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Abstract

We undertake a trade-growth accounting exercise by decomposing data on changes in bilateral international trade flows into their *direct* (endowment accumulation, productivity growth, changes in trade costs, changing preferences) and *indirect* components (general equilibrium effects). Furthermore, we distinguish between the (potentially partly endogenous) *direct* and the *deep* drivers of trade by extending standard new trade models to include endogenous factor accumulation, R&D driven productivity growth, and endogenous changes in expenditures shares on manufacturing goods and services. We quantify the importance of the direct and deep drivers of the growth of bilateral and multilateral trade of 67 economies over 20 consecutive years since 1988 for three trade outcomes: changes in growth rates across different country pairs, changes in levels of trade flows, and changes in trade to GDP ratio. The results suggest that changes in shocks to endogenous endowment accumulation and trade costs have been the most important drivers of trade in the sample at hand, whereas productivity growth and changes in preferences appear to have been quantitatively less important.

JEL-Codes: F100, F110, F140, O100.

Keywords: international trade, trade-growth accounting, trade costs.

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1 Introduction

Factor endowments, technology, and trade costs are the uncontested main drivers of goods-trade flows in both economic theory and empirical work.[1] Yet, in spite of this wisdom, little is known about the *relative quantitative importance* of these direct drivers for trade.[2] And to the extent that they are endogenous – e.g., due to induced endowment accumulation, induced technological change, and induced changes in preferences and expenditure structure – little is known about the role of deep fundamentals governing these factors for the growth of trade. Why did exports grow at such different rates across country pairs and countries in the past? What were the main drivers of the rapid growth in global trade flows in levels and relative to GDP observed in the last few decades? So far, trade economists have not provided a unified quantitative answer to these questions, at least not one in an integrated framework which simultaneously targets all aforementioned fundamental classes of determinants of trade.

The present paper aims at filling this gap in three ways. First, it proposes employing a method of trade-growth accounting consistent with recent general equilibrium models of trade (see Eaton and Kortum, 2002; Anderson and van Wincoop, 2003; Melitz, 2003) which is applied to real-world data for 67 countries and their bilateral exports, prices, and endowments between 1988 and 2007. The proposed procedure helps decomposing the variance in the growth rates of bilateral export flows over time into direct (but potentially partly endogenous) drivers – endowments, trade costs, technology, and preferences – and into endogenous (general-equilibrium or price) effects across country pairs and time. For the data at hand, this analysis reveals that the increase in the rising variance in bilateral exports growth rates over time went hand in hand with an increase in the variances in the growth of the direct drivers as well as of general equilibrium effects (prices). However, the rising variance in bilateral trade costs is the dominant component (followed by the ones of changes in technology and general equilibrium effects) in the overall variance of the growth of bilateral exports. Changes in endowments and in preferences contribute relatively lower shares to the variance of growth in trade across different country pairs. But, clearly, changes in prices (general-equilibrium effects) are endogenous, and they could depend more or less strongly on changes in the individual direct drivers of trade. The most important insight from the variance-decomposition part in the paper is that the correlation coefficients among the growth rates of direct drivers of trade are nonzero statistically, and this might point to a structural relationship between these drivers that could flow from their partial endogeneity.

Second, the paper uses the structural decomposition approach to conduct a series of counterfactual experiments to quantitatively assess the relative importance of the direct drivers (endowments, technology, trade costs, preferences) for the growth of trade around the globe (and between different country groups) overtime. This analysis is useful, since it acknowledges the endogeneity of price changes, and isolates the importance of direct drivers of trade. We employ two alternative models for this analysis which match the bilateral trade data in the sample equally well but differ in the treatment of the direct drivers of trade as fully exogenous (dubbed a *Static Exogenous Drivers (SXD)* model of the growth of trade) versus partly endogenous (dubbed a *Dynamic Endogenous Drivers (DND)* model of the growth of trade).[3] With the DND approach, we develop a dynamic trade model with endogenous factor

[1] For a discussion, see Harrigan (1995, 1997), Deardorff (1998), and Feenstra (1998).

[2] Clearly, there are strands of research which vividly debate to which extent the pattern of trade is consistent with Ricardian and/or Heckscher-Ohlin theory (e.g., see Trefler, 1995, Davies and Weinstein, 2001). Moreover, there is work considering how important absolute endowments and endowment differences are as drivers of the volume of trade relative to trade costs (e.g., see Baier and Bergstrand, 2001). However, when it comes to the question of how important quantitatively endowments versus technology versus trade costs are for trade, a clear answer is missing, since no unified quantitative attempt has been made to contrast the underlying drivers against each other.

[3] In almost all of the quantitative literature on bilateral trade, it is customary to assume that direct drivers of trade – in particular, endowments, technology, and preferences – are exogenous and constant. Examples are Eaton and Kortum (2002) or Arkolakis, Costinot, and Rodríguez-Clare (2012), or Bergstrand, Egger, and Larch (2013), and Anderson and van Wincoop (2003) for exogenous goods-endowment

accumulation, R&D-efficiency-driven productivity, and non-homothetic preferences and contrast its predictions to those of the SXD approach. While the two models produce heterogeneous results in terms of the relative importance of changing technologies and preferences, they both point to endowment accumulation and reductions in trade costs as the main drivers of the growth of bilateral exports. The SXD (DND) model predicts that under constant factor endowments (the absence of exogenous investment shocks) and constant trade costs relative to 1988, total world trade flows would have been lower by 68% (50%) and 35% (31%) in 2007, respectively. The results of the two models differ with regard to the relative importance of exogenous fundamentals to each other, suggesting that considering endogenous adjustments of factor accumulation, technology, and preferences to changes in deep parameters is quantitatively (and eventually even qualitatively) important. Moreover, we find and illustrate below that the pattern of relative importance of exogenous drivers of trade is heterogeneous across different groups of countries (low-, middle-, and high-income).

Finally, we use the two models to assess the importance of different drivers for growth rates in the ratio of trade (with all partner countries) to GDP in the sample. For this outcome, changes in trade costs appear to have had the largest quantitative impact. Both the SXD and the DND model suggest that under constant trade costs (relative to 1988) the trade-to-GDP ratio in 2007 would have been only slightly higher than the one in 1998, whereas it actually grew by 45% in the data.

The remainder of the paper is organized as follows. The next section elaborates on the relationship of the present manuscript to earlier work. We set out the SXD model in Section 3 and describe the calibration procedure and the data in Section 4. We conduct an analysis of variance of the changes in pair-specific trade flows in Section 5. Section 6 analyzes the relative importance of endowments, trade costs, productivity and preferences for the growth of trade levels among different groups of countries and the world in total. We develop the DND model and use it for a counterfactual analysis in Section 7. In Section 8, we examine the role of changes in the different drivers in the context of the two models for the trade-to-GDP ratio in the world. The last section provides a set of conclusions.

2 Related literature

The work in this paper is broadly related to several strands of research. One is the surprisingly scarce quantitative work on explaining the growth of bilateral trade flows over time. To our knowledge, the first contribution to this literature is Baier and Bergstrand's (2001), who were motivated by Krugman's (1991) work on trade and assessed the relative role of changes in tariffs, in transportation costs, and in income similarity for the growth of trade across country pairs in the OECD. Their approach allowed decomposing the growth of trade broadly into the directly attributable effects to trade costs and to real income (bilateral levels and similarity). However, since real income is endogenous, Baier and Bergstrand's approach could not decompose the growth of trade into the overall contributions of fundamental drivers such as factor accumulation, technology, preferences, and trade costs. In contrast, the present paper isolates these four types of shocks from each other. For example, we measure trade costs using data on trade flows and prices and do not rely on the usual gravity estimation of trade costs which may be problematic.[4] Moreover, the present paper is concerned with identifying the relative importance of all

levels and constant, identical preferences. For discussion see Costinot and Rodríguez-Clare (2014).

[4]The measured trade costs in the present paper fully encompass bilateral trade impediments such as geography (Eaton and Kortum, 2002, Anderson and van Wincoop, 2004), trade agreements (Baier and Bergstrand, 2007, 2009), bilateral information frictions (Allen, 2014), common language (Mélitz and Toubal, 2014; Egger and Lassmann, 2015), seaport infrastructure (Bernhofen, El-Sahli, and Kneller, 2013), and others. Trade costs are solved for in bulk rather than estimated by components with error. Hence, we choose examining total trade costs as

direct and the deep, exogenous parameters driving the growth of trade, and it eventually proposes a dynamic model where not only real demand (consumption) but also real supply (production) of goods and services changes endogenously and heterogeneously across countries and time.

A more recent important quantitative contribution which is closely related to ours is the one by Eaton, Kortum, Neiman, and Romalis (2013) who develop a dynamic Ricardian model of trade and use high-frequency data for a selected list of 20 large economies to examine the drivers of the Great Trade Collapse in 2008-2009. Their paper differs from ours in two important regards: first, they focus on a specific, short episode and a limited range of countries since they are concerned with understanding the Great Trade Collapse in particular; second, they do not incorporate aspects of demand-driven structural change through non-homothetic preferences or deep drivers of endogenous changes in technology. Eaton, Kortum, Neiman, and Romalis (2013) find that shocks to the value of capital explained the largest part of the acute drop in trade during the recession while changes in trade costs and technology were of minor importance in that time period. The present paper is about the structural, long-run drivers of the growth of trade. And in that longer run, we identify endowment changes (and their deep drivers), changes in trade costs, technological change (and its deep drivers), and structural change (and its deep drivers) – in this order – as the most important drivers of world trade over two recent decades.[5]

Moreover, analogously to Eaton, Kortum, Neiman, and Romalis (2013), the structural framework in the present paper builds on Eaton and Kortum's (2002) and Dekle, Eaton, and Kortum's (2007) approach – motivated by Dornbusch, Fischer, and Samuelson's (1977) view on trade through David Ricardo's lense – and to the steadily growing body of work based on various types of multi-country quantitative models of trade.[6] However, earlier work in those traditions has not made an attempt to decompose the growth of world trade and identify the relative importance of all its main drivers over a reasonably long time span. But rather, it focused on explaining trade flows in cross sections of data, and on emphasizing the role of individual drivers of trade – mostly trade costs.[7] The focus of this paper is on providing an encompassing view on the *growth* (rather than only the *level*) of trade and on identifying the relative importance of its drivers across countries and time.

Finally, the growth-accounting-type question of interest here is related to work in macroeconomics on GDP-growth accounting (see Solow, 1957; Hall and Jones, 1999; Caselli, 2005) in the sense that we use data and the model's structure to calibrate unobservable variables. In particular, the calibration strategy adopted in the present paper is inspired by Chari, Kehoe, and McGrattan's (2007) in gauging certain parameter values from *wedges* of the model's base predictions and the data. With its aim to fully trace the main drivers of the growth of trade in recent decades through quantitative modeling with many countries, the present paper is also related to earlier empirical work on trade and growth in macroeconomics (see Harrison, 1996; Frankel and Romer, 1999; Wacziarg, 2001).[8] It

opposed to gauging some individual effects (see Egger and Nigai, 2014).

[5]The present paper is also loosely related to Levchenko and Zhang (2015) who analyze the quantitative importance of technological change in a multi-sector version of the Eaton-Kortum model across multiple decades and find that there has been significant convergence in sectoral total factor productivity in both developing and developed countries. We also relate to Alessandria and Choi (2014a, 2014b) who assess the importance of falling trade costs for the growth of trade-to-GDP ratio and U.S. exports. Consistent with them, we find that falling barriers to trade constituted an important driver of world-trade flows in both absolute and relative-to-GDP dimensions.

[6]For a selected list of papers using Eaton-Kortum-type Ricardian models, see Alvarez and Lucas (2007), Arkolakis, Costinot, and Rodríguez-Clare (2012), Costinot and Donaldson (2012), Costinot, Donaldson, and Komunjer (2012), Levchenko and Zhang (2012), Costinot and Rodríguez-Clare (2014), Levchenko, di Giovanni, and Zhang (2014), Caliendo and Parro (2015), Egger and Nigai (2015). For recent quantitative Anderson- van-Wincoop-type Armington-model-type analyses of trade, see Anderson and Yotov (2010). For a multi-country quantitative analysis based on Krugman's increasing-returns-to-scale with monopolistic-competition model of trade see Bergstrand, Egger, and Larch (2013).

[7]Technology and geography in Eaton and Kortum (2002) and trade costs only in Anderson and van Wincoop (2003, 2004) or Bergstrand, Egger, and Larch (2013).

[8]The by not any means exhaustive list of papers that examine the correlation between openness includes Chow (1987), Lee (1993), Edwards (1998) and Irwin and Tervio (2002). The corresponding work tends to find a positive relationship between trade and economic growth.

is also related to recent work considering adjustments in firm and exporter numbers and real output (see Egger and Pfaffermayr, 2014) or capital stocks and real output (see Anderson, Larch, and Yotov, 2014) in response to trade liberalization in general equilibrium. However, gauging the relative importance of all drivers of trade and proposing a model with endogenous usable endowments for production, endogenous technology, and endogenous structural change, the questions posed here and the underlying theoretical model are largely different from the aforementioned dynamic work in trade and macroeconomics.

3 Trade and income in a generic cross section of country-pairs

Throughout the paper, bilateral trade will depend on factor endowments, technology, trade costs, and expenditure shares on manufactures versus services. In Section 6, we will treat factor endowments, average productivity, and expenditure shares on goods versus services as exogenous, country-time-specific parameters. In Section 7, these quantities will depend directly on deep parameters – investment shocks, innovation shocks, and non-homothetic preference parameters – and indirectly on trade costs. Hence, throughout the paper, the quantitative decomposition of the growth of bilateral trade into direct contributions from changes in endowments, productivity, trade costs, and expenditure shares on goods and services are the same, independent of the considered model variant. However, clearly, when considering endogenous factor accumulation, technological change, and expenditure shares, the relative overall importance of trade costs changes, since trade costs may induce indirect effects on trade through stimuli on factor accumulation, technological change, and (preference-induced) structural change.

We start with outlining a trade model for a generic cross section of N countries and N^2 country pairs. Each country i is populated by a single representative consumer who owns a measure $\ell_{i,t}$ of equipped labor in period t.[9] Workers supply their equipped labor to two sectors that produce services and manufactures, respectively. The manufacturing sector has a unit measure of heterogeneous firms that draw their total-factor-productivity parameters from country-specific distributions. The moments of the productivity distributions differ across sectors and countries. Manufactures are tradable subject to an iceberg trade cost, $\tau_{ij,t} \geq 1$ for $j \neq i$ and $\tau_{ii,t} = 1$. We model input-output linkages in the economy broadly through the use of output of both services and manufactures in the production of each of them.

We describe the model for two generic time periods, benchmark period s and an arbitrary period $t > s$. First, we characterize the open-economy equilibrium in period s. In country i, the representative consumer, who consumes services and manufacturers, and earns total income $\ell_{i,s} w_{i,s}$, exhibits the indirect utility function:

$$V(\ell_{i,s} w_{i,s}, p_{mi,s}, p_{ni,s}) = \frac{\ell_{i,s} w_{i,s}}{p_{mi,s}^{\varsigma_{i,t}} p_{ni,s}^{1-\varsigma_{i,t}}}, \tag{3.1}$$

where $p_{mi,s}$ and $p_{ni,s}$ are prices of tradable manufactures and non-tradable services, respectively. Parameter $\varsigma_{i,t}$ indicates the expenditure share of consumption of manufactures and it may vary across countries and time.

The non-tradable services output is produced by a perfectly competitive firm that employs labor, tradeable

[9] It is customary in the literature to refer to workers plus capital as *equipped labor* (see, e.g., Alvarez and Lucas, 2007). For the present purpose, it is not necessary to model labor and capital separately. Eaton, Kortum, Neiman, and Romalis (2013) develop a Ricardian framework, where capital accumulation is explicitly modeled, and Anderson, Larch, and Yotov (2013) propose a model with an aggregate (country-level) production function which uses labor and capital as primary production factors to produce goods. Focusing on deep fundamentals, we present a dynamic version of a Ricardian model with endogenous endowment accumulation, endogenous technological change, and endogenous structural change in Section 7.

intermediate manufactures and non-tradables, and it is priced according to

$$p_{ni,s} \equiv \phi_{i,s} \left(w_{i,s}^{\alpha} p_{mi,s}^{\beta} p_{ni,s}^{\gamma} \right) \text{ with } \alpha + \beta + \gamma = 1, \tag{3.2}$$

where $\phi_{i,s}$ measures the (inverse) average total factor productivity parameter of firms in services, and $p_{ni,s}$ and $p_{mi,s}$ are constant-elasticity-of-substitution (CES) aggregate price indices of services and manufactures, respectively.

Manufacturers draw their total productivity parameter from a Fréchet distribution (see Eaton and Kortum, 2002) with scale and shape parameters $\varphi_{i,s}$ and θ, respectively. They use equipped labor, tradeable intermediate manufactures, and a bundle of non-tradable services at Cobb-Douglas expenditure shares η, μ, and ν, respectively, with $\eta + \mu + \nu = 1$ (i.e., at constant returns to scale). Firms in different countries that produce the same varieties compete with each other such that only the lowest-cost producer gross of trade costs supplies to a particular market. In the aggregate, however, individual firms do not play a role and the model here captures aggregate rather then firm-specific exports. By the law of large numbers and CES aggregation of varieties, the price index of the bundle of manufactures is:

$$p_{mi,s} = \Omega_m \left(\sum_{k=1}^{J} \varphi_{k,s} \left(w_{k,s}^{\eta} p_{mk,s}^{\mu} p_{nk,s}^{\nu} \tau_{ik,s} \right)^{-\theta} \right)^{-\frac{1}{\theta}}, \tag{3.3}$$

where Ω_m is a normalizing constant. The share of country i's income spent on manufactures from exporter j is:

$$\lambda_{ij,s} = \frac{\varphi_{j,s} (w_{j,s}^{\eta} p_{mj,s}^{\mu} p_{nj,s}^{\nu} \tau_{ij,s})^{-\theta}}{\sum_{k=1}^{J} \varphi_{k,s} \left(w_{k,s}^{\eta} p_{mk,s}^{\mu} p_{nk,s}^{\nu} \tau_{ik,s} \right)^{-\theta}}. \tag{3.4}$$

Closing the model involves specifying the usual product-market-clearing condition such that total income equals total expenditures in each economy i up to a deficit-level parameter $D_{i,s}$:

$$X_{ij,s} = \lambda_{ij,s} d_{i,s} \varrho_{i,s} Y_{i,s}, \quad \varrho_{i,s} Y_{i,s} = \sum_{j=1}^{J} \lambda_{ji,s} \varrho_{j,s} Y_{j,s} d_{j,s}, \tag{3.5}$$

where $X_{ij,s}$ are total nominal exports from j to i at s, $\varrho_{j,s}$ is the share of total output of manufacturing in GDP, $Y_{j,s}$ is total GDP, and $d_{j,s} = 1 + D_{j,s}/(\varrho_{i,s} Y_{i,s})$ is an exogenous deficit-share constant which relates the level of trade deficit, $D_{j,s}$, to $\varrho_{j,s} Y_{j,s}$ at a constant rate. Equation (3.5) can be solved for $(N-1)$ endogenous rates of return on equipped labor, $w_{i,s}$, with one country's return serving as the numéraire. The properties of this class of models are well known (see Arkolakis, Costinot, and Rodrígues-Clare, 2012, for a discussion) and, under certain assumptions, the specification of bilateral goods trade here is isomorphic to the models of Anderson and van Wincoop (2003), Melitz (2003), and many others. The focus of this paper within such a framework is novel, however, since we aim at gauging the *relative quantitative importance of changes* in *all main* country-(time) and country-pair-(time-)specific *drivers* of the *growth* of trade: endowments ($\ell_{i,t}$), trade costs ($\tau_{ij,t}$),[10]technology ($\phi_{i,t}, \varphi_{i,t}$), and preferences ($\varrho_{i,t}$).

To pin down the share of manufacturers in all expenditures, $\varrho_{i,t}$, we consider the demand-supply equation for the manufacturing aggregate. Let ℓ_{mi} be the share of total labor employed in the manufacturing sector then the

[10]In this class of models, trade costs and pair-specific preference parameters cannot be disentangled. Though we refer to τ_{ij} as trade costs, it should be borne in mind that they also capture a taste-specific component which is specific to country-pairs or country-pair-time.

following holds:

$$\underbrace{\eta^{-1}\ell_{mi,t}\ell_{i,t}w_{i,t}}_{\text{Total supply of manufactures}} + D_{i,t} = \underbrace{\mu\eta^{-1}\ell_{mi,t}\ell_{i,t}w_{i,t} + \beta\alpha^{-1}(1-\ell_{mi,t})\ell_{i,t}w_{i,t}}_{\text{Intermediate demand}} + \underbrace{\varsigma_{i,t}(\ell_{i,t}w_{i,t} + D_{i,t})}_{\text{Final demand}}. \tag{3.6}$$

We divide both sides of the equation by total GDP and use definition of $d_{i,t}$ to obtain the following expression for $\varrho_{i,t}$:

$$\varrho_{i,t} = \frac{\beta\alpha^{-1} + \varsigma_{i,t}}{\eta\beta\alpha^{-1} - \mu + d_{i,t} - \varsigma_{i,t}(d_{i,t} - 1)}. \tag{3.7}$$

In words, changes in $\varrho_{i,t}$ are driven entirely by fundamental consumer preferences and other structural parameters of the model.

Suppose now that one fundamental driver of trade changes between two, eventually but not necessarily subsequent, time periods (years) t and $s < t$. Let us generally invoke the so-called *hat algebra* in the spirit of Jones (1965) and Dekle, Eaton, and Kortum (2007) for the corresponding analysis.[11] For any generic variable a, we use $\widehat{a}_t = a_t/a_s$ to denote the change in a in year t relative to the benchmark year s. In Sections 4-6, we treat changes in direct drivers $\{\widehat{\tau}_{ij,t}, \widehat{\phi}_{i,t}, \widehat{\varphi}_{i,t}, \widehat{\ell}_{i,t}, \widehat{\varrho}_{i,t}\}$ as given (exogenous).[12]

Using expressions for the price indices of services and manufactures in (3.1) and (3.3), respectively, we can express their changes as:

$$\widehat{p}_{ni,t} = \widehat{\phi}_{i,t}\widehat{w}_{i,t}^{\alpha}\widehat{p}_{mi,t}^{\beta}\widehat{p}_{ni,t}^{\gamma}, \quad \widehat{p}_{mi,t} = \left(\sum_k \lambda_{ik,s}\widehat{\varphi}_{k,t}\left(\widehat{w}_{k,t}^{\eta}\widehat{p}_{mk,t}^{\mu}\widehat{p}_{nk,t}^{\nu}\widehat{\tau}_{ik,t}\right)^{-\theta}\right)^{-\frac{1}{\theta}}, \tag{3.8}$$

and the change in bilateral trade shares based on (3.4) as:

$$\widehat{\lambda}_{ij,t} = \widehat{\varphi}_{j,t}\left(\frac{\widehat{w}_{j,t}^{\eta}\widehat{p}_{mj,t}^{\mu}\widehat{p}_{nj,t}^{\nu}\widehat{\tau}_{ij,t}}{\widehat{p}_{mi,t}}\right)^{-\theta}. \tag{3.9}$$

Finally, to close the model in period t, we specify product-market clearing in terms of relative changes to solve for endogenous changes in wage rates (returns to equipped labor) at time t from:

$$\widehat{w}_{i,t} = \frac{1}{\varrho_{s,t}\widehat{\varrho}_{i,t}Y_{i,s}\widehat{\ell}_{i,t}}\sum_{j=1}^{J}\lambda_{ji,s}\widehat{\lambda}_{ji,t}\varrho_{j,s}\widehat{\varrho}_{j,t}Y_{j,s}\widehat{w}_{j,t}\widehat{\ell}_{j,t}d_{j,t}\widehat{d}_{j,t}. \tag{3.10}$$

This completely characterizes the competitive open-economy equilibrium in period t, and it provides an expression for total changes in *nominal levels* of bilateral trade flows between periods s and t:

$$\widehat{X}_{ij,t} = \widehat{\lambda}_{ij,t}\widehat{\ell}_{i,t}\widehat{w}_{i,t}\widehat{\varrho}_{i,t}\widehat{d}_{i,t}. \tag{3.11}$$

Using the identities in this section, we may write changes in log bilateral exports based on the log-transformed counterpart to equation (3.11) as a function of shocks of direct drivers of trade, of general equilibrium effects

[11] This method has been utilized in a number of recent papers including but not limited to Ossa (2012) who assesses the importance of trade for welfare, and Eaton, Kortum, Neiman, and Romalis (2013) who identify drivers of the Great Trade Collapse.

[12] As said before, this will have an impact on the relative total importance of different drivers in counterfactual analysis but not the decomposition of the growth of bilateral trade data into the direct contributions of $\{\widehat{\tau}_{ij,t}, \widehat{\phi}_{i,t}, \widehat{\varphi}_{i,t}, \widehat{\ell}_{i,t}, \widehat{\varrho}_{i,t}\}$.

(endogenous variables), and of trade deficit as:

$$\ln\left(\widehat{X}_{ij,t}\right) = \underbrace{\ln\left(\widehat{\varphi}_{j,t}\ \widehat{\phi}_{j,t}^{\frac{-\theta\nu}{1-\gamma}}\ \widehat{\tau}_{ij,t}^{-\theta}\ \widehat{\varrho}_{i,t}\widehat{\ell}_{i,t}\right)}_{\text{Direct drivers}} + \underbrace{\ln\left(\widehat{w}_{j,t}^{\frac{\alpha\nu\theta}{\gamma-1}-\theta\eta}\ \widehat{p}_{mj,t}^{\frac{\beta\nu\theta}{\gamma-1}-\theta\mu}\ \widehat{p}_{mi,t}^{\theta}\ \widehat{w}_{i,t}\right)}_{\text{Endogenous variables}} + \underbrace{\ln\left(\widehat{d}_{i,t}\right)}_{\text{Trade deficit}}. \tag{3.12}$$

Within this framework we can assess the direct role of each included factor for changes in the variance and the level of bilateral exports across country pairs and time. In Sections 4-6 we will do so when considering $\{\widehat{\varphi}_{j,t}, \widehat{\phi}_{j,t}, \widehat{\tau}_{ij,t}, \widehat{\ell}_{i,t}, \widehat{\varrho}_{i,t}\}$ as exogenous factors in a static model, while relying on a richer, dynamic model in Section 7, where $\{\widehat{\varphi}_{j,t}, \widehat{\phi}_{j,t}, \widehat{\ell}_{i,t}, \widehat{\varrho}_{i,t}\}$ will be endogenous.

4 Data sources and calibration of general model parameters

4.1 Data

In the subsequent quantitative analysis, we will use annual data on 67 economies (see Appendix A) for the period between 1988 and 2007 from the following sources. Information on bilateral imports comes from the United Nations' COMTRADE database. Since we are interested in manufacturing trade, we keep *SITC. 1* categories under the main headings {0,1,6,7,8} broadly associated with manufactures. The vast majority of our trade flows are measured as imports. When such data are unavailable (i.e., bilateral imports are missing), we supplement them with exports reported by shipping countries. Finally, if neither exports nor imports are available, we interpret such observations as tiny positive trade flows. For computational purposes, we set such trade flows the minimal observed trade flow among any pair in the same year to avoid the problem of infinite trade costs. This procedure yields $N \times (N-1) \times T$ observations. To compute intra-trade flows (domestic sales), we need data on the value of production (sales) in each country and year. There are several sources that we use to obtain these data. First, for most OECD countries the respective data are available in the OECD's STAN database. We supplement them with data from the United Nation's UNIDO database. Finally, for those countries (years) with no observations available, we impute output of manufactures by regressing observable output on value added in manufacturing and use the estimated coefficients for prediction. The value added data come from the United Nation's Statistics Division. We calculate $X_{ii,t}$ as the difference between total production and total exports. This obtains $N \times T$ observations on intra-trade such that we have a full set of $N^2 \times T$ observations on bilateral sales among all possible pairs. In addition to the trade data, we use data on GDP, prices, and endowments. They are from the Penn World Tables 8.1. We discuss these variables and how they were used in what follows.

4.2 Calibration part I: general model parameters and variables

The calibration procedure consists of two main parts: (i) measuring relative changes in certain variables and (ii) inferring changes in the remaining variables via the structure of the model. Throughout this paper, we keep $w_{USA,t} = 1$ for all t, i.e., we use nominal wages in the United States as the numéraire and normalize variables accordingly. This is necessary for the counterfactual exercises that we perform. We start with specifying the values of preference and production parameters used in the calibration as summarized in Table 1.

Factor shares in the production functions, $\{\alpha, \beta, \gamma, \eta, \mu, \nu\}$ were calculated using data on input-output tables from

Table 1: PRE-CALIBRATED PARAMETERS

α	β	γ	η	μ	ν	θ
0.53	0.06	0.41	0.30	0.29	0.41	6.50

the OECD's STAN database for ARG, AUS, AUT, BEL, BRA, CAN, CHE, CHN, CZE, DEU, DNK, ESP, FIN, FRA, GBR, GRC, HUN, IDN, IRL, ISR, ITA, JPN, KOR, NLD, NOR, NZL, POL, PRT, SWE, THA, TUR, USA, ZAF. The value of θ is from Costinot, Donaldson, and Komunjer (2012). With these parameter values in hand that are kept constant throughout countries and time, we proceed by describing the calibration steps. In what follows we set the benchmark period at $s = 1988$ and t to generic years between 1989 and 2007.

We start with calculating relative changes in total output (measured by GDP) which provides us with the composite change in endowments and wage rate, or:

$$\widehat{\ell}_{i,t}\widehat{w}_{i,t} = \frac{GDP_{i,t}}{GDP_{i,s}}. \tag{4.1}$$

We measure changes in total endowment $\widehat{\ell}_{i,t}$ as:

$$\widehat{\ell}_{i,t} = \left[\left(\frac{ahw_{i,t}\times emp_{i,t}\times hci_{i,t}}{ahw_{i,s}\times emp_{i,s}\times hci_{i,s}}\right)^{r_{i,s}} \times \left(\frac{K_{i,t}}{K_{i,s}}\right)^{1-r_{i,s}}\right]^{1/2} \left[\left(\frac{ahw_{i,t}\times emp_{i,t}\times hci_{i,t}}{ahw_{i,s}\times emp_{i,s}\times hci_{i,s}}\right)^{r_{i,t}} \times \left(\frac{K_{i,t}}{K_{i,s}}\right)^{1-r_{i,t}}\right]^{1/2},$$

where ahw are average hours worked, $emp_{i,t}$ is the number of people employed, $hci_{i,t}$ is a human capital index, $K_{i,t}$ is the capital stock, and $r_{i,t}$ is the share of labor compensation in total costs. For countries (years) where data for $ahw_{i,t}$ and $r_{i,t}$ were unavailable, we used sample averages in that year. Altogether, equipped labor is a comprehensive measure of effective labor hours and capital stock per country in each period. Notice that since the share of labor in the production function ($r_{i,t}$) varies across periods we take the geometric average between two periods calculated using $r_{i,s}$ and $r_{i,t}$.[13] We further normalize $\widehat{\ell}_{i,t}$ such that $\widehat{w}_{USA,t} = 1$ for all t.

For the calibration of trade costs and productivity parameters we need price data for manufactures and services. Such data are not available on an annual basis. Instead we use two price vectors: the price level of household consumption, which we dub $p_{ci,t}$, and the price level of exports (measured as *free on board*), which we dub $p_{fi,t}$, to calculate model-implied prices, $p_{ni,t}$ and $p_{mi,t}$. According to the model, changes in the average export price are proportional to changes in average costs of production in the exporter country:

$$\widehat{p}_{fi,t} = \widehat{\varphi}_{i,t}^{-\frac{1}{\theta}}\left(\widehat{w}_{i,t}^{\eta}\widehat{p}_{mi,t}^{\mu}\widehat{p}_{ni,t}^{\nu}\right).^{14} \tag{4.2}$$

Changes in average costs allow us to recover changes in trade costs and, consequently, changes in $p_{mi,t}$ using identities of trade shares (calculated as bilateral exports over destination-country expenditures) from the following equations:

$$\widehat{\tau}_{ij,t}^{-\theta} = \frac{\widehat{\lambda}_{ij,t}}{\widehat{\lambda}_{ii,t}}\left(\frac{\widehat{p}_{fj,t}}{\widehat{p}_{fi,t}}\right)^{\theta}, \quad \widehat{p}_{mi,t} = \left(\sum_k \lambda_{ik,s}\widehat{p}_{fk,t}^{-\theta}\widehat{\tau}_{ik,t}^{-\theta}\right)^{-\frac{1}{\theta}}. \tag{4.3}$$

We interpret changes in the price of consumption as changes in the price of manufactures and services weighted

[13] The results do not change significantly when assuming a constant capital-labor ratio instead of a time-varying $r_{i,t}$.

[14] Note that due to the assumption of the Fréchet distribution, the geometric mean of productivities of firms in that sector is $\varphi_{i,t}^{-\frac{1}{\theta}}$. This leads to the expression of changes in the average variable cost.

by the expenditure shares. Hence, with $\widehat{p}_{mi,t}$ at hand, we can calibrate changes in the price of services as:

$$\widehat{p}_{ni,t} = \left[\widehat{p}_{ci,t}^{\frac{1}{1-\varsigma_{i,s}}}\widehat{p}_{mi,t}^{\frac{\varsigma_{i,s}}{\varsigma_{i,s}-1}}\right]^{1/2} \times \left[\widehat{p}_{ci,t}^{\frac{1}{1-\varsigma_{i,t}}}\widehat{p}_{mi,t}^{\frac{\varsigma_{i,t}}{\varsigma_{i,t}-1}}\right]^{1/2}. \tag{4.4}$$

We calculate the model-consistent $\varsigma_{i,t}$ (the expenditure share on manufactures) using parameters of the model, the ratio of expenses on manufactures in total expenses, and the deficit constants as:

$$\varsigma_{i,t} = \frac{\varrho_{i,t}(\eta\beta\alpha^{-1} - \mu + d_{i,t}) - \beta\alpha^{-1}}{\varrho_{i,t}(d_{i,t}-1)+1}, \tag{4.5}$$

where $\varrho_{i,t} = \left(\sum_{j=1}^{J} X_{ji,t}\right)/GDP_{i,t}$ and $d_{i,t} = (\sum_j X_{ij,t} - \sum_j X_{ji,t})/\sum_j X_{ji,t} + 1$ are directly calculated using data on bilateral goods sales and GDP.

Finally, given calibrated values of changes in wages and prices, we can calculate changes in technology parameters in services and manufactures as follows:

$$\widehat{\phi}_{i,t} = \widehat{w}_{i,t}^{-\alpha}\widehat{p}_{mi,t}^{-\beta}\widehat{p}_{ni,t}^{1-\gamma}, \quad \widehat{\varphi}_{i,t} = \widehat{p}_{fi,t}^{-\theta}\left(\widehat{w}_{i,t}^{\eta}\widehat{p}_{mi,t}^{\mu}\widehat{p}_{ni,t}^{\nu}\right)^{\theta}. \tag{4.6}$$

This completes the calibration of changes in the direct drivers of trade in the model, $\{\widehat{\ell}_{i,t}, \widehat{\phi}_{i,t}, \widehat{\varphi}_{i,t}, \widehat{\tau}_{ij,t}, \widehat{\varrho}_{i,t}, \widehat{d}_{i,t}\}$. Notice that the calibrated values of these drivers will be the same in both models considered here, the SXD and the DND approach. However, in the DND framework with endogenous factor accumulation, technological change, and consumer preferences, we need to further decompose $\{\widehat{\ell}_{i,t}, \widehat{\phi}_{i,t}, \widehat{\varphi}_{i,t}, \widehat{\varrho}_{i,t}\}$ into the contributions of their deep exogenous drivers and endogenous responses. This will be done in Section 7.

4.3 Fit of calibration: external validity check

In the world-trade growth-accounting exercises in Sections 5, 6, and 7 below, we exactly fit the data in many dimensions by design. In particular, we exactly fit the data on (i) international trade flows , (ii) output of manufactures, (iii) GDP, (iv) endowments, and (v) consumer price indices due to the calibration procedure outlined in Subsection 4.2.

Since we use many moments of the data for calibration, it is important to show that the model also fits moments of the data that had not been used for estimation or calibration. In this section, we provide some evidence on the latter, supporting the validity of the SXD and DND models in Sections 6 and 7, respectively. The models provide predictions regarding the allocation of labor in manufacturing and services across countries and time through equation (7.8). Hence, the predictions broadly capture labor adjustment to trade liberalization as discussed in Artuc, Chaudhuri, and McLaren (2010) and Dix-Carneiro (2014) but in a more aggregate setting. To shed light on what the model predicts relative to the data, we compare the share of value added in services in total GDP (which, in the present context, is identical to the ratio of equipped labor income in services relative to total labor income in manufacturing and services) in the data to the share of labor units in all employment, $\ell_{ni,t}$.[15] Overall, the model fares well in predicting the labor income share in services. The correlation coefficients between the actual and predicted values of $\ell_{ni,t}$ over time are high for every country. The average value of these coefficient across

[15] In the present context, the share of labor income in services is identical to the share of employment in services. The results are robust to using actual employment data.

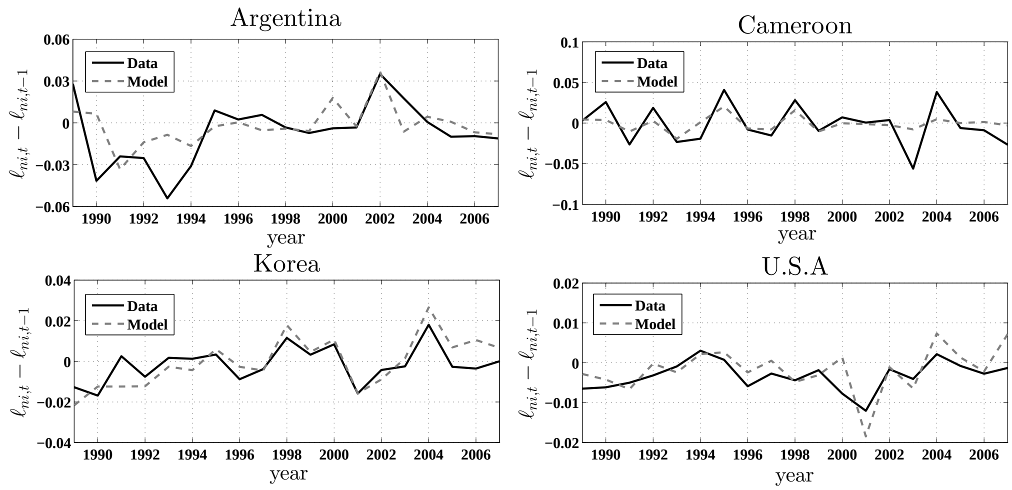

Figure 1: ANNUAL CHANGES IN SHARE OF VALUED ADDED IN SERVICES IN GDP FOR SELECTED COUNTRIES

countries is 0.63 with a variance of 0.11. In Figure 1, we plot the (SXD and DND) model predictions for annual changes $\ell_{ni,t}$ against the data for selected economies which belong in different income groups and continents.

The model here is also consistent with the general results of the macroeconomic growth-accounting literature (see Hall and Jones, 1999; Caselli 2005). However, there are a few important differences between the two approaches. First, we use prices rather than units of labor and capital to calibrate productivity parameters. Second, we account for large input shares of intermediate manufacturing inputs in both non-tradable and tradable sectors. Hence, we account for trade as a potentially important determinant of total factor productivity parameters (akin in spirit to Feenstra and Kee, 2008). Qualitative predictions of the model in Section 7 in terms of changes in productivity (across countries and time) are broadly consistent with those of macroeconomic models. In Figure 2, we plot changes in the calibrated productivity parameters, $\widehat{\phi}_{i,t}$, versus changes in (inverse) total factor productivity provided by the Penn World Tables 8.1.[16]

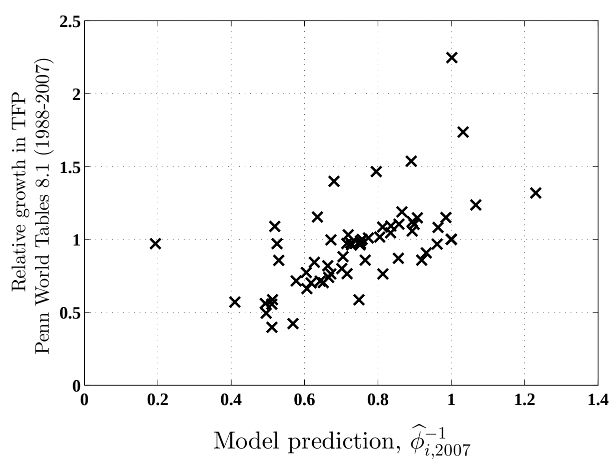

Figure 2: CONSISTENCY WITH MACROECONOMIC GROWTH ACCOUNTING APPROACH

[16]Note that, since we use price data to calibrate $\widehat{\phi}_{i,t}$, our measure should be interpreted as an inverse of the total factor productivity parameter. For details on calculating total factor productivity in the Penn World Tables 8.1, see Feenstra, Inklaar and Timmer (2015).

Figure 2 confirms that, qualitatively, our productivity estimates are consistent with those from the Penn World Tables. Hence, we conclude that not only does the proposed numerical approach (which is consistent with both models SXD and DND) exactly match the data in many dimensions, but it is also consistent with data moments that are not targeted in the calibration procedure, and it is largely consistent with productivity estimates that were calculated using an entirely different approach from the one employed here.

5 Decomposing the variance of changes in exports across country-pairs over time

5.1 Variance decomposition of bilateral export growth

The goal of this section is to decompose the variance of changes in log bilateral exports into contributions of direct drivers and other (price-, income-, general-equilibrium-related) components in a growth-accounting-type fashion that is consistent with the structure of the model and the insights from the previous section. The first group of factors labeled *Direct drivers* in equation (3.12) relates to the factors of particular interest to this study. The second group of factors labeled *Endogenous variables* in equation (3.12) relates to changes in country-specific aggregates (prices and income) which are induced by changes in the direct drivers of production, consumption, and trade. The last term in equation (3.12) labeled *Trade deficit* captures the (numerically negligible and exogenous) trade deficit as a fraction of total sales of manufacturies in each country.

For further convenience, let us use tilde to refer to variables in logs, suppressing the parameters on them, such that the following identities hold:

$$\widetilde{\varphi}_{j,t} \equiv \ln(\widehat{\varphi}_{j,t}),\ \widetilde{\phi}_{j,t} \equiv \ln\left(\widehat{\phi}_{j,t}^{\frac{-\theta\nu}{1-\gamma}}\right),\ \widetilde{\tau}_{ij,t} \equiv \ln\left(\widehat{\tau}_{ij,t}^{-\theta}\right),\ \widetilde{g}_{ij,t} \equiv \ln\left(\widehat{w}_{j,t}^{\frac{\alpha\nu\theta}{\gamma-1}-\theta\eta}\widehat{p}_{mj,t}^{\frac{\beta\nu\theta}{\gamma-1}-\theta\mu}\widehat{p}_{mi,t}^{\theta}\widehat{w}_{i,t}\right),\ \widetilde{\varrho}_{i,t} \equiv \ln\left(\widehat{\varrho}_{i,t}\right),\ \widetilde{d}_{i,t} \equiv \ln\left(\widehat{d}_{i,t}\right).$$

Moreover, use $\nu(a)$ and $\rho(a,h)$ to denote the variance of any generic variable a and the correlation coefficient for any pair of generic variables (a,h), respectively. Then, the overall variance of (log) changes in bilateral exports can be decomposed as:

$$\nu\left(\widetilde{X}_{ij,t}\right) = \nu\left(\widetilde{\varphi}_{j,t}\right) + \nu\left(\widetilde{\phi}_{j,t}\right) + \nu\left(\widetilde{\tau}_{ij,t}\right) + \nu\left(\widetilde{\ell}_{i,t}\right) + \nu\left(\widetilde{g}_{ij,t}\right) + \nu\left(\widetilde{\varrho}_{i,t}\right) + \nu\left(\widetilde{d}_{i,t}\right) + \underbrace{\sum_{h\neq a}\rho(h,a)[\nu(h)\cdot\nu(a)]^{\frac{1}{2}}}_{\text{Sum of covariance components}}, \quad (5.1)$$

where $a,h \in \left\{\widetilde{\varphi}_{j,t}, \widetilde{\phi}_{j,t}, \widetilde{\tau}_{ij,t}, \widetilde{\ell}_{i,t}, \widetilde{g}_{ij,t}, \widetilde{\varrho}_{ij,t}, \widetilde{d}_{i,t}\right\}$. We summarize the respective variances and the sum of all covariances for each year between 1989 and 2007 in Table 2 (for a list of countries entering the analysis, see Table 5 in Appendix A).

Table 2 suggests the following conclusions. First, the total variance of bilateral trade, all individual variance components, and the sum of all covariance components increased over time. This is not surprising, since variances and covariances are functions of the mean of the underlying variables, and bilateral exports are not mean stationary but grow over time. However, it is interesting to compare the relative size of these components to each other and track their changes over time. Among the variance components which are attributable to exogenous drivers of bilateral trade, the one of bilateral trade costs, $\nu\left(\widetilde{\tau}_{ij,t}\right)$, clearly dominates, followed by the ones of productivity in manufacturing, $\nu\left(\widetilde{\varphi}_{j,t}\right)$, and services, $\nu\left(\widetilde{\phi}_{j,t}\right)$. The smallest component is the one capturing changes in factor endowments, $v\left(\widetilde{\ell}_{i,t}\right)$.

Table 2: *Variances and sum of covariances of the determinants of changes in bilateral exports*

Year	$v\left(\widetilde{X}_{ij}\right)$	$\frac{v\left(\widetilde{\varphi}_{j,t}\right)}{v\left(\widetilde{X}_{ij}\right)}$	$\frac{v\left(\widetilde{\phi}_{j,t}\right)}{v\left(\widetilde{X}_{ij}\right)}$	$\frac{v\left(\widetilde{\tau}_{ij,t}\right)}{v\left(\widetilde{X}_{ij}\right)}$	$\frac{v\left(\widetilde{\ell}_{i,t}\right)}{v\left(\widetilde{X}_{ij}\right)}$	$\frac{v\left(\widetilde{g}_{ij,t}\right)}{v\left(\widetilde{X}_{ij}\right)}$	$\frac{v\left(\widetilde{\varrho}_{ij,t}\right)}{v\left(\widetilde{X}_{ij}\right)}$	$\frac{v\left(\widetilde{d}_{i,t}\right)}{v\left(\widetilde{X}_{ij}\right)}$	$\frac{\text{sum of cov.}}{v\left(\widetilde{X}_{ij}\right)}$
1989	8.775	0.450	0.261	1.008	0.000	0.052	0.003	0.000	-0.774
1990	10.487	0.221	0.116	0.995	0.000	0.052	0.003	0.000	-0.387
1991	10.515	0.401	0.202	0.996	0.001	0.092	0.005	0.001	-0.697
1992	11.984	0.468	0.275	1.034	0.001	0.103	0.004	0.001	-0.887
1993	12.039	0.560	0.354	1.008	0.002	0.112	0.004	0.001	-1.041
1994	13.127	0.468	0.213	1.010	0.002	0.151	0.005	0.001	-0.849
1995	13.906	0.412	0.189	1.008	0.003	0.152	0.006	0.001	-0.770
1996	14.302	0.385	0.179	0.997	0.004	0.150	0.004	0.001	-0.721
1997	14.783	0.396	0.190	1.000	0.004	0.157	0.005	0.001	-0.752
1998	14.709	0.433	0.217	1.010	0.004	0.171	0.005	0.002	-0.841
1999	14.569	0.348	0.182	1.012	0.004	0.157	0.005	0.002	-0.711
2000	14.970	0.401	0.202	1.009	0.004	0.170	0.006	0.002	-0.793
2001	15.017	0.410	0.207	1.012	0.004	0.163	0.005	0.002	-0.803
2002	15.281	0.382	0.183	1.014	0.005	0.184	0.005	0.002	-0.774
2003	15.818	0.275	0.123	1.010	0.005	0.169	0.005	0.002	-0.589
2004	15.980	0.247	0.107	1.044	0.005	0.206	0.005	0.002	-0.617
2005	15.699	0.259	0.106	1.020	0.006	0.208	0.005	0.002	-0.607
2006	15.825	0.259	0.115	1.066	0.007	0.223	0.009	0.002	-0.680
2007	16.085	0.231	0.099	1.024	0.007	0.200	0.008	0.002	-0.571

Taking into account the variance terms of exogenous components (direct drivers of trade) as well as endogenous components (general equilibrium effects), the endogenous terms together, i.e., changes in factor and output prices, $v\left(\widetilde{g}_{ij,t}\right)$, account for the second-biggest portion after trade costs. Obviously, the variance components add up to more than the overall variance in changes of log bilateral trade flows, which is balanced by the negative sum of covariance components. In 2007, the sum of all covariances among changes in fundamentals was relatively large in absolute value. Moreover, changes in trade costs remained important for the variation in changes of exports by 2007, while changes in technology have declined in importance. On the other hand, the variances of the changes in both endowments and preferences have grown but remained relatively unimportant. Hence, in relative terms, among the direct drivers of trade considered here, the variance of changes in trade costs has been important throughout the sample period (for which good data are available).

We report correlation coefficients $\rho(a,h)$ for all $7 \times (7-1)/2 = 21$ possible combinations of components and the year 2007 in Table 3. The corresponding estimates in that table point to a sizable negative correlation of changes between the log (inverse) productivity in services and log productivity in manufacturing. Moreover, the estimates indicate nontrivial correlations between changes in log endowments, trade costs, and $\widetilde{\varrho}_{i,t}$. This suggests that interpreting them as completely exogenous and independent of one another may be problematic. For that reason, Table 3 may be viewed as a motivation for treating endowment accumulation, technological change, and the structure of production and consumption (with regard to goods versus services) as endogenous in Section 7.

Table 3: *Correlation coefficients* $\rho(a,h)$ *for* $a,h = \{\widetilde{\varphi}_{j,t}, \widetilde{\phi}_{j,t}, \widetilde{\tau}_{ij,t}, \widetilde{\ell}_{i,t}, \widetilde{g}_{ij,t}, \widetilde{\varrho}_{i,t}, \widetilde{d}_{i,t}\}$ *and* $t = 2007$

	$\widetilde{\varphi}_{j,t}$	$\widetilde{\phi}_{j,t}$	$\widetilde{\tau}_{ij,t}$	$\widetilde{\ell}_{i,t}$	$\widetilde{g}_{ij,t}$	$\widetilde{\varrho}_{i,t}$	$\widetilde{d}_{i,t}$
$\widetilde{\varphi}_{j,t}$	1	-0.530	-0.027	0.000	-0.713	0.000	0.000
$\widetilde{\phi}_{j,t}$	-0.530	1	-0.130	0.000	-0.110	0.000	0.000
$\widetilde{\tau}_{ij,t}$	-0.027	-0.130	1	0.069	0.040	-0.062	0.069
$\widetilde{\ell}_{i,t}$	0.000	0.000	0.069	1	-0.057	0.382	-0.179
$\widetilde{g}_{ij,t}$	-0.713	-0.110	0.040	-0.057	1	-0.051	0.043
$\widetilde{\varrho}_{i,t}$	0.000	0.000	-0.062	0.382	-0.051	1	-0.631
$\widetilde{d}_{i,t}$	0.000	0.000	0.069	-0.179	0.043	-0.631	1

Though correlation coefficients are an important ingredient in the covariance components, what ultimately matters for the decomposition in (5.1) and for the last column in Table 2 are the covariance terms themselves. We summarize the latter for each possible pair of generic components $a,h = \{\widetilde{\varphi}_{j,t}, \widetilde{\phi}_{j,t}, \widetilde{\tau}_{ij,t}, \widetilde{\ell}_{i,t}, \widetilde{g}_{ij,t}, \widetilde{\varrho}_{i,t}, \widetilde{d}_{i,t}\}$ in Table 4.

Considering the year 2007, it is obvious that the largest among those terms in absolute value are the negative covariances between changes in technology parameters with changes in the endogenous factors captured by $\widetilde{g}_{ij,t}$, followed by the negative covariance between changes in productivity in manufacturing and changes in the (inverse) productivity in services. On the other hand, changes in trade costs $\tau_{ij,t}$ and in endowments $\ell_{i,t}$ display a moderate positive covariance and changes in $\tau_{ij,t}$ and $\widetilde{\varrho}_{i,t}$ have a small negative covariance.

Summing up, the analysis-of-variance exercise in this section and the results in Tables 2-4 shed light on the changing importance of components behind the *variability of the growth* of bilateral exports across country pairs over time. However, this analysis does not permit firm conclusions about the relative importance of the parameters $\{\widetilde{\varphi}_{j,t}, \widetilde{\phi}_{j,t}, \widetilde{\tau}_{ij,t}, \widetilde{\ell}_{i,t}, \widetilde{\varrho}_{i,t}\}$. The reason is that these parameters (which reflect changes of direct drivers of bilateral trade) exhibit indirect effects though the endogenous components in $\widetilde{g}_{ij,t}$.

In pursuit of an analysis of average effects of changes in direct drivers on the growth of bilateral exports, we need to resort to counterfactual analysis, taking direct as well as indirect (through general equilibrium) effects of the drivers into account. This is the goal of Section 6, maintaining the assumption that the direct drivers are exogenous in what we call the (static-exogenous-drivers) SXD model. In Section 7, we will go one step further and consider a structural relationship between the fundamentals as suggested by the correlation coefficients in Table 3. The latter will require abandoning the notion of a strict exogeneity of all fundamentals, calling for a dynamic model structure which will allude to the role of some deep parameters behind the direct drivers of the growth of exports in what we call the (dynamic-endogenous-drivers) DND model.

Table 4: *Covariance between a and h for* $a, h = \{\widetilde{\varphi}_{j,t}, \widetilde{\phi}_{j,t}, \widetilde{\tau}_{ij,t}, \widetilde{\ell}_{i,t}, \widetilde{g}_{ij,t}, \widetilde{\varrho}_{i,t}, \widetilde{d}_{i,t}\}$

$a =$	$h =$	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
$\widetilde{\varphi}_{j,t}$	$\widetilde{\phi}_{j,t}$	-5.81	-3.03	-5.37	-8.02	-9.86	-7.28	-6.54	-6.17	-6.63	-7.23	-5.67	-6.69	-6.94	-6.16	-3.85	-2.83	-2.86	-3.13	-2.58
	$\widetilde{\tau}_{ij,t}$	0.13	-0.08	0.19	-0.50	-0.59	-0.21	-0.11	-0.24	-0.03	-0.59	-0.53	-0.45	-0.46	-0.04	-0.35	-0.63	-0.31	-0.36	-0.42
	$\widetilde{\ell}_{i,t}$	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	$\widetilde{g}_{ij,t}$	-2.01	-1.53	-2.90	-3.03	-3.68	-4.97	-4.93	-4.88	-5.10	-5.40	-4.37	-5.33	-5.27	-5.61	-4.81	-5.01	-5.30	-5.10	-4.93
	$\widetilde{\varrho}_{i,t}$	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	$\widetilde{d}_{i,t}$	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
$\widetilde{\phi}_{j,t}$	$\widetilde{\tau}_{ij,t}$	-0.32	-0.23	-0.24	-0.11	-0.08	-0.51	-0.65	-0.63	-1.02	-0.92	-0.88	-1.04	-1.10	-1.32	-1.32	-1.05	-1.35	-1.46	-1.33
	$\widetilde{\ell}_{i,t}$	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	$\widetilde{g}_{ij,t}$	1.19	0.56	1.11	1.31	1.38	1.65	1.27	1.04	1.00	0.81	0.29	0.70	0.79	0.66	0.04	-0.53	-0.34	-0.43	-0.50
	$\widetilde{\varrho}_{i,t}$	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	$\widetilde{d}_{i,t}$	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
$\widetilde{\tau}_{ij,t}$	$\widetilde{\ell}_{i,t}$	0.00	0.03	0.02	0.02	0.05	0.11	0.13	0.16	0.16	0.18	0.20	0.19	0.15	0.18	0.22	0.24	0.22	0.24	0.18
	$\widetilde{g}_{ij,t}$	0.03	0.15	-0.10	-0.30	0.34	0.26	0.37	0.46	0.59	0.90	0.76	0.85	0.92	0.55	0.79	0.14	0.55	-0.22	0.58
	$\widetilde{\varrho}_{i,t}$	-0.02	0.01	0.00	-0.04	-0.10	-0.11	-0.18	-0.06	-0.03	0.04	0.02	0.03	-0.04	0.05	0.05	0.04	0.03	-0.22	-0.19
	$\widetilde{d}_{i,t}$	0.02	0.07	0.02	0.08	0.07	0.05	0.06	0.08	0.07	0.00	-0.02	0.03	0.04	0.01	0.11	0.06	0.07	0.06	0.10
$\widetilde{\ell}_{i,t}$	$\widetilde{g}_{ij,t}$	0.00	0.00	-0.01	0.00	-0.01	-0.04	-0.05	-0.05	-0.05	-0.07	-0.06	-0.04	-0.03	-0.05	-0.08	-0.13	-0.13	-0.11	-0.07
	$\widetilde{\varrho}_{i,t}$	0.00	0.00	0.01	0.01	0.01	0.01	0.02	0.01	0.02	0.02	0.03	0.03	0.03	0.05	0.06	0.07	0.07	0.08	0.09
	$\widetilde{d}_{i,t}$	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	-0.02	-0.02	-0.02	-0.02	-0.02	-0.03	-0.03	-0.02	-0.03	-0.02
$\widetilde{g}_{ij,t}$	$\widetilde{\varrho}_{i,t}$	-0.01	-0.02	-0.04	-0.03	-0.04	-0.09	-0.09	-0.06	-0.10	-0.12	-0.10	-0.10	-0.08	-0.10	-0.10	-0.15	-0.14	-0.04	-0.07
	$\widetilde{d}_{i,t}$	0.00	-0.01	-0.01	-0.03	0.00	0.01	0.03	0.03	0.03	0.05	0.03	0.01	0.00	0.00	0.02	0.03	0.04	0.04	0.03
$\widetilde{\varrho}_{i,t}$	$\widetilde{d}_{i,t}$	0.00	0.00	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.03	-0.04	-0.05	-0.05	-0.05	-0.05	-0.06	-0.05	-0.06	-0.08	-0.08

6 Changes in direct drivers trade and their effects on world-trade growth (the SXD model)

In this section, we shed light on the relative importance of direct drivers of trade, assuming that trade costs, endowments, and technology change fully independently of each other. For the ease of presentation, it focuses primarily on differences between the realized growth in exports across different country groups and various counterfactual scenarios where we keep one (or more) of the direct drivers of trade constant at the initial-period level (1988).

Here, we assess the effects of exogenous contributions of the four direct drivers of trade which are key to this paper – trade costs, productivity in services and goods, endowments, and preferences – to the observed growth of world trade among 67 economies between 1988 and 2007 in the structural static-exogenous-driver (SXD) framework. In comparison and in contrast to the previous section, we are interested here in accounting for direct and indirect non-(log-)linear effects of direct drivers of trade flows and their changes, taking their effects on endogenous (primary and secondary) factor prices into account. We evaluate quantitatively how much higher (or lower) different types of trade flows would have been (counterfactually) without the realized changes in certain direct drivers. For this analysis, we use the structure of the model in Sections 3-5 along with the results from the previous section to conduct counterfactual experiments, where we keep trade costs, productivity in services and goods, endowments, and relative expenditure shares constant one at a time at their values of 1988, letting the remaining fundamentals vary as observed.[17] We then compare the counterfactual growth in nominal exports with the data and draw conclusions about the quantitative importance of each factor for the remarkable growth in international trade flows observed in the covered data.

We summarize the associated results for the world as a whole as well as for blocs of three large (per-capita) income groups according to the year 2007: low-income (16 countries, L), middle-income (24 countries, M), and high-income (27 countries, H).[18] While high-income countries realized steady but low growth rates of their exports, middle-income countries enjoyed a drastic growth of their exports, and low-income countries experienced a modest increase in their exports over the period of investigation.

With three sets of country groups, L, M, and H, there are nine group-by-group combinations of export growth. Let us use $X'_{ij,t}(a)$ to denote counterfactual outcomes with respect to some fundamental $a \in \left\{\widetilde{\varphi}, \widetilde{\phi}, \widetilde{\tau}, \widetilde{\ell}, \widetilde{\varrho}\right\}$ of country pair ij at time t and define

$$\widehat{X}_{IJ,t}(a) = \frac{\sum_{(i\in I)\neq j}\sum_{(j\in J)\neq i} X'_{ij,t}(a)}{\sum_{(i\in I)\neq j}\sum_{(j\in J)\neq i} X_{ij,t}} \quad \text{for} \quad I,J \in \{L,M,H\}. \tag{6.1}$$

[17] Here is the fundamental difference between the SXD model in this section and the DND model in the subsequent one. In the SXD model, we ignore any fundamental structural relationship between the direct drivers of trade (i.e., we disregard the insights from Table 3) as is commonly done in the literature. In the DND model, instead, we think of endowment change, technological change, and changes in consumption and production patterns as ones that are jointly determined by fundamentals. This will lead to quantitative differences in the consequences of deep drivers of trade such as trade costs in the counterfactual analysis based on the SXD versus the DND model.

[18] The suggested classification is based on similar principles as the ones utilized by the World Bank. However, the associated income thresholds are slightly different from those used by the World Bank. There are two reasons for this. First, we distinguish between fewer groups of countries than the World Bank does. For instance, we do not discern between upper-middle and middle-income countries for the sake of presentation. Second, we define thresholds to avoid excessively large differences in sample sizes across different groups. For instance, if we used the World Bank's classification, we would end up with only six low-income countries such that the sample would be heavily biased towards the middle-income group. In our sample of countries, the threshold country between low- and middle-incomes is Guatemala with 2,440 US dollars per capita in 2007. For comparison, the World Bank's interval for lower middle-income countries was 936-3,705 US dollars. The threshold country between middle- and high-income countries is Malta with a per-capita income of 16,640 US dollars in 2007, whereas the World Bank's threshold in 2007 for high-income countries was 11,455 US dollars per capita. We list all countries and their corresponding association with the proposed groups in Table 5 in the Appendix.

Accordingly, $\widehat{X}_{IJ,t}(a)$ measures the importance of changes in driver a alone for all countries and country pairs in IJ trade between 1988 and year t, given everything else. A lower absolute value of $\widehat{X}_{IJ,t}(a)$ suggests that period-t IJ exports would have been lower to a larger extent, if fundamental a had stayed at its initial level. Since most of the fundamentals in $a \in \{\widetilde{\varphi}, \widetilde{\phi}, \widetilde{\tau}, \widetilde{\ell}, \widetilde{\varrho}\}$ have changed in a favorable way for export growth since 1988 on average, $\widehat{X}_{IJ,t}(a)$ is lower than unity and it is unity by design in 1988. We plot the values of $\widehat{X}_{IJ,t}(a)$ for all nine pairs of group-by-group exports in Figures 3-6, where each panel in a figure corresponds to a group of origin (L on the left, M in the centre, and H on the right), and each locus in a panel refers to imports by L (−▽−), M (−−), or H (−∘−). In addition to the group-by-group loci, we report total (from-to-all-67-countries) world exports denoted by $\widehat{X}_{WW}(a)$ (black solid lines) as an identical reference across all panels in a figure, which also captures results for the average country pair.

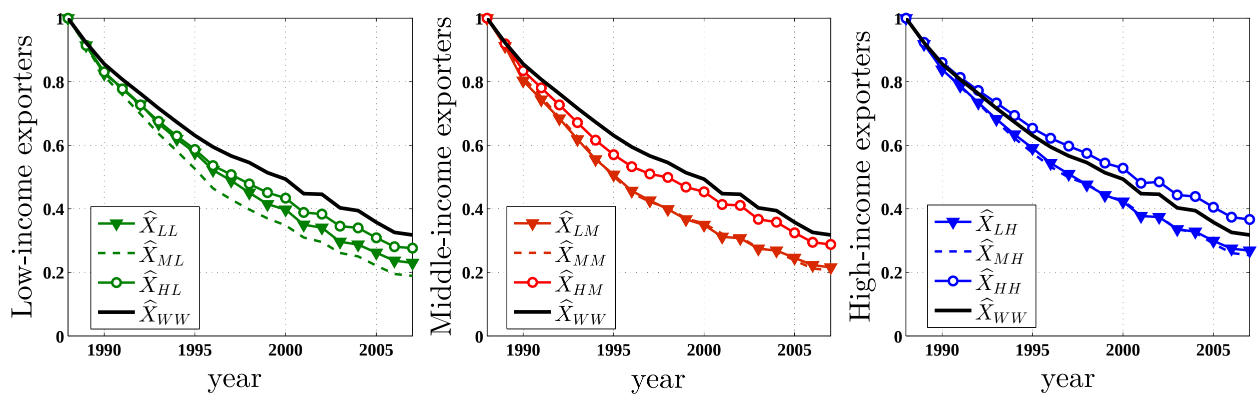

Figure 3: COUNTERFACTUAL EXPERIMENT WITH CONSTANT ENDOWMENTS

First of all, when considering $\{\widetilde{\varphi}, \widetilde{\phi}, \widetilde{\tau}, \widetilde{\ell}, \widetilde{\varrho}\}$ as exogenous fundamentals and taking their indirect effects through general equilibrium into account, the growth of world trade was stimulated to the largest extent by the change in factor endowments during the period of investigation. Without the realized change in endowments since 1988, world trade would have been around 68% lower than realized in 2007, according to the model and Figure 3. Relative to the world altogether and, in particular, relative to exports of high-income countries, exports by low-income and middle-income countries grew even faster due to the realized change in endowments. Consequently, endowment changes in middle- and low-income countries had a more important effect on the growth of their exports than on average. On the contrary, endowment changes in high-income countries appear to have had a relatively less important effect for changes in exports among these countries since they were relatively large, relatively productive, and relatively open beforehand. In particular, in terms of the changes in trade flows within the high-income group, changes in endowments mattered less than on average in the world.

Second, consider the role of trade-cost changes since 1988 as portrayed in Figure 4. According to that figure, without the realized change in trade costs since 1988, world trade would have been about one-quarter lower than realized in 2007. Relative to the consequences of changes in endowments, there is a large degree of heterogeneity in the relative importance of realized changes in trade costs on changes in exports. Relative to the world altogether, trade costs have on average declined the most for exports to and from middle-income countries. As a consequence, trade-cost changes stimulated trade by middle-income countries a lot. For example, exports from group M to low-, middle-, and high-income countries would have been lower by 86%, 83% and 71%, respectively, in 2007 if trade costs had stayed constant relative to the data. Hence, for exports by middle-income countries, changes in trade costs were even more important than changes in endowments. This is not the case for trade flows among other groups of countries. Since high-income countries were relatively more open (especially to exporters from other high-income countries) in 1988, trade-cost changes were relatively less important for trade flows within this group than changes in endowments: only 12% of the growth of export flows should be attributed to changes in trade impediments for those countries (which have a large weight in world sales and consumption).

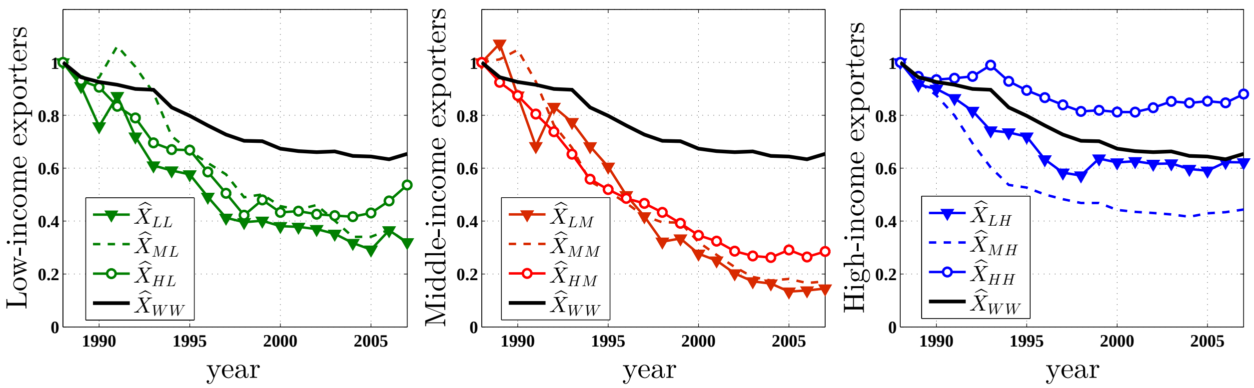

Figure 4: COUNTERFACTUAL EXPERIMENT WITH CONSTANT TRADE COSTS

Though changes in trade costs were relatively important for exports to low-income economies (but not as important as changes in endowments), they were less important for exports to high-income countries. Note that the right panel suggests that changes in trade costs within the high-income group played a relatively minor role in general (not only for exports from other high-income countries).

Third, in Figure 5 we consider changes in technology in tradable manufactures and non-tradable services sectors and their joint average impact on export growth. In this counterfactual experiment, we keep both of these productivity parameters constant at their levels of 1988. Among the three considered fundamentals, changes in technology apparently induced the smallest effects on the growth of world trade since the late 1980s. According to the results in the figure, world trade among the 67 considered economies would have remained at the level of the data in 2007. Moreover, the static model suggests that for many years and countries (and, especially, for the middle-income exporters) productivity shocks exerted a negative impact on the level of trade flows. These results are driven by the decreasing growth rates in the value added in manufacturing and to some extent by decreasing growth of GDPs between 1995 and 2003. We investigate reasons behind this peculiar result in more detail in the Appendix B. Let us say upfront that this insight will be modified when considering endogenous productivity growth in the DND model in Section 7 relative to the SXD model, here.[19]

Finally, in our last experiment in this section we keep the share of expenditures on tradable manufactures constant at its level of 1988. Changes of this share are governed by preference shocks. We report the corresponding results in Figure 6, which suggests that world trade in 2007 would have been higher by 12% if preferences had not changed. Hence, the average country had preference shocks towards the consumption of services rather than manufactures. This, however, is not the case for exports from the middle-income group, whose exports to low-income and middle-income countries would have been lower by 15% and 9% in 2007, respectively, if preferences had stayed constant since 1988.

[19]We will see that much of what is interpreted as negative productivity shocks must be attributed to changes in fundamental parameters and their consequences for endogenous productivity growth.

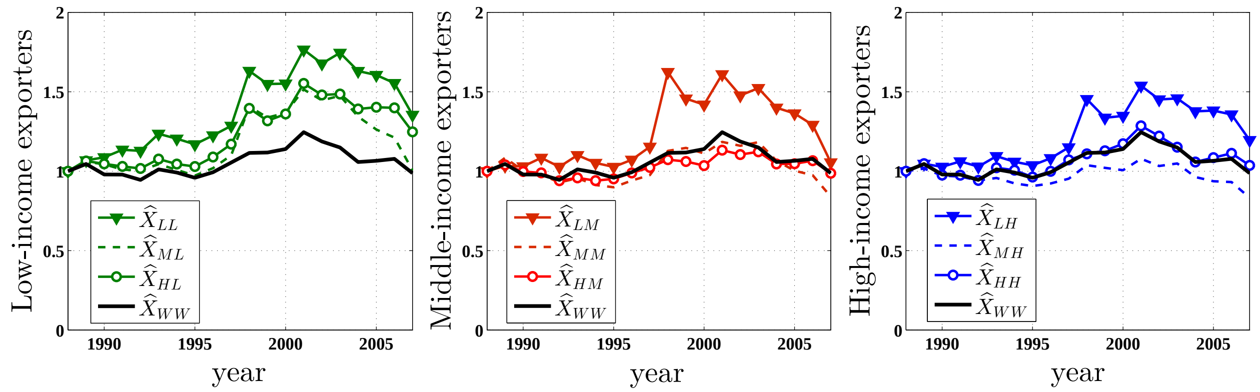

Figure 5: COUNTERFACTUAL EXPERIMENT WITH CONSTANT TECHNOLOGY

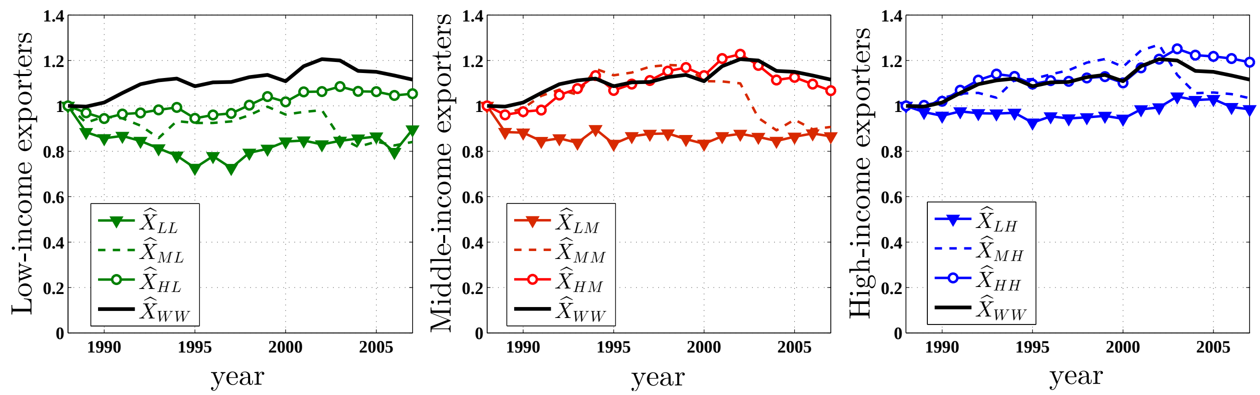

Figure 6: COUNTERFACTUAL EXPERIMENT WITH CONSTANT PREFERENCES

7 Changes in deep parameters as drivers of world-trade growth (the DND model)

7.1 DND model set-up

The parsimonious SXD model in Section 6 which underlies in its generic form most new-trade-theory (gravity) models of bilateral trade was fit to analyze consequences of shocks to the direct drivers of changes of trade, $\{\widetilde{\varphi}, \widetilde{\phi}, \widetilde{\tau}, \widetilde{\ell}, \widetilde{\varrho}\}$, under the assumption that these shocks were independent and not structurally related to each other.[20] In Ricardian endowment-economy models or in increasing-returns-to-scale monopolistic-competition models, this assumption implies that endowment-size and the level of technology as direct drivers of a country's supply potential are independent of each other and of the country's integration into the global market for goods (i.e., trade costs). However, at this point it is useful to recall the insights from Table 3, which suggested that changes in the direct drivers of the growth of trade are not independent of each other.

There is theoretical reasoning about and empirical evidence of a behavioral response of technology to other drivers of trade in earlier work. Feenstra and Kee (2008) were among the first to present a structural empirical trade

[20] This is the leading assumption made in most of the quantitative work on, e.g., the importance of trade costs for trade (see, e.g., Eaton and Kortum, 2002; Anderson and van Wincoop, 2003, 2004; Arkolakis, Costinot, and Rodrígues-Clare, 2012; Costinot, Donaldson, and Komunjer, 2012; Levchenko and Zhang, 2012; Bergstrand, Egger, and Larch, 2013; Levchenko, di Giovanni, and Zhang, 2014; Caliendo and Parro, 2015).

model with endogenous technology, employing data on 48 countries between 1980 and 2000. Bustos (2011) uses micro-data for Argentinean exporters to show that trade liberalization may induce exporters to upgrade their technology in response to falling trade costs. Moreover, there is evidence of factor accumulation in response to trade liberalization. For instance, Falvey, Greenaway, and Silva (2010) hypothesize that trade liberalization may lead to human-capital upgrading. Edmonds, Pavcnik, and Topalova (2010) use micro-data for India and show that indeed trade liberalization leads to an adjustment in the investment in education (though in a heterogeneous way). With regard to endowment accumulation, Anderson, Larch, and Yotov (2014) suggest and confirm that trade liberalization also leads to higher capital accumulation in an aggregate cross-country study.

In order to permit some adjustment of technology and factor supply to economic integration and each other, we offer a rich set-up for quantitative analysis in this subsection relative to the previous, SXD-based one. This set-up – dubbed the (dynamic-endogenous-driver) DND model – is capable of featuring the following stylized facts which were supported by earlier work mostly on macroeconomic growth as well as on international trade:

(i) *Endowment accumulation.* The model considered below incorporates an endogenous accumulation of equipped labor in the spirit of Lucas (1988). In the underlying model, we will place particular focus on an accumulation of *equipment* (or broad capital) in response to (endogenous) changes in technology and (exogenous) changes in trade frictions.

(ii) *Technological change.* Beyond endowment accumulation, we will consider an endogenous adjustment of technology in either sector and across countries in the spirit of Aghion and Howitt (1992, 1997), whereby average levels of productivity may adjust in response to (endogenous) changes in endowments and (exogenous) changes in trade frictions.[21]

(iii) *Non-homothetic preferences, income heterogeneity, and demand-driven structural change.* Non-homotheticity and income heterogeneity have been identified as important determinants of bilateral trade. There is now a number of papers that incorporate non-homotheticity (see Fieler, 2011; Simonovska, 2014) and consumer heterogeneity (Nigai, 2015) in new-trade-theory models. We consider a preference structure in this section which results in variable expenditure shares on manufactures versus services and a role of income heterogeneity within countries for demand-driven structural change and trade which shows in a rising relative consumption of services as consumers get richer (see Boppart, 2014) and a declining share of manufacturing as countries become richer on average (see Pierce and Schott, 2013, for evidence in the United States).

In comparison to the previous section, the set-up proposed in this section will lead to a structural linkage between endowment accumulation, technological change, structural change, and changing trade costs, whereas all of these changes had been assumed exogenous and independent of each other before.

Towards incorporating these features into the model we propose an inter-temporal optimization framework for both consumers and firms. For tractability relative to an infinite-horizon model with a multi-country structure in general equilibrium, we keep a relatively parsimonious two-period framework for the analysis as in Section 6. In this set-up consumers and firms can allocate consumption, investment, and production across two periods. Consumers and firms have perfect foresight such that under each scenario they can observe prices in both the benchmark period s and a subsequent period t. It is worthwhile to stress two important issues. First, we use the same data as in Section 6 but interpret them differently. It is key to understand that both the SXD and DND models are based on and consistent with identical changes $\{\widetilde{\varphi}_{j,t}, \widetilde{\phi}_{j,t}, \widetilde{\tau}_{ij,t}, \widetilde{\ell}_{i,t}, \widetilde{\varrho}_{i,t}\}$, but all direct drivers of trade except

[21] For trade models with endogenous growth see Grossman and Helpman (1990, 1991) and Baldwin and Forslid (2000).

for trade costs respond endogenously to trade costs, some fundamental shocks, and each other. Second, though we present a model using two periods, the convenient *hat algebra* approach would principally allow reformulating the model in terms of T consecutive periods. The latter would complicate the notation and the presentation but would not alter the results.

As before, we use s to denote the benchmark year (here, the first period) and t to denote any subsequent year (here, the second period). The consumers in country i now allocate their total life-time endowment across periods, $\ell_i = \ell_{i,s} + \ell_{i,t}$, where $\ell_{i,s}$ means working and earning income in the first period, $\ell_{i,s} = z_{i,t}\ell_i$ with $z_{i,t} \in (0,1)$. Consumers save a share of $(1-z_{i,t})$ of their total endowment which accumulates according to the following law of motion:

$$\ell_{i,t} = \delta_{i,t}(1-z_i)\ell_i, \tag{7.1}$$

where $\delta_{i,t}$ reflects a compound investment shock which can be related to investment efficiency and investment incentives (see Acemoglu and Ventura, 2002). Given this law of motion, we can recast the relative change in endowments in terms of the consumer decision as follows:

$$\widehat{\ell}_{i,t} = \frac{\ell_{i,t}}{\ell_{i,s}} = \delta_{i,t}\frac{(1-z_{i,t})}{z_{i,t}}. \tag{7.2}$$

Now relative changes in endowments are not fully exogenous but rather depend on the exogenous investment shock $\delta_{i,t}$ and the endogenous variable $z_{i,t}$ which is an outcome of consumer optimization given wages and prices. We will see below, after adding more structure to the model, how $z_{i,t}$ is chosen optimally by consumers. Notice that endogenous endowment accumulation can be a source of growth even under constant technology which is in the spirit of Uzawa (1965) and Lucas (1988).

We introduce non-homothetic, price-independent, generalized-linearity (PIGL) preferences in the spirit of Muellbauer (1975, 1976) by following Boppart (2014).[22] This allows using the framework of non-homotheticity of demand with a representative consumer, where aggregate expenditure shares may be characterized by those of a representative consumer (in Muellbauer's sense), involving some scale-invariant measure of the income distribution in the economy. Consumers allocate their total income in each period $b \in \{s,t\}$ across manufactures and services according to the following indirect utility function:

$$V_{i,b} = \frac{1}{\epsilon}\left[\frac{\ell_{i,b}w_{i,b}}{p_{ni,b}}\right]^{\epsilon} - \frac{\upsilon_{i,b}}{\xi}\left[\frac{p_{mi,b}}{p_{ni,b}}\right]^{\xi}, \tag{7.3}$$

where the parameters ϵ and ξ govern the relative income elasticity of demand and the elasticity of substitution between manufacturing goods and services, respectively, and $\upsilon_{i,t}$ is a period-specific preference shock which also subsumes changes in a scale-invariant measure of the income distribution in country i.[23] Given this intra-period optimization problem, consumers maximize the sum of $V_{i,s}$ and $V_{i,t}$ by allocating their total labor endowment across two periods while taking into account the law of motion for endowments:

$$\max_{z_{i,t}}\left\{\frac{1}{\epsilon}\left[\frac{z_{i,t}\ell_i w_{i,s}}{p_{ni,s}}\right]^{\epsilon} - \frac{\upsilon_{i,s}}{\xi}\left[\frac{p_{mi,s}}{p_{ni,s}}\right]^{\xi} + \frac{1}{\epsilon}\left[\frac{\delta_{i,t}(1-z_{i,t})\ell_i w_{i,t}}{p_{ni,t}}\right]^{\epsilon} - \frac{\upsilon_{i,t}}{\xi}\left[\frac{p_{mi,t}}{p_{ni,t}}\right]^{\xi}\right\}. \tag{7.4}$$

First, the intra-temporal optimization problem (allocating income in each period between services and manufac-

[22] E.g., Rydzek (2013) uses this preference structure in the context of Krugman's trade model.
[23] See Boppart (2014) for an additional discussion of this preference structure.

tures) yields the following expenditure shares on manufactures in two periods:

$$\varsigma_{mi,s} = \upsilon_{i,s} \left(z_{i,t}\ell_i w_{i,s}\right)^{-\epsilon} p_{ni,s}^{\epsilon-\xi} p_{mi,s}^{\xi}, \quad \varsigma_{mi,t} = \upsilon_{i,t} \left((1-z_{i,t})\delta_{i,t}\ell_{i,t} w_{i,t}\right)^{-\epsilon} p_{ni,t}^{\epsilon-\xi} p_{mi,t}^{\xi}, \tag{7.5}$$

whereby

$$\widehat{\varsigma}_{mi,t} = \frac{\varsigma_{mi,t}}{\varsigma_{mi,s}} = \widehat{\upsilon}_{i,t} \left(\frac{\delta_{i,t}(1-z_{i,t})}{z_{i,t}} \widehat{w}_{i,t} \right)^{-\epsilon} \widehat{p}_{ni,t}^{\epsilon-\xi} \widehat{p}_{mi,t}^{\xi}. \tag{7.6}$$

Here, the term $\widehat{\upsilon}_{i,t}$ reflects changes to preferences of the representative consumer in country i as well as changes in the scale-invariant measure of the income distribution in i, both measured in period t relative to s.[24]

Second, the inter-temporal optimization problem (allocating labor to maximize life-time consumption) yields an expression for optimal $z_{i,t}$:

$$z_{i,t} = \left(1 + \delta_{i,t}^{\frac{\epsilon}{1-\epsilon}} \left[\frac{\widehat{w}_{i,t}}{\widehat{p}_{ni,t}} \right]^{\frac{\epsilon}{1-\epsilon}} \right)^{-1}. \tag{7.7}$$

Combining this equation with (7.2) allows solving for equilibrium values of $z_{i,t}$ and $\widehat{\ell}_{i,t}$, given changes in prices and the realized investment shock. Given the parameter values, the optimal share of labor devoted to production in period s is decreasing in $\delta_{i,t}$ and in $(\widehat{w}_{i,t}/\widehat{p}_{ni,t})$. This is intuitive as a higher $\delta_{i,t}$ entails a higher opportunity cost of producing in period s versus saving for period t, and a larger increase in normalized income between periods s and t induces consumers to postpone consumption to period t.

The non-homotheticity of preferences and demand implies that, as countries get richer, the expenditure share on manufactures declines. Hence, the model is able to account for endogenous structural change as a demand-driven phenomenon, showing in a positive relation of the growth in relative employment in services with the growth in income in a country. Recall that $\ell_{mi,t}$ and $\ell_{ni,t} = 1-\ell_{mi,t}$ denote the share of total equipped labor employed in manufacturing and services, respectively. Then, using equation (3.6) we get the following identities:

$$\varrho_{i,t} = \frac{\beta\alpha^{-1} + \varsigma_{i,t}}{\eta\beta\alpha^{-1} - \mu + d_{i,t} - \varsigma_{i,t}(d_{i,t}-1)}, \;\; \ell_{mi} = \eta\varrho_{i,t} \;\; \widehat{\ell}_{mi,t} = \frac{\ell_{mi,t}}{\ell_{mi,s}}, \;\; \widehat{\ell}_{ni,t} = \frac{1-\ell_{mi,t}}{1-\ell_{mi,s}}. \tag{7.8}$$

Equation (7.8) indicates that the share of labor devoted to production of manufactures rises in the respective expenditure share. The latter is declining in real income, so that the model predicts employment in manufacturing to decline as countries get richer.

Next, let us consider a firm's inter-temporal problem, allowing firms to devote a certain share $\kappa_{ni,t}$ of their total output in period s to research and development (R&D investments) in order to improve their productivity in period t. We start with an example of a firm in the services sector. The technology evolves according to the following law of motion:

$$\phi_{i,t}^{-1} = \phi_{i,s}^{-1} e_{\phi i,t} \kappa_{ni,t}, \tag{7.9}$$

where $e_{\phi i,t}$ is the productivity of workers in R&D. Here, we follow Jones (1995a,b) in making the simplifying assumption that technological progress is increasing in the *share* of labor devoted to R&D rather than the *level*

[24] It would be straightforward to introduce a discount term in the consumer's optimization problem. This, however, would not alter the results as this discount term is analytically isomorphic to and in calibration would be subsumed under $\delta_{i,t}$.

thereof.[25] With this specification at hand, we may formulate the profit function of firms as follows:

$$\Pi_i = \left([1-\kappa_{ni,t}]n_{i,s}p_{ni,s} - \ell_{ni,s}w_{i,s} - m_{i,s}p_{mi,s}\right) + \left(n_{i,t}p_{ni,t} - \ell_{i,t}w_{i,t} - m_{i,t}p_{mi,t}\right), \tag{7.10}$$
$$\text{where } n_{i,s} = \phi_{i,s}^{-\frac{1}{1-\gamma}} \ell_{ni,s}^{\frac{\alpha}{1-\gamma}} m_{i,s}^{\frac{\beta}{1-\gamma}} \text{ and } n_{i,t} = \phi_{i,t}^{-\frac{1}{1-\gamma}} \kappa_{ni,t}^{\frac{1}{1-\gamma}} e_{\phi i,t}^{\frac{1}{1-\gamma}} \ell_{ni,t}^{\frac{\alpha}{1-\gamma}} m_{i,t}^{\frac{\beta}{1-\gamma}},$$

and $m_{i,b}$ denotes the amount of manufacturing inputs used in period $b \in \{s, t\}$. The terms $\ell_{ni,s}$ and $\ell_{ni,t}$ denote demanded labor in periods s and t, respectively. Now, in addition to the usual intra-temporal profit maximization, firms choose an optimal share $\kappa_{ni,t}$ to allocate production across periods. Using first-order conditions from the maximization problem in (7.10) and (ex-post) zero-profit conditions in each period, we obtain the equations determining the optimal level of $\kappa_{ni,t}$ and the change in the (inverse) productivity parameter:

$$\frac{1-\kappa_{ni,t}}{\kappa_{ni,t}} = \widehat{\ell}_{ni,t}\widehat{w}_{i,t} \quad \text{and} \quad \widehat{\phi}_{i,t} = \frac{\widehat{\ell}_{ni,t}\widehat{w}_{i,t}}{e_{\phi i,t}}. \tag{7.11}$$

As both sectors feature perfect competition, we may specify the problem for firms in manufacturing analogously to ones in services but keeping in mind that $\phi_{i,t}$ is an inverse productivity parameter whereas $\varphi_{i,t}$ is a direct productivity parameter:

$$\frac{1-\kappa_{mi,t}}{\kappa_{mi,t}} = \widehat{\ell}_{mi,t}\widehat{w}_{i,t} \quad \text{and} \quad \widehat{\varphi}_{i,t} = \frac{e_{\varphi i,t}}{\widehat{\ell}_{mi,t}\widehat{w}_{i,t}}, \tag{7.12}$$

where $\widehat{\ell}_{mi,t}$ is the change in the share of labor demanded by firms in manufacturing in country i between periods s and t, $\kappa_{mi,t}$ is the share of labor in that sector devoted to R&D, and $e_{\varphi i,t}$ is the effectiveness of this investment in terms of the increase in productivity.

International trade occurs in the same fashion as in Section 6 so that the change in the trade share for exporter j and importer i from period s to t is characterized as before. We close the model by noting that, in equilibrium, labor and goods markets clear, determining endogenous changes in wages.

7.2 Calibration part II: deep fundamental drivers behind factor accumulation, technological change, and changes in expenditure shares

Relative to the SXD model we need two additional parameters that relate to preferences: ϵ and ξ. We employ values estimated by Boppart (2014) and set them to $\epsilon = 0.22$ and $\xi = 0.41$. The endogenous growth model suggests that changes in endowments are driven by the exogenous investment shock $\delta_{i,t}$. We calculate this shock using the following two equations:

$$z_{i,t} = \left(1 + \delta_{i,t}^{\frac{\epsilon}{1-\epsilon}} \left[\frac{\widehat{w}_{i,t}}{\widehat{p}_{ni,t}}\right]^{\frac{\epsilon}{1-\epsilon}}\right)^{-1} \quad \text{and} \quad \widehat{\ell}_{i,t} = \delta_{i,t}\frac{(1-z_{i,t})}{z_{i,t}}. \tag{7.13}$$

Next, we calculate R&D shocks that explain changes in the productivity parameters in the manufacturing and service sectors. These are calibrated using equations (7.11) and (7.12):

$$e_{\phi i,t} = \widehat{\phi}_{i,t}^{-1}\widehat{\ell}_{ni,t}\widehat{w}_{i,t}, \quad e_{\varphi i,t} = \widehat{\varphi}_{i,t}\widehat{\ell}_{mi,t}\widehat{w}_{i,t}. \tag{7.14}$$

[25] Jones (1965) pointed out the problem of the scale effect in productivity growth in endogenous growth models.

Finally, the change in $\varrho_{i,t}$ is identical to the one in $\ell_{mi,t}$ and is governed by the preference shock $\upsilon_{i,t}$. We calibrate the latter using equation (7.6):

$$\widehat{\upsilon}_{i,t} = \widehat{\varsigma}_{mi,t} \left(\widehat{\ell}_{i,t} \widehat{w}_{i,t}\right)^{\epsilon} \widehat{p}_{ni,t}^{\xi-\epsilon} \widehat{p}_{mi,t}^{-\xi}. \tag{7.15}$$

This completes the calibration of the endogenous growth model and the vector of exogenous deep drivers $\{\delta_{i,t}, e_{\phi i,t}, e_{\varphi i,t}, \widehat{\upsilon}_{i,t}\}$.

7.3 Counterfactual analysis

Next, we conduct counterfactual experiments as in Section 6, noting that changes in labor endowments and technology are not deep parameters in the DND model but they are determined (apart from changing trade costs and preferences) by shocks to investment (in equipped labor), $\delta_{i,t}$, and to the efficiency of R&D in either sector, $\{e_{\phi i,t}, e_{\varphi i,t}\}$.

In the first experiment, we keep investment shocks fixed relative to the benchmark year 1988 such that $\delta_{i,t} = \delta_{i,s}$ for all years t. We plot the results of this experiment in the upper panel of Figure 7. We again use three horizontal blocs within which panels summarize the effects on exports (from left to right) by low-income, middle-income, and high-income countries. And, as before, we use $-\triangledown-$, $--$, and $-\circ-$ to denote exports to low-income, middle-income, and high-income importers in each panel. The black solid line corresponds to total world trade flows as before in each and every panel. First, in terms of the world trade flows, the DND model implies that trade would have been lower by 50% in 2007 than in the data under invariant investment shocks as of 1988. Hence, the difference between the SXD model and the DND model is significant: about 30 percentage points of the changes in exports attributed to endowment accumulation in the SXD model are in fact due to endogenous responses of endowment accumulation to other factors. This result is fairly homogeneous for all country groups which suggests that, although investment shocks were an important driver of trade, the SXD model potentially overestimates their role.

In the second horizontal bloc in Figure 7, we plot counterfactual changes in nominal trade flows under constant trade costs. Quantitatively, the results are similar to those in the SXD model. There are minor differences for overall exports – the model here predicts that world trade would have been lower by 31% in the DND model had trade costs stayed constant. Hence, the total effect of the SXD model is dampened by several percentage points. The largest differences between the predictions of the SXD and DND models are observed for trade flows from the middle-income exporters to low-income and high-income importers. The results suggest that, under constant trade costs, trade flows for these partners would have been lower by 61% and 48%, respectively. Again, these effects are smaller than in the SXD model by several percentage points, respectively. Overall, in comparison to the SXD model, the DND framework suggests somewhat smaller effects of changes in trade costs, accruing to endogenous responses not only in factor prices (which are present also in the SXD model) but of factor accumulation, technological change, and expenditure shares.

In the third experiment, we keep the R&D-efficiency parameters constant such that $e_{\phi i,t} = e_{\phi i,s}$ and $e_{\varphi i,t} = e_{\varphi i,s}$. Here the difference between the DND model and the SXD model in Section 6 is large. In the SXD model, treating technology parameters as exogenous and keeping them constant between 1988 and 2007 suggested that technology has had virtually no impact on trade and the lion's share in the growth of trade accrued to changes in endowments and trade costs. The results in the third horizontal bloc of Figure 7 suggest that trade would have been lower by 24% in 2007 had exogenous technology shocks in goods and services not happened. However, the growth effects

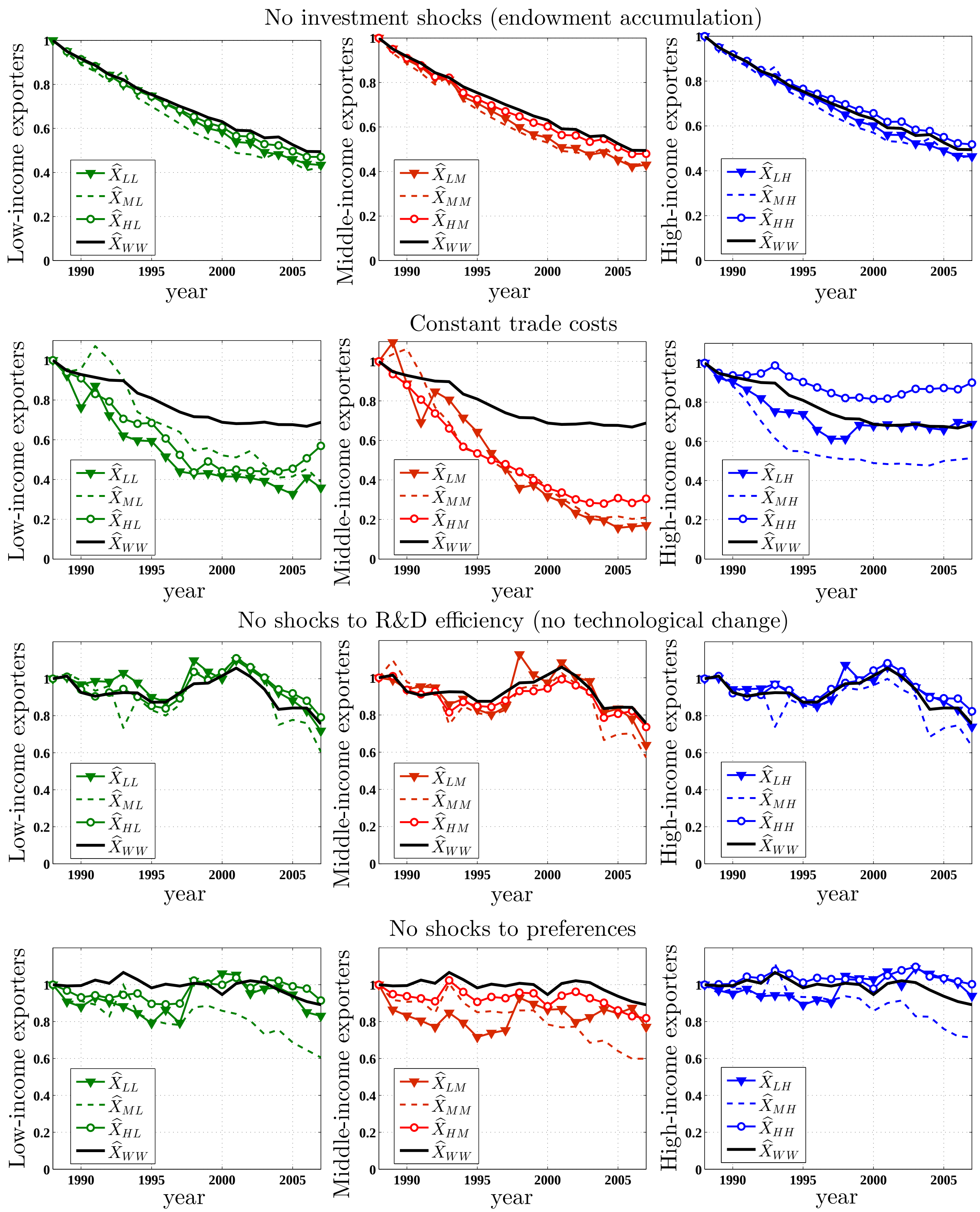

Figure 7: COUNTERFACTUAL EXPERIMENTS (ENDOGENOUS GROWTH MODEL)

of these shocks to trade had to some extent been undone by factor accumulation, changes in trade costs, and changes in preferences. There are also significant differences across country groups and years with regard to this effect. However, also the DND model shows the detrimental effects of productivity change on trade around the year 2001. We elaborate on this in Appendix B.

The results of our final experiment, where we keep preference shocks constant, are reported in the lower panel of Figure 7. They are again in stark contrast to the results suggested by the SXD model. The DND model suggests that there was a global fundamental preference shock towards manufacturing and not services. In other words, had this shock not happened, expenditures on services would have dropped in relative terms even more starkly than they actually did during the period of investigation. What was interpreted as a preference shock in the SXD model emerged from the non-homotheticity of consumer preferences and demand. The model here predicts that without preference shocks, global trade would be lower by 10%. It also appears that all country groups experienced positive preference shocks towards goods from the middle-income exporters, e.g., China. Under constant preferences, export flows from the middle-income exporters to low-income, middle-income and high-income importers would have been lower by 39%, 40% and 29% in 2007, respectively.

We may summarize the findings in this section relative to the previous one as follows: deep parameters behind the endowment accumulation still appear very (and for many country groups most) important among the considered drivers of trade but much less important in absolute terms that immediate and induced (by other factors) endowment changes are together, according to a comparison of the SXD- and the DND-model-based results. Changes in trade costs are among the most important drivers of exports, in particular for low- and middle-income exporters in both the SXD and DND models. Overall, calibrating new trade models without accounting for the potential endogeneity of factor accumulation, technology, and consumption patterns may be quantitatively very misleading with regard to the relative importance of these factors to each other.

8 Changes in world-trade openness and the drivers of trade

Apart from trade itself, trade openness – measured as a country's overall trade relative to GDP, in levels and changes – is a widely-used measure of globalization often employed in empirical work. Clearly, changes in the drivers of the growth of trade do not only affect the numerator of this measure but also the denominator through endogenous changes in prices and, eventually, factor accumulation. In this section, we investigate the role of the drivers of exports with regard to that measure, consulting both the SXD and the DND models. Let us use ω_t to denote the share of international trade flows in world GDP at any time t anchored in benchmark year s as:

$$\omega_t = \frac{\sum_{i=1}^{J}\sum_{j=1}^{J}\widehat{X}_{ij,t}X_{ij,s}}{\sum_{i=1}^{J}\widehat{Y}_{i,t}Y_{i,s}} = \frac{\sum_{i=1}^{J}\widehat{\ell}_{i,t}\widehat{w}_{i,t}Y_{i,s}\widehat{\varrho}_{i,t}\varrho_{i,s}\widehat{d}_{i,t}d_{i,s}}{\sum_{i=1}^{J}\widehat{\ell}_{i,t}\widehat{w}_{i,t}Y_{i,s}}\left(\sum_{j=1}^{J}\widehat{\lambda}_{ij,t}\lambda_{ij,s} - \widehat{\lambda}_{ii,t}\lambda_{ii,s}\right). \tag{8.1}$$

We may measure ω_t and its relative change, $\widehat{\omega}_t = \omega_t/\omega_s$, from the data. Again, the data are perfectly aligned with the calibrated SXD model in Section 6 as well as the calibrated DND model in Section 7. However, the two models differ in terms of the relative importance they attribute to the individual drivers of bilateral exports as outlined in Sections 6 and 7. Again, we report results of four counterfactual exercises where we hold endowments (or their fundamentals), technologies (or their fundamentals), trade costs, and expenditure shares on manufactures versus services (or their fundamentals) constant at their levels of 1988, comparing the counterfactual time series of $\widehat{\omega}_t$ with the data.

We summarize our findings in Figure 8, which contains four panels each of which corresponds to one counterfactual experiment. In each panel, we report three loci: (i) the data on $\widehat{\omega}_t$ which are the same in all four panels (solid blue locus); (ii) the counterfactual series based on the (exogenous-direct-driver) SXD model (dashed green locus); and (iii) the counterfactual series based on the (endogenous-direct-driver) DND model (dotted red locus).

In the upper left panel of Figure 8, we hold endowments (in the SXD model) as calculated in Section 6 or their deep fundamentals (in the DND model) as calculated in Section 7 constant at their levels of 1988. In the data, the world-trade openness grew by around 46% in the period of consideration. While the SXD model suggests that investment shocks raised world-trade openness by about 8 percentage points, the DND model comes to the opposite conclusion and suggests that investment shocks had little effect on world-trade openness and depressed it somewhat, if anything. Overall, this suggests that other factors (fundamental technology shocks, trade costs, and in particular, non-homotheticity-induced expenditure-share changes) induced endowment changes and, in turn, trade openness changes that should not be attributed to endowment accumulation directly.

In the upper right panel of Figure 8, we counterfactually hold trade costs constant relative to the benchmark year. In this case, the predictions of the two models are relatively similar to each other. Reductions in trade costs appear to be the most important driver of world-trade openness. Under constant trade costs, the world-trade openness would have been only slightly higher in 2007 than it was in 1988, according to the figure, no matter of whether the SXD or the DND model is considered.

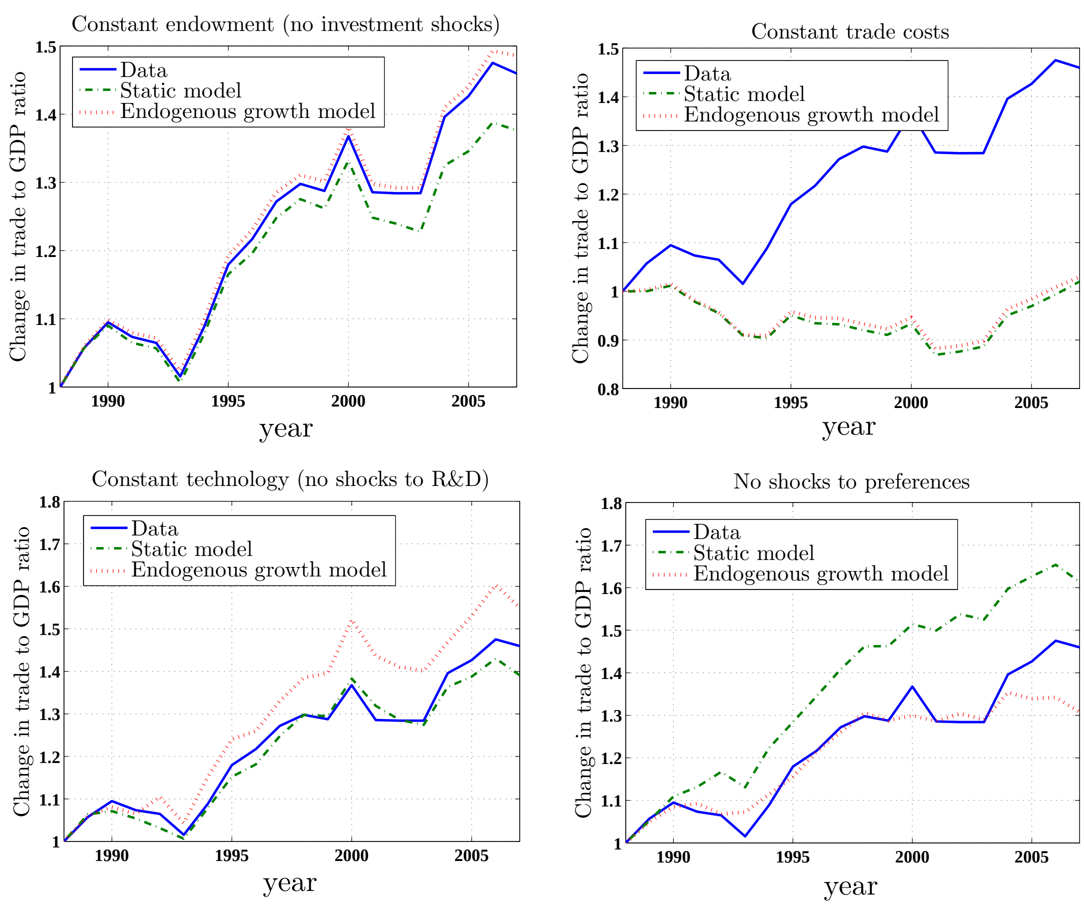

Figure 8: Counterfactual experiments (Endogenous growth model)

In the lower-left panel of Figure 8, we hold technologies (in the SXD model) as calculated in Section 6 or their deep fundamentals (in the DND model) as calculated in Section 7 constant at their levels of 1988. As with endowment changes, the two models come to qualitatively different conclusions relative to the data: the SXD model suggest that world-trade openness would have grown slightly less than observed if productivity levels in manufacturing and services had stayed constant at their values of 1988, while the DND model suggests that this development is largely induced by other factors, while exogenous fundamentals behind technological change actually depressed the growth in world openness on average between 1988 and 2007.

Finally, in the lower right panel of Figure 8, we hold expenditure shares (in the SXD model) as calculated in Section 6 or their deep fundamentals (in the DND model) as calculated in Section 7 constant at their levels of 1988. In that regard, the difference between the SXD and the DND models is most striking. For 2007, the predictions of the two models differ by 30 percentage points with the prediction of the static model being around 60% for the level of trade openness in that year, ω_{2007}. From the SXD model, we would conclude that the openness to trade would have been much higher in 2007 than it was, had expenditure shares not changed, and this change is due to preference shocks. But the DND model suggests that the experienced changes in expenditure shares were largely due to changes in the world economy which should not be attributed to changes in preferences but merely changes in income which changed expenditure shares at given preferences. The DND model identifies changes in expenditure shares as being largely due to income effects and suggests that actual preference shocks have been small and even raised trade openness on average.

Overall, the results of the experiments in this section indicate that reductions in trade costs were the main drivers of world-trade openness observed in the data. Moreover, the preferable DND model points to the importance of preference changes as a driver of trade openness and suggests that technology (R&D) shocks offset some of these effects on openness. In general, that model points to quantitatively important interaction effects among the drivers of trade openness.

9 Conclusion

This paper pursued a world-trade growth-accounting approach based on new-trade-theory models. The proposed approach allows decomposing changes in bilateral as well as unilateral exports into exogenous factors. A variance decomposition of growth rates of bilateral exports among the 67 most important economies on the globe between 1988 and 2007 suggested that the variance contributions of changes in endowments, in trade costs, sector-specific technology, and preferences changed not only in absolute terms but also relatively to each other. Moreover, the covariances and correlation coefficients among these factors suggested that they should probably be viewed as structurally linked to each other, which is rarely considered in quantitative work.

The paper started out with presenting a static quantitative model version which corresponds to a large number of settings used in quantitative work on trade. That model assumed that, apart from changes in trade costs, ones in endowments, sector-specific technology, and expenditure shares on manufactures versus services could be treated as exogenous, as is customary in the literature. Inspired by the insights from correlations among changes in the fundamental drivers of the growth of exports, the paper then proposed a dynamic quantitative model version, where factor accumulation, technological change, and expenditure shares on manufactures versus services could endogenously adjust to deep fundamentals. In that model, the latter were associated with shocks to equipment investment incentives, to R&D efficiency in either sector, and to consumer preferences and income distributions which, apart from changes in trade costs, determined endowment accumulation, technological change, structural change, and the growth of bilateral exports.

Either model version led to identical decompositions of bilateral changes in exports into changes in endowments, technology, trade costs, and expenditure shares. However, the two models gave starkly – sometimes even qualitatively – different answers regarding the consequences of shocks to exogenous drivers for bilateral exports and world-trade openness. The reasons for these stark differences were that the dynamic endogenous-driver model took into account that changes in deep fundamentals (trade costs, investment efficiency, innovation efficiency, consumer preferences) jointly determine factor accumulation, technological change, and the rise of the expenditure share on services relative to manufactures. Hence, the correlations of these drivers of trade identified in the data emerge endogenously there, while they are purely stochastic in models assuming exogenous endowments, technology, and expenditure shares.

Overall, 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. For comparison, the less preferable static, exogenous-endowments-and-technology model suggested that only (shocks to) endowment accumulation and trade costs (in that order) mattered while technological change was more or less irrelevant. The models also came to starkly, even qualitatively, different conclusions of the drivers of trade for world-trade openness (measured as trade over GDP). All of that suggests that a consideration of endogenous factor accumulation, technological change, and expenditure shares on manufactures versus services might be important – both qualitatively as well as quantitatively – when using trade general equilibrium models for comparative static analysis as is the case with virtually all quantitative work for policy analysis.

Appendix A

We classify countries into low-income, middle-income, and high-income groups according to the following Table.

Table 5: *Country group classification*

country	group	country	group	country	group
Bangladesh	L	Fiji	M	Finland	H
Bolivia	L	Hungary	M	France	H
Cameroon	L	Jamaica	M	Germany	H
Ghana	L	Jordan	M	Greece	H
Guatemala	L	Malaysia	M	Iceland	H
Honduras	L	Malta	M	Ireland	H
India	L	Mauritius	M	Israel	H
Indonesia	L	Mexico	M	Italy	H
Kenya	L	Oman	M	Japan	H
Madagascar	L	Peru	M	Korea, Rep.	H
Morocco	L	South Africa	M	Kuwait	H
Nepal	L	Thailand	M	Netherlands	H
Pakistan	L	Trinidad and Tobago	M	New Zealand	H
Philippines	L	Tunisia	M	Norway	H
Senegal	L	Turkey	M	Portugal	H
Sri Lanka	L	Uruguay	M	Singapore	H
Argentina	M	Venezuela, RB	M	Spain	H
Barbados	M	Australia	H	Sweden	H
Chile	M	Austria	H	Switzerland	H
China	M	Belgium	H	United Kingdom	H
Colombia	M	Canada	H	United States	H
Costa Rica	M	Cyprus	H		
Ecuador	M	Denmark	H		

L – low-income country, M – middle-income country, H – high-income country

The method is based on the average per-capita income observed in 1988. We discus the exact bounds for each group in Footnote 8.

Appendix B

In Sections 6 and 7 we obtained a peculiar results of negative technology shocks in some years. It is the purpose of this Appendix to shed light on the sources thereof. We plot counterfactual outcomes when keeping technology (R&D shocks) constant in the SXD (DND) model in Figure 9. Here, we also plot relative changes in value added in the manufacturing sector, $\widehat{VAM}_{WW}$, GDPs, $\widehat{GDP}_{WW}$, and capital accumulation (weighted by GDP) in the world, $\widehat{K}_{WW}$.

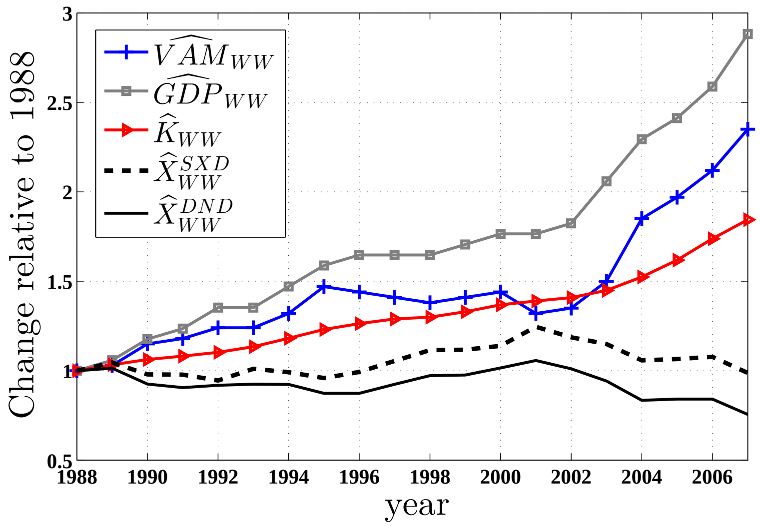

Figure 9: Recessions and trade flows

The results indicate that a significant drop in the growth rates in the manufacturing value added (and partially in GDPs) explain the humps in the counterfactual predictions of the two models. They are perfectly aligned in time and explain why the SXD model in particular produces results that may appear counter-intuitive at first glance.

References

1. Acemoglu, Daron and Jaume Ventura, 2002. The world income distribution. *The Quarterly Journal of Economics* 117(2), 659-694.
2. Aghion, Philippe and Peter Howitt, 1992. A model of growth through creative destruction. *Econometrica* 60(2), 323-351.
3. Aghion, Philippe and Peter Howitt, 2007. Capital, innovation, and growth accounting. *Oxford Review of Economic Policy* 23(1), 79-93.
4. Aghion, Philippe and Peter Howitt, 2009. *The Economics of Growth*. MIT Press.
5. Alessandria, George and Horag Choi. 2014a. Establishment heterogeneity, exporter dynamics, and the effects of trade liberalization. Journal of International Economics. 94(2): 207 - 223.
6. Alessandria, George and Horag Choi. 2014b. Do falling iceberg costs explain recent U.S. export growth? Journal of International Economics. 94(2): 311 - 325.
7. Alvarez, Fernando and Robert E. Jr. Lucas, 2007. General equilibrium analysis of the Eaton-Kortum model of international trade. *Journal of Monetary Economics* 54(6), 1726-1768.
8. Anderson, James E. and Eric van Wincoop, 2003. Gravity with gravitas: a solution to the border puzzle. *American Economic Review* 93(1), 170-192.
9. Anderson, James E. and Eric van Wincoop, 2004. Trade costs. *Journal of Economic Literature* 42(3), 691-751.
10. Anderson, James E. and Yoto V. Yotov, 2010. The changing incidence of geography. *American Economic Review* 100(5), 2157-2186.
11. Anderson, James E., Mario Larch, and Yoto V. Yotov, 2014. Trade and Growth: A Structural Approach. *Mimeo*.
12. Arkolakis, Costas, Arnaud Costinot, and Andrés Rodríguez-Clare, 2012. New trade models, same old gains? *American Economic Review* 102(1), 94-130.
13. Artuc Erhan, Shubham Chaudhuri and John McLaren, 2010. Trade shocks and labor adjustment: a structural empirical approach. *American Economic Review* 100(3), 1008-1045.
14. Baldwin, Richard E. and Rikard Forslid, 2000. Trade liberalisation and endogenous growth: a q-theory approach.*Journal of International Economics* 50(2), 497-517.
15. Baier, Scott and Jeffrey H. Bergstrand, 2001. The growth of world trade: tariffs, transport costs, and income similarity. *Journal of International Economics* 53(1), 1-27.
16. Baier, Scott and Jeffrey H. Bergstrand, 2007. Do free trade agreements actually increase members' international trade? *Journal of International Economics* 71(1), 72-95.
17. Baier, Scott and Jeffrey H. Bergstrand, 2009. Estimating the effects of free trade agreements on international trade flows using matching econometrics. *Journal of International Economics* 77(1), 63-76.
18. Bergstrand, Jeffrey H., Peter H. Egger, and Mario Larch, 2013. Gravity redux: estimation of gravity-equation coefficients, elasticities of substitution, and general equilibrium comparative statics under asymmetric bilateral trade costs. *Journal of International Economics* 89(1), 110-121.
19. Bernhofen, Daniel, Zouheir El-Sahli, and Richard Kneller, 2013. Estimating the effects of the container revolution on international trade. *GEP Research paper 2013/2, University of Nottingham.*
20. Boppart, Timo, 2014. Structural change and the Kaldor Facts in a growth model with relative price effects and non-Gorman preferences. *Econometrica* 82(6), 2167âĂŞ2196.
21. Bustos, Paula. 2011. Trade liberalization, exports, and technology upgrading: evidence on the impact of MERCOSUR on Argentinian firms. *American Economic Review* 101(1), 304-340.
22. Caliendo, Lorenzo and Fernando Parro, 2010. Welfare gains from changing partners in a trade bloc: the case of MERCOSUR. In: John Gilbert (ed.), *New Developments in Computable General Equilibrium Analysis for Trade Policy (Frontiers of Economics and Globalization, Volume 7)*, Chapter 3, Emerald Group Publishing Limited, 41-60.
23. Caliendo, Lorenzo and Fernando Parro, (2015). Estimates of the trade and welfare effects of NAFTA. *Review of Economic Studies*, forthcoming.
24. Chari, Varadarajan V. , Patrick J. Kehoe and Ellen R. McGrattan, 2007. Business cycle accounting. *Econometrica* 75(3), 781-836.
25. Costinot, Arnaud and David Donaldson, 2012. Ricardo's theory of comparative advantage: old idea, new evidence. *American Economic Review: Papers and Proceedings* 102(3), 453-458.

26. Costinot, Arnaud, David Donaldson, and Ivana Komunjer, 2012. What goods do countries trade? A quantitative exploration of Ricardo's ideas. *Review of Economic Studies* 79(2), 581-608.

27. Costinot, Arnaud and Andrés Rodríguez-Clare, 2014. Trade theory with numbers: quantifying the consequences of globalization. In; Gita Gopinath, Elhanan Helpman, and Kenneth R. Rogoff (eds.), *Handbook of International Economics, vol. 4*,

28. Davis, Donald R. and David E. Weinstein, 2001. An account of global factor trade. *American Economic Review* 91(5), 1423-1453.

29. Deardorff, Alan, 1998. Determinants of bilateral trade: does gravity work in a neoclassical world? In. Jeffrey Frankel (ed.), *The Regionalization of the World Economy*, 7-32.

30. Dekle, Robert, Jonathan Eaton, and Samuel S. Kortum, 2007. Unbalanced trade. *American Economic Review* 97(2), 351-355.

31. Dix-Carneiro, Rafael, 2014. Trade Liberalization and Labor Market Dynamics. *Econometrica* 82(3), 825-885.

32. Eaton, Jonathan and Samuel S. Kortum, 2002. Technology, geography, and trade. *Econometrica* 70(5), 1741-1779.

33. Eaton, Jonathan, Samuel S. Kortum, Brent Neiman, and John Romalis, 2013. Trade and the global recession. *Working Papers, University of Sydney, School of Economics*.

34. Edmonds, Eric V., Nina Pavcnik, and Petia Topalova. 2010. Trade Adjustment and Human Capital Investments: Evidence from Indian Tariff Reform. *American Economic Journal: Applied Economics* 2(4), 42-75.

35. Egger, Peter H. and Andrea Lassmann, 2015. The causal impact of common native language on international trade: evidence from a spatial regression discontinuity design. *Economic Journal* 125(584), 699âĂŞ745.

36. Egger, Peter H. and Sergey Nigai, 2015. Gravity with dummies only: structural constrained ANOVA-type estimation of gravity models. *Journal of International Economics*, forthcoming.

37. Egger, Peter H. and Michael Pfaffermayr, 2014. Iterated structural estimation of gravity models with market-entry dynamics. Revised CEPR Working Paper no. 8458.

38. Falvey Rod, David Greenaway and Joana Silva, 2010. Trade liberalisation and human capital adjustment. *Journal of International Economics* 81(2), 230-239.

39. Feenstra, Robert C., Robert Inklaar and Marcel P. Timmer, 2015. The Next Generation of the Penn World Table. *American Economic Review* forthcoming.

40. Feenstra Robert C. and Hiau Looi Kee, 2008. Export variety and country productivity: estimating the monopolistic competition model with endogenous productivity. *Journal of International Economics* 74(2), 500-518.

41. Grossman, Gene M. and Elhanan Helpman, 1990. Trade, innovation, and growth.*American Economic Review* 80(2), 86-91.

42. Grossman, Gene M. and Elhanan, Helpman, 1991. Trade, knowledge spillovers, and growth. *European Economic Review* 35(2-3), 517-526l.

43. Jones, Ronald W. 1965. The structure of simple general equilibrium models. *Journal of Political Economy* 73(6), 557-572.

44. Jones, Charles I. 1995. R&D-based models of economic growth. *Journal of Political Economy* 103(4), 759-84.

45. Jones, Charles I. 1995. Time series tests of endogenous growth models. *The Quarterly Journal of Economics* 110(2), 495-525.

46. Krugman, Paul. R. 1991. *Geography and Trade*. Cambridge, MA: MIT Press.

47. Levchenko, Andrei and Jing Zhang, 2015. The Evolution of Sectoral Productivity: Measurement and Implications. *Unpublished Manuscript*, University of Michigan.

48. Levchenko, Andrei, Julian di Giovanni, and Jing Zhang, 2014. The global welfare impact of China: trade integration and technological change. *American Economic Journal: Macroeconomics* 6(3), 153-183.

49. Levchenko, Andrei and Jing Zhang, 2012. Comparative advantage and the welfare impact of European integration. *Economic Policy* 27(72), 567-602.

50. Lucas, Robert E. 1988. On the mechanics of economic development. *Journal of Monetary Economics* 22(1), 3-42.

51. Melitz, Marc, 2003. The impact of trade on intra-industry reallocations and aggregate industry productivity. *Econometrica* 71(6), 1695-1725.

52. Mélitz, Jacques and Farid Toubal, 2014. Native language, spoken language, translation and trade. *Journal of International Economics* 93(2), 351-363.

53. Nigai, Sergey. (2015). On measuring the welfare gains from trade under consumer heterogeneity. *Economic Journal*, forthcoming.

54. Ossa, Ralph, 2012. Why trade matters after all. *NBER Working Paper 18113*.

55. Romer, Paul M., 1990. Endogenous technological change. *Journal of Political Economy* 98(5): 71-102.

56. Rydzek, Benedikt. 2013. Trade effects of income inequality within and between countries. *Working Paper, ETH Zurich.*

57. STAN Database, Organization for Economic Cooperation and Development, accessed in October, 2013 at http://stats.oecd.org.

58. Solow, Robert, 1957. Technical change and the aggregate production function. *Review of Economics and Statistics* 39 (3), 312-320.

59. Trefler, Daniel, 1995. The case of the missing trade and other mysteries. *American Economic Review* 85(5), 1029-1046.

60. Uzawa, Hirofumi, 1965. Optimum technical change in an aggregate model of economic growth. *International Economic Review* 6(1), 18-31.

61. World Bank Development Indicators Database, 2010, accessed in October, 2011 at http://web.worldbank.org/data.