RESEARCH SEMINAR IN INTERNATIONAL ECONOMICS

Gerald R. Ford School of Public Policy
The University of Michigan
Ann Arbor, Michigan 48109-3091

Discussion Paper No. 625

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

**Julian di Giovanni**
International Monetary Fund and University of Toronto

**Andrei A. Levchenko**
University of Michigan and NBER

**Jing Zhang**
University of Michigan

February 14, 2012

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

Julian di Giovanni
International Monetary Fund
and University of Toronto

Andrei A. Levchenko
University of Michigan
and NBER

Jing Zhang
University of Michigan

February 14, 2012

**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. We 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 large majority of countries in the sample, including the developed ones, experience an order of magnitude *larger* welfare gains when China's productivity growth is biased towards its comparative disadvantage sectors. We demonstrate both analytically and quantitatively that this finding is driven by the inherently multilateral nature of world trade. As a separate but related exercise we quantify the worldwide welfare gains from China's trade integration.

*JEL Classifications*: F11, F43, O33, O47

*Keywords*: China, productivity growth, international trade

*We are grateful to Olivier Blanchard, Alan Deardorff, Juan Carlos Hallak, Chris House, Fernando Parro, Matthew Shapiro, Bob Staiger, Heiwai Tang, and to seminar participants at the University of Michigan, UC San Diego, Geneva Graduate Institute, Michigan State University, 2011 NBER Chinese Economy Working Group, 2011 Toronto RMM Conference, 2011 NBER IFM Fall Meetings, and 2011 NBER ITI Winter Meetings for helpful suggestions, and to Aaron Flaaen for superb research assistance. The views expressed in this paper are those of the authors and should not be attributed to the International Monetary Fund, its Executive Board, or its management. E-mail (URL): `JdiGiovanni@imf.org` (`http://julian.digiovanni.ca`), `alev@umich.edu` (`http://alevchenko.com`), `jzhang@umich.edu` (`http://www-personal.umich.edu/~jzhang/`).

# 1 Introduction

The pace of China's integration into world trade has been nothing short of breathtaking. Figure 1(a) plots 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, far outpacing the 3-fold expansion of overall global trade during this period. Equally 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. In developed countries, a common concern is that China's growth will be 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 a country can experience welfare losses when its trading partner becomes more similar in relative technology (Hicks 1953, Dornbusch, Fischer and Samuelson 1977, Ju and Yang 2009). Samuelson (2004) brought up this theoretical possibility for the growth of China in particular, and thus we refer to it as the *Samuelson conjecture*.

This paper explores both qualitatively and quantitatively the global welfare consequences of different productivity growth scenarios in China. We first show analytically that the intuitive two-country result does not survive in a setting with more than two countries. Greater similarity in China's relative sectoral technology to that of the United States *per se* does not necessarily lower United States' welfare. Rather, what drives welfare changes in the United States is how (dis)similar China becomes to an appropriately input-and-trade-cost-weighted average productivity of the United States and 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 both itself and its trading partners.

To derive these results, we set up a simple multi-sector, multi-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. The gains to the U.S. consumers from access to Chinese goods are lowest when the relative prices at which China can supply the U.S. market are most similar to the relative prices facing U.S. consumers in the absence of China. With only two countries, those relative prices are the U.S. autarky prices, and thus welfare is lowest when relative sectoral productivity is identical in the two countries. This is a variant of Samuelson (2004)'s result in a setting in which the sectors have an Eaton and Kortum (2002) structure. However, with more than two countries, the prices that would prevail in the United States absent China are determined by technology of both the United States and all of its trading partners. Thus, with more than two countries welfare in any individual country 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 the welfare of a particular country actually increases as it becomes more similar to China.

These analytical results underscore the need for a quantitative assessment. Since the welfare outcomes hinge on third country effects and the specifics of productivity distributions of all trading partners, two key inputs are necessary to reach reliable conclusions. The first is a quantitative framework that is global both in country coverage and in the nature of equilibrium adjustments. The second is a comprehensive set of sectoral productivity estimates for a large set of countries. Our analysis employs the 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 embed these productivity estimates within 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.

To evaluate the importance of China's sectoral pattern of growth for global welfare, we simulate two counterfactual growth scenarios starting from the present day. In the first, China's productivity growth rate in each sector is identical, and equal to the average productivity growth we estimate for China between the 1990s and the 2000s, which is 14% (i.e. an average of 1.32% per annum). In this "balanced" growth scenario, China's comparative advantage vis-à-vis the world remains unchanged. In the second scenario China's comparative disadvantage sectors grow disproportionally faster. Specifically, in the "unbalanced" counterfactual China's relative productivity differences with respect to the world frontier are eliminated, and China's productivity in every sector becomes a constant ratio of the world frontier. By design, 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 welfare gains (the percentage change in real consumption) 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. Importantly, the large majority of countries that become more similar to China in the unbalanced growth scenario – most prominently the U.S. and the rest of the OECD – still gain much more from unbalanced growth in China compared to balanced growth.

Thus, when evaluated quantitatively the welfare impact of China's growth on the rest of the world turns out to be 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 theoretically correct weights will differ from country to country because of trade costs). Closer inspection reveals that China's current productivity is relatively high 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 relative productivity 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.

As a related exercise of independent interest, we also 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 welfare gain from adding China to world trade is 0.13%. Dispersion across countries within each region turns out to be 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%). 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 a welfare change for the U.S. of 0.11%.

An often-voiced concern is that China's export basket is similar to that of many developing countries and emerging markets, and therefore its integration into global trade will reduce the demand for these countries' exports and potentially lower their welfare (Devlin, Estevaeordal and Rodríguez-Clare, eds 2005, Gallagher, Moreno-Brid and Porzecanski 2008). Our results indeed show that 9 out of 75 countries experience welfare losses, the largest for Honduras (−0.27%) and El Salvador (−0.21%). We correlate the variation in the gains from China's trade integration with some simple heuristic indicators, such as the similarity of a country's export pattern to China's export pattern. Countries that have similar export baskets to China do tend to gain less/lose more from China's trade integration. Most obviously, all of the countries that experience absolute losses have large Textile and Apparel sectors.

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, and highlights both analytically and quantitatively the first-order importance of third country effects. Rather than being retrospective as in Hsieh and Ossa (2011), our counterfactual growth scenarios are prospective, and designed as a transparent test of a particular hypothesis. 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. Our work is also related to 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. Our global general equilibrium approach complements recent micro-level studies of the impact of China on developed countries, such as Autor, Dorn and Hanson (2011) and Bloom, Draca and Van Reenen (2011).

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 performs a set of robustness checks on the quantitative results. Section 6 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 costless trade model such as the one employed by Samuelson (2004), is that both countries' welfare is minimized when they have the same relative sectoral productivity. This influential insight must be modified when we step out of this simple environment and consider more than two countries and costly trade. This section derives analytical results and builds intuition in a simplified version of the quantitative model of the next section.

In particular, we analyze a multi-sector Eaton and Kortum (2002, henceforth EK) model, proceeding in three steps. We first consider a version of the model in which relative wages in all countries are fixed, and sectoral productivity affects welfare only through the consumption price level. This simplification makes analytical results possible, and allows us to demonstrate most simply the role of third countries in how sectoral technological similarity between two trading partners affects welfare.

Second, we move to the fully general equilibrium case in which changes in relative sectoral productivity can also affect countries' relative wages. Because even the simplest multi-sector model with more than two countries does not admit an analytical solution in wages, we demonstrate the results using numerical examples. The essential message of the model is equally strong under endogenous wages. While with 2 countries, welfare is minimized when relative sectoral productivity is the same in the two countries, with 3 countries that is no longer generically the case.

The first two comparative statics are not strictly speaking identical to Samuelson (2004). The classic treatment of unbalanced productivity growth assumes that productivity in one sector rises, while in the other sector it remains unchanged. Thus, there is net productivity growth on average in the partner country. By contrast, our first two comparative statics exercises consider changes in relative sectoral productivity while keeping the average productivity across sectors constant. This approach allows for the cleanest statement of the main results, especially under fixed wages, and corresponds precisely to the comparison between our two counterfactuals, in which we also constrain average productivity to be the same. The third and final step of this section presents the numerical results for the classic experiment, in which one sector's productivity grows while the other sector's productivity remains constant, resulting in net average productivity growth in China. The essential result that adding a third country can reverse the sign of the welfare changes from the same productivity growth is equally true in this experiment.

## 2.1 The Environment

There are $N$ countries, indexed by $n$ and $i$. For concreteness, we can think of country 1 as China, and evaluate the impact of technological changes in country 1 on itself and country 2, which we can think of as the United States. There are multiple sectors, indexed by $j$. Production in each sector 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:

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

where $\varepsilon$ 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 cumulative distribution function

$$F_i^j(z) = e^{-T_i^j z^{-\theta}}. \tag{2}$$

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 $\theta$ captures dispersion, with larger values of $\theta$ implying smaller dispersion in draws.

Labor is the only factor of production, with country endowments given by $L_n$ and wages denoted by $w_n$. The production cost of one unit of good $q$ in sector $j$ and country $i$ is thus equal to $w_i/z_i^j(q)$. 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

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

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

$$p_n^j(q) = \min_{i=1,\ldots,N} \left\{ p_{ni}^j(q) \right\}. \tag{3}$$

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, it is heplful to define

$$\Phi_n^j = \sum_{i=1}^{N} T_i^j \left( w_i d_{ni}^j \right)^{-\theta}. \tag{4}$$

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 ($w_i$). It will also be higher if the trade costs that country $n$ faces in this sector are low. Standard steps (Eaton and Kortum 2002) lead to the familiar result that the price of good $j$ in country $n$ is simply

$$p_n^j = \Gamma \left(\Phi_n^j\right)^{-\frac{1}{\theta}}, \tag{5}$$

where $\Gamma = \left[\mathbf{\Gamma}\left(\frac{\theta+1-\varepsilon}{\theta}\right)\right]^{\frac{1}{1-\varepsilon}}$, with $\mathbf{\Gamma}$ the Gamma function.

Consumer utility is identical across countries and Cobb-Douglas with sector $j$ receiving expenditure share $\eta_j$. The consumption price level in country $n$ is then proportional to

$$P_n \propto \prod_j \left(p_n^j\right)^{\eta_j}, \tag{6}$$

and welfare (indirect utility) is given by the real income $w_n/P_n$.

## 2.2 Fixed Relative Wages

Consider first the case in which relative wages are fixed. In particular, suppose there are three sectors, $j = A, B, H$. Sectors $A$ and $B$ have the EK structure described above. As in Helpman, Melitz and Yeaple (2004) and Chaney (2008), good $H$ is homogeneous and can be costlessly traded between any two countries in the world. Let the price of $H$ be the numeraire. In country $n$, one worker can produce $w_n$ units of $H$, implying that the wage in $n$ is given by $w_n$. To obtain the cleanest results, let $A$ and $B$ enter symmetrically in the utility function:

$$U_n = \left(A_n^{\frac{1}{2}} B_n^{\frac{1}{2}}\right)^{\alpha} H_n^{1-\alpha}. \tag{7}$$

Throughout, we assume that $\alpha$ is sufficiently small so 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.

We are now ready to perform the main comparative static: 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: $\left(T_1^A T_1^B\right)^{\frac{1}{2}} = c$ for some constant $c$. The exercise informs us of the welfare impact of the different growth scenarios in China, when we hold its average growth rate fixed.

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

$$\left(\frac{T_1^A}{T_1^B}\right)_n = \frac{\sum_{i=2}^N T_i^A \left(\frac{w_i d_{ni}^A}{w_1 d_{n1}^A}\right)^{-\theta}}{\sum_{i=2}^N T_i^B \left(\frac{w_i d_{ni}^B}{w_1 d_{n1}^B}\right)^{-\theta}}. \tag{8}$$

*Proof.* See Appendix A. □

Lemma 1 says that the country 1 relative technology that minimizes welfare in country $n$ is *not the one* that makes country 1 most similar to country $n$. That is, generically country $n$'s welfare is not minimized when $T_1^A/T_1^B = T_n^A/T_n^B$. What matters instead is the relative-unit-cost-weighted average technologies *of all the other countries serving n (including itself).* 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. Two simple examples under frictionless trade can illustrate the point most clearly.

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

$$\left(\frac{T_1^A}{T_1^B}\right)_1 = \left(\frac{T_1^A}{T_1^B}\right)_2 = \frac{T_2^A}{T_2^B}.$$

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

$$\left(\frac{T_1^A}{T_1^B}\right)_1 = \left(\frac{T_1^A}{T_1^B}\right)_2 = \left(\frac{T_1^A}{T_1^B}\right)_3 = \frac{T_2^A w_2^{-\theta} + T_3^A w_3^{-\theta}}{T_2^B w_2^{-\theta} + T_3^B w_3^{-\theta}}. \tag{9}$$

In the simple 2-country example the familiar Samuelson (2004) result obtains: both countries are worst off when $T_1^A/T_1^B = T_2^A/T_2^B$. The third country effect is immediate in expression (9). From the perspective of an individual country, it is generically not the case that in any country, welfare is minimized when it is most similar to country 1. In the absence of unit production cost differences ($w_2 = w_3$), welfare is lowest when country 1 is most similar to the simple average productivity of countries other than country 1. When unit costs differ, what matters for welfare is the production-cost-weighted average, and the lower-wage countries will receive a higher weight in this productivity average. Furthermore, as revealed by equation (8), in the presence of trade costs the welfare-minimizing relative productivity is no longer the same for each country as is the case under frictionless trade.

By comparing the three-country expression in (9) to the $N$-country case in (8), 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. 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.

### 2.3 Endogenous Wages

The preceding results were derived under the assumption that there is a homogeneous costlessly 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 there 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* (7) *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* $\left(T_1^A T_1^B\right)^{\frac{1}{2}} = c$ *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. The key to this outcome is in the assumptions that the average productivity in both countries is constant as we vary $T_1^A/T_1^B$, the two countries have the same size, and trade is costless. As a result, the relative wages remain constant as the relative sectoral productivity in country 1 changes.

However, we cannot provide a corresponding analytical result with three countries. Thus, we compare the outcomes under two and three countries using the following numerical example. Country 2's productivity is the same in the two sectors: $T_2^A = T_2^B = 0.5$. Exactly as above, we vary country 1's relative productivity subject to the constraint that its geometric average equals

0.5 (the same as in country 2). We solve for wages and welfare in all countries numerically for each set of country 1's relative productivities.

In the two-country case the welfare of both countries as a function of $T_1^A/T_1^B$ is plotted in Figure 2(a). As proven analytically, both countries' welfare is at its lowest point when $T_1^A/T_1^B = T_2^A/T_2^B = 1$. Indeed, only one line is distinguishable in the picture: the welfare of the two countries is always the same. Next, we introduce a third country of the same size but with a comparative advantage in sector $B$: $T_3^A = 0.25$ and $T_3^B = 1$ (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 its relative technology. Notice that 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 2 actually increases slightly. On the other hand, as we approach 1 from the left, the welfare of country 1 rises. All in all, it is clear that country 1 becoming more similar to country 2 no longer implies that either country's welfare falls.

Because the analytical solutions are not available under endogenous wages, we further dissect the mechanisms behind these welfare results by considering two particular values of country 1's technology parameters, and discussing the behavior of price levels and relative wages. The top panel of Table 1 presents the changes in welfare, price levels, and relative wages when moving from $T_1^A/T_1^B = 2$ to $T_1^A/T_1^B = 1$.[1] Since $T_2^A/T_2^B = 1$, with this technological change country 1 becomes more similar (indeed identical) to country 2. The left column presents the welfare change in the 2-country world. As already shown, greater similarity between the two countries lowers welfare in both. This effect operates entirely through a rise in the consumption price level: the relative wage between the countries does not move. The right column instead presents the results in the 3-country world. The exact same change in technology in country 1 now raises welfare in country 2. Part of what is happening is that due to this change in productivity, $w_3/w_2$ falls. Thus it appears that in this numerical example, changes in comparative advantage of country 1 lead to a "multilateral relative wage effect:" country 2 gains in welfare over this range partly because technology changes in country 1 lead to cheaper imports from country 3.

Table 1 also reports the changes in sector $A$ net exports as a share of GDP in all the countries (by balanced trade, net exports of sector $A$ and $B$ sum to zero in each country). A greater absolute deviation from zero implies a greater degree of inter-industry trade. With 2 countries, as country 1 becomes more similar to country 2 in relative technology, inter-industry trade disappears entirely: country 2 goes from being a net importer in sector $A$ to balanced trade within the sector. With 3 countries, the same exact change in country 1's technology leads to an *increase* in inter-industry trade in country 2 (a rise in sector $A$ net exports to GDP from 0.05 to 0.11). Thus, just as greater

[1] Welfare in country $n$ is given by $w_n/P$, where $P$ is the consumption price level. Only one change in $P$ is reported because in this example trade is costless so the consumption price level is the same everywhere.

similarity between countries 1 and 2 need not lower country 2's welfare when there are more than 2 countries, greater similarity also need not reduce inter-industry trade.

Finally, we circle all the way back to the original Samuelson (2004) comparative static in which productivity grows in country 1's comparative disadvantage sector, but stays constant in its comparative advantage sector, implying net average productivity growth in country 1 as it becomes more similar to country 2. In this experiment, $T_1^A = 0.5$ throughout, while $T_1^B$ rises from 0.1 to 0.5. Thus, by design, the end point of this technological change is exactly the same as in the experiment above: countries 1 and 2 end up identical. The bottom panel of Table 1 reports the results. With two countries, it is still the case that as country 1 becomes more similar, country 2 sees absolute welfare losses. Here, the mechanics for the effect are somewhat distinct. While the consumption price level expressed relative to the numeraire – the wage of country 1 – falls, country 2's relative wage falls by more, precipitating welfare losses. By contrast, with three countries, the same change in country 1's technology leads to welfare gains for country 2. Again, part of what is happening is that $w_3/w_2$ falls, leading to cheaper imports from country 3. Inter-industry trade in country 2 also rises in this experiment.

We conclude from both the analytical results with fixed wages, and the numerical examples 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. Before moving on to the quantitative analysis, it is worth mentioning the relationship between our results and a common interpretation that the mechanism in the Samuelson (2004)-type result operates through the terms of trade. In the $2 \times 2$ first-generation Ricardian model, terms of trade are isomorphic to welfare. The easiest way to see this is to suppose that utility is Cobb-Douglas in two symmetric sectors $A$ and $B$, country 1 produces $A$ with productivity $z_{1A}$, while country 2 produces $B$ with productivity $z_{2B}$. Then, welfare – indirect utility – in country 2 is given by $w_2/P_2 = w_2/(w_2 z_{2B} w_1 z_{1A})^{1/2} = (w_2/w_1)^{1/2}(z_{2B} z_{1A})^{-1/2}$. The terms of trade, on the other hand, are equal to $(w_2/w_1)(z_{2B}/z_{1A})$. Thus, as long as $z_{2B}$ and $z_{1A}$ are unchanged – as was the case in the comparative static considered by Samuelson (2004) – the terms of trade are the same as welfare up to a constant. This equivalence may be helpful to build intuition but it breaks down in more sophisticated models such as EK, where it is no longer the case that the terms of trade are isomorphic to welfare. The conceptually correct object of analysis is indirect utility rather than the terms of trade.

## 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 nontradeable 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 sector-level productivities. 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

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

where $\xi_n$ denotes the Cobb-Douglas weight for the tradeable sector composite good, $\eta$ 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 quantitative model adopts CES preferences and allows $\omega_j$ – 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 equation (1), and the unit input requirement $\frac{1}{z_i^j(q)}$ for variety $q$ is drawn from the country- and sector-specific productivity distribution given by equation (2). Production uses labor, capital, 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 $\alpha_j$, and the share of value added in total output by $\beta_j$. 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

$p^j_{ni}(q) = \left(\frac{c^j_i}{z^j_i(q)}\right) d^j_{ni}$. The price $p^j_n(q)$ that country $n$ actually pays for good $q$ is given by equation (3).

### 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.[2]

The set of prices includes the wage rate $w_n$, the rental rate $r_n$, the sectoral prices $\{p^j_n\}^{J+1}_{j=1}$, and the aggregate price $P_n$ in each country $n$. The allocation rules include the capital and labor allocation across sectors $\{K^j_n, L^j_n\}^{J+1}_{j=1}$, final consumption demand $\{Y^j_n\}^{J+1}_{j=1}$, and total demand $\{Q^j_n\}^{J+1}_{j=1}$ (both final and intermediate goods) for each sector. The trade shares include the expenditure share $\pi^j_{ni}$ 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 equations (4) and (5), with the only difference that the expression for $\Phi^j_n$ in equation (4) features $c^j_i$ instead of $w_i$. The consumption price index in country $n$ is then

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

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

$$\sum_{j=1}^{J+1} p^j_n Y^j_n = w_n L_n + r_n K_n, \tag{12}$$

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

Given the set of prices $\{w_n, r_n, P_n, \{p^j_n\}^{J+1}_{j=1}\}^N_{n=1}$, we first characterize the optimal allocations from final demand. Consumers maximize utility (10) subject to the budget constraint (12). The

[2] The assumption of balanced trade is not crucial for the results. Section 5.1 implements a model with unbalanced trade following the approach of Dekle, Eaton and Kortum (2007, 2008), and shows that the conclusions are quite similar.

first order conditions associated with this optimization problem imply the following final demand:

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

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 $i$, $\pi_{ni}^j$, 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, for any $n$ the feasibility conditions for factors are given by

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

### 3.3 Welfare

Welfare in this framework corresponds to 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 total income divided by the price level. Since both goods and factor markets are competitive, total income equals the total returns to factors of production. Thus total welfare in a country is given by $(w_n L_n + r_n K_n)/P_n$, where the consumption price level $P_n$ comes from equation (11). Expressed in per-capita terms it becomes

$$\frac{w_n + r_n k_n}{P_n}, \tag{14}$$

where $k_n = K_n/L_n$ is capital per worker. This expression is the 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) moments of the productivity distributions $T_n^j$ and $\theta$; (ii) trade costs $d_{ni}^j$; (iii) production function parameters $\alpha_j$, $\beta_j$, $\gamma_{k,j}$, and $\varepsilon$; (iv) country factor endowments $L_n$ and $K_n$; and (v) preference parameters $\xi_n$, $\omega_j$, and $\eta$. We discuss the calibration of each in turn.

The structure of the model is used to estimate many of its parameters, most importantly 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 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, and using the resulting estimates along with data on input costs to back out underlying technology. 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 sector-level trade costs $d_{ni}^{j}$. 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 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 $\omega_j$ 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.

We assume that the dispersion parameter $\theta$ 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.[3] 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 $\theta$. Lower $\theta$ 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 (Levchenko and Zhang 2011) 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 $\theta = 4$.

The production function parameters $\alpha_j$ and $\beta_j$ are estimated using the UNIDO Industrial Statistics Database, which reports output, value added, employment, and wage bills at the roughly 2-digit ISIC Revision 3 level of disaggregation. To compute $\alpha_j$ 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 $\beta_j$, we take the median of value added

[3]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 $\theta$ across sectors. Caliendo and Parro (2010) use tariff data and triple differencing to estimate sector-level $\theta$. However, their approach may suffer from significant measurement error: at times the values of $\theta$ 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 $\theta$'s meet this restriction in every case. Our approach is thus conservative by being agnostic on this variation across sectors.

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 to the input coefficients $\gamma_{k,j}$. Note that we assume these to be the same in all countries.[4] In addition, we use the U.S. I-O matrix to obtain $\alpha_{J+1}$ and $\beta_{J+1}$ in the nontradeable sector, which cannot be obtained from UNIDO.[5] The elasticity of substitution between varieties within each tradeable sector, $\varepsilon$, is set to 4.

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 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.[6] 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 $\gamma$ is the average growth rate of investment in the first 10 years for which data are available.

The share of expenditure on traded goods, $\xi_n$ 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 $\xi_n$ are imputed based their level of development. We fit a simple linear relationship between $\xi_n$ and log PPP-adjusted per capita GDP from the Penn World Tables on the countries in the Yi and Zhang (2010) dataset. The fit of this simple bivariate linear relationship is quite good, with an $R^2$ of 0.55. For the remaining countries, we then set $\xi_n$ to the value predicted by this bivariate regression at their level of income. The taste parameters for tradeable sectors $\omega_j$ were estimated 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, as described in Appendix B. The elasticity of substitution between broad sectors within the tradeable bundle, $\eta$, is set to 2. Since these are very large product categories, it is sensible that

[4]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.

[5]The U.S. I-O matrix provides an alternative way of computing $\alpha_j$ and $\beta_j$. 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 $\alpha_j$'s and $\beta_j$'s across sectors than does UNIDO.

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

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.

### 3.5 Summary of the Estimates and Basic Patterns

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 75 countries used in the analysis, separating them into the major country groups and regions. Appendix Table A2 lists the 20 sectors along with the key parameter values for each sector: $\alpha_j$, $\beta_j$, the share of nontradeable inputs in total inputs $\gamma_{J+1,j}$, and the taste parameter $\omega_j$.

Countries differ markedly with respect to their trade relationship with China. The top panel of Table 2 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 productivities with China. Since average sectoral productivity scales with $(T^j_n)^{1/\theta}$ rather than $T^j_n$, and since we want to focus on differences in comparative rather than absolute advantage, we compute the correlations on the vectors of $(T^j_n)^{1/\theta}$ demeaned by each country's geometric average of those sectoral productivities.

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., the U.K, and Germany are in the bottom 10. Technological similarity varies a great deal as well, from correlations in excess of 0.9 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 Welfare Analysis

This section analyzes the global welfare impact of China's trade integration and various productivity growth scenarios. We proceed by first solving the model under the baseline values of all the estimated parameters, and present a number of checks on the model fit with respect to observed data. Then, we compute counterfactual welfare under two main sets of experiments. The first assumes that China is in autarky, and is intended to give a measure of the worldwide gains from trade with China. The second instead starts from today's equilibrium, and evaluates the implications of alternative patterns of China's productivity growth going forward. The model solution algorithm is described in Levchenko and Zhang (2011).

## 4.1 Model Fit

Table 3 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 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 $\alpha$ 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 3 reports the spending on domestically produced goods as a share of overall spending, $\pi_{nn}^j$. 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 $\pi_{nn}^j$'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 $\pi_{ni}^j$'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.

## 4.2 Gains from Trade with China

Panel A of Table 4 reports the gains from trade with China around the world. To compute these, we compare welfare of 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. 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%, with the mean of 0.13%.[7]

[7]This is the unweighted mean across the 74 countries. The population-weighted mean is very close at 0.12%. One may also be interested in comparing the gains from trade with China to other commonly calculated magnitudes

The gains for the rest of the world from China's trade integration are smaller than for China itself because these gains are relative to the counterfactual that preserves all the global trade relationships other than with China.

The countries gaining the most tend to be close to China geographically: Malaysia (0.80%), Kazakhstan (0.78%), and Taiwan, POC (0.63%). Of the top 10, 7 are in Asia, and the remaining three are Peru (0.39%), 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 4 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, countries that lose tend to be producers of Textiles and Apparel: Sri Lanka, Bulgaria, Vietnam, Mauritius, and Portugal are all among the losing countries.

Our multi-country multi-sector model does not admit an analytical expression for the magnitude of the gains from trade with China, as those gains depend on all the parameters characterizing the country and all of its trading partners. Nonetheless, we investigate whether the variation in the gains from trade with China across countries can be explained – in the least-squares sense – by three simple measures of countries' multilateral trade linkages with China. The first is the correlation between a country's export shares and China's export shares. This measure is meant to capture the extent to which China competes with the country in world product markets. A high correlation means that the country has a very similar export basket to China, and thus will compete with it head-to-head. All else equal, we would expect countries with a higher correlation to experience smaller gains from integration of China.

The second measure is the correlation between a country's export shares and China's import shares. This indicator is meant to reflect China's demand for the goods that the country exports. If the correlation is high, this means China imports a lot of the goods that the country exports, and thus all else equal the country's gains from introducing China into the world economy should be higher. Finally, the last indicator is the correlation between China's export shares and the country's import shares. It is meant to measure the extent to which a country values the goods produced by China: a high correlation means that the country imports a lot of the goods that China exports, which should lead to greater gains, *ceteris paribus*.

In our sample of countries, we regress gains from integration of China on these three heuristic indicators, controlling for the (log) average $d^j_{ni}$ between the country and China, and (log) country

in these types of models, such as the total gains from trade. Elsewhere (Levchenko and Zhang 2011) we report that the median gain from trade in this type of model among these 75 countries is 4.5%, with the range from 0.5% to 12.2%.

population.[8] The overall $R^2$ in this regression is 0.38. All three are significant and have the expected sign. It is important to emphasize that we do not seek any kind of causal interpretation in this exercise. Instead, the goal is only to find some simple and intuitive indicators that can account for some of the cross-country variation in gains. With that caveat, Figure 4 depicts the partial correlations between the three indicators of interest and the welfare gains from China's integration. The top panel shows that countries with similar export baskets to China tend to gain less. The relationship is highly significant, with a $t$-statistic of nearly 4. The middle panel illustrates that countries that export goods imported by China tend to benefit more. The relationship is once again highly significant, with a $t$-statistic of 4. Finally, the bottom panel shows that countries whose import basket is similar to China's export basket tend to gain more. The relationship is less strong than the other two, but still significant at the 5% level. We conclude from this exercise that the gains from trade with China are well explained by some simple heuristic measures of head-to-head competition with China in world markets, Chinese demand for a country's goods, and Chinese supply of the goods that a country imports.

### 4.3 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 conjecture put forward by Samuelson (2004) is about uneven technical change in China going forward: given the prevailing level of trade costs, global welfare will be affected differently depending on the pattern of sectoral productivity growth in China.

To evaluate Samuelson's conjecture, we simulate two productivity growth scenarios starting from today's values of China's $T_n^j$'s. Figure 5 depicts these two counterfactuals graphically. The solid dots, labelled by the sector number, represent the actual ratio of productivity to the global frontier in each sector in China in the 2000s. 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.[9]

The two counterfactual productivity scenarios are plotted in the figure. In the balanced growth

[8] All the results are unchanged if we use total country GDP instead of population as a measure of size, or if we use levels of $d_{ni}^j$ and population or GDP instead of logs.

[9] 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 $T$.

scenario, we assume that in each sector China's distance to the global frontier has grown by the same proportional rate of 14% (or 1.32% per annum), which is the observed growth of average $T_n^j$'s in China relative to the world frontier over a decade between the 1990s and the 2000s. The balanced counterfactual productivities are depicted by the hollow dots. In the unbalanced growth counterfactual, we assume that China's average productivity grows by the same 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.[10]

Panels B and C of Table 4 present the results for the balanced and the unbalanced counterfactuals, respectively. The results are striking. 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 are 0.01–0.02%, they are 0.12–0.17% in the unbalanced growth case. For other regions the difference is even larger: 0.23–0.84% at the mean in the unbalanced case, compared to essentially zero in the balanced case.[11] Figure 6(a) presents the contrast between the the welfare changes in the two counterfactual scenarios graphically, by plotting the welfare changes in each country in the balanced case on the y-axis against the welfare changes in the unbalanced case on the x-axis, along with a 45-degree line. While there is a great deal of variation in the welfare changes under the unbalanced case, the balanced counterfactual welfare changes are all very close to zero. In the large majority of cases, the observation is well below the 45-degree line: the country gains more in the unbalanced counterfactual.

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. We devote the rest of this section to exploring in detail the mechanisms behind this finding. The analytical section derives the multilateral similarity effect in a simple model with exogenously fixed wages. To isolate the channel emphasized by the analytical results, as an intermediate step we compute an alternative change in welfare under the assumption that $w$ and $r$ do not change from their baseline values.[12] Doing so allows us to focus on the changes in the price levels driven purely by changes in technology parameters rather than relative factor prices. Figure 6(b) presents a scatterplot of the welfare changes in the balanced counterfactual against the welfare changes in

[10] 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.

[11] Once again, while we report the simple means across countries throughout, population-weighted averages turn out to be very similar. In the sample of 74 countries, under the balanced counterfactual both unweighted and population-weighted mean welfare changes are 0.01%. In the unbalanced counterfactual, the unweighted mean welfare change is 0.42%, compared to the population-weighted average of 0.39%.

[12] Note that this of course does not involve a solution to the model, and these values do not correspond to any actual equilibrium. They are simply the hypothetical values of the change in the welfare expression (14) that obtain when $w_n$ and $r_n$ remain at their baseline values but $T_n^j$'s for China change to their counterfactual values.

the unbalanced one under fixed factor prices. The essential result that the world gains much more from unbalanced growth in China still obtains when factor prices do not change. The mechanism highlighted in the analytical section clearly contributes to generating the quantitative results.

As demonstrated in Section 2, what matters for an individual country is how China's technology compares not to itself, but to appropriately averaged world productivity. Figure 7 plots China's distance to the global frontier in each sector 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 world average distance to the frontier captures in a simple way how productive countries are on average in each sector. Higher values imply that the world as a whole is fairly productive in those sectors. Lower values imply that the world is fairly unproductive in those sectors.

The relationship is striking: China's comparative advantage sectors are also the ones in which other countries tend to be more productive. The simple correlation between these two variables is a remarkable 0.86.[13] 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, for example Medical, Precision, and Optical Instruments. Thus, it is more valuable for the world if China improves productivity in the globally scarce sectors.

Having isolated the impact of multilateral similarity by fixing $w$ and $r$, we next explore the role of endogenous factor prices. Figure 8 plots the welfare change under endogenous $w$ and $r$ on the y-axis against the welfare change under fixed $w$ and $r$ on the x-axis. Panel (a) reports the scatterplot for the balanced counterfactual, while panel (b) for the unbalanced counterfactual. Several things stand out about the role of endogenous factor prices. First, in all countries (of course, except China) and both counterfactuals, the gains are larger under fixed factor prices. This is not surprising: when factor prices are fixed, the technological improvement in China is not accompanied by rising factor costs, giving all the countries except China a benefit of better technology without the cost of higher Chinese wages and returns to capital.

Second, in the balanced counterfactual, from the perspective of almost every country, the benefit from better Chinese technology is essentially perfectly cancelled out by the higher factor prices in China. While there is some dispersion in how much countries gain under fixed factor prices (from zero to 2%), that dispersion disappears when factor prices are allowed to adjust. Countries that gain more from better Chinese technology when $w$ and $r$ are fixed also lose more from higher $w$ and $r$ in China, such that the net gains to them are nil.

Third, the counteracting movements in $w$ and $r$ are weaker in the unbalanced counterfactual. In contrast to the balanced growth case, it is not generally the case that the benefits to countries

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

from Chinese technological change are perfectly undone by movements in factor prices. That off-setting effect exists, but it is much less strong. There is a clear positive relationship between welfare gains under fixed factor prices and gains with flexible ones: countries that gain the most from changes in Chinese technology when factor prices are fixed continue to gain more when factor prices adjust. Thus, there is an additional effect of unbalanced growth that works through endogenous factor prices: compared to balanced growth, Chinese relative factor prices do not rise as much, and thus wipe out less of the gains to other countries from average productivity increases in China.

Next we explore technological similarity as a determinant of the gains from unbalanced growth in China. Figure 9(a) plots the welfare change in the unbalanced counterfactual against the simple change in the correlation of $T$'s between the country and China. In other words, unbalanced growth in China makes China less technologically similar to the countries below zero on the x-axis, and more similar to the countries above zero on the x-axis. The figure also depicts the OLS fit through the data. The relationship is negative and very significant: in this bivariate regression, the $R^2$ is 0.3 and the robust $t$-statistic on the change in technological similarity variable is 5. Countries that become more similar to China as a result of China's unbalanced growth thus tend to gain less from that growth. (Note that as shown in Figure 6(a), nearly all countries, including ones that become more similar to China, nonetheless gain more from unbalanced growth compared to the balanced one.)

There could be two explanations for this robust negative correlation. The first is that when China becomes more similar, demand for the country's output goes down, pushing down factor prices. As a result, the country would gain less. The second explanation is about how trade costs affect multilateral similarity. Equation (8) shows that in the presence of trade costs, $T_n^A$ and $T_n^B$ will get a larger weight in the right-hand side expression for country $n$. That is, when $d_{ni}^j$'s are substantial, country $n$'s similarity with China matters more than China's similarity to some other country $i$. The multilateral similarity effect is still of first-order importance in explaining the difference between the balanced and unbalanced growth outcomes. But when examining the variation in welfare gains across countries under the unbalanced counterfactual, the changes in bilateral technological similarity with China become relevant. To isolate the second effect, Figure 9(b) relates changes in technological similarity to welfare changes in the unbalanced counterfactual but this time under fixed factor prices. The strength of the negative relationship is the same: both the $R^2$ and the $t$-statistic on the coefficient are virtually identical to the plot with endogenous wages. We conclude that the negative relationship in Figure 9(a) is not due purely to movements in factor prices.

Finally, 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 result is driven by uneven consumption weights across sectors. It turns out that Chinese sectoral productivity today is strongly positively correlated with the sectoral taste parameter $\omega_j$, with a correlation of nearly 0.5. In a world characterized by high trade costs, a country would be better off with higher productivity in sectors with high taste parameters, all else equal. In the unbalanced counterfactual, China's productivity in high-consumption-weight sectors becomes relatively lower.

# 5 Robustness

This section presents a number of robustness checks on the main results. We describe the results of (i) incorporating trade imbalances; (ii) adding non-manufacturing production and trade; (iii) using directly measured productivities in countries where they are available; and (iv) considering alternative specifications of the unbalanced counterfactual.

## 5.1 Trade Imbalances

One aspect of Chinese trade that has receives a lot of attention is its large surpluses in goods trade. Trade surpluses result from dynamic decisions, whereas our model is static in nature. In the absence of a working model that explains trade imbalances, we incorporate the impact of trade imbalances 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. Specifically, the budget constraint (or the resource constraint) of the consumer is now

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

where $D_n$ is the trade surplus of country $n$. When $D_n$ is negative, 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 transfers 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 how trade imbalances affect our quantitative results, 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 deficits, 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 without a working model of endogenous determination of $D_n$'s, there is no clearly superior alternative.

Table 5 reports the results in a model with trade imbalances. Not surprisingly, China gains about half a percentage point less compared to the model without trade imbalances, since in the trade equilibrium it is transferring resources abroad, while the rest of the world gains more with trade imbalances. Note that we are not counting the direct impact of income transfers in the welfare calculations. Thus, larger gains from trade with China to the rest of the world compared to the baseline model 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 the country sending out the transfer (China), factor prices will be lower relative to the model in which trade is balanced. Consequently, countries receiving the transfers gain more from trade with China in the model with trade imbalances (Dornbusch et al. 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.

### 5.2 Non-Manufacturing Sectors

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 $\alpha_j$, $\beta_j$, 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 $\omega_j$'s. We apply the same value of $\theta$ to non-manufacturing sectors as we do to the rest of the model. Note that because of input-output linkages between all the sectors, adding non-manufacturing affects all of the productivity estimates, including those of the manufacturing sector. Thus, adding non-manufacturing involves re-running the entire estimation procedure for all sectors from scratch.

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 6. 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.

### 5.3 Directly Measured Productivity

One may also be concerned that the results may be unduly influenced by the way sectoral productivity is measured. 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. As detailed in Levchenko and Zhang (2011), 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 7 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.

### 5.4 Alternative Unbalanced Counterfactuals

Finally, we assess to what extent the quantitative results are driven by the particular form of the unbalanced counterfactual we impose. One concern is that to make the Chinese sectoral productivity a constant fraction of the world frontier in every sector while at the same time keeping the average productivity the same as in the balanced counterfactual, some sectors must actually experience an absolute reduction in productivity relative to the baseline. Thus, it is important to check that our main results are not driven by absolute productivity reductions. To that end, we implement two alternative unbalanced counterfactuals. The first, which we call "linear," keeps the productivity of the top sector constant, and "rotates up" the relative productivities of the other sectors around the top sector. That is, the productivity of the second-most productive sector is set equal to the productivity of the top sector times a constant $\delta < 1$. The productivity of the third-most productive sector is then the productivity of the top sector times $\delta^2$ and so on. This is done subject to the constraint that the resulting average counterfactual productivity is the same as in the main balanced and unbalanced counterfactuals.

The second alternative unbalanced counterfactual, called "no regress," imposes productivity that is a constant fraction of the world frontier in every sector, unless that would imply an absolute productivity reduction in a sector, in which case productivity in the sector is kept constant. Once again, counterfactual productivities in this scenario are set such that the resulting average productivity is the same as in all the other balanced and unbalanced counterfactuals. Importantly, in both of these alternative counterfactuals no sector experiences an absolute productivity reduction.

The last counterfactual we implement is one in which Chinese productivity relative to the world frontier in each sector is the same as in the U.S., up to a multiplicative constant. That is, once again we constrain average Chinese productivity to be the same as in all the other counterfactuals, but the relative productivity across the sectors to the global frontier is the same as in the U.S.. This counterfactual does imply technological regress in some sectors relative to the baseline. However, it allows us to check whether there is something special about productivity in China becoming the same as the world frontier, as opposed to another individual country.

The sectoral productivities under the three alternative counterfactuals are depicted graphically in Appendix Figure A1. The counterfactual welfare results are summarized in Appendix Table A3.

The top panel presents the summary statistics for the welfare impact under each counterfactual on all the countries other than China. For ease of comparison, the top two rows present the two main counterfactuals in the paper, the balanced and the unbalanced. The last three rows describe the alternative unbalanced counterfactuals. All three alternative unbalanced counterfactuals produce average welfare impacts that are an order of magnitude greater than the balanced case. The smallest impact, produced by the "linear" counterfactual, is still 10 times larger on average compared to the balanced counterfactual. The fact that the "linear" counterfactual implies smaller welfare changes is not surprising, since it is by far the closest to the balanced case.

The bottom panel of Appendix Table A3 presents the correlations between the welfare impacts of the all five counterfactuals we consider. What is remarkable is that while the welfare impact of the balanced counterfactual is virtually uncorrelated with any of the unbalanced counterfactuals, all of the unbalanced counterfactuals are extremely highly correlated amongst themselves, with correlation coefficients ranging from 0.94 to virtually 1. We conclude from this exercise that the essential contrast between the balanced and the unbalanced cases is robust to alternative ways of defining the unbalanced counterfactual. In all cases, the world benefits much more from unbalanced growth in China.

The counterfactual in which we set Chinese relative productivity to the U.S. values can be used to check how welfare in the U.S. changes when China becomes *exactly* like the U.S. in relative productivity. It turns out that the gains to the U.S. from China becoming exactly like it, 0.178%, are actually slightly higher than the 0.174% U.S. gains in the main unbalanced counterfactual. Though the difference is obviously small, the U.S. turns out to gain *more* from China becoming exactly like itself than from China becoming the same as the world frontier.

## 6 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.

This paper investigates 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 if 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:** Combining equations (5) and (6), welfare can be expressed as:

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

From (A.1) and the constraint that $\left(T_1^A T_1^B\right)^{\frac{1}{2}} = c$, welfare in country $n$ as a function of $T_1^A$ becomes

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

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 $\left(T_1^A T_1^B\right)^{\frac{1}{2}} = c$ leads to the expression for relative technologies (8). Q.E.D.

**Proof of Lemma 2:** Since trade is costless, the price levels are equalized across countries, at both sectoral and aggregate levels. Thus for $j \in \{A, B\}$

$$P_1^j = P_2^j = P^j = \left[T_1^j w_1^{-\theta} + T_2^j w_2^{-\theta}\right]^{-\frac{1}{\theta}},$$

and the consumption price level in both countries is given by

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

The welfare of country 1, $w_1/P$, then becomes

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

When we normalize $w_1 = 1$, set $T_2^A = T_2^B = 1$, and constrain $T_1^A T_1^B = 1$ as $T_1^A$ varies,

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

Similarly, welfare in country 2 is

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

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

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

If the wages are pinned down by another homogeneous sector, it is clear that the welfare-minimizing $T_1^A$ satisfies $T_1^A/T_1^B = 1$ – the same ratio of productivities as in country 2. Now consider the general equilibrium effect on wages. The derivatives of welfare with respect to $T_1^A$ are equal to

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

and

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

Setting the first order conditions to zero, we have

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

and

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

At first glance, the welfare-minimizing points do not appear to be the same for countries 1 and 2. However, we will show next that in equilibrium, $dw_2/dT_1^A = 0$ and $w_2 = 1$ for any $T_1^A$. Thus the welfare-minimizing relative productivity is the same for both countries and is such that $T_1^A/T_1^B = 1$.

Under frictionless trade, trade shares are given by

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

and

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

Therefore, the net exports in each tradable sector $j \in \{A, B\}$ are given by

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

where the symmetric Cobb-Douglas preferences across the two sectors lead to expenditure shares $X_2^s = X_1^s = \frac{1}{2}$ and we used the assumption that $L_1 = L_2 = 1$. The balanced-trade condition then implies

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

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

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

Clearly $w_2 = 1$ is the solution to the above trade balance condition 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 $\omega_j$

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 (2010), we include an exporter fixed effect $ex_i^j$. Finally, there is an error term $\nu_{ni}^j$. 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:

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

This equation is estimated for each tradeable sector $j = 1, ...J$. 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. 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 Trade Costs

The bilateral, directional, sector-level trade costs of shipping from country $i$ to country $n$ in sector $j$ are then computed based on the estimated coefficients as:

$$\ln \hat{d}_{ni}^j = \theta \hat{d}_k^j + \theta \hat{b}_{ni}^j + \theta \widehat{CU}_{ni}^j + \theta \widehat{RTA}_{ni}^j + \theta \widehat{ex}_i^j + \theta \widehat{\nu}_{ni}^j,$$

for an assumed value of $\theta$. Note that the estimate of the trade costs includes the residual from the gravity regression $\theta \widehat{\nu}_{ni}^j$. Thus, the trade costs computed as above will fit bilateral sectoral trade flows exactly, given the estimated fixed effects. Note also that the exporter component of the trade costs $\widehat{ex}_i^j$ is part of the exporter fixed effect. Since each country in the sample appears as both an exporter and an importer, the exporter and importer estimated fixed effects are combined to extract an estimate of $\theta \widehat{ex}_i^j$.

## B.3 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 $\omega_j$, 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

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

where $\Lambda^j$ 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 $\Lambda_{us}^j$, 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 $\Phi_n^j$'s, and update prices according to equation (5), 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 $\omega_j$'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.

## References

**Autor, David, David Dorn, and Gordon Hanson**, "The China Syndrome: Local Labor Market Effects of Import Competition in the United States," August 2011. mimeo, MIT, CEMFI, and UC San Diego.

**Bartelsman, Eric J. and Wayne Gray**, "The NBER Manufacturing Productivity Database," October 1996. NBER Technical Working Paper 205.

**Bernanke, Ben and Refet Gürkaynak**, "Is Growth Exogenous? Taking Mankiw, Romer, and Weil Seriously," *NBER Macroeconomics Annual*, 2001, *16*, 11–57.

**Berthelon, Matias and Caroline Freund**, "On the Conservation of Distance in International Trade," *Journal of International Economics*, July 2008, *75* (2), 310–320.

**Bloom, Nicholas, Mirko Draca, and John Van Reenen**, "Trade Induced Technical Change: The Impact of Chinese Imports on Innovation, Diffusion and Productivity," January 2011. NBER WP 16717.

**Burstein, Ariel and Jonathan Vogel**, "Globalization, Technology, and the Skill Premium," October 2009. mimeo, UCLA and Columbia University.

**Caliendo, Lorenzo and Fernando Parro**, "Estimates of the Trade and Welfare Effects of NAFTA," January 2010. mimeo, University of Chicago.

**Caselli, Francesco**, "Accounting for Cross-Country Income Differences," in Steven Durlauf Philippe Aghion, ed., *Handbook of Economic Growth*, Vol. 1, Elsevier-North Holland, 2005, chapter 9, pp. 679–741.

**Chaney, Thomas**, "Distorted Gravity: The Intensive and Extensive Margins of International Trade," *American Economic Review*, September 2008, *98* (4), 1707–1721.

**Costinot, Arnaud, Dave Donaldson, and Ivana Komunjer**, "What Goods Do Countries Trade? A Quantitative Exploration of Ricardo's Ideas," April 2011. Forthcoming *Review of Economic Studies*.

**Dekle, Robert, Jonathan Eaton, and Samuel Kortum**, "Unbalanced Trade," *American Economic Review: Papers and Proceedings*, May 2007, *97* (2), 351–355.

**___ , ___ , and ___** , "Global Rebalancing with Gravity: Measuring the Burden of Adjustment," *IMF Staff Papers*, 2008 2008, *55* (3), 511–540.

**Devlin, Robert, Antoni Estevaeordal, and Andrés Rodríguez-Clare, eds**, *The Emergence of China: Opportunities and Challenges for Latin America and the Caribbean*, Cambridge, Mass.: Harvard University Press, 2005.

**di Giovanni, Julian and Andrei A. Levchenko**, "Putting the Parts Together: Trade, Vertical Linkages, and Business Cycle Comovement," *American Economic Journal: Macroeconomics*, April 2010, *2* (2), 95–124.

**Do, Quy-Toan and Andrei A. Levchenko**, "Comparative Advantage, Demand for External Finance, and Financial Development," *Journal of Financial Economics*, December 2007, *86* (3).

**Dornbusch, Rudiger, Stanley Fischer, and Paul Samuelson**, "Comparative Advantage, Trade, and Payments in a Ricardian Model with a Continuum of Goods," *American Economic Review*, 1977, *67*, 823–39.

**Eaton, Jonathan and Samuel Kortum**, "Technology, Geography, and Trade," *Econometrica*, September 2002, *70* (5), 1741–1779.

——, ——, **Brent Neiman, and John Romalis**, "Trade and the Global Recession," July 2010. mimeo, Penn State University and University of Chicago.

**Finicelli, Andrea, Patrizio Pagano, and Massimo Sbracia**, "Ricardian Selection," October 2009a. Bank of Italy *Temi di Discussione* (Working Paper) No. 728.

**Francois, Joseph F. and Ganeshan Wignaraja**, "Economic Implications of Asian Integration," *Global Economy Journal*, 2008, *8* (3).

**Gallagher, Kevin P., Juan Carlos Moreno-Brid, and Roberto Porzecanski**, "The Dynamism of Mexican Exports: Lost in (Chinese) Translation?," *World Development*, 2008, *36* (8), 1365–1380.

**Ghosh, Madanmohan and Someshwar Rao**, "Chinese Accession to the WTO: Economic Implications for China, Other Asian and North American Economies," *Journal of Policy Modeling*, May-June 2010, *32* (3), 389–98.

**Hall, Robert and Charles Jones**, "Why Do Some Countries Produce So Much More Output per Worker then Others," *Quarterly Journal of Economics*, 1999, *114*, 83–116.

**Helpman, Elhanan, Marc J. Melitz, and Stephen R. Yeaple**, "Export versus FDI with Heterogeneous Firms," *American Economic Review*, March 2004, *94* (1), 300–316.

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

**Hsieh, Chang-Tai and Ralph Ossa**, "A global view of productivity growth in China," February 2011. NBER Working Paper No. 16778.

**Hummels, David, Jun Ishii, and Kei-Mu Yi**, "The Nature and Growth of Vertical Specialization in World Trade," *Journal of International Economics*, June 2001, *54*, 75–96.

**Ju, Jiandong and Xuebing Yang**, "Hicks theorem: Effects of technological improvement in the Ricardian model," *International Review of Economics and Finance*, 2009, *18*, 239–247.

**Levchenko, Andrei A. and Jing Zhang**, "The Evolution of Comparative Advantage: Measurement and Welfare Implications," February 2011. NBER Working Paper No. 16806.

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

**Shikher, Serge**, "Putting industries into the Eaton-Kortum model," July 2004. Forthcoming, *Journal of International Trade and Economic Development.*

——, "Accounting for International Trade," August 2005. mimeo, Suffolk University.

——, "Capital, technology, and specialization in the neoclassical model," *Journal of International Economics*, March 2011, *83* (2), 229–242.

**Simonovska, Ina and Michael E. Waugh**, "The Elasticity of Trade: Estimates and Evidence," December 2010. Mimeo, UC Davis and NYU.

**Tokarick, Stephen**, "The Implications of China's Pattern of Growth For the Rest of the World," August 2011. mimeo, International Monetary Fund.

**Waugh, Michael**, "International Trade and Income Differences," *American Economic Review*, December 2010, *100* (5), 2093–2124.

**Yi, Kei-Mu and Jing Zhang**, "Structural Change in an Open Economy," April 2010. Mimeo, Federal Reserve Bank of Philadelphia and University of Michigan.

**Table 1.** Numerical Examples: the Impact of Technological Change in Country 1

| | **2 countries** | **3 countries** |
|---|---|---|
| | *Constant Average Productivity in Country 1* | |
| $\Delta(w_1/P)$ | $-0.181$ | $-0.849$ |
| $\Delta(w_2/P)$ | $-0.181$ | $0.158$ |
| $\Delta(w_3/P)$ | | $-0.655$ |
| $\Delta(P)$ | $0.181$ | $0.856$ |
| $\Delta(w_1/w_2)$ | $0.000$ | $-1.006$ |
| $\Delta(w_3/w_2)$ | | $-0.812$ |
| $NX_1^A$ (before, after) | $(0.09, 0.00)$ | $(0.21, 0.11)$ |
| $NX_2^A$ (before, after) | $(-0.09, 0.00)$ | $(0.05, 0.11)$ |
| $NX_3^A$ (before, after) | | $(-0.26, -0.22)$ |
| | *Net Productivity Growth in Country 1* | |
| $\Delta(w_1/P)$ | $8.490$ | $6.195$ |
| $\Delta(w_2/P)$ | $-0.362$ | $0.455$ |
| $\Delta(w_3/P)$ | | $-1.114$ |
| $\Delta(P)$ | $-7.825$ | $-5.834$ |
| $\Delta(w_1/w_2)$ | $8.883$ | $5.714$ |
| $\Delta(w_3/w_2)$ | | $-1.562$ |
| $NX_1^A$ (before, after) | $(0.20, 0.00)$ | $(0.33, 0.11)$ |
| $NX_2^A$ (before, after) | $(-0.18, 0.00)$ | $(0.00, 0.11)$ |
| $NX_2^A$ (before, after) | | $(-0.30, -0.22)$ |

Notes: This table presents the proportional changes (in percent) in welfare, the consumption price level expressed relative to the numeraire (wage in country 1), and the changes in relative wages, that come from a change in relative technology in country 1. The rows labeled "$NX_n^A$ (before, after)" for $n = 1, 2, 3$ report the net exports from country $n$ in sector $A$ relative to country $n$'s GDP, before and after the technological change considered in the experiment. The top panel reports the changes due to moving from $T_1^A/T_1^B = 2$ to $T_1^A/T_1^B = 1$ while keeping $\left(T_1^A T_1^B\right)^{\frac{1}{2}} = 0.5$. The bottom panel reports the changes due to moving from $\left\{T_1^A = 0.5, T_1^B = 0.1\right\}$ to $\left\{T_1^A = 0.5, T_1^B = 0.5\right\}$. The other model parameters are described in the main text.

**Table 2.** Top and Bottom Trade Costs and Technological Similarity

| **Trade costs (average $d^j_{ni}$)** | | | |
|---|---|---|---|
| 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 ($d^j_{ni}$) with China in the top panel, and in terms of technological similarity, defined as the correlation between the $\left(T^j_n\right)^{1/\theta}$'s of each country with China in the bottom panel.

**Table 3.** 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* | |
| $\pi^j_{nn}$ | | | |
| | mean | 0.626 | 0.568 |
| | median | 0.690 | 0.611 |
| | corr(model, data) | *0.911* | |
| $\pi^j_{ni}$, $i \neq n$ | | | |
| | 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 4.** 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 5.** 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 6.** 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 nontradeables. 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 7.** 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

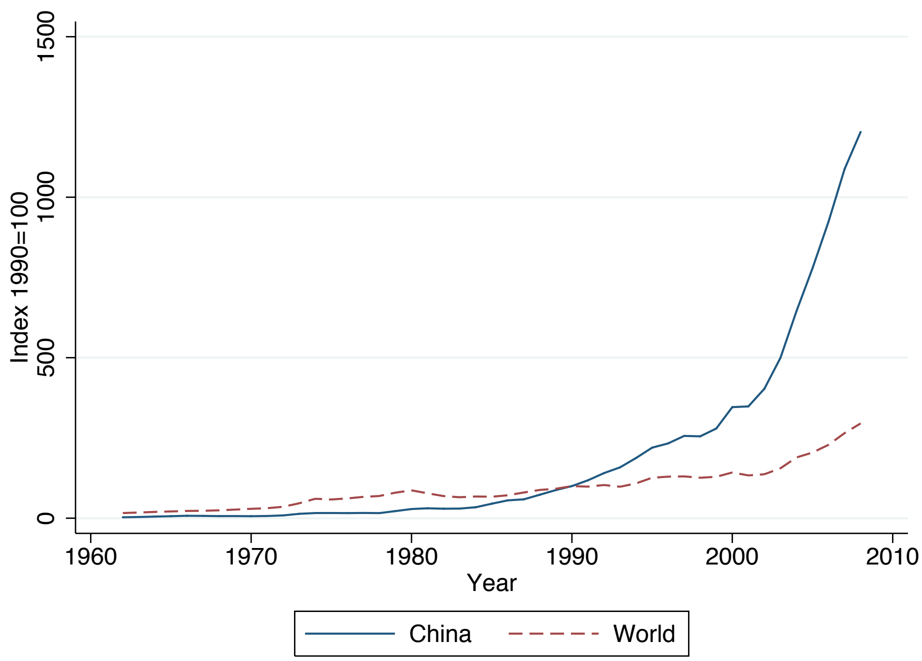
| | Mean | Median | Min | Max | Countries |
|---|---|---|---|---|---|
| China | 11.41 | | | | |
| OECD | 0.01 | 0.02 | -0.01 | 0.04 | 22 |
| East and South Asia | 0.02 | 0.03 | -0.05 | 0.09 | 12 |
| East. Europe and Cent. Asia | 0.00 | 0.01 | -0.02 | 0.05 | 11 |
| Latin America and Caribbean | -0.01 | 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

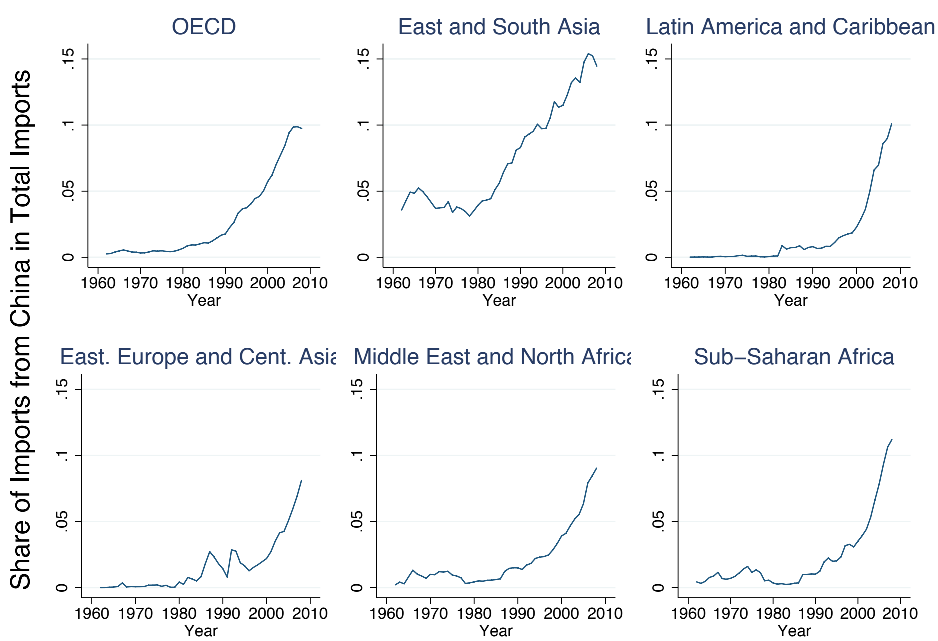
| | Mean | Median | Min | Max | Countries |
|---|---|---|---|---|---|
| China | 10.71 | | | | |
| OECD | 0.17 | 0.14 | -0.42 | 0.77 | 22 |
| East and South Asia | 0.86 | 0.73 | 0.21 | 1.68 | 12 |
| East. Europe and Cent. Asia | 0.43 | 0.41 | -0.03 | 1.45 | 11 |
| Latin America and Caribbean | 0.50 | 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



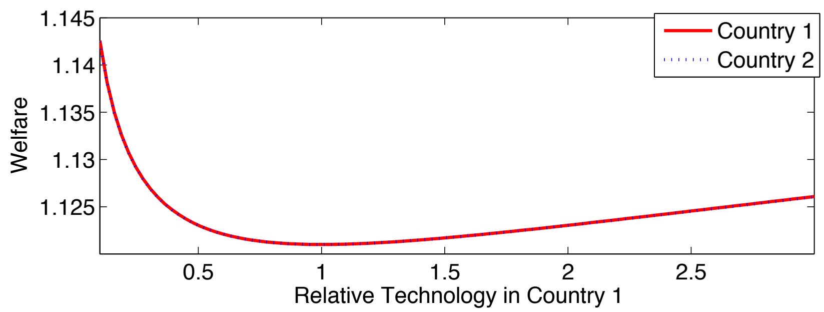

(a) China and World Trade, Index Number, 1990=100



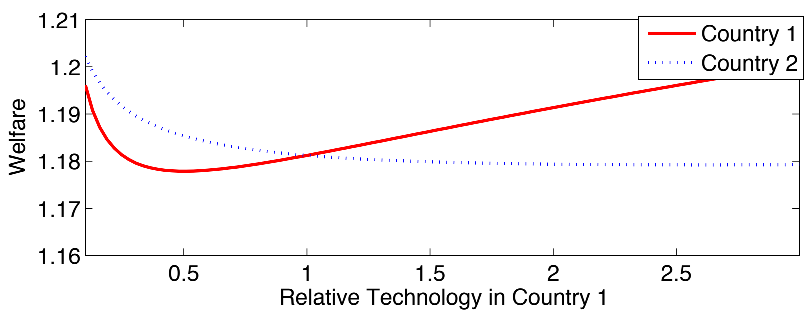

(b) Share of Imports from China in Total Imports, by Region

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



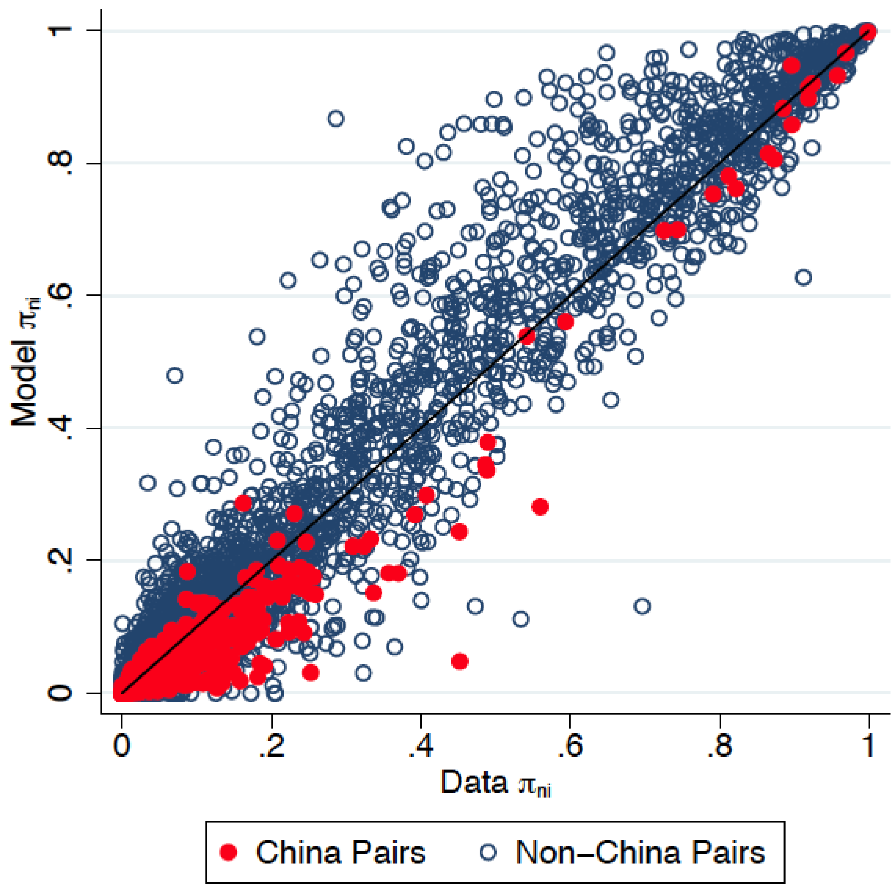

(a) 2-Country Model




(b) 3-Country Model

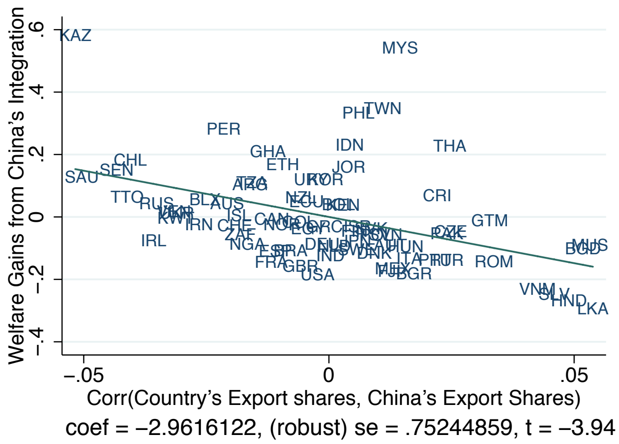
Notes: This figure plots welfare in country 1 and country 2 as a function of $T_1^A/T_1^B$. The top panel considers a 2-country model, whereas the bottom panel a 3-country model. For country 2, $T_2^A/T_2^B = 1$, so countries 1 and 2 have the same technology when the value on the x-axis equals 1. Exact parameter values are decribed in Section 2.3.

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

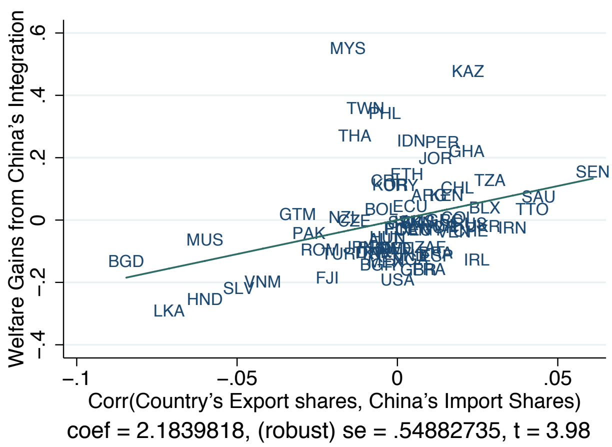



Notes: This figure displays the model-implied values of $\pi_{ni}^{j}$ on the y-axis against the values of $\pi_{ni}^{j}$ in the data on the x-axis. Solid red dots depict $\pi_{ni}^{j}$ in which either $n$ or $i$ equals China. Hollow dots represent the non-China $\pi_{ni}^{j}$'s. The line through the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

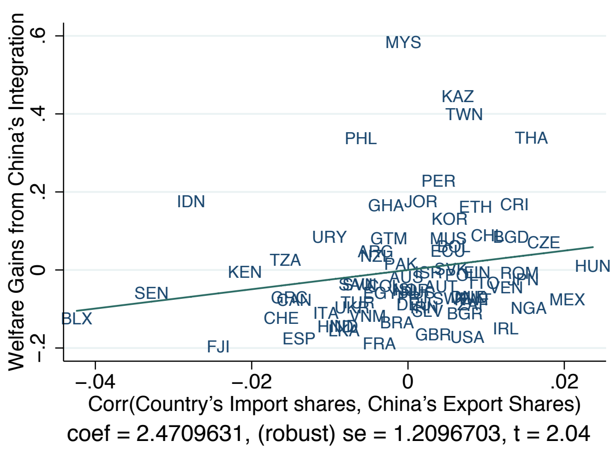
**Figure 4.** Gains from Trade with China




(a) Country's Export Pattern and China's Export Pattern



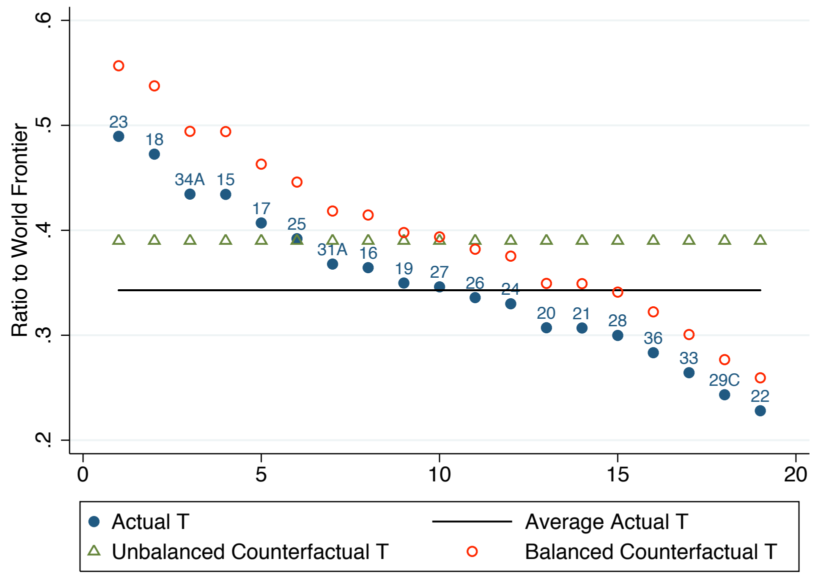

(b) Country's Export Pattern and China's Import Pattern




(c) Country's Import Pattern and China's Export Pattern

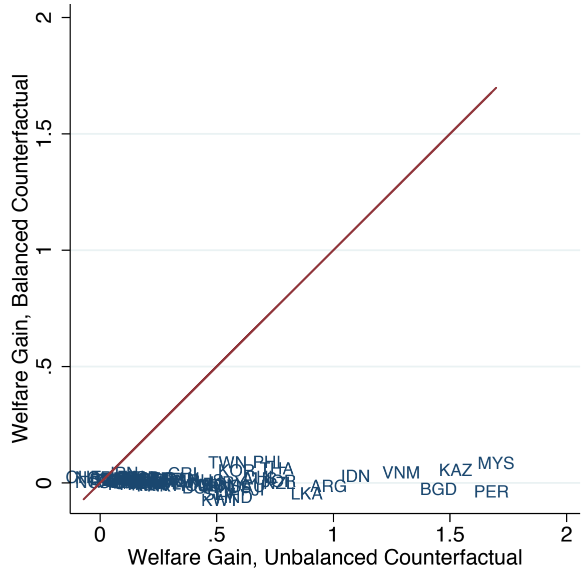
Notes: This figure reports the partial correlation plots between the gains from trade with China on the y-axis against the indicator on the x-axis. The units on the y-axis are percentage points. In each plot, the other two indicators, log average $d_{ni}^{j}$, and log population are the control variables. The $R^2$ of the regression that includes all variables is 0.38.

**Figure 5.** China: Actual and Counterfactual Productivities

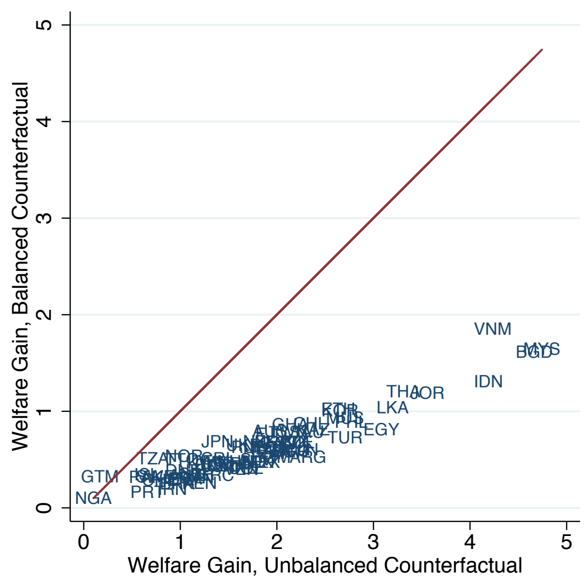



Notes: This figure displays the actual and counterfactual productivities in China, by sector. The key for sector labels is reported in Table A2. The formula for the balanced counterfactual $T$'s is: $\left(T_n^j\right)_{\text{balanced}} = \left(T_n^j\right)_{2000s} \times g_T$, where $g_T = \left(\prod_{k=1}^{J}(T_n^k/T_F^k)_{2000s}\right)^{\frac{1}{J}} / \left(\prod_{k=1}^{J}(T_n^k/T_F^k)_{1990s}\right)^{\frac{1}{J}}$ is the growth rate of the average productivity relative to world frontier between the 1990s and the 2000s, with $T_F^j$ the world frontier productivity in sector $j$, calculated as the geometric average of the top two values of $T_n^j$ in the world. The formula for the unbalanced counterfactual $T$'s is $\left(T_n^j\right)_{\text{unbalanced}} = \left(T_F^j\right)_{2000s} \times \left(\prod_{k=1}^{J}(T_n^k/T_F^k)_{2000s}\right)^{\frac{1}{J}} \times g_T$.

**Figure 6.** Welfare Gains in the Balanced and Unbalanced Counterfactuals



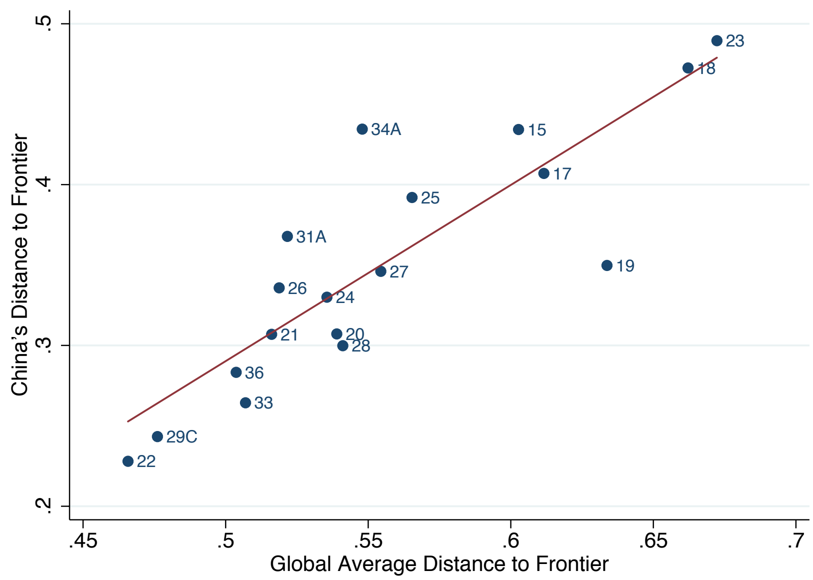

(a) Endogenous Factor Prices




(b) Fixed Factor Prices

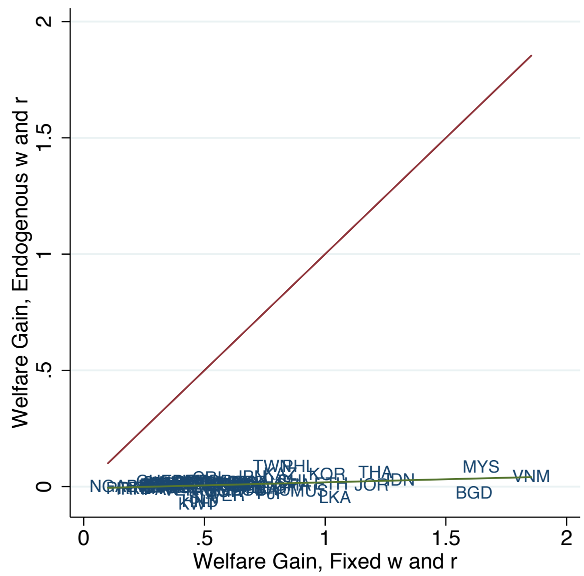
Notes: This figure displays the scatterplots of the welfare gains in the balanced counterfactual on the y-axis against the welfare gain in the unbalanced counterfactual on the x-axis. The units on all of the axes are percentage points. The top panel reports the results from the complete model in which the factor prices $w$ and $r$ adjust to clear goods and factor markets. The bottom panel reports the welfare changes under the assumption that $w$ and $r$ remain constant at their baseline values. The 45-degree line is added to both plots.

**Figure 7.** China's and World Average Comparative Advantage

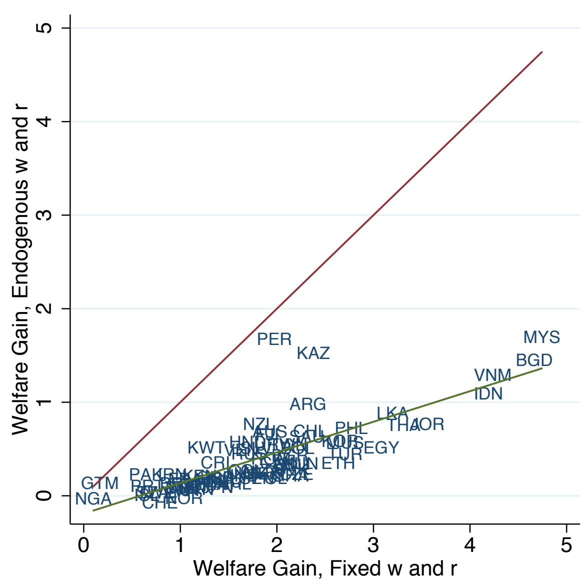



Notes: This figure displays the distance to the global frontier in each sector in China (y-axis) against the simple average of the distance to frontier in that sector in the world excluding China. The key for sector labels is reported in Table A2.

**Figure 8.** Welfare Gains Under Fixed and Endogenous Factor Prices



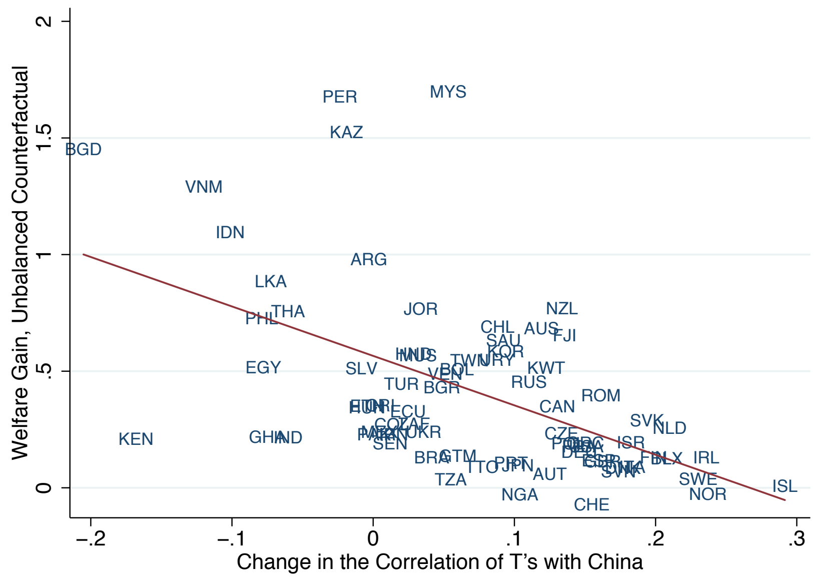

(a) Balanced Counterfactual



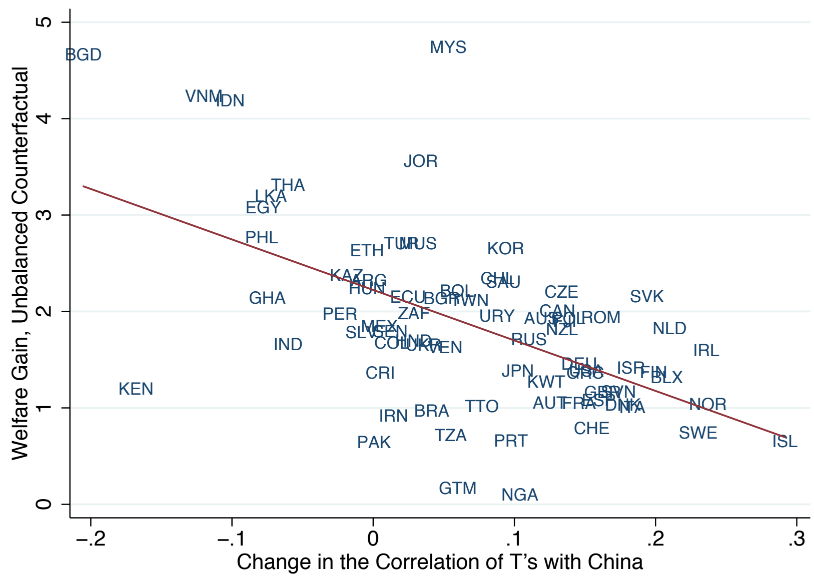

(b) Unbalanced Counterfactual

Notes: This figure displays the scatterplots of the welfare gains under fixed factor prices on the x-axis against the welfare gains under endogenous factor prices on the y-axis in the balanced counterfactual (top panel) and the unbalanced counterfactual (bottom panel). The units on all of the axes are percentage points. The 45-degree line is added to both plots.

**Figure 9.** Unbalanced Counterfactual Welfare Gains and Technological Similarity




(a) Endogenous Factor Prices




(b) Fixed Factor Prices

Notes: This figure displays the scatterplots of the welfare gains in the unbalanced counterfactual on the y-axis against the change in the technological between the country and China. The units on the y-axis are percentage points. Technological similarity is measured as the correlation coefficient of the T's between the country and China. On the y-axis is the simple change in that correlation coefficient. The top panel reports the results from the complete model in which the factor prices $w$ and $r$ adjust to clear goods and factor markets. The bottom panel reports the welfare changes under the assumption that $w$ and $r$ remain constant at their baseline values. The OLS best fit line is added to both plots.

**Table A1.** Country Coverage

| **OECD** | **Latin America and Caribbean** |
|---|---|
| Australia | Argentina |
| Austria | Bolivia |
| Belgium-Luxembourg | Brazil |
| Canada | Chile |
| Denmark | Colombia |
| Finland | Costa Rica |
| France | Ecuador |
| Germany | El Salvador |
| Greece | Guatemala |
| Iceland | Honduras |
| Ireland | Mexico |
| Italy | Peru |
| Japan | Trinidad and Tobago |
| Netherlands | Uruguay |
| New Zealand | Venezuela, RB |
| Norway | |
| Portugal | **Eastern Europe and Central Asia** |
| Spain | Bulgaria |
| Sweden | Czech Republic |
| Switzerland | Hungary |
| United Kingdom | Kazakhstan |
| United States | Poland |
| | Romania |
| **East and South Asia** | Russian Federation |
| Bangladesh | Slovak Republic |
| China | Slovenia |
| Fiji | Turkey |
| India | Ukraine |
| Indonesia | |
| Korea, Rep. | **Middle East and North Africa** |
| Malaysia | Egypt, Arab Rep. |
| Pakistan | Iran, Islamic Rep. |
| Philippines | Israel |
| Sri Lanka | Jordan |
| Taiwan Province of China | Kuwait |
| Thailand | Saudi Arabia |
| Vietnam | |
| | **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 | $\alpha_j$ | $\beta_j$ | $\gamma_{J+1,j}$ | $\omega_j$ |
|---|---|---|---|---|---|
| 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. $\alpha_j$ is the value-added based labor intensity; $\beta_j$ is the share of value added in total output; $\gamma_{J+1,j}$ is the share of nontradeable inputs in total intermediate inputs; $\omega_j$ is the taste parameter for tradeable sector $j$, estimated using the procedure described in Section B.3. Variable definitions and sources are described in detail in the text.

**Table A3.** Alternative Counterfactuals

Panel A: Summary Statistics

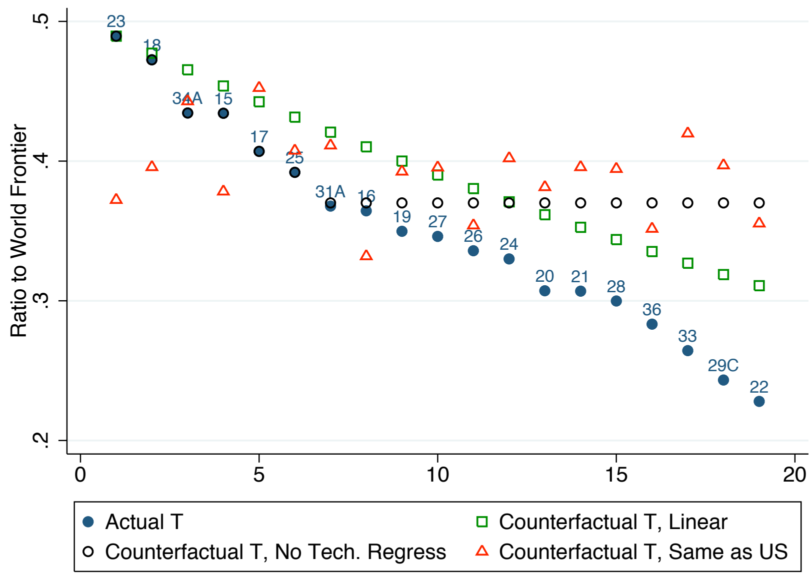
| | Mean | St. Dev. | Min | Max |
|---|---|---|---|---|
| Balanced | 0.01 | 0.03 | -0.07 | 0.09 |
| Unbalanced | 0.42 | 0.39 | -0.07 | 1.70 |
| Unbalanced – Linear | 0.11 | 0.12 | -0.02 | 0.56 |
| Unbalanced – No Regress | 0.28 | 0.28 | -0.06 | 1.28 |
| Unbalanced – U.S. Values | 0.43 | 0.42 | -0.10 | 1.89 |

Panel B: Correlations

| | Balanced | Unbalanced | Unbalanced – Linear | Unbalanced – No Regress |
|---|---|---|---|---|
| Balanced | 1.000 | | | |
| Unbalanced | 0.065 | 1.000 | | |
| Unbalanced – Linear | -0.157 | 0.946 | 1.000 | |
| Unbalanced – No Regress | 0.131 | 0.984 | 0.939 | 1.000 |
| Unbalanced – U.S. Values | 0.054 | 0.997 | 0.937 | 0.973 |

Notes: The top panel of this table reports the summary statistics for the different counterfactual scenarios for Chinese productivity growth. "Balanced" and "Unbalanced" are the two main counterfactuals in the paper, depicted graphically in Figure 5. "Unbalanced – Linear" is a counterfactual in which the most productive Chinese sector relative to the world frontier keeps the same productivity, while each successive sectors's productivity relative to the world frontier is lower by a fixed multiplicative constant. "Unbalanced – No Regress" is a counterfactual in which productivity in each Chinese sector becomes a constant ratio to the world frontier, unless that would imply an absolute reduction in sectoral productivity, in which case the productivity remains unchanged. "Unbalanced – U.S. Values" is a counterfactual in which Chinese productivity relative to the world frontier is the same as in the U.S. Across all counterfactuals, the geometric average sectoral productivity in Chinese sectors is kept the same. The counterfactuals are depicted graphically in Figure A1.

**Figure A1.** China: Alternative Counterfactual Productivities




Notes: This figure displays the sectoral productivities unter three alternative unbalanced counterfactual scenarios in China. The construction of the three scenarios is described in detail in the text. The key for sector labels is reported in Table A2.