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The Global Welfare Impact of China: Trade Integration and Technological Change[†]

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This paper evaluates the global welfare impact of China's trade integration and technological change in a multi-country quantitative Ricardian-Heckscher-Ohlin model. We simulate two alternative 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 experience significantly larger welfare gains when China's productivity growth is biased toward its comparative disadvantage sectors. This finding is driven by the inherently multilateral nature of world trade. (*JEL* F14, F43, 019, 033, 047, P24, P33)

The real value of Chinese exports has increased by a factor of 12 between 1990 and 2007, far outpacing the three-fold expansion of overall global trade during this period. Naturally, such rapid integration and growth leads to some anxiety. In developed countries, a common concern is that China's productivity growth will be biased toward 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; Samuelson 2004; Ju and Yang 2009).

This paper explores, both qualitatively and quantitatively, the global welfare consequences of different productivity growth scenarios in China. Analytically, we show that in a multi-country world, third-country effects are a key determinant of how a country's sectoral productivity changes affect welfare of all trading partners. For instance, 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

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an appropriately input-and-trade-cost-weighted average productivity of the United States and all other countries serving the United States market.

The 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 nontraded sector, the full specification of input-output linkages between the sectors, and both inter- and intra-industry trade, among others.

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 percent (i.e., an average of 1.32 percent 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.

Our main result is that the mean welfare gains (the percentage change in real consumption) from the unbalanced growth in China, 0.42 percent in our sample of 74 countries, are an order of magnitude larger than the mean gains in the balanced scenario, which are nearly nil at 0.01 percent. 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 United States and the rest of the OECD—still gain much more from unbalanced growth in China compared to balanced growth.

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. 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.

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 percent. 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 percent relative to autarky, the economies with the largest positive welfare changes are Malaysia (0.80 percent), Kazakhstan (0.78 percent), and Taiwan, POC (0.63 percent). Nine out of 75 countries experience welfare losses, the largest for Honduras (−0.27 percent) and El Salvador (−0.21 percent).

Our paper is related to recent quantitative welfare assessments of trade integration and technological change in multi-sector Ricardian models (Caliendo and Parro 2010; Shikher 2011; Costinot, Donaldson, and Komunjer 2012), as well as Computable General Equilibrium (CGE) assessments of China's trade integration (e.g., Francois and Wignaraja 2008; Ghosh and Rao 2010; Tokarick 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 four broad world regions, and Levchenko and Zhang (2011), who examine the long-run evolution of sectoral technology between the 1960s and the 2000s in a broad range of countries.

The main contribution of this paper relative to existing literature is to reveal the importance of third-country effects, which were not well understood either theoretically or quantitatively. From a theoretical standpoint, we show that any comparative statics exercise on the impact of parameter changes in one country on another country could be fundamentally misleading if carried out in a two-country setting. Our quantitative analysis then shows that these effects are strong enough to overturn an influential conjecture about the global impact of changes in China's comparative advantage. To demonstrate our result as transparently as possible, our counterfactual growth scenarios are prospective and designed as a test of a particular hypothesis, rather than retrospective as in Hsieh and Ossa (2011). Aside from the novel theoretical results on the third-country effects, this paper differs from Levchenko and Zhang (2011) in its set of substantive questions. Levchenko and Zhang (2011) documents the long-run evolution of comparative advantage and emphasizes how comparative advantage changes in individual countries affected their own welfare. This paper's focus is instead on the impact of changes in one country's comparative advantage on the rest of the world, with a particular emphasis on China. Our global general equilibrium approach complements recent micro-level studies of the impact of China on developed (e.g., Autor, Dorn, and Hanson 2013; Bloom, Draca, and Van Reenen 2011; Bitzer, Görg, and Schröder 2012) as well as developing (e.g., Hanson and Robertson 2010) countries.

The rest of the paper is organized as follows. Section I derives a set of analytical results using a simplified multi-sector N-country Eaton and Kortum (2002)—henceforth, EK—model of Ricardian trade. Section II lays out the quantitative framework and describes the details of the calibration. Section III examines the welfare implications of both the trade integration of China, and the hypothetical scenarios for Chinese growth. Section IV concludes. The online Appendix collects a number of additional results and exercises, including (i) further analytical results; (ii) details of model estimation; and (iii) an extensive set of robustness checks on the quantitative results.

I. 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. We analyze a multi-sector EK model, in which relative factor prices 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 transparently the role of third countries in how sectoral technological similarity between two trading partners affects welfare. Online Appendix A uses numerical examples to show that the results still hold when relative wages adjust in general equilibrium.

The objective of these simple analytical examples is not to use a two-sector, three-country setting to capture the precise story of China, the United States, and the rest of the world—that is the job of the quantitative exercise. Rather, the analytical examples serve to illustrate two main points. First, the exact same productivity change in country 1 can result in welfare changes of opposite signs in country 2, depending on whether there are two or three countries. Second, when there are more than two countries, it is easy to construct examples in which as relative productivity in country 1 becomes *more* similar to country 2, country 2's welfare actually rises. These two points help understand the mechanisms behind the quantitative results.

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

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

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

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 (EK) lead to the familiar result that the price of good j in country n is simply

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

where $\Gamma = \left[\text{Gamma}\left(\frac{\theta + 1 - \varepsilon}{\theta}\right)\right]^{\frac{1}{1-\varepsilon}}$.

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

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

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

B. *Main Analytical Result*

Consider 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 α 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, $(T_1^A T_1^B)^{\frac{1}{2}} = c$ 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* $(T_1^A/T_1^B)_n$, *which minimizes welfare in country n subject to the constraint* $(T_1^A T_1^B)_n^{\frac{1}{2}} = c$, *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 online 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.

II. 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 I, the complete quantitative framework features (i) full general equilibrium with endogenous relative factor prices; (ii) multiple factors of production—capital and labor; (iii) an explicit nontradeable sector; (iv) input-output linkages between all sectors; (v) 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 EK (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.

A. *Preferences and Technology*

There are $n, i = 1, \ldots, N$ 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 ξ_n denotes the Cobb-Douglas weight for the tradeable sector composite good, η is the elasticity of substitution between the tradeable sectors, Y_n^{J+1} is final consumption of the nontradeable-sector composite good, and Y_n^j is the final consumption of the composite good in tradeable sector j. Importantly, while Section I relied on Cobb-Douglas preferences and symmetry of the tradeable sectors in the utility function, the quantitative model adopts CES preferences and allows ω_j—the taste parameter for tradeable sector j—to differ across sectors.

As in Section I, 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 α_j, and the share of value added in total output by β_j. Both vary by sector. The shares of inputs from other sectors $\gamma_{k,j}$ vary by output industry j as well as input industry k. The production cost of one unit of good q in sector j and country n is thus equal to $c_i^j/z_i^j(q)$, and the price at which country i can serve market n is $p_{ni}^j(q) = \left(\frac{c_i^j}{z_i^j(q)}\right)d_{ni}^j$. The price $p_n^j(q)$ that country n actually pays for good q is given by equation (3).

B. *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; and (iv) trade shares ensure balanced trade for each country.[1]

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

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 Φ_n^j in equation (4) features c_i^j instead of w_i. The consumption price index in country n is then

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

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

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

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

[1] The assumption of balanced trade is not crucial for the results. Online Appendix Section C.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.

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

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

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

and

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

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

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

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,

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

Total expenditure in sector $j = 1, \ldots, J + 1$ 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 $\sum_{k=1}^{J}(1 - \beta_k)\gamma_{j,k}\left(\sum_{i=1}^{N}\pi_{in}^k p_i^k Q_i^k\right)$, and (iii) expenditure on the j's sector intermediate inputs in the domestic nontraded 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 $EX_n^j = \sum_{i=1}^{N}\mathbb{I}_{i \neq n}\pi_{in}^j p_i^j Q_i^j$, and its imports in sector j are given by $IM_n^j = \sum_{i=1}^{N}\mathbb{I}_{i \neq n}\pi_{ni}^j p_n^j Q_n^j$, where $\mathbb{I}_{i \neq n}$ 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

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

C. *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.

D. *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 θ; (ii) trade costs d_{ni}^j; (iii) production function parameters α_j, β_j, $\gamma_{k,j}$, and ε; (iv) country factor endowments L_n and K_n; and (v) preference parameters ξ_n, ω_j, and η. 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 United States) 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 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 United States. This procedure requires directly measuring TFP at the sectoral level using data on real output and inputs, and then correcting measured TFP for selection due to trade. The taste parameters for all tradeable sectors ω_j are also calibrated in this step. The third step is to calibrate the nontradeable technology for all countries using the first-order condition of the model and the relative prices of nontradeables observed in the data. The detailed procedures for all three steps are described in Levchenko and Zhang (2011) and reproduced in online Appendix B.

In the baseline analysis, we assume that the dispersion parameter θ does not vary across sectors and set $\theta = 8.28$, which is the preferred estimate of EK. Online Appendix Section C.4 checks the robustness of the results to this assumption in two ways. First, one may be concerned about how the results change under lower values of θ. A lower θ implies greater within-sector heterogeneity in the random productivity draws. Thus, trade flows become less sensitive to the costs of the input bundles (c_i^j), and the gains from intra-sectoral trade become larger relative to the gains from inter-sectoral trade. We repeat the analysis under the assumption that $\theta = 4$, a value that has been advocated by Simonovska and Waugh (2014). This value is at or near the bottom of the range that has been used in the literature. The main conclusions are robust to this alternative value of θ. Second, a number of studies have suggested that θ varies across sectors (see, e.g., Imbs and Méjean 2009; Caliendo and Parro 2010; Chen and Novy 2011). We repeat the analysis allowing θ to be sector-specific, with sectoral values of θ sourced from Caliendo and Parro (2010). Our results are robust to this alternative specification of θ.

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

The intermediate input coefficients $\gamma_{k,j}$ are obtained from the Direct Requirements Table for the United States. We use the 1997 Benchmark Detailed Make and Use

Tables (covering approximately 500 distinct sectors), as well as a concordance to the ISIC Revision 3 classification to build a Direct Requirements Table at the 2-digit ISIC level. The Direct Requirements Table gives the value of the intermediate input in row k required to produce one dollar of final output in column j. Thus, it is the direct counterpart to the input coefficients $\gamma_{k,j}$. Note that in the baseline analysis we assume these to be the same in all countries. Online Appendix Section C.5 establishes the robustness of the results to using country-specific I-O matrices instead. In addition, we use the US I-O matrix to obtain α_{J+1} and β_{J+1} in the nontradeable sector, which cannot be obtained from UNIDO.[2] The elasticity of substitution between varieties within each tradeable sector, ε, is set to 4 (as is well known, in the EK model this elasticity plays no role, entering only the constant Γ).

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.[3] The total capital is calculated using the perpetual inventory method that assumes a depreciation rate of 6 percent: $K_{n,t} = (1 - 0.06)K_{n,t-1} + I_{n,t}$, where $I_{n,t}$ is total investment in country n in period t. For most countries, investment data start in 1950, and the initial value of K_n is set equal to $I_{n,0}/(\gamma + 0.06)$, where γ is the average growth rate of investment in the first 10 years for which data are available.

The share of expenditure on traded goods, ξ_n in each country is sourced from Yi and Zhang (2013), who compile this information for 36 developed and developing countries. For countries unavailable in the Yi and Zhang data, values of ξ_n are imputed based on their level of development. We fit a simple linear relationship between ξ_n and log PPP-adjusted per capita GDP from the Penn World Tables on the countries in the Yi and Zhang (2013) 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 ξ_n to the value predicted by this bivariate regression at their level of income. The taste parameters for tradeable sectors ω_j were estimated by combining the model structure above with data on final consumption expenditure shares in the United States sourced from the US Input-Output matrix, as described in online Appendix B. The elasticity of substitution between broad sectors within the tradeable bundle, η, is set to 2. Since these are very large product categories, it is sensible that this elasticity would be relatively low. It is higher, however, than the elasticity of substitution between tradeable and nontradeable goods, which is set to 1 by the Cobb-Douglas assumption.

E. *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.

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

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

Table 1—Top and Bottom Trade Costs and Technological Similarity

Panel A. Trade costs (average d^j_{ni})

Top ten lowest		Top ten 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

Panel B. Technological similarity

Top ten highest		Top ten 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 ten 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 $(T^j_n)^{1/\theta}$s of each country with China in the bottom panel.

Appendix Table A1 lists the 74 countries (besides China) 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: α_j, β_j, the share of nontradeable inputs in total inputs $\gamma_{J+1,j}$, and the taste parameter ω_j. In the baseline analysis tradeables are comprised of manufacturing sectors. Online Appendix Section C.3 presents the results of augmenting the model to include nonmanufacturing tradeables (agriculture and mining) and shows that all of the results are robust.

Countries differ markedly with respect to their trade relationship with China. The top panel of Table 1 lists the top ten and bottom ten countries in terms of the average trade costs (d^j_{ni}) with China, while the bottom panel reports the top ten and bottom ten 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 the 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 United States, the United Kingdom, and Germany are in the bottom ten. 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

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

	Model		Data
Panel A. Wages			
Mean	0.369		0.333
Median	0.133		0.145
corr(model, data)		*0.993*	
Panel B. Return to capital			
Mean	0.850		0.919
Median	0.718		0.698
corr(model, data)		*0.955*	
Panel C. π^j_{nn}			
Mean	0.626		0.568
Median	0.690		0.611
corr(model, data)		*0.911*	
Panel D. $\pi^j_{ni}, i \neq n$			
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 United States (panel A); return to capital relative to the United States (panel B), share of domestically produced goods in overall spending (panel C), and share of goods from country *i* in overall spending (panel D) in the model and in the data.

that the regional component is not as prevalent here, with both most similar and most different countries drawn from different parts of the world.

III. 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).

A. *Model Fit*

Table 2 compares the wages, returns to capital, and the trade shares in the baseline model solution and in the data. Panel A 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. Panel B 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^j_n's and impute r_n from an aggregate factor market clearing condition: $r_n/w_n = (1 - \alpha)L_n/(\alpha K_n)$, where α is the aggregate share of labor in GDP, assumed

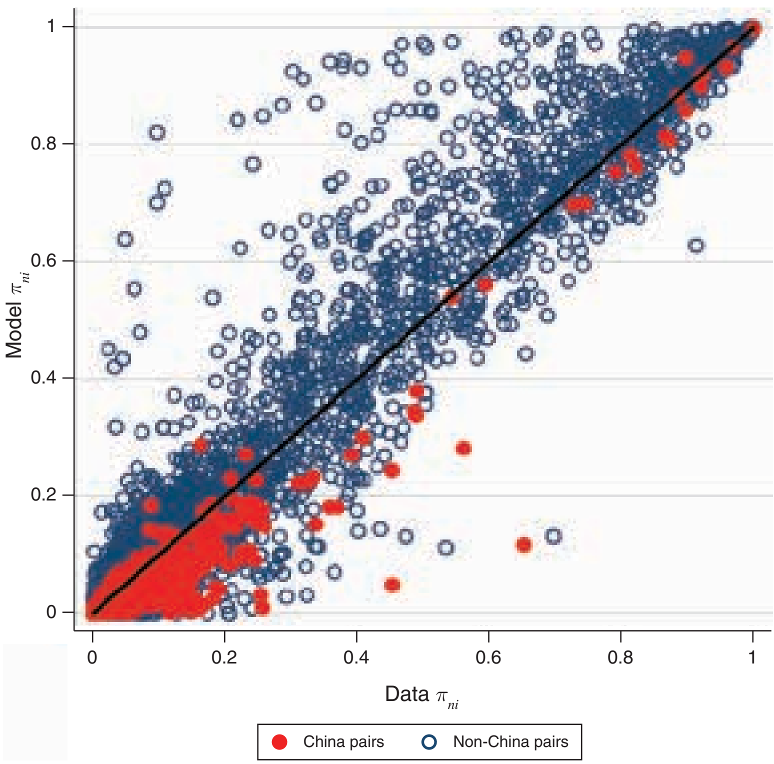

Figure 1. Benchmark Model versus Data: π^j_{ni} for China and the Rest of the Sample

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

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. Panel C of Table 2 reports the spending on domestically produced goods as a share of overall spending, π^j_{nn}. These values reflect the overall trade openness, with lower values implying higher international trade as a share of absorption. Though we underpredict overall trade slightly (model π^j_{nn}'s tend to be higher), the averages are quite similar, and the correlation between the model and data values is 0.91. Finally, the panel D 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 1 presents the comparison of trade flows graphically, by depicting the model-implied trade values against the data, along with a 45-degree line. Solid dots indicate π^j_{ni}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

Table 3—Welfare Changes

	Mean	Median	Min	Max	Countries
Panel A. Welfare gains from trade with China					
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					
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					
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 the 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.

the gains from trade with China as it stands now. The other considers two possible growth patterns for China.

B. *Gains from Trade with China*

Panel A of Table 3 reports the gains from trade with China around the world. To compute these, we compare welfare 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 percent. Elsewhere in the world, the gains range from −0.27 percent to 0.80 percent, with the mean of 0.13 percent.[4] The gains for the rest of the world from China's trade

[4] This is the unweighted mean across the 74 countries. The population-weighted mean is very close at 0.12 percent. One may also be interested in comparing the gains from trade with China to other commonly calculated magnitudes 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 percent, with the range from 0.5 percent to 12.2 percent.

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 percent), Kazakhstan (0.78 percent), and Taiwan, POC (0.63 percent). Of the top ten, seven are in Asia, and the remaining three are Peru (0.39 percent), Chile (0.37 percent), and Australia (0.30 percent). The OECD countries to gain the most are Australia, New Zealand, and Japan at 0.26 percent–0.30 percent. The mean gain in the OECD is 0.13 percent, and the welfare change for the United States is 0.11 percent. Table 3 also reveals that in nearly every major country group, the welfare changes range from negative to positive. The countries to lose the most from entry of China into world trade are Honduras (−0.27 percent) and El Salvador (−21 percent). 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.[5]

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_{ni}^{j} between the country

[5] The magnitudes of our welfare results are quite typical for the large literature on the quantitative gains from trade. This literature normally finds total gains from trade relative to complete autarky of a few percent. More incremental comparative statics (introduction of a new trade partner, signing a free trade agreement) normally produce welfare changes on the order of a fraction of 1 percent. To give but a few examples, Baldwin, Francois, and Portes (1997) and Brown et al. (1997) find that Western Europe's gains from integration of Central and Eastern European countries about 0.1–0.2 percent. More recently, using a quantitative framework similar to ours, Caliendo and Parro (2010) report US gains from NAFTA of 0.17 percent.

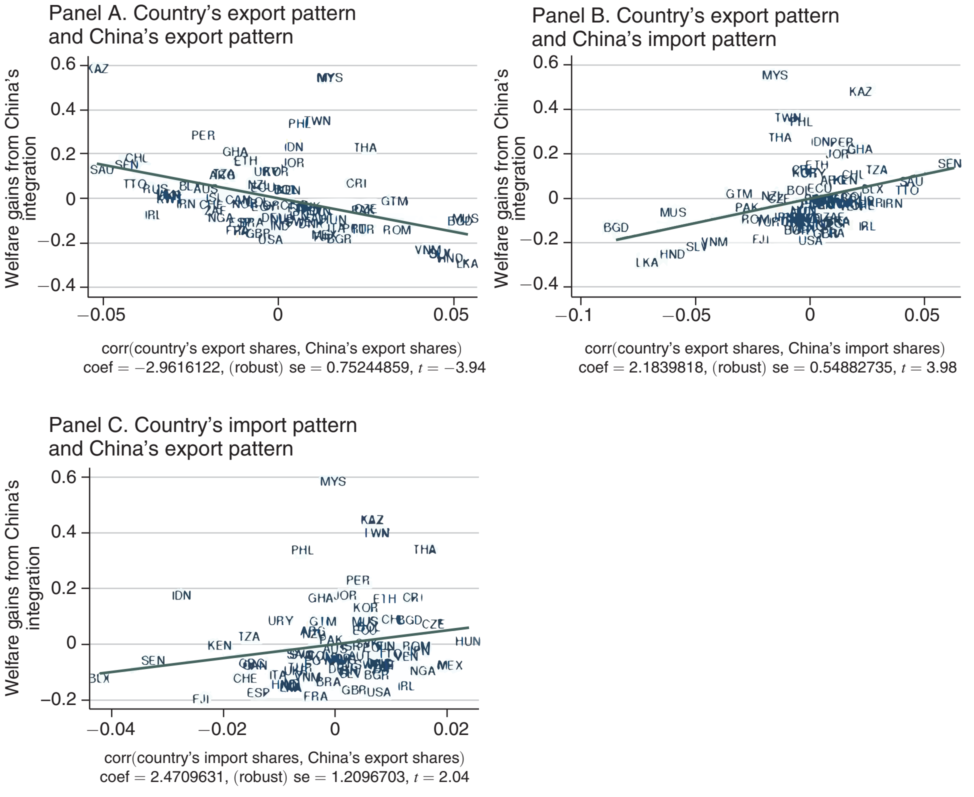

FIGURE 2. GAINS FROM TRADE WITH CHINA

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.

and China, and (log) country population.[6] 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 2 depicts the partial correlations between the three indicators of interest and the welfare gains from China's integration. The top left 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 four. The top right 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 four. 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 percent level. We conclude from this exercise that the gains from trade with China are well explained by some

[6] 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.

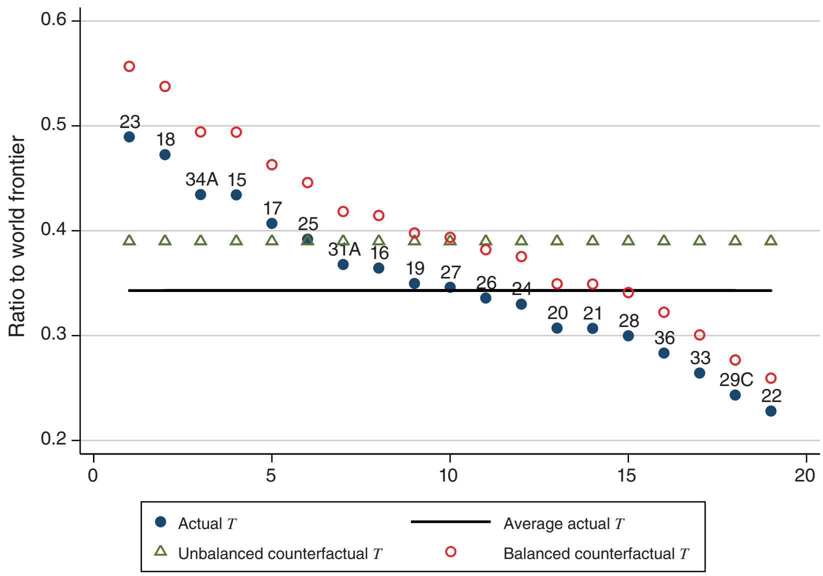

Figure 3. China: Actual and Counterfactual Productivities

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 Ts is: $(T_n^j)_{balanced} = (T_n^j)_{2000s} \times g_T$, 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 $(T_n^j)_{unbalanced} = (T_F^j)_{2000s} \times \left(\prod_{k=1}^{j} (T_n^k/T_F^k)_{2000s}\right)^{\frac{1}{J}} \times g_T$.

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.

C. *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^js. Figure 3 depicts these two counterfactuals graphically. The solid dots, labeled 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.[7]

The two counterfactual productivity scenarios are plotted in the figure. In the balanced growth scenario, we assume that in each sector China's distance to the global frontier has grown by the same proportional rate of 14 percent (or 1.32 percent per annum), which is the observed growth of average T_n^js 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.[8] 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.[9]

Panels B and C of Table 3 present the results for the balanced and the unbalanced counterfactuals, respectively. Appendix Table A1 reports the welfare changes for each individual country. 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 percent, they are 0.12–0.17 percent in the unbalanced growth case. For other regions the difference is even larger: 0.23–0.84 percent at the mean in the unbalanced case, compared to essentially zero in the balanced case.[10] Figure 4, panel 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 the mechanisms behind this finding. The analytical section derives the multilateral

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

[8] Between the 1990s and the 2000s, actual productivity growth has been balanced according to our estimates. While there is some dispersion in sectoral growth rates, comparative disadvantage sectors as of the 1990s had not caught up disproportionately faster to the world frontier.

[9] These counterfactuals match unweighted average productivities. Online Appendix Section C.6 considers an alternative counterfactual scenario in which weighted-average productivities are matched instead, with the weights being shares of value added or employment. The results are virtually indistinguishable from the main results. 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.

[10] 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 percent. In the unbalanced counterfactual, the unweighted mean welfare change is 0.42 percent, compared to the population-weighted average of 0.39 percent.

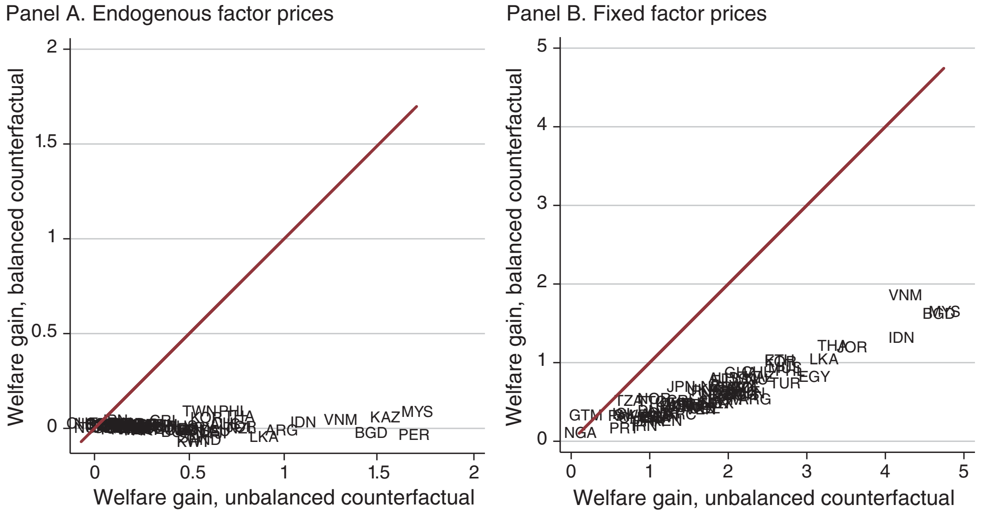

Figure 4. Welfare Gains in the Balanced and Unbalanced Counterfactuals

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 left panel reports the results from the complete model in which the factor prices *w* and *r* adjust to clear goods and factor markets. The right 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.

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.[11] 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 4, panel B presents a scatterplot of the welfare changes in the balanced counterfactual against the welfare changes in 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 I, what matters for an individual country is how China's technology compares not to itself, but to appropriately averaged world productivity. Figure 5 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.

[11] 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^js for China change to their counterfactual values.

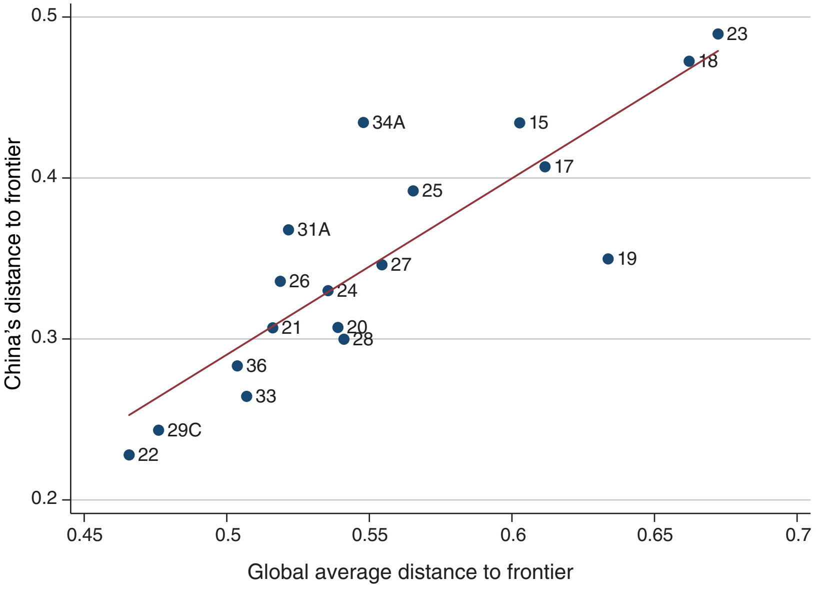

Figure 5. China's and World Average Comparative Advantage

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.

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 0.86.[12] 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 6 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.

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

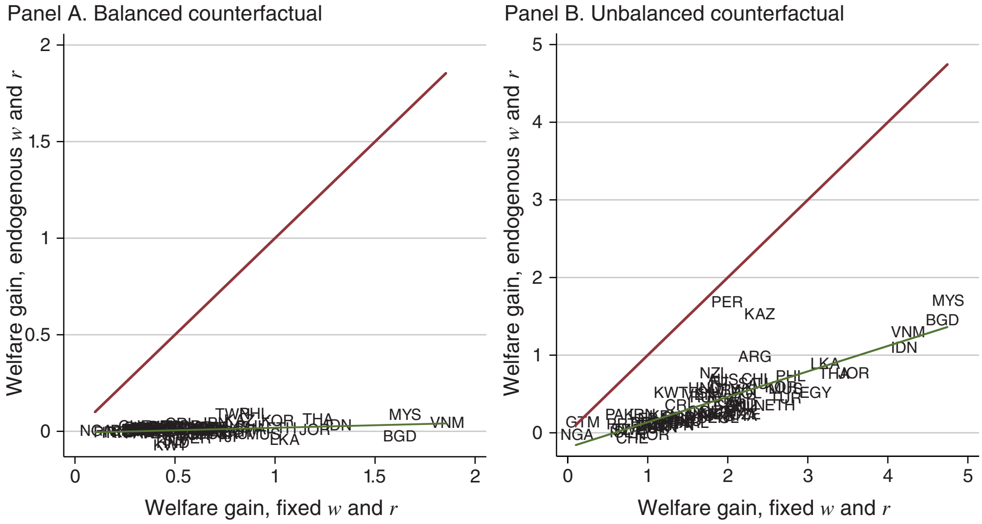

Figure 6. Welfare Gains under Fixed and Endogenous Factor Prices

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 (panel A) and the unbalanced counterfactual (panel B). The units on all of the axes are percentage points. The 45-degree line is added to both plots.

Second, in the balanced counterfactual, from the perspective of almost every country, the benefit from better Chinese technology is essentially perfectly canceled 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 percent), 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 from Chinese technological change are perfectly undone by movements in factor prices. That offsetting 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 7, panel A plots the welfare change in the unbalanced counterfactual against the simple change in the correlation of Ts 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

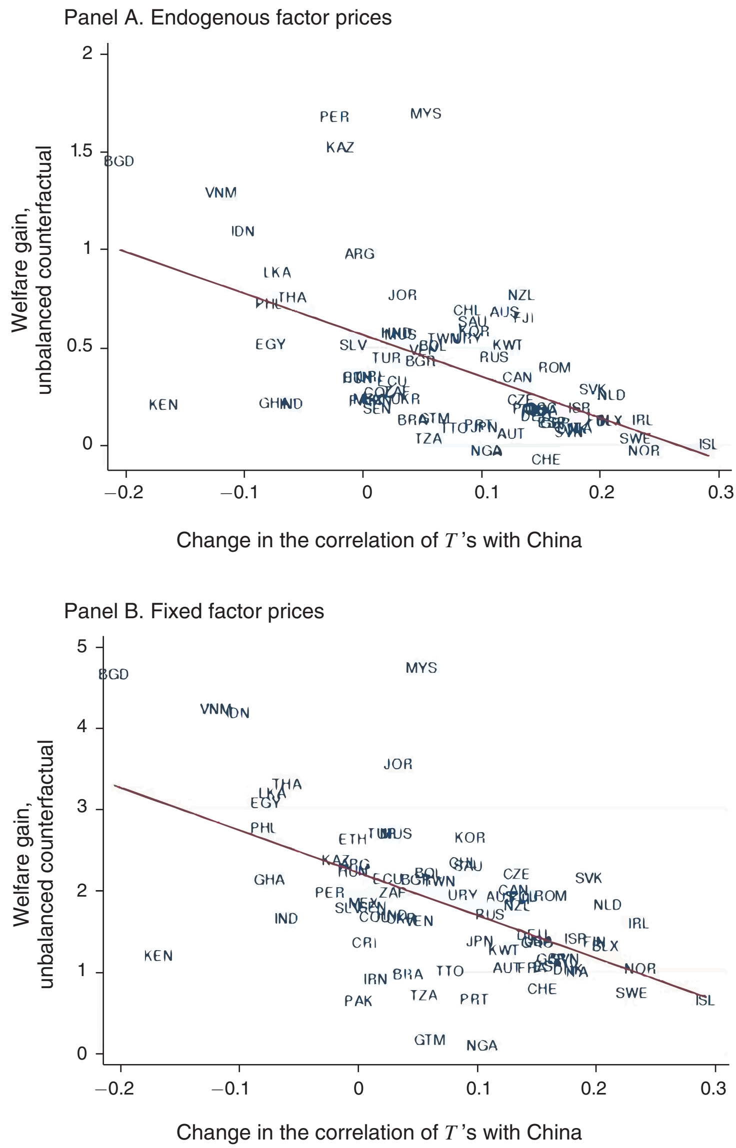

Figure 7. Unbalanced Counterfactual Welfare Gains and Technological Similarity

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.

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 five. 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 4, panel A, nearly all countries, including ones that become more similar to China, none the less 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}^js 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 7, panel 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 7, panel 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 percent compared to 10.57 percent, 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 ω_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.

Online Appendix C describes an extensive set of robustness checks on the main results, including (i) incorporating trade imbalances; (ii) adding nonmanufacturing production and trade; (iii) using directly measured productivities in countries where they are available; (iv) carrying out all of the analysis under alternative assumptions on the dispersion parameter θ; (v) using country-specific I-O matrices; and (vi) considering alternative specifications of the unbalanced counterfactual. The essential contrast between the balanced and the unbalanced cases is robust to all of these alternative approaches. In all cases, the world benefits much more from unbalanced growth in China.

IV. 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

Table A1—Country Coverage and Welfare Changes in the Main Counterfactuals

Country	ΔWelfare Balanced	ΔWelfare Unbalanced
OECD		
Australia	0.020	0.684
Austria	0.014	0.059
Belgium-Luxembourg	0.019	0.125
Canada	0.018	0.350
Denmark	0.016	0.085
Finland	0.024	0.131
France	0.008	0.177
Germany	0.023	0.153
Greece	−0.001	0.193
Iceland	0.008	0.008
Ireland	0.022	0.130
Italy	0.006	0.089
Japan	0.042	0.095
Netherlands	0.019	0.258
New Zealand	−0.001	0.769
Norway	0.024	−0.027
Portugal	−0.006	0.107
Spain	0.004	0.118
Sweden	0.017	0.037
Switzerland	0.024	−0.070
United Kingdom	0.012	0.113
United States	0.014	0.178
East and South Asia		
Bangladesh	−0.026	1.452
Fiji	−0.028	0.654
India	0.000	0.215
Indonesia	0.030	1.096
Korea, Rep.	0.054	0.586
Malaysia	0.086	1.698
Pakistan	−0.011	0.229
Philippines	0.089	0.726
Sri Lanka	−0.045	0.886
Taiwan Province of China	0.088	0.547
Thailand	0.061	0.758
Vietnam	0.044	1.291
Eastern Europe and Central Asia		
Bulgaria	−0.019	0.431
Czech Republic	0.018	0.234
Hungary	0.009	0.345
Kazakhstan	0.056	1.524
Poland	0.011	0.190
Romania	−0.008	0.397
Russian Federation	0.010	0.454
Slovak Republic	0.005	0.288
Slovenia	0.003	0.070
Turkey	−0.011	0.446
Ukraine	0.014	0.240
Latin America and Caribbean		
Argentina	−0.013	0.980
Bolivia	−0.012	0.508
Brazil	0.001	0.130
Chile	0.026	0.690
Colombia	−0.002	0.271
Costa Rica	0.039	0.354
Ecuador	0.005	0.328
El Salvador	−0.048	0.512
Guatemala	−0.001	0.137
Honduras	−0.061	0.575
Mexico	0.012	0.239
Peru	−0.036	1.678
Trinidad and Tobago	0.008	0.090
Uruguay	0.002	0.548
Venezuela, RB	−0.012	0.488
Middle East and North Africa		
Egypt, Arab Rep.	−0.005	0.517
Iran, Islamic Rep.	−0.009	0.229
Israel	0.023	0.194
Jordan	0.008	0.768
Kuwait	−0.074	0.515
Saudi Arabia	−0.013	0.633
Ethiopia	0.014	0.351
Ghana	0.009	0.218
Kenya	−0.006	0.210
Mauritius	−0.017	0.567
Nigeria	0.003	−0.028
Senegal	0.003	0.190
South Africa	0.018	0.274
Tanzania	0.013	0.036

Notes: This table reports the countries in the sample, in addition to China, and the welfare change in each country under the balanced and the unbalanced counterfactuals relative to the benchmark. Units are in percentage points.

TABLE A2—SECTORS

SIC code	Sector name	α_j	β_j	$\gamma_{J+1,j}$	ω_j
15	Food and beverages	0.315	0.281	0.303	0.209
16	Tobacco products	0.264	0.520	0.527	0.010
17	Textiles	0.467	0.371	0.295	0.025
18	Wearing apparel, fur	0.493	0.377	0.320	0.089
19	Leather, leather products, footwear	0.485	0.359	0.330	0.014
20	Wood products (excl. furniture)	0.452	0.372	0.288	0.009
21	Paper and paper products	0.366	0.344	0.407	0.012
22	Printing and publishing	0.484	0.469	0.407	0.004
23	Coke, refined petroleum products, nuclear fuel	0.244	0.243	0.246	0.092
24	Chemical and chemical products	0.308	0.373	0.479	0.008
25	Rubber and plastics products	0.385	0.387	0.350	0.014
26	Nonmetallic mineral products	0.365	0.459	0.499	0.071
27	Basic metals	0.381	0.299	0.451	0.002
28	Fabricated metal products	0.448	0.398	0.364	0.012
29C	Office, accounting, computing, and other machinery	0.473	0.390	0.388	0.094
31A	Electrical machinery, communication equipment	0.405	0.380	0.416	0.057
33	Medical, precision, and optical instruments	0.456	0.428	0.441	0.036
34A	Transport equipment	0.464	0.343	0.286	0.175
36	Furniture and other manufacturing	0.460	0.407	0.397	0.065
4A	Nontradeables	0.561	0.651	0.788	
	Mean	0.414	0.393	0.399	0.053
	Min	0.244	0.243	0.246	0.002
	Max	0.561	0.651	0.788	0.209

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

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