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Feeding China's Rise: The Growth Effects of Trading with China, 1993-2011

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Abstract

I construct a dynamic, multi-sector model of trade and growth and use it to quantify how China's rapid expansion of trade over the last two decades has contributed to world economic growth. The model notably features a rich interplay between changes in sectoral-level trade and the usage of each sector in consumption, investment, and intermediate goods production. I find the changing sectoral structure of China's trade during the period 1993-2011 has generally incentivized increased capital accumulation in other countries, both through its increased exports of capital goods (which serve as key inputs for investment) and through its increased appetite for non-manufacturing imports (which tend to be capital-intensive). These "dynamic sectoral linkages" greatly enrich the welfare implications of an equivalent "static" framework without capital formation: long-run real income gains from the dynamic model exceed static gains by a factor of more than ten, largely due to favorable changes in industry-level prices. They also reverse short-run losses for some countries that suffer initially from China's change in comparative advantage. Nonetheless, because capital takes time in order to fully adjust to changes in sectoral prices, the majority of China's spillover effects on world growth may still have yet to be felt.

(Latest version `here`*)*

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1 Introduction

Analysts and policymakers across the world are concerned about the effect that a slowdown in China will have on future world economic growth. As the *Financial Times* recently warned, a "new normal" of "sub-8% growth" in China is expected to have complex, far-reaching effects spanning many different industries and regions of the world: "China will cast a long shadow from the ore mines of Brazil to the car factories of Germany. As the largest source of future economic growth globally, the world is relying on the Chinese."[1]

These concerns reflect a widely-held view that the rapid industrialization and globalization of China has been one of the major drivers of economic growth over the last two decades. But just how large has this impact been? This paper looks back through China's growing, changing contribution to world trade over time in order to ask: What would world GDP look like today if China had only grown and opened its borders at the same rate as the rest of the world?

To shed new light on this question, I specifically investigate how incentives for capital formation in the world at large have been shaped by the changing sectoral composition of China's trade. In doing so, I build off of recent research that has highlighted the importance of "sectoral linkages" in quantifying the real income gains from trade (Costinot & Rodríguez-Clare 2014; Caliendo & Parro 2015) and in particular how China's opening to trade has affected other countries (Di Giovanni, Levchenko, & Zhang, 2014; Hsieh & Ossa, 2016). The strength of these frameworks is their ability to incorporate the "shadow" China casts both up and down the global production chain, whereby imported inputs in one sector may stimulate increased output in other sectors. However, these models are strictly "static" in that they omit (among other things) how trade may induce increased capital formation over time. In the framework I propose, by contrast, different sectors are differentiated not only by input usage patterns, but also differ in their importance as inputs to capital formation as well as in their own usage of capital in production. The *dynamic* sectoral linkages highlighted by this setting notably deliver a richer set of implications for the gains from trade and, ultimately, larger real income gains from China's trade expansion, especially in the long run.

Figure 1 presents some key facts from the data that this perspective is specifically intended to confront. In 1993, China was a net exporter of non-manufactured raw materials and a net importer of manufactured goods. As its overall share of world trade has grown, the structure of its trade has dramatically reversed in favor of exports of manufactured goods, and of "capital goods" (e.g., machinery, equipment) in particular. The former shift—from non-manufacturing to manufacturing—has motivated several recent investigations (discussed below) into the negative effects China's change in comparative advantage may have had on the terms of trade of other manufacturing exporters. The latter shift—to capital goods in particular—has been highlighted in other work as a viable mechanism for trade-induced capital accumulation (Eaton & Kortum, 2001; Mutreja, Ravikumar, & Sposi, 2016). How these potentially competing factors play out in a fully-specified setting is ultimately a matter of quantification, which this paper sets out to provide.

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[1] Kate Allen & Simon Rabinovitch, "The China slowdown, in numbers", *Financial Times*, 15 July 2013.

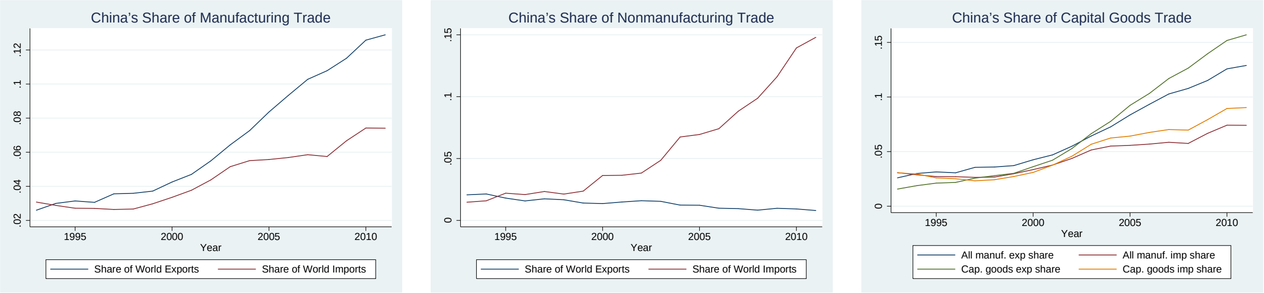

Figure 1: China's growing, changing contribution to world trade, 1993-2011

The analytical framework needed to bring together these elements is ambitious. In general terms, I construct a dynamic, multi-sector trade and growth model which can exactly match the evolution of trade, output, and capital formation for a sample of 72 countries over the period 1993-2011. The model explicitly nests the input-output structure and gains from trade emphasized in the static frameworks described above: as in Caliendo & Parro (2015), there will be immediate, intuitive efficiency gains when trade lowers the price of key inputs to production. Unique to this paper, however, the model also reproduces each country's overall investment and consumption prices in each year and (in counterfactuals) allows these aggregate prices to vary endogenously with the prices of the different sectors that feed into investment and consumption. Forward-looking agents weigh current and future investment prices against future returns to capital in deciding how much to invest in each period. Importantly, changes in trade that lower the relative price of key production inputs will not necessarily work in favor of lower investment prices. Thus, the model offers a highly nuanced view into how the usual static gains from trade may be complemented (or not) from additional real income gains from increased investment and capital accumulation.

To bring the model to the data, I draw extensively upon the "dynamic trade accounting" methodology of Eaton, Kortum, Neiman, & Romalis (2015) (henceforth, "EKNR").[2] As in EKNR, extracting counterfactuals from the model first involves a meticulous treatment of the different "wedges" (or "structural residuals") that enable an initial equilibrium in the model to exactly match all observed data in each period under perfect-foresight. However, the analysis performed in this paper adopts an overall larger-scale perspective than that of EKNR and necessitates, in some key places, the use of different accounting techniques. In particular, because I require more information on sectoral prices than the data can provide, I introduce a flexible method for estimating changes in sectoral productivity levels and trade frictions over time. These estimates then serve as the basis for constructing my main counterfactual: How would growth, investment, and welfare in China's trade partners have evolved differently if China's rates of productivity growth and trade liberalization across each sector had been merely "normal" as compared to the rest of the world?

For my headline results, I perform two main simulations, one for the period 1993-2007 (incorporating the period leading up to the Great Recession) and one for 2008-2011 (covering the recession and recovery

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[2] EKNR's methodology itself builds on the earlier closed economy accounting framework of Chari, Kehoe, & McGrattan (2007) and the two country open economy setting of Kehoe, Ruhl, & Steinberg (2013). Note that I only discuss similarities and differences with EKNR in terms of *accounting* here. Other key differences, in terms of *modeling*, are highlighted further below.

period). For the 1993-2007 period, I find that China's high rates productivity growth and trade liberalization, while impressive in their own right, only contributed 1.21% of the combined real GDP growth in the world outside China. For the 2008-2011 period, however, because productivity suffered across many countries during the 2008-2009 recession, China's continued rapid expansion of trade acted as an important buffer for the world economy during this time, contributing 0.59 percentage points—or 8.79%—of the 7.16% growth the rest of the world struggled to achieve during this period.

What is especially interesting about these results, however, is how I arrive at them. The 1.21% number computed for the 1993-2007 period may seem, to many observers at least, surprisingly small. A closer look reveals the advantage of using a dynamic, multi-sector perspective. By comparing my full dynamic results with outcomes from an otherwise-equivalent "static" model (which takes capital endowments as exogenous), I am able to show that almost half of China's effects on 1993-2007 growth are due to capital accumulation. Furthermore, the sectoral dimension itself plays a crucial role. In a subsequent counterfactual, where I remove all sectoral differences in final usage (i.e., in investment versus consumption) and factor intensity (i.e., of capital versus labor), I find that "dynamic sectoral linkages" can explain fully three-fourths of China's effects on capital accumulation.

At the sectoral level, the main drivers of these effects are two-fold: first, as strongly hinted by Figure 1, China's productivity growth has been heavily biased towards manufacturing industries as opposed to non-manufacturing goods. Since the non-manufacturing sector is relatively capital-intensive in many countries—and is itself an important input for other capital-intensive industries—this change in comparative advantage has induced increased capital investment in other countries in order to feed China's import demand for raw materials. Indeed, the highest overall "winners" from China's rise include several relatively resource-oriented economies such as Australia, Kazakhstan, Peru, and Tanzania.

Second, China's general shift in comparative advantage towards manufacturing as a whole has prominently included increased productivity in capital goods in particular, which serve as an important input to investment. The effects of this shift have been strengthened further still by a remarkable reduction in China's overall barriers to trade in capital goods, which fell by about a half between 1993 and 2007.

In addition, while capital accumulation between 1993 to 2007 makes up about half of China's overall contribution to the real GDP growth of its trading partners, focusing only on year 2007 outcomes (or 2011 outcomes) greatly understates the full implications of China's rise. Because capital stocks accumulate slowly over time in response to long-term changes in sectoral prices, the majority of the "dynamic gains" from China's trade expansion likely have yet to materialize, even disregarding whether a slowdown occurs in the present day. Focusing on long-run steady state outcomes from the dynamic model, I find in all cases that the implications for long-run GDP and long-run (discounted) consumer welfare are substantially larger than any of the contemporaneous real GDP effects.

The recent literature on the macroeconomic impact of increased trade with China draws its motivation from an influential argument put forward by Samuelson (2004). According to this argument (which itself dates back to Hicks, 1953), if China's productivity growth favors industries in which it has an initial comparative disadvantage, other countries may suffer welfare losses via an erosion of their terms of trade. The present paper shares with Di Giovanni, Levchenko, & Zhang (2014) and Hsieh & Ossa (2016) an interest in exploring this mechanism in a many-country quantitative setting.[3] Like each of these papers, I find that a handful of countries suffer small losses from China's change in sectoral productivities from a "static" perspective. In my case, these are strictly high income countries such as Italy, Germany, Japan, and Sweden. Interestingly, however, when incentives for capital accumulation are taken into account—the specific contribution of this paper—long-run real GDP effects are positive in all countries and discounted future welfare is higher everywhere except Italy.[4]

Productivity changes aside, however, this paper is unique in this literature in also contemplating the quantitative implications of China's rapidly falling barriers to trade during this period. Again, the implications vary significantly from a static setting to a fully dynamic setting. While reductions in trade frictions explain relatively more of China's impact on the rest of the world from a static point of view, it is actually the sectoral productivity shifts that, by shifting sectoral prices in the short-run, have a relatively larger dynamic impact in the long run.

Baldwin & Seghezza (1996), Wacziarg (2001), Wacziarg & Welch (2008), and Anderson, Larch, & Yotov (2015) have all found empirically that capital accumulation is a primary component of the overall real income gains from trade. This paper shares with Anderson, Larch, & Yotov (2015) in particular—as well as another recent contribution by Ravikumar, Santacreu, & Sposi (2016)—an interest in characterizing the additional "gains from trade" that arise from capital accumulation.[5] Relative to these papers, the key addition of this paper is the inclusion of a rich sectoral dimension.[6] Accordingly, an additional contribution of this paper is to provide an instructive formula for the "dynamic gains from trade" that both embeds and extends the (static) gains from the multi-sector setting of Caliendo & Parro (2015), clarifying in particular how the formation of capital thrives on favorable changes in sectoral prices.

The most related framework, however, is that of EKNR. As in EKNR, I build and quantify a model with multiple sectors, endogenous capital, and an input-output structure in production. Aside from having more sectors, my setting differs from EKNR's in several other key respects, which follow from the needs of the exercises I perform. Most notably, I do not solve for all outcomes in terms of changes in capital over time. Instead, I require my model to match (in levels) national statistics on capital stocks, investment spending, and investment and consumption prices, none of which feature in EKNR. Without capital stocks, it would not

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[3] In this way, I also contribute to a broader literature that, like Di Giovanni, Levchenko, & Zhang (2014) and Hsieh & Ossa (2016) has tried to quantify the "Ricardian" aspects of comparative advantage in a many-country world. This literature includes Shikher (2011, 2012), Costinot, Donaldson, & Komunjer (2012), Hanson, Lind, & Muendler (2015), and Levchenko & Zhang (2016).

[4] There are important methodological differences in how I compute sectoral technology levels versus these other papers. Like Levchenko & Zhang (2016) (who produce the estimates used in Di Giovanni, Levchenko, & Zhang 2014), I structurally estimate technology levels using international trade and production data. However, I use a more flexible specification for trade costs, which lends itself more readily to a "trade accounting" context *a la* EKNR. Hsieh & Ossa (2016) estimate productivities based on Chinese firm-level data, which should be seen as a complementary approach.

[5] Other, similarly related dynamic trade frameworks include Alvarez & Lucas (2007) and Fitzgerald (2012).

[6] The sectoral dimension does play an important role in other recent work by Mutreja, Ravikumar, & Sposi (2016)—specifically, the effects of high trade frictions found in capital goods sectors. However, their work differs methodologically in that they compare changes in steady state outcomes based on one year of data, rather than quantifying the effects of actual changes in trade over time.

be possible to compare one-period static outcomes with dynamic outcomes. Similarly, without a mapping between sectoral prices and investment and consumption prices, I would not be able to decompose how final usage differences contribute to the real income gains from trade.[7]

As such, my main focus is not to untangle "puzzling" aspects of the data as in EKNR (as well as subsequent work by Eaton, Kortum, & Neiman, 2015). Rather, I aim to examine, more generally, how changes in the sectoral structure of trade affect "static" gains from trade (via favorable changes in prices) versus "dynamic" gains from trade (via trade-induced factor accumulation), using the changing structure of trade with China as a suitably rich illustration. In this way, this paper also provides a quantitative contribution to an earlier, more theoretically-oriented literature that has tried to integrate "factor proportions"-based motivations for trade from neoclassical "Hecksher-Ohlin" trade theory with factor accumulation-led growth from neoclassical growth theory. This literature includes notable works by Chen (1992), Ventura (1997), Bajona & Kehoe (2010), and Caliendo (2010).[8]

In service of these stated goals, this paper also makes several methodological and computational contributions that may be useful to other researchers working in related areas. These include: (i) a straightforward, scalable algorithm for solving dynamic trade models with complex sectoral linkages; (ii) a fast, flexible, "dummy variables only" method for estimating changes in trade frictions and and technology levels over time using Poisson PML; and (iii) a method for inferring trade frictions for sectors for which bilateral trade data is not observed directly (as is typically the case with services).

Lastly, before turning to the analysis, it is is important to carefully state what limitations are still being left on the table. For example, while the model I use differs from a Hecksher-Ohlin model in several important respects—e.g., Ricardian technology differences across sectors, intra-industry trade, etc.—I still take from the canonical Hecksher-Ohlin model the standard assumptions of constant returns to scale and perfect factor mobility across industries. The latter assumption in particular is not innocuous with respect to China, because of its diverse economic geography and its well-known restrictions on labor movement. Similarly, the model also abstracts from other, non-trade aspects of China's rapid globalization—e.g., multinational sales, foreign direct investment, or other notions of technology transfer.

In addition, I cannot in good conscience treat the 1993 to 2011 period as a continuous perfect-foresight equilibrium path. Thus, I break up the period into two sub-periods, one for 1993-2007 and one for 2008-2011. I also take all national trade balances to be exogenous. As shown by Reyes-Heroles (2015), allowing for endogenous trade balances would likely lead to higher dynamic welfare gains from trade, by allowing agents to engage in increased inter-temporal trade. Finally, productivity levels for the services sectors are computed in order to match each country's investment and consumption prices from the data. In the case of China, this leads to some unreasonably high TFP values for Chinese services. In the sensitivity analysis, I show the main results are largely unaffected by varying China's services TFP levels.

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[7] Because of the overall difference in focus, this paper also differs from EKNR in several other technical aspects: I assume only one capital series per country—rather than two–which is invested by households and used by firms. In addition, my perspective is annual, not monthly. Finally, each country's overall trade balance in EKNR is endogenous but trade in services is treated as an exogenous endowment. I allow services to be endogenously traded, but restrict the overall trade balance to exogenous.

[8] Caliendo (2010) reviews a large wider literature in this area.

2 A Dynamic Multi-Sector Trade & Growth Model

This section develops, in general terms, an infinite period model of trade and capital accumulation with many countries and multiple sectors. Section 3 then discusses the quantification of the model using real-world data, before turning to Sections 4 and 5, which present the main quantitative results.

2.1 Overview

The model itself has two basic (modular) components. First, the "dynamic" component of the model involves infinitely-lived households deciding how much of their income to invest versus consume in each period in order to maximize their lifetime utility, given perfect-foresight about the future prices of investment and consumption and the future rewards to capital and labor. Second, in the "static" component of the model, all prices within each period, including investment and consumption prices as well as all factor rewards, are competitively determined via costly trade with other countries.

The production of all non-final goods—i.e., excluding consumption and investment—requires differing combinations of labor, capital, and intermediate inputs produced by other industries. The input requirements for consumption and investment likewise involve different combinations of goods sourced from the different industries. Therefore, a change in sectoral prices in any one period can promote incentives for capital accumulation either via an increase in the price of a capital-intensive sector (i.e., by raising the return to capital) or via a decrease in the prices of goods used predominantly for investment (i.e., by lowering the price of investment).

Trade between countries within periods will be modeled via a standard CES "Armington" (or "love of varieties") assumption, in which all countries produce nationally differentiated products within each industry. This assumption naturally creates scope for *intra*-industry trade.[9] In addition, relative unit cost differences across industries will also give rise to comparative advantage and *inter*-industry trade. Not all industries are traded. For a non-traded industry (e.g., Construction), a country will only consume its own variety.

An equilibrium in the full model is a perfect-foresight equilibrium, which itself consists of two main elements: a competitive steady state equilibrium—after which, all capital stocks optimally remain unchanged ever after—and a perfect-foresight transition path across time from an initial period until steady state is reached. For the equilibrium path to be valid, the competitive equilibrium conditions from the static model must be satisfied in every period, including at steady state. Furthermore, investment decisions must satisfy an Euler condition in every period and future capital stocks must satisfy a transversality condition as the world economy reaches steady state.

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[9] An equally popular micro-foundation for intra-industry trade is the Ricardian micro-foundation of Eaton & Kortum (2002), as is used in EKNR. The Armington perspective is adopted for its simplicity. As will become apparent in Section 2.3, both the Ricardian and Armington perspectives lead to the same essential set of equations for solving for the competitive equilibrium in each period.

2.2 Consumption, Investment, and Utility

I start by describing the basic dynamic framework, abstracting initially from trade. The (aggregated) inter-temporal problem of households in country i is to maximize

$$\mathbf{U}_i = \sum_{t=0}^{\infty} \rho^t \cdot \phi_{i,t} \cdot \log C_{i,t} \tag{1}$$

subject to an inter-temporal budget constraint and a law of motion for capital.

$$w_{i,t} L_{i,t} + r_{i,t} K_{i,t} + D_{i,t} = P_{i,C,t} \cdot C_{i,t} + P_{i,IV,t} \cdot I_{i,t} \tag{2}$$

$$K_{i,t+1} = \chi_{i,t} K_{i,t}^{1\text{-}\kappa} I_{i,t}^{\kappa} + (1-\delta) K_{i,t} \tag{3}$$

Taking (for now) the prices of consumption and investment $P_{i,C,t}$ and $P_{i,IV,t}$ as given, (1)-(3) describe a standard inter-temporal problem: households trade off some consumption in the present period in order to build the stock of available capital they will have in future periods. Their income in each period consistent of three elements: labor and capital income $w_{i,t}$ and $r_{i,t}$—which will ultimately be determined endogenously—as well a trade deficit $D_{i,t}$—which is taken to be exogenous.

Note that not every year enters the representative household's optimization problem equally. Not only does a standard discount factor ρ apply, but there is also an allowance for an "inter-temporal preference" shock, $\phi_{i,t}$, which will be used in the quantification of the model in order to fit each country's investment and consumption choices in each year from the data.

The law of motion for capital, (3), takes its form originally from Lucas & Prescott (1971), by way of EKNR. There are two key differences from the standard law of motion with linear depreciation. First, the presence of the "capital adjustment" parameter $\kappa \in (0,1)$ governs how quickly a country's capital stock can accumulate over time. As Lucas & Prescott (1971) observe, capital stocks tends to respond slower to the same level of investment for countries that start from a low capital base. Second, following EKNR, I also include an "investment efficiency" term $\chi_{i,t}$, which, like $\phi_{i,t}$ in (1) is used as a structural residual to ensure the model fits the data exactly (in this case, the data on a country's capital endowment). Current period capital is also subject to a common linear depreciation rate δ, as is standard.

To hint briefly at the role played by trade (which I turn to shortly), the prices of investment and consumption can be described further in terms of their dependence on industry-level prices. Let both consumption and investment be described as Cobb-Douglas combinations of goods drawn from the different industries. Then,

$$P_{i,C,t} = \prod_k P_{i,k,t}^{\gamma_{i,C,t}^k}; \qquad P_{i,IV,t} = \prod_k P_{i,k,t}^{\gamma_{i,IV,t}^k} \tag{4}$$

describes the dependence of consumption and investment prices on the prices of traded and non-traded goods.

The first-order condition for next period capital, K_{t+1}, then delivers the following Euler condition for investment at time t:

$$\frac{P_{i,IV,t}}{E_{i,C,t}}\left(\frac{I_{i,t}}{K_{i,t}}\right)^{1\text{-}\kappa} = \rho\,\frac{\widehat{\phi}_{i,t+1}\chi_{i,t}}{E_{i,C,t+1}}\left\{\kappa\cdot r_{i,t+1} + (1-\kappa)\,\frac{E_{i,IV,t+1}}{K_{i,t+1}} + (1-\delta)\,\frac{P_{i,IV,t+1}}{\chi_{i,t+1}}\left(\frac{I_{i,t+1}}{K_{i,t+1}}\right)^{1\text{-}\kappa}\right\} \tag{5}$$

Each of the moving parts in (5) has an intuitive interpretation. Most obviously, investment at time t will be higher when the next period rental rate r_{t+1} is higher and when the current period investment price $P_{IV,t}$ is lower. In addition, however, because the efficacy of investment depends on the existing capital stock (via the κ parameter), and because capital depreciates over time, current period investment is more valuable if next period investment expenditure is expected to be high relative to the next period capital stock or if next period investment is expected to relatively expensive and/or relatively inefficient.

Finally, the transversality condition can be expressed as

$$\lim_{t\to\infty} K_{i,t} = K_{i,SS} < \infty. \tag{6}$$

In other words, satisfying transversality in this setting requires that all countries' capital stocks remain finite as the world economy approaches steady state.

2.3 Trade, Prices, and Technology

To condense notation—and to emphasize the modularity of the model—let us set aside (for now) the time subscript t and instead focus on establishing the conditions for a competitive trade equilibrium, which must prevail in any period. This section will thus take each country's capital stock and expenditure on investment, which derive solely from the dynamic component of the model, as though they were exogenously given.

By the Armington-CES assumption, trade in industry k from an origin country i to an importing country j can be expressed the following standard "gravity" form:

$$X_{ij,k} = \frac{A_{i,k}\left(c_{i,k}d_{ij,k}\right)^{-\theta}}{P_{j,k}^{-\theta}}E_{j,k}, \tag{7}$$

where $d_{ij,k}$ is an iceberg trade cost, $A_{i,k}$ is i's "technology" level for producing k, $c_{i,k}$ is the cost of an "input bundle" for producing k in i, $E_{j,k}$ is the importing country's total expenditure on industry k, and

$$P_{j,k}^{-\theta} = \sum_i A_{i,k}\left(c_{i,k}d_{ij,k}\right)^{-\theta} \tag{8}$$

captures the overall price level for industry k in market j, by the structure of the Armington-CES trade model (as well as other such models).

The "trade elasticity" term, θ, governs the degree of product differentiation within industries. Under the Armington assumption, θ has a strict interpretation as the elasticity of substitution between varieties, σ, minus 1 (that is, $\theta \equiv \sigma - 1$). Treating the trade elasticity as a single parameter in this way helps emphasize the generality of the overall framework—since many different trade models produce the same gravity equation for trade flows—and also specifically illustrates the connection with the notation of Eaton & Kortum (2002) and EKNR.

The production technology for producing good k in country i can then be described via the "input bundle cost" $c_{i,k}$:

$$c_{i,k} = \left(w_i^{\alpha^w_{i,k}} \cdot r_i^{\alpha^r_{i,k}} \right)^{\beta^v_{i,k}} \cdot \left(\prod_l P_{i,l}^{\alpha^l_{i,k}} \right)^{1-\beta^v_{i,k}} \tag{9}$$

In (9), the input bundle cost is shown to depend not only on the prevailing local wage and rental rate w_i and r_i, but also on the local prices of intermediates. Accordingly, α^w_k and α^r_k are (respectively) the "factor intensities" for labor and capital associated with i's production function industry k, with $\alpha^w_{i,k} + \alpha^r_{i,k} = 1, \forall i, k$. Similarly, the set of $\alpha^l_{i,k}$'s describe the usage intensity of each sector l as an input for producing good k in i (with, again, $\sum_l \alpha^l_{i,k} = 1, \forall i, k$). $\beta^v_{i,k}$ is then the value-added share.[10]

An important observation regarding (9) is that the prices of intermediate inputs that appear in (9) are the same price indices that appear in both (4) and (8). That is, inputs to both final demand and production use the same aggregates from each industry, as is commonly assumed in other, similar trade frameworks with input-output linkages across sectors–c.f. Shikher (2012); Caliendo & Parro (2015); Levchenko & Zhang (2016).

Closing the static model. Closing the within-period model formally requires specifying the following additional conditions. First, summing (7) across all destinations j delivers an equilibrium expression for the value of i's sectoral output, $Y_{i,k}$, in the form of a goods market clearing condition:

$$\sum_j X_{ij,k} = Y_{i,k} \qquad \Longrightarrow \qquad Y_{i,k} = A_{i,k} c_{i,k}^{-\theta} \cdot \sum_j \frac{d_{ij,k}^{-\theta}}{P_{j,k}^{-\theta}} E_{j,k}. \tag{10}$$

Next, to ensure that factor rewards are competitively determined, all wages and rental rates must satisfy the following set of factor market clearing conditions:

$$w_i L_i = \sum_k \alpha^w_{i,k} \cdot \beta^v_{i,k} \cdot Y_{i,k}; \qquad r_i K_i = \sum_k \alpha^r_{i,k} \cdot \beta^v_{i,k} \cdot Y_{i,k} \tag{11}$$

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[10] The production function associated with (9) is

$$y_{i,k} = b_{i,k} \cdot A_{i,k}^{1/\theta} \cdot L_{i,k}^{\beta^w_{i,k}} \cdot K_{i,k}^{\beta^r_{i,k}} \cdot \prod_l (M^l_{i,k})^{\beta^l_{i,k}},$$

where $b_{i,k} \equiv (\beta^w_k)^{-\beta^w_k} \cdot (\beta^r_k)^{-\beta^r_k} \cdot \prod_l (\beta^l_k)^{-\beta^l_k}$ is a combined parameter of input shares, with $\beta^w_k = \alpha^w_{i,k}\beta^v_{i,k}$; $\beta^r_k = \alpha^r_{i,k}\beta^v_{i,k}$; $\beta^l_k = (1-\beta^v_{i,k})\alpha^l_{i,k}$. $M^l_{i,k}$ denotes k's use of l as an intermediate input.

Similarly, note that the sum of a country's factor income also gives its nominal GDP. That is,

$$GDP_i = w_i L_i + r_i K_i = \sum_k \beta^v_{i,k} \cdot Y_{i,k}. \tag{12}$$

Finally, define $x_i \equiv E_{i,IV}/(GDP_i + D_i)$ as the share of i's total expenditure spent on investment. Taking x_i as given (since it is determined from the dynamic component of the problem), i's sectoral expenditure on each industry k, $E_{i,k}$, is

$$E_{i,k} = \gamma^k_i \cdot (GDP_i + D_i) + \sum_l \beta^k_{i,l} Y_{i,l}, \tag{13}$$

where $\gamma^k_i \equiv (1 - x_i) \cdot \gamma^k_{i,C} + x_i \cdot \gamma^k_{i,IV}$ is the share of k in i's final demand and $\beta^k_{i,l} \equiv (1 - \beta^v_{i,k}) \cdot \alpha^k_{i,l}$ is the input share of k as an intermediate input for producing goods in each sector l.

A **competitive equilibrium** in any given period then requires that: (i) input bundle costs are consistent with (9); (ii) sectoral output values, goods prices, are factor prices are each competitively determined by the market clearing conditions (10), (8), and (11); (iii) nominal GDP is given by (12); (iv) sectoral expenditure levels are given by (13); (v) bilateral trade values are given by (7).

2.4 Solving the Model

To bring together the static and dynamic dimensions of the model, consider first the more basic problem of solving for changes in competitive prices and output values in period t in response to a "shock" to technology levels and/or trade barrier levels. Conceptually, once these values are known, the full solution method simply requires updating each country's investment shares and capital stocks using the dynamic equilibrium conditions, then obtaining new competitive prices in each period, repeating until convergence.

Equilibrium in changes. To best demonstrate this complex set of linkages, first let $\widehat{z} = z'/z$ denote the equilibrium change in a variable from an initial level z to a new equilibrium level z', adopting the "hat algebra" notation of Dekle, Eaton, & Kortum (2007). Also let $\pi_{ij,k} = X_{ij,k}/E_{j,k}$ denote a bilateral trade share. Following Dekle, Eaton, & Kortum (2007), I again collect the necessary conditions for a competitive equilibrium at time t, only this time as an *equilibrium in changes:*

$$\widehat{c}_{i,k} = \left(\widehat{w}_i^{\alpha^w_{i,k}} \cdot \widehat{r}_i^{\alpha^r_{i,k}}\right)^{\beta^v_{i,k}} \cdot \prod_l \widehat{P}_{i,l}^{\beta^l_{i,k}} \tag{14}$$

$$\widehat{P}^{-\theta}_{j,k} = \sum_i \pi_{ij,k} \cdot \widehat{A}_{i,k} \left(\widehat{c}_{i,k} \widehat{d}_{ij,k}\right)^{-\theta} \tag{15}$$

$$Y'_{i,k} = \sum_j \pi_{ij,k} \cdot \frac{\widehat{A}_{i,k} \left(\widehat{c}_{i,k} \widehat{d}_{ij,k}\right)^{-\theta}}{\widehat{P}^{-\theta}_{j,k}} E'_{j,k} \tag{16}$$

$$GDP'_i = \sum_k \beta^v_{i,k} \cdot Y'_{i,k} \tag{17}$$

$$\begin{aligned} E'_{i,k} = \gamma^{k\prime}_i \cdot \left(GDP'_i + D_i\right) \\ + \sum_l \beta^k_{i,l} Y'_{i,l} \end{aligned} \tag{18}$$

$$\widehat{w}_i = \frac{L_{i,k}}{L'_{i,k}} \frac{\sum_k \alpha^w_{i,k} \cdot \beta^v_{i,k} \cdot Y'_{i,k}}{\sum_k \alpha^w_{i,k} \cdot \beta^v_{i,k} \cdot Y_{i,k}}; \tag{19a}$$

$$\widehat{r}_i = \frac{K_{i,k}}{K'_{i,k}} \frac{\sum_k \alpha^r_{i,k} \cdot \beta^v_{i,k} \cdot Y'_{i,k}}{\sum_k \alpha^r_{i,k} \cdot \beta^v_{i,k} \cdot Y_{i,k}} \tag{19b}$$

Equations (14)-(19) pin down (in particular) equilibrium changes in factor prices and industry prices, as well as new values for sectoral output and GDP, in response to changes in technologies $\{\widehat{A}_{i,k}\}$ and/or trade barriers $\{\widehat{d}_{ij,k}\}$. Rather than dwell on the full complexity of the above system, I wish to focus attention on three key mechanisms in particular: first, by (15) and (16), the direct effect of a shock in (or with) any one foreign trade partner is directly proportional to the initial trade share, $\pi_{ij,k}$; that is, shocks reverberate more strongly across countries with closer trade ties.

Second, when local industry price of k falls in a given destination j—perhaps through a positive technology shock in a major trade partner—it not only negatively affects the total output of other countries selling to j, via (16), it also expands j's own production of any sector that uses k intensively as an intermediate input, by lowering its production cost in (15).

Third, relative changes in the rental rate, r_i, versus the wage rate, w_i, directly depend on how the sectoral structure of i's output changes from the initial equilibrium to the new one. By (19a) and (19b), the rental-wage ratio will increase if i's output increases relatively more in sectors with a higher capital share in production. In addition, changes in factor prices also depend on changes in endowments. For simplicity, changes in the labor endowment over time are taken as exogenous to match the data. The capital endowment, however, together with the investment share, must be determined by solving the full dynamic model.

Linking static outcomes with dynamic outcomes. For a new investment share value $x'_{i,t}$ at time t, new values for total national consumption and consumption and expenditure at time t—$E'_{i,C,t}$ and $E'_{i,IV,t}$—depend only on a country's GDP and trade deficit:

$$E'_{i,C,t} = \left(1 - x'_{it}\right) \cdot \left(GDP'_{i,t} + D_{i,t}\right) \qquad\qquad E'_{i,IV,t} = x'_{it} \cdot \left(GDP'_{i,t} + D_{i,t}\right). \tag{20}$$

Furthermore, given changes in goods prices, changes in consumption prices and investment prices then follow directly from (4). Explicitly, $\widehat{P}_{i,C,t}$ and $\widehat{P}_{i,IV,t}$ are given by

$$\widehat{P}_{i,C,t} = \prod_k \widehat{P}_{i,k,t}^{\gamma^k_{i,C,t}}; \qquad\qquad \widehat{P}_{i,IV,t} = \prod_k \widehat{P}_{i,k,t}^{\gamma^k_{i,IV,t}}. \tag{21}$$

Together with the change in the rental rate of capital, changes in final demand and final demand prices form the main link from the static component of the model to the dynamic component.

Solving the full model. To incorporate dynamic linkages across periods—via the endogenously chosen investment share—all that needs to be added to the above set-up is the following three elements:

First, I update a new value for each country's investment share, $x'_{i,t}$, by re-writing the Euler equation as follows:

$$\frac{x'_{i,t}}{1 - x'_{i,t}} = \rho \frac{\widehat{\phi}_{i,t+1}\widetilde{\chi}_{i,t}}{E'_{i,C,t+1}} \cdot \frac{\kappa \cdot r_{i,t+1}\widehat{r}_{i,t+1} + (1-\kappa)\frac{E'_{i,IV,t+1}}{K_{i,t+1}} + (1-\delta)\frac{\widehat{P}^{\kappa}_{i,IV,t+1}}{\widetilde{\chi}_{i,t+1}}\frac{E'^{1-\kappa}_{i,IV,t+1}}{K^{1-\kappa}_{i,t+1}}}{\widehat{P}^{\kappa}_{i,IV,t} \cdot \frac{E'^{-\kappa}_{i,IV,t}}{K^{1-\kappa}_{i,t}}}, \tag{22}$$

where, as a convenience, $\widetilde{\chi}_{i,t} \equiv \chi_{i,t}/P^{\kappa}_{i,IV,t}$ collects both i's investment efficiency as well as its investment price (in levels). $r_{i,t+1}$, meanwhile, is computed from the initial equilibrium at time $t+1$.

Second, given the new value for $x'_{i,t}$ obtained from (22), updating $t+1$ capital values only requires inserting the new investment share into the law of motion for capital:

$$K'_{i,t+1} = \widetilde{\chi}_{i,t} K^{1-\kappa}_{i,t} \left[\frac{x'_{i,t} \cdot \left(GDP'_{i,t} + D_{i,t} \right)}{\widehat{P}_{i,IV,t}} \right]^{\kappa} + (1-\delta) K_{i,t}, \tag{23}$$

Third, the new investment share also delivers the total final demand share for each sector $\gamma^k_{i,t}$:

$$\gamma^{k\prime}_{i,t} = (1 - x'_{i,t}) \cdot \gamma^k_{i,C,t} + x'_{i,t} \cdot \gamma^k_{i,IV,t}. \tag{24}$$

Inserting the new values for $K'_{i,t+1}$ into the static system at time $t+1$ then implies new values for $\widehat{r}_{i,t+1}$, $\widehat{P}_{i,IV,t+1}$, $E'_{i,C,t+1}$, and $E'_{i,IV,t+1}$. The procedure continues moving forward through time until a pre-determined steady state is reached, then returns to $t=0$ and starts over—with newly populated values for all endogenous variables—iterating repeatedly along the path to steady state until all countries' capital stocks converge in every period. By necessity, the conditions for a competitive equilibrium will also be satisfied within every period.

In practice, I need to solve the full dynamic system twice to produce a counterfactual. The first time through, I need to solve for a steady state and initial perfect-foresight path through time that exactly reproduces all data on GDP, trade, output, investment, and capital stocks for each of the years being studied.

2.5 Static versus Dynamic Gains from Trade

Before turning to the quantification of the model, it is instructive to first pause here and ask: how might incorporating incentives for capital accumulation contribute to the gains from trade? And, in particular, when would we expect changes in the sectoral composition of trade to amplify (or dampen) these incentives?

Arkolakis, Costinot, & Rodríguez-Clare (2012) famously establish a simple rubric for characterizing the gains from trade based on the change in a country's internal trade share (here, "π_{ii}"). Caliendo & Parro (2015), upon which the static framework of this paper is built, then generalize the one-sector formula of Arkolakis, Costinot, & Rodríguez-Clare (2012) to the case of multiple sectors with input-output linkages across sectors. Following Caliendo & Parro (2015), but adding capital as a second factor of production, the gains from trade in the static framework in the present paper can be written as

$$\widehat{G}_i = \vartheta_w \prod_k \left\{ \widehat{\pi}_{ii,k}^{-\frac{1}{\beta^w_{i,k}\theta}} \times \left[\frac{\widehat{r}_i}{\widehat{P}_{i,k}} \right]^{-\frac{\beta^r_{i,k}}{\beta^w_{i,k}}} \times \prod_l \left[\frac{\widehat{P}_{i,l}}{\widehat{P}_{i,k}} \right]^{-\frac{\beta^l_{i,k}}{\beta^w_{i,k}}} \right\}^{\gamma^k_{i,C}} + \vartheta_r \prod_k \left\{ \frac{\widehat{r}_i}{\widehat{P}_{i,k}} \right\}^{\gamma^k_{i,C}}, \tag{25}$$

where $\vartheta_w \equiv wL/GDP$ and $\vartheta_r \equiv rK/GDP$ are, respectively, the shares of labor and capital in initial income and $\widehat{G} = \widehat{GDP}/\widehat{P}_C$ is the change in GDP with respect to the price of consumption.[11]

The term on the left in (25) may thus be thought of as the change of in the "real wage" for a given change in domestic trade shares ($\widehat{\pi}_{ii,k}$) and non-labor input prices ($\widehat{r}_i$, $\widehat{P}_{i,k}$). Notably, this first term is near-identical to the expression for the real wage from Caliendo & Parro (2015), only with capital entering as an additional input (with price change $\widehat{r}_i$). As is standard, in the the absence of input-output linkages, changes in internal trade shares provide an unadjusted measure of the change in the real wage, weighted (inversely) by the trade elasticity θ and the use of labor in production β^w. The real wage may then expand further if trade lowers the price of intermediate inputs ($\widehat{P}_{i,l}$) and/or the rental price of capital ($\widehat{r}_i$), especially if these are used intensively in a sector with a high share in consumption ($\gamma^C_{i,k}$). The second term then accounts for additional real income gains due to changes in the reward to capital, which are not present in Caliendo & Parro (2015).

To derive an analogous expression for the "dynamic" gains from trade, the natural criterion to focus on is the change in steady state real consumption. In steady state, it is useful to note that the law of motion for capital and Euler equation respectively imply that:

$$I_{i,SS} = \left(\frac{\chi}{\delta}\right)^{1/\kappa} K_{i,SS} \qquad \text{and} \qquad \frac{r_{i,SS}}{P_{i,IV,SS}} = \frac{1-\rho+\delta\kappa\rho}{\kappa\delta\rho}\left(\frac{\chi}{\delta}\right)^{1/\kappa}. \tag{26}$$

In other words, in the long-run, real investment converges to a fixed share of the capital stock. Furthermore, the real price of capital (measured relative to the price of investment) must eventually converge to the same value across all countries.

Combining (26) with (25) and (21), and allowing for endogenously determined capital, then (with some work) delivers the following expression for the dynamic gains from trade:

$$\widehat{G}_i = \underbrace{\frac{\widehat{\left(1-x_i\right)}}{\widehat{\vartheta}_w}}_{\substack{\text{standard}\\ \text{intertemporal}\\ \text{tradeoff}}} \times \underbrace{\prod_k \left\{ \widehat{\pi}_{ii,k}^{-\frac{\gamma^k_{i,C}}{\beta^w_{i,k}\theta}} \times \prod_l \left[\frac{\widehat{P}_{i,l}}{\widehat{P}_{i,k}}\right]^{-\frac{\beta^l_{i,k}\gamma^k_{i,C}}{\beta^w_{i,k}}} \right\}}_{\text{static real wage gains}} \times \underbrace{\prod_k \prod_l \left[\frac{\widehat{P}_{i,l}}{\widehat{P}_{i,k}}\right]^{-\gamma^l_{i,IV}\frac{\beta^r_{i,k}\gamma^k_{i,C}}{\beta^w_{i,k}}}}_{\substack{\text{dynamic sectoral}\\ \text{linkages}}} \tag{27}$$

As indicated in (27), dynamic gains from trade can be broken down into three basic components. The first component, which I call a "standard intertemporal tradeoff", only involves changes in the consumption share of expenditure $(1-x)$ and the labor share (ϑ_w). I refer to it as "standard" because it is the same expression for steady state gains in a model without trade and without multiple sectors (i.e., a standard neoclassical growth model): intuitively, increases in the consumption share directly raises real consumption—holding income constant—but come at the expense of capital income (reflected here in the labor share) because of the tradeoff with investment.

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[11] I also (for simplicity) assume trade is balanced for this exercise.

The second term in (27) then directly incorporates (once again) the overall gains from trade from the static model of Caliendo & Parro (2015). As in Caliendo & Parro (2015), this term accounts for increases in the real wage due to trade expansion and favorable changes in sectoral input prices. Unlike the earlier (static) literature, however, sectoral linkages now also contribute a second, strictly *dynamic* component. The double product that makes up the third term in (27) is slightly difficult to interpret, but its message is highly intuitive: when a given $\widehat{P}_{i,l}$ falls, there are additional dynamic benefits (in terms of increased capital accumulation) when its usage in investment ($\gamma^{l}_{i,IV}$) is relatively high and when the share of capital in production (β^{r}_{l}) for that same sector is low. Conversely, *increases* in a given sectoral price can contribute additional dynamic effects here if that sector has a relatively high capital intensity—by raising the return to capital—but only if its usage in investment is relatively low.

Admittedly, (27) shares the same essential weakness of other such "gains from trade" formulas in it cannot be easily computed *ex ante* for a given change in trade frictions or technologies. This decomposition does, however, still allow me to make some useful points, both to highlight the overall modularity of the model as well as to shed light on the specific role played by changes in the sectoral composition of trade. One last point of interest here is the role played by the trade elasticity, θ. As is apparent from (27) (and as is typical), a higher θ strongly limits the (static) gains from trade, by directly lowering the scope for intra-industry trade. However, the "sectoral dynamic linkages" term in (27) does not depend on θ, nor does the inter-temporal tradeoff term. Thus, all else equal, we might expect dynamic linkages to potentially contribute a relatively larger portion of the overall gains when θ is larger. Indeed, the sensitivity analysis for θ will find this to be the case.

3 Fitting the Model to Data

Quantifying the model described in the previous section requires data on trade, investment, output, production technologies, and—in particular—a set of procedures for extracting the "shocks" to technology levels and trade frictions. I now turn to describing the data sources, techniques, and external parameters that will be used to fit all moments of the model. In addition, in keeping with the main goals of the paper, I will also discuss how all shocks to be used in the counterfactuals will be structured to specifically characterize the expansion of trade with China.

3.1 Data Description

The data used to fit the model spans 6 broad industry groupings for 72 countries over the 19 year period 1993-2011. In line with the goals of the analysis, the sample includes not only 32 OECD countries, but also 40 non-OECD countries, including many developing and emerging economies from Latin America, East Asia, South Asia, the Middle East, Africa, and Eastern Europe. In addition, to account for trade outside this

Table 1: Included Countries

Countries/regions included (72)
OECD (32 countries/regions): Australia, Austria, Belgium-Luxembourg, Canada, Switzerland, Chile, Czech Republic, Germany, Denmark, Spain, Finland, France, United Kingdom, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, South Korea, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Slovenia, Sweden, Turkey, United States
Non-OECD (40 countries/regions): Argentina, Bangladesh, Bulgaria, Bolivia, Brazil, China, Colombia, Costa Rica, Ecuador, Egypt, Ethiopia, Fiji, Ghana, Guatemala, Honduras, Hungary, Indonesia, India, Iran, Jordan, Kenya, Sri Lanka, Mauritius, Nigeria, Nepal, New Zealand, Panama, Pakistan, Peru, Russia, Senegal, Thailand, Trinidad & Tobago, Tanzania, Ukraine, Uruguay, Venezuela, Vietnam, South Africa, "Rest of World"

main sample, I also include a "Rest of World" aggregate to stand in for all excluded countries.[12]

Tables 1 and 2 provide exact listings of the countries and industry categories used, as well as the original ISIC rev. 3 industries collected within each industry grouping. The 6 industry categories used have been intentionally aggregated to emphasize broad differences in production technologies—and, especially, differences in factor intensities—across the different types of economic activities.

These differences can best be seen in the representative input-output table shown in Table 3, which uses median input-output shares across all countries and years from the input-output data described below. As the bottom two rows of Table 3 show, the "Capital-Intensive" and "Labor-Intensive" intermediate manufacturing categories differ accordingly in their respective capital and labor intensities. The Capital Goods category is also relatively labor-intensive, but differs from the other two manufacturing categories in that it is used much more intensively in investment demand, as can be seen from the two final use columns on the right. Construction similarly feeds into final demand much differently than Other Services; thus, I keep these two categories separate.

Table 3 also highlights several important facts regarding the Non-Manufacturing sector in particular. First, it is relatively upstream and is especially important as an input to capital-intensive industries. This strong upstream linkage of course reflects the fact that all four of the "MK" industries listed in Table 1 prominently involve the refining of raw materials. Second, Non-Manufacturing itself tends to be highly capital-intensive, moreso than any manufacturing sector. Third, it is also by far the highest value added industry. In sum, these observations collectively go to show that trade in non-manufacturing industries—often set aside in the related literature—may be relatively important for understanding how sectoral linkages shape the gains from trade and, similarly, how trade affects incentives for capital accumulation and growth.

Data sources. Altogether, I require data on sectoral trade and production, national aggregates—e.g., GDP, real endowments, trade balances, and investment—and information on prices for all of the countries in the

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[12] The sample of included countries is, following Di Giovanni, Levchenko, & Zhang (2014) and Levchenko & Zhang (2016) as a guide, nearly identical to the one used in these papers. The only two differences are that I do not include Taiwan, since trade data for Taiwan is difficult to obtain, and the inclusion of a "Rest of the World" region.

Table 2: Included Industries

Industry categories used (6)		
Industry category	*Code*	*Included industries*[*]
Non-Manufacturing	NM	Agriculture, Forestry, & Fishing (01-09), Mining & Quarrying (10-14)
Capital-Intensive Intermediates	MK	Food, Beverages, & Tobacco (15-16), Refined Fuels (23), Chemicals (24), Basic Metal products (27)
Labor-Intensive Intermediates	ML	Textiles & Apparel (17-19), Wood products (20), Paper products (21), Publishing & Printing (22), Rubber products (25), Mineral products (26), Fabricated Metal products (28)
Capital Goods	K	Machinery & Equipment n.e.c. (29), Electrical machinery n.e.c. (31), Computer, Electronic, & Optical equipment (30, 32-33) Motor Vehicles (34), Other Transportation equipment (35), Manufacturing n.e.c. (36)
Construction	F	Construction (45)
Other Services	O	Electricity, Gas, & Water Supply (40-41), Retail & Hospitality (50-55), Logistics (60-64), Financial, Social, & Public Services (65-95)

[*] Numerical industry codes shown in parentheses are ISIC rev. 3 2 digit level industry classifications, collected according to common reporting conventions in OECD STAN & UN National Accounts.

sample, plus the “Rest of the World”. Appendix A discusses at length how each of these variables are obtained. The main sources and methods are as follows:

Trade data is taken from UN COMTRADE. For *sectoral output,* several different sources are required. For the OECD countries, the OECD STAN database provides comprehensive production data for all manufacturing as well as non-manufacturing sectors (including construction and other services). For non-OECD countries, however, it is necessary to consult two different sources: UNIDO INDSTAT2 (which provides gross output data for all manufacturing industries) and U.N. National Accounts (which provides data for all other sectors for these countries).

The *internal trade* of a sector is then defined as a country’s gross output for that sector less its total exports. For the manufacturing sectors (and the UNIDO data in particular), output values reported in the data are occasionally either missing or less than total exports (implying negative internal trade). In these cases, I impute the missing and unreasonable values using the evolution of a country’s internal trade shares over time.

Production technologies—including input-output coefficients and factor intensities—are taken from the national input-output tables provided with the OECD Input-Output database. I also take information on the shares of each industry in investment and consumption demand from the these sources as well. All input usage and factor usage shares—i.e., the α’s in (9)—are the median coefficients for each country across all available years of input-output data. These usage shares therefore are allowed to vary across countries—reflecting differences across the different national input-output tables—but not across time. Value added shares and final demand shares, however, are also allowed to evolve over time in order to perfectly match the

Table 3: Representative Input-Output Table

	Input-Output Table (*Median Coefficients*)							
	Using industry						*Final Use*	
	NM	MK	ML	K	F	O	C	IV
Input industry								
Non-Manufacturing (NM)	0.096	0.263	0.072	0.006	0.018	0.016	0.038	0.018
Capital-Intensive Manufacturing (MK)	0.074	0.167	0.099	0.084	0.086	0.031	0.121	0.010
Labor-Intensive Manufacturing (ML)	0.012	0.034	0.185	0.091	0.162	0.022	0.042	0.020
Capital Goods (K)	0.012	0.008	0.016	0.255	0.050	0.244	0.042	0.283
Construction (F)	0.007	0.003	0.003	0.002	0.003	0.017	0.000	0.446
Other Services (O)	0.132	0.200	0.255	0.226	0.196	0.277	0.672	0.177
Value Added								
Value added share (β^v)	0.623	0.286	0.305	0.286	0.358	0.596		
Labor share (α^w)	0.260	0.440	0.570	0.570	0.560	0.520		
Capital share (α^r)	0.740	0.560	0.430	0.430	0.440	0.480		

Table shows median input and final use shares across all countries and years in the sample, using national Input-Output tables from the OECD Input-Output database

data, as I discuss further below.

As with the output data, *GDP, trade balances,* and *investment* are similarly taken from either OECD STAN (for OECD countries) or U.N. National Accounts (for the non-OECD countries). *Real endowments*, i.e., the sizes of the labor force and capital stock, are taken from the Penn World Table. Each country's set of *factor prices*—$w_{i,t}$ and $r_{i,t}$—are computed directly from the factor market clearing conditions in (11) using the data on output and endowments.

For the other prices: *investment prices* and *consumption prices* are also taken from the Penn World Table. The *industry-level prices* I use for the U.S. are available from the Bureau of Economic Analysis. Finally, all nominal values—including trade, output, prices, GDP, investment, and trade balances—are converted to 2005 U.S. dollar equivalents using the U.S. GDP deflator, so that the U.S. price level may serve as a consistent numeraire in every period.

3.2 Recovering Trade Frictions and Technology Levels

As can be readily seen from (10), a standard difficulty in identifying a country's technology level is that countries that enjoy lower trade frictions tend to produce more output, regardless of their underlying technology level. Furthermore, countries that trade more also enjoy lower input prices in the form of imported intermediate goods. Disentangling the role each of these factors play in determining sectoral output patterns therefore requires a series of steps: first, I will estimate the levels of bilateral trading frictions using a highly flexible "dummy variables only" Poisson PML specification. This estimation will also (indirectly) reveal the prices of intermediate input goods in each country. These prices, together with the exporter fixed effects from the estimation, can then be used to recover the values of each country's technology parameters.

Estimating trade frictions. Consider again the equation for industry-level trade flows in (7), which I now write in the following (nonlinear) estimable form:

$$X_{ij,k,t} = \exp\left[\underbrace{\ln\left(A_{i,k,t}c_{i,k,t}^{-\theta}\right)}_{\ln\Gamma_{ikt}} + \underbrace{\ln\left(\frac{E_{j,k,t}}{P_{j,k,t}^{-\theta}}\right)}_{\ln\Phi_{jkt}} + \underbrace{\ln d_{ij,k,t}^{-\theta}}_{\ln\eta_{ijkt}}\right] + \varepsilon_{ijkt}. \tag{28}$$

In (28), $\ln\Gamma_{ikt}$, $\ln\Phi_{jkt}$, and $\ln\eta_{ijkt}$ are explicitly written as sets of *fixed effects* that apply, respectively, to each exporter i, importer j, and symmetric trading pair $(i,j) = (j,i)$ for trade within each industry k at time t.

The use of the exporter and importer fixed effect terms $\ln\Gamma_{ikt}$ and $\ln\Phi_{jkt}$ is of course not new and is widely practiced in the trade literature to absorb the general equilibrium terms $A_{i,k,t}c_{i,k,t}^{-\theta}$ and $E_{j,k,t}/P_{j,k,t}^{-\theta}$ when estimating trade frictions. Less typical, however, is the use of a *time-varying*, *pair-specific* fixed effect $\ln\eta_{ijkt}$ to flexibly account for variation in trade frictions both across trading pairs and over time, rather than estimating trade costs based on observable proxies such as distance, colonial relationships, etc. As Egger & Nigai (2015) observe, the strict parameterization imposed by such proxies still relegates substantial "unobservable trade costs" to the error term and therefore fails to capture much of the overall variation in trade frictions. By contrast, the approach taken here only stipulates that trade costs be symmetric between pairs in each period and in each industry.[13]

Piermartini & Yotov (2016) highlight several useful properties that make Poisson PML an especially suitable estimator in this context. Most obviously, a nonlinear estimator such as Poisson PML readily allows for the inclusion of zero trade flows (whereas a log-OLS specification would not). In addition, Santos Silva & Tenreyro (2006) find Poisson PML performs well against other nonlinear estimators in the presence of different patterns of heteroskedasticity in the error term. In subsequent work, Fally (2015) shows that trade frictions estimated with Poisson PML with exporter and importer fixed effects automatically satisfy the market clearing conditions implied by "structural gravity" (e.g., as in Anderson & van Wincoop 2003, as well as in the model considered here).[14]

Less well-known, however, is the fact that a Poisson PML regression on *only dummy variables*, such as (28), can be computed numerically using simple-to-program methods borrowed from the "high-dimensional fixed effects" literature (c.f., Guimarães & Portugal, 2010; Figueiredo, Guimarães, & Woodward, 2015.) These methods permit me to swiftly and simultaneously recover all $210,748$ parameters implied by (28), a task that would normally be considered computationally infeasible using direct estimation.[15]

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[13] To be precise, I adopt "Model S" from Egger & Nigai (2015). This approach notably involves including the "internal trade" term $X_{ij,k,t}$ on the left-hand side of (28) and "dropping" the internal trade fixed effect $\ln\eta_{iikt}$ for all i, k, t. This equates to the standard assumption assuming internal trade is "frictionless"—i.e., that $d_{ii,k,t} = 1\ \forall i,k,t$. For more discussion, see footnote 11 in their paper.

[14] Technically speaking, since the error term ε_{ijkt} is effectively absorbed into $d_{ijkt}^{-\theta}$ (in order to fit the trade data exactly), this property does not depend on the choice of estimator. Nonetheless, it should still be considered desirable that *fitted* values for trade frictions – i.e., the η_{ijkt}'s— are computed with the general equilibrium constraints from the model taken into account. Appendix B adds further details on how PPML implicitly enforces these constraints.

[15] Alternatively, another feasible approach would be to instead use a "ratio" method to infer trade frictions *a la* Head & Ries

Aggregating trade frictions. Ideally, instead of tracking changes in bilateral trade costs between each pair of countries over time, I would like a single measure of each country's aggregate level of "globalization" in each period, such that China's rate of globalization may be consistently and succinctly compared against those of its trading partners. To this end, I introduce the following decomposition of trade frictions,

$$\ln d_{ij,k,t}^{-\theta} = \underbrace{\ln d_{i,k,t}^{-\theta} + \ln d_{j,k,t}^{-\theta}}_{\text{border costs}} + \underbrace{\ln \widetilde{d}_{ij,k,t}^{-\theta}}_{\substack{\text{bilateral} \\ \text{component}}}, \tag{29}$$

where the country-specific "border cost" term $d_{i,k,t}$ is intended to summarize the aggregate *level* of a country's trade costs in sector k at time t. Note this term is *symmetric*, in that these costs apply equivalently to a country's exports—where it appears as "$d_{i,k,t}^{-\theta}$"—as well as its imports—where it appears again as "$d_{j,k,t}^{-\theta}$". This choice is to recognize that globalization may occur either through import-based measures—e.g., through the lowering tariffs and other import restrictions—or though the adoption policies and/or technologies that specifically promote exporting.

To make these "border cost" terms consistently comparable over time, I assume that the bilateral component of trade costs, $\{\widetilde{d}_{ij,k,t}\}$, have no "aggregate effect" on any country's total trade flows. In other words, each country m's border cost for industry k at time t may be obtained by solving the following system:

$$d_{m,k,t}^{-\theta} = \frac{EX_{m,k,t} + IM_{m,k,t}}{\sum_{j \neq m} \left\{ \Gamma_{mkt} \Phi_{jkt} + \Gamma_{jkt} \Phi_{mkt} \right\} d_{j,k,t}^{-\theta}}. \tag{30}$$

(30) is obtained by stipulating that each country's aggregate industry-level trade volume in each year, $EX_{m,k,t} + IM_{m,k,t}$, does not depend on the "bilateral component" of trade costs, $\{\widetilde{d}_{ij,k,t}\}$. In more intuitive terms, this decomposition assures that all "melting" of the world's total level of iceberg trade costs (i.e., globalization) can only occur through changes in each country's unilateral component of trade costs, $d_{i,k,t}$. Changes in the bilateral component, $\widetilde{d}_{ij,k,t}$, on the other hand, can only shuffle some of the overall "world iceberg" present in each period from one pair of trading partners to another.

Recovering Prices and Technology levels. In principle, after estimating (28), theory-consistent values for all prices and technology levels may be obtained using the fixed effects terms Φ_{jkt} and Γ_{ikt}. In practice, however, recovering technology levels in particular requires following a detailed series of steps, which must be described carefully.

For most sectors, the importer fixed effect directly delivers the importing country's price level, $P_{j,k,t}$; that is,

$$P_{j,k,t} = \Phi_{jkt}^{1/\theta} \cdot E_{j,k,t},$$

(2001) or Novy (2013). One downside of using ratios here is that, by construction, this method fails to simultaneously recover the exporter and importer terms $A_{ikt} c_{ikt}^{-\theta}$ and $E_{jkt}/P_{jkt}^{-\theta}$ (as the main benefit of using ratios is to eliminate these terms algebraically).

where $E_{j,k,t}$ is j's total level of expenditure from the data. Identifying the full set of price levels for all countries within each industry-year does require specifying one country's price level as a numeraire. Accordingly, I set all industry-level price levels for the U.S., $\{P_{US,k,t}\}$, equal to actual U.S. industry prices taken from data.[16]

The technology level of each exporter is similarly contained within the exporter fixed effect Γ_{ikt}, but extracting this term specifically requires some additional work. By the definition of Γ_{ikt}, we have that $A_{i,k,t}^{1/\theta} = \Gamma_{ikt}^{1/\theta} \cdot c_{i,k,t}$. The input bundle cost, $c_{i,k,t}$, in turn depends not only on factor prices $w_{i,t}$ and $r_{i,t}$ (which can be computed from data), but also on the set of local intermediate goods prices $\{P_{i,k,t}\}$. For the four sectors for which I have bilateral trade data, the price levels recovered in the previous step—the $P_{j,k,t}$'s—also serve as the intermediate input prices that enter the input bundle cost in (9).[17] However, I do not yet have a complete set of intermediates prices, since I cannot use (28) to estimate prices for Construction (which is non-traded) nor Services (for which bilateral trade data is generally not available).

Usefully, since price levels for all sectors except two are now known, I can back out the remaining sectoral prices using data on national consumption and investment price levels from the Penn World Table, $P_{i,C,t}$ and $P_{i,IV,t}$. In particular, $P_{i,O,t}$ and $P_{i,F,t}$ must be given by

$$P_{i,O,t} = \left[\frac{P_{i,C,t}}{\prod_{k \neq O} P_{i,k,t}^{\gamma_{i,C}^{k}}}\right]^{\frac{1}{\gamma_{i,C}^{O}}}; \qquad P_{i,F,t} = \left[\frac{P_{i,IV,t}}{\prod_{k \neq F} P_{i,k,t}^{\gamma_{i,IV,t}^{k}}}\right]^{\frac{1}{\gamma_{i,IV}^{F}}}. \tag{31}$$

This step is made simpler by the fact that construction is not used in consumption demand, i.e., $\gamma_{i,C}^{F} = 0$. $P_{i,O,t}$ can then be computed directly using prices from the "traded" sectors plus the consumption price level $P_{i,C,t}$, with $P_{i,F,t}$ then immediately following by way of the investment price.

Input bundle costs for all sectors may now be computed from (9) using information on factor prices and the now-recovered price levels for each sector. Furthermore, a generalized way of recovering the technology level for *all* sectors may now be written as follows:

$$A_{i,k,t}^{1/\theta} = \pi_{ii,k,t}^{1/\theta} \cdot \left(\frac{c_{i,k,t}}{P_{i,k,t}}\right), \tag{32}$$

where I have used the fact that the internal trade share, $\pi_{ii,k,t}$, is equal to $\Gamma_{ikt} \cdot P_{ikt}^{\theta}$.[18] Note that, for Services, even though I do not observe bilateral Services trade, the model still dictates that Services technology can be determined from (32) using *internal trade* values, which I do observe. Finally, the technology level for Construction also follows the same form, only using $\pi_{ii,F,t} = 1$, since Construction is non-traded.

Trade frictions for Services. As noted, I do not observe bilateral trade in Services. Yet the Services trade

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[16] In econometric terms, the fixed effects Γ_{ikt} and Φ_{jkt} are naturally collinear within each industry and time period. One additional restriction per industry-year is required in order to recover all needed parameters, which is provided by the U.S. price level.

[17] The factor prices which appear in (9) are computed via the factor market clearing conditions in (11).

[18] Using $A_{i,k,t}^{1/\theta} = \Gamma_{ikt}^{1/\theta} \cdot c_{i,k,t}$ also yields the same answers. In the Appendix, I show the "dummies only" Poisson PML approach used in (28) ensures $X_{ii,k,t} = \Gamma_{ikt} \cdot \Phi_{ikt}$ always.

volumes of each country need to be accounted for in order to match its overall trade balance. How then can we model trade for a sector in we only have information on unilateral trade flow values rather than bilateral flows?

The "trick" for modeling Services trade relies on a similar aggregation of total trade frictions as in (30). While I obviously cannot estimate bilateral trade frictions in this case, I do in fact have all the needed parameters to estimate the equivalent "border costs" that would apply to services trade in any period. Specifically, since I now have values $\{A_{i,O,t}\}$, $\{c_{i,O,t}\}$, and $\{P_{i,O,t}\}$, I can now write the following:

$$d_{m,O,t}^{-\theta} = \frac{EX_{m,O,t} + IM_{m,O,t}}{\sum_{j \neq m} \left\{ A_{m,O,t} c_{m,O,t}^{-\theta} \frac{E_{j,O,t}}{P_{j,O,t}^{-\theta}} + A_{j,O,t} c_{j,O,t}^{-\theta} \frac{E_{m,O,t}}{P_{m,O,t}^{-\theta}} \right\} d_{j,O,t}^{-\theta}}, \tag{33}$$

which follows the same form as (30), only with the components of Γ_{ikt} and Φ_{jkt} written out explicitly.

Similarly, it is also useful to define the following "export-side" and "import-side" border costs $d_{m,O,t}^{ex}$ and $d_{m,O,t}^{im}$ for each country's Services trade:

$$d_{m,O,t}^{ex-\theta} = \frac{EX_{m,O,t}}{A_{m,O,t} c_{m,O,t}^{-\theta} \sum_{j \neq m} \frac{E_{j,O,t}}{P_{j,O,t}^{-\theta}} d_{j,O,t}^{im-\theta}}; \qquad d_{m,O,t}^{im-\theta} = \frac{IM_{m,O,t}}{\frac{E_{m,O,t}}{P_{m,O,t}^{-\theta}} \sum_{j \neq m} A_{j,O,t} c_{j,O,t}^{-\theta} d_{j,O,t}^{ex-\theta}}. \tag{34}$$

By solving for $d_{m,O,t}^{ex}$ and $d_{m,O,t}^{im}$ from (34), I can then construct an artificial bilateral trade cost matrix for Services $\{d_{ij,O,t}\} = \{d_{i,O,t}^{ex} \cdot d_{j,O,t}^{im}\}$ which will exactly match each country's total exports and imports from the data. This artificial trade cost matrix will then be used to model Services trade in the counterfactual.

3.3 Constructing Shocks

The relevant counterfactual for the simulation analysis will be: "What if China's sectoral productivities and aggregate trade barriers had evolved at *merely* the same rate as those of the rest of the world?" This perspective will help isolate China's unique contribution to overall world trade growth in each industry as well as anticipate a possible near-future where China grows and liberalizes at the same rate as the rest of the world.

Define $\widehat{A}_{i,k,t}^{1/\theta} \equiv A_{i,k,t}^{1/\theta} / A_{i,k,t\text{-}1}^{1/\theta}$ as i's rate of productivity growth in sector k at time t and, similarly, define $\widehat{d}_{i,k,t} \equiv d_{i,k,t} / d_{i,k,t\text{-}1}$ as its rate of trade liberalization. The main set of counterfactual shocks I will consider will be to isolate and then subtract China's specific contribution to world technology growth and trade liberalization, $\{\widehat{A}_{CHN^+,k,t}^{1/\theta}\}$ and $\{\widehat{d}_{CHN^+,k,t}\}$, where the "$CHN^+$" subscript denotes the denotes the difference in rate of growth between China and the rest of the world.

Obtaining these shocks of course first requires constructing aggregate measures of both sectoral productivity growth and trade liberalization for all non-China countries. For productivity, this is just the level of technology that would preserve the total level of output in each industry were all non-China countries treated as a single country. In other words,

$$A_{nonCHN,k,t}^{1/\theta} \equiv \left\{ \sum_{i \in nonCHN} A_{i,k,t}^{-1/\theta} \times Y_{i,k,t} \right\}^{-1} \times \sum_{i \in nonCHN} Y_{i,k,t}. \tag{35}$$

Trade barrier levels in the non-China region are then aggregated using each country's internal trade value in each industry-year, $X_{ii,k,t}$, and using the assumption that the "border effect", $d_{i,k,t}^{-\theta}$, affects trade symmetrically in both directions.[19] Explicitly,

$$d_{nonCHN} \equiv \left\{ \sum_{i \in nonCHN} d_{i,k,t}^{-2\theta} \times X_{ii,k,t} \right\}^{-\frac{1}{2\theta}} \times \left\{ \sum_{i \in nonCHN} X_{ii,k,t} \right\}^{\frac{1}{2\theta}}. \tag{36}$$

Full set of "shocks". The full shock vector at time t may be summarized as

$$\Psi_t = \{\widehat{A}_{i,k,t}^{1/\theta}, \widehat{d}_{ij,k,t}, \gamma_{i,C,t}^{k}, \gamma_{i,IV,t}^{k}, \beta_{i,k,t}^{v}, D_{i,t}, L_{i,t}, \chi_{i,t}, \widehat{\phi}_{i,t+1}\}.$$

In addition to changes in technologies and trade barriers, Ψ_t also allows for time-variation in (respectively) the composition of consumption and investment demand, sectoral value added shares, national trade balances, labor endowments, investment efficiencies, and inter-temporal preference shocks. Of these, only investment efficiencies and preference shocks remain to be specified.

The set of investment efficiencies$\{\chi_{i,t}\}$ are backed out of the law of motion for capital, (3), using data on capital and investment. These shocks ensure that initial equilibrium investment values in one period will always re-produce the correct values for capital in the next period. The additional set of time preference shocks $\{\widehat{\phi}_{i,t+1}\}$ are then also needed so that the Euler equation in (5) always reproduces investment expenditure from the data in the absence of shocks. Note that investment choices in the present year depend dynamically on expectations about future years, including expectations about years beyond the end of the data. Thus, these shocks must be solved for numerically, using a procedure I describe in the the Appendix.[20]

External parameters. Values for key external parameters are shown in Table 4. The value for the trade elasticity, $\theta = 4$—which is common across all sectors—is taken from Simonovska & Waugh (2014). The parameters governing capital adjustment costs (κ), capital depreciation (δ), and time preferences (ρ) are taken to resemble those used in EKNR.

In the sensitivity analysis, I will examine how results depend on the values used for the trade elasticity and

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[19] Since $X_{ii,k,t} = \Gamma_{ikt} \cdot \Phi_{ikt}$, the idea here is to implicitly weight by each country i by its intrinsic desirability as a trade partner, both as an exporter and as an importer.

[20] Note that I differ from EKNR in the recovery of these two shock vectors. EKNR recover their investment efficiency shocks dynamically in order to match data on investment, similar to how I recover time preference shocks here. This is because they do not observe capital stocks in each period directly. The time preference shocks in their paper are used to match each country's trade balance, which is taken as exogenous in the present paper. In principle, I could follow EKNR in also having an endogenous trade balance. However, this would require an additional set of shocks in order for actual trade balances, actual investment, and actual capital stocks to all hold in the initial equilibrium. See the Appendix for notes on endogenizing the trade balance in this framework.

Table 4: Parameter Values

Industry	Value
Trade elasticity (θ)	4.00
capital adjustment (κ)	0.55
Depreciation (δ)	0.05
Time preference (ρ)	0.95

for capital adjustment. As is well-known from ACR, a higher trade elasticity should generally mean lower "gains from trade". However, in a multi-sector context, higher θ also means that the sectoral composition of output will be more sensitive to changes in relative prices. Thus, it will be worth investigating whether a higher trade elasticity can actually work in favor of "dynamic" gains from trade by promoting incentives for capital accumulation.[21]

For the capital adjustment parameter, a higher κ implies lower capital adjustment costs, whereas a lower value implies capital stocks adjust more slowly over time. As I will show, while incentives for investment vary intuitively with κ, the main results are only mildly sensitive to this parameter.

4 China versus the World, 1993-2011

To take stock of the analysis thus far, I have constructed a dynamic model of the world economy and described how to use that model to forensically recover changes in sectoral productivities and trade frictions over time. Before turning to the simulation results, this section first documents what the model reveals about the exceptionally high rates in productivity growth and trade barrier reduction seen in China versus in the other parts of the world.

Figures 2-7 present this comparison for each sector for the years 1993-2011. Consider first the Non-Manufactured goods sector, depicted in the left-hand panel of Figure 2. The figure confirms that China's Non-Manufacturing productivities have been relatively flat throughout the period, as have those of other countries. In the U.S., they have actually been gradually decreasing. While this may seem curious, note that, because I compute all prices in the model using actual U.S. industry-level prices as a benchmark, all productivity levels for the U.S. should be regarded as having a close connection to the data. It is also notable that the U.S.'s productivity for Non-Manufactured products is substantially higher than the world average, implying that the U.S. actually has a strong comparative advantage in this sector.

Turning to trade frictions, the right-hand panel of Figure 2 shows that China's rate of trade liberalization has exceeded those of its trading partners in Non-Manufacturing, but only by a moderate amount. It is also notable that China's level of trade barriers still greatly exceeds those of the rest of the world, suggesting there still exists substantial potential for further gains from trade liberalization by China in the future.

Figure 3 then focuses on Labor-intensive Intermediates. In this case, I observe significantly more pronounced productivity growth and trade liberalization in China than in the world as a whole, though China's

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[21] Naturally, experimenting with sector-specific θ's, as in Caliendo & Parro (2015), would be another useful extension here.

barriers to trade do spike upwards during the "trade collapse" of 2008 and 2009 (as do the U.S.'s). Compared with Non-Manufactured goods, it is notable that China's level of technology in the ML sector (a manufacturing sector) both starts out lower relative to that of the world at large and also rises faster during the period. We also do see (weak) productivity growth for the world as a whole, including for the U.S.

The other two manufacturing sectors, Capital-intensive Intermediates and Capital Goods, also display similar results. In each of these sectors, China's productivity starts out relatively low relative to the rest of the world in each of the other manufacturing sectors—implying an initial comparative disadvantage—then narrows the gap rapidly over the period. One important difference between the three manufacturing sectors, however, is that China's trade liberalization in Capital Goods has been by far the most dramatic, bringing its level of trade frictions much more closely in line with those of the rest of the world as compared with the other traded sectors. Indeed, the right-hand panel of Figure 5 shows that China's trade barriers in capital goods fell by more than a third during 1997-2003 alone.

Finally, Figures 6 and 7 show results for the Construction sector (which is non-traded) and for Other Services (which is only lightly traded). Notably, as discussed in Section 3.2, the productivities for these sectors are inferred (respectively) from national investment and consumption prices. For the construction sector, inferred productivities are actually falling throughout the period, reflecting large, steady increases in construction prices throughout the world. China's construction productivity similarly falls, but exhibits substantially more volatility, especially during the Asian financial crisis of the late 1990s (which likely weighed heavily on Chinese investment).

Results for the Other Services sector, meanwhile, find that services productivities have increased overall, albeit unevenly. One questionable finding that arises here is that China's services productivity appears to be consistently higher than that of the U.S. The reason behind this strange calculation is the low level of China's consumption price relative to the prices of tradable goods during the period. In order to match this pattern, the model infers that China's price for Other Services is correspondingly low—implying a high level of productivity. In addition, because China's Other Services productivity is measured to be so high, its level of trade frictions must be similarly large, in order to match China's relatively low level of services exports in the data.

Obviously, this finding illustrates an important limitation in trying to back out services productivities using national consumption prices. I address this concern in two different ways. First, for the counterfactual exercises, I only consider shocking the four tradable good sectors, such that the Construction and Other Services are not directly affected. Second, as an additional sensitivity check, I re-calculate all sectoral prices and technologies, including China's consumption price, under the assumption that China's TFP for Other Services is the same as the aggregate Other Services TFP computed for all non-China countries. Reassuringly, this exercise leaves the main conclusions of the paper intact, as I will show in Section 5.4.

Summarizing the 1993-2007 period. Table 5 summarizes these results in terms of broad (annualized) trends for the years 1993-2007 preceding the Great Recession. As Figures 2-5 have already suggested, China's rates productivity growth and trade liberalization have exceeded those of the rest of the world for all four tradable goods sectors. Furthermore, comparing how these trends differ across individual sectors, Table 5 likewise confirms that China's "catch-up" in productivity growth has been strongly biased towards the manufacturing sector (as opposed to Non-Manufacturing) and that China's trade liberalization has been heavily concentrated in Capital Goods.

Recalling one of the principal goals of this paper—examining how the changing sectoral structure of trade can induce static versus dynamic gains from trade—these last two observations are worth highlighting. Since the Non-Manufacturing sector tends to be highly capital-intensive, China's change in comparative advantage with respect to non-manufactured goods should stimulate investment and capital accumulation for most countries. Similarly, as China becomes a major producer and exporter of capital goods, this drive should capital accumulation from the other direction, by lowering the prices of investment goods worldwide. The following section considers the quantitative implications of these two observations in detail.

The 2008-2011 period. Before turning to the quantitative analysis, however, I pause first to also summarize how these trends continued to play out during the recession and recovery period of 2008-2011 period. These further results are shown in Table 6. Notably, the gap in productivity growth between China and the world outside of China grows larger across all four traded goods sectors. Even though China's tendency towards more open borders reverses in two of the four sectors, it will be worth examining to what extent the continued expansion of trade with China supported the world economy during a period of instability and weakness.

5 Quantifying China's contribution to World Growth

Having fully characterized how China's productivity growth and globalization differed across sectors than in the world at large over the last two decades, I now wish to know: what quantitative effects did these changes have on world GDP, investment, and welfare?

Each table in this section shows how much changes in China's sectoral productivities and/or trade barriers during each of these period contributed to actual real world GDP growth and other outcomes, versus a counterfactual in which one or both of these factors is adjusted to match changes in the world at large. In all cases, I quantify these effects in three different ways: (i) from a strictly "short-run" static perspective, treating the capital endowment as given, (ii) from a fully dynamic "medium-term" perspective, examining how much China's rise stimulated capital accumulation during the period, and (iii) from a "long-run" dynamic perspective, focusing on the implications for steady state outcomes and long-run discounted welfare.

For space reasons, I only show results for a representative sample of the 72 countries included in the analysis. Full results will be made available separately at a later date.

5.1 China's contribution to World Growth, 1993-2007

In Table 7, I first examine the combined effects of China's high rates of productivity growth and trade liberalization—in essence, using the bolded $\{\widehat{A}^{1/\theta}_{CHN^{+},k,t}\}$ and $\{\widehat{d}_{CHN^{+},k,t}\}$ that were highlighted in Table 5.

The first main takeaway from Table 7 is that the combined effects of these shocks on other countries are not especially large in most cases, at least not from a short-term or medium-term perspective. Overall, the full dynamic model finds that these trends raised 2007 real GDP in the rest of the world by 0.48%.[22] Since non-China world real GDP grew by 64.94% between 1993 and 2007, this amounts to saying that these factors have contributed 1.21% of that growth, as mentioned in the introduction.[23] Compared with the corresponding figure for the Static model (0.28%), I find that about $\sim 40\%$ of these effects can be attributed to increased investment and accumulation of capital. Meanwhile, China itself, as the direct beneficiary of its own productivity growth, exhibits much larger effects across the board.

Can China's massive expansion of trade during this period really have had only such a seemingly small effect on growth in other countries? Skeptical readers should keep in mind some particular aspects of the analysis that tend to work against large gains from trade—in particular, the adherence to constant returns and the inclusion of the non-traded portions of the economy. Nonetheless, an alternative interpretation of the findings in Table 7 is that, because capital takes time to accumulate in response to trade shocks, most of the transitional growth effects induced by China are actually still in the process of materializing. Sticking with the year 2007 dynamic results, note that one of the main effects of China's rise has been to raise almost every country's 2007 investment share of expenditure ("x").[24] While the increase in capital accumulation due to this shift only has a (relatively) modest effect on growth as of 2007, the last three columns of Table 7 suggest much larger implications for the long-run, when the world economy reaches its eventual steady state. All in all, I find that China's productivity growth and trade liberalization has raised long-run real GDP for other countries by a combined 5.30% and has raised their expected long-run consumer welfare (**U**) by 0.75%.[25]

The largest real GDP gains are mostly concentrated in developing countries and/or near-neighbors of China. The largest gainers according to the static framework prominently include Viet Nam (2.42%), Kazakhstan (1.34%), Malaysia (1.27%), and the Philippines (0.59%). Other resource-oriented economies across other regions—e.g., Australia, Chile, Ethiopia, Jordan, Peru, and Tanzania—also do comparatively well. Naturally enough, these countries also tend to enjoy the largest real GDP growth when capital accumulation is taken into account. Vietnam, however, is an slight exception in this regard. Unlike most countries, its non-manufacturing sector is highly labor-intensive; thus, its rental-wage ratio falls, dampening its incentive to accumulate capital over the long-run.

Looking beyond the largest beneficiaries of China's rise, it is decidedly not true in general that real GDP

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[22] "Real GDP" here always refers to an "expenditure-side" measure, using a geometric average of a country's overall price level for expenditure: $rGDP_{i,t} = \left[P^{1-x_{i,t}}_{i,C,t} P^{x_{i,t}}_{i,IV,t}\right]^{-1} \cdot GDP_{i,t}$.

[23] Here, the relevant calculation for "contribution to growth" is: $1.6494/1.0048 = 1.6415$; $1-(1.6415-1)/(1.6494-1) = 0.0121$

[24] The only exceptions shown in the table are Bolivia, India, and Vietnam. Of the countries not shown, Ireland and Norway are the only other exceptions.

[25] Obviously, these calculations suffer from ruling out any further shocks after the year 2007, a subject I return to in Section 5.3.

outcomes obtained from the static model correspond directly to dynamic outcomes from the full model. Take Germany as a useful example. Germany is one of a handful of countries that, if we simply take its capital endowment and investment decisions as given in 2007, at first appears to only realize a very small (0.01%) increase in real GDP from a static perspective. However, the additional results for the static model also show an increase in Germany's rental-wage ratio (r/w) as well as a decrease in the relative price of investment versus consumption in Germany. Intuitively, these additional results suggest that, in addition to the effects identified by the static model, we should also expect to see higher rates of investment and capital accumulation for Germany when we turn to the dynamic model. Indeed, this is exactly what I observe: in the dynamic model, Germany's 2007 capital stock is 0.25% higher in the baseline than in the counterfactual, its investment share is 0.69% higher, and its real GDP now increases by 0.13%—still only a small gain, but considerably larger than the result obtained from the static model.

Similar results are also present for several other, mostly developed countries. France, Czech Republic, Iceland, Mexico and Japan offer other examples of OECD countries for which "static" real GDP gains fall short of a tenth of a percent. One country, Italy, even suffers a small loss of 0.04%. However, like Germany, all of these economies enjoy a higher rental-wage ratio and a lower relative price of investment goods in a static setting, which again translate into larger real GDP gains when dynamics are taken into account. Furthermore, all of these countries are expected to realize quantitatively large real GDP gains (in excess of 1%) at the long-run steady state, as well as positive overall long-run welfare gains.

Tables 8 and 9 then consider, respectively, the effects that China's trade barrier reductions and sectoral productivity changes and each have had in isolation. To be brief, this decomposition reveals two main takeaways of interest. First, even though China's productivity growth has by far a larger effect on China itself, it is actually trade barrier reductions that have a larger positive impact on other countries in a strictly static setting (0.22% vs. 0.17%). Yet, second, dynamic outcomes for real GDP, investment, capital stocks, and welfare are all generally larger for the case when I only shock China's sectoral productivities (in Table 9). That is to say, even though China's sectoral productivity growth contributes relatively less of the combined effect in a strictly static setting, it has nonetheless induced disproportionately more of the ensuing dynamic effects through its impact on the rental rate of capital and the price of investment.

5.2 The Sectoral Dimension in Focus

Continuing, for now, with the 1993-2007 period, I wish to understand further: what is it exactly about the changing sectoral structure of China's trade that produces such a strong dynamic response in other countries? I tackle this question using two additional sets of counterfactuals. First, I perform a set of "balancing" exercises which preserve China's overall productivity growth, but remove its change in comparative advantage across one or more different sectors. Second, shifting the focus to the dynamic responses occurring in other countries, I consider various modifications of the model which specifically shut off the "dynamic sectoral linkages" highlighted in Section 2.5.[26]

Removing changes in comparative advantage. The thought experiment I undertake here is as follows: what if, rather than growing at different rates, China's sectoral productivities all grew at a common rate relative to the rest of the world, but leaving China's overall real GDP growth unchanged? More precisely, I compute $\{\widetilde{A}^{1/\theta}_{CHN,k,t}\}$, the counterfactual set of sectoral productivities for China at time t (for tradable goods only), using the following:

$$\frac{\widetilde{A}^{1/\theta}_{CHN,k,t}/\widetilde{A}^{1/\theta}_{CHN,k,t-1}}{A^{1/\theta}_{nonCHN,k,t}/A^{1/\theta}_{nonCHN,k,t-1}} = g_t,$$

where g_t is a common relative growth rate across sectors that reproduces China's real GDP when solving the static model, in order to provide a consistent basis for comparison.

Table 10 shows the results of removing China's overall change in comparative advantage across all sectors. Echoing the results of a similar exercise by Di Giovanni, Levchenko, & Zhang (2014), I find that China's relative changes in sectoral productivities have had a (small) net positive impact on the other countries of the world in a static setting. Several countries are made worse off in this case, however. This group not only includes France, Germany, Sweden, and Iceland—countries which only experienced small gains before—but also now notably includes South Korea and Japan, two countries with close trade ties to China that have apparently suffered from China's change in comparative advantage.

The dynamic implications in this case are similar to those shown in Table 9, which also included absolute TFP changes, but for the fact that relative price of investment in other countries is not impacted nearly as much. As a result, while all countries eventually attain higher long-run real GDPs at steady state, Germany and South Korea do not realize higher long-run welfare.

Table 11 then digs deeper into this set of results by decomposing China's change in comparative advantage into two basic components: (i) a change in comparative advantage *across* manufacturing versus the Non-Manufacturing sector, and (ii) a change in comparative advantage *within* manufacturing, focusing only on the three manufacturing sectors. To examine the first component, I eliminate the difference in relative TFP growth between China's Non-Manufacturing sector and the three manufacturing sectors (as a whole). To examine the second, I preserve this difference and instead eliminate relative TFP growth differences within manufacturing. In both cases, I again adjust China's overall productivity growth so that its real GDP remains unchanged.

Interestingly, the shift in China's comparative advantage from Non-Manufacturing to manufacturing as a whole explains virtually all of the positive effects of its overall shift in comparative advantage, and then some. Furthermore, this holds true both in a static as well as a dynamic setting. Recall from Section 4 that, within manufacturing, China's TFP growth relative to the rest of the world has been fastest in Capital-

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[26] The use of the term "balancing" is intentionally meant to evoke similar TFP "balancing" exercises performed in Di Giovanni, Levchenko, & Zhang (2014) and Levchenko & Zhang (2016).

intensive Intermediates, as opposed to Labor-intensive Intermediates and Capital Goods. Panel B of Table 11 therefore captures the effect of this relative shift within China's manufacturing towards the MK sector, which, in isolation, has depressed capital-intensive production in other countries and driven up the price of investment. These effects are both generally dominated, however, by the general shift of China's comparative advantage towards manufacturing as a whole.

Appraising "dynamic sectoral linkages". As shown analytically in Section 2.5, the overall dynamic gains from trade may hinge crucially on the interplay between changes in sectoral prices and incentives for capital formation. The results presented thus far suggest these linkages are indeed important for assessing the effects of increased trade with China, but have not attempted to quantify their contribution specifically.

To provide this clarity, I consider modifications of the full model which remove differences in factor intensities across sectors and/or differences in the final usage of each sector in consumption versus investment. As can be readily seen from re-examining 27, setting $\alpha_{i,k} = \alpha_i$ (which removes factor intensity differences) and then $\gamma^k_{i,C,t} = \gamma^k_{i,IV,t} = \gamma^k_{i,t}$ (which removes final usage differences) completely nullifies the contribution of "dynamic sectoral linkages" to the gains from trade. Importantly, I construct α_i and $\gamma^k_{i,t}$ such to preserve (respectively) the overall capital share in value added and overall final demand share of each sector, such that the model can be again be fitted to the original data as before.[27]

Table 12 shows how my main results are affected by removing these linkages from the model. To facilitate direct comparisons, each panel in 12 repeats the main experiment of analyzing the combined effects of productivity changes and trade barrier reductions, as in Table 7. As I show in Panel A of Table 12, removing both factor intensity differences and final usage differences dramatically shrinks the effect of China's rise on long-run real GDP, from 5.30% (in Table 7) now down to only 0.83%. Panels B and C then reveal that, of the two, factor intensity differences have contributed relatively more to dynamic gains, though removing heterogeneity in final demand still reduces effects on long-run GDP by 45% (from 5.30% to 2.94%). Long-run discounted welfare is also affected similarly across the three experiments (albeit less severely).

Finally, an interesting (and useful) curiosity found in Table 12 is the *very* close correspondence between "static" real GDP effects with and without dynamic sectoral linkages. This is for two reasons. First, note that the adjustment applied to final usage shares does not affect how I compute changes in a country's overall price level in the static model (that is, $\widehat{P} = \widehat{P}_C^{1-x}\widehat{P}_{IV}^{x} = \prod_k \widehat{P}_k^{\gamma_k}$ always.) Second (and more interestingly), recall from Table 7 that the changes shown for the rental-wage ratio ($\widehat{r}/\widehat{w}$), while clearly important for the dynamic results, were actually quite small in magnitude (typically no larger than 0.10%). These small changes in relative factor rewards simply are not large enough to affect the gains from trade in a static setting.

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[27] Specifically, since $\alpha_{i,k}$ does not vary across time, I take α_i to b the median value (across years) of $(\sum_k \alpha^r_{i,k} \cdot \beta^v_{i,k,t} \cdot Y_{i,k,t})/GDP_{i,k,t}$. The implied time-variation in α_i (which I discard) is minimal. $\gamma^k_{i,t}$ is simply $(1-x_{i,t}) \cdot \gamma^k_{i,C,t} + x_{i,t} \cdot \gamma^k_{i,IV,t}$.

5.3 The 2008-2011 Recession and Recovery Period

An admitted weakness of the preceding exercises is that I treat the 1993-2007 period in isolation, under the assumption the world economy transitions smoothly to a future steady state and ignoring any further shocks. Obviously, this perspective fails to take into account the major global recession that followed in 2008-2009. This section examines this latter period more specifically, again asking the same question: what would have happened to world GDP during the period had China's productivity growth and openness to trade matched those seen in the rest of the world?

The focus here is more general than the preceding analysis of the 1993-2007 period. In Table 13, I again examine the combined effects of both China's sectoral productivity growth and trade barrier changes, only this time for the years 2008-2011. The idea is to simply quantify how much China's continued rapid expansion of trade during this period supported the world economy during a period of economic instability. Notably, when I examine the overall effect on 2011 real GDP computed using the dynamic model, I find a further increase of 0.59% in the rest of the world's real GDP for this period alone, actually exceeding its contribution to real GDP growth from the earlier (and much longer) 1993-2007 period. Since the rest of the world adds 7.164 percentage points of real GDP growth between 2008 and 2011, this finding implies that China contributes fully 8.78% of this growth, a much larger contribution than in the pre-recession period.[28]

Why is China's impact so much larger in this latter period? Naturally, the recession itself played a role, creating a void for China to step into. Referring back to Figures 2-5, notice that overall world productivities in all four traded goods sectors suffered a "dip" during the 2008-2009 period. Meanwhile, Chinese productivity continue to grow and close the gap. As Table 6 shows, non-China TFP growth is overall negative during the period, buoyed only by a surge in non-manufacturing TFP in 2009 (following the dip in 2008).

Meanwhile, China's TFP growth in the traded goods sectors is found to be, if anything, faster than it was before the recession. Importantly, there is one exception: whereas before, China's surge in manufacturing productivity was (weakly) biased towards capital-intensive goods, here, the MK sector is the one sector that grows more slowly than the others. Thus, the net effect of these productivity changes with respect of the world would have been, in all cases, to raise the rental/wage ratio in the rest of the world and/or drive down the price of investment. Accordingly, capital accumulation plays a much larger role in determining the overall effects on 2011 real GDP growth and (projected) long-term growth than for the earlier period.

5.4 Sensitivity Analysis

I perform two main sensitivity checks, both using the 1993-2007 period. The first is to check whether the method used to construct China's TFP for Other Services—which led to relatively high services productivity values—is driving how I compute China's change in comparative advantage and its effects. As an alternative, I re-calculate China's consumption price, and adjust all of China's sectoral TFPs accordingly, under the assumption that China's TFP for Other Services matches the average Other Services TFP of all other

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[28] To obtain this figure: $1.0716/1.0059 = 1.0653$; $1-(1.0653-1)/(1.0716-1) = 8.79\%$.

countries, which is computed using (35). Table 14 then re-examines the effect of China's changing sectoral productivities and trade barrier reductions using this alternate set of TFPs. Reassuringly, these results are mostly very similar to those originally shown in Table 7.

In the second part of the sensitivity analysis, in Table 15, I experiment with varying both the trade elasticity (θ) and the capital adjustment cost parameter (κ). The set of countries shown is the same as in Table 11. For the trade elasticity, as one might expect based on the logic of Arkolakis, Costinot, & Rodríguez-Clare (2012), both real GDP and welfare effects are generally larger when θ is small (as in Panel A, where $\theta = 2$) than when θ is larger (as in Panel B, where $\theta = 6$). Nonetheless, it is interesting to note that, as θ increases, the effects identified by the static model contribute relatively less of the overall gains in real GDP obtained in a dynamic setting. Indeed, when $\theta = 6$, static real GDP gains for China's trading partners are lower by a full three-quarters versus when $\theta = 4$ (from 0.28% to 0.07%). Meanwhile, the change in long-run welfare from the full dynamic model ($\widehat{\mathbf{U}}$) falls by only a third (from 0.75% to 0.51%).

Panels C and D of Table 15 then experiment with varying the degree of capital adjustment costs, κ. Intuitively, higher κ implies that capital is able to accumulate more quickly over time. Indeed, Panel C shows that, when $\kappa = 0.75$, the effects of China on medium-term (1993-2007) real GDP growth are mildly larger as compared to the baseline (where $\kappa = 0.55$). Using a lower value for κ, in Panel D, then leads to an opposite (but still similar) result. The main implications of varying κ only become evident in the long-run: because capital takes longer to accumulate when κ is low, steady state takes longer to reach, and the eventual steady state capital stocks and GDP levels wind up being significantly larger. Nonetheless, the implications for the overall change in long-run discounted welfare ($\mathbf{U}$) remain strikingly similar regardless of capital adjustment costs and, furthermore, actually tend to be larger when κ is smaller.

6 Conclusion

In this paper, I construct a dynamic, many-country model of trade and capital accumulation and uses it to investigate how China's rapid expansion of trade during the period 1993-2011 has contributed to world real GDP growth and other outcomes. Specifically, I ask what growth during this period would have looked like China's sectoral productivity growth and trade liberalization had merely been "normal" during this period, compared with those of other countries.

I find that China's rise only explains 1.21% of total world economic growth outside of China between 1993 and 2007. For the years 2008 to 2011, however, China's impact was substantially larger, both due to a major recession in the rest of the world and because its relative productivity gains strongly favored Capital Goods during this period. Both of these findings for the contemporaneous effects of China's expansion are still small, however, in comparison to long-run effects reflecting how long term changes in sectoral prices will continue to incentivize a higher level of capital accumulation across most of the world going forward.

A key aspect of the analysis is the allowance for multiple sectors differing in their capital intensities and, similarly, in their importance as inputs into capital formation. I find that the changing structure of China's trade has mostly raised the relative return to capital of other countries—through its increased comparative advantage in manufacturing (versus non-manufacturing)—and has also mostly lowered the relative price of investment—through its emergence as a major producer and exporter of capital goods. While China's changes in sectoral trade barriers have quantitatively large effects on growth in the rest of the world (especially from a static perspective), China's productivity growth and change in comparative advantage explain most of the overall effect on capital accumulation.

Placing these findings against current worries of a "slowdown" or "new normal" in China obviously requires many caveats. For example, financial ties between China and the rest of the world, likely to cause short-term volatility in the event of a China slowdown, are wholly abstracted from. Still, this analysis suggests immediate spillover effects via trade from China suddenly becoming "normal" would be mild for most countries, with near-neighbors of China and exporters of raw materials most likely to be negatively affected. Furthermore, even if China's general productivity growth does slow down significantly, I still observe that China's trade barriers—despite their high rate of liberalization in recent years—are still relatively high relative to the rest of the world. There would thus appear to be substantial room for continued benefits from the further opening of China to global trade, especially in non-capital goods sectors.

Overall, the model, while rich in its structure, still leaves many important avenues relatively unexplored. Unquestionably, the rise of China over the past several decades has changed the world economy. Yet, while this paper focuses solely on the national level, China's most dramatic effects have taken place at the local level within countries, disrupting local labor markets and changing the economic geographies of entire regions. Whether the China-driven commodity booms of recent years may be expected to cement perpetually increased prosperity in Western Australia, North Dakota, and the copper producing regions across South America remains an appealing topic for further research.

References

Alvarez, F. & Lucas, R. E. J. (2007), "Capital Accumulation and International Trade", Tech. rep., mimeo, University of Chicago.

Anderson, J. E., Larch, M., & Yotov, Y. V. (2015), "Growth and Trade with Frictions: A Structural Estimation Framework", Working Paper 21377, National Bureau of Economic Research.

Anderson, J. E. & van Wincoop, E. (2003), "Gravity with Gravitas: A Solution to the Border Puzzle", *American Economic Review* **93**(1), 170–192.

Anderson, J. E. & Yotov, Y. V. (2010), "Specialization: Pro- and Anti-globalizing, 1990-2002", Working Paper 16301, National Bureau of Economic Research.

Anderson, J. E. & Yotov, Y. V. (2016), "Terms of Trade and Global Efficiency Effects of Free Trade Agreements, 1990-2002", *Journal of International Economics* **(in press)**.

Arkolakis, C., Costinot, A., & Rodríguez-Clare, A. (2012), "New Trade Models, Same Old Gains?", *The American Economic Review* **102**(1), 94–130.

Bajona, C. & Kehoe, T. J. (2010), "Trade, growth, and convergence in a dynamic Heckscher–Ohlin model", *Review of Economic Dynamics* **13**(3), 487–513.

Baldwin, R. E. & Seghezza, E. (1996), "Trade-Induced Investment-led Growth", Working Paper 5582, National Bureau of Economic Research.

Caliendo, L. (2010), "On the Dynamics of the Hecksher-Ohlin Theory", Working Paper 2010-011, Milton Friedman Institute for Research in Economics, Chicago, IL.

Caliendo, L. & Parro, F. (2015), "Estimates of the Trade and Welfare Effects of NAFTA", *Review of Economic Studies* **82**(1), 1–44.

Chari, V. V., Kehoe, P. J., & McGrattan, E. R. (2007), "Business Cycle Accounting", *Econometrica* **75**(3), 781–836.

Chen, Z. (1992), "Long-Run Equilibria in a Dynamic Heckscher-Ohlin Model", *The Canadian Journal of Economics / Revue canadienne d'Economique* **25**(4), 923–943.

Costinot, A., Donaldson, D., & Komunjer, I. (2012), "What Goods Do Countries Trade? A Quantitative Exploration of Ricardo's Ideas", *Review of Economic Studies* **79**(2), 581–608.

Costinot, A. & Rodríguez-Clare, A. (2014), "Trade Theory with Numbers: Quantifying the Consequences of Globalization", *Handbook of International Economics* **4**, 197–261.

Dekle, R., Eaton, J., & Kortum, S. (2007), "Unbalanced Trade", *American Economic Review* **97**(2), 351–355.

Di Giovanni, J., Levchenko, A. A., & Zhang, J. (2014), "The Global Welfare Impact of China: Trade Integration and Technological Change", *American Economic Journal: Macroeconomics* **6**(3), 153–183.

Eaton, J. & Kortum, S. (2001), "Trade in capital goods", *European Economic Review* **45**(7), 1195–1235.

Eaton, J. & Kortum, S. (2002), "Technology, Geography, and Trade", *Econometrica* **70**(5), 1741–1779.

Eaton, J., Kortum, S., Neiman, B., & Romalis, J. (2015), "Trade and the Global Recession", .

Eaton, J., Kortum, S. S., & Neiman, B. (2015), "Obstfeld and Rogoff's International Macro Puzzles: A

Quantitative Assessment", Working Paper 21774, National Bureau of Economic Research.

Egger, P. H. & Nigai, S. (2015), "Structural gravity with dummies only: Constrained ANOVA-type estimation of gravity models", *Journal of International Economics* **97**(1), 86–99.

Fally, T. (2015), "Structural gravity and fixed effects", *Journal of International Economics* **97**(1), 76–85.

Feenstra, R. C., Inklaar, R., & Timmer, M. P. (2015), "The Next Generation of the Penn World Table", *The American Economic Review* **105**(10), 3150–3182.

Feenstra, R. C., Lipsey, R. E., Deng, H., Ma, A. C., & Mo, H. (2005), "World Trade Flows: 1962-2000", Working Paper 11040, National Bureau of Economic Research.

Figueiredo, O., Guimarães, P., & Woodward, D. (2015), "Industry localization, distance decay, and knowledge spillovers: Following the patent paper trail", *Journal of Urban Economics* **89**(C), 21–31.

Finicelli, A., Pagano, P., & Sbracia, M. (2013), "Ricardian selection", *Journal of International Economics* **89**(1), 96–109.

Fitzgerald, D. (2012), "Trade Costs, Asset Market Frictions, and Risk Sharing", *The American Economic Review* **102**(6), 2700–2733.

Guimarães, P. & Portugal, P. (2010), "A simple feasible procedure to fit models with high-dimensional fixed effects", *Stata Journal* **10**(4), 628–649.

Hanson, G. H., Lind, N., & Muendler, M.-A. (2015), "The Dynamics of Comparative Advantage", Working Paper 21753, National Bureau of Economic Research.

Head, K. & Mayer, T. (2014), "Gravity equations: Workhorse, toolkit, and cookbook", *Handbook of International Economics* **4**, 131–196.

Head, K. & Ries, J. (2001), "Increasing Returns versus National Product Differentiation as an Explanation for the Pattern of U.S.-Canada Trade", *The American Economic Review* **91**(4), 858–876.

Hicks, J. R. (1953), "An Inaugural Lecture", *Oxford Economic Papers* **5**(2), 117–135.

Hsieh, C.-T. & Ossa, R. (2016), "A global view of productivity growth in China", *Journal of International Economics* **102**, 209–224.

Kehoe, T. J., Ruhl, K. J., & Steinberg, J. B. (2013), "Global Imbalances and Structural Change in the United States", Working Paper 19339, National Bureau of Economic Research.

Levchenko, A. A. & Zhang, J. (2016), "The evolution of comparative advantage: Measurement and welfare implications", *Journal of Monetary Economics* **78**, 96–111.

Lucas, R. E. & Prescott, E. C. (1971), "Investment Under Uncertainty", *Econometrica* **39**(5), 659–681.

Mutreja, P., Ravikumar, B., & Sposi, M. (2016), "Capital Goods Trade and Economic Development", Working Paper.

Novy, D. (2013), "Gravity Redux: Measuring International Trade Costs with Panel Data", *Economic Inquiry* **51**(1), 101–121.

Obstfeld, M. & Rogoff, K. (2001), "The six major puzzles in international macroeconomics: is there a common cause?", in *NBER Macroeconomics Annual 2000, Volume 15*, pp. 339–412, MIT press.

Piermartini, R. & Yotov, Y. (2016), “Estimating Trade Policy Effects with Structural Gravity”, School of Economics Working Paper Series 2016-10, LeBow College of Business, Drexel University.

Ravikumar, B., Santacreu, A. M., & Sposi, M. (2016), “Capital Accumulation and the Dynamic Gains from Trade”, Working Paper.

Reyes-Heroles, R. (2015), “The Role of Trade Costs in the Surge of Trade Imbalances”, .

Samuelson, P. A. (2004), “Where Ricardo and Mill Rebut and Confirm Arguments of Mainstream Economists Supporting Globalization”, *The Journal of Economic Perspectives* **18**(3), 135–146H.

Santos Silva, J. M. C. & Tenreyro, S. (2006), “The Log of Gravity”, *Review of Economics and Statistics* **88**(4), 641–658.

Shikher, S. (2011), “Capital, technology, and specialization in the neoclassical model”, *Journal of International Economics* **83**(2), 229–242.

Shikher, S. (2012), “Putting industries into the Eaton–Kortum model”, *The Journal of International Trade & Economic Development* **21**(6), 807–837.

Simonovska, I. & Waugh, M. E. (2014), “The elasticity of trade: Estimates and evidence”, *Journal of International Economics* **92**(1), 34–50.

Ventura, J. (1997), “Growth and Interdependence”, *The Quarterly Journal of Economics* **112**(1), 57–84.

Wacziarg, R. (2001), “Measuring the Dynamic Gains from Trade”, *World Bank Economic Review* **15**(3), 393–429.

Wacziarg, R. & Welch, K. (2008), “Trade Liberalization and Growth: New Evidence”, *World Bank Economic Review* **22**(2), 187–231.

Main Tables and Figures

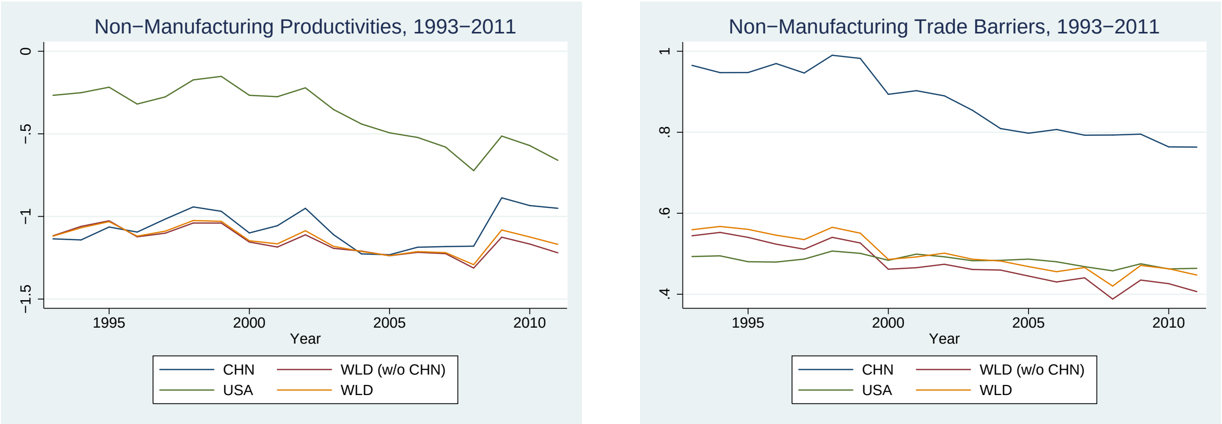

Figure 2: (Log) changes in sectoral productivity and trade barriers: Non-manufactured Goods

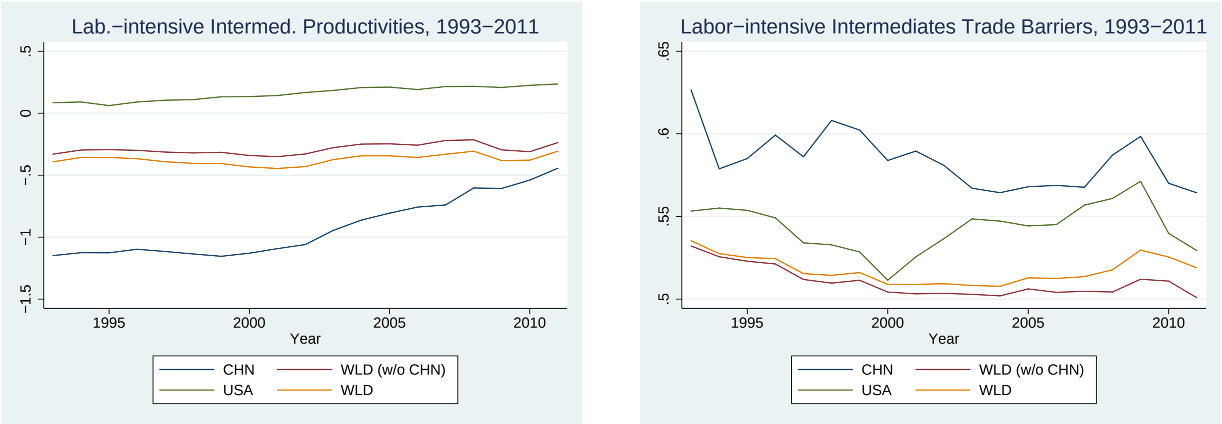

Figure 3: (Log) changes in sectoral productivity and trade barriers: Labor-intensive Intermediates

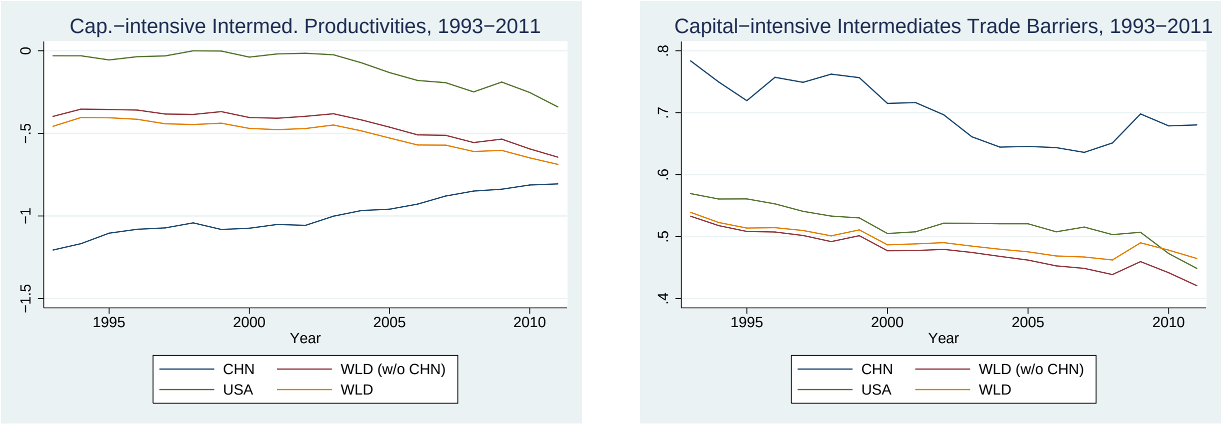

Figure 4: (Log) changes in sectoral productivity and trade barriers: Capital-intensive Intermediates

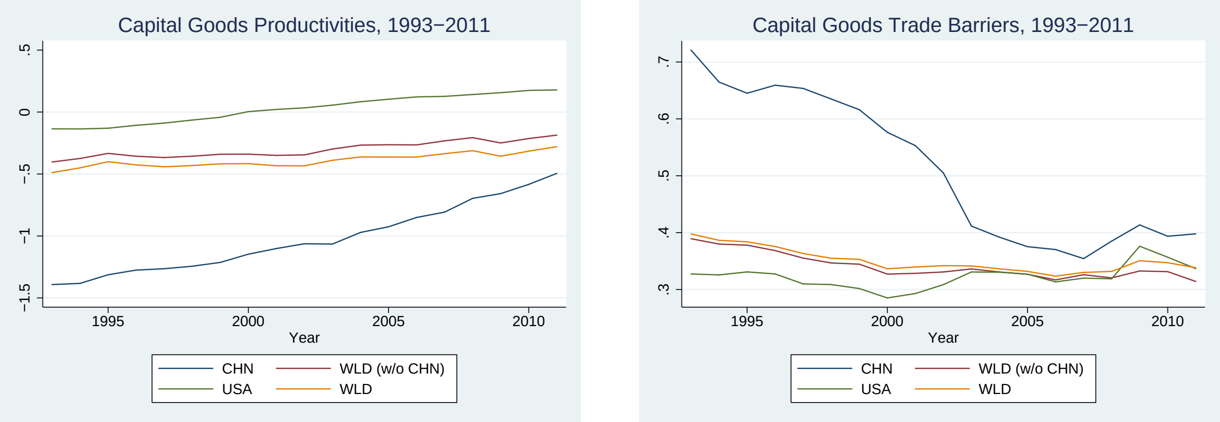

Figure 5: (Log) changes in sectoral productivity and trade barriers: Capital Goods

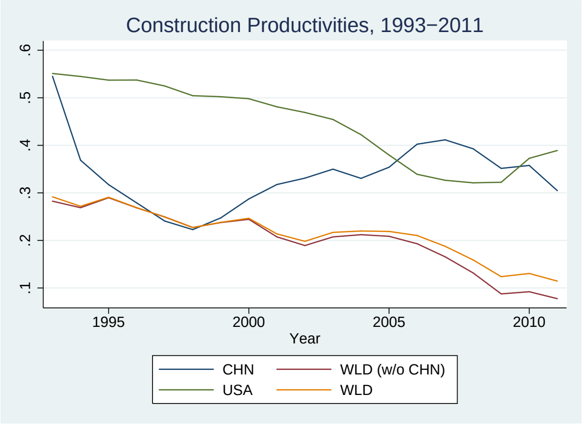

Figure 6: (Log) changes in sectoral productivity: Construction

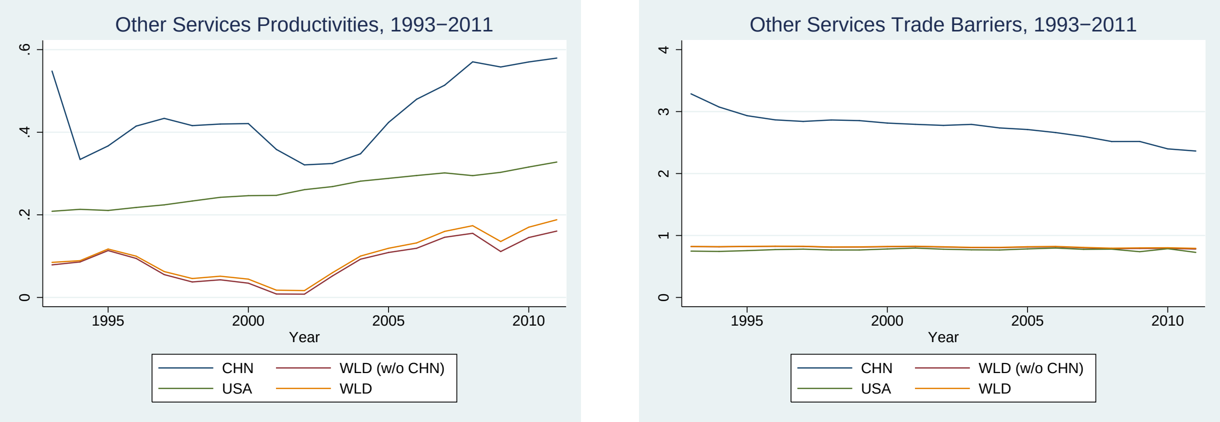

Figure 7: (Log) changes in sectoral productivity and trade barriers: Other Services

Table 5: China's productivity growth and globalization vs. the Rest of the World, 1993-2007

Industry	$\widehat{A}^{1/\theta}_{nonCHN}$	$\widehat{A}^{1/\theta}_{CHN}$	$\widehat{A}^{1/\theta}_{CHN+}$	$\widehat{d}_{nonCHN}$	$\widehat{d}_{CHN}$	$\widehat{d}_{CHN+}$
Non-Manufacturing	-.008	-.003	**.004**	-.007	-.012	**-.005**
Capital-intensive Manuf.	-.008	.023	**.032**	-.006	-.011	**-.005**
Labor-intensive Manuf.	.008	.029	**.021**	-.002	-.004	**-.002**
Capital Goods	.012	.042	**.030**	-.005	-.026	**-.022**
Construction	-.008	-.01	-.001	.	.	.
Other services	.005	-.002	-.007	-.001	-.049	-.048
Manufacturing	.002	.032	.030	-.004	-.016	-.012
Total	.002	.024	.022	-.003	-.015	-.013

Notes: Annualized percentage changes over time. Shocks highlighted in bold are those are used in the counterfactuals.

Table 6: China's productivity growth and globalization vs. the Rest of the World, 2008-2011

Industry	$\widehat{A}^{1/\theta}_{nonCHN}$	$\widehat{A}^{1/\theta}_{CHN}$	$\widehat{A}^{1/\theta}_{CHN+}$	$\widehat{d}_{nonCHN}$	$\widehat{d}_{CHN}$	$\widehat{d}_{CHN+}$
Non-Manufacturing	.031	.076	**.046**	.006	-.01	**-.016**
Capital-intensive Manuf.	-.029	.014	**.044**	-.006	.01	**.016**
Labor-intensive Manuf.	-.008	.053	**.061**	-.001	-.008	**-.006**
Capital Goods	.007	.067	**.060**	-.002	.004	**.006**
Construction	-.018	-.029	-.011	.	.	.
Other services	.002	.003	.001	-.002	-.051	-.049
Manufacturing	-.016	.039	.055	-.004	.001	.005
Total	0	.038	.038	0	-.002	-.002

Notes: Annualized percentage changes over time. Shocks highlighted in bold are those are used in the counterfactuals.

Table 7: Effects of Sectoral Productivity Changes and Trade Barrier Reductions (1993-2007)

	Model Outcomes for Selected Countries								
	Static Model (2007 values)			*Dynamic Model (2007 values)*			*Dynamic Model (Steady State)*		
	Real GDP	$\widehat{r}/\widehat{w}$	$\widehat{P}_{IV}/\widehat{P}_C$	Real GDP	$\widehat{K}$	$\hat{x}$	Real GDP	$\widehat{K}$	$\widehat{\mathbf{U}}$
ARG	0.0030	0.0023	-0.0083	0.0041	0.0019	0.0056	0.0526	0.0822	0.0064
AUS	0.0043	0.0088	-0.0045	0.0073	0.0063	0.0142	0.0799	0.1306	0.0093
BOL	0.0017	-0.0007	-0.0017	0.0020	0.0003	0.0004	0.0209	0.0257	0.0033
BRA	0.0012	0.0035	-0.0033	0.0023	0.0022	0.0059	0.0303	0.0487	0.0028
CAN	0.0017	0.0017	-0.0041	0.0025	0.0016	0.0035	0.0256	0.0411	0.0033
CHL	0.0070	0.0002	-0.0020	0.0083	0.0014	0.0004	0.0549	0.0594	0.0165
CHN	0.6386	0.0442	-0.2005	0.7800	0.2049	0.1079	2.2631	3.0027	1.0583
CZE	0.0009	0.0026	-0.0053	0.0018	0.0013	0.0030	0.0253	0.0408	0.0019
DEU	0.0001	0.0061	-0.0051	0.0013	0.0025	0.0069	0.0208	0.0438	0.0008
ESP	0.0009	0.0023	-0.0024	0.0017	0.0014	0.0028	0.0169	0.0257	0.0016
ETH	0.0066	0.0009	-0.0074	0.0083	0.0029	0.0086	0.0711	0.0932	0.0098
FIN	0.0030	-0.0002	-0.0042	0.0035	0.0007	0.0018	0.0253	0.0354	0.0046
FRA	0.0004	0.0020	-0.0022	0.0009	0.0009	0.0026	0.0114	0.0205	0.0008
GBR	0.0014	0.0024	-0.0032	0.0021	0.0015	0.0042	0.0202	0.0329	0.0024
HUN	0.0052	-0.0006	-0.0056	0.0059	0.0009	0.0030	0.0384	0.0510	0.0071
IDN	0.0038	0.0068	-0.0063	0.0071	0.0047	0.0083	0.0749	0.0922	0.0137
IND	0.0021	-0.0028	-0.0067	0.0022	-0.0001	0.0001	0.0077	0.0126	0.0018
ISR	0.0010	0.0042	-0.0044	0.0022	0.0021	0.0052	0.0277	0.0442	0.0028
ITA	-0.0004	0.0031	-0.0026	0.0004	0.0012	0.0032	0.0135	0.0226	0.0001
JOR	0.0058	0.0001	-0.0063	0.0084	0.0048	0.0072	0.0575	0.0743	0.0073
JPN	0.0009	0.0026	-0.0062	0.0019	0.0015	0.0048	0.0227	0.0422	0.0010
KAZ	0.0134	0.0069	-0.0115	0.0167	0.0053	0.0100	0.1532	0.2118	0.0337
KEN	0.0039	0.0006	-0.0101	0.0059	0.0035	0.0066	0.0566	0.0830	0.0069
KOR	0.0037	0.0009	-0.0080	0.0054	0.0024	0.0036	0.0313	0.0494	0.0058
MEX	0.0005	0.0039	-0.0020	0.0013	0.0012	0.0035	0.0294	0.0374	0.0022
MYS	0.0127	0.0020	-0.0248	0.0170	0.0057	0.0099	0.2133	0.2720	0.0457
PER	0.0052	0.0083	-0.0080	0.0075	0.0044	0.0131	0.1099	0.1643	0.0161
PHL	0.0059	-0.0021	-0.0156	0.0082	0.0031	0.0072	0.0880	0.1152	0.0135
PRT	0.0006	0.0019	-0.0033	0.0012	0.0012	0.0033	0.0148	0.0258	0.0007
RUS	0.0034	0.0052	-0.0049	0.0047	0.0019	0.0057	0.0669	0.0887	0.0114
SEN	0.0034	-0.0008	-0.0066	0.0045	0.0018	0.0046	0.0401	0.0576	0.0033
SWE	0.0002	0.0017	-0.0038	0.0007	0.0008	0.0020	0.0125	0.0248	0.0012
TUR	0.0010	0.0027	-0.0065	0.0030	0.0026	0.0050	0.0356	0.0437	0.0074
TZA	0.0051	0.0023	-0.0072	0.0076	0.0046	0.0104	0.0995	0.1407	0.0131
USA	0.0018	0.0013	-0.0051	0.0024	0.0012	0.0038	0.0202	0.0354	0.0022
VEN	0.0033	0.0023	-0.0067	0.0042	0.0017	0.0040	0.0585	0.0869	0.0096
VNM	0.0242	-0.0117	-0.0100	0.0264	0.0034	-0.0006	0.0712	0.0789	0.0302
ZAF	0.0035	0.0030	-0.0062	0.0048	0.0024	0.0071	0.0442	0.0694	0.0064
World	0.0272	0.0097	-0.0118	0.0675	0.0266	0.0071	0.2099	0.3282	0.1308
Non-China	0.0028	0.0029	-0.0058	0.0048	0.0025	0.0048	0.0530	0.0762	0.0075

Notes: Table shows how much changes in China's sectoral TFPs and trade barriers during the period 1993-2007 contributed to actual outcomes, versus a counterfactual where China's sectoral TFP changes and trade barrier reductions matched those of its trade partners.

Table 8: Effects of Trade Barrier Reductions only (1993-2007)

	Model Outcomes for Selected Countries								
	Static Model (2007 values)			*Dynamic Model (2007 values)*			*Dynamic Model (Steady State)*		
	Real GDP	$\widehat{r}/\widehat{w}$	$\widehat{P}_{IV}/\widehat{P}_C$	Real GDP	$\widehat{K}$	$\hat{x}$	Real GDP	$\widehat{K}$	$\widehat{\mathbf{U}}$
ARG	0.0020	0.0014	-0.0055	0.0026	0.0011	0.0034	0.0261	0.0411	0.0035
AUS	0.0027	0.0047	-0.0027	0.0040	0.0029	0.0064	0.0286	0.0448	0.0046
BOL	0.0012	0.0005	-0.0006	0.0013	0.0002	0.0006	0.0085	0.0102	0.0018
BRA	0.0008	0.0022	-0.0020	0.0014	0.0012	0.0034	0.0148	0.0239	0.0015
CAN	0.0012	0.0017	-0.0021	0.0017	0.0010	0.0022	0.0120	0.0186	0.0020
CHL	0.0050	0.0013	-0.0010	0.0056	0.0009	0.0009	0.0286	0.0304	0.0099
CHN	0.0361	0.0135	-0.0235	0.0490	0.0248	0.0139	0.1141	0.1352	0.0594
CZE	0.0011	0.0013	-0.0032	0.0016	0.0008	0.0018	0.0160	0.0248	0.0017
DEU	0.0009	0.0024	-0.0031	0.0014	0.0013	0.0036	0.0123	0.0243	0.0011
ESP	0.0006	0.0014	-0.0013	0.0010	0.0007	0.0015	0.0082	0.0122	0.0010
ETH	0.0043	0.0008	-0.0048	0.0052	0.0016	0.0051	0.0337	0.0433	0.0057
FIN	0.0030	0.0003	-0.0024	0.0033	0.0006	0.0016	0.0163	0.0214	0.0040
FRA	0.0006	0.0011	-0.0012	0.0009	0.0005	0.0015	0.0064	0.0108	0.0008
GBR	0.0010	0.0013	-0.0017	0.0014	0.0008	0.0023	0.0101	0.0163	0.0015
HUN	0.0041	-0.0001	-0.0034	0.0045	0.0007	0.0023	0.0230	0.0299	0.0051
IDN	0.0028	0.0038	-0.0032	0.0045	0.0024	0.0043	0.0322	0.0390	0.0073
IND	0.0013	-0.0007	-0.0038	0.0015	0.0003	0.0006	0.0057	0.0090	0.0013
ISR	0.0005	0.0023	-0.0022	0.0011	0.0011	0.0027	0.0138	0.0223	0.0015
ITA	0.0001	0.0015	-0.0015	0.0005	0.0006	0.0018	0.0075	0.0123	0.0003
JOR	0.0027	0.0014	-0.0042	0.0043	0.0031	0.0048	0.0284	0.0374	0.0034
JPN	0.0014	0.0015	-0.0042	0.0019	0.0010	0.0032	0.0137	0.0241	0.0014
KAZ	0.0074	0.0037	-0.0074	0.0088	0.0026	0.0048	0.0535	0.0760	0.0145
KEN	0.0022	0.0009	-0.0067	0.0034	0.0022	0.0042	0.0282	0.0420	0.0038
KOR	0.0047	0.0012	-0.0054	0.0060	0.0022	0.0034	0.0216	0.0318	0.0059
MEX	0.0004	0.0028	-0.0011	0.0009	0.0008	0.0022	0.0157	0.0198	0.0014
MYS	0.0106	0.0028	-0.0170	0.0131	0.0038	0.0070	0.1127	0.1415	0.0308
PER	0.0029	0.0041	-0.0051	0.0040	0.0020	0.0060	0.0386	0.0574	0.0073
PHL	0.0040	0.0005	-0.0105	0.0057	0.0025	0.0061	0.0531	0.0696	0.0088
PRT	0.0004	0.0012	-0.0019	0.0008	0.0007	0.0019	0.0082	0.0138	0.0006
RUS	0.0022	0.0027	-0.0027	0.0028	0.0010	0.0027	0.0265	0.0349	0.0059
SEN	0.0019	0.0007	-0.0038	0.0026	0.0012	0.0034	0.0191	0.0278	0.0017
SWE	0.0007	0.0014	-0.0020	0.0010	0.0007	0.0016	0.0075	0.0142	0.0012
TUR	0.0007	0.0015	-0.0042	0.0019	0.0016	0.0030	0.0192	0.0235	0.0044
TZA	0.0024	0.0014	-0.0041	0.0036	0.0021	0.0046	0.0333	0.0459	0.0056
USA	0.0013	0.0010	-0.0033	0.0017	0.0008	0.0025	0.0110	0.0193	0.0014
VEN	0.0024	0.0014	-0.0042	0.0029	0.0010	0.0023	0.0255	0.0375	0.0054
VNM	0.0107	-0.0043	-0.0088	0.0121	0.0029	0.0013	0.0327	0.0433	0.0122
ZAF	0.0022	0.0021	-0.0037	0.0029	0.0014	0.0039	0.0191	0.0298	0.0033
World	0.0042	0.0031	-0.0034	0.0092	0.0046	0.0032	0.0418	0.0609	0.0158
Non-China	0.0022	0.0018	-0.0035	0.0033	0.0014	0.0030	0.0261	0.0371	0.0045

Notes: Table shows how much changes in China's trade barriers during the period 1993-2007 contributed to actual outcomes, versus a counterfactual where China's sectoral TFP changes matched those of its trade partners.

Table 9: Effects of Sectoral Productivity Changes only (1993-2007)

	Model Outcomes for Selected Countries								
	Static Model (2007 values)			*Dynamic Model (2007 values)*			*Dynamic Model (Steady State)*		
	Real GDP	$\widehat{r}/\widehat{w}$	$\widehat{P}_{IV}/\widehat{P}_{C}$	Real GDP	$\widehat{K}$	$\hat{x}$	Real GDP	$\widehat{K}$	$\widehat{\mathbf{U}}$
ARG	0.0023	0.0019	-0.0063	0.0032	0.0015	0.0045	0.0462	0.0720	0.0054
AUS	0.0034	0.0077	-0.0036	0.0060	0.0054	0.0126	0.0722	0.1179	0.0080
BOL	0.0014	-0.0007	-0.0014	0.0015	0.0001	0.0003	0.0193	0.0239	0.0029
BRA	0.0009	0.0028	-0.0026	0.0018	0.0017	0.0050	0.0272	0.0437	0.0024
CAN	0.0012	0.0011	-0.0032	0.0018	0.0011	0.0027	0.0222	0.0358	0.0026
CHL	0.0048	-0.0005	-0.0014	0.0057	0.0006	-0.0002	0.0451	0.0488	0.0128
CHN	0.5527	0.0446	-0.1626	0.6710	0.1791	0.0906	1.8694	2.3972	0.9229
CZE	0.0005	0.0022	-0.0042	0.0012	0.0010	0.0024	0.0217	0.0351	0.0013
DEU	-0.0004	0.0055	-0.0039	0.0007	0.0020	0.0060	0.0175	0.0379	0.0002
ESP	0.0006	0.0018	-0.0019	0.0012	0.0011	0.0023	0.0147	0.0225	0.0012
ETH	0.0049	0.0007	-0.0055	0.0063	0.0022	0.0069	0.0617	0.0807	0.0080
FIN	0.0018	-0.0002	-0.0032	0.0022	0.0003	0.0012	0.0207	0.0294	0.0032
FRA	0.0001	0.0016	-0.0017	0.0005	0.0007	0.0022	0.0097	0.0177	0.0004
GBR	0.0009	0.0019	-0.0025	0.0015	0.0012	0.0034	0.0175	0.0286	0.0019
HUN	0.0036	-0.0006	-0.0044	0.0041	0.0004	0.0021	0.0322	0.0430	0.0054
IDN	0.0025	0.0061	-0.0051	0.0052	0.0037	0.0070	0.0663	0.0815	0.0114
IND	0.0016	-0.0026	-0.0053	0.0016	-0.0003	-0.0002	0.0063	0.0104	0.0014
ISR	0.0007	0.0034	-0.0035	0.0016	0.0016	0.0043	0.0241	0.0386	0.0023
ITA	-0.0005	0.0026	-0.0020	0.0001	0.0009	0.0027	0.0116	0.0197	-0.0001
JOR	0.0045	-0.0006	-0.0048	0.0064	0.0033	0.0054	0.0489	0.0630	0.0058
JPN	-0.0001	0.0022	-0.0046	0.0007	0.0011	0.0036	0.0173	0.0340	0.0000
KAZ	0.0099	0.0059	-0.0091	0.0126	0.0040	0.0084	0.1343	0.1856	0.0281
KEN	0.0029	0.0001	-0.0076	0.0044	0.0024	0.0049	0.0484	0.0708	0.0055
KOR	0.0005	0.0007	-0.0057	0.0017	0.0011	0.0019	0.0218	0.0366	0.0022
MEX	0.0003	0.0029	-0.0016	0.0010	0.0010	0.0028	0.0255	0.0325	0.0018
MYS	0.0077	0.0020	-0.0185	0.0109	0.0037	0.0074	0.1768	0.2253	0.0345
PER	0.0042	0.0073	-0.0063	0.0062	0.0037	0.0116	0.0992	0.1477	0.0142
PHL	0.0037	-0.0023	-0.0119	0.0052	0.0017	0.0047	0.0722	0.0944	0.0102
PRT	0.0004	0.0015	-0.0026	0.0009	0.0009	0.0027	0.0128	0.0225	0.0005
RUS	0.0024	0.0042	-0.0038	0.0035	0.0014	0.0047	0.0589	0.0781	0.0094
SEN	0.0024	-0.0009	-0.0050	0.0032	0.0012	0.0033	0.0339	0.0486	0.0025
SWE	-0.0001	0.0013	-0.0030	0.0003	0.0005	0.0015	0.0104	0.0212	0.0007
TUR	0.0007	0.0023	-0.0051	0.0022	0.0019	0.0041	0.0314	0.0385	0.0061
TZA	0.0041	0.0021	-0.0055	0.0062	0.0038	0.0091	0.0897	0.1265	0.0114
USA	0.0013	0.0010	-0.0039	0.0017	0.0009	0.0029	0.0172	0.0302	0.0017
VEN	0.0024	0.0020	-0.0052	0.0032	0.0012	0.0033	0.0522	0.0776	0.0081
VNM	0.0196	-0.0113	-0.0071	0.0209	0.0011	-0.0018	0.0616	0.0664	0.0257
ZAF	0.0027	0.0023	-0.0048	0.0037	0.0018	0.0058	0.0390	0.0612	0.0053
World	0.0240	0.0092	-0.0063	0.0603	0.0233	0.0058	0.1909	0.2974	0.1199
Non-China	0.0017	0.0025	-0.0045	0.0033	0.0018	0.0038	0.0460	0.0664	0.0058

Notes: Table shows how much changes in China's sectoral TFPs during the period 1993-2007 contributed to actual outcomes, versus a counterfactual where China's sectoral TFP changes matched those of its trade partners.

Table 10: Effects of Relative Sectoral Productivity Changes (1993-2007)

	Model Outcomes for Selected Countries								
	Static Model (2007 values)			*Dynamic Model (2007 values)*			*Dynamic Model (Steady State)*		
	Real GDP	$\widehat{r}/\widehat{w}$	$\widehat{P}_{IV}/\widehat{P}_C$	Real GDP	$\widehat{K}$	$\hat{x}$	Real GDP	$\widehat{K}$	$\widehat{\mathbf{U}}$
ARG	0.0013	0.0017	-0.0029	0.0018	0.0009	0.0026	0.0211	0.0327	0.0029
AUS	0.0017	0.0067	-0.0012	0.0034	0.0036	0.0084	0.0329	0.0529	0.0042
BOL	0.0006	0.0013	-0.0002	0.0007	0.0002	0.0011	0.0095	0.0120	0.0014
BRA	0.0006	0.0021	-0.0010	0.0011	0.0011	0.0030	0.0135	0.0214	0.0014
CAN	0.0003	0.0013	-0.0005	0.0006	0.0007	0.0014	0.0084	0.0134	0.0009
CHL	0.0019	0.0005	0.0003	0.0021	0.0001	-0.0005	0.0157	0.0164	0.0052
CHN	0.0000	0.0376	-0.0416	0.0122	0.0255	0.0203	0.1441	0.2171	0.0204
CZE	0.0002	0.0007	-0.0014	0.0004	0.0002	0.0008	0.0096	0.0150	0.0004
DEU	-0.0004	0.0021	-0.0010	0.0000	0.0008	0.0022	0.0066	0.0143	-0.0003
ESP	0.0000	0.0008	-0.0004	0.0002	0.0004	0.0008	0.0051	0.0077	0.0002
ETH	0.0017	0.0010	-0.0013	0.0022	0.0009	0.0032	0.0246	0.0319	0.0028
FIN	0.0007	0.0004	-0.0007	0.0009	0.0002	0.0007	0.0089	0.0119	0.0013
FRA	-0.0001	0.0008	-0.0003	0.0000	0.0003	0.0008	0.0034	0.0061	0.0000
GBR	0.0001	0.0009	-0.0006	0.0003	0.0004	0.0011	0.0063	0.0102	0.0005
HUN	0.0012	-0.0003	-0.0014	0.0013	-0.0001	0.0007	0.0132	0.0173	0.0019
IDN	0.0011	0.0057	-0.0016	0.0025	0.0021	0.0039	0.0298	0.0360	0.0059
IND	0.0006	-0.0009	-0.0018	0.0006	-0.0001	-0.0001	0.0028	0.0045	0.0005
ISR	-0.0004	0.0013	-0.0003	-0.0002	0.0004	0.0011	0.0082	0.0130	0.0002
ITA	-0.0003	0.0010	-0.0005	-0.0001	0.0003	0.0009	0.0043	0.0074	-0.0002
JOR	-0.0007	0.0003	-0.0016	-0.0001	0.0008	0.0010	0.0149	0.0197	-0.0002
JPN	-0.0012	0.0010	-0.0015	-0.0010	0.0003	0.0008	0.0030	0.0085	-0.0013
KAZ	0.0021	0.0054	-0.0046	0.0031	0.0019	0.0047	0.0502	0.0732	0.0099
KEN	0.0003	0.0004	-0.0028	0.0008	0.0009	0.0017	0.0177	0.0265	0.0014
KOR	-0.0026	0.0016	-0.0010	-0.0023	0.0001	-0.0001	0.0029	0.0069	-0.0020
MEX	0.0000	0.0017	-0.0003	0.0003	0.0004	0.0013	0.0109	0.0138	0.0007
MYS	0.0016	0.0063	-0.0076	0.0034	0.0025	0.0045	0.0726	0.0917	0.0137
PER	0.0025	0.0063	-0.0031	0.0038	0.0025	0.0077	0.0453	0.0663	0.0081
PHL	-0.0005	0.0000	-0.0048	0.0000	0.0005	0.0013	0.0283	0.0373	0.0028
PRT	-0.0001	0.0008	-0.0008	0.0002	0.0004	0.0011	0.0050	0.0087	0.0000
RUS	0.0007	0.0022	-0.0009	0.0010	0.0004	0.0016	0.0213	0.0283	0.0036
SEN	-0.0004	0.0012	-0.0003	-0.0001	0.0003	0.0010	0.0105	0.0151	0.0000
SWE	-0.0001	0.0010	-0.0007	0.0000	0.0003	0.0008	0.0043	0.0084	0.0001
TUR	0.0001	0.0012	-0.0021	0.0007	0.0008	0.0017	0.0144	0.0177	0.0026
TZA	0.0009	0.0028	-0.0011	0.0022	0.0023	0.0054	0.0379	0.0529	0.0047
USA	0.0002	0.0007	-0.0012	0.0004	0.0004	0.0011	0.0062	0.0112	0.0004
VEN	0.0013	0.0019	-0.0020	0.0017	0.0008	0.0021	0.0241	0.0357	0.0043
VNM	0.0075	-0.0089	-0.0037	0.0075	-0.0007	-0.0025	0.0266	0.0282	0.0100
ZAF	0.0008	0.0018	-0.0015	0.0013	0.0009	0.0029	0.0151	0.0238	0.0020
World	0.0004	0.0046	-0.0026	0.0026	0.0043	0.0023	0.0416	0.0719	0.0062
Non-China	0.0004	0.0022	-0.0013	0.0011	0.0010	0.0018	0.0199	0.0289	0.0023

Notes: Table shows how much *relative* changes in China's sectoral TFPs during the period 1993-2007 contributed to actual outcomes, versus a counterfactual where China's sectoral TFPs all changed at a common, constant rate relative to those of its trading partners. China's overall level of TFP growth is constructed to preserve China's overall level of real GDP growth.

Table 11: Effects of Relative TFP Changes, by Sector (1993-2007)

	Model Outcomes for Selected Countries								
	Static Model (2007 values)			*Dynamic Model (2007 values)*			*Dynamic Model (Steady State)*		
	Real GDP	$\widehat{r}/\widehat{w}$	$\widehat{P}_{IV}/\widehat{P}_C$	Real GDP	$\widehat{K}$	$\hat{x}$	Real GDP	$\widehat{K}$	$\widehat{\mathbf{U}}$
A. Effect of China's relative TFP change across Manufacturing vs. Non-manufacturing									
CHN	0.0000	0.0384	-0.0551	0.0120	0.0256	0.0223	0.1548	0.2430	0.0196
DEU	-0.0003	0.0020	-0.0012	0.0001	0.0007	0.0022	0.0076	0.0156	-0.0001
KOR	-0.0026	0.0037	-0.0019	-0.0020	0.0008	0.0011	0.0073	0.0138	-0.0013
PER	0.0030	0.0079	-0.0033	0.0045	0.0029	0.0091	0.0513	0.0748	0.0093
USA	0.0004	0.0011	-0.0014	0.0006	0.0005	0.0016	0.0076	0.0133	0.0006
VNM	0.0063	-0.0116	-0.0057	0.0058	-0.0021	-0.0038	0.0225	0.0233	0.0083
All Non-China	0.0007	0.0030	-0.0016	0.0016	0.0012	0.0025	0.0226	0.0325	0.0030
B. Effect of China's reflative TFP changes within Manufacturing only									
CHN	0.0000	0.0019	0.0094	0.0011	0.0024	-0.0006	-0.0006	-0.0057	0.0017
DEU	-0.0002	0.0004	0.0001	-0.0001	0.0002	0.0002	-0.0004	0.0000	-0.0003
KOR	-0.0004	-0.0018	0.0008	-0.0007	-0.0007	-0.0013	-0.0044	-0.0065	-0.0009
PER	-0.0004	-0.0015	0.0000	-0.0006	-0.0003	-0.0012	-0.0027	-0.0032	-0.0008
USA	-0.0002	-0.0004	0.0000	-0.0002	-0.0001	-0.0004	-0.0010	-0.0013	-0.0002
VNM	0.0010	0.0020	0.0015	0.0015	0.0014	0.0010	0.0065	0.0077	0.0020
All Non-China	-0.0003	-0.0006	0.0002	-0.0004	-0.0001	-0.0006	-0.0012	-0.0013	-0.0006

Notes: Table examines how much *relative* changes in China's sectoral TFPs during the period 1993-2007 contributed to actual outcomes. Panel A isolates the effect of China's growing comparative advantage in manufactured versus non-manufactured goods. Panel B leaves China's relative sectoral productivity growth in Non-Manufacturing versus Manufacturing as-is and instead focuses on China's change in comparative advantage *within* the three manufacturing sectors. Both exercises are constructed to preserve China's overall level of real GDP growth.

Table 12: Effects of Removing Dynamic Sectoral Linkages (1993-2007)

	Model Outcomes for Selected Countries								
	Static Model (2007 values)			*Dynamic Model (2007 values)*			*Dynamic Model (Steady State)*		
	Real GDP	$\widehat{r}/\widehat{w}$	$\widehat{P}_{IV}/\widehat{P}_C$	Real GDP	$\widehat{K}$	$\hat{x}$	Real GDP	$\widehat{K}$	$\widehat{\mathbf{U}}$
A. No factor intensity differences or final usage differences									
CHN	0.6381	0.0000	0.0000	0.7474	0.1401	0.0555	1.6296	1.6201	1.0647
DEU	0.0002	0.0000	0.0000	0.0003	0.0000	-0.0001	0.0021	0.0021	0.0007
KOR	0.0037	0.0000	0.0000	0.0044	0.0008	0.0010	0.0150	0.0150	0.0061
PER	0.0051	0.0000	0.0000	0.0051	-0.0001	0.0008	0.0132	0.0132	0.0066
USA	0.0018	0.0000	0.0000	0.0020	0.0003	0.0009	0.0055	0.0055	0.0020
VNM	0.0242	0.0000	0.0000	0.0278	0.0081	0.0061	0.0534	0.0535	0.0287
All Non-China	0.0028	0.0000	0.0000	0.0038	0.0007	0.0013	0.0083	0.0080	0.0053
B. Remove factor intensity differences only									
CHN	0.6381	0.0000	-0.2002	0.7664	0.1844	0.0812	1.7596	2.2717	0.9954
DEU	0.0002	0.0000	-0.0048	0.0005	0.0005	0.0014	0.0065	0.0128	0.0007
KOR	0.0037	0.0000	-0.0080	0.0052	0.0019	0.0028	0.0223	0.0317	0.0059
PER	0.0051	0.0000	-0.0080	0.0055	0.0007	0.0030	0.0209	0.0284	0.0075
USA	0.0018	0.0000	-0.0051	0.0022	0.0008	0.0026	0.0101	0.0168	0.0019
VNM	0.0242	0.0000	-0.0098	0.0288	0.0101	0.0073	0.0609	0.0719	0.0285
All Non-China	0.0028	0.0005	-0.0057	0.0043	0.0015	0.0031	0.0161	0.0209	0.0054
C. Remove differences in final demand shares only									
CHN	0.6386	0.0442	0.0000	0.7648	0.1603	0.0810	2.1277	2.2704	1.1239
DEU	0.0001	0.0061	0.0000	0.0011	0.0022	0.0058	0.0104	0.0211	0.0007
KOR	0.0037	0.0009	0.0000	0.0047	0.0015	0.0021	0.0161	0.0181	0.0057
PER	0.0052	0.0083	0.0000	0.0071	0.0036	0.0107	0.0833	0.1087	0.0150
USA	0.0018	0.0013	0.0000	0.0023	0.0009	0.0025	0.0106	0.0133	0.0023
VNM	0.0242	-0.0117	0.0000	0.0253	0.0014	-0.0018	0.0501	0.0367	0.0303
All Non-China	0.0028	0.0029	0.0000	0.0043	0.0017	0.0032	0.0294	0.0347	0.0073

Notes: Table examines how earlier results are affected in variations of the model which remove factor intensity differences across sectors and/or differences in the final usage of each sector in consumption versus investment. More precisely, Panel A imposes $\alpha^r_{i,k} = \alpha^r_i$ and $\gamma^k_{i,C} = \gamma^k_{i,IV} = \gamma^k_i$ for all i, k. Panel B considers only the former restriction and Panel C considers only the latter. All results reflect the combined effects of changes in China's sectoral TFPs and trade barriers during the period 1993-2007.

Table 13: Effects of Sectoral Productivity Changes and Trade Barrier Reductions (2008-2011)

	Model Outcomes for Selected Countries								
	Static Model (2011 values)			*Dynamic Model (2011 values)*			*Dynamic Model (Steady State)*		
	Real GDP	$\widehat{r}/\widehat{w}$	$\widehat{P}_{IV}/\widehat{P}_C$	Real GDP	$\widehat{K}$	$\hat{x}$	Real GDP	$\widehat{K}$	$\widehat{\mathbf{U}}$
ARG	0.0016	0.0012	-0.0046	0.0044	0.0013	0.0086	0.0733	0.1167	0.0118
AUS	0.0041	0.0104	-0.0032	0.0113	0.0050	0.0303	0.1676	0.2702	0.0270
BOL	0.0030	0.0009	-0.0038	0.0075	0.0010	0.0062	0.0924	0.1261	0.0250
BRA	0.0014	0.0030	-0.0022	0.0038	0.0018	0.0121	0.0616	0.0977	0.0092
CAN	0.0013	0.0016	-0.0023	0.0033	0.0013	0.0069	0.0436	0.0717	0.0067
CHL	0.0046	0.0005	-0.0061	0.0131	0.0033	0.0068	0.1160	0.1513	0.0369
CHN	0.3051	0.0116	-0.0696	1.7342	0.1557	0.3024	7.1785	9.6281	2.7962
CZE	0.0005	0.0015	-0.0032	0.0016	0.0012	0.0062	0.0439	0.0736	0.0021
DEU	-0.0001	0.0037	-0.0027	0.0004	0.0014	0.0118	0.0318	0.0675	0.0003
ESP	0.0005	0.0017	-0.0018	0.0011	0.0008	0.0059	0.0270	0.0454	0.0019
ETH	0.0029	0.0012	-0.0021	0.0082	0.0032	0.0107	0.0756	0.0977	0.0141
FIN	0.0010	0.0005	-0.0019	0.0021	0.0006	0.0035	0.0318	0.0491	0.0042
FRA	0.0005	0.0015	-0.0019	0.0008	0.0007	0.0057	0.0228	0.0435	0.0010
GBR	0.0014	0.0018	-0.0021	0.0031	0.0011	0.0091	0.0376	0.0620	0.0054
HUN	0.0018	0.0001	-0.0037	0.0051	0.0012	0.0051	0.0532	0.0820	0.0084
IDN	0.0024	0.0045	-0.0024	0.0080	0.0024	0.0092	0.1014	0.1224	0.0271
IND	0.0005	-0.0011	-0.0025	0.0016	0.0006	-0.0008	0.0059	0.0133	0.0003
ISR	0.0004	0.0026	-0.0028	0.0015	0.0017	0.0089	0.0409	0.0711	0.0052
ITA	-0.0002	0.0019	-0.0019	-0.0003	0.0007	0.0064	0.0273	0.0470	-0.0004
JOR	0.0051	0.0007	-0.0044	0.0140	0.0025	0.0148	0.1082	0.1405	0.0202
JPN	-0.0003	0.0026	-0.0031	0.0009	0.0009	0.0081	0.0291	0.0574	0.0005
KAZ	0.0078	0.0048	-0.0087	0.0200	0.0032	0.0060	0.2186	0.3188	0.0654
KEN	0.0032	0.0017	-0.0056	0.0114	0.0038	0.0157	0.1157	0.1691	0.0243
KOR	-0.0010	0.0017	-0.0040	0.0035	0.0010	0.0051	0.0431	0.0764	0.0032
MEX	0.0009	0.0028	-0.0016	0.0031	0.0011	0.0082	0.0852	0.1072	0.0101
MYS	0.0050	0.0038	-0.0103	0.0182	0.0053	0.0159	0.2882	0.3724	0.0674
PER	0.0037	0.0056	-0.0054	0.0110	0.0045	0.0180	0.1651	0.2490	0.0348
PHL	0.0036	-0.0012	-0.0092	0.0134	0.0031	0.0113	0.1330	0.1765	0.0349
PRT	0.0004	0.0013	-0.0020	0.0009	0.0007	0.0060	0.0244	0.0428	0.0012
RUS	0.0023	0.0037	-0.0028	0.0057	0.0013	0.0093	0.0994	0.1325	0.0181
SEN	0.0034	-0.0005	-0.0061	0.0101	0.0025	0.0103	0.0960	0.1409	0.0157
SWE	0.0005	0.0014	-0.0020	0.0000	0.0008	0.0042	0.0192	0.0408	0.0007
TUR	0.0005	0.0019	-0.0031	0.0025	0.0019	0.0068	0.0552	0.0679	0.0145
TZA	0.0056	0.0047	-0.0060	0.0179	0.0070	0.0272	0.2523	0.3526	0.0426
USA	0.0013	0.0012	-0.0035	0.0036	0.0009	0.0086	0.0399	0.0711	0.0051
VEN	0.0035	0.0031	-0.0061	0.0089	0.0010	0.0112	0.1477	0.2210	0.0234
VNM	0.0106	-0.0057	-0.0105	0.0365	0.0034	0.0043	0.1448	0.1833	0.0559
ZAF	0.0030	0.0044	-0.0050	0.0078	0.0031	0.0173	0.0924	0.1503	0.0182
World	0.0259	0.0081	-0.0036	0.1114	0.0278	0.0156	0.3223	0.6285	0.2182
Non-China	0.0017	0.0029	-0.0033	0.0059	0.0017	0.0089	0.0844	0.1244	0.0124

Notes: Table shows how much changes in China's sectoral TFPs and trade barriers during the period 2008-2011 contributed to actual outcomes, versus a counterfactual where China's sectoral TFP changes and trade barrier reductions matched those of its trade partners.

Table 14: Robustness: China Services TFP equals Average non-China Services TFP (1993-2007)

	Model Outcomes for Selected Countries								
	Static Model (2007 values)			*Dynamic Model (2007 values)*			*Dynamic Model (Steady State)*		
	Real GDP	$\widehat{r}/\widehat{w}$	$\widehat{P}_{IV}/\widehat{P}_C$	Real GDP	$\widehat{K}$	$\hat{x}$	Real GDP	$\widehat{K}$	$\widehat{\mathbf{U}}$
ARG	0.0030	0.0022	-0.0082	0.0041	0.0020	0.0055	0.0528	0.0825	0.0064
AUS	0.0043	0.0085	-0.0046	0.0073	0.0064	0.0141	0.0803	0.1318	0.0094
BOL	0.0017	-0.0010	-0.0018	0.0020	0.0003	0.0003	0.0211	0.0260	0.0033
BRA	0.0011	0.0034	-0.0033	0.0023	0.0022	0.0059	0.0304	0.0490	0.0028
CAN	0.0017	0.0015	-0.0042	0.0025	0.0016	0.0033	0.0256	0.0412	0.0033
CHL	0.0067	-0.0002	-0.0020	0.0081	0.0015	0.0002	0.0544	0.0588	0.0162
CHN	0.7010	0.0436	-0.2066	0.8682	0.2339	0.1104	2.4921	3.3154	1.3077
CZE	0.0009	0.0027	-0.0054	0.0018	0.0014	0.0030	0.0254	0.0410	0.0019
DEU	0.0000	0.0062	-0.0052	0.0013	0.0025	0.0070	0.0209	0.0441	0.0007
ESP	0.0009	0.0023	-0.0024	0.0017	0.0014	0.0028	0.0170	0.0259	0.0016
ETH	0.0065	0.0008	-0.0074	0.0083	0.0029	0.0085	0.0715	0.0938	0.0099
FIN	0.0029	-0.0003	-0.0042	0.0035	0.0007	0.0018	0.0253	0.0356	0.0046
FRA	0.0003	0.0019	-0.0022	0.0009	0.0010	0.0026	0.0115	0.0206	0.0008
GBR	0.0013	0.0023	-0.0032	0.0021	0.0016	0.0042	0.0203	0.0331	0.0024
HUN	0.0052	-0.0007	-0.0057	0.0059	0.0010	0.0030	0.0386	0.0513	0.0072
IDN	0.0038	0.0063	-0.0063	0.0072	0.0048	0.0081	0.0752	0.0927	0.0137
IND	0.0021	-0.0030	-0.0068	0.0022	-0.0001	0.0000	0.0076	0.0125	0.0018
ISL	0.0005	0.0003	-0.0025	0.0011	0.0012	0.0016	0.0118	0.0184	0.0007
ISR	0.0011	0.0042	-0.0045	0.0022	0.0022	0.0052	0.0279	0.0446	0.0029
JOR	0.0060	-0.0003	-0.0062	0.0086	0.0048	0.0070	0.0577	0.0746	0.0074
JPN	0.0009	0.0024	-0.0061	0.0019	0.0015	0.0046	0.0227	0.0422	0.0010
KAZ	0.0131	0.0066	-0.0117	0.0166	0.0055	0.0099	0.1541	0.2134	0.0336
KEN	0.0040	0.0003	-0.0101	0.0060	0.0036	0.0064	0.0568	0.0834	0.0069
KOR	0.0037	0.0003	-0.0080	0.0054	0.0023	0.0033	0.0311	0.0492	0.0057
MEX	0.0005	0.0038	-0.0020	0.0013	0.0012	0.0035	0.0294	0.0376	0.0022
MYS	0.0125	0.0008	-0.0248	0.0168	0.0057	0.0095	0.2132	0.2720	0.0455
PER	0.0051	0.0080	-0.0080	0.0075	0.0044	0.0131	0.1107	0.1658	0.0161
PHL	0.0061	-0.0024	-0.0156	0.0084	0.0032	0.0071	0.0882	0.1154	0.0136
PRT	0.0006	0.0018	-0.0033	0.0012	0.0012	0.0033	0.0148	0.0260	0.0007
RUS	0.0033	0.0050	-0.0049	0.0047	0.0020	0.0056	0.0672	0.0893	0.0113
SEN	0.0034	-0.0012	-0.0067	0.0045	0.0018	0.0044	0.0402	0.0577	0.0034
SWE	0.0001	0.0016	-0.0039	0.0007	0.0008	0.0019	0.0124	0.0249	0.0012
TUR	0.0011	0.0027	-0.0065	0.0031	0.0027	0.0050	0.0358	0.0439	0.0074
TZA	0.0052	0.0022	-0.0072	0.0077	0.0047	0.0104	0.1004	0.1422	0.0132
USA	0.0018	0.0012	-0.0052	0.0025	0.0013	0.0038	0.0203	0.0356	0.0023
VEN	0.0032	0.0022	-0.0067	0.0042	0.0017	0.0039	0.0587	0.0874	0.0096
VNM	0.0249	-0.0115	-0.0097	0.0273	0.0041	-0.0006	0.0723	0.0799	0.0311
ZAF	0.0035	0.0028	-0.0062	0.0048	0.0025	0.0070	0.0443	0.0697	0.0064
World	0.0286	0.0097	-0.0121	0.0339	0.0295	0.0071	0.1053	0.3369	0.0398
Non-China	0.0027	0.0026	-0.0059	0.0047	0.0025	0.0047	0.0532	0.0765	0.0075

Notes: Table shows how much changes in China's sectoral TFPs and trade barriers during the period 1993-2007 contributed to actual outcomes, versus a counterfactual where China's sectoral TFP changes and trade barrier reductions matched those of its trade partners. In this case, all prices and TFPs have been computed under the assumption that China's "Other Services" TFP equals the aggregate "Other Services" TFP of all other countries.

Table 15: Robustness: Varying Key Parameters

	Model Outcomes for Selected Countries								
	Static Model (2007 values)			*Dynamic Model (2007 values)*			*Dynamic Model (Steady State)*		
	Real GDP	$\widehat{r}/\widehat{w}$	$\widehat{P}_{IV}/\widehat{P}_C$	Real GDP	$\widehat{K}$	$\hat{x}$	Real GDP	$\widehat{K}$	$\widehat{\mathbf{U}}$
A. Lower trade elasticity ($\theta = 2.00$; $\kappa = 0.55$)									
CHN	0.9235	0.0500	-0.2982	1.1268	0.2755	0.1355	3.2431	4.6286	1.5008
DEU	0.0020	0.0048	-0.0093	0.0035	0.0025	0.0072	0.0286	0.0502	0.0037
KOR	0.0096	0.0026	-0.0159	0.0132	0.0052	0.0073	0.0620	0.0875	0.0155
PER	0.0109	0.0095	-0.0152	0.0134	0.0046	0.0140	0.1010	0.1463	0.0214
USA	0.0042	0.0015	-0.0098	0.0052	0.0020	0.0064	0.0304	0.0499	0.0048
VNM	0.0468	-0.0138	-0.0203	0.0538	0.0140	0.0063	0.1459	0.1640	0.0582
All Non-China	0.0066	0.0039	-0.0110	0.0100	0.0039	0.0076	0.0634	0.0885	0.0132
B. Higher trade elasticity ($\theta = 6.00$; $\kappa = 0.55$)									
CHN	0.5440	0.0375	-0.1613	0.6642	0.1791	0.0973	1.9319	2.4403	0.9145
DEU	-0.0005	0.0074	-0.0038	0.0009	0.0029	0.0081	0.0212	0.0492	-0.0001
KOR	0.0017	-0.0012	-0.0054	0.0028	0.0013	0.0018	0.0185	0.0334	0.0021
PER	0.0030	0.0063	-0.0055	0.0054	0.0045	0.0136	0.1093	0.1660	0.0144
USA	0.0011	0.0010	-0.0036	0.0016	0.0010	0.0030	0.0162	0.0297	0.0014
VNM	0.0165	-0.0094	-0.0064	0.0170	0.0000	-0.0027	0.0396	0.0465	0.0195
All Non-China	0.0014	0.0020	-0.0042	0.0029	0.0020	0.0039	0.0507	0.0745	0.0054
C. Lower capital adjustment costs ($\theta = 4.00$; $\kappa = 0.75$)									
CHN	0.6386	0.0442	-0.2005	0.8105	0.2590	0.1692	2.2012	2.8814	1.0596
DEU	0.0001	0.0061	-0.0051	0.0017	0.0032	0.0082	0.0150	0.0309	0.0011
KOR	0.0037	0.0009	-0.0080	0.0059	0.0031	0.0049	0.0261	0.0393	0.0061
PER	0.0052	0.0083	-0.0080	0.0083	0.0060	0.0175	0.0818	0.1212	0.0147
USA	0.0018	0.0013	-0.0051	0.0026	0.0015	0.0053	0.0147	0.0254	0.0021
VNM	0.0242	-0.0117	-0.0100	0.0271	0.0048	0.0010	0.0612	0.0653	0.0280
All Non-China	0.0028	0.0029	-0.0058	0.0052	0.0033	0.0065	0.0393	0.0573	0.0071
D. Higher capital adjustment costs ($\theta = 4.00$; $\kappa = 0.35$)									
CHN	0.6386	0.0442	-0.2005	0.7397	0.1414	0.0621	2.4603	3.2415	1.0207
DEU	0.0001	0.0061	-0.0051	0.0009	0.0017	0.0061	0.0460	0.0977	0.0004
KOR	0.0037	0.0009	-0.0080	0.0049	0.0017	0.0025	0.0521	0.0868	0.0050
PER	0.0052	0.0083	-0.0080	0.0068	0.0030	0.0103	0.1899	0.2881	0.0181
USA	0.0018	0.0013	-0.0051	0.0023	0.0009	0.0028	0.0411	0.0726	0.0024
VNM	0.0242	-0.0117	-0.0100	0.0256	0.0020	-0.0023	0.0971	0.1171	0.0330
All Non-China	0.0028	0.0029	-0.0058	0.0043	0.0017	0.0035	0.0891	0.1208	0.0081

Notes: Table shows how much changes in China's sectoral TFPs and trade barriers during the period 1993-2007 contributed to actual outcomes for a small selection of countries, versus a counterfactual where China's sectoral TFP changes and trade barrier reductions matched those of its trade partners. Each panel experiments with varying a key parameter from the model.

Appendix

The Appendix is organized into the following three main parts:

- Appendix A, which provides full details on the construction and sourcing of the data using in the quantitative analysis.
- Appendix B, which describes all numerical methods used to quantify the model and compute counterfactuals, both for the static version of the model as well as for the full dynamic model.
- Appendix C, which provides supplementary notes clarifying various key expressions and results used in the analysis as well as how to extend the framework to allow for endogenous trade balances.

Appendix A: Data Construction

All trade and output data is first downloaded and assembled at the ISIC rev. 3 2 digit level and then aggregated to the broader industry categories used in the analysis. The aggregated trade and output data must then be carefully harmonized with the input-sourcing requirements implied by each country's (aggregated) input-output table. This Appendix describes the steps taken to combine these various data sources and provides additional information on the construction of the other variables used in the analysis.

Trade

Trade data is mostly taken from U.N. COMTRADE, downloaded at the ISIC rev. 3 2 digit industry level. For some countries, trade data is not reported using ISIC rev. 3 classification for the first few years in the data. In these cases, I fill in earlier years using trade data from the World Trade Flows data base of Feenstra *et al.* (2005)—which is provided at the highly disaggregated SITC rev. 2 4 digit level—and convert the World Trade Flows data to ISIC rev. 3 using country-specific concordances.

Output

As described in the main text, all output data for OECD countries is taken from OECD STAN, whereas for non-OECD countries, I combine manufacturing output data from UNIDO INDSTAT2 with non-manufacturing output data from U.N. National Accounts. Industry-level value added is also drawn from these sources whenever possible.

The U.N. National Accounts system itself consists of two different data series, "Official Country Data" and "Estimates of Main Aggregates". Of these, Estimates of Main Aggregates is the most comprehensive in terms of country coverage. However, it has two main deficiencies: (i) it provides industry-level value added only, not gross output; (ii) the mining and utilities sectors are reported together under a combined industry code.[29] When data from the Estimates of Main Aggregates series is used, the value added share from the closest year from U.N. Official Country Data or OECD STAN is used to infer gross output, if available. Otherwise, value added shares from the OECD Input-Output tables are used. These same sources are also used, in the same manner, to split mining and utilities output in the Estimates of Main Aggregates data.

An important note regarding these various output data sources is that both UNIDO and U.N. Estimates of Main Aggregates report values in U.S. dollars, whereas the other sources report only in local currencies. The OECD STAN database conveniently includes annual exchange rates for converting to U.S. dollars. For

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[29] Technically speaking, the Estimates of Main Aggregates reports Mining & Quarrying, Manufacturing, and Utilities as a single combined industry "C-E". However, value added for Manufacturing ("D") is almost always available separately. When it is not, I take the value for total manufacturing value added from UNIDO.

U.N. Official Country Data, I infer the correct exchange rate by comparing the annual GDP value reported in local currencies with the corresponding U.S. dollar equivalent reported in the Estimates of Main Aggregates series.[30]

National Aggregates

National aggregate values for GDP, investment, trade balances (including Services trade volumes) are taken from OECD STAN (for OECD countries) as well as U.N. National Accounts (for non-OECD countries).

Data on capital and labor endowments is from the Penn World Table v. 8.1 (Feenstra, Inklaar, & Timmer, 2015). For the capital endowment, I use the real capital stock variable, RK^{NA}. A country's labor endowment is the total number of hours worked multiplied by that country's human capital index. With factor endowments in hand, factor prices $w_{i,t}$ and $r_{i,t}$ can then be computed using (11).

Production Technologies

Input-output coefficients and other production technology parameters are sourced from the OECD Input-Output Database. This database provides annual input-output tables—complete with value added shares, labor shares, and absorption shares—for all OECD countries for the years 1995-2011, plus several non-OECD countries included in the sample as well as a "Rest of World" aggregate table for modeling excluded countries.[31]

The *usage* coefficients used in the analysis—i.e., the $\alpha^{l}_{i,k}$'s in (9)—are the median usage coefficients across all years in the data. These are constructed by first aggregating total usage values from the 2 digit ISIC rev. 3 codes used in the Input-Output tables to the broader industry classifications used in the analysis, then taking the median usage shares across all years for each country. By aggregating in this way, usage coefficients will differ even for countries that do not have their own dedicated Input-Output tables.

The labor share in value added—α^{w}_{k} in (9), is constructed in the same way—by first aggregating and then taking the median across years. The capital share in value added, α^{r}_{k}, is just $1-\alpha^{w}_{k}$.

For the value added shares (i.e., the $\beta^{v}_{i,k}$'s), I rely on the value added information provided with the output data whenever possible and supplement with value added shares from the Input-Output database as needed. Finally, both the value added shares as well as the shares of shares of absorption used for investment versus consumption (i.e., the $\gamma^{k}_{i,C}$'s and $\gamma^{k}_{i,IV}$'s) typically need to be adjusted, at least to some small degree, in order to reconcile the input-usage patterns implied by the Input-Output tables with the levels of output, trade, and expenditure present in the trade and output data. I discuss the procedure for this reconciliation in more detail below.

Constructing Internal Trade

Once the raw data for trade and output is obtained, there are two main accounting rules that must be kept in mind:

1. A country's exports in an industry cannot exceed its gross output.
2. A country's total usage of an industry as an intermediate input for other industries cannot exceed that country's total expenditure on that industry.

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[30] The original source for the exchange rate conversions used by the U.N. is average end-of-month market exchange rates from the IMF's International Financial Statistics. I have independently confirmed that the exchange rates provided in OECD STAN match those used by the U.N.

[31] In addition to the OECD countries, the non-OECD countries included in the study that have their own dedicated Input-Output tables in the OECD database are: Argentina, Brazil, Bulgaria, China, Colombia, Costa Rica, India, Indonesia, Malaysia, Nigeria, Philippines, Romania, Russia, Thailand, and Viet Nam.

The first of these is a well-known issue with international trade statistics (c.f., Head & Mayer, 2014, p. 178.) To resolve this issue, I develop a method for imputing missing internal trade values that builds upon the approach used by Anderson & Yotov (2010, 2016). The second of these rules also routinely presents an issue when combining Input-Output tables with other data sources. Ensuring this rule is not violated requires working carefully with the input-output structure of the data and will be dealt with in more detail in the following subsection.

The general strategy for imputing missing internal trade values is, as in Anderson & Yotov (2010, 2016), to exploit the industry-level detail of the production data and the relative stability of internal trade shares over time. Generally, this procedure is only needed for manufacturing industries, since output data coverage for Agriculture and Mining is relatively thorough and since internal trade shares for these sectors tend to be relatively large. To proceed:

Let "s" denote an ISIC rev. 3 2 digit manufacturing industry. Whenever possible, the "internal trade" of country m in industry s at time t, $X_{mm,s,t}$, is constructed as its gross output value from the data, $Y_{m,s,t}$, less its total exports to all destinations, $EX_{m,s,t} \equiv \sum_{j \neq m} X_{mj,s,t}$. However, if exports exceed the value of output reported in the data—or if output is missing to begin with—$X_{mm,s,t}$ is treated as missing. To aid in imputing these values, define $\xi_{m,s,t} = X_{mm,s,t}/IM_{m,s,t}$ as the ratio of internal trade to imports for country m and industry s at time t.[32] If output is missing, or if $Y_{m,s,t} < EX_{m,s,t}$, the following three steps are taken:

First, I interpolate $\xi_{m,s,t}$ linearly based on non-missing values. This first step alone resolves the majority of missing values, leaving only cases where either a country's internal trade is *always* missing for a particular 2 digit industry or where values are missing at either end of the period and need to be extrapolated. In addition, because I have production data pre-dating 1993 in most cases, the need to extrapolate is mainly limited to the very end of the period (usually the years 2009-2011).

Second, for the cases where a country always has missing values for a particular 2 digit industry s, then:

i) Define "$\xi_{m,t}$" as the internal trade-to-imports ratio for all *non-missing* manufacturing industries in country m at time t.

ii) Define "$\xi_{s,t}$" as the *world* internal trade-to-imports ratio for industry s at time t.

iii) Define "ξ_t" as the world internal trade-to-imports ratio across *all* manufacturing industries at time t.

$\xi_{m,s,t}$ in these cases is then constructed as: $\xi_{m,s,t} = \xi_{m,t} \cdot \xi_{s,t}/\xi_t$. In other words, the imputed internal trade-to-imports ratio is assumed to evolve with a country's overall openness to trade in manufacturing, scaled by how open that sector tends to be relative to all other manufacturing sectors in the world at large at time t. The resulting internal trade value is then simply $X_{mm,s,t} = \xi_{m,s,t} \cdot IM_{m,s,t}$.

Third, for the remaining missing values (which need to be extrapolated), the procedure is:

- for extrapolating values at the end of the period: $\xi_{m,s,t} = \xi_{m,s,t\text{-}1} \cdot \Delta\xi_{m,t} \cdot \Delta\xi_{s,t}/\Delta\xi_t$;
- for extrapolating values at the beginning of the period: $\xi_{m,s,t} = \xi_{m,s,t+1}/\Delta\xi_{m,t}/\Delta\xi_{s,t} \cdot \Delta\xi_t$,

where a "Δ" indicates a change in a variable from one period to the next. Again, the idea is that missing values should evolve with the non-missing values for that country, adjusted by the relative rate of change for that sector in the rest of the world. The remaining internal trade values are again calculated using $\xi_{m,s,t}$ and $IM_{m,s,t}$. Finally, once all values for $X_{mm,s,t}$ are populated at the 2 digit level of disaggregation, I aggregate up to the broader categories used in the analysis and adjust each country's output and expenditure for these categories accordingly.

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[32] Anderson & Yotov (2010, 2016) impute missing values using the internal trade share, $\pi_{mm,s,t} \equiv X_{mm,s,t}/E_{m,s,t}$. However, the internal trade share cannot exceed 1. Since $\xi_{m,s,t} = \pi_{mm,s,t}/(1-\pi_{mm,s,t})$, it provides an unbounded transformation of $\pi_{mm,s,t}$, which is more convenient to work with for extrapolation.

As noted, imputing missing internal trade values is typically a necessity when working with trade and output data. I favor the approach taken here for two main reasons: first, using the disaggregated industry-level detail allows me to isolate unreasonable values often to one or two disaggregated industries, which can using be inferred from data from surrounding years. Second, the implicit assumption that a country's relative demand for domestic versus foreign produced goods is relatively stable over time helps generate steady, reasonable progressions for output values, whereas, e.g., using exports to extrapolate missing values may overstate the volatility of output, especially for small countries close to the margin between exporting versus not.

Absorption & Value Added Shares

For compactness, I ignore the subscripts i and t in this subsection and instead focus on the case of a single country at a single point in time. This same method used here to adjust the absorption and value added shares is then applied to all countries and years. The need for such an adjustment follows from the following accounting identity:

Accounting Identity: *Define the following objects:*

- $\mathbf{G} \equiv [\{\gamma_C^k\}, \{\gamma_{IV}^k\}]$, *a* $K \times 2$ *matrix of absorption shares;*
- $\mathbf{A} \equiv [\{\alpha_k^l\}]$, *a* $K \times K$ *matrix of input usage coefficients, arranged so the row industry (l) feeds into the column industry (k);*
- $\mathbf{B} \equiv [\{\beta_k^v\}]$, *a* $K \times 1$ *vector of value added shares, with* $\mathbf{1} - \mathbf{B} = [\{1 - \beta_k^v)\}]$ *a* $K \times 1$ *vector of intermediate usage shares;*
- $\mathbf{D} \equiv [\{IM_k - EX_k\}]$, *a* $K \times 1$ *vector of sectoral trade balances;*
- $\mathbf{X} \equiv [E_C, E_{IV}]$, *a* 2×1 *"absorption" vector, containing only national consumption* (E_C) *and investment* (E_{IV})*.*

Then the output vector, $\mathbf{Y} \equiv [\{Y_k\}]$, *must satisfy the following accounting identity:*

$$\underbrace{\mathbf{Y}+\mathbf{D}}_{expenditure} = \underbrace{[\mathbf{A}\,(\mathbf{1}-\mathbf{B})]\mathbf{Y}}_{input\ usage} + \underbrace{\mathbf{GX}}_{absorption}. \tag{A.1}$$

In words, total national expenditure on any one industry k consists of two elements: demand for k as an input for production and final demand for k for use in investment and consumption. The key observation from (A.1) is that, given ($\mathbf{G}$, $\mathbf{A}$, $\mathbf{B}$, $\mathbf{D}$, $\mathbf{X}$), the output values in $\mathbf{Y}$ are completely determined, without any reference to the actual data on output.[33] Furthermore, given data on $\{Y_k\}$, there is no guarantee that the implied input usage term will not exceed the overall level of expenditure for at least one industry (which would violate "rule 2" from the preceding subsection).

Define $\{Y_k(\mathbf{G},\mathbf{B};\cdot)\}$ as the sectoral output values that satisfy the identity in (A.1). Let a "*data*" superscript imply a value taken from the data and let $Y = \sum_k Y_k^{data}$ be total gross output. I then obtain value added shares and final demand shares from the following constrained minimization problem:

$$\min_{\{\gamma_k^C\},\{\gamma_k^{IV}\},\{\beta_k^v\}} \sum_k \frac{1}{Y^2}\left\{Y_k(\mathbf{G},\mathbf{B};\cdot) - Y_k^{data}\right\}^2 + \omega_{C,k}\left\{\gamma_C^k - \gamma_C^{k,data}\right\}^2 + \omega_{IV,k}\left\{\gamma_{IV}^k - \gamma_{IV}^{k,data}\right\}^2$$
$$+ \omega_{B,k}\left\{\beta_k^v - \beta_k^{v,data}\right\}^2 \tag{A.2}$$

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[33] Specifically, $\mathbf{Y} = \{\mathbf{I} - [\mathbf{A}\,(\mathbf{1}-\mathbf{B})]\}^{-\mathbf{1}} \times [\mathbf{GX} - \mathbf{D}]$.

such that

$$\sum_k \gamma_C^k = 1; \quad \sum_k \gamma_{IV}^k = 1; \quad \sum_k \beta_k^v Y_k = GDP; \quad Y_k \geq EX_k; \quad \gamma_C^k, \gamma_{IV}^k \geq 0.$$

$\omega_{C,k}$, $\omega_{IV,k}$, and $\omega_{B,k}$ here are weights used to help fit the available data series on absorption and value added shares. Note that these weights need not be large. Conceptually, because there are more free parameters than sectors, there will usually be many admissible values for $Y_k(\mathbf{G}, \mathbf{B}; \cdot)$ that fit the data on output. The presence of these weights then effectively "selects" a solution that requires only minimal adjustments to the value added and absorption coefficients. By construction, this method also produces final demand and value added coefficients that are relatively stable over time within countries.

For the weights themselves, I use $\omega_{C,k} = \omega_{IV,k} = .005$ and $\omega_{B,k} = .025$ for most sectors. For the construction and services sectors, which tend to play outsized roles in investment and consumption demand, I use larger weights: specifically, I use $\omega_{IV,F} = .1$, $\omega_{C,O} = \omega_{IV,O} = .02$.[34] After applying this procedure to all countries and years, the overall correlations between the data and the new, "adjusted" values are as follows. Output: 0.9997; γ_C^k: 0.9399; γ_{IV}^k: 0.9760; β_k^v: 0.9901.

The "Rest of the World"

The "Rest of the World" region (or "RoW") is a synthetic aggregate region that absorbs the sectoral trade balances of other countries and contributes the remainder of world GDP, which is consistently about 7% throughout the period. For sectoral output values, I combine production data for all excluded countries and use the methods for imputing missing output values described above when necessary. All other RoW aggregates—e.g., investment, factor endowments—are similarly constructed by aggregating data from excluded countries.

Prices

As noted in the main text, investment and consumption prices are from the Penn World Table. For U.S. industry price levels, the original source is the Bureau of Economic Analysis's Annual Industry Accounts. Specifically, I use the "gross output price index" ("GOPI") from the BEA's "Gross Domestic Product (GDP) by Industry" series.

However, because these indices only take into account U.S. firm output prices, they must be adjusted by the U.S. internal trade share to obtain the overall U.S. price level from the model, which should also take into account the prices of imported goods. Mechanically, if $p^*_{US,k,t}$ is the U.S. output price from the BEA data for industry k at time t, then

$$P_{US,k,t} = p^*_{US,k,t} \times (\pi_{USUS,k,t})^{1/\theta}.$$

In other words, as the U.S. imports more, the overall industry price level $P_{US,k,t}$ should fall relative to the observed U.S. producer price level $p^*_{US,k,t}$. This adjustment of course directly mirrors Finicelli, Pagano, & Sbracia (2013)'s use of the internal trade share to infer "theory-consistent" values for a country's TFP and and, as in their work, makes a material difference for appraising the U.S.'s technology level.[35]

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[34] Admittedly, I arrived at these weights mainly using trial and error. I have experimented with using other values for the ω's and generally found that the key conclusions of the analysis are not meaningfully affected.

[35] Note that theory dictates that $p^*_{i,k,t} = A^{-1/\theta}_{i,k,t} c_{i,k,t}$. Standard TFP accounting effectively assumes $TFP_{i,k,t} = c_{i,k,t}/P_{i,k,t}$, again treating the producer price and the overall price level as one and the same (which is not the case when there is trade). The "corrected" value for TFP is then $A^{1/\theta}_{i,k,t} = TFP_{i,k,t} \times \pi^{1/\theta}_{ii,k,t}$. To see the connection with Finicelli, Pagano, & Sbracia (2013), refer to "Proposition 5" in their paper, noting that their "Ω_i" variable is the inverse of the internal trade share.

Finally, all nominal values—including prices, trade, output, expenditure, and GDP—are converted to 2005 USD equivalents using the U.S. GDP deflator, such that the overall U.S. price level in any period stays constant over time. Changes in price levels in other countries are then always measured relative to the price level in the U.S.

Appendix B: Quantitative Methods

The first part of this Appendix describes how trade frictions, prices, and technology levels are recovered from the data. This procedure closely follows the "fixed effects algebra" approach of Shikher (2012) and Levchenko & Zhang (2016), but with two main differences: first, instead of a using more traditional log-OLS "gravity" specification to estimate trade frictions (depending on distance, colonial relationships, etc.), I estimate a dummy variables-only specification using Poisson PML. Second, instead of using U.S. technology levels as a baseline for price and technology levels in other countries, I use U.S. industry-level prices. The justification for the former choice is for improved flexibility in accounting for variability in trade frictions across countries and over time, as well as allowing for zeros and exploiting the tighter connection to the structural model provided by Poisson PML. In the case of the latter choice, I use U.S. price levels because U.S. TFP data is not readily available for the agriculture and mining sectors.

The remainder of Appendix B goes on to describe the iterative algorithms used to solve for counterfactuals in both the "static" and "dynamic" versions of the model.

Poisson PML estimation with only dummy variables

Consider again the estimation specification for trade flows implied by (28):

$$X_{ijkt} = \exp\left[\ln \Gamma_{ikt} + \ln \Phi_{jkt} + \ln \eta_{ijkt}\right] + \varepsilon_{ijkt}, \tag{B.1}$$

where it should be re-iterated that the pair-specific term $\ln \eta_{ijkt} = \ln \eta_{jikt}$ is symmetric within each i, j pair.[36] Because the underlying estimator is Poisson PML—and noting that $\{\ln \Gamma_{ikt}\}$, $\{\ln \Phi_{jkt}\}$, and $\{\ln \eta_{ijkt}\}$ are themselves the coefficients of various sets of $0/1$ dummy variables—the first order conditions associated with each of these fixed effects terms can be expressed as follows:

$$\ln \Gamma_{ikt}: \quad \sum_j X_{ij,k,t} - \exp\left[\ln \Gamma_{ikt} + \ln \Phi_{jkt} + \ln \eta_{ijkt}\right] = 0 \tag{B.2a}$$

$$\ln \Phi_{jkt}: \quad \sum_i X_{ij,k,t} - \exp\left[\ln \Gamma_{ikt} + \ln \Phi_{jkt} + \ln \eta_{ijkt}\right] = 0 \tag{B.2b}$$

$$\ln \eta_{ijkt}: \quad X_{ij,k,t} + X_{ji,k,t} - \exp\left[\ln \eta_{ijkt}\right]\left\{\exp\left[\ln \Gamma_{ikt} + \ln \Phi_{jkt}\right] - \exp\left[\ln \Gamma_{jkt} + \ln \Phi_{ikt}\right]\right\} = 0. \tag{B.2c}$$

Manipulating (B.2a)-(B.2c) then results in the following analytical solutions for each Γ_{ikt}, Φ_{jkt}, and η_{ijkt}:

$$\Gamma_{ikt} = \frac{Y_{i,k,t}}{\sum_j \Phi_{jkt} \cdot \eta_{ijkt}}; \qquad \Phi_{jkt} = \frac{E_{j,k,t}}{\sum_i \Gamma_{ikt} \cdot \eta_{ijkt}}; \qquad \eta_{ijkt} = \frac{X_{ij,k,t} + X_{ji,k,t}}{\Gamma_{ikt} \cdot \Phi_{jkt} + \Gamma_{jkt} \cdot \Phi_{ikt}}. \tag{B.3}$$

A solution for $\{\Gamma_{ikt}, \Phi_{jkt}, \eta_{ijkt}\}$ can then be obtained by iterating repeatedly on these three expressions. The system converges converges very quickly using modern software despite the large number of parameters to be solved for ($210,824$ in this case).

Note, however, that any analytical solution to (B.3) will not be unique unless 2 further normalizations are applied. The first of these is the standard assumption that internal trade is "frictionless"—i.e., that

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[36] Otherwise, one would trivially obtain $\eta_{ijkt} = X_{ijkt}$, $\Gamma_{ikt} = \Phi_{jkt} = 1$.

$\eta_{iikt} = d_{ii,k,t} = 1\ \forall i,k,t$. The second is to insist that the price level of the U.S. for industry k at time t, P_{USkt}, is equal to the actual U.S. industry price level taken from data published by the Bureau of Economic Analysis.

Finally, in order to match the trade data perfectly, the error term from the estimation ε_{ijkt} is treated as reflecting residual variation in trade frictions. Fortunately, this necessity does not change any of the structural interpretations thus far discussed. This is because, as with the the η_{ijkt}'s, the error term has "no aggregate effect" on any one country's trade in industry k at time t, as I elaborate on further in Appendix C.

Computing counterfactuals

This set of numerical procedures takes as given that all "shocks" needed to fit the model to the original data have already been computed. With these shocks in hand, static and/or dynamic counterfactual outcomes can be computed by varying one or more of these shock vectors. I describe the methods used to solve each of these models in turn, starting with the static model:

The Static Model

The procedure for solving the static model is the easiest to describe. Simply put, it involves iterating continuously through the system of equations laid out in (14)-(19), with one (minor) alteration, discussed below. This procedure for solving the static model will then in turn be nested within the procedure used to solve the dynamic model described below.

Explicitly, I solve for the "equilibrium in changes" within a single period t using the following iteration loop:

S.0. Guess values for new output, $\{Y'_{i,k,t}\}$, new expenditure $\{E'_{i,k,t}\}$, changes in price levels $\{\widehat{P}_{i,k,t}\}$ and changes in factor rewards $\{\widehat{w}_{i,t}, \widehat{r}_{i,t}\}$ consistent with the initial equilibrium:

$$Y'_{i,k,t} = Y_{i,k,t}; \qquad E'_{i,k,t} = E_{i,k,t}; \qquad \widehat{P}_{i,k,t} = \widehat{w}_{i,t} = \widehat{r}_{i,t} = 1.$$

S.1. Update changes in factor prices, $\{\widehat{w}_{i,t}, \widehat{r}_{i,t}\}$, using (19a) and (19b). The first time through the loop, these will be unchanged.

S.2. Update changes in input bundle costs, $\{\widehat{c}_{i,k,t}\}$, using (14). The first time through the loop, this step will return $\widehat{c}_{i,k,t} = 1$.

S.3. Update changes in sectoral price levels, $\{\widehat{P}_{i,k,t}\}$, using (15). Note these price levels depend on technology shocks, $\{\widehat{A}_{i,k,t}\}$, and trade barrier shocks $\{\widehat{d}_{ij,k,t}\}$. Thus, this is where changes from the initial equilibrium are first introduced.

S.4. Update new sectoral output levels, $\{Y'_{i,k,t}\}$, in two steps:

(a) First, as an intermediate step, use the goods market clearing condition, (16), to construct a set of temporary new output values, $\{\widetilde{Y}'_{i,k,t}\}$.

(b) Second, the new output values that will be carried forward are constructed by applying only half the change between the temporary new values and the last set of values from the previous iteration. Specifically, the updated new values for $\{Y'_{i,k,t}\}$ are

$$Y'_{i,k,t} = Y^0_{i,k,t} \times \left(\widetilde{Y}'_{i,k,t} / Y^0_{i,k,t}\right)^{1/2},$$

where $\{Y^0_{i,k,t}\}$ are the previously stored values for new output.

S.5. Update new values for nominal GDP, $\{GDP'_{i,k,t}\}$, using (17).

S.6. Update new values for sectoral expenditure values, $\{E'_{i,k,t}\}$, using (18).

S.7. If output values and changes in prices have not converged, carry forward $\{Y'_{i,k,t}\}$ and $\{E'_{i,k,t}\}$ as the new starting values for output and expenditure and return to step S.1, iterating continuously until convergence.

Obviously, the loop closely follows the "equilibrium in changes" system of equations laid out in Section 2.4. The one slight difference is that I do not fully update output values each time through the loop. This is done in order to eliminate large swings in output values from one iteration to the next, which tend to hinder convergence. Also note that the numeraire—$P_{US} = P_C^{1-x_{US}} \cdot P_{IV}^{x_{US}} = 1$—must be enforced each time through the loop by dividing all nominal variables by $\widehat{P}_{US}$. In addition to being relatively straightforward, this approach also proves to be highly efficient: a single counterfactual for a single year takes only a fraction of a second to compute.

The full dynamic model

Given the steps described above for solving the static model, the procedure for recovering dynamic counterfactuals again directly follows the equilibrium conditions described in the main text. However, three important details remain to be clarified: (i) how to solve for the competitive steady state, (ii) how to initialize values for "future" years beyond year T leading up to the steady state, and (iii) how to dynamically recover the "time preference shock" parameters $\{\widehat{\phi}_{i,t+1}\}$ needed to fit the data.

To clarify each of these details, I will first describe a generalized iteration loop for solving the full dynamic model, assuming that the competitive steady state and all preference shocks have already been determined. I will then discuss how the loop may be altered in order to first recover these objects.

Procedure:

D.1. Using the currently stored values for time t, proceed one time through steps S.1-S.7 from the procedure above for solving the static model. This will result in, in particular, new values for changes in the return to capital $\{\widehat{r}_{i,t}\}$, changes in the price of investment $\left\{\widehat{P}_{i,IV,t}\right\}$, and GDPs $\left\{GDP'_{i,t}\right\}$.

D.2. Update the contemporaneous investment rate $\left\{x'_{i,t}\right\}$ at time t using the Euler equation as expressed in (22).

D.3. Update next-period capital stocks $\left\{K'_{i,t+1}\right\}$ using the Law of Motion as expressed in (23).

D.4. If $t < T_{SS} - 1$, move ahead to the next year (i.e., $t \to t+1$) and return to step D.1. If $t = T_{SS} - 1$, check to see if the sequence of capital stocks $\left\{K'_{i,t}\right\}_{t=0}^{T_{SS}}$ has converged for all countries. If not, go back to $t = 0$ and return to step D.1.

As with the static model, it is necessary to enforce the numeraire—that the aggregate price level in the U.S. equals 1—in every period in order to pin down all other prices.

Initializing the path to steady state: The only alteration to the above procedure needed to solve for the steady state is to relax the notion of proceeding chronologically through time. Instead, take the last year of "actual" data, $t = T$, as the starting point and iterate continuously on the capital stock until a fixed point is reached.

Once the steady state equilibrium is known, I "pin" the steady state a fixed number of years in the (distant) future, T_{SS}.[37] To populate initial values for the years after $t = T$ leading up to $t = T_{SS}$, I make use of the first $T_{SS} - T - 1$ iterations used to recover the steady state.

Recovering time preference shocks: Before any actual counterfactuals can be computed, there is one last set of "shocks" that must be obtained in order for the initial equilibrium to perfectly match the data. Note from (22) that each country's investment expenditure in any given year depends dynamically on its investment expenditure in future years, including all future years beyond the last year of actual data. The set of time preference shocks $\{\widehat{\phi}_{i,t+1}\}$ thus are needed in order to ensure the investment versus consumption choices seen in the data are consistent with a viable perfect-foresight equilibrium path to the steady state.

To recover this last set of shocks, simply insert the following additional step in between steps D.1 and D.2:

D.1.5. If $t \leq T$, update time preference shocks $\{\widehat{\phi}_{i,t+1}\}$ at time t using the following expression

$$\widehat{\phi}_{i,t+1} = \frac{\frac{\widetilde{\chi}_{i,t}}{\rho} \cdot \frac{E'_{C,t+1}}{E'_{C,t}} \cdot \widehat{P}^{\kappa}_{i,IV,t} \cdot \frac{E'^{-\kappa}_{i,IV,t}}{K^{1-\kappa}_{i,t}}}{\kappa \cdot r_{i,t+1} \widehat{r}_{i,t+1} + (1-\kappa) \frac{E'_{i,IV,t+1}}{K_{i,t+1}} + (1-\delta) \frac{\widehat{P}^{\kappa}_{i,IV,t+1}}{\widetilde{\chi}_{i,t+1}} \frac{E'^{1-\kappa}_{i,IV,t+1}}{K^{1-\kappa}_{i,t+1}}} \tag{B.4}$$

The insertion of this step ensures that, when computing the initial perfect-foresight equilibrium, the investment rate $x'_{i,t}$ computed in step D.3. will always match the actual investment rate $x_{i,t} = E_{i,IV,t}/(GDP_{i,t} + D_{i,t})$ from the data for years $t \in [0, T]$. Note this step is only used beforehand to establish the baseline perfect-foresight equilibrium path. All dynamic counterfactuals then take $\{\widehat{\phi}_{i,t+1}\}$ as given.

Given the full set of shocks, computing each counterfactual using the dynamic model takes around 5 to 10 minutes. Backing out the time preference shocks $\{\widehat{\phi}_{i,t+1}\}$, which only needs to be done once for each constellation of parameters, also takes about 10 minutes.

Appendix C: Supplementary notes

Gains from trade

"Gains from trade" here will always refer to real consumption. Trade is assumed to be balanced (such that $D = 0$) and I assume no local technology shocks (such that $\widehat{A}_{i,k} = 1$). I can always write real consumption, in any given period, as

$$G_i = (1 - x_i) \frac{w_i L_i + r_i K_i}{P^C_i}.$$

In general, changes in real consumption are then

$$\widehat{G}_i = \left(\widehat{1 - x_i}\right) \times \left(\vartheta_w \widehat{w}_i + \vartheta_r \widehat{r}_i \widehat{K}_i\right) \times \prod_k \widehat{P}_{i,k}^{-\gamma^k_{i,C}}. \tag{C.1}$$

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[37] In general, I have found that pinning the steady state 350 years in the future is "about right".

Furthermore, I can simplify $\widehat{G}_i$ by using the analytical expression for the change in the sectoral internal trade share ($\pi_{ii,k}$) implied by the model:

$$\begin{aligned}\widehat{\pi}_{ii,k}^{-1/\theta} &= \widehat{c}_{i,k}/\widehat{P}_{i,k} \\ &= \widehat{w}_i^{\beta_{i,k}^{w}} \times \widehat{r}_i^{\beta_{i,k}^{r}} \times \prod_l \widehat{P}_{i,l}^{\beta_{i,k}^{l}} \times \widehat{P}_{i,k}^{-1}.\end{aligned}$$

By taking a product across sectors, using each sector's share of consumption as an exponent, I back out changes in the "real wage" (with respect to the price of consumption) as

$$\begin{aligned}\frac{\widehat{w}_i}{\widehat{P}_i^C} &= \prod_k \left\{ \widehat{\pi}_{ii,k}^{-\frac{1}{\beta_{i,k}^{w}\theta}} \times \widehat{r}_i^{-\frac{\beta_{i,k}^{r}}{\beta_{i,k}^{w}}} \times \prod_l \widehat{P}_{i,l}^{-\frac{\beta_{i,k}^{l}}{\beta_{i,k}^{w}}} \times \widehat{P}_{i,k}^{\frac{1}{\beta_{i,k}^{w}}} \right\}^{\gamma_{i,C}^{k}} \times \prod_k \widehat{P}_{i,k}^{-\gamma_{i,C}^{k}} \\ &= \prod_k \left\{ \widehat{\pi}_{ii,k}^{-\frac{1}{\beta_{i,k}^{w}\theta}} \times \left[\frac{\widehat{r}_i}{\widehat{P}_{i,k}}\right]^{-\frac{\beta_{i,k}^{r}}{\beta_{i,k}^{w}}} \times \prod_l \left[\frac{\widehat{P}_{i,l}}{\widehat{P}_{i,k}}\right]^{-\frac{\beta_{i,k}^{l}}{\beta_{i,k}^{w}}} \right\}^{\gamma_{i,C}^{k}},\end{aligned}$$

where, in the last step, I have used the fact that each sector's expenditure share on intermediates plus its expenditure share on capital—$\sum_i \beta_{i,k}^{l} + \beta_{i,k}^{r}$—is equal to one minus the labor share $(1-\beta_{i,k}^{w})$.

As noted in this text, this expression directly mirrors the expression for the change in the real wage from Caliendo & Parro (2015), only with capital treated as an additional input to production, with price r_i. Plugging the change in the real wage into (C.1) then delivers

$$\widehat{G}_i = \left(\widehat{1-x_i}\right) \vartheta_w \prod_k \left\{ \widehat{\pi}_{ii,k}^{-\frac{1}{\beta_{k}^{w}\theta}} \times \left[\frac{\widehat{r}_i}{\widehat{P}_{i,k}}\right]^{-\frac{\beta_{k}^{r}}{\beta_{k}^{w}}} \times \prod_l \left[\frac{\widehat{P}_{i,l}}{\widehat{P}_{i,k}}\right]^{-\frac{\beta_{i,k}^{l}}{\beta_{k}^{w}}} \right\}^{\gamma_{i,C}^{k}} + \left(\widehat{1-x_i}\right) \vartheta_r \frac{\widehat{r}_i \widehat{K}_i}{\prod_k \widehat{P}_{i,k}^{\gamma_{i,C}^{k}}} \tag{C.2}$$

In the static model, x_i and K_i are pre-determined. Thus, the "static gains from trade" can be written as:

$$\widehat{G}_i = \vartheta_w \prod_k \left\{ \widehat{\pi}_{ii,k}^{-\frac{1}{\beta_{i,k}^{w}\theta}} \times \left[\frac{\widehat{r}_i}{\widehat{P}_{i,k}}\right]^{-\frac{\beta_{i,k}^{r}}{\beta_{i,k}^{w}}} \times \prod_l \left[\frac{\widehat{P}_{i,l}}{\widehat{P}_{i,k}}\right]^{-\frac{\beta_{i,k}^{l}}{\beta_{i,k}^{w}}} \right\}^{\gamma_{i,C}^{k}} + \vartheta_r \prod_k \left\{ \frac{\widehat{r}_i}{\widehat{P}_{i,k}} \right\}^{\gamma_{i,C}^{k}}, \tag{C.3}$$

For the "dynamic" gains from trade, focusing on steady state ensures that $\widehat{r}_i = \widehat{P}_i^{IV}$ and, furthermore, that

$\widehat{x}_i = \widehat{r}_i \widehat{K}_i / \widehat{GDP}_i = \widehat{\vartheta}_r$. Introducing these relationships into (C.2), I obtain

$$\begin{aligned}
\widehat{G}_i &= \left(\widehat{1-x_i}\right) \vartheta_w \prod_k \left\{ \widehat{\pi}_{ii,k}^{-\frac{1}{\beta_k^w \theta}} \times \left[\frac{\widehat{P}_i^{IV}}{\widehat{P}_{i,k}}\right]^{-\frac{\beta_k^r}{\beta_k^w}} \times \prod_l \left[\frac{\widehat{P}_{i,l}}{\widehat{P}_{i,k}}\right]^{-\frac{\beta_{i,k}^l}{\beta_k^w}} \right\}^{\gamma_{i,C}^k} + \widehat{x}\vartheta_r \frac{\left(\widehat{1-x_i}\right)\widehat{GDP}_i}{\prod_k \widehat{P}_{i,k}^{\gamma_{i,C}^k}} \\
&= \left(\widehat{1-x_i}\right) \vartheta_w \prod_k \left\{ \widehat{\pi}_{ii,k}^{-\frac{1}{\beta_k^w \theta}} \times \prod_l \left[\frac{\widehat{P}_{i,l}}{\widehat{P}_{i,k}}\right]^{-\gamma_{i,IV}^l \frac{\beta_k^r}{\beta_k^w}} \times \prod_l \left[\frac{\widehat{P}_{i,l}}{\widehat{P}_{i,k}}\right]^{-\frac{\beta_{i,k}^l}{\beta_k^w}} \right\}^{\gamma_{i,C}^k} + \widehat{x}\vartheta_r \widehat{G}_i \\
&= \vartheta_w \frac{\left(\widehat{1-x}\right)}{1-\vartheta_r \widehat{x}} \times \prod_k \left\{ \widehat{\pi}_{ii,k}^{-\frac{1}{\beta_k^w \theta}} \times \prod_l \left[\frac{\widehat{P}_{i,l}}{\widehat{P}_{i,k}}\right]^{-\gamma_{i,IV}^l \frac{\beta_k^r}{\beta_k^w}} \times \prod_l \left[\frac{\widehat{P}_{i,l}}{\widehat{P}_{i,k}}\right]^{-\frac{\beta_{i,k}^l}{\beta_k^w}} \right\}^{\gamma_{i,C}^k} .
\end{aligned}$$

Finally, obtaining the formula in the text requires recognizing that $1-\vartheta_r \widehat{x} = 1-\vartheta_r \widehat{\vartheta}_r = 1-\vartheta_r' = \vartheta_w'$ and (in turn) that $\vartheta_w'/\vartheta_w = \widehat{\vartheta}_w$.

On the "adding up" properties of Poisson PML with fixed effects

As has now been widely disseminated thanks to Fally (2015), structural gravity estimation with exporter and importer fixed effects (and consistently measured internal trade), effectively constrains each country's fitted output and expenditure values to be equal to their actual counterparts from the data.

Some other useful aspects of the Poisson PML specification used in (28), which also includes *pair* fixed effects, may not be as well-known, however. In particular:

- As with output and expenditure, total fitted export and import volumes for each country are likewise constrained to be equal to their actual counterparts from the data;
- Each country's actual "internal trade", $X_{ii,k,t}$, will similarly be equal to its fitted internal trade, $\Gamma_{ikt} \cdot \Phi_{ikt}$;
- The error term ε_{ijkt}, which contributes asymmetries in trade frictions, has "no aggregate effect" on trade within any trading pair in any industry-year. That is, $\varepsilon_{ijkt} + \varepsilon_{jikt} = 0, \forall i, j, k, t$.
- ε_{ijkt} similarly has no aggregate effect on any country's total exports or imports. Thus, it may be absorbed into the "bilateral component" of trade costs, $\widetilde{d}_{ij,k,t}$, without loss of generality.

Proof: To verify the first two statements, recall the normalizing assumption that $\eta_{iikt} = 1 \; \forall i, k, t$ and let "$\overline{z}$" denote the fitted value for variable z. It follows from (B.3) that $\overline{EX}_{ikt} = Y_{ikt} - \Gamma_{ikt}\Phi_{ikt}$ and, similarly, $\overline{IM}_{ikt} = E_{ikt} - \Gamma_{ikt}\Phi_{ikt}$. Furthermore, the Poisson PML solution for η_{ijkt} implies (after aggregating across all $j \neq i$ partners) that $EX_{ikt} + IM_{ikt} = \overline{EX}_{ikt} + \overline{IM}_{ikt}$. Altogether, we now have that

$$\Gamma_{ikt}\Phi_{ikt} = \frac{Y_{ikt} + E_{ikt} - \left(\overline{EX}_{ikt} + \overline{IM}_{ikt}\right)}{2} = \frac{Y_{ikt} - EX_{ikt}}{2} + \frac{E_{ikt} - IM_{ikt}}{2} = X_{ii,k,t}.$$

Since $X_{ii,k,t} = \Gamma_{ikt}\Phi_{ikt}$ (proving the second statement), it also must hold that $\overline{EX}_{ikt} = Y_{ikt} - X_{ii,k,t} = EX_{ikt}$, $\overline{IM}_{ikt} = E_{ikt} - X_{ii,k,t} = IM_{ikt}$ (which in turn proves the first).

For the third statement, note that the first-order condition for $\ln \eta_{ijkt}$, (B.2c), directly implies that $\varepsilon_{ijkt} + \varepsilon_{jikt} = 0, \forall i, j, k, t$. The fourth statement is simply a corollary of the second: since both actual and fitted total exports are the same, the sum of the error term for these flows must be zero. The same goes for imports. $\|$

Deriving an intuitive expression for trade openness

Take the expression for m's "border effect" in (30) and multiply both sides by $X_{mm,k,t}$. The resulting expression may be written as:

$$X_{mm,k,t} d_{m,k,t}^{-\theta} = \frac{EX_{m,k,t} + IM_{m,k,t}}{X_{mm,k,t}^{-1} \sum_{j \neq m} \left\{ \Gamma_{mkt} \Phi_{jkt} + \Gamma_{jkt} \Phi_{mkt} \right\} d_{j,k,t}^{-\theta}}.$$

Replacing $X_{mm,k,t}$ on the right-hand side with $X_{mm,k,t} = \Gamma_{mkt} \cdot \Phi_{mkt}$—and solving again for $d_{m,k,t}^{-\theta}$—then yields the following intuitive expression for a country's openness to trade in industry k at time t:

$$d_{m,k,t}^{-\theta} = \underbrace{\left\{ \frac{EX_{m,k,t} + IM_{m,k,t}}{X_{mm,k,t}} \right\}}_{\substack{unadjusted \\ \text{“}openness\text{”}}} \times \underbrace{\left\{ \sum_{n \neq m} \left(\frac{\Phi_{nkt}}{\Phi_{mkt}} + \frac{\Gamma_{nkt}}{\Gamma_{mkt}} \right) d_{n,k,t}^{-\theta} \right\}^{-1}}_{\substack{adjusts\,for \\ \text{“}geography\text{”}}} \tag{C.4}$$

The first term on the right-hand side of (C.4) is a typical "back of the envelope" measure of a country's trade openness: literally, how much it trades with the rest of the world ($EX_{m,k,t} + IM_{m,k,t}$) relative to how much it trades with itself ($X_{mm,k,t}$). This simple ratio is not by itself completely indicative of the level of a country's trade barriers, however since some countries have a more favorable geography for trade. Specifically, all else equal, i will have a higher unadjusted openness ratio when its set of trading partners $n \neq m$: (i) are relatively competitive as producers (high Γ_{nkt}); (ii) have relatively attractive markets (high Φ_{nkt}); and/or (iii) have relatively high trade openness themselves (high $d_{n,k,t}^{-\theta}$). The second term on the right-hand side then "corrects" for these factors using the structure of the model.

A model with endogenous trade balances

The model used in the analysis can also be extended to allow for endogenous trade balances. This can be done by introducing inter-temporal trade in savings *a la* Reyes-Heroles (2015). In this version of the model, since trade costs effectively serve as a "tax" on trade balances (to use the analogy of Obstfeld & Rogoff, 2001), gains from trade should generally be larger, in the sense that it will make it easier for countries to smooth their consumption path across time.

Unlike in Reyes-Heroles (2015), however, inter-temporal trade here will not be taken to be frictionless. Instead, all borrowing in a given period will be subject to a set of country-specific borrowing frictions, given by $\{\varphi_{i,t}\}$, which will provide an additional "wedge" for fitting the model to the data. With this in mind, the budget constraint for households now becomes:

$$w_{i,t} L_{i,t} + r_{i,t} K_{i,t} + \underbrace{B_{i,t} - \varphi_{i,t} R_t B_{i,t-1}}_{D_{i,t}} = P_{i,C,t} \cdot C_{i,t} + P_{i,IV,t} \cdot I_{i,t},$$

which elaborates upon each country's trade balance, $D_{i,t}$, as the difference between new borrowing at time t, $B_{i,t}$, and interest payments owed on the previous period's borrowing, $\varphi_{i,t} R_t B_{i,t-1}$, where R_t denotes the world (nominal) interest rate at time t.

After deriving a first-order condition for new borrowing ($B_{i,t}$), we now have that each country's consumption path must satisfy:

$$\frac{1}{E_{i,C,t}} = \rho \widehat{\phi}_{i,t+1} \varphi_{i,t+1} R_{t+1} \frac{1}{E_{i,C,t+1}}. \tag{C.5}$$

In Reyes-Heroles (2015), which does not feature endogenous investment, an equation such as (C.5) can be used to back out each country's set of "time preference shocks" $\{\widehat{\phi}_{i,t+1}\}$. In my case, however, this parameter is already pinned down by each country's observed choices over investment versus consumption in each period. Thus, I introduce the set of "borrowing frictions" $\{\varphi_{i,t}\}$ in order to also match each country's trade balance. Importantly, introducing these frictions fundamentally means that international lending markets will not be "perfect", consistent with the findings of Fitzgerald (2012).

The world interest rate R_{t+1} must then always adjust in order to enforce market clearing in the world borrowing market. That is, there must be zero world net lending in the prior period:

$$\sum_i B_{i,t} = 0 \ \forall t, \tag{C.6}$$

which, since $D_{i,t} = B_{i,t} - \varphi_{i,t} R_t B_{i,t-1}$, also ensures global trade balance in each period as well.

Fitting this extended version of the model to the data then requires values for borrowing frictions $\{\varphi_{i,t}\}$, which can be recovered from the first-order condition for borrowing (C.5). Importantly, this step also requires the time preference shocks $\{\widehat{\phi}_{i,t+1}\}$, which must be recovered (as before) using the Euler equation for investment (B.4). In addition, the initial equilibrium world interest rate R_t can be distinguished from the $\varphi_{i,t}$'s by imposing a normalization—e.g., by setting the U.S.'s borrowing friction, $\varphi_{US,t}$, equal to 1.

In counterfactuals, when, for example, reductions in future trade costs increase future consumption, increased demand for borrowing raises the world interest rate in earlier years and lowers it in later years. These dynamics are incorporated via (C.5), which governs how households use borrowing as a means to shift consumption across time periods, and by (C.6), which ensures that R_t adjusts such that trade remains globally balanced in all periods.