The Global Welfare Impact of China: Trade Integration and Technological Change*

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Abstract

This paper evaluates the global welfare impact of China's trade integration and technological change in a quantitative Ricardian-Heckscher-Ohlin model implemented on 75 countries. The model implies that the mean gain from trade with China is 0.13%, with a range from −0.27% to 0.80%. Countries in East Asia tend to gain the most, while many Textile- and Apparel-producing countries experience welfare losses. We then simulate two alternative productivity growth scenarios: a "balanced" one in which China's productivity grows at the same rate in each sector, and an "unbalanced" one in which China's comparative disadvantage sectors catch up disproportionately faster to the world productivity frontier. Contrary to a well-known conjecture (Samuelson 2004), the average country in the world experiences an order of magnitude larger welfare gains when China's growth is unbalanced.

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1 Introduction

The pace of China's integration into world trade has been nothing short of breathtaking. Figure 1(a) plots the inflation-adjusted Chinese exports between 1962 and 2007, expressed as an index number relative to 1990. The value of Chinese exports has increased by a staggering factor of 12 between 1990 and 2007. Though this period is an era of globalization, with trade expanding all over the world, the growth of Chinese trade over this period far outpaces the growth of global trade as a whole. The dashed line of Figure 1(a) plots the value of world exports. They grew by a factor of 3 over the same period. What is remarkable is the extent to which the emergence of Chinese exports is global in nature. Figure 1(b) reports the share of China in the total imports of all major world regions. The expansion of Chinese exports proceeded at a similar pace all over the world: in all the major regions, the share of imports coming from China currently stands at about 10%, with the exception of East and South Asia, for which it is 15%. China is a global presence, penetrating all world regions about equally.

Naturally, such rapid integration and growth leads to some anxiety. For developing countries and emerging markets, the often-voiced concern is that China has a similar export basket, and its integration into global trade leads to lower prices of these countries' exports and thus potentially lower welfare (Devlin, Estevaeordal and Rodríguez-Clare, eds 2005, Gallagher, Moreno-Brid and Porzecanski 2008). For developed countries, the concern is not with respect to the trade integration *per se*, but rather with the possibility that growth in China is biased towards sectors in which the developed world currently has a comparative advantage. In a two-country setting, a well-known theoretical result is that when a country's trading partner becomes more similar in relative technology, it can experience welfare losses (Samuelson 2004).

This paper explores both qualitatively and quantitatively the global welfare consequences of unbalanced growth in China. We first show analytically that the intuitive two-country result does not survive in a setting with more than two countries. What matters for welfare in the United States is not how much more similar China's sectoral relative productivity becomes to that of the United States *per se*. Rather, what is relevant to the United States' welfare is how (dis)similar China becomes to an appropriately input-and-trade-cost weighted average productivity of all other countries serving the United States market. In a multi-country world, third-country effects are of first-order importance for evaluating the impact of changes in relative technology in one country on itself and its trading partners.

To derive these results, we set up a simple multi-sector, N-country Eaton and Kortum (2002) model, and examine how changes in relative sectoral productivities in an individual country – which we think of as China – affect both its own welfare and the welfare of its trading partners. When $N = 2$, welfare in both trading partners is lowest when relative sectoral productivity is the same in the two countries. This is a generalization of the Samuelson (2004)'s result to a setting in which the sectors have an Eaton and Kortum (2002) structure. However, with more than 2 countries welfare in any individual country n is generically not minimized when its relative technology is the same as in China. In fact, it is very easy to construct examples in which as China becomes more similar to country n, country n's welfare actually increases.

These analytical results set the stage for a quantitative exploration. In order to evaluate the global welfare impact of the different Chinese growth scenarios, we start with the set of productivity estimates recently developed by Levchenko and Zhang (2011) for a sample of 19 manufacturing sectors and 75 economies that includes China along with a variety of countries representing all continents and a wide range of income levels and other characteristics. We use these productivity estimates to evaluate several counterfactual scenarios in a quantitative multi-country, multi-sector model with a number of realistic features, such as multiple factors of production, an explicit non-traded sector, the full specification of input-output linkages between the sectors, and both inter- and intra-industry trade, among others.

As a preliminary exercise, we compare welfare in the baseline model estimated on the world today to a counterfactual in which China is in autarky. This reveals the global distribution of the gains from trade with China as it stands today. The mean gain from adding China to world trade is 0.13%. Geographical proximity matters somewhat, but not overwhelmingly: East and South Asian countries gain 0.23%, less than twice the world average. Dispersion across countries within each region turns it large: in nearly every major region or country group, gains range from positive to negative. Aside from China itself, for which the model implies gains of 3.72% relative to autarky, the economies with the largest positive welfare changes are Malaysia (0.80%), Kazakhstan (0.78%), and Taiwan, POC (0.63%). On the other hand, 9 out of 75 countries experience welfare losses, the largest for Honduras (−0.27%) and El Salvador (−0.21%). The OECD countries to gain the most are Australia, New Zealand, and Japan (0.26-0.30%). The mean gain in the OECD is 0.13%, with the welfare change for the U.S. of 0.11%.

The main counterfactual scenario then evaluates the importance of the sectoral pattern of growth in China for global welfare. To that end, we simulate two growth scenarios for China starting from the present day. In the first, the productivity growth rate in each sector is the same, and equal to the average productivity growth we estimate for China between the 1990s and the 2000s, which is 14%. In this "balanced" growth scenario, all sectors grow at the same rate, and thus China's comparative advantage vis-a-vis the world remains unchanged. The second scenario instead assumes that China's comparative disadvantage sectors grow disproportionally faster. To make the exercise as stark as possible, the counterfactual assumes that China's productivity in every sector is a constant ratio of the world frontier. This is the "unbalanced" growth scenario. By construction, the average productivity in China is the same in the two counterfactuals. What differs is the relative productivities across sectors.

The results are striking. The mean gains from the unbalanced growth in China, 0.42% in our sample of 74 countries, are some 40 times larger than the mean gains in the balanced scenario, which are nearly nil at 0.01%. This pattern holds for every region and broad country group. Intriguingly, China itself gains slightly more in the balanced growth scenario relative to the unbalanced growth, 11.43% compared to 10.57%. Thus, while balanced growth makes China itself better off relative to the unbalanced alternative, the rest of the world would prefer unbalanced growth in China.

When evaluated quantitatively, it turns out that the welfare impact of China's growth on the rest of the world is the opposite of what had been conjectured by Samuelson (2004). The analytical results help us understand why this is the case. What matters is not China's similarity to any individual country, but its similarity to the world weighted average productivity (although the weights will differ from country to country because of trade costs). Closer inspection of China's comparative advantage reveals that it is currently good in sectors – such as Wearing Apparel – that are "common," in the sense that many countries also have high productivity in those sectors. By contrast, China's comparative disadvantage sectors – such as Office, Accounting, and Computing Machinery – are "scarce," in the sense that not many other countries are close to the global productivity frontier in those sectors. This regularity is very strong in the data: the correlation between China's comparative advantage in a sector and the average productivity in that sector in the rest of the world is 0.86. Put another way, China's pattern of sectoral productivity is actually fairly similar to the world average. Thus, while balanced growth in China keeps it similar to the typical country, unbalanced growth actually makes it more different. Consistent with theory, our quantitative results imply that the rest of the world would find it more valuable for China to experience productivity growth in the scarce sectors – by a large margin.

Our paper follows up on the Computable General Equilibrium (CGE) assessments of China's trade integration (e.g., Francois and Wignaraja 2008, Ghosh and Rao 2010, Tokarick 2011). Unlike the traditional CGE approach, our quantitative framework is based on Eaton and Kortum (2002)'s Ricardian model of trade with endogenous specialization both within and across sectors, and the focus of the study is on the role of comparative advantage. In this respect, our paper is related to recent quantitative welfare assessments of trade integration and technological change in multi-sector models (Caliendo and Parro 2010, Costinot, Donaldson and Komunjer 2011, Shikher 2011). Most closely related is the work of Hsieh and Ossa (2011), who consider the welfare impact of the observed pattern of sector-level growth in China from 1992 to 2007 on 14 major countries and 4 broad world regions. Our paper evaluates a different set of substantive questions: it first derives a set of analytical results on the impact of relative technology changes in a multi-country setting, and then considers hypothetical growth scenarios starting from today's trade equilibrium.

We also estimate the welfare impact of China's trade integration to date. Finally, our model has several additional features important for a reliable quantitative assessment, such as 75 individual countries, as well as a production structure that includes multiple factors (labor and capital) and the full set of input-output linkages between all sectors.

The rest of the paper is organized as follows. Section 2 derives a set of analytical results using a simplified multi-sector N-country Eaton and Kortum (2002) model of Ricardian trade. Section 3 lays out the quantitative framework and describes the details of the calibration. Section 4 examines the welfare implications of both the trade integration of China, and the hypothetical scenarios for Chinese growth. Section 5 concludes.

2 Analytical Results

How will the evolution of relative sectoral technology in a country affect its own welfare and the welfare of its trading partners? The answer, based on a two-country free trade model as in Samuelson (2004), is that both countries' welfare is minimized when they have the same relative sectoral productivity. This influential insight needs to be modified when we step out the simple environment and consider more than two countries and costly trade. To derive analytical results and build intuition, this section analyzes a simplified version of the quantitative model of the next section.

In particular, consider a multi-sector Eaton and Kortum (2002, henceforth EK) model. There are N countries, indexed by n and i. For concreteness, we can think of country 1 as China, and evaluate the impact of changes in technology in country 1 on itself and country 2, which we can think of as the United States. There are three sectors, A, B, and H, indexed by j. Consumer utility is identical across countries and Cobb-Douglas in the three sectors. To obtain the cleanest results, we will assume that A and B enter symmetrically in the utility function:

$$U_n = \left(A_n^{\frac{1}{2}} B_n^{\frac{1}{2}}\right)^{\alpha} H_n^{1-\alpha}. \tag{1}$$

As in Helpman, Melitz and Yeaple (2004) and Chaney (2008), good H is homogeneous and can be freely traded between any two countries in the world. Let the price of H be the numeraire. Labor is the only factor of production, with country endowments given by L_n. In country n, one worker can produce w_n units of H, implying that the wage in n is given by w_n. Throughout, we assume that α is sufficiently small that some amount of H is always produced in all the countries in the world. This assumption pins down wages in all the countries, making analytical results possible. (Section 2.1 solves this model under $\alpha = 1$ and wages endogenously determined in global equilibrium. In the quantitative exercise of the next section, all the prices are fully endogenously determined.)

Production in sector $j = A, B$ follows the EK structure. Output Q_n^j of sector j in country n is a CES aggregate of a continuum of varieties $q = [0, 1]$ unique to each sector:

$$Q_n^j = \left[\int_0^1 Q_n^j(q)^{\frac{\varepsilon-1}{\varepsilon}} dq \right]^{\frac{\varepsilon}{\varepsilon-1}}, \tag{2}$$

where ε denotes the elasticity of substitution across varieties q, and $Q_n^j(q)$ is the amount of variety q that is used in production in sector j and country n.

Producing one unit of good q in sector j in country i requires $\frac{1}{z_i^j(q)}$ units of labor. Productivity $z_i^j(q)$ for each $q \in [0, 1]$ in each country i and sector j is random, drawn from the Fréchet distribution with cdf:

$$F_i^j(z) = e^{-T_i^j z^{-\theta}}. \tag{3}$$

In this distribution, the absolute advantage term T_i^j varies by both country and sector, with higher values of T_i^j implying higher average productivity draws in sector j in country i. The parameter θ captures dispersion, with larger values of θ implying smaller dispersion in draws.

The production cost of one unit of good q in sector j and country i is thus equal to $w_i^j / z_i^j(q)$. Each country can produce each good in each sector, and international trade is subject to iceberg costs: $d_{ni}^j > 1$ units of good q produced in sector j in country i must be shipped to country n in order for one unit to be available for consumption there. The trade costs need not be symmetric – d_{ni}^j need not equal d_{in}^j – and will vary by sector. We normalize $d_{nn}^j = 1 \; \forall \; n$ and j.

All the product and factor markets are perfectly competitive, and thus the price at which country i can supply tradeable good q in sector j to country n is:

$$p_{ni}^j(q) = \left(\frac{w_i^j}{z_i^j(q)} \right) d_{ni}^j.$$

Buyers of each good q in tradeable sector j in country n will only buy from the cheapest source country, and thus the price actually paid for this good in country n will be:

$$p_n^j(q) = \min_{i=1,\ldots,N} \left\{ p_{ni}^j(q) \right\}. \tag{4}$$

It is well known that the price of sector j's output is given by:

$$p_n^j = \left[\int_0^1 p_n^j(q)^{1-\varepsilon} dq \right]^{\frac{1}{1-\varepsilon}}.$$

Following the standard EK approach, define the "multilateral resistance" term

$$\Phi_n^j = \sum_{i=1}^{N} T_i^j \left(w_i d_{ni}^j\right)^{-\theta}. \tag{5}$$

This value summarizes, for country n, the access to production technologies in sector j. Its value will be higher if in sector j, country n's trading partners have high productivity (T_i^j) or low cost (w_i^j). It will also be higher if the trade costs that country n faces in this sector are low. Standard steps lead to the familiar result that the price of good j in country n is simply

$$p_n^j = \Gamma \left(\Phi_n^j\right)^{-\frac{1}{\theta}}, \tag{6}$$

where $\Gamma = \left[\mathbf{\Gamma}\left(\frac{\theta+1-\varepsilon}{\theta}\right)\right]^{\frac{1}{1-\varepsilon}}$, with $\mathbf{\Gamma}$ the Gamma function. The consumption price level in country n is then proportional to:

$$P_n \propto \left(p_n^A p_n^B\right)^{\frac{1}{2}\alpha} \left(p_n^H\right)^{1-\alpha}. \tag{7}$$

Welfare (indirect utility) is given by w_n/P_n:

$$\begin{aligned} w_n/P_n &= w_n \left(p_n^A p_n^B\right)^{-\frac{1}{2}\alpha} \left(p_n^H\right)^{\alpha-1} \\ &\propto \left\{\left[\sum_{i=1}^{N} T_i^A \left(w_i d_{ni}^A\right)^{-\theta}\right]\left[\sum_{i=1}^{N} T_i^B \left(w_i d_{ni}^B\right)^{-\theta}\right]\right\}^{\frac{\alpha}{2\theta}}. \end{aligned} \tag{8}$$

We now evaluate the welfare impact of changes in the relative technology in country 1, T_1^A/T_1^B, subject to the constraint that its geometric average stays the same: $\left(T_1^A T_2^B\right)^{\frac{1}{2}} = c$ for some constant c. The exercise informs us the welfare impact of the different growth scenarios in China, when we hold its average growth rate fixed. We have the following result.

Lemma 1. *The relative technology* $(T_1^A/T_1^B)_n$ *of country 1 that minimizes welfare in country* n *subject to the constraint that* $\left(T_1^A T_2^B\right)_n^{\frac{1}{2}} = c$ *is given by:*

$$(T_1^A/T_1^B)_n = \frac{\sum_{i=2}^{N} T_i^A \left(\frac{w_i d_{ni}^A}{w_1 d_{n1}^A}\right)^{-\theta}}{\sum_{i=2}^{N} T_i^B \left(\frac{w_i d_{ni}^B}{w_1 d_{n1}^B}\right)^{-\theta}}. \tag{9}$$

Proof. See Appendix A. □

The Lemma says that the relative technology of country 1 that minimizes welfare in country n is not the one that makes country 1 most similar to country n. That is, generically the country n's welfare is not minimized when $T_1^A/T_1^B = T_n^A/T_n^B$. What matters instead is in some sense the relative-unit-cost-weighted average technologies *of all the countries serving* n. Third countries matter through their technology, but also through their relative unit costs and trade costs of serving market n. Because of third country effects, it is easy to construct examples in which country 1 becomes more technologically similar to country n, and yet country n's welfare increases. We now provide two simple examples that illustrate the point most clearly. We start with the 2-country case in which the familiar Samuelson (2004) result obtains.

Example 1. *Suppose there are two countries. Then the country 1 relative technology* T_1^A/T_1^B *that minimizes welfare in countries 1 and 2 is:*

$$(T_1^A/T_1^B)_1 = \frac{T_2^A\left(d_{12}^A\right)^{-\theta}}{T_2^B\left(d_{12}^B\right)^{-\theta}}$$

and

$$(T_1^A/T_1^B)_2 = \frac{T_2^A\left(d_{21}^A\right)^{\theta}}{T_2^B\left(d_{21}^B\right)^{\theta}}.$$

It is immediate that even with 2 countries, when trade costs are not the same in the two sectors ($d_{12}^A \neq d_{12}^B$ and $d_{21}^A \neq d_{21}^B$), the country 1 relative technology that minimizes welfare of the two trading partners is not equal to the relative technology of country 2, T_2^A/T_2^B. This result is intuitive. Suppose that it costs more to import in sector A compared to B: $d_{12}^A > d_{12}^B$. Then all else equal, country 1 will want to have higher productivity in A, even if – over some range – it makes its relative productivity more similar to country 2.

The classic result about the welfare of the two trading partners being at its lowest point when they are most similar obtains of course when trade costs are symmetric across sectors: $d_{12}^A = d_{12}^B$ and $d_{21}^A = d_{21}^B$. In that case, both countries are worst off when $T_1^A/T_1^B = T_2^A/T_2^B$. This is the Samuelson (2004) result.

Example 2. *Suppose there are three countries. Then the country 1 relative technology* T_1^A/T_1^B *that minimizes welfare in the three countries is:*

$$(T_1^A/T_1^B)_1 = \frac{T_2^A\left(w_2 d_{12}^A\right)^{-\theta} + T_3^A\left(w_3 d_{13}^A\right)^{-\theta}}{T_2^B\left(w_2 d_{12}^B\right)^{-\theta} + T_3^B\left(w_3 d_{13}^B\right)^{-\theta}},$$

$$(T_1^A/T_1^B)_2 = \frac{T_2^A\left(\frac{w_2}{d_{21}^A}\right)^{-\theta} + T_3^A\left(\frac{w_3 d_{23}^A}{d_{21}^A}\right)^{-\theta}}{T_2^B\left(\frac{w_2}{d_{21}^B}\right)^{-\theta} + T_3^B\left(\frac{w_3 d_{23}^B}{d_{21}^B}\right)^{-\theta}},$$

and

$$(T_1^A/T_1^B)_3 = \frac{T_2^A\left(\frac{w_2 d_{32}^A}{d_{31}^A}\right)^{-\theta} + T_3^A\left(\frac{w_3}{d_{31}^A}\right)^{-\theta}}{T_2^B\left(\frac{w_2 d_{32}^B}{d_{31}^B}\right)^{-\theta} + T_3^B\left(\frac{w_3}{d_{31}^B}\right)^{-\theta}}.$$

The third country effect is immediate in this expression. Even in the absence of differentials in bilateral trade costs and unit production costs, it is generically not the case that in any country, welfare is minimized when it is most similar to country 1. From the perspective of an individual country, welfare is lowest when country 1 is most similar to the *production-and-trade-cost weighted average productivity* of countries other than country 1.

By comparing the three-country expressions to the N-country case in (9), it is also clear that as the number of countries increases, the bilateral technological similarity starts to matter less and less, as the weight of the country itself in the summation decreases. By contrast, as the number of countries goes up, for country n's welfare it becomes more and more important how country 1 compares to the countries other than country n rather than to country n itself.

2.1 Endogenous Wages

The preceding results were derived under the assumption that there is a homogeneous freely traded good and thus the relative wages do not change in response to relative technology changes in country 1. The advantage of this approach is that we could obtain the main results analytically even with multiple countries and arbitrary iceberg trade costs, and demonstrate most clearly the roles of the various simplifying assumptions. The disadvantage is that general equilibrium movements in relative wages could potentially have independent effects on welfare. Note that as the number of countries increases, the general equilibrium changes in relative wages in response to technical change in an individual country are likely to become smaller and smaller. Nonetheless, it is important to examine whether allowing wages to adjust in the global trade equilibrium weakens any of the analytical results above.

This subsection implements a 2-sector model in which wages adjust in the global trade equilibrium. To that end, we remove the homogeneous good from the model: $\alpha = 1$. To simplify the model further, we assume here are no trade costs ($d_{ni}^j = 1 \ \forall j, n, i$). Unfortunately, even in the simplest cases, there is no closed-form solution for wages with more than two countries. We first prove analytically that with 2 countries, the welfare-minimizing relative productivity has the same form as in Lemma 1 under these parameter values but now with endogenous wages.

Lemma 2. *Let there be 2 countries and 2 tradeable sectors, with utility given by* (1) *with* $\alpha = 1$. *Let there be no international trade costs:* $d_{ni}^j = 1 \ \forall j, n, i$. *Assume* $T_2^A = T_2^B = 1$ *and* $L_1 = L_2 = 1$.

The country 1 relative technology T_1^A/T_1^B that minimizes welfare in both countries subject to the constraint that $\left(T_1^A T_2^B\right)^{\frac{1}{2}} = c$ is given by:

$$\frac{T_1^A}{T_1^B} = \frac{T_2^A}{T_2^B}.$$

Proof. See Appendix A. □

In other words, in this special case the result that perfect similarity minimizes welfare generalizes to a setting with endogenously determined wages. However, we cannot provide a similar analytical result with three countries. Thus, we compare the outcomes under two and three countries using the following numerical example. Country 2 has $T_2^A = T_2^B = 0.5$ – its productivity is the same in the two sectors. Exactly as above, we vary country 1 productivity subject to the constraint that its geometric average equals 0.5 (same as in country 2), solve for wages numerically for each set of country 1 relative productivities, and trace out welfare in all the countries as a function of relative productivities in country 1.

In the two-country case welfare of both countries as a function of T_1^A/T_1^B is plotted in Figure 2(a). As proved analytically, both countries' welfare is at its lowest point when $T_1^A/T_1^B = T_2^A/T_2^B = 1$. Next, we introduce the a third country with a comparative advantage in sector B: $T_3^A = 0.25$, $T_3^B = 1$ (we again pick the numbers so that the geometric average productivity in country 3 is the same as in 1 and 2). Figure 2(b) reports the results. Now, no country's welfare is minimized when T_1^A/T_1^B is the same as another country's. Notice that for country 2, if we start from the right and approach 1 – the point at which $T_1^A/T_1^B = T_2^A/T_2^B$ – welfare of country 1 actually increases slightly.

We conclude from both the analytical results with fixed wages, and the numerical example with endogenous wages, that third country effects are of first-order importance for evaluating the impact of changes in relative technology in one country on itself and its trading partners. Intuitively, what matters is not bilateral, but "multilateral" similarity: for any individual country n, the relevant question is whether country 1 is becoming more similar to the average country serving n, rather than simply to n itself.

3 Quantitative Framework

To evaluate quantitatively the global welfare impact of balanced and unbalanced sectoral productivity growth in China, we build on the conceptual framework and results above in two respects. First, we enrich the model in a number of dimensions to make it suitable for quantitative analysis. Relative to the simple model in Section 2, the complete quantitative framework features (i) multiple factors of production – capital and labor; (ii) an explicit non-tradeable sector; (iii) input-output linkages between all sectors; (iv) CES aggregation of tradeable consumption goods, with taste differences across goods. Second, we require sectoral productivity estimates (T_n^j) for a large number of countries and sectors in the world. Sectoral productivities are obtained from Levchenko and Zhang (2011), which extends the approach of Eaton and Kortum (2002) and uses bilateral trade data at sector level combined with a model-implied gravity relationship to estimate productivities at sector level. The quantitative framework is implemented on a sample of 75 countries, which in addition to China includes countries from all continents and major world regions.

3.1 The Environment

There are $n, i = 1, ..., N$ countries, J tradeable sectors, and one nontradeable sector $J+1$. Utility over the sectors in country n is given by

$$U_n = \left(\sum_{j=1}^{J} \omega_j^{\frac{1}{\eta}} \left(Y_n^j \right)^{\frac{\eta-1}{\eta}} \right)^{\frac{\eta}{\eta-1}\xi_n} \left(Y_n^{J+1} \right)^{1-\xi_n}, \qquad (10)$$

where ξ_n denotes the Cobb-Douglas weight for the tradeable sector composite good, η is the elasticity of substitution between the tradeable sectors, Y_n^{J+1} is final consumption of the nontradeable-sector composite good, and Y_n^j is the final consumption of the composite good in tradeable sector j. Importantly, while Section 2 relied on Cobb-Douglas preferences and symmetry of the tradeable sectors in the utility function, the complete model adopts CES preferences and allows ω_j – the taste parameter for tradeable sector j – to differ across sectors.

As in Section 2, output in sector j aggregates a continuum of varieties $q \in [0,1]$ according to (2), and the unit input requirement $\frac{1}{z_i^j(q)}$ for variety q is drawn from the country- and sector-specific productivity distribution (3). Production uses labor (L), capital (K), and intermediate inputs from other sectors. The cost of an input bundle in country i is:

$$c_i^j = \left(w_i^{\alpha_j} r_i^{1-\alpha_j} \right)^{\beta_j} \left(\prod_{k=1}^{J+1} \left(p_i^k \right)^{\gamma_{k,j}} \right)^{1-\beta_j},$$

where w_i is the wage, r_i is the return to capital, and p_i^k is the price of intermediate input from sector k. The value-added based labor intensity is given by α_j, and the share of value added in total output by β_j. Both vary by sector. The shares of inputs from other sectors, $\gamma_{k,j}$ vary by output industry j as well as input industry k. The production cost of one unit of good q in sector j and country n is thus equal to $c_i^j/z_i^j(q)$, and the price at which country i can serve market n is $p_{ni}^j(q) = \left(\frac{c_i^j}{z_i^j(q)} \right) d_{ni}^j$. The price $p_n^j(q)$ that country n actually pays for good q is given by (4).

3.2 Characterization of Equilibrium

The **competitive equilibrium** of this model world economy consists of a set of prices, allocation rules, and trade shares such that (i) given the prices, all firms' inputs satisfy the first-order conditions, and their output is given by the production function; (ii) given the prices, the consumers' demand satisfies the first-order conditions; (iii) the prices ensure the market clearing conditions for labor, capital, tradeable goods and nontradeable goods; (iv) trade shares ensure balanced trade for each country.[1]

The set of prices includes the wage rate w_n, the rental rate r_n, the sectoral prices $\{p_n^j\}_{j=1}^{J+1}$, and the aggregate price P_n in each country n. The allocation rules include the capital and labor allocation across sectors $\{K_n^j, L_n^j\}_{j=1}^{J+1}$, final consumption demand $\{Y_n^j\}_{j=1}^{J+1}$, and total demand $\{Q_n^j\}_{j=1}^{J+1}$ (both final and intermediate goods) for each sector. The trade shares include the expenditure share π_{ni}^j in country n on goods coming from country i in sector j.

3.2.1 Demand and Prices

The price of sector j output in country n is given by (5) and (6), with the only difference that the expression for Φ_n^j in (5) features c_i^j instead of w_i. The consumption price index in country n is then:

$$P_n = B_n \left(\sum_{j=1}^{J} \omega_j (p_n^j)^{1-\eta} \right)^{\frac{1}{1-\eta}\xi_n} (p_n^{J+1})^{1-\xi_n}, \tag{11}$$

where $B_n = \xi_n^{-\xi_n}(1-\xi_n)^{-(1-\xi_n)}$.

Both capital and labor are mobile across sectors and immobile across countries, and trade is balanced. The budget constraint (or the resource constraint) of the consumer is thus given by

$$\sum_{j=1}^{J+1} p_n^j Y_n^j = w_n L_n + r_n K_n, \tag{12}$$

where K_n and L_n are the endowments of capital and labor in country n.

Given the set of prices $\{w_n, r_n, P_n, \{p_n^j\}_{j=1}^{J+1}\}_{n=1}^{N}$, we first characterize the optimal allocations from final demand. Consumers maximize utility (10) subject to the budget constraint (12). The first order conditions associated with this optimization problem imply the following final demand:

$$p_n^j Y_n^j = \xi_n (w_n L_n + r_n K_n) \frac{\omega_j (p_n^j)^{1-\eta}}{\sum_{k=1}^{J} \omega_k (p_n^k)^{1-\eta}}, \text{ for all } j = \{1, .., J\} \tag{13}$$

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[1] The assumption of balanced trade is not crucial for the results. The estimates of productivity are completely unaffected by this assumption. Section 4.5 implements a model with unbalanced trade following the approach of Dekle, Eaton and Kortum (2007, 2008), and shows that the conclusions are quite similar.

and

$$p_n^{J+1} Y_n^{J+1} = (1 - \xi_n)(w_n L_n + r_n K_n).$$

3.2.2 Production Allocation and Market Clearing

The EK structure in each sector j delivers the standard result that the probability of importing good q from country i, π_{ni}^j is equal to the share of total spending on goods coming from country i, X_{ni}^j / X_n^j, and is given by:

$$\frac{X_{ni}^j}{X_n^j} = \pi_{ni}^j = \frac{T_i^j \left(c_i^j d_{ni}^j \right)^{-\theta}}{\Phi_n^j}.$$

Let Q_n^j denote the total sectoral demand in country n and sector j. Q_n^j is used for both final consumption and intermediate inputs in domestic production of all sectors. That is,

$$p_n^j Q_n^j = p_n^j Y_n^j + \sum_{k=1}^{J} (1 - \beta_k) \gamma_{j,k} \left(\sum_{i=1}^{N} \pi_{in}^k p_i^k Q_i^k \right) + (1 - \beta_{J+1}) \gamma_{j,J+1} p_n^{J+1} Q_n^{J+1}$$

for tradeable sectors $j = 1, ..., J$, and

$$p_n^{J+1} Q_n^{J+1} = p_n^{J+1} Y_n^{J+1} + \sum_{k=1}^{J+1} (1 - \beta_k) \gamma_{j,k} p_n^k Q_n^k$$

in the nontradeable sector. That is, total expenditure in sector $j = 1, ..., J$ of country n, $p_n^j Q_n^j$, is the sum of (i) domestic final consumption expenditure $p_n^j Y_n^j$; (ii) expenditure on sector j goods as intermediate inputs in all the traded sectors $\sum_{k=1}^{J} (1-\beta_k) \gamma_{j,k} (\sum_{i=1}^{N} \pi_{in}^k p_i^k Q_i^k)$, and (iii) expenditure on the j's sector intermediate inputs in the domestic non-traded sector $(1 - \beta_{J+1}) \gamma_{j,J+1} p_n^{J+1} Q_n^{J+1}$. These market clearing conditions summarize the two important features of the world economy captured by our model: complex international production linkages, as much of world trade is in intermediate inputs, and a good crosses borders multiple times before being consumed (Hummels, Ishii and Yi 2001); and two-way input linkages between the tradeable and the nontradeable sectors.

In each tradeable sector j, some goods q are imported from abroad and some goods q are exported to the rest of the world. Country n's exports in sector j are given by $EX_n^j = \sum_{i=1}^{N} \mathbb{1}_{i \neq n} \pi_{in}^j p_i^j Q_i^j$, and its imports in sector j are given by $IM_n^j = \sum_{i=1}^{N} \mathbb{1}_{i \neq n} \pi_{ni}^j p_n^j Q_n^j$, where $\mathbb{1}_{i \neq n}$ is the indicator function. The total exports of country n are then $EX_n = \sum_{j=1}^{J} EX_n^j$, and total imports are $IM_n = \sum_{j=1}^{J} IM_n^j$. Trade balance requires that for any country n, $EX_n - IM_n = 0$.

Given the total production revenue in tradeable sector j in country n, $\sum_{i=1}^{N} \pi_{in}^j p_i^j Q_i^j$, the optimal sectoral factor allocations must satisfy

$$\sum_{i=1}^{N} \pi_{in}^{j} p_i^j Q_i^j = \frac{w_n L_n^j}{\alpha_j \beta_j} = \frac{r_n K_n^j}{(1-\alpha_j)\beta_j}.$$

For the nontradeable sector $J+1$, the optimal factor allocations in country n are simply given by

$$p_n^{J+1} Q_n^{J+1} = \frac{w_n L_n^{J+1}}{\alpha_{J+1}\beta_{J+1}} = \frac{r_n K_n^{J+1}}{(1-\alpha_{J+1})\beta_{J+1}}.$$

Finally, the feasibility conditions for factors are given by, for any n,

$$\sum_{j=1}^{J+1} L_n^j = L_n \text{ and } \sum_{j=1}^{J+1} K_n^j = K_n.$$

Given all of the model parameters, factor endowments, trade costs, and productivities, the model is solved using the algorithm described in Levchenko and Zhang (2011). This model is used to estimate the sector-level technology parameters T_n^j for a large set of countries. The first step, most relevant to this study, is to estimate the technology parameters in the tradeable sectors relative to the a reference country (the U.S.) using data on sectoral output and bilateral trade. The procedure relies on fitting a structural gravity equation implied by the model. Intuitively, if controlling for the typical gravity determinants of trade, a country spends relatively more on domestically produced goods in a particular sector, it is revealed to have either a high relative productivity or a low relative unit cost in that sector. The procedure then uses data on factor and intermediate input prices to net out the role of factor costs, yielding an estimate of relative productivity. This step also produces estimates of bilateral trade costs at the sectoral level over time. The second step is to estimate the technology parameters in the tradeable sectors for the U.S.. This procedure requires directly measuring TFP at the sectoral level using data on real output and inputs, and then correcting measured TFP for selection due to trade. The taste parameters for all tradeable sectors ω_j are also calibrated in this step. The third step is to calibrate the nontradeable technology for all countries using the first-order condition of the model and the relative prices of nontradeables observed in the data. The detailed procedures for all three steps are described in Levchenko and Zhang (2011) and reproduced in Appendix B.

3.3 Welfare

Welfare in this framework is defined as the indirect utility function. Straightforward steps using the CES functional form can be used to show that the indirect utility in each country n is equal to the total income divided by the price level. Since the model is competitive, total income equals the total returns to factors of production. This implies that total welfare in a country is given by

$(w_nL_n + r_nK_n)/P_n$, where the consumption price level P_n comes from equation (11). Expressed in per capita terms it becomes:

$$\frac{w_n + r_nk_n}{P_n}, \tag{14}$$

where $k_n = K_n/L_n$ is capital per worker. We take this to be our metric of welfare in all counterfactual exercises below.

3.4 Calibration

In order to implement the model numerically, we must calibrate the following sets of parameters: (i) preference parameters ω_j, ξ_n, and η; (ii) production function parameters ε, α_j, β_j, $\gamma_{k,j}$ for all sectors j and k; (iii) moments of the productivity distributions T_n^j and θ; (iv) trade costs d_{ni}^j; and (v) country factor endowments L_n and K_n. We discuss the calibration of each in turn.

The share of expenditure on traded goods, ξ_n in each country is sourced from Yi and Zhang (2010), who compile this information for 36 developed and developing countries. For countries unavailable in the Yi and Zhang data, values of ξ_n are imputed based on fitting a simple linear relationship to log PPP-adjusted per capita GDP from the Penn World Tables. The fit of this simple bivariate linear relationship is quite good, with the R^2 of 0.55. The taste parameters for tradeable sectors ω_j were estimated by Levchenko and Zhang (2011) by combining the model structure above with data on final consumption expenditure shares in the U.S. sourced from the U.S. Input-Output matrix. The elasticity of substitution between broad sectors within the tradeable bundle, η, is set to 2. Since these are very large product categories, it is sensible that this elasticity would be relatively low. It is higher, however, than the elasticity of substitution between tradeable and nontradeable goods, which is set to 1 by the Cobb-Douglas assumption.

The production function parameters α_j and β_j are estimated using the UNIDO Industrial Statistics Database, which reports output, value added, employment, and wage bills at roughly 2-digit ISIC Revision 3 level of disaggregation. To compute α_j for each sector, we calculate the share of the total wage bill in value added, and take a simple median across countries (taking the mean yields essentially the same results). To compute β_j, take the median of value added divided by total output.

The intermediate input coefficients $\gamma_{k,j}$ are obtained from the Direct Requirements Table for the United States. We use the 1997 Benchmark Detailed Make and Use Tables (covering approximately 500 distinct sectors), as well as a concordance to the ISIC Revision 3 classification to build a Direct Requirements Table at the 2-digit ISIC level. The Direct Requirements Table gives the value of the intermediate input in row k required to produce one dollar of final output in column j. Thus, it is the direct counterpart of the input coefficients $\gamma_{k,j}$. Note that we assume these to be the same in all countries.[2] In addition, we use the U.S. I-O matrix to obtain the shares of total final consumption expenditure going to each sector, which we use to pin down taste parameters ω_j in traded sectors $1, ..., J$; as well as α_{J+1} and β_{J+1} in the nontradeable sector, which cannot be obtained from UNIDO.[3] The elasticity of substitution between varieties within each tradeable sector, ε, is set to 4.

The technology parameters T_n^j and trade costs d_{ni}^j were estimated by Levchenko and Zhang (2011), who use data on bilateral trade to fit a a structural gravity equation, and use the resulting estimates along with data on input costs to back out underlying technology. We assume that the dispersion parameter θ does not vary across sectors. There are no reliable estimates of how it varies across sectors, and thus we do not model this variation. We pick the value of $\theta = 8.28$, which is the preferred estimate of EK.[4] It is important to assess how the results below are affected by the value of this parameter. One may be especially concerned about how the results change under lower values of θ. Lower θ implies greater within-sector heterogeneity in the random productivity draws. Thus, trade flows become less sensitive to the costs of the input bundles (c_i^j), and the gains from intra-sectoral trade become larger relative to the gains from inter-sectoral trade. Elsewhere we re-estimated all the technology parameters using instead a value of $\theta = 4$, which has been advocated by Simonovska and Waugh (2010) and is at or near the bottom of the range that has been used in the literature. Overall, the outcome was remarkably similar. The correlation between estimated T_i^j's under $\theta = 4$ and the baseline is above 0.95, and there is actually somewhat greater variability in T_i^j's under $\theta = 4$. Appendix B describes the Levchenko and Zhang (2011) procedures to estimate T_n^j, d_{ni}^j, and ω_j. The parametric model for iceberg trade costs includes the common geographic variables such as distance and common border, as well as policy variables, such as regional trade agreements and currency unions.

The total labor force in each country, L_n, and the total capital stock, K_n, are obtained from the Penn World Tables 6.3. Following the standard approach in the literature (see, e.g. Hall and

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[2] di Giovanni and Levchenko (2010) provide suggestive evidence that at such a coarse level of aggregation, Input-Output matrices are indeed similar across countries. To check robustness of the results, we collected country-specific I-O matrices from the GTAP database. Productivities computed based on country-specific I-O matrices were very similar to the baseline values. In our sample of countries, the median correlation was 0.98, with all but 3 out of 75 countries having a correlation of 0.93 or above, and the minimum correlation of 0.65.

[3] The U.S. I-O matrix provides an alternative way of computing α_j and β_j. These parameters calculated based on the U.S. I-O table are very similar to those obtained from UNIDO, with the correlation coefficients between them above 0.85 in each case. The U.S. I-O table implies greater variability in α_j's and β_j's across sectors than does UNIDO.

[4] Shikher (2004, 2005, 2011), Burstein and Vogel (2009), and Eaton, Kortum, Neiman and Romalis (2010), among others, follow the same approach of assuming the same θ across sectors. Caliendo and Parro (2010) use tariff data and triple differencing to estimate sector-level θ. However, their approach may impose too much structure and/or be dominated by measurement error: at times the values of θ they estimate are negative. In addition, in each sector the restriction that $\theta > \varepsilon - 1$ must be satisfied, and it is not clear whether Caliendo and Parro (2010)'s estimated sectoral θ's meet this restriction in every case. Our approach is thus conservative by being agnostic on this variation across sectors.

Jones 1999, Bernanke and Gürkaynak 2001, Caselli 2005), the total labor force is calculated from the data on the total GDP per capita and per worker.[5] The total capital is calculated using the perpetual inventory method that assumes a depreciation rate of 6%: $K_{n,t} = (1-0.06)K_{n,t-1} + I_{n,t}$, where $I_{n,t}$ is total investment in country n in period t. For most countries, investment data start in 1950, and the initial value of K_n is set equal to $I_{n,0}/(\gamma + 0.06)$, where γ is the average growth rate of investment in the first 10 years for which data are available.

All of the variables that vary over time are averaged for the period 2000-2007 (the latest available year), which is the time period on which we carry out the analysis. Appendix Table A1 lists the countries used in the analysis, separating them into the major country groups and regions. Appendix Table A2 lists the sectors along with the key parameter values for each sector: α_j, β_j, the share of nontradeable inputs in total inputs $\gamma_{J+1,j}$, and the taste parameter ω_j.

4 Welfare Analysis

4.1 Basic Patterns

Countries differ markedly with respect to their trade relationship with China. The top panel of Table 1 lists the top 10 and bottom 10 countries in terms of the average trade costs (d^j_{ni}) with China, while the bottom panel reports the top 10 and bottom 10 countries in terms of the correlation between the tradeable sector $\left(T^j_n\right)^{1/\theta}$'s with China. In order to focus on differences in comparative rather than absolute advantage, we compute these correlations on the vectors of T^j_n demeaned by each country's geometric average $\left(T^j_n\right)^{1/\theta}$.

Average trade costs vary from 1.6–1.7 for Japan, Korea and United States, to 3.95 for Trinidad and Tobago and Ethiopia. Not surprisingly, the trade costs implied by our model correlate positively with distance, with the countries in Asia as the ones with lowest trade costs, though not without exception: the U.S., U.K, and Germany are in the bottom 10. Technological similarity varies a great deal as well, from more than 0.9 correlation with India, Turkey, and Indonesia, to correlations below 0.6 with Sri Lanka, Bolivia, and Iceland. It is clear that the regional component is not as prevalent here, with both most similar and most different countries drawn from different parts of the world.

4.2 Model Fit

Table 2 compares the wages, returns to capital, and the trade shares in the baseline model solution and in the data. The top panel shows that mean and median wages implied by the model are very close to the data. The correlation coefficient between model-implied wages and those in the

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[5] Using the variable name conventions in the Penn World Tables, $L_n = 1000 * pop * rgdpch/rgdpwok$.

data is above 0.99. The second panel performs the same comparison for the return to capital. Since it is difficult to observe the return to capital in the data, we follow the approach adopted in the estimation of T_n^j's, and impute r_n from an aggregate factor market clearing condition: $r_n/w_n = ((1-\alpha)L_n)\,/\,(\alpha K_n)$, where α is the aggregate share of labor in GDP, assumed to be 2/3. Once again, the average levels of r_n are very similar in the model and the data, and the correlation between the two is in excess of 0.95.

Next, we compare the trade shares implied by the model to those in the data. The third panel of Table 2 reports the spending on domestically produced goods as a share of overall spending, π_{nn}^j. These values reflect the overall trade openness, with lower values implying higher international trade as a share of absorption. Though we under-predict overall trade slightly (model π_{nn}^j's tend to be higher), the averages are quite similar, and the correlation between the model and data values is 0.91. Finally, the bottom panel compares the international trade flows in the model and the data. The averages are very close, and the correlation between model and data is 0.9.

Figure 3 presents the comparison of trade flows graphically, by depicting the model-implied trade values against the data, along with a 45-degree line. Red/solid dots indicate π_{ni}^j's that involve China, that is, trade flows in which China is either an exporter or an importer. All in all the fit of the model to trade flows is quite good. China is unexceptional, with Chinese flows clustered together with the rest of the observations.

We conclude from this exercise that our model matches quite closely the relative incomes of countries as well as bilateral and overall trade flows observed in the data. We now use the model to carry out the two counterfactual scenarios. One captures the gains from trade with China as it stands now. The other considers two possible growth patterns for China.

4.3 Gains from Trade with China

Panel A of Table 3 reports the gains from trade with China around the world. To compute these, we compare welfare in each country in the baseline (current levels of trade costs and productivities as we estimate them in the world today) against a counterfactual scenario in which China is in autarky. The table reports the change in welfare for China itself, as well as the summary statistics for each region and country group.

Our model implies that China's gains from trade relative to complete autarky are 3.72%. Elsewhere in the world, the gains range from -0.27 to 0.80%. The top gainers tend to be close to China geographically: Malaysia (0.80%), Kazakhstan (0.78%), and Taiwan, POC (0.63%). Of the top 10 gainers, 7 are in Asia, and the remaining three are Peru (0.39%) and Chile (0.37%), and Australia (0.30%). The OECD countries to gain the most are Australia, New Zealand, and Japan at 0.26-0.30%. The mean gain in the OECD is 0.13%, and the welfare change for the U.S.

is 0.11%. Table 3 also reveals that in nearly every major country group, the welfare changes range from negative to positive. The countries to lose the most from entry of China into world trade are Honduras (−0.27%) and El Salvador (−21%). All in all, 9 out of 75 countries experience negative welfare changes. By and large, these tend to be producers of Textiles and Apparel: Sri Lanka, Bulgaria, Vietnam, Mauritius, and Portugal are all among the losing countries.

Figure 4 presents the results graphically on the world map. The figure reinforces the point that while closer countries tend to experience larger gains on average, the within-region dispersion is also important.

4.4 Balanced and Unbalanced Growth

The preceding counterfactual was with respect to trade costs: it assumed that trade costs faced by China were prohibitive, and thus it was in autarky. The concern put forward by Samuelson (2004) is about uneven technical change in China: given the prevailing level of trade costs, welfare globally will be affected differently depending on the pattern of sectoral growth in China.

To evaluate the role of uneven growth, we now simulate two productivity growth scenarios. In the first, we assume that starting from today's values of China's T_n^j's, it grows by the same rate in each sector relative to the world frontier. This is the "balanced growth" scenario, that effectively assumes that China's comparative advantage vis-à-vis the world is not changing as it grows. The average productivity growth rate we apply is the observed growth of average T_n^j's in China relative to the world frontier between the 1990s and the 2000s, which according to our estimates is about 14%. Precisely, the counterfactual T's in the balanced growth scenario are calculated as:

$$\frac{\left(T_n^j\right)_{\text{balanced}}}{\left(T_F^j\right)_{2000s}} = \left(\frac{T_n^j}{T_F^j}\right)_{2000s} \times \frac{\left(\prod_{k=1}^{J} (T_n^k/T_F^k)_{2000s}\right)^{\frac{1}{J}}}{\left(\prod_{k=1}^{J} (T_n^k/T_F^k)_{1990s}\right)^{\frac{1}{J}}},$$

where T_F^j is the world frontier productivity in sector j, calculated as the geometric average of the 2 highest values of T_n^j in the world.[6]

Next, we assume that technology in China evolves unevenly, and it catches up to the world frontier faster in its comparative disadvantage sectors. To make the analysis as stark as possible, we suppose that its productivity in each sector is now a constant fraction of the world frontier productivity. This counterfactual also builds in average growth in productivity in each sector,

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[6] The use of geometric averages has two appealing features. The first is that even though the counterfactual T's are calculated to keep their distance to the frontier, the geometric average of counterfactual T's is equal to the geometric average of the country's actual T's in the 2000s, times the average growth rate that we assume. The second appealing feature is that this formulation produces identical counterfactual T's whether the experiment is carried out on absolute T's or $T^{1/\theta}$'s, which are the mean productivities. We keep productivity in the nontradeable sector at the benchmark value in all the counterfactual experiments, since our focus is on the welfare impact of changes in comparative advantage.

by assuming that in this counterfactual, average productivity grows at the same rate as it did in China between the 1990s and the 2000s. The unbalanced growth counterfactual T's are thus calculated as:

$$\frac{\left(T_n^j\right)_{\text{unbalanced}}}{\left(T_F^j\right)_{2000s}} = \left(\prod_{k=1}^{J} (T_n^k/T_F^k)_{2000s}\right)^{\frac{1}{J}} \times \frac{\left(\prod_{k=1}^{J} (T_n^k/T_F^k)_{2000s}\right)^{\frac{1}{J}}}{\left(\prod_{k=1}^{J} (T_n^k/T_F^k)_{1990s}\right)^{\frac{1}{J}}}.$$

Figure 5 depicts these two counterfactuals graphically.[7] The solid dots, labelled by the sector number, represent the actual ratio of productivity to the global frontier in the 2000s in China in each sector. We can see that the comparative advantage sectors are Coke, Refined Petroleum Products, Nuclear Fuel; Wearing Apparel; and Transport Equipment. The productivity of these sectors is about $0.45-0.5$ of the world frontier productivity. The sectors at the greatest comparative disadvantage are Printing and Publishing; Office, Accounting, Computing, and Other Machinery; and Medical, Precision, and Optical Instruments. The productivity of these sectors is around 0.25 of the world frontier. The solid line denotes the geometric average of China's productivity as a ratio to the world frontier productivity in the 2000s, which is about 0.34.

The two counterfactual productivity scenarios are as plotted in the figure. In the balanced growth scenario, we assume that in each sector, China's distance to the global frontier has grown by the same proportional rate, which we set equal to the average growth rate we estimate for China between the 1990s and the 2000s, 14%. Thus, the balanced counterfactual productivities are depicted by the hollow dots. In the unbalanced counterfactual, we assume that China's average productivity grows by the same average rate, but its comparative advantage relative to world frontier is erased: in each sector, its productivity is a constant fraction of world frontier. That scenario is depicted by the hollow triangles. An attractive feature of this setup is that in the two counterfactuals, the geometric average productivity across sectors in China is the same. The only thing that is different is the comparative advantage.

Panels B and C of Table 5 present the results for the balanced and the unbalanced counterfactuals, respectively. Figures 6 and 7 present the world map of the global distribution of gains. The results are striking. First of all, China itself gains slightly more from a balanced growth scenario than from unbalanced growth, 11.43% compared to 10.57%, a difference of almost a percentage point. This is not surprising: stronger comparative advantage increases China's gains from trade with the rest of the world, and thus weakening comparative advantage, as in the unbalanced scenario, will tend to lower welfare. These results, both in direction and magnitude, are in line with what has been found in similar counterfactuals by Levchenko and Zhang (2011) in the broad

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[7] Since mean productivity in each sector is equal to $T^{1/\theta}$, the figure reports the distance to the global frontier expressed in terms of $T^{1/\theta}$, rather than T.

sample of countries.

Second, and much more intriguingly, the rest of the world gains much more from unbalanced growth in China. The difference is of an order of magnitude or more. While mean and median gains from balanced growth for the OECD is 0.01-0.02%, they are 0.12-0.17% in the unbalanced case. For other regions the difference is even larger: 0.23-0.84% at the mean, compared to essentially zero in the balanced case.

These results are diametrically opposite to what has been conjectured by Samuelson (2004), who feared that China's growth in its comparative disadvantage sectors will hurt the rest of the world. Our results imply that the world actually gains much more from unbalanced growth in China, relative to balanced one. What is going on? Why does the world find growth in Chinese comparative disadvantage sectors so much more valuable than growth in Chinese comparative advantage sectors? Section 2 argues that in the presence of multiple countries, this is actually not surprising. What matters for an individual country is how China's technology compares not to itself, but to an appropriate world average productivity. Figure 8 thus correlates China's distance to the global frontier in each sector on the y-axis against the simple average of the distance to the global frontier in all the countries in the sample except China, along with the least-squares fit. The x-axis variable captures in a simple way how productive other countries are on average in each sector. Higher values of that variable imply that many countries are close to the world frontier, and thus the world as a whole is fairly productive in that sector. Lower values imply that the world frontier is populated by only a few countries, and most countries are very far from it.

The relationship is striking: China's comparative advantage sectors also happen to be the ones in which other countries tend to be more productive. The simple correlation between these two variables is a remarkable 0.86.[8] Thus, China's comparative advantage is in "common" sectors, those in which many other countries are already productive, most obviously Wearing Apparel. By contrast, China's comparative disadvantage is in "scarce" sectors, in which not many countries are productive. Thus, it is more valuable for the world if China improves productivity in the globally scarce sectors.

4.5 Robustness

One aspect of Chinese trade that received a lot of attention is its goods trade surpluses. We currently do not have a good understanding of what features of the Chinese and world economies are responsible for this pattern. In addition, unbalanced trade is an essentially dynamic phenomenon, in which consumption gains to the deficit countries today are (presumably) being offset by con-

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[8] The plot and the reported correlation drop Tobacco, which is a small sector and an outlier. With Tobacco, the correlation is 0.78.

sumption losses in the future. In the absence of a working model of what determines that tradeoff, we incorporate the impact of trade imbalances by following the approach of Dekle, Eaton and Kortum (2007, 2008) and assuming that at a point in time, a trade imbalance represents a transfer from the surplus to the deficit country. In particular, we suppose that the budget constraint (or the resource constraint) of the consumer is now

$$\sum_{j=1}^{J+1} p_n^j Y_n^j = w_n L_n + r_n K_n - D_n.$$

The total resources available to consumers include not only factor income but a deficit term D_n, which is negative when countries are running a deficit and consume more than their factor income. The deficits add up to zero globally, $\sum_n D_n = 0$, and are thus trasfers of resources between countries. The rest of the model remains the same. In implementing the model, the deficits are taken directly from the data. To evaluate the impact of unbalanced trade on welfare, we want to ignore the transfer itself. In other words, when the U.S. opens to trade with China, in this model there will be gains from goods trade, but also direct income gains from the transfer of resources from China to the U.S.. In calculating the welfare impact, we abstract from the latter, since in the intertemporal sense, it is not really a transfer. Thus, in the model with deficit, the metric for welfare continues to be (14).

In evaluating the welfare gains from trade with China, we assume that when China is in autarky, its bilateral imports and exports (and thus bilateral deficits) with each country are set to zero. Thus, the rest of the world's bilateral trade imbalances remain unchanged, and trade is still generically not balanced for the other 74 countries. In the balanced and unbalanced growth counterfactuals, we assume that the vector of D_n's in the world remains the same. Both assumptions are not perfect, but this is the best we can do since we do not have a model of endogenous determination of D_n's.

Table 4 reports the results under unbalanced trade. Not surprisingly, China gains about half a percentage point less from unbalanced trade, since in the trade equilibrium it is transferring resources abroad, while the rest of the world gains more than under balanced trade. Note that we are not counting the direct impact of income transfers in welfare. Thus, larger gains from trade with China with unbalanced trade compared to balanced one come from the general equilibrium effects on goods and factor prices. Intuitively, a country receiving a transfer will experience an increase in demand, which will push up factor prices, while in country sending out the transfer (China), factor prices will be lower relative to balanced trade. This implies an improvement in the terms of trade of the receiving country, and thus larger gains from trade with China relative to the balanced trade case (Dornbusch, Fischer and Samuelson 1977).

The global impact of balanced and unbalanced growth in China is very similar to the baseline results. The mean welfare impact of balanced growth in China, 0.003%, is slightly smaller than without trade deficits, but of the same order of magnitude. The mean gains from unbalanced growth, 0.39%, are very similar to the baseline case. In each growth scenario, the gains across countries with and without trade deficits have a correlation coefficient of above 0.93.

Another concern is that the baseline model includes only manufacturing sectors. Exclusion of agricultural and mining production and trade is unlikely to have a large impact on the results, as agriculture and mining account for only about 14% of global trade in the 2000s. To check robustness of the results, we collected data on total output in Agriculture, Hunting, Forestry and Fishing ("Agriculture" for short) and Mining and Quarrying ("Mining") from the United Nations Statistics Division. The output data are not available at a finer level of disaggregation. Several countries in our sample did not have information on agricultural and mining output in this database. In those cases, we imputed total output in these sectors by using agricultural and mining value added data from the World Bank's World Development indicators, and "grossing up" value added data by $1/(1-\beta_j)$ to obtain a guess for total gross output. Though we performed extensive quality and consistency checks on the resulting data points, one must treat them with caution, as they come from different sources than the manufacturing data, are in several important cases imputed, and are clearly observed at a coarser level of aggregation than manufacturing.

Combining agricultural and mining output data with information on bilateral trade, we estimate T_n^j's and d_{ni}^j's in those two sectors in each country using the same procedure as for manufacturing, described in Appendix B. We use the U.S. Input-Output table, which includes information on non-manufacturing, to compute α_j, β_j, and all the $\gamma_{k,j}$'s associated with agriculture and mining as either output or input sectors. We also use the U.S. Input-Output table for the final consumption shares of those sectors, in order to estimate non-manufacturing ω_j's. We apply the same value of θ to non-manufacturing sectors as we do to the rest of the model.

Having estimated all the technology and trade cost parameters for non-manufacturing, we then solve the full model augmented with the non-manufacturing sectors, and perform all of the counterfactuals. The results are reported in Table 5. By and large, the conclusions are unchanged. The magnitudes of the gains/losses from trade with China are remarkably similar. Exactly as in the baseline model, the gains from unbalanced growth are an order of magnitude larger than the gains from balanced growth.

One may also be concerned that the results may be unduly influenced by the way sectoral productivity is measured. As detailed in Levchenko and Zhang (2011), the productivity estimates used in this analysis rely on extracting information from international trade flows. An alternative approach would be to use sectoral data on output and inputs and measure TFP using the standard Solow residual approach. The basic difficulty in directly measuring sectoral TFP in a large sample of countries and over time is the lack of comparable data on real sectoral output and inputs. To our knowledge, the most comprehensive database that can be used to measure sectoral TFP on a consistent basis across countries and time is the OECD Structural Analysis (STAN) database. It contains the required information on only 11 developed countries: Austria, Belgium, Czech Republic, Denmark, Finland, France, Greece, Italy, Norway, Slovenia, and Sweden (though upon closer inspection it turns out that the time and sectoral coverage is poor even in that small set of countries). Nonetheless, to check robustness of our results, we built direct TFP estimates for those 11 countries, and used them instead of the international trade-implied baseline estimates.

The resulting welfare changes are quite similar to the baseline results: for all three counterfactuals, the correlation between the welfare changes in the main analysis and the welfare changes using STAN-based estimates is above 0.99. The magnitudes of the welfare changes are very similar to the main results as well. Table 6 replicates all of the welfare results using the STAN-based productivity estimates for the available countries. The average welfare impacts in all three panels are very similar, and the contrast between the balanced and the unbalanced growth counterfactuals is equally stark. We conclude from this exercise that using direct estimates of productivity wherever those are available does not change the main message of the analysis.

5 Conclusion

The sheer size of the Chinese economy and the breathtaking speed of its integration into global trade have led to concerns about the possible negative welfare effects of China's integration and productivity growth. These concerns correspond to the theoretically possible – though not necessary – outcomes in fully articulated models of international trade, and thus have been taken seriously by economists. However, it is ultimately a quantitative question whether the negative welfare effects of China on its trading partners actually obtain in a calibrated model of the world economy, with a realistic production structure, trade costs, and the inherently multilateral nature of international trade.

In this paper, we investigate the global welfare impact of China's trade integration and productivity growth in a multi-country, multi-sector Ricardian-Heckscher-Ohlin model of production and trade. With respect to China's trade integration, our main finding is that the gains range from negative to positive, with Asian countries on average gaining more, while many countries in which Textile and Apparel sectors are important actually experiencing small welfare losses. With respect to technological change, our results are more surprising: contrary to a well-known conjecture, the world will actually gain much more in welfare is China's growth is unbalanced. This is because China's current pattern of comparative advantage is common in the world, and thus unbalanced growth in China actually makes it more different than the average country. Both analytical and quantitative results point to the crucial importance of taking explicit account of the multilateral nature of both Ricardian comparative advantage and trade flows in evaluating the global welfare impact of China.

Appendix A Proofs for Lemmas in Section 2

Proof of Lemma 1: From (8) and the constraint that $\left(T_1^A T_2^B\right)^{\frac{1}{2}} = c$, welfare in country n as a function of T_1^A can be written as:

$$\left\{\left[T_1^A + \sum_{i=2}^{N} T_i^A \left(\frac{w_i d_{ni}^A}{w_1 d_{n1}^A}\right)^{-\theta}\right]\left[\frac{1}{T_1^A} + \frac{1}{c^2}\sum_{i=2}^{N} T_i^B \left(\frac{w_i d_{ni}^B}{w_1 d_{n1}^B}\right)^{-\theta}\right]\right\}^{\frac{\alpha}{2\theta}}.$$

Taking the first-order condition with respect to T_1^A yields the following welfare-minimizing value:

$$T_1^A = c\sqrt{\frac{\sum_{i=2}^{N} T_i^A \left(\frac{w_i d_{ni}^A}{w_1 d_{n1}^A}\right)^{-\theta}}{\sum_{i=2}^{N} T_i^B \left(\frac{w_i d_{ni}^B}{w_1 d_{n1}^B}\right)^{-\theta}}}.$$

The second-order condition easily verifies that this is indeed a (global) minimum. Using the welfare-minimizing T_1^A together with $\left(T_1^A T_2^B\right)^{\frac{1}{2}} = c$ leads to the expression for relative technologies (9). Q.E.D.

Proof of Lemma 2: The welfare of each country is given by

$$W_1 = \frac{w_1}{P_1} \text{ and } W_2 = \frac{w_2}{P_2},$$

where P_n is the aggregate price of country n, given by

$$P_n = \sqrt{P_n^A P_n^B}.$$

Since trade is costly, the good prices are equalized across countries, both at the sectoral level and at the aggregate level:

$$P_1^s = P_2^s = \left[\left(\frac{w_1}{T_1^s}\right)^{-\theta} + \left(\frac{w_2}{T_2^s}\right)^{-\theta}\right]^{-\frac{1}{\theta}}.$$

Thus, we have

$$W_1^{2\theta} = \left[w_1^{-\theta}\left(T_1^A\right)^{\theta} + w_2^{-\theta}\left(T_2^A\right)^{\theta}\right]\left[w_1^{-\theta}\left(T_1^B\right)^{\theta} + w_2^{-\theta}\left(T_2^B\right)^{\theta}\right].$$

We control $T_1^A T_1^B = 1$ while varying T_1^A. We normalize $w_1 = 1$. Given that $T_2^A = T_2^B = 1$, we have

$$W_1^{2\theta} = \left[\left(T_1^A\right)^{\theta} + w_2^{-\theta}\right]\left[\left(T_1^A\right)^{-\theta} + w_2^{-\theta}\right] = 1 + w_2^{-\theta}\left[\left(T_1^A\right)^{\theta} + \left(T_1^A\right)^{-\theta}\right] + w_2^{-2\theta}.$$

Similarly, we have

$$W_2^{2\theta} = w_2^{2\theta} + w_2^{\theta}\left[\left(T_1^A\right)^{\theta} + \left(T_1^A\right)^{-\theta}\right] + 1.$$

Clearly, since the prices are equalized across countries, the ratio of welfares equals the ratio of wages across two countries:

$$\frac{W_2}{W_1} = w_2.$$

If the wages are pinned down by another homogeneous sector, it is clearly that the welfare minimizing T_1^A satisfies $T_1^A = T_1^B = 1$, which has the same ratio of country 2. Now consider the general equilibrium effect of wages. Taking derivatives of welfare with respect to T_1^A gives rise to

$$\frac{dW_1^{2\theta}}{dT_1^A} = -\theta w_2^{-\theta-1}\left[\left(T_1^A\right)^{\theta} + \left(T_1^A\right)^{-\theta} + 2w_2^{-\theta}\right]\frac{dw_2}{dT_1^A} + \theta w_2^{-\theta}\left[\left(T_1^A\right)^{\theta-1} - \left(T_1^A\right)^{-\theta-1}\right],$$

and

$$\frac{dW_2^{2\theta}}{dT_1^A} = \theta w_2^{\theta-1}\left[\left(T_1^A\right)^{\theta} + \left(T_1^A\right)^{-\theta} + 2w_2^{\theta}\right]\frac{dw_2}{dT_1^A} + \theta w_2^{\theta}\left[\left(T_1^A\right)^{\theta-1} - \left(T_1^A\right)^{-\theta-1}\right].$$

Setting the first order condition to zero, we have

$$\frac{dw_2}{dT_1^A} = -w_2\frac{\left(T_1^A\right)^{\theta-1} - \left(T_1^A\right)^{-\theta-1}}{\left(T_1^A\right)^{\theta} + \left(T_1^A\right)^{-\theta} + 2w_2^{-\theta}},$$

and

$$\frac{dw_2}{dT_1^A} = -w_2\frac{\left(T_1^A\right)^{\theta-1} - \left(T_1^A\right)^{-\theta-1}}{\left(T_1^A\right)^{\theta} + \left(T_1^A\right)^{-\theta} + 2w_2^{\theta}}.$$

Thus, the welfare minimizing points seem to be not the same for country 1 and 2. However, we will show next that in equilibrium from the balanced trade condition, $\frac{dw_2}{dT_1^A} = 0$ and $w_2 = 1$ for any T_1^A. Thus the welfare minimizing points are the same for both countries: $T_1^A = 1$.

The net exports in each tradable sector $s \in \{A, B\}$ are given by

$$NX_1^s = \pi_{21}^s X_2^s w_2 L_2 - \pi_{12}^s X_1^s w_1 L_1 = \frac{1}{2}(\pi_{21}^s w_2 - \pi_{12}^s w_1),$$

where the symmetric Cobb-Douglas preferences across the two sectors give expenditure shares $X_2^s = X_1^s = \frac{1}{2}$ and the symmetric country size leads to $L_1 = L_2$.

Under free trade, trade shares in our example are given by

$$\pi_{12}^A = \frac{w_2^{-\theta}}{\left(T_1^A\right)^{\theta} + w_2^{-\theta}} = 1 - \pi_{21}^A$$

and

$$\pi_{12}^B = \frac{w_2^{-\theta}}{\left(T_1^A\right)^{-\theta} + w_2^{-\theta}} = 1 - \pi_{21}^B.$$

The net export in sector $s \in \{A, B\}$ of country 1 is given by

$$NX_1^s = \frac{1}{2}\left(\pi_{21}^s w_2 - \pi_{12}^s\right) = \frac{1}{2}\left(\pi_{21}^s\left(w_2 + 1\right) - 1\right).$$

The balanced-trade condition implies that

$$w_2 = \frac{\pi_{12}^A + \pi_{12}^B}{\pi_{21}^A + \pi_{21}^B}.$$

Plugging in the expressions for the trade shares in the above equation yields

$$2w_2^{\theta+1} + w_2\left[\left(T_1^A\right)^{-\theta} + \left(T_1^A\right)^{\theta}\right] - 2w_2^{-\theta} - \left[\left(T_1^A\right)^{-\theta} + \left(T_1^A\right)^{\theta}\right] = 0$$

Clearly $w_2 = 1$ is the solution to the above trade balance equation for any T_1^A, which also implies $\frac{dw_2}{dT_1^A} = 0$. Q.E.D.

Appendix B Procedure for Estimating T_n^j, d_{ni}^j, and ω_j

This appendix reproduces from Levchenko and Zhang (2011) the details of the procedure for estimating technology, trade costs, and taste parameters required to implement the model. Interested readers should consult that paper for further details on estimation steps and data sources.

B.1 Tradeable Sector Relative Technology

We now focus on the tradeable sectors. Following the standard EK approach, first divide trade shares by their domestic counterpart:

$$\frac{\pi_{ni}^j}{\pi_{nn}^j} = \frac{X_{ni}^j}{X_{nn}^j} = \frac{T_i^j\left(c_i^j d_{ni}^j\right)^{-\theta}}{T_n^j\left(c_n^j\right)^{-\theta}},$$

which in logs becomes:

$$\ln\left(\frac{X_{ni}^j}{X_{nn}^j}\right) = \ln\left(T_i^j (c_i^j)^{-\theta}\right) - \ln\left(T_n^j (c_n^j)^{-\theta}\right) - \theta \ln d_{ni}^j.$$

Let the (log) iceberg costs be given by the following expression:

$$\ln d_{ni}^j = d_k^j + b_{ni}^j + CU_{ni}^j + RTA_{ni}^j + ex_i^j + \nu_{ni}^j,$$

where d_k^j is an indicator variable for a distance interval. Following EK, we set the distance intervals, in miles, to [0, 350], [350, 750], [750, 1500], [1500, 3000], [3000, 6000], [6000, maximum). Additional variables are whether the two countries share a common border (b_{ni}^j), belong to a currency union (CU_{ni}^j), or to a regional trade agreement (RTA_{ni}^j). Following the arguments in Waugh (2009), we include an exporter fixed effect ex_i^j. Finally, there is an error term ν_{ni}^j. Note that all the variables have a sector superscript j: we allow all the trade cost proxy variables to affect true iceberg trade costs d_{ni}^j differentially across sectors. There is a range of evidence that trade volumes at sector level vary in their sensitivity to distance or common border (see, among many others, Do and Levchenko 2007, Berthelon and Freund 2008).

This leads to the following final estimating equation:

$$\ln\left(\frac{X_{ni}^j}{X_{nn}^j}\right) = \underbrace{\ln\left(T_i^j (c_i^j)^{-\theta}\right) - \theta ex_i^j}_{\text{Exporter Fixed Effect}} \underbrace{- \ln\left(T_n^j \left(c_n^j\right)^{-\theta}\right)}_{\text{Importer Fixed Effect}}$$
$$\underbrace{-\theta d_k^j - \theta b_{ni}^j - \theta CU_{ni}^j - \theta RTA_{ni}^j}_{\text{Bilateral Observables}} \underbrace{-\theta \nu_{ni}^j}_{\text{Error Term}} .$$

Estimating this relationship will thus yield, for each country, an estimate of its technology-cum-unit-cost term in each sector j, $T_n^j (c_n^j)^{-\theta}$, which is obtained by exponentiating the importer fixed effect. The available degrees of freedom imply that these estimates are of each country's $T_n^j (c_n^j)^{-\theta}$ relative to a reference country, which in our estimation is the United States. We denote this estimated value by S_n^j:

$$S_n^j = \frac{T_n^j}{T_{us}^j}\left(\frac{c_n^j}{c_{us}^j}\right)^{-\theta},$$

where the subscript us denotes the United States. It is immediate from this expression that estimation delivers a convolution of technology parameters T_n^j and cost parameters c_n^j. Both will of course affect trade volumes, but we would like to extract technology T_n^j from these estimates. In order to do that, we follow the approach of Shikher (2004). In particular, for each country n, the share of total spending going to home-produced goods is given by

$$\frac{X_{nn}^j}{X_n^j} = T_n^j \left(\frac{\Gamma c_n^j}{p_n^j}\right)^{-\theta}.$$

Dividing by its U.S. counterpart yields:

$$\frac{X_{nn}^j / X_n^j}{X_{us,us}^j / X_{us}^j} = \frac{T_n^j}{T_{us}^j}\left(\frac{c_n^j}{c_{us}^j}\frac{p_{us}^j}{p_n^j}\right)^{-\theta} = S_n^j \left(\frac{p_{us}^j}{p_n^j}\right)^{-\theta},$$

and thus the ratio of price levels in sector j relative to the U.S. becomes:

$$\frac{p_n^j}{p_{us}^j} = \left(\frac{X_{nn}^j / X_n^j}{X_{us,us}^j / X_{us}^j}\frac{1}{S_n^j}\right)^{\frac{1}{\theta}}. \tag{B.1}$$

The entire right-hand side of this expression is either observable or estimated. Thus, we can impute the price levels relative to the U.S. in each country and each tradeable sector.

The cost of the input bundles relative to the U.S. can be written as:

$$\frac{c_n^j}{c_{us}^j} = \left(\frac{w_n}{w_{us}}\right)^{\alpha_j \beta_j}\left(\frac{r_n}{r_{us}}\right)^{(1-\alpha_j)\beta_j}\left(\prod_{k=1}^{J}\left(\frac{p_n^k}{p_{us}^k}\right)^{\gamma_{k,j}}\right)^{1-\beta_j}\left(\frac{p_n^{J+1}}{p_{us}^{J+1}}\right)^{\gamma_{J+1,j}(1-\beta_j)}.$$

Using information on relative wages, returns to capital, price in each tradeable sector from (B.1), and the nontradeable sector price relative to the U.S., we can thus impute the costs of the input bundles relative to the U.S. in each country and each sector. To compute r_n, we use an aggregate factor market clearing condition: $r_n/w_n = ((1-\alpha)L_n)/(\alpha K_n)$, where α is the aggregate share of labor in GDP, which we set to 2/3. Armed with those values, it is straightforward to back out the relative technology parameters:

$$\frac{T_n^j}{T_{us}^j} = S_n^j \left(\frac{c_n^j}{c_{us}^j} \right)^\theta .$$

B.2 Complete Estimation

So far we have estimated the levels of technology of the tradeable sectors relative to the United States. To complete our estimation, we still need to find (i) the levels of T for the tradeable sectors in the United States; (ii) the taste parameters ω_j, and (iii) the nontradeable technology levels for all countries.

To obtain (i), we use the NBER-CES Manufacturing Industry Database for the U.S. (Bartelsman and Gray 1996). We start by measuring the observed TFP levels for the tradeable sectors in the U.S.. The form of the production function gives

$$\ln Z_{us}^j = \ln \Lambda_{us}^j + \beta_j \alpha_j \ln L_{us}^j + \beta_j (1 - \alpha_j) \ln K_{us}^j + (1 - \beta_j) \sum_{k=1}^{J+1} \gamma_{k,j} \ln M_{us}^{k,j}, \tag{B.2}$$

where Λ^j denotes the measured TFP in sector j, Z^j denotes the output, L^j denotes the labor input, K^j denotes the capital input, and $M^{k,j}$ denotes the intermediate input from sector k. The NBER-CES Manufacturing Industry Database offers information on output, and inputs of labor, capital, and intermediates, along with deflators for each. Thus, we can estimate the observed TFP level for each manufacturing tradeable sector using the above equation.

If the United States were a closed economy, the observed TFP level for sector j would be given by $\Lambda_{us}^j = (T_{us}^j)^{\frac{1}{\theta}}$. In the open economies, the goods with inefficient domestic productivity draws will not be produced and will be imported instead. Thus, international trade and competition introduce selection in the observed TFP level, as demonstrated by Finicelli, Pagano and Sbracia (2009a). We thus use the model to back out the true level of T_{us}^j of each tradeable sector in the United States. Here we follow Finicelli et al. (2009a) and use the following relationship:

$$(\Lambda_{us}^j)^\theta = T_{us}^j + \sum_{i \neq us} T_i^j \left(\frac{c_i^j d_{us,i}^j}{c_{us}^j} \right)^{-\theta} .$$

Thus, we have

$$(\Lambda_{us}^j)^\theta = T_{us}^j \left[1 + \sum_{i \neq us} \frac{T_i^j}{T_{us}^j} \left(\frac{c_i^j d_{us,i}^j}{c_{us}^j} \right)^{-\theta} \right] = T_{us}^j \left[1 + \sum_{i \neq us} S_i^j \left(d_{us,i}^j \right)^{-\theta} \right] . \tag{B.3}$$

This equation can be solved for underlying technology parameters T_{us}^j in the U.S., given estimated observed TFP Λ_{us}^j, and all the S_i^j's and $d_{us,i}^j$'s estimated in the previous subsection.

To estimate the taste parameters $\{\omega_j\}_{j=1}^J$, we use information on final consumption shares in the tradeable sectors in the U.S.. We start with a guess of $\{\omega_j\}_{j=1}^J$ and find sectoral prices p_n^k as follows. For an initial guess of sectoral prices, we compute the tradeable sector aggregate price and the nontradeable sector price using the data on the relative prices of nontradeables to tradeables. Using these prices, we calculate sectoral unit costs and Φ_n^j's, and update prices according to equation (6), iterating until the prices converge. We then update the taste parameters according to equation (13), using the data on final sectoral expenditure shares in the U.S.. We normalize the vector of ω_j's to have a sum of one, and repeat the above procedure until the values for the taste parameters converge.

Finally, we estimate the nontradeable sector TFP using the relative prices. In the model, the nontradeable sector price is given by

$$p_n^{J+1} = \Gamma (T_n^{J+1})^{-\frac{1}{\theta}} c_n^{J+1}.$$

Since we know the aggregate price level in the tradeable sector p_n^T, c_n^{J+1}, and the relative price of nontradeables (which we take from the data), we can back out T_n^{J+1} from the equation above for all countries.

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Table 1. Top and Bottom Trade Costs and Technological Similarity

Trade costs (average d_{ni}^{j})

Top 10 lowest		Top 10 highest	
Japan	1.638	Trinidad and Tobago	3.952
Korea, Rep.	1.653	Ghana	3.944
United States	1.699	Ethiopia	3.783
Malaysia	1.760	Senegal	3.777
Taiwan Province of China	1.784	Bolivia	3.639
Germany	1.846	Honduras	3.631
Australia	1.880	Jordan	3.614
Canada	1.890	Mauritius	3.506
United Kingdom	1.931	Nigeria	3.503
Indonesia	1.933	El Salvador	3.486

Technological similarity

Top 10 highest		Top 10 lowest	
India	0.928	Sri Lanka	0.578
Turkey	0.907	Bolivia	0.592
Indonesia	0.904	Iceland	0.595
Hungary	0.897	Honduras	0.611
Brazil	0.896	El Salvador	0.654
Philippines	0.889	Fiji	0.662
Mexico	0.879	Ethiopia	0.662
Egypt, Arab Rep.	0.873	Bangladesh	0.663
Vietnam	0.868	Iran, Islamic Rep.	0.665
Korea, Rep.	0.862	Saudi Arabia	0.710

Notes: This table reports the top and bottom 10 countries in terms of the average iceberg costs (d_{ni}^{j}) with China in the top panel, and in terms of technological similarity, defined as the correlation between the $\left(T_n^j\right)^{1/\theta}$'s of each country with China in the bottom panel.

Table 2. The Fit of the Baseline Model with the Data

		model	data
Wages:			
	mean	0.369	0.333
	median	0.133	0.145
	corr(model, data)	*0.993*	
Return to capital:			
	mean	0.850	0.919
	median	0.718	0.698
	corr(model, data)	*0.955*	
π_{nn}^{j}			
	mean	0.626	0.568
	median	0.690	0.611
	corr(model, data)	*0.911*	
π_{ni}^{j}, $i \neq n$			
	mean	0.0054	0.0058
	median	0.0002	0.0002
	corr(model, data)	*0.902*	

Notes: This table reports the means and medians of wages relative to the U.S. (top panel); return to capital relative to the U.S. (second panel), share of domestically produced goods in overall spending (third panel), and share of goods from country i in overall spending (bottom panel) in the model and in the data. Wages and return to capital in the data are calculated as described in Section B.

Table 3. Welfare Changes

Panel A: Welfare Gains from Trade with China

	Mean	Median	Min	Max	Countries
China	3.72				
OECD	0.13	0.12	-0.03	0.30	22
East and South Asia	0.23	0.20	-0.20	0.80	12
East. Europe and Cent. Asia	0.14	0.09	-0.08	0.78	11
Latin America and Caribbean	0.09	0.09	-0.27	0.39	15
Middle East and North Africa	0.12	0.13	0.04	0.22	6
Sub-Saharan Africa	0.08	0.06	-0.04	0.21	8

Panel B: Welfare Gains from Balanced Growth in China

	Mean	Median	Min	Max	Countries
China	11.43				
OECD	0.01	0.02	-0.01	0.04	22
East and South Asia	0.03	0.04	-0.05	0.09	12
East. Europe and Cent. Asia	0.01	0.01	-0.02	0.06	11
Latin America and Caribbean	-0.01	0.00	-0.06	0.04	15
Middle East and North Africa	-0.01	-0.01	-0.07	0.02	6
Sub-Saharan Africa	0.00	0.01	-0.02	0.02	8

Panel C: Welfare Gains from Unbalanced Growth in China

	Mean	Median	Min	Max	Countries
China	10.57				
OECD	0.17	0.12	-0.07	0.77	22
East and South Asia	0.84	0.74	0.22	1.70	12
East. Europe and Cent. Asia	0.42	0.34	0.07	1.52	11
Latin America and Caribbean	0.50	0.49	0.09	1.68	15
Middle East and North Africa	0.48	0.52	0.19	0.77	6
Sub-Saharan Africa	0.23	0.21	-0.03	0.57	8

Notes: Units are in percentage points. This table reports the changes in welfare from three counterfactual scenarios. Panel A presents the welfare gains in the benchmark for 2000s, relative to the scenario in which China is in autarky. Panel B presents the changes in welfare under the counterfactual scenario that growth is balanced in China across sectors, relative to the benchmark. Panel C presents the changes in welfare under the counterfactual scenario of unbalanced growth in China, relative to the benchmark. The technological changes assumed under the counterfactual scenarios are described in detail in the text.

Table 4. Welfare Changes, Unbalanced Trade

Panel A: Welfare Gains from Trade with China

	Mean	Median	Min	Max	Countries
China	3.09				
OECD	0.30	0.27	0.04	0.89	22
East and South Asia	0.32	0.22	-0.29	1.92	12
East. Europe and Cent. Asia	0.44	0.32	0.03	0.99	11
Latin America and Caribbean	0.25	0.26	-0.36	1.13	15
Middle East and North Africa	0.80	0.49	0.18	2.37	6
Sub-Saharan Africa	0.63	0.55	0.10	1.95	8

Panel B: Welfare Gains from Balanced Growth in China

	Mean	Median	Min	Max	Countries
China	11.56				
OECD	0.01	0.01	-0.01	0.04	22
East and South Asia	0.01	0.02	-0.09	0.07	12
East. Europe and Cent. Asia	0.00	0.00	-0.02	0.05	11
Latin America and Caribbean	-0.01	0.00	-0.09	0.03	15
Middle East and North Africa	-0.01	0.00	-0.08	0.02	6
Sub-Saharan Africa	0.00	0.00	-0.02	0.01	8

Panel C: Welfare Gains from Unbalanced Growth in China

	Mean	Median	Min	Max	Countries
China	10.64				
OECD	0.14	0.12	-0.10	0.69	22
East and South Asia	0.83	0.76	0.23	1.69	12
East. Europe and Cent. Asia	0.36	0.36	0.09	0.83	11
Latin America and Caribbean	0.49	0.42	-0.20	1.49	15
Middle East and North Africa	0.43	0.44	0.18	0.69	6
Sub-Saharan Africa	0.22	0.25	-0.12	0.58	8

Notes: Units are in percentage points. This table reports the changes in welfare from three counterfactual scenarios under the assumption of unbalanced trade. Panel A presents the welfare gains in the benchmark for 2000s, relative to the scenario in which China is in autarky. Panel B presents the changes in welfare under the counterfactual scenario that growth is balanced in China across sectors, relative to the benchmark. Panel C presents the changes in welfare under the counterfactual scenario of unbalanced growth in China, relative to the benchmark. The technological changes assumed under the counterfactual scenarios are described in detail in the text.

Table 5. Welfare Changes, with Non-Manufacturing Sectors

Panel A: Welfare Gains from Trade with China

	Mean	Median	Min	Max	Countries
China	3.53				
OECD	0.12	0.11	-0.04	0.31	22
East and South Asia	0.18	0.12	-0.26	0.69	12
East. Europe and Cent. Asia	0.06	0.07	-0.12	0.27	11
Latin America and Caribbean	0.04	0.04	-0.27	0.25	15
Middle East and North Africa	0.01	0.05	-0.16	0.13	6
Sub-Saharan Africa	0.08	0.09	-0.04	0.23	8

Panel B: Welfare Gains from Balanced Growth in China

	Mean	Median	Min	Max	Countries
China	10.60				
OECD	0.01	0.02	-0.01	0.04	22
East and South Asia	0.02	0.03	-0.04	0.09	12
East. Europe and Cent. Asia	0.00	0.01	-0.03	0.04	11
Latin America and Caribbean	0.00	0.00	-0.05	0.02	15
Middle East and North Africa	0.01	0.01	-0.02	0.02	6
Sub-Saharan Africa	0.01	0.01	-0.02	0.02	8

Panel C: Welfare Gains from Unbalanced Growth in China

	Mean	Median	Min	Max	Countries
China	8.59				
OECD	0.13	0.08	-0.09	0.59	22
East and South Asia	0.70	0.67	0.20	1.33	12
East. Europe and Cent. Asia	0.31	0.30	0.06	0.62	11
Latin America and Caribbean	0.39	0.41	0.05	0.99	15
Middle East and North Africa	0.51	0.59	0.11	0.68	6
Sub-Saharan Africa	0.28	0.26	-0.09	0.58	8

Notes: Units are in percentage points. This table reports the changes in welfare from three counterfactual scenarios in the model that includes Agriculture and Mining sectors in addition to manufacturing and non-tradeables. Panel A presents the welfare gains in the benchmark for 2000s, relative to the scenario in which China is in autarky. Panel B presents the changes in welfare under the counterfactual scenario that growth is balanced in China across sectors, relative to the benchmark. Panel C presents the changes in welfare under the counterfactual scenario of unbalanced growth in China, relative to the benchmark. The technological changes assumed under the counterfactual scenarios are described in detail in the text.

Table 6. Welfare Changes, Direct Measures of Productivity

Panel A: Welfare Gains from Trade with China

	Mean	Median	Min	Max	Countries
China	3.81				
OECD	0.15	0.14	-0.04	0.30	22
East and South Asia	0.22	0.18	-0.24	0.79	12
East. Europe and Cent. Asia	0.14	0.09	-0.13	0.71	11
Latin America and Caribbean	0.09	0.08	-0.28	0.38	15
Middle East and North Africa	0.11	0.13	0.02	0.22	6
Sub-Saharan Africa	0.07	0.05	-0.06	0.19	8

Panel B: Welfare Gains from Balanced Growth in China

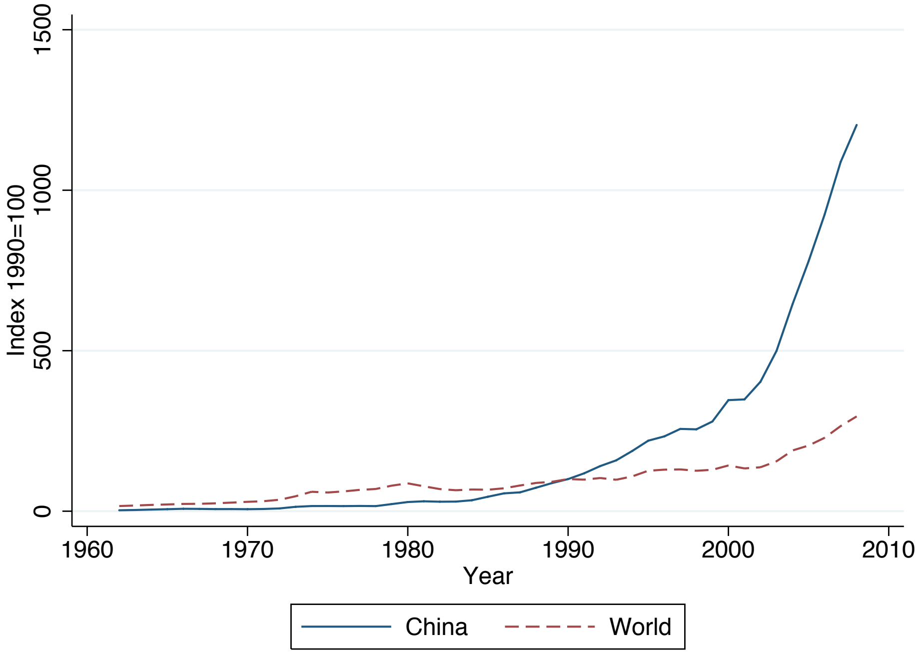
	Mean	Median	Min	Max	Countries
China	11.41				
OECD	0.01	0.02	-0.01	0.04	22
East and South Asia	0.02	0.03	-0.05	0.09	12
East. Europe and Cent. Asia	0.00	0.01	-0.02	0.05	11
Latin America and Caribbean	-0.01	0.00	-0.07	0.04	15
Middle East and North Africa	-0.01	-0.01	-0.06	0.02	6
Sub-Saharan Africa	0.00	0.00	-0.02	0.02	8

Panel C: Welfare Gains from Unbalanced Growth in China

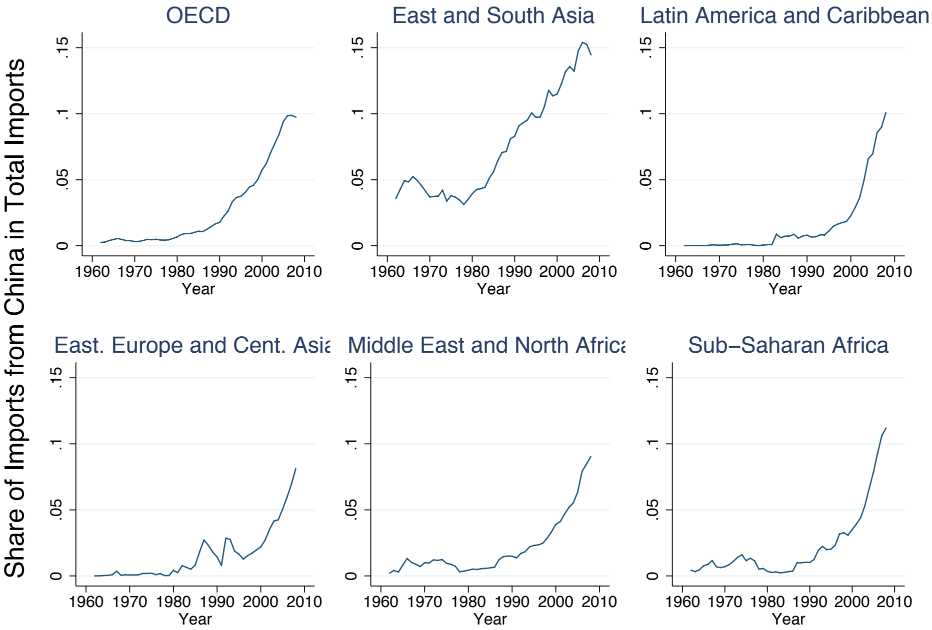
	Mean	Median	Min	Max	Countries
China	10.71				
OECD	0.17	0.14	-0.42	0.77	22
East and South Asia	0.86	0.73	0.21	1.68	12
East. Europe and Cent. Asia	0.43	0.41	-0.03	1.45	11
Latin America and Caribbean	0.50	0.44	0.08	1.68	15
Middle East and North Africa	0.45	0.50	0.19	0.77	6
Sub-Saharan Africa	0.23	0.21	-0.03	0.62	8

Notes: Units are in percentage points. This table reports the changes in welfare from three counterfactual scenarios. The productivity estimates used in this exercise are directly estimated using production data for 11 OECD countries. Panel A presents the welfare gains in the benchmark for 2000s, relative to the scenario in which China is in autarky. Panel B presents the changes in welfare under the counterfactual scenario that growth is balanced in China across sectors, relative to the benchmark. Panel C presents the changes in welfare under the counterfactual scenario of unbalanced growth in China, relative to the benchmark. The technological changes assumed under the counterfactual scenarios are described in detail in the text.

Figure 1. Chinese Trade, 1962-2007



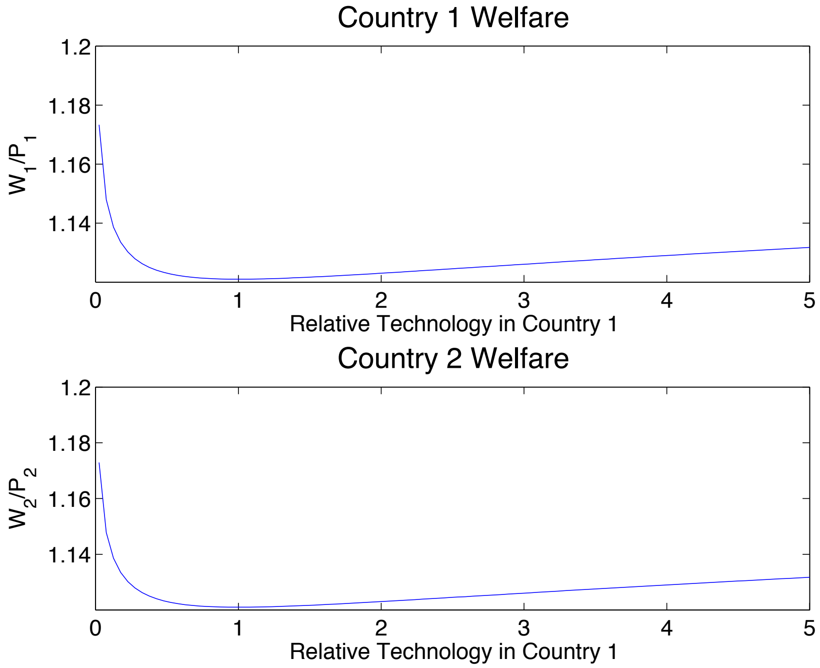
(a) China and World Trade, Index Number, 1990=100



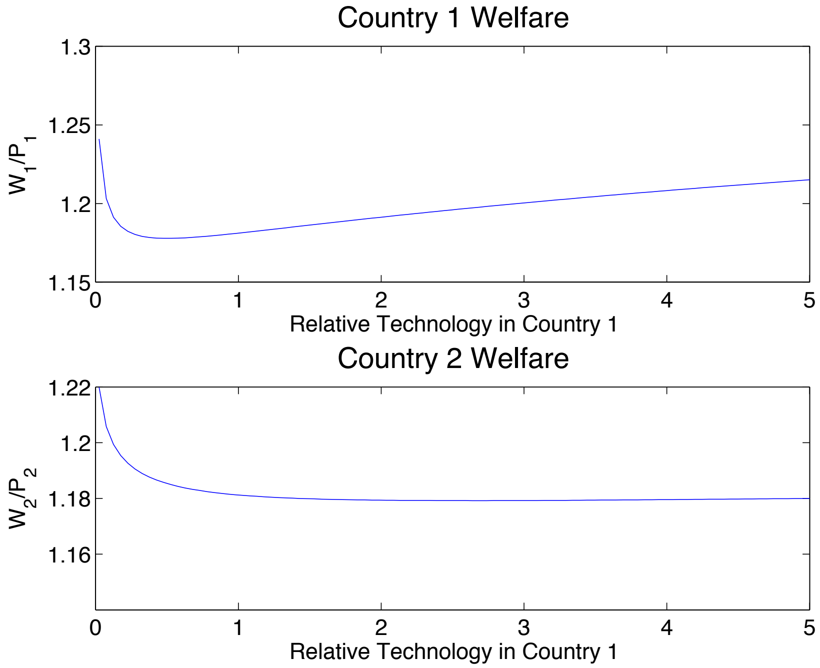
(b) Share of Imports from China in Total Imports, by Region

Notes: Figure 1(a) plots the total real (inflation-adjusted) exports from China (solid line), and the total real (inflation-adjusted) world exports (dashed line), for the period 1962-2007. Both series are normalized such that the 1990 value equals 100. Figure 1(b) plots the share of imports coming from China in the total imports of the major world regions, 1962-2007.

Figure 2. Welfare and Technological Similarity: A Numerical Example



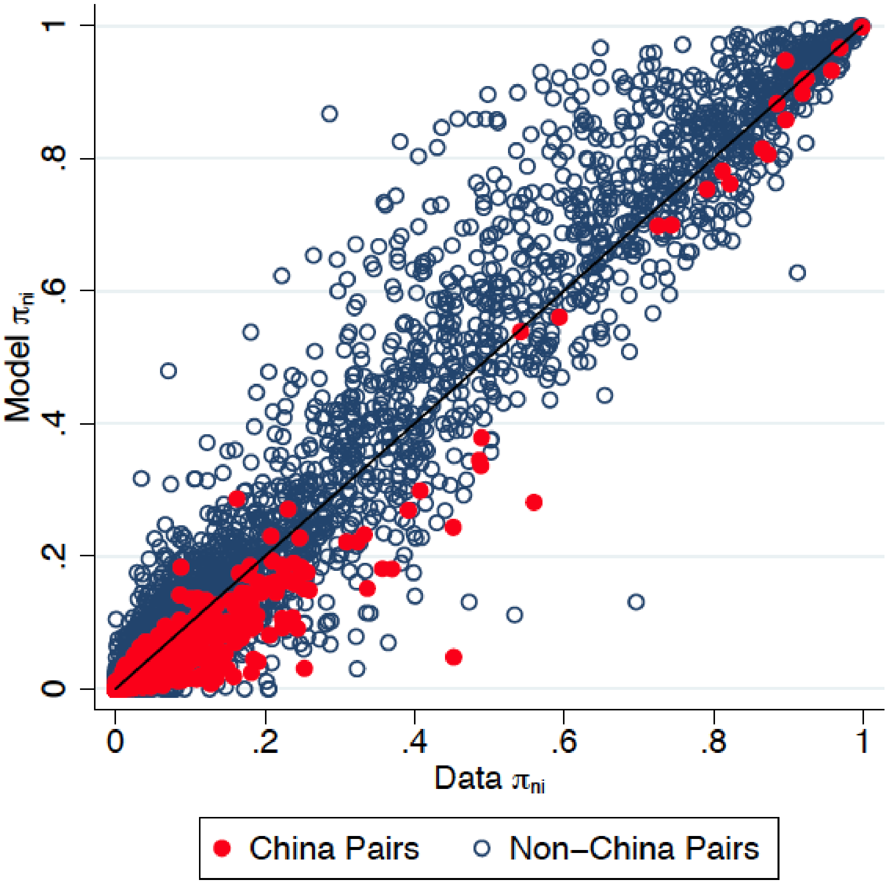
(a) 2-Country Model



(b) 3-Country Model

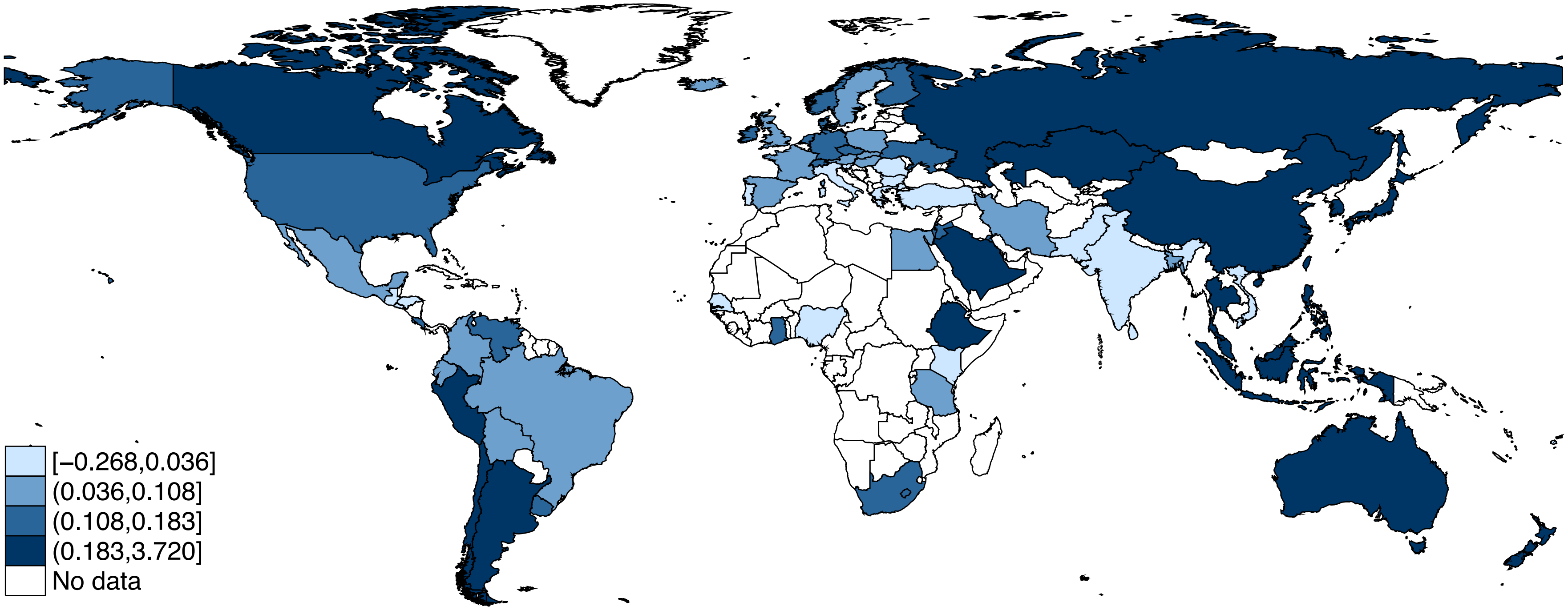
Notes: This Figure plots welfare in country 1 and country 2 as a function of T_1^A/T_1^B. The top panel considers a 2-country model, whereas the bottom panel the 3-country model. For country 2, $T_2^A/T_2^B = 1$, so countries 1 and 2 have the same technology when the value on the x-axis equals 1. Exact parameter values are decribed in Section 2.1.

Figure 3. Benchmark Model vs. Data: π_{ni}^{j} for China and the Rest of the Sample



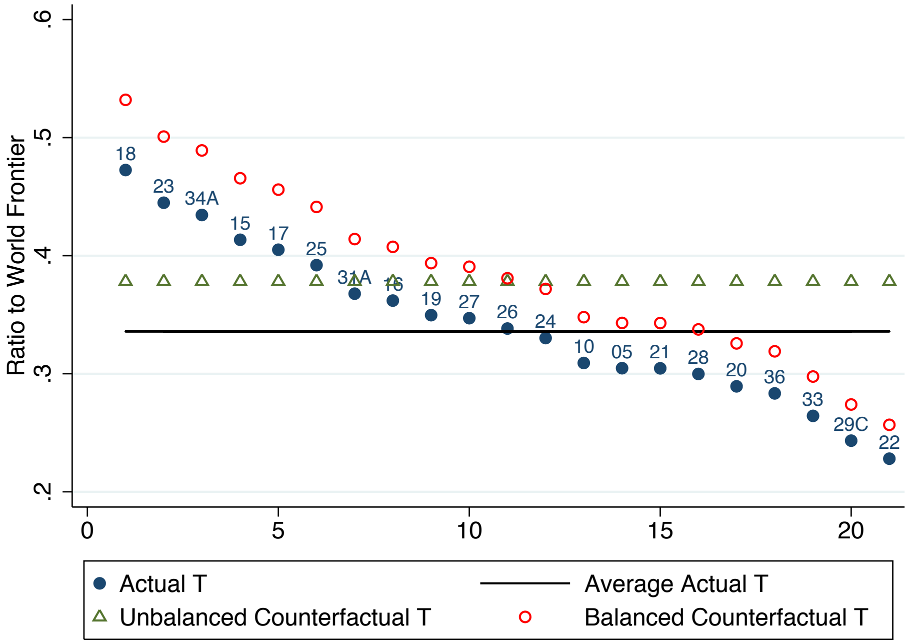
Notes: This figure displays the model-implied values of π_{ni}^{j} on the y-axis against the values of π_{ni}^{j} in the data on the x-axis. Solid red dots depict π_{ni}^{j} in which either n or i equals China. Hollow dots represent the non-China π_{ni}^{j}'s. The line through the points is the 45-degree line.

Figure 4. Gains from Trade with China



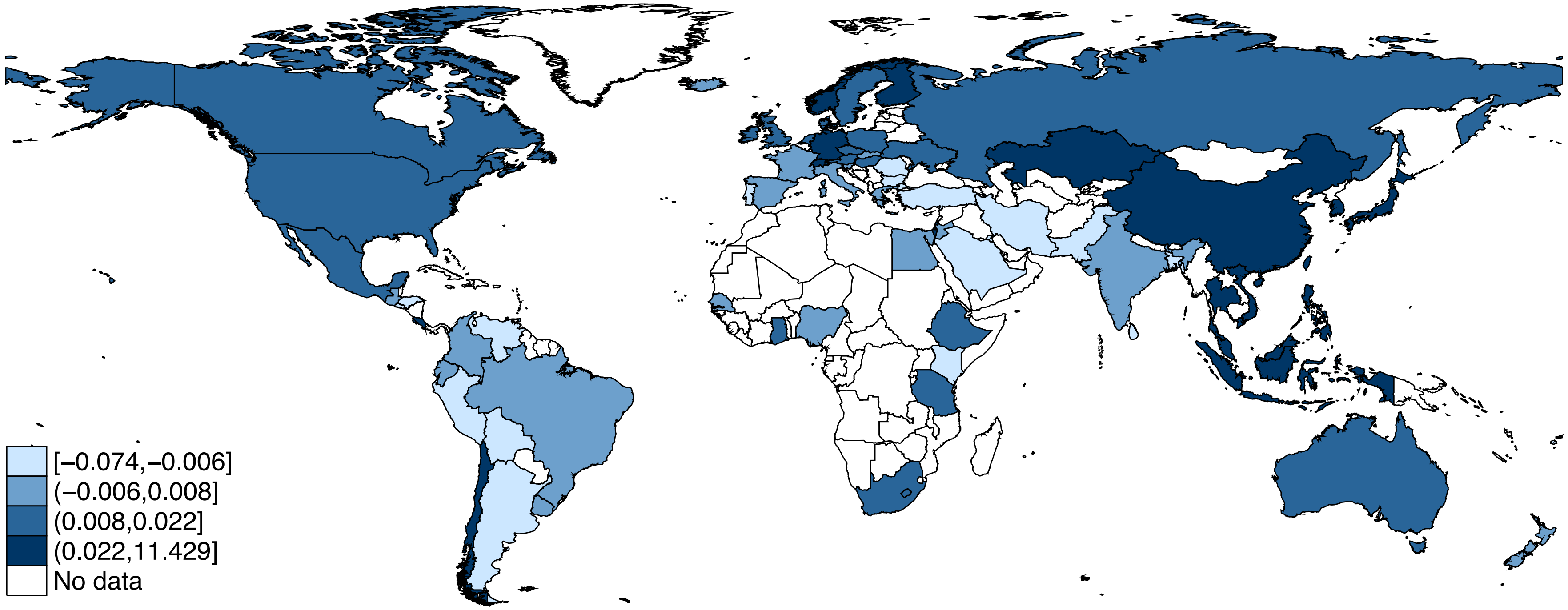
Notes: This figure displays the global distribution of gains from trade with China.

Figure 5. China: Actual and Counterfactual Productivities



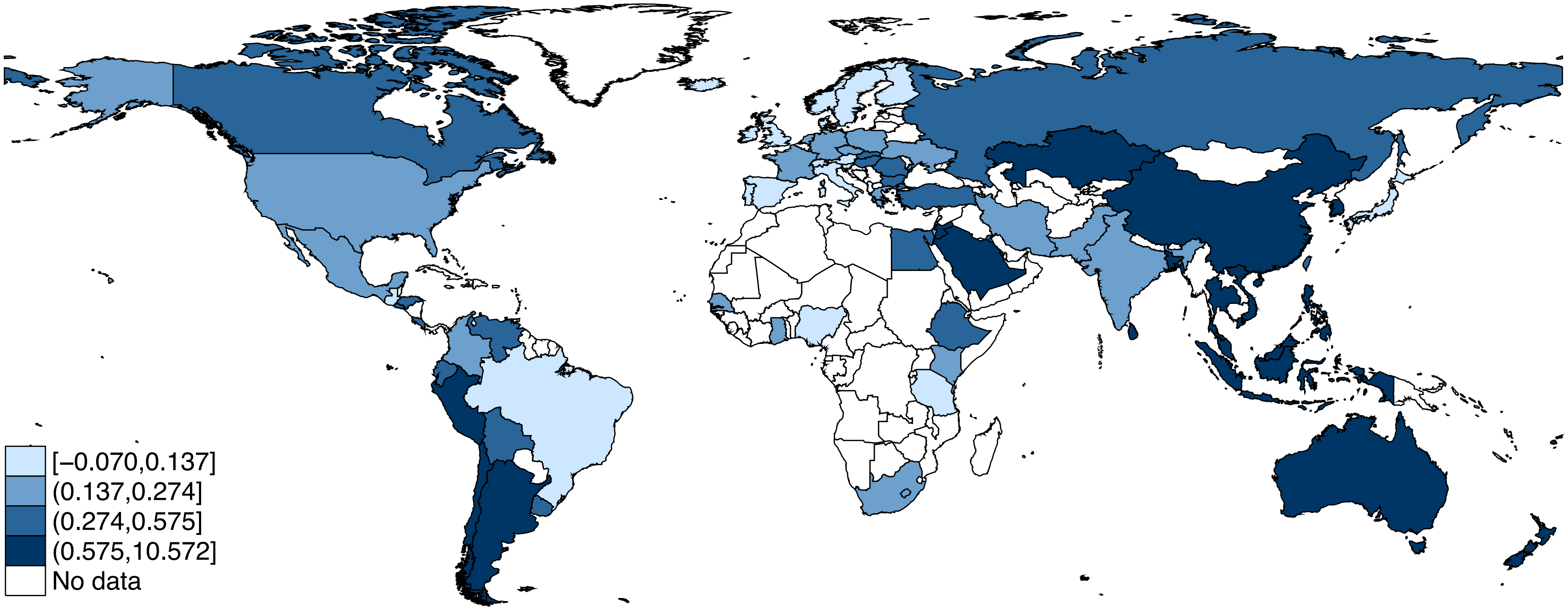
Notes: This figure displays the actual and counterfactual productivities in China, by sector. The key for sector labels is reported in Table A2.

Figure 6. Gains from the Balanced Counterfactual



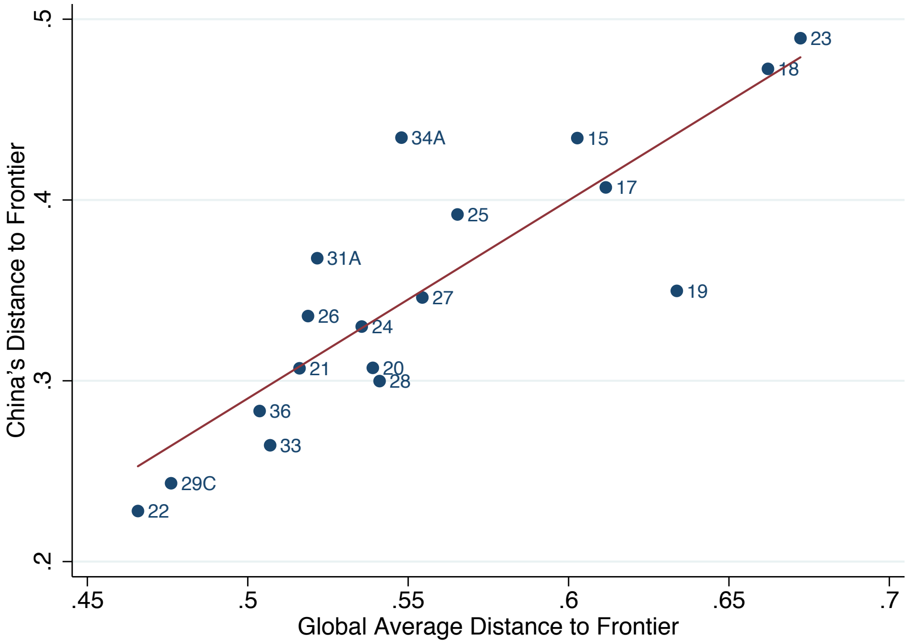
Notes: This figure displays the global distribution of gains from the balanced growth in China.

Figure 7. Gains from the Unbalanced Artefactual



Notes: This figure displays the global distribution of gains from the unbalanced growth in China.

Figure 8. China's and World Average Comparative Advantage



Notes: This figure displays the distance to the global frontier in each sector China (y-axis) against the simple average of the distance to frontier in that sector in the world excluding China.

Table A1. Country Coverage

OECD
Australia
Austria
Belgium-Luxembourg
Canada
Denmark
Finland
France
Germany
Greece
Iceland
Ireland
Italy
Japan
Netherlands
New Zealand
Norway
Portugal
Spain
Sweden
Switzerland
United Kingdom
United States

East and South Asia
Bangladesh
China
Fiji
India
Indonesia
Korea, Rep.
Malaysia
Pakistan
Philippines
Sri Lanka
Taiwan Province of China
Thailand
Vietnam

Latin America and Caribbean
Argentina
Bolivia
Brazil
Chile
Colombia
Costa Rica
Ecuador
El Salvador
Guatemala
Honduras
Mexico
Peru
Trinidad and Tobago
Uruguay
Venezuela, RB

Eastern Europe and Central Asia
Bulgaria
Czech Republic
Hungary
Kazakhstan
Poland
Romania
Russian Federation
Slovak Republic
Slovenia
Turkey
Ukraine

Middle East and North Africa
Egypt, Arab Rep.
Iran, Islamic Rep.
Israel
Jordan
Kuwait
Saudi Arabia

Sub-Saharan Africa
Ethiopia
Ghana
Kenya
Mauritius
Nigeria
Senegal
South Africa
Tanzania

Notes: This table reports the countries in the sample.

Table A2. Sectors

ISIC code	Sector Name	α_j	β_j	$\gamma_{J+1,j}$	ω_j
15	Food and Beverages	0.315	0.281	0.303	0.209
16	Tobacco Products	0.264	0.520	0.527	0.010
17	Textiles	0.467	0.371	0.295	0.025
18	Wearing Apparel, Fur	0.493	0.377	0.320	0.089
19	Leather, Leather Products, Footwear	0.485	0.359	0.330	0.014
20	Wood Products (Excl. Furniture)	0.452	0.372	0.288	0.009
21	Paper and Paper Products	0.366	0.344	0.407	0.012
22	Printing and Publishing	0.484	0.469	0.407	0.004
23	Coke, Refined Petroleum Products, Nuclear Fuel	0.244	0.243	0.246	0.092
24	Chemical and Chemical Products	0.308	0.373	0.479	0.008
25	Rubber and Plastics Products	0.385	0.387	0.350	0.014
26	Non-Metallic Mineral Products	0.365	0.459	0.499	0.071
27	Basic Metals	0.381	0.299	0.451	0.002
28	Fabricated Metal Products	0.448	0.398	0.364	0.012
29C	Office, Accounting, Computing, and Other Machinery	0.473	0.390	0.388	0.094
31A	Electrical Machinery, Communication Equipment	0.405	0.380	0.416	0.057
33	Medical, Precision, and Optical Instruments	0.456	0.428	0.441	0.036
34A	Transport Equipment	0.464	0.343	0.286	0.175
36	Furniture and Other Manufacturing	0.460	0.407	0.397	0.065
4A	Nontradeables	0.561	0.651	0.788	
	Mean	0.414	0.393	0.399	0.053
	Min	0.244	0.243	0.246	0.002
	Max	0.561	0.651	0.788	0.209

Notes: This table reports the sectors used in the analysis. The classification corresponds to the ISIC Revision 3 2-digit, aggregated further due to data availability. α_j is the value-added based labor intensity; β_j is the share of value added in total output; $\gamma_{J+1,j}$ is the share of nontradeable inputs in total intermediate inputs; ω_j is the taste parameter for tradeable sector j, estimated using the procedure described in Section B.2. Variable definitions and sources are described in detail in the text.