# On the Growth Effects of the Transatlantic Trade and Investment Partnership

## An Extended Abstract

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The Transatlantic Trade and Investment Partnership (TTIP) between the United States (US) and the European Union (EU) is by far the largest integration effort to ever be carried in the world.[1] Together, the two potential partners represent more than 50% of GDP in the world, more than 30% of goods trade in the world, more than 40% of services trade in the world, and 11.8% of the world's population. In addition, the US and the EU are very well integrated in the world trading system and both regions are the major trading partners for most other countries in the rest of the world. Accordingly, TTIP will not only influence the negotiating countries, but it will have significant economic impact on many non-member countries throughout the world.

The expectations for a positive impact of TTIP are high on both negotiating sides. EU analysts and policy makers hope that TTIP will "liberalise trade and investment between the EU and the US and will result in more jobs and growth and assist Europe in its long-term recovery from the economic crisis,"[2] and that "[t]he extra economic growth will benefit everyone; boosting trade is a good way of boosting our economies by creating increased demand and supply without having to increase public spending or borrowing."[3] Similar hopes were expressed by presidents Obama of US and Rajoy of Spain during their meeting in January 2014, where the presidents pledged "to continue to cooperate closely to promote strategies for growth and job creation. One of those strategies is to put together a transatlantic trade agreement. [They] both agreed that there is enormous potential for increasing trade and growth between two of the largest economic actors in the world."[4]

[1]The initial negotiations between the US and the EU started in July 2013. Since then, three rounds of negotiation have taken place already, and a fourth round is scheduled for late March in 2014. Optimistic policy makers, such as the European Union Trade Commissioner Karel De Gucht, hope "to clinch U.S. trade deal by late 2014" (Emmott, Robin (2013-02-27), "EU trade chief hopes to clinch U.S. trade deal by late 2014", Uk.reuters.com, http://uk.reuters.com/article/2013/02/27/us-euro-summit-trade-idUKBRE91Q0QM20130227).

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

[3]http://ec.europa.eu/trade/policy/in-focus/ttip/. Similar statements can be found in various documents of the EU. One Example is the document "Transatlantic Trade and Investment Partnership - The Regulatory Part" available at http://trade.ec.europa.eu/doclib/docs/2013/july/tradoc_151605.pdf, stating on page 2: "Studies suggest this could be worth billions in new growth for our economies."

[4]"Remarks by president Obama and president Mariano Rajoy of Spain af-

As evident from these statements, both negotiating parties expect that, in addition to promoting trade and removing trade barriers, TTIP will trigger significant growth effects without additional fiscal spendings. Despite the great political interest in TTIP and the expectations for large potential payoffs in terms of economic growth, most quantitative analysis of TTIP are static.[5] We are aware of only two attempts (Fontagné, Gourdon, and Jean (2013) and Francois, Manchin, Norberg, Pindyuk, and Tomberger (2013)) to evaluate the dynamic effects of TTIP. Both of these studies are based on the GTAP (Global Trade Analysis Project) model and as such they offer estimates of the dynamic effects of TTIP within a comprehensive but very complex structural framework.

The lack of interest in the growth effects of TTIP is surprising, especially given that this was one of the main motives for TTIP, both, for the US and for the EU. In addition, the complex CGE structure of the GTAP model does not allow clear decomposition of the relationships between the trade and growth effects of the TTIP. The goal of our study is to fill these gaps by evaluating the relationship between TTIP, trade and growth within a tractable estimating general equilibrium framework. We will complement the GTAP studies with a dynamic framework that is simpler but more tractable. We will isolate the effects of trade liberalization on growth through capital accumulation and we will decompose and quantify the additional feedback effects of growth on trade. Importantly, we will devote special attention to a realistic measurement of actual trade costs in accordance with the latest developments in the gravity literature.

We will analyse the structural relationship between TTIP and growth within the framework developed by Anderson, Larch, and Yotov (2014), who extend the static structural trade gravity set-up of Anderson and van Wincoop (2003)[6] to allow for endogenous pro-

ter bilateral meeting", Office of the Press Secretary, White House, January, 2014, http://iipdigital.usembassy.gov/st/english/texttrans/2014/01/20140114290784.html#axzz2u59pirmD.

[5] For example, the National Board of Trade has made a model simulation of the economic implications of TTIP based on an initiative from the Ministry of Foreign Affairs (Kommerskollegium, 2013). Similarly, Francois and Pindyuk (2013) investigate the effects of TTIP for Austria, and Felbermayr, Larch, Flach, Yalcin, and Benz (2013) and Felbermayr, Heid, and Lehwald (2013) for Germany. These studies highlight important effects of TTIP, but focus on static models.

[6] The gravity model is the workhorse in international trade. Anderson (1979) is the first to build a

duction and growth through capital accumulation[7] in the spirit of the dynamic, general equilibrium models developed by Hercowitz and Sampson (1991) and Eckstein, Foulides, and Kollintzas (1996).[8] The model captures the causal relationships between growth and trade while decomposing and quantifying the various competing channels through which trade affects growth and through which growth impacts trade.

The effects of trade on production and growth are channeled through physical capital accumulation, which is triggered by changes in trade costs that in turn lead to changes in producer prices and in consumer prices. Trade affects relative prices, which affect accumulation, which in the next period affects trade. The relationship between producer prices and capital accumulation is a direct one. The intuition is that when faced with higher returns to investment, consumers are willing to give up more of their current income in order to increase future consumption. The relationship between capital accumulation and aggregate consumer prices is an inverse one. The intuition is that an increase in consumer prices means that a higher share of income will be spent on consumption today and less will be saved and transferred for future consumption via capital accumulation.

Importantly, the model captures the possibility that changes in trade costs between any two trading partners may potentially affect producer prices and consumer prices in any

gravity theory of trade. Bergstrand (1985) offers an alternative theoretical foundation. More recently, Eaton and Kortum (2002), Helpman, Melitz, and Rubinstein (2008), and Chaney (2008) refined gravity equation estimation further for a Ricardian framework, firm heterogeneity in productivity and zero trade flows. As noted by Eaton and Kortum (2002) and Arkolakis, Costinot, and Rodríguez-Clare (2012), actually a large class of models with constant-elasticity-of-substitution (CES) preferences, iceberg trade costs, and complete specialization generate isomorphic gravity equations. Anderson (2011) summarizes the alternative theoretical foundations of economic gravity.

[7]We focus on growth effects driven by capital accumulation as this has been shown to be one of the most important transmission mechanism for channelling the effects of trade liberalization on growth.For example, using a panel of 57 countries for the period of 1970 to 1989, Wacziarg (2001) finds that physical capital accumulation accounts for about 60% of the total positive impact of openness on economic growth. Baldwin and Seghezza (2008) and Wacziarg and Welch (2008) confirm these findings with alternative samples of 39 countries (1965-1989) and 118 countries (1950-1998), respectively. Cuñat and Maffezzoli (2007) demonstrate the role of factor accumulation to reproduce the large observed increases in trade shares after modest tariff reductions.

[8]Anderson, Larch, and Yotov (2014) adapt Hercowitz and Sampson (1991) and Eckstein, Foulides, and Kollintzas (1996) over alternative theoretical models from the dynamic, stochastic, general equilibrium (DSGE) open economy macroeconomics literature, such as Backus, Kehoe, and Kydland (1992) and Backus, Kehoe, and Kydland (1994) for example, because the former deliver a tractable analytical solution that facilitates the interpretation of the complex relationships between growth and trade.

nation in the world, regardless of whether this nation takes part in integration and trade liberalization or not. This is especially relevant for an analysis of the effects of TTIP for two reasons. First, due to the fact that the US and the EU are among the largest trade players in the world, we expect that the effects on third parties will be large. Second, due to the advanced integration and strong trade connections within the EU, we expect that the additional general equilibrium effects within the EU region will be (i) very strong as well and (ii) quite heterogeneous among the EU members.

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 its trading partners. The indirect effect of growth on trade is channeled trough changes in trade costs. In particular, changes in country size translate into changes in the multilateral resistance for a given country, which lead to changes in trade flows. Importantly, the indirect channel through which growth affects trade is a general equilibrium channel, i.e., capital accumulation in one country may affect trade costs and impact welfare in any other country in the world. For example, the model reveals that growth in a given country translates into lower sellers incidence on the producers in this country and, therefore, an increase in real income. 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. Finally, it should be noted that growth-led changes in trade costs may lead to additional changes in capital stock, which could mitigate or amplify the initial effect of trade costs on growth.

The finding that growth in one country may affect trade costs and welfare in other countries is an important dynamic result in the context of TTIP because, in combination with the effects of trade on growth that we discussed above, it reveals a channel through which TTIP will (i) trigger additional and differential general equilibrium effects for each of the EU countries, and (ii) will affect, and most likely benefit, non-members as well. The intuition is that by making investments more attractive, TTIP will stimulate growth in the member countries (in the EU case these effects will be heterogeneous across member countries). This will lead to lower sellers incidence for these countries, but also to lower buyers incidence in non-members. We expect that this channel will be especially strong within the European Union because of the large intra-EU trade. In addition, we expect to find very strong effects on third parties due to fact that, as noted above, the US and the EU are very well integrated in the world trading system and both regions are the major trading partners for most countries in the rest of the world.

The theoretical model translates into a simple structural econometric system (similar to the reduced-form specification of Frankel and Romer (1999)), that will be used to obtain estimates of trade costs and most of the model's parameters that will be used to perform a series of counterfactual experiments in order to capture and to decompose the relationships between TTIP and growth in member and non-member countries.

We will quantify our model with the latest available data. We expect that the data coverage will span to at least 2012 and we are confident that our sample will include all countries within the EU, the US, and all major trading partners of the EU and US for a total of close to 100 countries that together account for more than 98% of world's trade and GDP.

We will devote special attention to the estimation of bilateral trade costs. Proper account for existing trade barriers between each of the EU member and the US is crucial for sound simulation of the effects of TTIP and we view this as an additional contribution of our project. We will use the latest developments in the empirical gravity literature to obtain precise bilateral trade costs estimates for each possible pair in our sample. Despite the close geographic proximity between the EU regions, we expect to find significant heterogeneity among the bilateral trade costs that EU members face with the US. In addition, we will attempt to identify all relevant bilateral trade barriers between each EU member and the US that are expected to be removed by TTIP.

We intend to perform counterfactual experiments that simulate the effects of both trade liberalization as well as capital accumulation. On the trade liberalization side, we plan to quantify the effects of uniform trade liberalization between EU and the US as well as trade liberalization on a bilateral basis between US and each of the EU members. The experiments on the growth side will stimulate growth in US and EU as a region as well as differential growth by specific EU members.

The proposed project is already at a very advanced stage of development, and we are confident that we will be able to deliver a complete draft in time for the conference. The theory is already completely developed. Appendix A offers details for the interested reader. The econometric specification is complete as well. It is summarized in Appendix B. We already have written all simulation codes and we have collected most of the data that is needed for the analysis. The main outstanding task is to carefully construct bilateral trade costs for each of the pairs in our sample. In addition to relying on the latest econometric developments in the estimation of trade costs, we will devote special attention to identify and account for all relevant bilateral trade barriers between each EU member and the US that are expected to be removed by TTIP.

# A Theoretical Foundation

The theoretical foundation used here to quantify the relationships between trade and growth combines the static structural trade gravity setup of Anderson and van Wincoop (2003) with dynamically endogenous production and capital accumulation in the spirit of the dynamic general equilibrium models developed by Hercowitz and Sampson (1991) and Eckstein, Foulides, and Kollintzas (1996).

Goods are differentiated by place of origin and each of the $N$ countries in the world is specialized in the production of a single good $j$. Total nominal output in country $j$ at time $t$ ($y_{j,t}$) is produced subject to the following constant returns to scale (CRS) Cobb-Douglas production function:

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

where $p_{j,t}$ denotes the factory-gate price of good (country) $j$ at time $t$ and $A_{j,t}$ denotes technology in country $j$ at time $t$. $L_{j,t}$ is the inelastically supplied amount of labor in country $j$ at time $t$ and $K_{j,t}$ is the stock of capital in $j$ at $t$. Capital and labor are country-specific (internationally immobile), and capital accumulates according to a Cobb-Douglas transition function following Hercowitz and Sampson (1991) and Eckstein, Foulides, and Kollintzas (1996):

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

where $\Omega_{j,t}$ denotes the flow of investment in country $j$ at time $t$ and $\delta$ is the depreciation rate.

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

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

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

The aggregate consumption good and aggregate investments are both comprised by domestic and foreign goods. Consumption and investment goods from different countries $i$, i.e., $c_{ij,t}$ and $I_{ij,t}$, respectively, are combined according to equations (7)-(8) to an aggregate consumption good and to aggregate investments:

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

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

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

Let $p_{ij,t} = p_{i,t} t_{ij,t}$ denote the price of country $i$ goods for country $j$ consumers, where $t_{ij,t}$ is the variable bilateral trade cost factor on shipment of commodities from $i$ to $j$ at time $t$.

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

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

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

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

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

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

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

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

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

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

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

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

Equation (12) links intuitively bilateral exports to market size (the first term on the right-hand side) and trade frictions (the second term on the right-hand side). Coined by Anderson and van Wincoop (2003), $\Pi_{i,t}^{1-\sigma}$ and $P_{j,t}^{1-\sigma}$ are the multilateral resistance (MR) terms (outward and inward, respectively), which consistently aggregate bilateral trade costs and decompose their incidence on the producers and the consumers in each region. The multilateral resistances are key to our analysis because they represent the endogenous structural link between the 'lower level' trade analysis and the 'upper level' production and growth equilibrium.[9] On the one hand, the MRs translate changes in bilateral trade costs at the upper level into changes in factory gate prices, which stimulate or discourage investment and growth. On the other hand, by changing output shares in the multilateral resistances, capital accumulation and growth alter the incidence of trade costs in the world.

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

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

following policy function for capital:

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

Alongside parameters, capital stock in period $t+1$ is determined as a function of the prices of domestically produced goods $p_{j,t}$, technology $A_{j,t}$, labor endowments $L_{j,t}$, the current capital stock $K_{j,t}$, and the aggregate consumer price index across all products in the world $P_{j,t}$. As expected, (15) depicts the direct relationship between capital accumulation and the levels of technology, labor endowment, and current capital stock. More importantly for the purposes of this paper, (15) suggests a direct relationship between capital accumulation and the prices of domestically produced goods and an inverse relationship between capital accumulation and the aggregate consumer price index $P_{j,t}$.[10] The intuition behind the positive relationship between the prices of domestic goods and capital accumulation is that when faced with higher returns to investment, consumers will be willing to give up more of their current income in order to increase future consumption. The intuition behind the negative relationship between capital accumulation and aggregate consumer prices is that an increase in $P_{j,t}$ means that a higher share of income will be spent on consumption today and less will be saved and transferred for future consumption via capital accumulation. As we demonstrate more formally below, the relationships between prices and capital accumulation are crucial for understanding the relationships between growth and trade because changes in trade costs will result in changes in international prices, which will affect capital accumulation.

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

[10]It should be noted that the price of domestic goods enters the aggregate price index and, via this channel, it has a negative effect on capital accumulation. However, as long as country $j$ consumes at least some foreign goods, this negative effect will be dominated by the direct positive effect of domestic prices on capital accumulation.

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

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

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

The combination of the lower-level gravity system given in Equations (12)-(14), the market clearing conditions given in Equation (11), the policy function for capital as given in Equation (15) as well as the definition of income as given in Equation (1) delivers our theoretical growth and trade model:

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

Our strategy in the subsequent sections is to translate system (16)-(21) into an econometric model, which we estimate in order to recover the structural parameters of the model (as well as some data), which are needed to perform our counterfactual experiments. Before that, however, we discuss the structural relationships of trade liberalization on growth that our model offers.

## A.1 Growth and Trade: A Discussion

To shed light on the relationships between growth and trade, we use system (16)-(21) to trace the effects of trade liberalization, measured as a reduction of bilateral trade costs $t_{ij}$ at some point in time $t$. First, the direct (partial-equilibrium) effect of a fall in $t_{ij,t}$ is an immediate increase in bilateral trade between partners $i$ and $j$ at time $t$ without any implications for the rest of the countries. This effect is captured by Equation (16) for given output and multilateral resistances.

Second, trade liberalization between countries $i$ and $j$ at time $t$ has an indirect effect on trade flows through the multilateral resistance terms given in Equations (17) and (18). This effect is emphasized by Anderson and van Wincoop (2003). Importantly, a reduction in trade costs between any two countries will affect trade flows between all other country pairs in time $t$ as the multilateral resistance terms are general equilibrium constructs, which aggregate consistently all bilateral trade costs faced by the producers in a given country as if they ship to a unified world market and all bilateral trade costs faced by the consumer in a given country as if they buy from a unified world market. Hence, those terms capture the third-country effects through trade creation and trade diversion.

Third, and most important for the purposes of this paper, trade liberalizations acts on output and growth via changes in prices in the world. In combination, equations (19)-(20) depict the contemporaneous effects of changes in trade costs on factory-gate prices $p_{j,t}$, via Equation (19), and on the value of domestic production/income $y_{j,t}$, via Equation (20). Importantly, these effects are channeled through the outward multilateral resistance, which, as discussed above, means that a change in trade costs between any two countries may affect prices and output in any other country in the world.

Fourth, in combination, Equations (19)-(21) capture the effects of trade liberalization on capital accumulation. A change in trade costs will cause a change in factory-gate prices via Equation (19), which will translate into a change in the capital stock via Equation (21). As discussed earlier, the relationship between prices of domestically produced goods and capital accumulation is direct, while the relationship between foreign factory-gate prices and capital accumulation, which is channeled via the inward miltilateral resistance $P_{j,t}$ in Equation (21), is inverse. In combination, accumulation has elasticity with respect to the terms of trade $p_{j,t}/P_{j,t}$ equal to $\delta$, the depreciation rate.

Finally, we note that the changes in the value of output will have additional (direct and indirect) effects on trade and world prices. The direct, positive effects of output on trade are captured by Equation (16). In addition, changes in output will affect trade flows indirectly via changes in the multilateral resistances that are captured by Equations (17) and (18). In turn, the changes in the MR terms will lead to additional, third-order changes in output and capital accumulation, and so forth.

In our model, growth affects trade via two channels, directly and indirectly. The direct effect of growth on trade is strictly positive and it is channeled through changes in country size. An increase in the size of an economy results in more exports and in more imports between this country and its trading partners. The indirect effect of growth on trade is channeled trough changes in trade costs. In particular, changes in country size translate into changes in the multilateral resistance for a given country, which lead to changes in trade flows. Importantly, the indirect channel through which growth affects trade is a general equilibrium channel, i.e. capital accumulation in one country may affect trade costs and impact welfare in any other country in the world. Our theory reveals that growth in a given country translates into lower sellers incidence on the producers in this country. In addition, all else equal, the benefits of growth in one country are shared with the rest of the world through lower buyers incidence in its trading partners.

The finding that growth in one country may affect trade costs and welfare in other countries is an important dynamic result because, in combination with the effects of trade on growth that we discussed above, it reveals a channel through which preferential trade liberalization (e.g. a Free Trade Agreement, FTA) may benefit non-members. In particular, by making investments more attractive, a free trade agreement will stimulate growth in the member countries. This will lead to lower sellers incidence for these countries, but also to lower buyers incidence in non-members.

It is clear from this discussion that system (16)-(21) accounts for a series of complex and simultaneous relationships between trade and growth in a particularly simple way. Our structural approach can disentangle and decompose these relationships. We demonstrate how with a series of counterfactual experiments. Before that, we discuss the empirical implications of our model.

# B Empirical Analysis

The main objective of this section is to construct the bilateral trade costs and the multilateral resistances, which are needed to complete the data requirements for our counterfactual experiments below. As discussed earlier, all of the parameters needed to simulate the relationship between trade and growth are available and routinely used in the macroeconomic and trade literature. Nevertheless, in this section we translate our structural growth-trade model into a very simple and intuitive estimation system and we obtain our own estimates of some key parameters. The latter are compared with standard values from the existing literature to establish the credibility of our methods. An additional advantage of our econometric framework is that it very much resembles the reduced-form specification from Frankel and Romer (1999) while highlighting important contributions of our structural approach. Next, we present our estimation strategy and we discuss some econometric challenges. Then, we describe the data and we offer a discussion of our estimates.

## B.1 Econometric Specification

Following the expositional development from the theory section, we translate our structural model into an econometric specification in two steps. First, we discuss the estimation of the lower-level, which governs the evolution of trade flows. Then, we describe the estimation strategy for the upper level, where output is determined as a function of endowments, technology and trade costs.

### B.1.1 Econometric Specification: Lower Level (Trade)

We capitalize on the latest developments in the trade literature in the specification and estimation of our lower-level trade system (16)-(18). In order to obtain sound econometric estimates of bilateral trade costs and, subsequently, of the multilateral resistances that enter our growth equation, we need to address several econometric challenges. First, we follow Santos Silva and Tenreyro (2006) who advocate the use of the Poisson Pseudo-Maximum-Likelihood (PPML) estimator to simultaneously account for the zeros and for the presence of heteroskedasticity in trade data. Second, we use time-varying, directional, country-specific fixed effects to account for the unobservable multilateral resistances. Importantly, in addition to controlling for the multilateral resistances, the fixed effects in our econometric specification also absorb national output and expenditures and, therefore, control for all dynamic forces from our theory. Third, to avoid the critique from Cheng and Wall (2005) that '[f]ixed-effects estimation is sometimes criticized when applied to data pooled over consecutive years on the grounds that dependent and independent variables cannot fully adjust in a single year's time.' (footnote 8, p. 52), we use 3-year intervals.[11] The final step, which completes the econometric specification of our trade system, is to provide structure behind the unobservable

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

bilateral trade costs. To do this, we employ the standard set of gravity variables from the existing literature:

$$t_{ij}{}^{1-\sigma} = e^{\gamma_1 RTA_{ij} + \sum_{m=2}^{5} \gamma_m \ln DIST_{ij}^m + \gamma_6 BRDR_{ij} + \gamma_7 LANG_{ij} + \gamma_8 CLNY_{ij} + \gamma_9 SMCTRY_{ij}}. \qquad (22)$$

Here, $RTA_{ij}$ is a dummy variable equal to 1 when $i$ and $j$ have formed a Regional Trade Agreement (RTA) and zero elsewhere.[12] We will use the estimate of the coefficient on $RTA$ to simulate the effects of trade liberalization in our counterfactual experiments below. $\ln DIST_{ij}^m$ is the logarithm of bilateral distance between trading partners $i$ and $j$. We follow Eaton and Kortum (2002) to decompose the distance effects into four intervals, $m \in \{2, 3, 4, 5\}$. The distance intervals, in kilometers, are: [0, 3000); [3000, 7000); [7000, 10000); [10000, maximum]. $BRDR_{ij}$ captures the presence of a contiguous border between partners $i$ and $j$. $LANG_{ij}$ and $CLNY_{ij}$ account for common language and colonial ties, respectively. Finally, $SMCTRY_{ij}$ is a dummy variable equal to 1 when $i = j$ and zero elsewhere. $SMCTRY_{ij}$ picks up all the relevant forces that discriminate between internal and international trade.

One final consideration that we address is the potential endogeneity of regional trade agreements, which we will use to measure the effects of trade liberalization. The issue of RTA endogeneity is well-known in the trade literature[13] and to address it, we resort to the average treatment effect methods (see for example Wooldridge, 2010) that have proven to be successful in the treatment of RTA endogeneity by Baier and Bergstrand (2007). In particular, Baier and Bergstrand (2007) propose two solutions to the endogeneity problem. In order to account for the unobservable linkages between the endogenous RTA covariate and the error term in trade regressions, one should either use first-differenced data or employ bilateral (country-pair) fixed effects. We chose the second option because, as we demonstrate

[12] We use all regional trade agreements as notified to the World Trade Organization. The data were augmented and corrected by using information from RTA secretariat web pages and they were compiled to obtain a binary dummy variable $RTA_{ij}$ reflecting the existence of at least one RTA between countries $i$ and $j$.

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

below, it enables us to construct bilateral trade costs from the estimates of the country-pair fixed effects.

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

$$x_{ij,t} = \exp[\gamma_1 RTA_{ij} + \eta_{i,t} + \theta_{j,t} + \mu_{ij}] + \epsilon_{ij,t}. \tag{23}$$

Here, $\eta_{i,t}$ denotes the time-varying source-country dummies, which control for the outward multilateral resistances and countries' output shares. $\theta_{j,t}$ encompasses the time varying destination country dummy variables that account for the inward multilateral resistances and total expenditure. $\mu_{ij}$ denotes the set of country-pair fixed effects that should absorb the linkages between $RTA_{ij}$ and $\epsilon_{ij,t}$ in order to control for potential endogeneity of the former. Importantly, $\mu_{ij}$ will absorb all time-invariant gravity covariates from (22) along with any other time-invariant determinants of trade costs that are not observable by the researcher. Below, we study the distribution of the pair fixed effects to argue that they are an appropriate proxy for time-invariant trade costs and we use the estimates of $\mu_{ij}$ together with the estimate of the RTA effects to construct the bilateral trade costs $t_{ij}$ needed for our counterfactuals:

$$\hat{t}_{ij}^{1-\sigma} = e^{\hat{\gamma}_1 RTA_{ij} + \hat{\mu}_{ij}}, \tag{24}$$

where the estimates of the country-pair fixed effects $\mu_{ij}, \forall i \neq j$, are obtained relative to the fixed effect for internal trade, $\mu_{ii}$, which corresponds to the internal trade dummy variable $SMCTRY_{ij}$ form specification (22). In order to gauge how appropriate our estimates of the pair fixed effects are to proxy for bilateral trade costs, we estimate a second stage regression, where the bilateral fixed effects estimates are regressed on the set of standard gravity variables:

$$\hat{\mu}_{ij} = \sum_{m=1}^{4} \gamma_m \ln DIST_{ij}^{m} + \gamma_5 BRDR_{ij} + \gamma_6 LANG_{ij} + \gamma_7 CLNY_{ij} + \varepsilon_{ij}. \tag{25}$$

To take advantage of the information contained in the standard errors of the $\hat{\mu}_{ij}$'s, we estimate (25) with weighted ordinary least squares (WOLS), where the weights are equal to the inverse squared standard errors of the pair fixed effect estimates from (23). The intuition being that more precise estimates should be given a higher weight in the estimations. Below we find that the correlation between the bilateral trade costs constructed from (24) and the corresponding indexes based on the estimates from (24) is high, but not perfect, and we experiment with both measures of trade costs in the counterfactual experiments.

### B.1.2 Econometric Specification: Upper Level (Output)

We now turn to the upper-level, where output and growth are determined as functions of technology, factor endowments and trade costs. In this section, we concentrate on the estimation equation for output because it is readily comparable with corresponding specifications from the existing literature (e.g. Frankel and Romer, 1999). Transforming the specification for output into an estimation equation for growth is straight forward. To obtain the estimation equation for output, we substitute equation (19) for prices into equation (20) and we express the resulting equation in natural logarithmic form:

$$\ln y_{j,t} \;=\; \frac{1}{\sigma}\ln y_t + \frac{\sigma-1}{\sigma}\ln\frac{A_{j,t}}{\gamma_j} + \frac{(\sigma-1)(1-\alpha)}{\sigma}\ln L_{j,t} + \frac{(\sigma-1)\alpha}{\sigma}K_{j,t} - \frac{1}{\sigma}\ln\left(\frac{1}{\Pi_{j,t}^{1-\sigma}}\right). \quad (26)$$

We keep the expression for the outward multilateral resistance as a power transform, $\ln(1/\Pi_{j,t}^{1-\sigma})$, because we can recover this power term directly from the lower-level estimation procedures without the need to assume any value for the trade elasticity of substitution $\sigma$. As demonstrated below, our methods enable us to obtain our own estimates of $\sigma$.

Two steps deliver a simple estimation equation for output. First, we experiment with a time trend and with year dummies $\nu_t$ to control for $\frac{1}{\sigma}\ln y_t$, which may be measured with error and also to control for any other time-varying variables that may affect output in addition to the industry-time varying covariates that enter our specification explicitly. Second, we do not observe $A_{j,t}$ and data on $\gamma_j$ is not available. Therefore, we sum the term $(\sigma-1)/\sigma\ln(A_{j,t}/\gamma_j)$

in the residual $\varepsilon_{j,t}$. (26) becomes

$$\ln y_{j,t} = \beta_1 \ln L_{j,t} + \beta_2 K_{j,t} + \beta_3 \ln\left(\frac{1}{\Pi_{j,t}^{1-\sigma}}\right) + \nu_t + \varepsilon_{j,t}. \tag{27}$$

Here, $\beta_1 = (\sigma - 1)(1 - \alpha)/\sigma$, $\beta_2 = (\sigma - 1)\alpha/\sigma$, and $\beta_3 = -1/\sigma$. The estimate of the coefficient on the multilateral resistance term, $\hat{\beta}_3$, can be used to recover the trade elasticity of substitution directly as $\hat{\sigma} = -1/\hat{\beta}_3$. Being able to estimate $\sigma$ 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 Arkolakis, Costinot, and Rodríguez-Clare, 2012). Furthermore, we will be able to compare our estimate with existing indexes in order to gauge the success of our methods. With $\sigma$ at hand, we can also obtain the capital share of production as $\alpha = \hat{\beta}_2\sigma/(\sigma - 1) = \hat{\beta}_2/(1 + \hat{\beta}_3)$. The conventional estimate of the capital share is 1/4, and we use this value as a benchmark for our own estimate. Finally, our model implies the following structural relationship between the coefficients on the three covariates in (27), $\beta_1 + \beta_2 = 1 + \beta_3$.

In addition to affording to recover some key parameters, (27) highlights three of our main contributions to the literature. First, the introduction of $\ln(1/\Pi_{j,t}^{1-\sigma})$ in (27) has implications for the calculations and the analysis of total factor productivity. As discussed in Anderson (2011), a change in the outward multilateral resistance, which measures the incidence of trade costs on producers, can be interpreted as a productivity shock. For example, lower multilateral resistance has positive effects on producers and can be viewed as an increase in productivity. Equation (27) accounts for these effects explicitly and implies that the TFP estimates from empirical specifications that do not control for the influence of trade costs might be biased.

Third, in combination equations (23) and (27) deliver a structural foundation for the influential reduced-form specification of the relationship between trade and growth from

Frankel and Romer (1999):

$$\textit{Trade}: \quad x_{ij,t} = \exp[\gamma_1 RTA_{ij} + \gamma_{ij} + \eta_{i,t} + \theta_{j,t}] + \epsilon_{ij,t}, \tag{28}$$

$$\textit{Output}: \quad \ln y_{j,t} = \beta_1 \ln L_{j,t} + \beta_2 K_{j,t} + \beta_3 \ln\left(\frac{1}{\Pi_{j,t}^{1-\sigma}}\right) + \nu_t + \varepsilon_{j,t}. \tag{29}$$

Frankel and Romer (1999) use a version of the gravity equation (28) to instrument for trade, which enters their *Output* equation directly. Instead, in our specification the effects of trade and trade costs are channeled directly via the structural trade term $\ln\left(1/\Pi_{j,t}^{1-\sigma}\right)$.

One final consideration that we address before estimating system (28)-(29) is that the trade term $\ln(1/\Pi_{j,t}^{1-\sigma})$ in equation (29) is endogenous by construction, because it includes own national income. We eliminate this endogeneity concern mechanically by calculating the multilateral resistances based on international trade linkages only. Specifically, to obtain the incidence that domestic producers face when shipping to foreign markets ($\tilde{\Pi}_{j,t}^{1-\sigma}$), we solve:

$$\tilde{\Pi}_{i,t}^{1-\sigma} = \sum_{\bar{i}} \left(t_{i\bar{i},t}/\tilde{P}_{\bar{i},t}\right)^{1-\sigma} y_{\bar{i},t}/y_t, \tag{30}$$

$$\tilde{P}_{j,t}^{1-\sigma} = \sum_{\bar{j}} \left(t_{\bar{j}j,t}/\tilde{\Pi}_{\bar{j},t}\right)^{1-\sigma} y_{\bar{j},t}/y_t, \tag{31}$$

where $\bar{i}$ and $\bar{j}$ denote all foreign countries besides $i$ and $j$, respectively. This procedure is akin to the methods from Anderson and Yotov (2012) who use $\tilde{\Pi}_{j,t}^{1-\sigma}$ 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 $\Pi_{j,t}^{1-\sigma}$ is the standard, all-inclusive outward multilateral resistance.

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