income $Y_{j,t}$. Intuitively, equation (23) 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 values of domestic production/income via equation (24). 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 (25) 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 (23). In response, a change in the capital stock begins via equation (25). 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 (25)). 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 (20). In addition, changes in output will affect trade flows indirectly via changes in the multilateral resistances that are captured by equations (21) and (22). In turn, the changes in the MRs will lead to additional, third-order changes in output and capital accumulation, and so forth.

Table A4: Evaluation of NAFTA

	Trade effects			MR effects			Welfare effects			Capital
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Country	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.
AGO	-0.575	-0.520	-0.376	0.034	0.048	0.081	-0.034	-0.059	-0.079	-0.093
ARG	-0.437	-0.383	-0.252	0.007	0.022	0.059	-0.007	-0.012	-0.016	-0.019
AUS	-0.323	-0.283	-0.182	0.007	0.023	0.059	-0.007	-0.013	-0.018	-0.021
AUT	-0.038	-0.023	0.016	0.005	0.021	0.057	-0.005	-0.009	-0.013	-0.015
AZE	-0.261	-0.222	-0.128	0.005	0.021	0.057	-0.005	-0.010	-0.013	-0.015
BEL	-0.018	-0.009	0.019	0.012	0.027	0.062	-0.012	-0.021	-0.027	-0.032
BGD	-0.415	-0.362	-0.234	0.003	0.019	0.055	-0.003	-0.005	-0.008	-0.009
BGR	-0.037	-0.020	0.022	0.001	0.017	0.054	-0.001	-0.002	-0.003	-0.004
BLR	-0.012	0.004	0.042	0.000	0.016	0.053	-0.000	-0.001	-0.001	-0.002
BRA	-0.652	-0.577	-0.396	0.006	0.022	0.058	-0.006	-0.011	-0.016	-0.019
CAN	66.950	69.652	76.053	-2.843	-3.050	-3.520	2.927	5.859	9.572	12.899
CHE	-0.090	-0.076	-0.033	0.017	0.032	0.066	-0.017	-0.029	-0.038	-0.044
CHL	-0.652	-0.586	-0.418	0.027	0.042	0.075	-0.027	-0.048	-0.064	-0.076
CHN	-0.553	-0.489	-0.333	0.008	0.024	0.060	-0.008	-0.015	-0.020	-0.024

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Table A4 – *Continued from previous page*

	Trade effects			MR effects			Welfare effects			Capital
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Country	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.
COL	-1.447	-1.296	-0.936	0.015	0.030	0.066	-0.015	-0.027	-0.036	-0.043
CZE	-0.018	-0.003	0.034	0.002	0.018	0.055	-0.002	-0.003	-0.005	-0.006
DEU	-0.099	-0.080	-0.029	0.008	0.023	0.059	-0.008	-0.014	-0.019	-0.022
DNK	-0.052	-0.037	0.004	0.006	0.022	0.058	-0.006	-0.011	-0.016	-0.019
DOM	-1.407	-1.274	-0.943	0.023	0.038	0.073	-0.023	-0.041	-0.056	-0.067
ECU	-0.689	-0.619	-0.442	0.018	0.033	0.068	-0.018	-0.032	-0.044	-0.052
EGY	-0.205	-0.173	-0.094	0.002	0.018	0.055	-0.002	-0.004	-0.006	-0.007
ESP	-0.109	-0.087	-0.031	0.005	0.020	0.057	-0.005	-0.009	-0.012	-0.014
ETH	-0.208	-0.175	-0.095	0.001	0.017	0.054	-0.001	-0.002	-0.002	-0.003
FIN	-0.077	-0.060	-0.015	0.008	0.024	0.060	-0.008	-0.015	-0.020	-0.024
FRA	-0.094	-0.074	-0.023	0.005	0.021	0.057	-0.005	-0.009	-0.013	-0.015
GBR	-0.215	-0.186	-0.109	0.010	0.025	0.061	-0.010	-0.017	-0.023	-0.028
GHA	-0.325	-0.282	-0.175	0.004	0.020	0.057	-0.004	-0.008	-0.011	-0.013
GRC	-0.046	-0.029	0.015	0.001	0.017	0.054	-0.001	-0.002	-0.003	-0.003
GTM	-1.846	-1.669	-1.235	0.031	0.046	0.080	-0.031	-0.056	-0.076	-0.090
HKG	-0.162	-0.140	-0.079	0.012	0.028	0.063	-0.012	-0.022	-0.030	-0.035
HRV	-0.067	-0.047	0.002	0.001	0.017	0.054	-0.001	-0.002	-0.003	-0.004
HUN	-0.029	-0.014	0.025	0.003	0.019	0.056	-0.003	-0.005	-0.008	-0.009
IDN	-0.167	-0.141	-0.075	0.003	0.019	0.055	-0.003	-0.005	-0.007	-0.009
IND	-0.333	-0.289	-0.182	0.002	0.018	0.055	-0.002	-0.004	-0.005	-0.006
IRL	-0.066	-0.066	-0.043	0.032	0.046	0.077	-0.032	-0.055	-0.071	-0.081
IRN	-0.032	-0.016	0.025	0.000	0.016	0.053	-0.000	-0.001	-0.001	-0.001
IRQ	-0.531	-0.473	-0.328	0.018	0.034	0.068	-0.018	-0.033	-0.044	-0.052
ISR	-0.509	-0.465	-0.342	0.033	0.048	0.081	-0.033	-0.058	-0.078	-0.093
ITA	-0.103	-0.081	-0.027	0.004	0.020	0.056	-0.004	-0.007	-0.010	-0.012
JPN	-0.634	-0.562	-0.388	0.009	0.024	0.060	-0.009	-0.016	-0.021	-0.025
KAZ	-0.130	-0.103	-0.038	0.004	0.019	0.056	-0.004	-0.007	-0.009	-0.011
KEN	-0.206	-0.173	-0.093	0.001	0.017	0.054	-0.001	-0.002	-0.003	-0.004
KOR	-0.402	-0.357	-0.242	0.017	0.033	0.067	-0.017	-0.031	-0.041	-0.049
KWT	-0.164	-0.139	-0.075	0.005	0.021	0.058	-0.005	-0.010	-0.014	-0.017
LBN	-0.124	-0.100	-0.041	0.004	0.019	0.056	-0.004	-0.007	-0.009	-0.011
LKA	-0.364	-0.317	-0.204	0.004	0.020	0.057	-0.004	-0.008	-0.011	-0.013
LTU	-0.154	-0.127	-0.060	0.006	0.021	0.058	-0.006	-0.010	-0.014	-0.016
MAR	-0.154	-0.127	-0.060	0.004	0.019	0.056	-0.004	-0.007	-0.009	-0.011
MEX	70.060	71.784	75.893	-1.733	-1.864	-2.168	1.764	3.532	5.748	7.778
MYS	-0.181	-0.169	-0.120	0.032	0.047	0.079	-0.032	-0.056	-0.074	-0.087
NGA	-0.453	-0.411	-0.295	0.029	0.044	0.077	-0.029	-0.051	-0.069	-0.081
NLD	-0.037	-0.025	0.010	0.009	0.024	0.060	-0.009	-0.016	-0.022	-0.026
NOR	-0.310	-0.283	-0.198	0.037	0.051	0.082	-0.037	-0.065	-0.084	-0.097
NZL	-0.291	-0.254	-0.160	0.010	0.026	0.062	-0.010	-0.018	-0.025	-0.030
OMN	-0.098	-0.079	-0.029	0.005	0.021	0.057	-0.005	-0.009	-0.012	-0.015
PAK	-0.335	-0.290	-0.181	0.002	0.018	0.054	-0.002	-0.003	-0.005	-0.006
PER	-1.218	-1.092	-0.787	0.026	0.041	0.075	-0.026	-0.046	-0.062	-0.073
PHL	-0.346	-0.305	-0.200	0.008	0.024	0.060	-0.008	-0.014	-0.020	-0.023
POL	-0.027	-0.011	0.028	0.001	0.017	0.054	-0.001	-0.002	-0.003	-0.004
PRT	-0.049	-0.032	0.011	0.003	0.018	0.055	-0.003	-0.005	-0.007	-0.008
QAT	-0.037	-0.023	0.015	0.003	0.019	0.056	-0.003	-0.006	-0.009	-0.011
ROM	-0.041	-0.024	0.019	0.001	0.017	0.054	-0.001	-0.003	-0.004	-0.004
RUS	-0.115	-0.091	-0.031	0.001	0.017	0.054	-0.001	-0.002	-0.003	-0.004
SAU	-0.325	-0.286	-0.186	0.010	0.026	0.062	-0.010	-0.018	-0.025	-0.030
SDN	-0.131	-0.105	-0.040	0.002	0.018	0.054	-0.002	-0.003	-0.005	-0.005
SER	-0.057	-0.038	0.010	0.001	0.017	0.053	-0.001	-0.001	-0.002	-0.002
SGP	-0.013	-0.028	-0.028	0.042	0.055	0.084	-0.042	-0.072	-0.092	-0.105
SVK	-0.007	0.007	0.043	0.001	0.017	0.054	-0.001	-0.002	-0.003	-0.004
SWE	-0.063	-0.048	-0.007	0.008	0.024	0.060	-0.008	-0.015	-0.021	-0.025
SYR	-0.050	-0.033	0.011	0.003	0.018	0.055	-0.003	-0.005	-0.007	-0.008
THA	-0.236	-0.205	-0.126	0.009	0.025	0.061	-0.009	-0.016	-0.022	-0.026
TKM	-0.024	-0.007	0.034	0.000	0.016	0.053	-0.000	-0.001	-0.001	-0.001
TUN	-0.034	-0.017	0.024	0.001	0.017	0.054	-0.001	-0.002	-0.003	-0.004
TUR	-0.107	-0.084	-0.027	0.002	0.018	0.055	-0.002	-0.004	-0.005	-0.006
TZA	-0.138	-0.111	-0.045	0.001	0.017	0.054	-0.001	-0.002	-0.003	-0.004

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Table A4 – *Continued from previous page*

	Trade effects			MR effects			Welfare effects			Capital
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Country	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.
UKR	-0.052	-0.032	0.014	0.001	0.017	0.054	-0.001	-0.002	-0.003	-0.003
USA	32.382	33.103	34.798	-0.315	-0.331	-0.372	0.316	0.637	1.031	1.428
UZB	-0.044	-0.026	0.019	0.000	0.016	0.053	-0.000	-0.001	-0.001	-0.001
VEN	-1.153	-1.039	-0.759	0.024	0.039	0.074	-0.024	-0.043	-0.059	-0.070
VNM	-0.172	-0.146	-0.081	0.006	0.022	0.059	-0.006	-0.012	-0.016	-0.020
ZAF	-0.242	-0.207	-0.122	0.005	0.021	0.057	-0.005	-0.009	-0.012	-0.015
ZWE	-0.085	-0.064	-0.011	0.000	0.016	0.053	-0.000	-0.001	-0.001	-0.002
World	6.500	6.657	7.024	-0.051	-0.040	-0.016	0.171	0.344	0.562	0.767
NAFTA	100.028	102.824	109.461	-1.631	-1.748	-2.020	0.630	1.265	2.056	2.496
ROW	-0.467	-0.412	-0.276	0.009	0.025	0.061	-0.007	-0.013	-0.018	-0.021

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 (30) and recovered theory-consistent, steady-state capital stocks according to the capital accumulation equation (25). We calculate baseline preference-adjusted technology A_j/γ_j according to the market-clearing equation (23) and the production function equation (24). Finally, the counterfactual is based on our own estimates of the elasticity of substitution $\widehat{\sigma} = 5.847$, the share of capital in the Cobb-Douglas production function $\widehat{\alpha} = 0.545$, and the capital depreciation rate $\widehat{\delta} = 0.061$. 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 "Cond. 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 changes 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 I.

K Linear Capital Accumulation Function

In this section, 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:

$$K_{j,t+1} = \Omega_{j,t} + (1-\delta)K_{j,t}. \tag{A42}$$

Start with the utility function:

$$U_{j,t} = \sum_{t=0}^{\infty} \beta^t \ln(C_{j,t}).$$

Combine the budget constraint with the production function:

$$P_{j,t}C_{j,t} + P_{j,t}\Omega_{j,t} = \phi_{j,t}p_{j,t}A_{j,t}L_{j,t}^{1-\alpha}K_{j,t}^{\alpha}.$$

Use the linear transition function for capital to express $\Omega_{j,t}$ as $K_{j,t+1} - (1-\delta)K_{j,t}$:

$$P_{j,t}C_{j,t} + P_{j,t}\left(K_{j,t+1} - (1-\delta)K_{j,t}\right) = \phi_{j,t}p_{j,t}A_{j,t}L_{j,t}^{1-\alpha}K_{j,t}^{\alpha}.$$

Set up the Lagrangian:

$$\mathcal{L} = \sum_{t=0}^{\infty} \beta^t \left[\ln(C_{j,t}) + \lambda_{j,t}\left(\phi_{j,t}p_{j,t}A_{j,t}L_{j,t}^{1-\alpha}K_{j,t}^{\alpha} - P_{j,t}C_{j,t} - P_{j,t}\left(K_{j,t+1} - (1-\delta)K_{j,t}\right)\right)\right].$$

Take derivatives with respect to $C_{j,t}$, $K_{j,t+1}$ and $\lambda_{j,t}$:

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

Use the first-order condition for consumption to express $\lambda_{j,t}$ as:

$$\lambda_{j,t} = \frac{1}{C_{j,t}P_{j,t}} \quad \text{for all } j \text{ and } t.$$

Replace this in the first-order condition for capital:

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

Simplify and re-arrange:

$$\frac{\beta \phi_{j,t+1} p_{j,t+1} A_{j,t+1} L_{j,t+1}^{1-\alpha} \alpha K_{j,t+1}^{\alpha-1}}{C_{j,t+1} P_{j,t+1}} = \frac{1}{C_{j,t}} - \frac{\beta}{C_{j,t+1}}(1-\delta) \quad \text{for all } j \text{ and } t.$$

Use the definition of $Y_{j,t}$ to re-write the left-hand side of the above expression:

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

Rearrange to obtain:

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

which is the familiar and standard consumption Euler equation. Note that there are three forward-looking variables for each country in this system: $Y_{j,t}$, $C_{j,t}$, and $P_{j,t}$ ($K_{j,t+1}$ 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, alongside $\Pi_{j,t}$ and $K_{j,t}$, 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:

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

The first equation is the production function from equation (24) replacing $p_{j,t}$ using equation (23). The second equation is the definition of world GDP. The third equation is the budget constraint, where we use equation (A42) to replace $\Omega_{j,t}$. The fourth and fifth equations are the MRs as given by equations (21) and (22), respectively, and the last equation is the Euler equation just derived above. The Euler equation is the only main 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 (A12)-(A17); the other difference is the way investments are expressed in the third equation of the systems). Finally, we note that, similar to the case of Cobb-Douglas capital accumulation, we can demonstrate (following the steps in Section A.2) that the transversality condition is also satisfied in the case of linear capital accumulation.

We also can formulate the original system for the case of a linear capital accumulation function:

$$
\begin{aligned}
X_{ij,t} &= \frac{Y_{i,t}\phi_{j,t}Y_{j,t}}{Y_t}\left(\frac{t_{ij,t}}{\Pi_{i,t}P_{j,t}}\right)^{1-\sigma}, && \text{(A43)}\\
P_{j,t} &= \left[\sum_i \left(\frac{t_{ij,t}}{\Pi_{i,t}}\right)^{1-\sigma}\frac{Y_{i,t}}{Y_t}\right]^{\frac{1}{1-\sigma}}, && \text{(A44)}\\
\Pi_{i,t} &= \left[\sum_j \left(\frac{t_{ij,t}}{P_{j,t}}\right)^{1-\sigma}\frac{\phi_{j,t}Y_{j,t}}{Y_t}\right]^{\frac{1}{1-\sigma}}, && \text{(A45)}\\
p_{j,t} &= \frac{(Y_{j,t}/Y_t)^{\frac{1}{1-\sigma}}}{\gamma_j\Pi_{j,t}}, && \text{(A46)}\\
Y_{j,t} &= p_{j,t}A_{j,t}L_{j,t}^{1-\alpha}K_{j,t}^{\alpha}, && \text{(A47)}\\
\frac{1}{C_{j,t}} &= \frac{\beta}{C_{j,t+1}}\left(\frac{\alpha\phi_{j,t+1}Y_{j,t+1}}{K_{j,t+1}P_{j,t+1}}+1-\delta\right), && \text{(A48)}\\
K_{j,0} & \quad \text{given.}
\end{aligned}
$$

When we compare the above equations with our original system given by equations (20)-(25), we see that the only differing equation is the expression for capital accumulation. As noted above, equation (A48) 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 $t_{ij,t}^{1-\sigma}$, 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 cannot 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 capital accumulation.

2. The steady state version of equation (A48) is:

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

Given this solution for the steady-state capital stock, which is again a function of parameters and Y_j/P_j, all our analytical insights from Section 3.1 go through. Actually, the only difference to the case with log-linear capital accumulation is the missing δ in the numerator for the steady-state capital stock. However, when plugging in $\phi_j Y_j = P_j C_j + P_j (K_j - (1-\delta)K_j) = P_j C_j + \delta P_j K_j$, we see that δ reappears. From this equation we also can calculate steady-state consumption:

$$\begin{aligned} C_j &= \frac{\phi_j Y_j}{P_j} - \delta K_j = \frac{\phi_j Y_j}{P_j} - \frac{\alpha\beta\delta\phi_j Y_j}{(1-\beta+\beta\delta)\,P_j} = \\ &= \left[\frac{1-\beta+\beta\delta-\alpha\beta\delta}{1-\beta+\beta\delta}\right]\frac{\phi_j Y_j}{P_j}. \end{aligned}$$

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 $\delta K_{j,t}$ is identical. With our estimated parameters of $\alpha = 0.545$, $\beta = 0.98$, $\delta = 0.061$, we end up with $\Omega_j P_j / (\phi_j Y_j) = 0.4084$ and $C_j P_j / (\phi_j Y_j) = 0.5916$ in steady state. Note, however, that the steady-state capital stock as a share of GDP is now given by $K_j P_j / (\phi_j Y_j) = 6.6947$.

3. Finally, for our counterfactuals, we have to back out A_j/γ_j. This can be done in the exact same fashion as in the case with the log-linear transition function for capital, given that we can determine the steady-state capital stock.

We provide detailed results for our NAFTA counterfactual using the linear capital accumulation function in Table A5. 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 I, Step 4. When comparing the results with the one of our log-linear transition function for capital, we see that all results besides the welfare effects are identical. The reason is that the steady states do not change, and only welfare is calculated as a discounted sum.

Table A5: Evaluation of NAFTA with Linear Capital Accumulation Function

	Trade effects			MR effects			Welfare effects			Capital
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
	Cond.	Full	Full	Cond.	Full	Full	Cond.	Full	Full	Full
Country	GE	Static	Dynamic	GE	Static	Dynamic	GE	Static	Dynamic	Dynamic
		GE	GE, trans.		GE	GE, trans.		GE	GE, trans.	GE, trans.
AGO	-0.575	-0.520	-0.376	0.034	0.048	0.081	-0.034	-0.059	-0.076	-0.093
ARG	-0.437	-0.383	-0.252	0.007	0.022	0.059	-0.007	-0.012	-0.016	-0.019
AUS	-0.323	-0.283	-0.182	0.007	0.023	0.059	-0.007	-0.013	-0.017	-0.021
AUT	-0.038	-0.023	0.016	0.005	0.021	0.057	-0.005	-0.009	-0.012	-0.015
AZE	-0.261	-0.222	-0.128	0.005	0.021	0.057	-0.005	-0.010	-0.013	-0.015
BEL	-0.018	-0.009	0.019	0.012	0.027	0.062	-0.012	-0.021	-0.026	-0.032
BGD	-0.415	-0.362	-0.234	0.003	0.019	0.055	-0.003	-0.005	-0.007	-0.009
BGR	-0.037	-0.020	0.022	0.001	0.017	0.054	-0.001	-0.002	-0.003	-0.004
BLR	-0.012	0.004	0.042	0.000	0.016	0.053	-0.000	-0.001	-0.001	-0.002
BRA	-0.652	-0.577	-0.396	0.006	0.022	0.058	-0.006	-0.011	-0.015	-0.019
CAN	66.950	69.652	76.053	-2.843	-3.050	-3.520	2.927	5.859	9.545	12.899
CHE	-0.090	-0.076	-0.033	0.017	0.032	0.066	-0.017	-0.029	-0.037	-0.044
CHL	-0.652	-0.586	-0.418	0.027	0.042	0.075	-0.027	-0.048	-0.062	-0.076

Continued on next page

Table A5 – *Continued from previous page*

(1)	Trade effects (2)	(3)	(4)	MR effects (5)	(6)	(7)	Welfare effects (8)	(9)	(10)	Capital (11)
Country	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.
CHN	-0.553	-0.489	-0.333	0.008	0.024	0.060	-0.008	-0.015	-0.019	-0.024
COL	-1.447	-1.296	-0.936	0.015	0.030	0.066	-0.015	-0.027	-0.035	-0.043
CZE	-0.018	-0.003	0.034	0.002	0.018	0.055	-0.002	-0.003	-0.005	-0.006
DEU	-0.099	-0.080	-0.029	0.008	0.023	0.059	-0.008	-0.014	-0.018	-0.022
DNK	-0.052	-0.037	0.004	0.006	0.022	0.058	-0.006	-0.011	-0.015	-0.019
DOM	-1.407	-1.274	-0.943	0.023	0.038	0.073	-0.023	-0.041	-0.054	-0.067
ECU	-0.689	-0.619	-0.442	0.018	0.033	0.068	-0.018	-0.032	-0.042	-0.052
EGY	-0.205	-0.173	-0.094	0.002	0.018	0.055	-0.002	-0.004	-0.006	-0.007
ESP	-0.109	-0.087	-0.031	0.005	0.020	0.057	-0.005	-0.009	-0.011	-0.014
ETH	-0.208	-0.175	-0.095	0.001	0.017	0.054	-0.001	-0.002	-0.002	-0.003
FIN	-0.077	-0.060	-0.015	0.008	0.024	0.060	-0.008	-0.015	-0.019	-0.024
FRA	-0.094	-0.074	-0.023	0.005	0.021	0.057	-0.005	-0.009	-0.012	-0.015
GBR	-0.215	-0.186	-0.109	0.010	0.025	0.061	-0.010	-0.017	-0.022	-0.028
GHA	-0.325	-0.282	-0.175	0.004	0.020	0.057	-0.004	-0.008	-0.010	-0.013
GRC	-0.046	-0.029	0.015	0.001	0.017	0.054	-0.001	-0.002	-0.003	-0.003
GTM	-1.846	-1.669	-1.235	0.031	0.046	0.080	-0.031	-0.056	-0.073	-0.090
HKG	-0.162	-0.140	-0.079	0.012	0.028	0.063	-0.012	-0.022	-0.029	-0.035
HRV	-0.067	-0.047	0.002	0.001	0.017	0.054	-0.001	-0.002	-0.003	-0.004
HUN	-0.029	-0.014	0.025	0.003	0.019	0.056	-0.003	-0.005	-0.007	-0.009
IDN	-0.167	-0.141	-0.075	0.003	0.019	0.055	-0.003	-0.005	-0.007	-0.009
IND	-0.333	-0.289	-0.182	0.002	0.018	0.055	-0.002	-0.004	-0.005	-0.006
IRL	-0.066	-0.066	-0.043	0.032	0.046	0.077	-0.032	-0.055	-0.068	-0.081
IRN	-0.032	-0.016	0.025	0.000	0.016	0.053	-0.000	-0.001	-0.001	-0.001
IRQ	-0.531	-0.473	-0.328	0.018	0.034	0.068	-0.018	-0.033	-0.043	-0.052
ISR	-0.509	-0.465	-0.342	0.033	0.048	0.081	-0.033	-0.058	-0.076	-0.093
ITA	-0.103	-0.081	-0.027	0.004	0.020	0.056	-0.004	-0.007	-0.010	-0.012
JPN	-0.634	-0.562	-0.388	0.009	0.024	0.060	-0.009	-0.016	-0.020	-0.025
KAZ	-0.130	-0.103	-0.038	0.004	0.019	0.056	-0.004	-0.007	-0.009	-0.011
KEN	-0.206	-0.173	-0.093	0.001	0.017	0.054	-0.001	-0.002	-0.003	-0.004
KOR	-0.402	-0.357	-0.242	0.017	0.033	0.067	-0.017	-0.031	-0.040	-0.049
KWT	-0.164	-0.139	-0.075	0.005	0.021	0.058	-0.005	-0.010	-0.013	-0.017
LBN	-0.124	-0.100	-0.041	0.004	0.019	0.056	-0.004	-0.007	-0.009	-0.011
LKA	-0.364	-0.317	-0.204	0.004	0.020	0.057	-0.004	-0.008	-0.011	-0.013
LTU	-0.154	-0.127	-0.060	0.006	0.021	0.058	-0.006	-0.010	-0.013	-0.016
MAR	-0.154	-0.127	-0.060	0.004	0.019	0.056	-0.004	-0.007	-0.009	-0.011
MEX	70.060	71.784	75.893	-1.733	-1.864	-2.168	1.764	3.532	5.740	7.778
MYS	-0.181	-0.169	-0.120	0.032	0.047	0.079	-0.032	-0.056	-0.071	-0.087
NGA	-0.453	-0.411	-0.295	0.029	0.044	0.077	-0.029	-0.051	-0.066	-0.081
NLD	-0.037	-0.025	0.010	0.009	0.024	0.060	-0.009	-0.016	-0.021	-0.026
NOR	-0.310	-0.283	-0.198	0.037	0.051	0.082	-0.037	-0.065	-0.080	-0.097
NZL	-0.291	-0.254	-0.160	0.010	0.026	0.062	-0.010	-0.018	-0.024	-0.030
OMN	-0.098	-0.079	-0.029	0.005	0.021	0.057	-0.005	-0.009	-0.012	-0.015
PAK	-0.335	-0.290	-0.181	0.002	0.018	0.054	-0.002	-0.003	-0.004	-0.006
PER	-1.218	-1.092	-0.787	0.026	0.041	0.075	-0.026	-0.046	-0.060	-0.073
PHL	-0.346	-0.305	-0.200	0.008	0.024	0.060	-0.008	-0.014	-0.019	-0.023
POL	-0.027	-0.011	0.028	0.001	0.017	0.054	-0.001	-0.002	-0.003	-0.004
PRT	-0.049	-0.032	0.011	0.003	0.018	0.055	-0.003	-0.005	-0.006	-0.008
QAT	-0.037	-0.023	0.015	0.003	0.019	0.056	-0.003	-0.006	-0.009	-0.011
ROM	-0.041	-0.024	0.019	0.001	0.017	0.054	-0.001	-0.003	-0.004	-0.004
RUS	-0.115	-0.091	-0.031	0.001	0.017	0.054	-0.001	-0.002	-0.003	-0.004
SAU	-0.325	-0.286	-0.186	0.010	0.026	0.062	-0.010	-0.018	-0.024	-0.030
SDN	-0.131	-0.105	-0.040	0.002	0.018	0.054	-0.002	-0.003	-0.004	-0.005
SER	-0.057	-0.038	0.010	0.001	0.017	0.053	-0.001	-0.001	-0.002	-0.002
SGP	-0.013	-0.028	-0.028	0.042	0.055	0.084	-0.042	-0.072	-0.088	-0.105
SVK	-0.007	0.007	0.043	0.001	0.017	0.054	-0.001	-0.002	-0.003	-0.004
SWE	-0.063	-0.048	-0.007	0.008	0.024	0.060	-0.008	-0.015	-0.020	-0.025
SYR	-0.050	-0.033	0.011	0.003	0.018	0.055	-0.003	-0.005	-0.007	-0.008
THA	-0.236	-0.205	-0.126	0.009	0.025	0.061	-0.009	-0.016	-0.021	-0.026
TKM	-0.024	-0.007	0.034	0.000	0.016	0.053	-0.000	-0.001	-0.001	-0.001
TUN	-0.034	-0.017	0.024	0.001	0.017	0.054	-0.001	-0.002	-0.003	-0.004
TUR	-0.107	-0.084	-0.027	0.002	0.018	0.055	-0.002	-0.004	-0.005	-0.006

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Table A5 – *Continued from previous page*

	Trade effects			MR effects			Welfare effects			Capital
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Country	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.
TZA	-0.138	-0.111	-0.045	0.001	0.017	0.054	-0.001	-0.002	-0.003	-0.004
UKR	-0.052	-0.032	0.014	0.001	0.017	0.054	-0.001	-0.002	-0.003	-0.003
USA	32.382	33.103	34.798	-0.315	-0.331	-0.372	0.316	0.637	1.037	1.428
UZB	-0.044	-0.026	0.019	0.000	0.016	0.053	-0.000	-0.001	-0.001	-0.001
VEN	-1.153	-1.039	-0.759	0.024	0.039	0.074	-0.024	-0.043	-0.056	-0.070
VNM	-0.172	-0.146	-0.081	0.006	0.022	0.059	-0.006	-0.012	-0.016	-0.020
ZAF	-0.242	-0.207	-0.122	0.005	0.021	0.057	-0.005	-0.009	-0.012	-0.015
ZWE	-0.085	-0.064	-0.011	0.000	0.016	0.053	-0.000	-0.001	-0.001	-0.002
World	6.500	6.657	7.024	-0.051	-0.040	-0.016	0.171	0.344	0.564	0.767
NAFTA	100.028	102.824	109.461	-1.631	-1.748	-2.020	0.630	1.265	2.059	2.496
ROW	-0.467	-0.412	-0.276	0.009	0.025	0.061	-0.007	-0.013	-0.017	-0.021

Notes: This table reports results from our NAFTA counterfactual assuming a linear capital transition function. 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 (30) and recovered theory-consistent, steady-state capital stocks according to the capital accumulation equation (25). We calculate baseline preference-adjusted technology A_j/γ_j according to the market-clearing equation (23) and the production function equation (24). Finally, the counterfactual is based on our own estimates of the elasticity of substitution $\widehat{\sigma} = 5.847$, the share of capital in the Cobb-Douglas production function $\widehat{\alpha} = 0.545$, and the capital depreciation rate $\widehat{\delta} = 0.061$. 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 "Cond. 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 changes 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 I.

To further compare the log-linear capital transition function with the linear one, we re-simulate both models with a depreciation rate half the value of the original one ($\delta = 0.03$ instead of $\delta = 0.061$). Note that the depreciation rate is the only parameter that cannot be recovered with the linear transition function for capital. Figure 4 plots the comparison for the capital transition for both cases, similar as Figure 3 for the baseline value of $\delta = 0.061$. Our main findings are that 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, and that the dynamic NAFTA effects are exhausted a bit faster with the linear capital accumulation function also hold with a lower depreciation rate. The differences in the transition of capital between the linear and the log-linear transition function of capital are a bit larger with a lower depreciation rate. However, the welfare effects obtained with the linear versus the log-linear capital transition function are again very similar. The average welfare effect for the NAFTA members is 1.80, and identical up to the second digit between the two cases. Also the results for the World (0.49) and for the rest of the world (-0.016) are identical up to the second digit with a depreciation rate of $\delta = 0.3$.

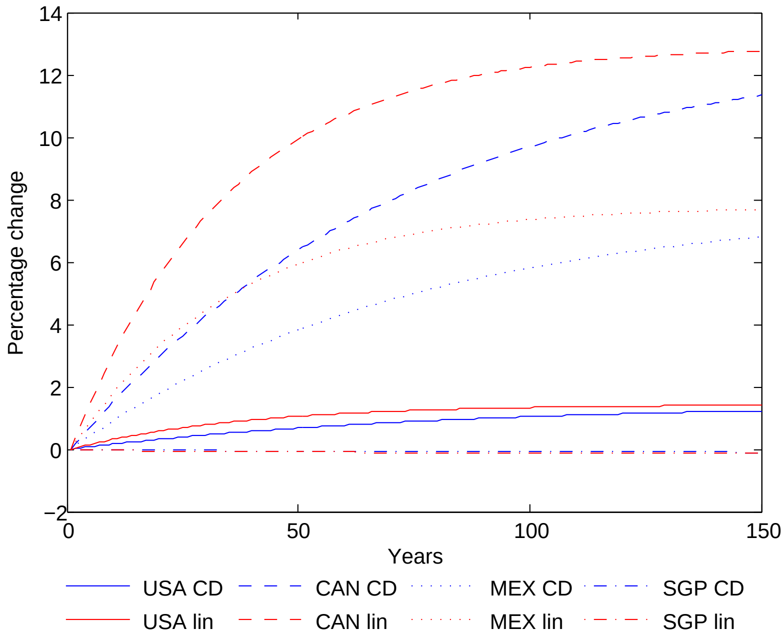

Figure 4: Linear vs. Log-Linear (Cobb-Douglas, CD) Capital Accumulation

L Solution of the Upper Level with Intermediates

This section extends our model to allow for intermediates. Intermediates in country j at time t, $Q_{j,t}$, are assumed as an additional production factor in our Cobb-Douglas production function following Eaton and Kortum (2002) and Caliendo and Parro (2015).

L.1 Derivation of the Policy Functions of the Upper Level with Intermediates

While α still denotes the capital share of production, we now introduce ξ as the labor share of production. 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., $Q_{j,t} = \left(\sum_i \gamma_i^{(1-\sigma)/\sigma} q_{ij,t}^{(\sigma-1)/\sigma}\right)^{\sigma/(\sigma-1)}$. All other assumptions are maintained.

Define the upper-level optimization problem with intermediates:

$$
\begin{aligned}
\max_{\{C_{j,t},\Omega_{j,t},Q_{j,t}\}} \quad & \sum_{t=0}^{\infty} \beta^t \ln(C_{j,t}) && \text{(A49)} \\
K_{j,t+1} &= \Omega_{j,t}^{\delta} K_{j,t}^{1-\delta}, \ \forall t && \text{(A50)} \\
Y_{j,t} &= p_{j,t} A_{j,t} K_{j,t}^{\alpha} L_{j,t}^{\xi} Q_{j,t}^{1-\alpha-\xi}, \ \forall t && \text{(A51)} \\
E_{j,t} &= P_{j,t} C_{j,t} + P_{j,t} \Omega_{j,t} + P_{j,t} Q_{j,t}, \ \forall t && \text{(A52)} \\
E_{j,t} &= \phi_{j,t} Y_{j,t}, \ \forall t && \text{(A53)} \\
K_{j,0} & \quad \text{given.} && \text{(A54)}
\end{aligned}
$$

Solve for $C_{j,t}$ using (A52) and (A53) to obtain $C_{j,t} = \phi_{j,t} Y_{j,t}/P_{j,t} - \Omega_{j,t} - Q_{j,t}$. Use $Y_{j,t}$, as given by (A51), and plug in for $Y_{j,t}$ in $C_{j,t} = \phi_{j,t} Y_{j,t}/P_{j,t} - \Omega_{j,t} - Q_{j,t}$:

$$
C_{j,t} = \phi_{j,t} p_{j,t} A_{j,t} K_{j,t}^{\alpha} L_{j,t}^{\xi} Q_{j,t}^{1-\alpha-\xi}/P_{j,t} - \Omega_{j,t} - Q_{j,t}.
$$

Use (A50) to replace $\Omega_{j,t}$:

$$
C_{j,t} = \phi_{j,t} p_{j,t} A_{j,t} K_{j,t}^{\alpha} L_{j,t}^{\xi} Q_{j,t}^{1-\alpha-\xi}/P_{j,t} - \left(K_{j,t+1}/K_{j,t}^{1-\delta}\right)^{1/\delta} - Q_{j,t}.
$$

Define the following objective function:

$$
\max_{\{K_{j,t},Q_{j,t}\}} \sum_{t=0}^{\infty} \beta^t \ln\left[\phi_{j,t} p_{j,t} A_{j,t} K_{j,t}^{\alpha} L_{j,t}^{\xi} Q_{j,t}^{1-\alpha-\xi}/P_{j,t} - \left(K_{j,t+1}/K_{j,t}^{1-\delta}\right)^{1/\delta} - Q_{j,t}\right].
$$

Obtain first-order conditions:

$$
\frac{\beta^t}{C_{j,t}}\left(\frac{\alpha \phi_{j,t} Y_{j,t}}{P_{j,t} K_{j,t}} - \frac{(\delta-1)}{\delta} K_{j,t+1}^{1/\delta} K_{j,t}^{-1/\delta}\right) - \frac{1}{\delta}\frac{\beta^{t-1}}{C_{j,t-1}} K_{j,t-1}^{(\delta-1)/\delta} K_{j,t}^{1/\delta-1} \stackrel{!}{=} 0, \qquad \text{(A55)}
$$

$$\frac{\beta^t}{C_{j,t}}\left(\frac{(1-\alpha-\xi)\phi_{j,t}Y_{j,t}}{P_{j,t}Q_{j,t}}-1\right)\stackrel{!}{=}0, \tag{A56}$$

which hold for all j's and t's.

Simplify the first-order condition in equation (A56):

$$(1-\alpha-\xi)\phi_{j,t}Y_{j,t}\stackrel{!}{=}P_{j,t}Q_{j,t}. \tag{A57}$$

Simplify the first-order condition in equation (A55):

$$\frac{\delta\beta C_{j,t-1}}{C_{j,t}}\left(\frac{\alpha\phi_{j,t}Y_{j,t}}{P_{j,t}K_{j,t}}-\frac{(\delta-1)}{\delta}K_{j,t+1}^{1/\delta}K_{j,t}^{-1/\delta}\right)\stackrel{!}{=}K_{j,t-1}^{(\delta-1)/\delta}K_{j,t}^{1/\delta-1}. \tag{A58}$$

Replace $C_{j,t}$ and $C_{j,t-1}$ by $C_{j,t}=\phi_{j,t}Y_{j,t}/P_{j,t}-\Omega_{j,t}-Q_{j,t}$ using $Q_{j,t}=(1-\alpha-\xi)\phi_{j,t}Y_{j,t}/P_{j,t}$ and $\Omega_{j,t}=\left(K_{j,t+1}/K_{j,t}^{1-\delta}\right)^{1/\delta}$:

$$\frac{\delta\beta\left((\alpha+\xi)\,\phi_{j,t-1}Y_{j,t-1}/P_{j,t-1}-\left(K_{j,t}/K_{j,t-1}^{1-\delta}\right)^{1/\delta}\right)}{\left((\alpha+\xi)\,\phi_{j,t}Y_{j,t}/P_{j,t}-\left(K_{j,t+1}/K_{j,t}^{1-\delta}\right)^{1/\delta}\right)}\left(\frac{\alpha\phi_{j,t}Y_{j,t}}{P_{j,t}K_{j,t}}-\frac{(\delta-1)}{\delta}K_{j,t+1}^{1/\delta}K_{j,t}^{-1/\delta}\right)$$
$$\stackrel{!}{=}K_{j,t-1}^{(\delta-1)/\delta}K_{j,t}^{1/\delta-1}\Rightarrow$$

$$\delta\beta\left(\frac{(\alpha+\xi)\,\phi_{j,t-1}Y_{j,t-1}}{P_{j,t-1}}-\left(\frac{K_{j,t}}{K_{j,t-1}^{1-\delta}}\right)^{1/\delta}\right)\left(\frac{\alpha\phi_{j,t}Y_{j,t}}{P_{j,t}K_{j,t}}-\frac{(\delta-1)}{\delta}K_{j,t+1}^{1/\delta}K_{j,t}^{-1/\delta}\right)$$
$$\stackrel{!}{=}\frac{K_{j,t-1}^{(\delta-1)/\delta}K_{j,t}^{1/\delta-1}\,(\alpha+\xi)\,\phi_{j,t}Y_{j,t}}{P_{j,t}}-K_{j,t-1}^{(\delta-1)/\delta}K_{j,t}^{1/\delta-1}\left(\frac{K_{j,t+1}}{K_{j,t}^{1-\delta}}\right)^{1/\delta}\Rightarrow$$

$$\delta\beta\left(\frac{(\alpha+\xi)\,\phi_{j,t-1}Y_{j,t-1}}{P_{j,t-1}}-\left(\frac{K_{j,t}}{K_{j,t-1}^{1-\delta}}\right)^{1/\delta}\right)\left(\frac{\alpha\phi_{j,t}Y_{j,t}}{P_{j,t}K_{j,t}}-\frac{(\delta-1)}{\delta}K_{j,t+1}^{1/\delta}K_{j,t}^{-1/\delta}\right)$$
$$\stackrel{!}{=}\frac{K_{j,t-1}^{(\delta-1)/\delta}K_{j,t}^{1/\delta-1}\,(\alpha+\xi)\,\phi_{j,t}Y_{j,t}}{P_{j,t}}-K_{j,t-1}^{(\delta-1)/\delta}K_{j,t+1}^{1/\delta}\Rightarrow$$

$$\frac{\alpha\beta\delta\,(\alpha+\xi)\,\phi_{j,t}Y_{j,t}\phi_{j,t-1}Y_{j,t-1}}{P_{j,t}K_{j,t}P_{j,t-1}}-\frac{(\delta-1)\delta\beta\,(\alpha+\xi)}{\delta}\frac{K_{j,t+1}^{1/\delta}\phi_{j,t-1}Y_{j,t-1}}{K_{j,t}^{1/\delta}P_{j,t-1}}$$
$$-\delta\beta\left(\frac{K_{j,t}}{K_{j,t-1}^{1-\delta}}\right)^{1/\delta}\frac{\alpha\phi_{j,t}Y_{j,t}}{P_{j,t}K_{j,t}}+\frac{\delta\beta(\delta-1)}{\delta}\left(\frac{K_{j,t+1}K_{j,t}}{K_{j,t}K_{j,t-1}^{1-\delta}}\right)^{1/\delta}$$
$$\stackrel{!}{=}\frac{K_{j,t-1}^{(\delta-1)/\delta}K_{j,t}^{1/\delta-1}\,(\alpha+\xi)\,\phi_{j,t}Y_{j,t}}{P_{j,t}}-K_{j,t-1}^{(\delta-1)/\delta}K_{j,t+1}^{1/\delta}\Rightarrow$$

$$\frac{\alpha\beta\delta\left(\alpha+\xi\right)\phi_{j,t}Y_{j,t}\phi_{j,t-1}Y_{j,t-1}}{P_{j,t}K_{j,t}P_{j,t-1}}-(\delta-1)\beta\left(\alpha+\xi\right)\frac{K_{j,t+1}^{1/\delta}\phi_{j,t-1}Y_{j,t-1}}{K_{j,t}^{1/\delta}P_{j,t-1}}$$
$$-\left(\frac{K_{j,t}}{K_{j,t-1}^{1-\delta}}\right)^{1/\delta}\frac{\alpha\beta\delta\phi_{j,t}Y_{j,t}}{P_{j,t}K_{j,t}}+\beta(\delta-1)\left(\frac{K_{j,t+1}}{K_{j,t-1}^{1-\delta}}\right)^{1/\delta}$$
$$\stackrel{!}{=}K_{j,t-1}^{(\delta-1)/\delta}\left(\frac{K_{j,t}^{1/\delta-1}\left(\alpha+\xi\right)\phi_{j,t}Y_{j,t}}{P_{j,t}}-K_{j,t+1}^{1/\delta}\right)\Rightarrow$$

$$\frac{\alpha\beta\delta\left(\alpha+\xi\right)\phi_{j,t}Y_{j,t}\phi_{j,t-1}Y_{j,t-1}}{P_{j,t}K_{j,t}P_{j,t-1}}-(\delta-1)\beta\left(\alpha+\xi\right)\frac{K_{j,t+1}^{1/\delta}\phi_{j,t-1}Y_{j,t-1}}{K_{j,t}^{1/\delta}P_{j,t-1}}$$
$$+\beta(\delta-1)\left(\frac{K_{j,t+1}}{K_{j,t-1}^{1-\delta}}\right)^{1/\delta}$$
$$\stackrel{!}{=}K_{j,t-1}^{(\delta-1)/\delta}\left(\frac{K_{j,t}^{1/\delta-1}\left(\alpha+\xi\right)\phi_{j,t}Y_{j,t}}{P_{j,t}}-K_{j,t+1}^{1/\delta}+\frac{\alpha\beta\delta\phi_{j,t}Y_{j,t}K_{j,t}^{1/\delta-1}}{P_{j,t}}\right)\Rightarrow$$

$$\frac{\alpha\beta\delta\left(\alpha+\xi\right)\phi_{j,t}Y_{j,t}\phi_{j,t-1}Y_{j,t-1}}{P_{j,t}K_{j,t}P_{j,t-1}}-(\delta-1)\beta\left(\alpha+\xi\right)\frac{K_{j,t+1}^{1/\delta}\phi_{j,t-1}Y_{j,t-1}}{K_{j,t}^{1/\delta}P_{j,t-1}}$$
$$+\beta(\delta-1)\left(\frac{K_{j,t+1}}{K_{j,t-1}^{1-\delta}}\right)^{1/\delta}$$
$$\stackrel{!}{=}K_{j,t-1}^{(\delta-1)/\delta}\left(\frac{K_{j,t}^{1/\delta-1}\phi_{j,t}Y_{j,t}}{P_{j,t}}\left(\alpha+\xi+\alpha\beta\delta\right)-K_{j,t+1}^{1/\delta}\right)\Rightarrow$$

$$\frac{\alpha\beta\delta\left(\alpha+\xi\right)\phi_{j,t}Y_{j,t}\phi_{j,t-1}Y_{j,t-1}}{P_{j,t}P_{j,t-1}}-(\delta-1)\beta\left(\alpha+\xi\right)\frac{K_{j,t+1}^{1/\delta}\phi_{j,t-1}Y_{j,t-1}}{K_{j,t}^{(1-\delta)/\delta}P_{j,t-1}}$$
$$+\beta(\delta-1)K_{j,t}\left(\frac{K_{j,t+1}}{K_{j,t-1}^{1-\delta}}\right)^{1/\delta}$$
$$\stackrel{!}{=}K_{j,t-1}^{(\delta-1)/\delta}\left(\frac{K_{j,t}^{1/\delta}\phi_{j,t}Y_{j,t}}{P_{j,t}}\left(\alpha+\xi+\alpha\beta\delta\right)-K_{j,t}K_{j,t+1}^{1/\delta}\right)\Rightarrow$$

$$
\begin{aligned}
&\frac{\alpha\beta\delta\left(\alpha+\xi\right)\phi_{j,t}Y_{j,t}\phi_{j,t-1}Y_{j,t-1}}{P_{j,t}P_{j,t-1}}-(\delta-1)\beta\left(\alpha+\xi\right)\left(\frac{K_{j,t+1}}{K_{j,t}^{1-\delta}}\right)^{1/\delta}\frac{\phi_{j,t-1}Y_{j,t-1}}{P_{j,t-1}}\\
&\qquad\qquad+\beta(\delta-1)K_{j,t}\left(\frac{K_{j,t+1}}{K_{j,t-1}^{1-\delta}}\right)^{1/\delta}\\
&\stackrel{!}{=}\left(\frac{K_{j,t}}{K_{j,t-1}^{1-\delta}}\right)^{1/\delta}\frac{\phi_{j,t}Y_{j,t}}{P_{j,t}}\left(\alpha+\xi+\alpha\beta\delta\right)-K_{j,t}\left(\frac{K_{j,t+1}}{K_{j,t-1}^{1-\delta}}\right)^{1/\delta}\Rightarrow
\end{aligned}
$$

$$
\begin{aligned}
&\frac{\alpha\beta\delta\left(\alpha+\xi\right)\phi_{j,t}Y_{j,t}\phi_{j,t-1}Y_{j,t-1}}{P_{j,t}P_{j,t-1}}+(1+\beta(\delta-1))K_{j,t}\left(\frac{K_{j,t+1}}{K_{j,t-1}^{1-\delta}}\right)^{1/\delta}\\
&\stackrel{!}{=}\left(\frac{K_{j,t}}{K_{j,t-1}^{1-\delta}}\right)^{1/\delta}\frac{\phi_{j,t}Y_{j,t}}{P_{j,t}}\left(\alpha+\xi+\alpha\beta\delta\right)+(\delta-1)\beta\left(\alpha+\xi\right)\left(\frac{K_{j,t+1}}{K_{j,t}^{1-\delta}}\right)^{1/\delta}\frac{\phi_{j,t-1}Y_{j,t-1}}{P_{j,t-1}}\Rightarrow
\end{aligned}
$$

$$
\begin{aligned}
&\frac{\alpha\beta\delta\left(\alpha+\xi\right)\phi_{j,t}Y_{j,t}\phi_{j,t-1}Y_{j,t-1}}{P_{j,t}P_{j,t-1}}+(1+\beta(\delta-1))K_{j,t}\frac{K_{j,t}^{(1-\delta)/\delta}}{K_{j,t}^{(1-\delta)/\delta}}\left(\frac{K_{j,t+1}}{K_{j,t-1}^{1-\delta}}\right)^{1/\delta}\\
&\stackrel{!}{=}\left(\frac{K_{j,t}}{K_{j,t-1}^{1-\delta}}\right)^{1/\delta}\frac{\phi_{j,t}Y_{j,t}}{P_{j,t}}\left(\alpha+\xi+\alpha\beta\delta\right)+(\delta-1)\beta\left(\alpha+\xi\right)\left(\frac{K_{j,t+1}}{K_{j,t}^{1-\delta}}\right)^{1/\delta}\frac{\phi_{j,t-1}Y_{j,t-1}}{P_{j,t-1}}\Rightarrow
\end{aligned}
$$

$$
\begin{aligned}
&\frac{\alpha\beta\delta\left(\alpha+\xi\right)\phi_{j,t}Y_{j,t}\phi_{j,t-1}Y_{j,t-1}}{P_{j,t}P_{j,t-1}}+(1+\beta(\delta-1))\left(\frac{K_{j,t}}{K_{j,t-1}^{1-\delta}}\right)^{1/\delta}\left(\frac{K_{j,t+1}}{K_{j,t}^{1-\delta}}\right)^{1/\delta}\\
&\stackrel{!}{=}\left(\frac{K_{j,t}}{K_{j,t-1}^{1-\delta}}\right)^{1/\delta}\frac{\phi_{j,t}Y_{j,t}}{P_{j,t}}\left(\alpha+\xi+\alpha\beta\delta\right)+(\delta-1)\beta\left(\alpha+\xi\right)\left(\frac{K_{j,t+1}}{K_{j,t}^{1-\delta}}\right)^{1/\delta}\frac{\phi_{j,t-1}Y_{j,t-1}}{P_{j,t-1}}\Rightarrow
\end{aligned}
$$

$$
\begin{aligned}
&\alpha\beta\delta\left(\alpha+\xi\right)+(1+\beta(\delta-1))\left(\frac{K_{j,t}}{K_{j,t-1}^{1-\delta}}\right)^{1/\delta}\left(\frac{K_{j,t+1}}{K_{j,t}^{1-\delta}}\right)^{1/\delta}\frac{P_{j,t}P_{j,t-1}}{\phi_{j,t}Y_{j,t}\phi_{j,t-1}Y_{j,t-1}}\\
&\stackrel{!}{=}\left(\frac{K_{j,t}}{K_{j,t-1}^{1-\delta}}\right)^{1/\delta}\frac{P_{j,t-1}}{\phi_{j,t-1}Y_{j,t-1}}\left(\alpha+\xi+\alpha\beta\delta\right)+(\delta-1)\beta\left(\alpha+\xi\right)\left(\frac{K_{j,t+1}}{K_{j,t}^{1-\delta}}\right)^{1/\delta}\frac{P_{j,t}}{\phi_{j,t}Y_{j,t}}.
\end{aligned}
$$

Define $B_{j,t-1} \equiv \left(\frac{K_{j,t}}{K_{j,t-1}^{1-\delta}}\right)^{1/\delta} \frac{P_{j,t-1}}{\phi_{j,t-1}Y_{j,t-1}}$:

$$(1+\beta(\delta-1))B_{j,t-1}B_{j,t} - (\delta-1)\beta(\alpha+\xi)B_{j,t} \overset{!}{=} B_{j,t-1}\left(\alpha+\xi+\alpha\beta\delta\right) - \alpha\beta\delta(\alpha+\xi).$$

$$B_{j,t} \overset{!}{=} \frac{\left(\alpha+\xi+\alpha\beta\delta\right)B_{j,t-1} - \alpha\beta\delta(\alpha+\xi)}{(1+\beta(\delta-1))B_{j,t-1} - (\delta-1)\beta(\alpha+\xi)}. \quad \text{(A59)}$$

Note that $B_{j,t-1} \equiv \left(\frac{K_{j,t}}{K_{j,t-1}^{1-\delta}}\right)^{1/\delta} \frac{P_{j,t-1}}{\phi_{j,t-1}Y_{j,t-1}} = \Omega_{j,t-1}\frac{P_{j,t-1}}{\phi_{j,t-1}Y_{j,t-1}} \Rightarrow \Omega_{j,t-1} = B_{j,t-1}\times \frac{\phi_{j,t-1}Y_{j,t-1}}{P_{j,t-1}}$. Hence, $B_{j,t-1}$ gives the share of total real expenditure spent on investment in country j in period $t-1$. This share is bounded between zero and one. Note also that (A59) holds for all t. There are two steady states for (A59) where $B_{j,t} = B_{j,t-1} = B_j$, which are given by:

$$(1+\beta(\delta-1))B_j^2 - \left(\alpha+\xi+\alpha\beta\delta\right)B_j - (\delta-1)\beta(\alpha+\xi)B_j + \alpha\beta\delta(\alpha+\xi) \overset{!}{=} 0 \Rightarrow$$

$$B_j^2 - \frac{(\alpha+\xi+\alpha\beta\delta+\alpha\beta\delta+\beta\delta\xi-\alpha\beta-\beta\xi)}{(1+\beta\delta-\beta)}B_j + \frac{\alpha\beta\delta(\alpha+\xi)}{1+\beta\delta-\beta} \overset{!}{=} 0 \Rightarrow$$

$$B_j^2 - \frac{(\alpha+\xi+2\alpha\beta\delta+\beta\delta\xi-\alpha\beta-\beta\xi)}{(1+\beta\delta-\beta)}B_j + \frac{\alpha\beta\delta(\alpha+\xi)}{1+\beta\delta-\beta} \overset{!}{=} 0 \Rightarrow$$

$$\begin{aligned}
B_j = {} & \frac{\alpha+\xi+2\alpha\beta\delta+\beta\delta\xi-\alpha\beta-\beta\xi}{2(1+\beta\delta-\beta)} \\
& \pm \left(\frac{(\alpha+\xi+2\alpha\beta\delta+\beta\delta\xi-\alpha\beta-\beta\xi)^2}{4(1+\beta\delta-\beta)^2} - \frac{\alpha\beta\delta(\alpha+\xi)}{1+\beta\delta-\beta}\right)^{1/2} \Rightarrow \\
B_j = {} & \frac{\alpha+\xi+2\alpha\beta\delta+\beta\delta\xi-\alpha\beta-\beta\xi}{2(1+\beta\delta-\beta)} \\
& \pm \left(\frac{(\alpha+\xi+2\alpha\beta\delta+\beta\delta\xi-\alpha\beta-\beta\xi)^2 - 4(1+\beta\delta-\beta)\alpha\beta\delta(\alpha+\xi)}{4(1+\beta\delta-\beta)^2}\right)^{1/2} \Rightarrow \\
B_j = {} & \frac{\alpha+\xi+2\alpha\beta\delta+\beta\delta\xi-\alpha\beta-\beta\xi}{2(1+\beta\delta-\beta)} \\
& \pm \left(\frac{(-\alpha+\alpha\beta-\xi+\beta\xi-\beta\delta\xi-2\alpha\beta\delta)^2 - 4(1+\beta\delta-\beta)\alpha\beta\delta(\alpha+\xi)}{4(1+\beta\delta-\beta)^2}\right)^{1/2} \Rightarrow \\
B_j = {} & \frac{\alpha+\xi+2\alpha\beta\delta+\beta\delta\xi-\alpha\beta-\beta\xi}{2(1+\beta\delta-\beta)} \\
& \pm \left(\frac{(-\alpha+\alpha\beta-\xi+\beta\xi-\beta\delta\xi)^2 - 4\alpha\beta\delta(-\alpha+\alpha\beta-\xi+\beta\xi-\beta\delta\xi)}{4(1+\beta\delta-\beta)^2}\right. \\
& \left. + \frac{(-2\alpha\beta\delta)^2 - 4(1+\beta\delta-\beta)\alpha\beta\delta(\alpha+\xi)}{4(1+\beta\delta-\beta)^2}\right)^{1/2} \Rightarrow
\end{aligned}$$

$$
\begin{aligned}
B_j &= \frac{\alpha+\xi+2\alpha\beta\delta+\beta\delta\xi-\alpha\beta-\beta\xi}{2(1+\beta\delta-\beta)} \\
&\pm \Bigg(\frac{(-\alpha+\alpha\beta-\xi+\beta\xi-\beta\delta\xi)^2+4\alpha^2\beta\delta-4\alpha^2\beta^2\delta+4\alpha\beta\delta\xi-4\alpha\beta^2\delta\xi+4\alpha\beta^2\delta^2\xi}{4(1+\beta\delta-\beta)^2} \\
&+ \frac{(2\alpha\beta\delta)^2-4\alpha^2\beta\delta-4\alpha\beta\delta\xi-4\alpha^2\beta^2\delta^2-4\alpha\beta^2\delta^2\xi+4\alpha^2\beta^2\delta+4\alpha\beta^2\delta\xi}{4(1+\beta\delta-\beta)^2}\Bigg)^{1/2} \Rightarrow \\
B_j &= \frac{\alpha+\xi+2\alpha\beta\delta+\beta\delta\xi-\alpha\beta-\beta\xi}{2(1+\beta\delta-\beta)} \pm \left(\frac{(-\alpha+\alpha\beta-\xi+\beta\xi-\beta\delta\xi)^2}{4(1+\beta\delta-\beta)^2}\right)^{1/2} \Rightarrow \\
B_j &= \frac{\alpha+\xi+2\alpha\beta\delta+\beta\delta\xi-\alpha\beta-\beta\xi}{2(1+\beta\delta-\beta)} \pm \left(\frac{(\alpha(\beta-1)+(\beta-1-\beta\delta)\xi)^2}{4(1+\beta\delta-\beta)^2}\right)^{1/2} \Rightarrow \\
B_j &= \frac{\alpha+\xi+2\alpha\beta\delta+\beta\delta\xi-\alpha\beta-\beta\xi}{2(1+\beta\delta-\beta)} \pm \frac{\alpha(\beta-1)+(\beta-1-\beta\delta)\xi}{2(1+\beta\delta-\beta)} \Rightarrow \\
B_j &= \frac{(\alpha+\xi+2\alpha\beta\delta+\beta\delta\xi-\alpha\beta-\beta\xi)\pm(\alpha(\beta-1)+(\beta-1-\beta\delta)\xi)}{2(1+\beta\delta-\beta)} \Rightarrow \\
B_j^- &= \frac{\alpha+\xi+2\alpha\beta\delta+\beta\delta\xi-\alpha\beta-\beta\xi-(\alpha(\beta-1)+(\beta-1-\beta\delta)\xi)}{2(1+\beta\delta-\beta)} \\
&= \frac{\alpha+\xi+2\alpha\beta\delta+\beta\delta\xi-\alpha\beta-\beta\xi-\alpha\beta+\alpha-\beta\xi+\xi+\beta\delta\xi}{2(1+\beta\delta-\beta)} \\
&= \frac{2\alpha+2\xi+2\alpha\beta\delta+2\beta\delta\xi-2\alpha\beta-2\beta\xi}{2(1+\beta\delta-\beta)} \\
&= \frac{\alpha+\xi+\alpha\beta\delta+\beta\delta\xi-\alpha\beta-\beta\xi}{1+\beta\delta-\beta} \\
&= \frac{(\alpha+\xi)(1+\beta\delta-\beta)}{1+\beta\delta-\beta} = \alpha+\xi. \\
B_j^+ &= \frac{(\alpha+\xi+2\alpha\beta\delta+\beta\delta\xi-\alpha\beta-\beta\xi)+(\alpha(\beta-1)+(\beta-1-\beta\delta)\xi)}{2(1+\beta\delta-\beta)} \\
&= \frac{\alpha+\xi+2\alpha\beta\delta+\beta\delta\xi-\alpha\beta-\beta\xi+\alpha\beta-\alpha+\beta\xi-\xi-\beta\delta\xi}{2(1+\beta\delta-\beta)} \\
&= \frac{\alpha\beta\delta}{1+\beta\delta-\beta}.
\end{aligned}
$$

Remember that $\Omega_{j,t-1} = B_{j,t-1}\frac{\phi_{j,t-1}Y_{j,t-1}}{P_{j,t-1}}$. Hence, $B_j = B_j^- = \alpha+\xi$, $(\alpha+\xi)\phi_{j,t-1}Y_{j,t-1} = P_{j,t-1}\Omega_{j,t-1}$ implies that the amount of total expenditures remaining after payments for intermediates (which is $(1-\alpha-\xi)\phi_{j,t-1}Y_{j,t-1}$) would be invested and nothing consumed. This cannot be optimal, as $\ln(0) = -\infty$. It also violates the transversality condition (see Section L.2). Alternatively, $B = B_j^+ = \frac{\alpha\beta\delta}{1+\beta\delta-\beta}$, $\Omega_{j,t-1} = \frac{\alpha\beta\delta}{(1+\beta\delta-\beta)}\frac{\phi_{j,t-1}Y_{j,t-1}}{P_{j,t-1}}$ implies that a constant share of total real expenditures is invested for all countries. It also satisfies the transversality condition (see again Section L.2).

Next, we demonstrate that $B_j^+ = \frac{\alpha\beta\delta}{1-\beta+\beta\delta}$ is an unstable equilibrium. First, we linearize equation (A59) around $B_{j,0}$:

$$B_{j,t}(B_{j,t-1}) = \frac{(\alpha+\xi+\alpha\beta\delta)\,B_{j,0} - \alpha\beta\delta(\alpha+\xi)}{(1+\beta(\delta-1))B_{j,0} - (\delta-1)\beta(\alpha+\xi)} + \frac{(\alpha+\xi)\beta[\alpha+\xi(1-\delta)]}{[(1-\beta(1-\delta))B_{j,0} + (1-\delta)\beta(\alpha+\xi)]^2}\left(B_{j,t-1} - B_{j,0}\right),$$

where we used the following expression for the partial derivative of equation (A59) with respect to $B_{j,t-1}$:

$$\begin{aligned}
\frac{\partial B_{j,t}}{\partial B_{j,t-1}} =& \frac{(\alpha+\xi+\alpha\beta\delta)\,[(1+\beta(\delta-1))B_{j,t-1} - (\delta-1)\beta(\alpha+\xi)]}{[(1+\beta(\delta-1))B_{j,t-1} - (\delta-1)\beta(\alpha+\xi)]^2} \\
&- \frac{(1+\beta(\delta-1))\,[(\alpha+\xi+\alpha\beta\delta)\,B_{j,t-1} - \alpha\beta\delta(\alpha+\xi)]}{[(1+\beta(\delta-1))B_{j,t-1} - (\delta-1)\beta(\alpha+\xi)]^2} \\
=& \frac{-\,(\alpha+\xi+\alpha\beta\delta)\,(\delta-1)\beta(\alpha+\xi) + (1+\beta(\delta-1))\alpha\beta\delta(\alpha+\xi)}{[(1+\beta(\delta-1))B_{j,t-1} - (\delta-1)\beta(\alpha+\xi)]^2} \\
=& \frac{-(\delta-1)\beta(\alpha+\xi)^2 - \alpha\beta\delta(\delta-1)\beta(\alpha+\xi) + \alpha\beta\delta(\alpha+\xi) + \beta(\delta-1)\alpha\beta\delta(\alpha+\xi)}{[(1+\beta(\delta-1))B_{j,t-1} - (\delta-1)\beta(\alpha+\xi)]^2} \\
=& \frac{-(\delta-1)\beta(\alpha+\xi)^2 + \alpha\beta\delta(\alpha+\xi)}{[(1+\beta(\delta-1))B_{j,t-1} - (\delta-1)\beta(\alpha+\xi)]^2} \\
=& \frac{(\alpha+\xi)\beta[-(\delta-1)(\alpha+\xi) + \alpha\delta]}{[(1+\beta(\delta-1))B_{j,t-1} - (\delta-1)\beta(\alpha+\xi)]^2} \\
=& \frac{(\alpha+\xi)\beta[-\delta\alpha + \alpha - \delta\xi + \xi + \alpha\delta]}{[(1+\beta(\delta-1))B_{j,t-1} - (\delta-1)\beta(\alpha+\xi)]^2} \\
=& \frac{(\alpha+\xi)\beta[\alpha+\xi(1-\delta)]}{[(1+\beta(\delta-1))B_{j,t-1} - (\delta-1)\beta(\alpha+\xi)]^2} \\
=& \frac{(\alpha+\xi)\beta[\alpha+\xi(1-\delta)]}{[(1-\beta(1-\delta))B_{j,t-1} + (1-\delta)\beta(\alpha+\xi)]^2}.
\end{aligned}$$

Evaluate at point $B_{j,0} = B_j^+ = \frac{\alpha\beta\delta}{(1-\beta+\beta\delta)}$:

$$B_{j,t}(B_{j,t-1}) = \frac{(\alpha+\xi+\alpha\beta\delta)\,\frac{\alpha\beta\delta}{(1-\beta+\beta\delta)} - \alpha\beta\delta(\alpha+\xi)}{(1+\beta(\delta-1))\frac{\alpha\beta\delta}{(1-\beta+\beta\delta)} - (\delta-1)\beta(\alpha+\xi)} + \frac{(\alpha+\xi)\beta[\alpha+\xi(1-\delta)]}{[(1-\beta(1-\delta))\frac{\alpha\beta\delta}{(1-\beta+\beta\delta)} + (1-\delta)\beta(\alpha+\xi)]^2}\left(B_{j,t-1} - \frac{\alpha\beta\delta}{(1-\beta+\beta\delta)}\right) \Rightarrow$$

$$
\begin{aligned}
B_{j,t}(B_{j,t-1}) &= \frac{\alpha\beta\delta\left(\frac{\alpha+\xi+\alpha\beta\delta}{1-\beta+\beta\delta}-(\alpha+\xi)\right)}{\alpha\beta\delta-(\delta-1)\beta(\alpha+\xi)} \\
&\quad + \frac{(\alpha+\xi)\beta[\alpha+\xi(1-\delta)]}{[\alpha\beta\delta+(1-\delta)\beta(\alpha+\xi)]^2}\left(B_{j,t-1}-\frac{\alpha\beta\delta}{(1-\beta+\beta\delta)}\right) \Rightarrow \\
B_{j,t}(B_{j,t-1}) &= \frac{\alpha\beta\delta\left(\frac{\alpha\beta\delta+\beta(\alpha+\xi)-\beta\delta(\alpha+\xi)}{1-\beta+\beta\delta}\right)}{\alpha\beta\delta-(\delta-1)\beta(\alpha+\xi)} \\
&\quad + \frac{(\alpha+\xi)[\alpha+\xi(1-\delta)]}{\beta[\alpha\delta+(1-\delta)(\alpha+\xi)]^2}\left(B_{j,t-1}-\frac{\alpha\beta\delta}{(1-\beta+\beta\delta)}\right) \Rightarrow \\
B_{j,t}(B_{j,t-1}) &= \frac{\alpha\beta\delta\left(\alpha\beta\delta+\beta(\alpha+\xi)-\beta\delta(\alpha+\xi)\right)}{\left(\alpha\beta\delta+\beta(\alpha+\xi)-\beta\delta(\alpha+\xi)\right)(1-\beta+\beta\delta)} \\
&\quad + \frac{(\alpha+\xi)[\alpha+\xi(1-\delta)]}{\beta[\alpha\delta+\alpha-\alpha\delta+\xi(1-\delta)]^2}\left(B_{j,t-1}-\frac{\alpha\beta\delta}{(1-\beta+\beta\delta)}\right) \Rightarrow \\
B_{j,t}(B_{j,t-1}) &= \frac{\alpha\beta\delta}{1-\beta+\beta\delta} \\
&\quad + \frac{(\alpha+\xi)}{\beta[\alpha+\xi(1-\delta)]}\left(B_{j,t-1}-\frac{\alpha\beta\delta}{(1-\beta+\beta\delta)}\right).
\end{aligned}
$$

Note that $0<\beta<1$, $0<\delta\leq 1$, $0<\alpha<1$ and $0<\xi<1$ and therefore $(\alpha\beta\delta)/(1-\beta+\beta\delta)>0$ and $(\alpha+\xi)/\left\{\beta[\alpha+\xi(1-\delta)]\right\}>1$. Hence, all values starting above $B^+_{j,t-1}=\frac{\alpha\beta\delta}{(1-\beta+\beta\delta)}$ will converge to one. This implies that everything is invested and nothing consumed which is not optimal and violates the transversality condition. Alternatively, all values starting below $B^+_{j,t-1}=\frac{\alpha\beta\delta}{(1-\beta+\beta\delta)}$, will converge to 0. This implies that nothing is invested, which is not feasible either because in this case capital stock, output, and income will all be equal to zero (see equations (A50) and (A51)). It follows that $B^+_j=\frac{\alpha\beta\delta}{(1-\beta+\beta\delta)}$ is the *only* solution of (A59) that is consistent with the transversality condition and with positive investments and output in each period. Hence, the optimal solution requires $B_{j,t}$ to be constant along the transition path and to be equal to $\frac{\alpha\beta\delta}{(1-\beta+\beta\delta)}$. We can use this result, together with $K_{j,t+1}=\Omega^{\delta}_{j,t}K^{1-\delta}_{j,t}$ and $Y_{j,t}=p_{j,t}A_{j,t}K^{\alpha}_{j,t}L^{\xi}_{j,t}Q^{1-\alpha-\xi}_{j,t}$, to obtain the policy function for capital:

$$
\begin{aligned}
K_{j,t+1} &= \left(\frac{\alpha\beta\delta}{(1-\beta+\beta\delta)}\frac{\phi_{j,t}Y_{j,t}}{P_{j,t}}\right)^{\delta}K^{1-\delta}_{j,t} \\
&= \left(\frac{\alpha\beta\delta}{(1-\beta+\beta\delta)}\frac{\phi_{j,t}p_{j,t}A_{j,t}K^{\alpha}_{j,t}L^{\xi}_{j,t}Q^{1-\alpha-\xi}_{j,t}}{P_{j,t}}\right)^{\delta}K^{1-\delta}_{j,t} \\
&= \left(\frac{\alpha\beta\delta}{(1-\beta+\beta\delta)}\frac{\phi_{j,t}p_{j,t}A_{j,t}L^{\xi}_{j,t}Q^{1-\alpha-\xi}_{j,t}}{P_{j,t}}\right)^{\delta}K^{\alpha\delta+1-\delta}_{j,t}.
\end{aligned}
$$

The policy function for the capital stock with intermediates looks very similar to the one in our main system without intermediates as given in equation (16). As discussed in online Appendix C.5, the main implications are that the effects of domestic investment in our model are magnified through the appearance of intermediates, 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 $K_{j,t+1}$ and $K_{j,t}$, we can determine the level of investment:

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

In addition, we can obtain the optimal level of current consumption by using the policy function for capital and reformulating $Y_{j,t} = P_{j,t}C_{j,t} + P_{j,t}\Omega_{j,t} + P_{j,t}Q_{j,t}$, i.e.:

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

Note again, that $Q_{j,t}$ can be calculated as:

$$\begin{aligned}
Q_{j,t} &= (1-\alpha-\xi)\frac{\phi_{j,t}p_{j,t}A_{j,t}K_{j,t}^{\alpha}L_{j,t}^{\xi}Q_{j,t}^{1-\alpha-\xi}}{P_{j,t}} \Rightarrow \\
Q_{j,t} &= \left[(1-\alpha-\xi)\frac{\phi_{j,t}p_{j,t}A_{j,t}K_{j,t}^{\alpha}L_{j,t}^{\xi}}{P_{j,t}}\right]^{\frac{1}{\alpha+\xi}}.
\end{aligned}$$

L.2 Derivation of the Transversality Condition

This section demonstrates that our system (A49)-(A54) is a well-behaved dynamic problem and that the following transversality condition is satisfied:

$$\lim_{t\to\infty} \beta^t \frac{\partial F(x_t^*, x_{t+1}^*)}{\partial x_t} x_t^* = 0,$$

where '*' denote the solutions of the dynamic problem. To apply the transversality condition to our model with intermediates we start with the objective function:

$$\max_{\{K_{j,t}, Q_{j,t}\}} \sum_{t=0}^{\infty} \beta^t \ln\left[\phi_{j,t} p_{j,t} A_{j,t} K_{j,t}^{\alpha} L_{j,t}^{\xi} Q_{j,t}^{1-\alpha-\xi}/P_{j,t} - \left(K_{j,t+1}/K_{j,t}^{1-\delta}\right)^{1/\delta} - Q_{j,t}\right],$$

which is only a function of $K_{j,t}$, $K_{j,t+1}$ and $Q_{j,t}$, alongside exogenous variables for the consumer (such as $p_{j,t}$ and $P_{j,t}$) and parameters. Let:

$$F \equiv \ln\left[\phi_{j,t} p_{j,t} A_{j,t} K_{j,t}^{\alpha} L_{j,t}^{\xi} Q_{j,t}^{1-\alpha-\xi}/P_{j,t} - \left(K_{j,t+1}/K_{j,t}^{1-\delta}\right)^{1/\delta} - Q_{j,t}\right].$$

The transversality condition with respect to capital becomes:

$$\lim_{t\to\infty} \beta^t \frac{\partial F(K_{j,t}^*, K_{j,t+1}^*)}{\partial K_{j,t}} K_{j,t}^* = 0.$$

To show that the transversality condition is satisfied, we take the derivative of F with respect to $K_{j,t}$ and plug it into the transversality condition:

$$\begin{aligned}
&\lim_{t\to\infty} \frac{\beta^t}{C_{j,t}^*} \left(\frac{\alpha\phi_{j,t} Y_{j,t}^*}{P_{j,t}^* K_{j,t}^*} - \frac{(\delta-1)}{\delta} \left(K_{j,t+1}^*\right)^{1/\delta} \left(K_{j,t}^*\right)^{-1/\delta} \right) K_{j,t}^* = \\
&\lim_{t\to\infty} \frac{\beta^t}{C_{j,t}^*} \left(\frac{\alpha\phi_{j,t} Y_{j,t}^*}{P_{j,t}^*} - \frac{(\delta-1)}{\delta} \left(K_{j,t+1}^*\right)^{1/\delta} \left(K_{j,t}^*\right)^{1-1/\delta} \right) = \\
&\lim_{t\to\infty} \beta^t \left(\frac{\alpha\phi_{j,t} Y_{j,t}^*}{C_{j,t}^* P_{j,t}^*} - \frac{(\delta-1)\Omega_{j,t}^*}{\delta C_{j,t}^*} \right).
\end{aligned}$$

Remembering that $\Omega^*_{j,t} = \frac{\alpha\beta\delta}{(1-\beta+\beta\delta)}\frac{\phi_{j,t}Y^*_{j,t}}{P^*_{j,t}}$, and $C^*_{j,t} = \left[\frac{(\alpha+\xi)(1-\beta+\beta\delta)-\alpha\beta\delta}{(1-\beta+\beta\delta)}\right]\frac{\phi_{j,t}Y^*_{j,t}}{P^*_{j,t}}$, we can replace $\frac{\phi_{j,t}Y^*_{j,t}}{C^*_{j,t}P^*_{j,t}}$ by $\frac{1-\beta+\beta\delta}{(\alpha+\xi)(1-\beta+\beta\delta)-\alpha\beta\delta}$ and $\frac{\Omega^*_{j,t}}{C^*_{j,t}}$ by $\frac{\alpha\beta\delta}{(\alpha+\xi)(1-\beta+\beta\delta)-\alpha\beta\delta}$ to obtain:

$$\begin{aligned}
\lim_{t\to\infty}\beta^t\left(\frac{\alpha-\alpha\beta+\alpha\beta\delta}{(\alpha+\xi)(1-\beta+\beta\delta)-\alpha\beta\delta}-\frac{(\delta-1)\alpha\beta\delta}{\delta\left[(\alpha+\xi)(1-\beta+\beta\delta)-\alpha\beta\delta\right]}\right) &= \\
\lim_{t\to\infty}\beta^t\left(\frac{\alpha\delta-\alpha\beta\delta+\alpha\beta\delta^2-\alpha\beta\delta^2+\alpha\beta\delta}{\delta\left[(\alpha+\xi)(1-\beta+\beta\delta)-\alpha\beta\delta\right]}\right) &= \\
\lim_{t\to\infty}\beta^t\left(\frac{\alpha}{(\alpha+\xi)(1-\beta+\beta\delta)-\alpha\beta\delta}\right) &= \\
\lim_{t\to\infty}\beta^t\left(\frac{\alpha}{\alpha-\alpha\beta+\alpha\beta\delta+\xi-\beta\xi+\beta\delta\xi-\alpha\beta\delta}\right) &= \\
\lim_{t\to\infty}\beta^t\left(\frac{\alpha}{\alpha(1-\beta)+\xi(1-\beta)+\beta\delta\xi}\right) &= 0,
\end{aligned}$$

where the result that the transversality condition holds follows from the theoretical constraints on the model parameters $0<\beta<1$, $0<\delta\leq 1$, $0<\alpha<1$ and $0<\xi<1$.

The transversality condition with respect to intermediates can be expressed as follows:

$$\lim_{t\to\infty}\beta^t\frac{\partial F(Q^*_{j,t})}{\partial Q_{j,t}}Q^*_{j,t}=0.$$

To show that the transversality condition is satisfied, we take the derivative of F with respect to $Q_{j,t}$ and plug it into the transversality condition:

$$\begin{aligned}
\lim_{t\to\infty}\frac{\beta^t}{C^*_{j,t}}\left(\frac{(1-\alpha-\xi)\phi_{j,t}Y^*_{j,t}}{P^*_{j,t}Q^*_{j,t}}\right)Q^*_{j,t} &= \\
\lim_{t\to\infty}\beta^t\left(\frac{(1-\alpha-\xi)\phi_{j,t}Y^*_{j,t}}{C^*_{j,t}P^*_{j,t}}\right)&.
\end{aligned}$$

Using $C^*_{j,t} = \left[\frac{(\alpha+\xi)(1-\beta+\beta\delta)-\alpha\beta\delta}{(1-\beta+\beta\delta)}\right]\frac{\phi_{j,t}Y^*_{j,t}}{P^*_{j,t}}$, we can replace $\frac{\phi_{j,t}Y^*_{j,t}}{C^*_{j,t}P^*_{j,t}}$ by $\frac{1-\beta+\beta\delta}{(\alpha+\xi)(1-\beta+\beta\delta)-\alpha\beta\delta}$:

$$\begin{aligned}
\lim_{t\to\infty}\beta^t\left(\frac{(1-\alpha-\xi)(1-\beta+\beta\delta)}{(\alpha+\xi)(1-\beta+\beta\delta)-\alpha\beta\delta}\right) &= \\
\lim_{t\to\infty}\beta^t\left(\frac{(1-\alpha-\xi)(1-\beta+\beta\delta)}{\alpha(1-\beta)+\xi(1-\beta+\beta\delta)}\right) &= 0,
\end{aligned}$$

where the result that the transversality condition holds follows from the theoretical constraints on the model parameters $0<\beta<1$, $0<\delta\leq 1$, $0<\alpha<1$ and $0<\xi<1$.

M 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 (2016). In order to investigate the sensitivity of our results with respect to the log-linear utility specification, we generalize our utility function to an iso-elastic one:

$$U_{j,t} = \sum_{t=0}^{\infty} \beta^t \frac{C_{j,t}^{1-\rho} - 1}{1-\rho}, \quad \rho > 0,$$

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

Combine the budget constraint with the production function:

$$P_{j,t}C_{j,t} + P_{j,t}\Omega_{j,t} = \phi_{j,t}p_{j,t}A_{j,t}L_{j,t}^{1-\alpha}K_{j,t}^{\alpha}.$$

Use the capital transition function to solve for $\Omega_{j,t} = \left(\frac{K_{j,t+1}}{K_{j,t}^{1-\delta}}\right)^{\frac{1}{\delta}}$ and substitute in the budget constraint:

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

Set up the Lagrangian:

$$\mathcal{L} = \sum_{t=0}^{\infty} \beta^t \left[\frac{C_{j,t}^{1-\rho} - 1}{1-\rho} + \lambda_{j,t}\left(\phi_{j,t}p_{j,t}A_{j,t}L_{j,t}^{1-\alpha}K_{j,t}^{\alpha} - P_{j,t}C_{j,t} - P_{j,t}\left(\frac{K_{j,t+1}}{K_{j,t}^{1-\delta}}\right)^{\frac{1}{\delta}}\right)\right].$$

Differentiate with respect to $C_{j,t}$, $K_{j,t+1}$ and $\lambda_{j,t}$ to obtain the following set of first-order conditions:

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

Use the first-order condition for consumption to solve for $\lambda_{j,t}$:

$$\lambda_{j,t} = \frac{C_{j,t}^{-\rho}}{P_{j,t}} \quad \text{for all } j \text{ and } t.$$

Substitute $\lambda_{j,t}$ in the first-order condition for capital:

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

Simplify and re-arrange:

$$\begin{aligned}&\frac{\beta C_{j,t+1}^{-\rho}\phi_{j,t+1}p_{j,t+1}A_{j,t+1}L_{j,t+1}^{1-\alpha}\alpha K_{j,t+1}^{\alpha-1}}{P_{j,t+1}} = \\ &C_{j,t}^{-\rho}\left(\frac{1}{K_{j,t}^{1-\delta}}\right)^{\frac{1}{\delta}}\frac{1}{\delta}K_{j,t+1}^{\frac{1}{\delta}-1} + C_{j,t+1}^{-\rho}\frac{(\delta-1)\beta}{\delta}K_{j,t+2}^{\frac{1}{\delta}}K_{j,t+1}^{-\frac{1}{\delta}} \quad \text{for all } j \text{ and } t.\end{aligned}$$

Use the definition of $Y_{j,t}$ and simplify further:

$$\frac{\alpha\beta C_{j,t+1}^{-\rho}\phi_{j,t+1}Y_{j,t+1}}{K_{j,t+1}P_{j,t+1}} = \frac{C_{j,t}^{-\rho}}{\delta}\frac{K_{j,t+1}^{\frac{1}{\delta}-1}}{K_{j,t}^{\frac{1-\delta}{\delta}}} + \frac{\beta(\delta-1)C_{j,t+1}^{-\rho}}{\delta}\left(\frac{K_{j,t+2}}{K_{j,t+1}}\right)^{\frac{1}{\delta}} \quad \text{for all } j \text{ and } t.$$

This is the standard consumption Euler equation. Note that we have four forward-looking variables for each country: $Y_{j,t}$, $K_{j,t}$, $C_{j,t}$ and $P_{j,t}$. Hence, overall we have $4N$ forward-looking variables in our system here. These are, alongside $\Pi_{j,t}$, the endogenous variables we have to solve for.

To check whether the transversality condition to the model with the iso-elastic utility function is satisfied, we start with the following objective function:

$$\max_{\{K_{j,t}\}}\sum_{t=0}^{\infty}\beta^t\frac{1}{1-\rho}\left\{\left[\left(\phi_{j,t}p_{j,t}A_{j,t}L_{j,t}^{1-\alpha}K_{j,t}^{\alpha}\right)/P_{j,t} - \left(\frac{K_{j,t+1}}{K_{j,t}^{1-\delta}}\right)^{\frac{1}{\delta}}\right]^{1-\rho} - 1\right\},$$

which is only a function of $K_{j,t}$ and $K_{j,t+1}$ alongside exogenous variables for the consumer (such as $p_{j,t}$ and $P_{j,t}$). Let:

$$F \equiv \frac{1}{1-\rho}\left\{\left[\left(\phi_{j,t}p_{j,t}A_{j,t}L_{j,t}^{1-\alpha}K_{j,t}^{\alpha}\right)/P_{j,t} - \left(\frac{K_{j,t+1}}{K_{j,t}^{1-\delta}}\right)^{\frac{1}{\delta}}\right]^{1-\rho} - 1\right\},$$

and define the transversality condition:

$$\lim_{t\to\infty} \beta^t \frac{\partial F(K^*_{j,t}, K^*_{j,t+1})}{\partial K_{j,t}} K^*_{j,t} = 0.$$

To show that the transversality condition is satisfied, differentiate F with respect to $K_{j,t}$ and plug it into the transversality condition:

$$\begin{aligned}
\lim_{t\to\infty} \frac{\beta^t}{\left(C^*_{j,t}\right)^\rho} \left(\frac{\alpha \phi_{j,t} Y^*_{j,t}}{P^*_{j,t} K^*_{j,t}} - \frac{(\delta-1)}{\delta} \left(K^*_{j,t+1}\right)^{1/\delta} \left(K^*_{j,t}\right)^{-1/\delta} \right) K^*_{j,t} &= \\
\lim_{t\to\infty} \beta^t \left(\frac{\alpha \phi_{j,t} Y^*_{j,t}}{\left(C^*_{j,t}\right)^\rho P^*_{j,t}} - \frac{(\delta-1)}{\delta \left(C^*_{j,t}\right)^\rho} \left(K^*_{j,t+1}\right)^{1/\delta} \left(K^*_{j,t}\right)^{1-1/\delta} \right) &= \\
\lim_{t\to\infty} \beta^t \left(\frac{\alpha \phi_{j,t} Y^*_{j,t}}{\left(C^*_{j,t}\right)^\rho P^*_{j,t}} - \frac{(\delta-1)\Omega^*_{j,t}}{\delta \left(C^*_{j,t}\right)^\rho} \right) &= 0,
\end{aligned}$$

which holds as all endogenously variables converge to the long-run steady state when $t \to \infty$ and $\beta < 1$.

Similar to the case with linear capital accumulation, there is no analytical solution in the case with iso-elastic utility. Therefore, we solve our model by feeding Dynare the following system of equations:

$$\begin{aligned}
Y_{j,t} &= \frac{(Y_{j,t}/Y_t)^{\frac{1}{1-\sigma}}}{\gamma_j P_{j,t}} A_{j,t} L_{j,t}^{1-\alpha} K_{j,t}^{\alpha} \quad \text{for all } j \text{ and } t, \\
Y_t &= \sum_j Y_{j,t} \quad \text{for all } t, \\
Y_{j,t} &= P_{j,t} C_{j,t} + P_{j,t} \left(\frac{K_{j,t+1}}{K_{j,t}^{1-\delta}} \right)^{\frac{1}{\delta}} \quad \text{for all } j \text{ and } t, \\
P_{j,t} &= \left[\sum_i \left(\frac{t_{ij,t}}{P_{i,t}} \right)^{1-\sigma} \frac{Y_{i,t}}{Y_t} \right]^{\frac{1}{1-\sigma}} \quad \text{for all } j \text{ and } t, \\
\Pi_{i,t} &= \left[\sum_j \left(\frac{t_{ij,t}}{P_{j,t}} \right)^{1-\sigma} \frac{\phi_{j,t} Y_{j,t}}{Y_t} \right]^{\frac{1}{1-\sigma}} \quad \text{for all } i \text{ and } t, \\
\frac{\alpha \beta C_{j,t+1}^{-\rho} \phi_{j,t+1} Y_{j,t+1}}{K_{j,t+1} P_{j,t+1}} &= \frac{C_{j,t}^{-\rho}}{\delta} \frac{K_{j,t+1}^{\frac{1}{\delta}-1}}{K_{j,t}^{\frac{1-\delta}{\delta}}} + \frac{\beta(\delta-1) C_{j,t+1}^{-\rho}}{\delta} \left(\frac{K_{j,t+2}}{K_{j,t+1}} \right)^{\frac{1}{\delta}} \quad \text{for all } j \text{ and } t. \qquad \text{(A60)}
\end{aligned}$$

The first equation is the production function from equation (24), where we have replaced $p_{j,t}$ using equation (23). The second equation is the definition of world GDP. The third equation is the budget constraint, where we use equation (2) to replace $\Omega_{j,t}$. The fourth and fifth equations are the MRs as given by equations (21) and (22), respectively. Finally, the last equation is the Euler equation just derived above. Note that equation (A60) 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 *Income equation* estimates do not change at all. Hence, trade costs, α and σ would be estimated as we did so far. However, as in the case with a linear transition function for capital, we no longer have a closed-form solution for our policy function. We therefore cannot derive an estimable *Capital equation*. Hence, we are no longer able to back out the depreciation rate δ and test for causal effects of trade on capital accumulation.

2. To study the implications for the steady state consider equation (A60):

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

   Given this solution for the steady-state capital stock, which is again a function of parameters and Y_j/P_j, all our analytical insights from Section 3.1 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.

   The expression for consumption in steady state with iso-elastic utility is also identical to the corresponding expression that we obtained with the log-linear intertemporal utility function:

$$
\begin{aligned}
C_j &= \frac{\phi_j Y_j}{P_j} - K_j = \frac{\phi_j Y_j}{P_j} - \frac{\alpha\beta\delta\phi_j Y_j}{\left(1-\beta+\beta\delta\right)P_j} = \\
&= \left[\frac{1-\beta+\beta\delta-\alpha\beta\delta}{1-\beta+\beta\delta}\right]\frac{\phi_j Y_j}{P_j}.
\end{aligned}
$$

3. For our counterfactuals, we have to back out A_j/γ_j. This can be done in the exact same fashion as in the case with the log-linear intertemporal utility function, given that we can determine the steady-state capital stock.

Finally, concerning welfare, we have to use the iso-elastic utility function. This changes our

Lucas discount formula as follows:

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

Taking all of the above considerations into account, in section C.6 of this appendix we study the empirical consequences of replacing the log-linear intertemporal utility function with an iso-elastic one.

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