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A GLOBAL VIEW OF PRODUCTIVITY GROWTH IN CHINA

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ABSTRACT

How does a country's productivity growth affect worldwide real incomes through international trade? In this paper, we take this classic question to the data by measuring the spillover effects of China's productivity growth. Our framework features traditional terms-of-trade effects and new trade home market effects as suggested by the theoretical literature and works from a reference point which perfectly matches industry-level trade. Focusing on the years 1995 to 2007, we find that the cumulative welfare effect on individual regions ranges between -1.2 percent and 3.6 percent and only 3.0 percent of the worldwide gains of China's productivity growth accrue to the rest of the world.

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1 Introduction

One of the classic propositions of international economics is that a country's productivity growth can not only benefit but also harm its trading partners. In traditional models of inter-industry trade based on comparative advantage, productivity shocks transmit only through terms-of-trade effects. They tend to benefit the trading partners if productivity growth is biased towards export-oriented industries and harm the trading partners otherwise (Hicks, 1953). In newer models of intra-industry trade based on product differentiation, productivity shocks also transmit through home market effects. They tend to benefit the trading partners if productivity growth is biased towards industries with a relatively high trade elasticity and harm the trading partners otherwise (Venables, 1987).

Specifically, if a country's productivity growth is biased towards export-oriented industries, its trading partners' imports become cheaper relative to their exports so that their exports command more imports in world markets. The resulting welfare gains are the traditional terms-of-trade effects mentioned above. Moreover, if a country's productivity growth is biased towards industries with a relatively high trade elasticity, the increase in its trading partners' aggregate price indices resulting from domestic exit out of these industries is smaller than the decrease in their aggregate price indices resulting from domestic entry into the other industries so that their aggregate price indices fall overall. The ensuing welfare gains are the new trade home market effects referred to above.[1]

In this paper, we take this proposition to the data by measuring the global spillover effects of China's productivity growth. We focus on two-digit manufacturing industries and the years 1995 to 2007. We find that the pattern of China's productivity growth exhibits no strong correlation with the export-orientation or trade elasticity of China's industries so that the resulting spillover effects are relatively small. Specifically, our analysis suggests that the welfare of China's trading partners increases by a cumulative 0.7 percent due to terms-of-trade

[1] In a Krugman (1980) model, the trade elasticity would be the elasticity of substitution between varieties. In a Melitz (2003) model in which firm productivities are Pareto distributed, the trade elasticity would be the shape parameter of the Pareto distribution.

effects but decreases by a cumulative 0.3 percent due to home market effects on average. The cumulative welfare effect on individual regions ranges between -1.2 percent for Russia and 3.6 percent for Asia (except Japan) and only 3.0 percent of the worldwide gains of China's productivity growth accrue to the rest of the world. In the US, welfare rises by a cumulative 0.4 percent due to China's productivity growth.

Our analysis is based on a multi-country multi-industry general equilibrium model of international trade featuring inter-industry trade as in Ricardo (1817), intra-industry trade as in Krugman (1980), and firm heterogeneity as in Melitz (2003). On the theoretical side, it features terms-of-trade effects as well as home market effects which seems desirable in light of the forecited theoretical results. On the empirical side, it implies an industry-level gravity structure which allows us to measure the spillover effects of China's productivity growth from a reference point which perfectly matches worldwide industry-level trade. The firm-level dimension is not essential to account for terms-of-trade and home market effects, but is important to correct for Melitz (2003) selection effects when estimating China's productivity growth.

Despite the considerable attention our subject received in the theoretical literature, there is relatively little related empirical work. Our paper is preceded mainly by Eaton and Kortum (2002) who illustrate their seminal framework by quantifying the spillover effects of hypothetical US and German productivity shocks on other OECD countries. Eaton and Kortum's framework features only terms-of-trade effects but no home market effects and therefore ignores one of the channels through which productivity shocks transmit. Also, it predicts full specialization according to comparative advantage but allows only for aggregate productivity shocks so that productivity growth is always export-biased in effect.[2]

The remainder of the paper is organized as follows. Section 2 lays out the theoretical frame-

[2] Fieler (forthcoming) provides a similar exercise in an Eaton and Kortum (2002) model with non-homothetic preferences. Additional work has emerged after our paper. Levchenko and Zhang (2011) calibrate a multi-sector Eaton and Kortum (2002) model to quantify the effects of changes in Ricardian comparative advantage. Di Giovanni et al (2011) build on this and assess the welfare impact of China's trade integration and technological change.

work: it describes the basic setup, characterizes the equilibrium for given productivities, shows how to calculate the general equilibrium effects of productivity shocks, and demonstrates how to isolate the welfare effects of productivity shocks. Section 3 turns to the empirical application: it introduces the data, describes the estimation of the model parameters, explains the estimation of China's productivity growth, and reports the empirical results.[3]

2 Theoretical framework

2.1 Basic setup

Our framework is based on a multi-industry extension of the Melitz (2003) model used by Arkolakis et al (2011). There are N countries and S industries. Each industry provides consumers with a continuum of differentiated varieties. Preferences over these varieties are summarized by the following utility functions

$$U_j = \prod_{s=1}^{S} \left(\sum_{i=1}^{N} \int_{0}^{M_{ijs}} x_{ijs} \left(\nu_{is}\right)^{\frac{\sigma_s - 1}{\sigma_s}} d\nu_{is} \right)^{\frac{\sigma_s}{\sigma_s - 1} \mu_{js}} \tag{1}$$

where x_{ijs} is the quantity of an industry s variety from country i consumed in country j, M_{ijs} is the number of industry s varieties from country i available in country j, $\sigma_s > 1$ is the elasticity of substitution between industry s varieties, and μ_{js} is the fraction of country j income spent on industry s varieties.

Firms are technologically heterogeneous which is captured by the following production process. Entrants into industry s of country i have to hire f_{is}^{e} units of labor in country i to draw their productivities φ from a Pareto distribution $G_{is}(\varphi) = 1 - \left(\frac{b_{is}}{\varphi}\right)^{\theta_s}$, where f_{is}^{e} is a fixed cost of entry, b_{is} is the Pareto location parameter, and θ_s is the Pareto shape parameter. Entrants into industry s of country i wishing to sell to country j further need to hire $\frac{x_{ijs}\tau_{ijs}}{\varphi}$ units of labor in country i and f_{ijs} units of labor in country j to deliver x_{ijs} units of output to

[3] In the interest of brevity, derivations are kept to a minimum in the main text. A detailed technical appendix is available upon request.

country j, where $\tau_{ijs} \geq 1$ is an iceberg trade barrier and f_{ijs} is a fixed cost of serving market j. Both the number of entrants into industry s of country i M^e_{is} and the fraction of entrants selling to country j $\frac{M_{ijs}}{M^e_{is}}$ are endogenous.[4]

Given only these basics, we can already anticipate some of the roles the model's traditional and new trade elements will play. In particular, the model will feature inter-industry trade as in Ricardo (1817) since the productivity distributions vary by country and industry. Also, there will be intra-industry trade as in Krugman (1980) since goods are differentiated and consumers value variety. We will model an industry's productivity growth as an increase in the Pareto location parameter b_{is} which shifts the entire distribution of possible productivity draws to the right. Since this will lead to changes in the number of entrants, productivity growth will not only have terms-of-trade effects but also home market effects which would not arise in Eaton and Kortum (2002) type environments.

2.2 Equilibrium for given productivities

Utility maximization implies that firms in industry s of country i face demands

$$x_{ijs} = \frac{p_{ijs}^{-\sigma_s}}{P_{js}^{1-\sigma_s}} \mu_{js} w_j L_j \tag{2}$$

where p_{ijs} is the delivered price of an industry s variety, P_{js} the ideal price index of all industry s varieties, w_j the wage rate, and L_j the number of consumers or workers.

Profit maximization requires that firms in industry s of country i whose productivity draws exceed φ^*_{ijs} charge

$$p_{ijs} = \frac{\sigma_s}{\sigma_s - 1} \frac{\tau_{ijs} w_i}{\varphi} \tag{3}$$

where $\varphi^*_{ijs} = \frac{\sigma_s}{\sigma_s - 1} \frac{\tau_{ijs} w_i}{P_{js}} \left(\frac{\sigma_s f_{ijs}}{\mu_{js} L_j}\right)^{\frac{1}{\sigma_s - 1}}$ denotes the productivity cutoff above which revenues are sufficiently high to justify incurring the fixed costs of serving market j.

[4] In order to clearly expose the novel features of our framework, we do not allow for intermediate goods or nontraded goods which is in line with much of the theoretical literature. The idea is that intermediate goods tend to magnify the spillover effects of productivity shocks while nontraded goods tend to dampen the spillover effects of productivity shocks so that abstracting from both seems like a reasonable simplification.

As usual, the ideal price index is given by $P_{js} = \left(\sum_{i=1}^{N} \int_{0}^{M_{ijs}} p_{ijs}\left(\nu_{is}\right)^{1-\sigma_s} d\nu_{is}\right)^{\frac{1}{1-\sigma_s}}$. With the help of equation (3), it can be rewritten as

$$P_{js} = \left(\sum_{i=1}^{N} M_{ijs} p_{ijs} \left(\widetilde{\varphi}_{ijs}\right)^{1-\sigma_s} \right)^{\frac{1}{1-\sigma_s}} \tag{4}$$

where $\widetilde{\varphi}_{ijs} = \left(\int_{\varphi_{ijs}^{*}}^{\infty} \varphi^{\sigma_s - 1} g_{is}(\varphi|\varphi > \varphi^{*}) d\varphi\right)^{\frac{1}{\sigma_s-1}}$ denotes the productivity of the representative firm in industry s of country i selling to country j which can be simplified to $\widetilde{\varphi}_{ijs} = \left(\frac{\theta_s}{\theta_s - \sigma_s + 1}\right)^{\frac{1}{\sigma_s - 1}} \varphi_{ijs}^{*}$ by imposing the Pareto assumption.

Free entry drives expected profits down to zero so that

$$\sum_{j=1}^{N} prob\left(\varphi > \varphi_{ijs}^{*}\right) E\left(\pi_{ijs}|\varphi > \varphi_{ijs}^{*}\right) = w_i f_{is}^{e} \tag{5}$$

where $prob(\varphi > \varphi_{ijs}^{*}) = \left(\frac{b_{is}}{\varphi_{ijs}^{*}}\right)^{\theta_s}$ is the probability that an entrant into industry s of country i sells to country j and $E(\pi_{ijs}|\varphi > \varphi_{ijs}^{*}) = \frac{\sigma_s - 1}{\theta_s - \sigma_s + 1} w_j f_{ijs}$ are the expected operating profits of an entrant into industry s of country i from selling to country j conditional on selling to country j.

Finally, labor market clearing ensures

$$\delta_i L_i = \sum_{s=1}^{S} M_{is}^{e} \left(\theta_s + 1\right) f_{js}^{e} \tag{6}$$

where $\delta_i \equiv \sum_{s=1}^{S} \frac{(\theta_s+1)(\sigma_s - 1)}{\theta_s \sigma_s} \mu_{js}$ is the fraction of country i workers hired by country i entrants to cover their fixed costs of entry as well as their variable costs of production and $(\theta_s+1) f_{js}^{e}$ captures the expected number of workers required by entrants into industry s of country i to cover their fixed costs of entry as well as their variable costs of production.

Upon noticing that $M_{ijs}= (\frac{b_{is}}{\varphi^*_{ijs}})^{\theta_s} M^e_{is}$, equations (3) - (5) can be combined to

$$w_i \frac{\theta_s \sigma_s}{\sigma_s - 1} f^e_{is} = \sum_{j=1}^{N} \frac{(f_{ijs})^{\frac{\sigma_s - \theta_s - 1}{\sigma_s - 1}} \left(\frac{\tau_{ijs} w_i}{b_{is}}\right)^{-\theta_s}}{\sum_{m=1}^{N} M^e_{ms} (f_{mjs})^{\frac{\sigma_s - \theta_s - 1}{\sigma_s - 1}} \left(\frac{\tau_{mjs} w_m}{b_{ms}}\right)^{-\theta_s}} \mu_{js} w_j L_j \tag{7}$$

Together with condition (6), this represents a system of N+NS equations in the N+NS unknowns w_i and M^e_{is} which can be solved up to a numeraire. An obvious problem, however, is that this system depends on a large set of unknown parameters which are all difficult to estimate empirically.

2.3 General equilibrium effects of productivity shocks

We avoid this problem by computing the general equilibrium effects of productivity shocks using a method inspired by Dekle et al (2007). In particular, conditions (6) and (7) can be written in changes as

$$1 = \sum_{s=1}^{S} {}_{is} \widehat{M}^e_{is} \tag{8}$$

$$\widehat{w}_v = \sum_{j=1}^{N} \frac{\beta_{vjs} \left(\frac{\widehat{w}_v}{\widehat{b}_{vs}}\right)^{-\theta_s}}{\sum_{i=1}^{N} \alpha_{ijs} \widehat{M}^e_{is} \left(\frac{\widehat{w}_i}{\widehat{b}_{is}}\right)^{-\theta_s}} \widehat{w}_j \tag{9}$$

where a hat denotes the ratio between the counterfactual and factual value, $\alpha_{ijs} \equiv \frac{T_{ijs}}{\sum_{m=1}^{N} T_{mjs}}$, $\beta_{ijs} \equiv \frac{T_{ijs}}{\sum_{n=1}^{N} T_{ins}}$, ${}_{is} \equiv \frac{\sum_{n=1}^{N} \frac{(\sigma_s - 1)(\theta_s + 1)}{\theta_s \sigma_s} T_{ins}}{\sum_{n=1}^{N} \sum_{t=1}^{S} \frac{(\sigma_t - 1)(\theta_t + 1)}{\theta_t \sigma_t} T_{int}}$, and T_{ijs} denotes the factual value of industry s trade from country i to country j.

Equations (8) and (9) represent a system of N+NS equations in the N+NS unknowns $\widehat{w}_i$ and $\widehat{M}^e_{is}$. Crucially, their coefficients depend on σ_s, θ_s, and observable trade flows only so that the full general equilibrium response to productivity shocks can be determined without further information on any of the remaining model parameters. Notice that this procedure ensures that the general equilibrium effects are calculated from a reference point which perfectly matches industry-level trade. Essentially, it imposes a restriction on the set of unknown parameters $\{b_{is}, \tau_{ijs}, f_{ijs}, f^e_{is}, L_i\}$ such that the predicted T_{ijs} perfectly match the observed T_{ijs} for given values of σ_s and θ_s.

To provide a sense of the nature of these general equilibrium adjustments, Table 1 reports the effects of a hypothetical productivity shock in a simple example economy consisting of two countries (China and the US) and two industries (1 and 2). Productivity is assumed to grow by 10 percent in industry 1 of China and trade flows are taken to be fully symmetric as detailed in the note to Table 1. As can be seen, the productivity growth in industry 1 of China is predicted to cause an increase in the relative wage of China as well as entry into industry 1 of China, exit out of industry 1 of the US, exit out of industry 2 of China, and entry into industry 2 of the US.

Intuitively, expected profits from entering into industry 1 become positive in China and negative in the US. As a result, there is entry into industry 1 of China bidding up wages so that there is also exit out of industry 2. Also, there is exit out of industry 1 of the US depressing wages so that there is also entry into industry 2. The pattern of entry and exit can also be understood in terms of two basic equilibrium constraints. First, labor market clearing requires that entry into one industry leads to exit out of the other industry in the same country. Second, constant expenditure shares imply that entry into one industry leads to exit out of the same industry in the other country.

2.4 Welfare effects of productivity shocks

Given these general equilibrium adjustments of productivity shocks, the implied welfare effects can be computed relatively straightforwardly. Changes in welfare are given by changes in real labor income which are changes in nominal labor income deflated by changes in the ideal aggregate price index: $\widehat{V}_j = \frac{\widehat{w}_j}{\widehat{P}_j}$. Given the Cobb-Douglas structure of aggregate preferences, this can be rewritten in terms of changes in the ideal industry price indices as $\widehat{V}_j = \frac{\widehat{w}_j}{\Pi_{s=1}^{S}(\widehat{P}_{js})^{\mu_{js}}}$. The trick is now to express changes in the ideal industry price indices as functions of changes in wages and entry only. This can be accomplished by rewriting equation (4) in changes after substituting the relationship $M_{ijs} = (\frac{b_{is}}{\varphi^*_{ijs}})^{\theta_s} M^e_{is}$ and the definitions of φ^*_{ijs} and $\widetilde{\varphi}_{ijs}$ which yields $\widehat{P}_{js} = (\sum_{i=1}^N \alpha_{ijs}\widehat{M}^e_{is}(\frac{\widehat{w}_i}{\widehat{b}_{is}})^{-\theta_s})^{-\frac{1}{\theta_s}}$. As a result, changes in welfare can then be computed from[5]

$$\widehat{V}_j = \prod_{s=1}^S \left(\sum_{i=1}^N \alpha_{ijs}\left(\widehat{b}_{is}\frac{\widehat{w}_j}{\widehat{w}_i}\right)^{\theta_s}\widehat{M}^e_{is}\right)^{\frac{\mu_{js}}{\theta_s}} \tag{10}$$

To understand precisely how productivity shocks affect welfare, it is useful to begin by contrasting two linear approximations of the growth rates of industry price indices. The first follows from equation (4) and reveals that changes in industry price indices are expenditure share weighted averages of changes in average prices and elasticity of substitution adjusted changes in available variety as one intuitively expects: $\frac{\Delta P_{js}}{P_{js}} \approx \sum_{i=1}^N \alpha_{ijs}(-\frac{\Delta\widetilde{\varphi}_{ijs}}{\widetilde{\varphi}_{ijs}} + \frac{\Delta w_i}{w_i} - \frac{1}{\sigma_s - 1}\frac{\Delta M_{ijs}}{M_{ijs}})$. The second follows from the expression for $\widehat{P}_{js}$ given above and shows that productivity shocks ultimately affect industry price indices either directly or indirectly through changes in wages or entry: $\frac{\Delta P_{js}}{P_{js}} \approx \sum_{i=1}^N \alpha_{ijs}(-\frac{\Delta b_{is}}{b_{is}} + \frac{\Delta w_i}{w_i} - \frac{1}{\theta_s}\frac{\Delta M^e_{is}}{M^e_{is}})$. The links between these two approximations are given by two equations which can be derived using the relationship $M_{ijs} = (\frac{b_{is}}{\varphi^*_{ijs}})^{\theta_s} M^e_{is}$ and the definitions of φ^*_{ijs} and $\widetilde{\varphi}_{ijs}$.

The first link is that $\sum_{i=1}^N \alpha_{ijs}\frac{\Delta M_{ijs}}{M_{ijs}} \approx 0$ which implies that changes in available variety have no net effect on industry price indices so that the last term out of the first approximation simply drops out. The basic intuition for this result can be understood by considering the following variety effects of China's productivity growth on the US economy. On the one hand, China's productivity growth implies that more Chinese varieties become available to US consumers as additional Chinese firms start exporting to the US. On the other hand, China's productivity growth means that fewer US varieties remain available to US consumers since some US firms are forced to shut down. The price index implications of these two effects are exactly offsetting so that changes in the overall number of varieties available to US consumers can be ignored.

The second link is that $\sum_{i=1}^N \alpha_{ijs}\frac{\Delta\widetilde{\varphi}_{ijs}}{\widetilde{\varphi}_{ijs}} \approx \sum_{i=1}^N \alpha_{ijs}\frac{\Delta b_{is}}{b_{is}} + \frac{1}{\theta_s}\sum_{i=1}^N \alpha_{ijs}\frac{\Delta M^e_{is}}{M^e_{is}}$ which implies

[5] Notice that no further parameter estimates are required for this computation since $\mu_{js} = \frac{\sum_i T_{ijs}}{\sum_i \sum_s T_{ijs}}$.

that only changes in average productivity induced either directly by changes in b_{is} or indirectly by changes in M_{is}^e have a net effect on P_{js}. A corollary is that the basic Melitz (2003) selection effects also cancel which is not too surprising since they mirror the abovementioned variety effects. One the one hand, the fact that additional Chinese firms start exporting to the US means that the average productivity of Chinese firms serving the US market grows at a slower rate than China's productivity since these additional firms have below average productivity. On the other hand, the fact that some US firms are forced to shut down means that the average productivity of US firms serving the US market rises since the surviving firms have above average productivity.[6]

The only Melitz (2003) selection effects which continue to matter are the entry effects known from Bernard et al (2007). Their basic intuition can be understood by considering how industry 1 of the US is affected by productivity growth in industry 1 of China. The resulting exit out of industry 1 of the US reduces competition in industry 1 of the US which increases the industry 1 price index of the US by allowing some lower productivity firms to serve the US market. At the same time, the resulting entry into industry 1 of China increases competition in industry 1 of the US which decreases the industry price index of the US by forcing some lower productivity firms out of the US market. Under a realistic parametrization of industry expenditure shares, entry in the US has a stronger effect on US competition than entry in China so that the former effect dominates.

Given this background on how productivity shocks affect industry price indices, it is now easy to see how productivity shocks affect welfare. In particular, changes in welfare can be approximated as $\frac{\Delta V_j}{V_j} \approx \frac{\Delta w_j}{w_j} - \sum_{s=1}^{S} \mu_{js} \frac{\Delta P_{js}}{P_{js}}$ which can be rewritten by substituting the second approximation $\frac{\Delta P_{js}}{P_{js}} \approx \sum_{i=1}^{N} \alpha_{ijs} (-\frac{\Delta b_{is}}{b_{is}} + \frac{\Delta w_i}{w_i} - \frac{1}{\theta_s} \frac{\Delta M_{is}^e}{M_{is}^e})$ from above. The resulting

[6] These findings are related to the recent results by Arkolakis et al (2011), Feenstra (2009), and Atkeson and Burstein (2010) that changes in trade barriers often have similar aggregate effects in models with and without firm heterogeneity. The firm-level dimension of our setup proves useful in our empirical application where it allows us to correct for Melitz (2003) selection effects when estimating China's productivity growth.

expression is just a linearized version of equation (10):

$$\frac{\Delta V_j}{V_j} \approx \sum_{i=1}^{N} \sum_{s=1}^{S} \mu_{js} \alpha_{ijs} \left(\left(\left(\frac{\Delta w_j}{w_j} - \frac{\Delta b_{js}}{b_{js}} \right) - \left(\frac{\Delta w_i}{w_i} - \frac{\Delta b_{is}}{b_{is}} \right) \right) + \frac{1}{\theta_s} \frac{\Delta M_{is}^e}{M_{is}^e} + \frac{\Delta b_{js}}{b_{js}} \right) \tag{11}$$

The first term $\sum_{i=1}^{N} \sum_{s=1}^{S} \mu_{js} \alpha_{ijs} \left(\left(\frac{\Delta w_j}{w_j} - \frac{\Delta b_{js}}{b_{js}} \right) - \left(\frac{\Delta w_i}{w_i} - \frac{\Delta b_{is}}{b_{is}} \right) \right)$ is the traditional terms-of-trade effect emphasized by Hicks (1953). It captures the direct effect changes in wages and productivities have on the prices of the goods produced by country j relative to the direct effect changes in wages and productivities have on the prices of the goods consumed by country j. Country j benefits from an increase in the price of its production bundle relative to the price of its consumption bundle since its exports then command more imports in world markets.

The second term $\sum_{i=1}^{N} \sum_{s=1}^{S} \frac{\mu_{js} \alpha_{ijs}}{\theta_s} \frac{\Delta M_{is}^e}{M_{is}^e}$ is the new trade home market effect in Venables (1987). It captures the indirect effect adjustments in entry and exit have on the aggregate price index in country j. Recall that entry into one industry of country j always comes along with exit out of another industry in country j. Recall also that entry into an industry of country j typically reduces the price index of that industry in country j. Hence, the counteracting entry effects give rise to counteracting industry price index effects so that the sign of the aggregate price index effect is not immediately clear.

The last term $\sum_{i=1}^{N} \sum_{s=1}^{S} \mu_{js} \alpha_{ijs} \frac{\Delta b_{js}}{b_{js}} = \sum_{s=1}^{S} \mu_{js} \frac{\Delta b_{js}}{b_{js}}$ is the effect productivity shocks in country j have on welfare in country j under autarky as follows straightforwardly from setting $N = 1$ in equations (9) and (11). It simply says that a country's welfare growth under autarky is an expenditure share weighted average of that country's industry-level productivity growth as one intuitively expects. The previous two terms therefore capture the additional effects arising under trade relative to autarky and thereby identify the channels through which productivity shocks transmit under trade.[7]

[7] Internationally, the terms-of-trade and home market effects have a zero sum character. This can be seen most clearly in the special case $\sigma_s = \sigma$ and $\theta_s = \theta$ for all s since the worldwide average welfare effect is then completely independent of terms-of-trade and home market effects. In particular, it can be shown that equation (11) then implies $\frac{\Delta \overline{V}}{\overline{V}} = \sum_i \sum_j \sum_s \frac{T_{ijs}}{\sum_v w_v L_v} \frac{\Delta b_{is}}{b_{is}}$, where $\frac{\Delta \overline{V}}{\overline{V}} = \sum_j \frac{w_j L_j}{\sum_v w_v L_v} \frac{\Delta V_j}{V_j}$.

To illustrate the key determinants of the signs of these spillover effects, we now return to our simple example economy introduced above. Table 2 reports the effects of a hypothetical 10 percent productivity growth in industry 1 of China on US welfare for three different scenarios: China is a net exporter in industry 1, China is a net importer in industry 1, and there is no inter-industry trade. As one expects from the classic literature, the US experiences a terms-of-trade gain if China's productivity growth is biased towards China's export-oriented industry but a terms-of-trade loss if China's productivity growth is biased towards China's import-competing industry.

One subtle difference from the textbook analysis is that the terms-of-trade gain the US experiences if China's productivity growth is biased towards China's export-oriented industry exceeds the terms-of-trade loss it experiences if China's productivity growth is biased towards China's import-competing industry. This is also reflected in the fact that the US experiences a positive terms-of-trade effect even if there is no inter-industry trade. This difference is due to the existence of Krugman (1980) type intra-industry trade. In a sense, productivity growth always features an export-bias in a Krugman (1980) model since each country specializes in a unique set of varieties.

Table 3 returns to the case of fully symmetric trade flows and illustrates the role played by cross-industry differences in θ_s. It again reports the effects of a 10 percent productivity growth in industry 1 of China on US welfare. As can be seen, the US experiences a positive home market effect if China's productivity growth is biased towards the high θ_s industry and a negative home market effect if it is biased towards the low θ_s industry. The intuition is that the θ_s parameters govern the strengths of the counteracting industry price index effects. If θ_s is low, there is a lot of variation in firm productivity so that changes in the number of entrants lead to large changes in average productivity.

For example, if China's productivity growth is biased towards the high θ_s industry, there is exit out of the high θ_s industry in the US which tends to increase the aggregate price index in the US. At the same time, there is also entry into the low θ_s industry in the US which tends to decrease the aggregate price index in the US. However, the latter effect tends to dominate the former effect since changes in the number of entrants induce larger changes in average productivity in the low θ_s industry. This is because firm productivity is more dispersed in the low θ_s industry so that adding or dropping marginal firms has a larger effect on average productivity in that industry.

Overall, this discussion suggests two key determinants of the sign of the global spillover effects of China's productivity growth: the correlation between China's productivity growth and China's export-orientation, and the correlation between China's productivity growth and the Pareto shape parameters θ_s which can alternatively be interpreted as trade elasticities in this environment. Of course, the magnitude of the global spillover effects of China's productivity growth also depends critically on the pattern and volume of international trade as captured by the import shares $\mu_{js}\alpha_{ijs}$ in equation (11).

3 Empirical application

We now apply our framework to isolate and decompose the spillover effects of China's productivity growth between 1995 and 2007.[8] For this purpose, we need the complete matrix of industry-level trade flows T_{ijs}, industry-level estimates of the elasticity parameters σ_s and θ_s, and industry-level estimates of China's productivity growths $\widehat{b}_{is}$. We obtain this information on an annual basis for 34 2-digit manufacturing industries and 17 countries or regions comprising the world. We explicitly include only the largest economies and aggregate all other countries by nearest continent.

[8] Before we apply our framework, we actually extend it in two simple ways. First, we introduce an exogenous trade surplus parameter along the lines of Eaton and Kortum (2002) to deal with the aggregate trade imbalances observed empirically. Second, we relax the implicit assumption that the free entry condition always binds in all countries and industries to allow for possible corner solutions in which some countries abandon some industries entirely. We discuss the resulting generalizations of equations (8) - (10) together with our solution algorithm in the appendix.

3.1 Estimation procedure for T_{ijs}

Our data on international trade flows is from the standard NBER-UN database which covers most countries in the world.[9] For the US and China, we compute internal trade flows as industry output minus industry exports which we take from the standard NBER-CES database and the Annual Survey of Industrial Production. The Annual Survey of Industrial Production is a census of all state-owned plants and all large private plants collected by China's National Bureau of Statistics. Additional details on this dataset can be found, for example, in Hsieh and Klenow (2009).[10]

For all other countries, we estimate internal trade flows from aggregate production data using the following procedure: First, we impute aggregate output by dividing aggregate value added from the standard World Bank-WDI database by 0.312 which is the number for value added reported by Dekle et al (2007). Then, we compute aggregate expenditure from aggregate output, minus aggregate exports, plus aggregate imports. Finally, we calculate internal trade flows by multiplying aggregate expenditure with US industry expenditure shares and subtracting industry imports.

3.2 Estimation procedure for σ_s and θ_s

We estimate the demand elasticities σ_s using the theoretical prediction that industry wage payments are proportional to industry revenues with the factor of proportionality being equal to $\frac{\sigma_s - 1}{\sigma_s}$.[11] Instead of using wage payments, we use factor payments, that is the sum of payments to capital and labor. Calculating factor payments involves the rental rate of capital which we obtain by assuming that the sum of factor payments across all industries amounts

[9] We use the most recent version of this data which was generously made available to us by Robert Feenstra.

[10] The NBER-CES data is only available until 2005. We estimate internal trade flows for the US and other countries in 2006 and 2007 based on the 2005 US industry expenditure shares using the procedure explained below.

[11] Strictly speaking, the model predicts that *variable* industry wage payments are proportional to industry revenues given the assumption that fixed costs are also incurred in terms of labor. We do not take this assumption literally when taking the model to the data and treat all reported factor payments as variable factor payments.

to $\frac{2}{3}$ of the sum of revenues across all industries. We make this assumption since it implies a plausible aggregate profit share of $\frac{1}{3}$.

We estimate the trade elasticities θ_s using the estimates of σ_s and the theoretical prediction that firm sales follow a Pareto distribution with shape parameter $\frac{\theta_s}{\sigma_s - 1}$ within industries. We follow Eaton et al (forthcoming) in restricting attention to exporters only and back out the shape parameter of the firm sales distribution from a regression of the logarithm of the firm sales rank on the logarithm of firm sales. For our estimation of σ_s and θ_s, we use data on wage payments, capital stocks, and firm sales from the Chinese Annual Survey of Industrial Production described above.

3.3 Estimation procedure for $\widehat{b}_{is}$

Our estimation of China's productivity growth proceeds in two steps. In the first step, we estimate the productivity growth of the representative Chinese firm in each industry $\widehat{\widetilde{\varphi}}_{iis}$. In the second step, we calculate the fundamental Chinese productivity growth $\widehat{b}_{is}$ in each industry from $\widehat{\widetilde{\varphi}}_{iis}$ by correcting for Melitz (2003) selection effects. Recall that an increase in the Pareto location parameter b_{is} shifts the entire distribution of possible productivity draws to the right. It differs from $\widetilde{\varphi}_{iis}$ because not all Chinese entrants find it optimal to serve the Chinese market given the fixed costs f_{iis}.

Our model suggests to estimate $\widehat{\widetilde{\varphi}}_{iis}$ as the growth rate of real industry output per worker. To see this, recall that employment in a given firm is given by $\sum_j \frac{\tau_{ijs} x_{ijs}(\varphi)}{\varphi}$ which can be manipulated after substituting the pricing formula to yield $\widehat{\widetilde{\varphi}}_{iis} = \widehat{\frac{1}{p_{iis}(\widetilde{\varphi}_{iis})}} \frac{\widehat{S}_{is}}{\widehat{L}_{is}}$, where S_{is} are the total sales in industry s of country i and L_{is} is the total employment in industry s of country i.[12] The representative price $p_{iis}(\widetilde{\varphi}_{iis})$ is an output share weighted average of the prices charged by domestic producers in the industry which follows from rewriting it as $p_{iis}(\widetilde{\varphi}_{iis}) = \int_{\varphi^*_{iis}}^{\infty} p_{iis}(\varphi) \frac{x_{iis}(\varphi)}{x_{iis}(\widetilde{\varphi}_{iis})} g_{si}(\varphi | \varphi > \varphi^*_{iis}) \, d\varphi$.

[12] Strictly speaking, L_{is} is the total employment in industry s of country i *net of fixed costs* because we have assumed fixed costs to be incurred in terms of labor. As explained in the previous footnote, we do not take this assumption literally when taking the model to the data.

We estimate $\widehat{\widetilde{\varphi}}_{iis}$ using our data from the Annual Survey of Industrial Production. Instead of computing the growth rate of industry output per worker, we compute the growth rate of industry output per composite factor of production which we take to be a Cobb-Douglas aggregate of capital and labor. We calculate the labor shares from the shares of wage payments in industry revenues net of profits and the capital shares as the residuals of these labor shares. We proxy for the representative price $p_{iis}\left(\widetilde{\varphi}_{iis}\right)$ using producer price deflators which we obtain from the China Statistical Yearbook.

Our model further implies $b_{is} = \left(\frac{\theta_s}{\theta_s - \sigma_s + 1}\right)^{\frac{1}{1-\sigma_s}} \left(\frac{\theta_s - \sigma_s + 1}{\sigma_s - 1}\frac{f^e_{is}}{f_{iis}}\lambda_{iis}\right)^{\frac{1}{\theta_s}} \widetilde{\varphi}_{iis}$, where $\lambda_{iis} \equiv \frac{T_{iis}}{\sum_m T_{ims}}$ is an inverse measure of trade openness. Assuming that $\widehat{f^e}_{is} = \widehat{f}_{iis}$, $\widehat{b}_{is}$ can therefore be inferred from $\widehat{\widetilde{\varphi}}_{iis}$ using the relationship $\widehat{b}_{is} = \left(\widehat{\lambda}_{iis}\right)^{\frac{1}{\theta_s}} \widehat{\widetilde{\varphi}}_{iis}$. Intuitively, the term $\left(\widehat{\lambda}_{iis}\right)^{\frac{1}{\theta_s}}$ corrects for the effects changes in trade openness have on representative productivity (the Melitz (2003) selection effects). It is well-known that such selection effects are often important and ignoring them would have indeed biased our productivity growth estimates for some industries to a sizeable degree.[13]

3.4 Results

Table 4 reports the share of manufacturing imports from all countries in domestic manufacturing expenditure by country. Excluding China, this share has increased from 20.8 percent to 26.6 percent over the sample period on average. Table 5 presents the share of manufacturing imports from China in domestic manufacturing expenditure by country. Excluding China, this share has increased from 1.1 percent to 3.9 percent over the sample period on average. While manufacturing imports from China therefore only account for 5.3 percent of total manufacturing imports in 1995 on average, they already account for 14.7 percent of total manufacturing imports in 2007 on average, reflecting the rising importance of China to the world economy.

Table 6 lists our estimates for the elasticities σ_s and θ_s for all industries. As can be seen,

[13] In particular, the correction ranges from -5.8 percentage points until 0.4 percentage points and averages -0.2 percentage points for the annualized productivity growth estimates which we present below.

our estimates of σ_s range from 1.7 to 19.5 and average 7.4 and our estimates of θ_s range from 0.8 to 22.0 and average 7.9. These averages are within the range of existing estimates found in the literature. Eaton and Kortum (2002), for example, estimate the trade elasticity to be 3.6 in one specification and 8.3 in another specification. Notice that our estimates of σ_s and θ_s are such θ_s is sightly larger that $\sigma_s - 1$ throughout. This is consistent with our earlier theoretical assumption that $\theta_s > \sigma_s - 1$ and implies that the sales distribution slightly deviates from Zipf's law. It ensures that the expected profits of entrants are always finite in all industries.

To attenuate possible measurement error in our productivity growth estimation, we take China's productivity growth rates in each year to be the geometric average of the estimated productivity growth rates over all years. These averages are also listed in Table 6 and their distribution is plotted in Figure 1. As can be seen, China's productivity growth rates are large and vary substantially across industries. They range from 7.4 percent to 24.3 percent and average 13.8 percent. Figures 2 and 3 relate these productivity growth rates to China's export-orientation and the trade elasticity θ_s. Most notably, there is no strong correlation visible in either figure which suggests that the spillover effects of China's productivity growth will not be large.

Figure 4 plots the distribution across China's trading partners of the simple average of the predicted annual changes in wages relative to China's wage over all years.[14] The underlying annual wage changes are computed from the extensions of equations (8) and (9) given in the appendix and capture what would have happened to relative wages if nothing but China's productivity had changed. Not surprisingly, all countries' wages are predicted to fall relative to China's wage. The predicted wage adjustments range from -11.0 percent to -10.4 percent and average -10.8 percent. Notice that China's productivity growth slightly exceeds China's relative wage growth on average which indicates that China's trading partners will benefit

[14] Recall that we take "labor" to be a Cobb-Douglas aggregate of capital and labor in our empirical application. As a consequence, changes in "wages" should then also be thought of as changes in Cobb-Douglas aggregates of interest rates and wages. For expositional simplicity, we continue to use the term "wages" in the text.

somewhat through terms-of-trade effects.

The upper panel of Figure 5 plots the simple average of the predicted annual changes in the number of entrants in China over all years against China's estimated productivity growth. The underlying annual changes in the number of entrants in China are again computed from the extensions of equations (8) and (9) given in the appendix and capture what would have happened to the number of entrants in China if nothing but China's productivity had changed. Not surprisingly, the model tends to predict entry into China's fast-growing industries and exit out of China's slow-growing industries. Moreover, the lower panel of Figure 5 illustrates that the extent of entry and exit in China is particularly large in high trade elasticity industries as one intuitively expects.

Table 7 summarizes the predicted welfare effects of China's productivity growth. The first column gives the predicted welfare effects on China, the second and third columns the predicted welfare effects on the "World" and the "Rest of the World" defined as the output share weighted averages of the predicted welfare effects on all countries and all countries other than China, and the last column the ratios of the entries in columns three and two. The predicted welfare effects are computed using the extension of equation (10) given in the appendix and capture what would have happened to welfare if nothing but China's productivity had changed. The last row computes the cumulative effects by taking geometric averages of the annual effects in the previous rows.

As can be seen, China's welfare is predicted to increase by a cumulative 520.5 percent, "World" welfare is predicted to increase by a cumulative 21.18 percent, and "Rest of the World" welfare is predicted to increase by a cumulative 0.634 percent. This implies that only 3.0 percent of the worldwide benefits of China's productivity growth are predicted to spill over to other countries. There are three main reasons for this result. First, there is no strong correlation between China's productivity growth and China's export orientation so that there are no large terms-of-trade effects. Second, there is no strong correlation between China's productivity growth and the trade elasticity θ_s so that there are no large home market effects.

And finally, the share of Chinese imports in total expenditures is still fairly small in most countries even though it has grown fast over time.

Table 8 reports the cumulative spillover effects on all countries and decomposes them into terms-of-trade and home market effects following approximation (11). As can be seen, the welfare effects range from -1.23 percent to 3.64 percent and average 0.29 percent. The decomposition reveals that the terms-of-trade effects are always positive and the home market effects are typically negative. The terms-of-trade effects are always positive despite the slight negative correlation between China's productivity growth and China's export-orientation due to the abovementioned Krugman (1980) intra-industry trade effects. The home market effects are typically negative because of the slight negative correlation between China's productivity growth and the trade elasticity θ_s. Notice that part of the variation in the magnitudes of the spillover effects is simply explained by the variation in the extent of trade integration with China documented in Table 5. For example, the welfare effects on Other Asia are large because of the strong trade integration with China. Similarly, the welfare effects on Brazil are small because of the weak trade integration with China.

Table 9 decomposes the terms-of-trade effects into their bilateral components vis-a-vis China and their multilateral components vis-a-vis all other countries. The former component is the direct effect of China's productivity growth combined with the indirect effect resulting from the adjustments of relative wages vis-a-vis China. The latter component is the indirect effect resulting from the adjustments of relative wages vis-a-vis all other countries. China's productivity growth is often feared to impose strong adverse multilateral terms-of-trade effects on economies whose exports compete directly with Chinese exports in third markets.[15] While our analysis confirms the existence of such adverse effects for some emerging economies like Brazil and Mexico and some manufacturing strongholds like Germany and Japan, it also suggests that their overall welfare implications are rather small.

[15] The analysis of Hanson and Robertson (2010) suggests that fears of adverse terms-of-trade effects are not unjustified in the case of Mexico. Using a gravity model, they estimate the effect of Chinese export growth on the demand for Mexican products in third markets and find adverse effects of up to 4 percent.

4 Conclusion

How does a country's productivity growth affect worldwide real incomes through international trade? In this paper, we took this classic question to the data by measuring the spillover effects of China's productivity growth. Our framework featured traditional terms-of-trade effects and new trade home market effects as suggested by the theoretical literature and worked from a reference point which perfectly matched industry-level trade. Focusing on the years 1995 to 2007, we found that the cumulative welfare effect on individual regions ranged between -1.2 percent and 3.6 percent and only 3.0 percent of the worldwide gains of China's productivity growth accrued to the rest of the world.

Our analysis is only a first pass at this question. Of the many possible extensions, a particularly interesting one would be to let aggregate manufacturing employment respond endogenously to productivity growth. On the one hand, this would dampen relative wage growth in China thereby generating additional terms-of-trade gains for the rest of the world. On the other hand, this would relocate aggregate manufacturing employment to China thereby inflicting additional home market losses on the rest of the world. These counteracting effects may well been quantitatively important in the case of China given the extent of rural-urban migration observed during the sample period.

5 Appendix

As mentioned in footnote (8), we extend our basic framework in two simple ways before taking it to the data. First, we introduce an exogenous trade surplus parameter NX_j along the lines of Eaton and Kortum (2002). This yields the following generalizations of equations (8) - (10):

$$1 = \sum_{s=1}^{S} \quad _{is} \widehat{M}_{is}^{e} \quad _{i} \tag{12}$$

$$\widehat{w}_v = \sum_{j=1}^{N} \frac{\beta_{vjs} \left(\frac{\widehat{w}_v}{\widehat{b}_{vs}} \right)^{-\theta_s}}{\sum_{i=1}^{N} \alpha_{ijs} \widehat{M}_{is}^{e} \left(\frac{\widehat{w}_i}{\widehat{b}_{is}} \right)^{-\theta_s}} \widehat{w}_j \Psi_j \tag{13}$$

$$\widehat{V}_j = \prod_{s=1}^{S} \left(\sum_{i=1}^{N} \alpha_{ijs} \left(\widehat{b}_{is} \frac{\widehat{w}_j}{\widehat{w}_i} \right)^{\theta_s} \widehat{M}_{is}^{e} \Psi_j^{\frac{\theta_s \sigma_s - \sigma_s + 1}{\sigma_s - 1}} \right)^{\frac{\mu_{js}}{\theta_s}} \tag{14}$$

where $\Psi_j \equiv \left(\frac{w_j L_j}{w_j L_j - NX_j} - \frac{NX_j}{w_j L_j - NX_j} \widehat{w}_j^{-1} \right)$ and $\quad _j \equiv \frac{1 - \left(\sum_{s=1}^{S} \frac{\theta_s - \sigma_s + 1}{\theta_s \sigma_s} \mu_{js} \right) \left(1 - \frac{NX_j}{w_j L_j} \right)}{1 - \left(\sum_{s=1}^{S} \frac{\theta_s - \sigma_s + 1}{\theta_s \sigma_s} \mu_{js} \right) \left(1 - \frac{NX_j}{w_j L_j} \right) \Psi_j}$ are adjustment terms which reduce to 1 if $NX_j = 0$. NX_j can be computed from observed industry net exports NX_{is} using the relationship $NX_j \equiv \sum_{s=1}^{S} \frac{(\sigma_s - 1)(\theta_s + 1)}{\theta_s \sigma_s} NX_{js}$.[16]

Second, we relax the implicit assumption that the free entry condition always binds in all countries and industries which results in the prediction of negative entry if zero profits are not compatible with positive production. Specifically, we do not immediately compute the counterfactuals with the actual vector of productivity growths but instead take slowly increasing fractions of it, starting at zero and progressing in one percentage point steps. Whenever the number of entrants is predicted to be less than 1 percent of its original value in a particular country and industry, $\widehat{M}_{is}^{e} < 0.01$, we replace equation (13) for that country and industry with the condition that there is no entry in that country and industry, $\widehat{M}_{is}^{e} = 0$, thereby imposing a corner solution.

[16] The factor $\frac{(\sigma_s - 1)(\theta_s + 1)}{\theta_s \sigma_s}$ is necessary since the model also features endogenous aggregate net exports in general due to the assumption that the fixed cost of exporting are paid in destination country labor which generates international transfers of income.

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6 Tables

TABLE 1: Hypothetical Effect of Chinese Productivity Growth on Relative Wages and Entry

$\widehat{w}_{CH} \square \widehat{w}_{US}$	$\widehat{M}^e_{CH,1}$	$\widehat{M}^e_{CH,2}$	$\widehat{M}^e_{US,1}$	$\widehat{M}^e_{US,2}$
4.1%	21.5%	-21.5%	-22.4%	22.4%

Notes: Entries are predicted growth rates in Chinese wage relative to US wage (column 1), Chinese number of entrants in industry 1 and 2 (columns 2 and 3), and US number of entrants in industry 1 and 2 (columns 4 and 5) from 10% productivity growth in China in industry 1. Simulation assumes that nominal incomes are the same in both countries, industry expenditure shares are 50% in both countries and industries, import expenditure shares are 10% in both countries and industries, theta1=theta2=5, and sigma1=sigma2=3.

TABLE 2: Hypothetical Effect of Chinese Productivity Growth on US Welfare

	Terms-of-trade	+	Home market	$\approx$	Total
$NX_{CH,1} > 0$	0.7%		0.0%		0.8%
$NX_{CH,1} = 0$	0.2%		0.0%		0.4%
$NX_{CH,1} < 0$	-0.3%		0.0%		-0.2%

Notes: Entries are predicted growth rates in US real income due to the terms-of-trade effect (column 1) and the home market effect (column 2) from 10% productivity growth in China in industry 1 following equation (11). Column 3 calculates net welfare gain following equation (10). Simulation assumes that nominal incomes are the same in both countries, industry expenditure shares are 50% in both countries and industries, theta1=theta2=5, and sigma1=sigma2=3. In the first row, China is assumed to have an import expenditure share of 5% in industry 1 and an import expenditure share of 15% in industry 2 with the US being the mirror image so that China is a net exporter in industry 1. In the second row, import expenditure shares are assumed to be 10% in both countries and industries so that there is only intra-industry trade. In the third row, China is assumed to have an import expenditure share of 15% in industry 1 and an import expenditure share of 5% in industry 2 with the US being the mirror image so that China is a net importer in industry 1.

TABLE 3: Hypothetical Effect of Chinese Productivity Growth on US Welfare

	Terms-of-trade	+	Home market	$\approx$	Total
$\theta_1 > \theta_2$	-0.1%		1.0%		1.0%
$\theta_1 = \theta_2$	0.2%		0.0%		0.4%
$\theta_1 < \theta_2$	0.4%		-0.9%		-0.2%

Notes: Entries are predicted growth rates in US real income due to the terms-of-trade effect (column 1) and the home market effect (column 2) from 10% productivity growth in China in industry 1 following equation (11). Column 3 calculates net welfare gain following equation (10). Simulation assumes that nominal incomes are the same in both countries, industry expenditure shares are 50% in both countries, import expenditure shares are 10% in both countries and industries, and sigma1=sigma2=3. In the first row, theta1=7 and theta2=3. In the second row, theta1=5 and theta2=5. In the third row, theta1=3 and theta2=7.

TABLE 4: Share of Imports in Total Expenditure

	1995	2001	2007
United States	15.8%	21.4%	21.8%
Argentina	11.2%	11.7%	19.7%
Brazil	9.1%	15.9%	13.9%
Canada	36.1%	38.4%	40.0%
France	32.0%	38.1%	40.0%
Germany	22.1%	30.3%	33.9%
India	10.7%	11.1%	17.9%
Italy	20.3%	25.6%	28.2%
Japan	4.8%	7.3%	11.5%
Mexico	30.6%	34.5%	31.7%
Russia	-	18.3%	22.4%
United Kingdom	28.1%	30.8%	35.0%
Africa	23.4%	22.1%	31.9%
Other Asia	23.5%	23.0%	23.5%
Other Europe	24.1%	27.8%	28.3%
Other Latin America	20.6%	19.7%	26.1%
Average	20.8%	23.5%	26.6%

Notes: Entries are manufacturing imports/total manufacturing expenditure. We have no trade data for Russia until 1996.

TABLE 5: Share of Chinese Imports in Total Expenditure

	1995	2001	2007
United States	2.3%	3.5%	5.6%
Argentina	0.6%	0.9%	2.7%
Brazil	0.5%	0.6%	1.7%
Canada	1.4%	2.1%	4.6%
France	1.2%	1.8%	3.4%
Germany	1.2%	1.9%	3.5%
India	0.6%	1.0%	4.0%
Italy	0.9%	1.3%	2.8%
Japan	1.1%	2.2%	4.6%
Mexico	0.5%	1.2%	3.9%
Russia	-	1.2%	3.3%
United Kingdom	1.3%	2.5%	4.2%
Africa	1.4%	1.5%	4.7%
Other Asia	2.3%	3.6%	6.8%
Other Europe	1.1%	1.7%	3.5%
Other Latin America	1.0%	1.5%	3.7%
Average	1.1%	1.8%	3.9%

Notes: Entries are manufacturing imports from China/total manufacturing expenditure. We have no trade data for Russia until 1996.

Table 6: Estimated elasticities and productivity growth

	SITC	σ	θ	$\triangle b/b$
Organic chemicals	51	3.1	2.6	9.5%
Inorganic chemicals	52	9.5	9.5	9.1%
Coloring materials	53	3.9	3.7	13.6%
Pharmaceuticals	54	7.8	9.0	22.5%
Cleaning products	55	5.5	5.6	24.3%
Fertilizers	56	11.3	11.0	8.9%
Plastics (primary)	57	17.7	24.0	14.2%
Plastics (non-primary)	58	2.6	2.1	12.2%
Chemical products	59	3.5	3.1	13.0%
Leather manufactures	61	6.8	7.3	9.4%
Rubber manufactures	62	6.1	5.6	12.8%
Wood manufactures	63	3.8	4.0	13.8%
Paper articles	64	5.8	5.9	11.0%
Yarn and fabrics	65	2.7	2.0	7.4%
Mineral manufactures	66	6.3	7.4	15.5%
Iron and steel	67	3.6	2.9	11.8%
Metal manufactures	69	3.5	3.5	13.0%
Power generators	71	3.4	2.5	17.7%
Specialized machinery	72	7.6	8.0	16.3%
Metalworking machinery	73	19.5	22.0	13.5%
Industrial machinery	74	6.1	6.3	18.3%
Office machines	75	1.7	0.8	17.6%
Telecom. equipment	76	2.4	1.4	19.7%
Electrical machinery	77	6.5	6.4	16.1%
Road vehicles	78	5.1	4.7	15.3%
Other transp. equipment	79	15.7	14.9	13.9%
Fixtures and fittings	81	13.9	16.4	13.8%
Furniture	82	5.3	6.0	13.0%
Travel goods	83	14.8	19.9	9.5%
Apparel and clothing	84	8.8	11.1	10.0%
Footwear	85	16.3	16.1	7.4%
Professional instruments	87	6.7	7.1	18.7%
Optical goods	88	8.1	7.9	14.7%
Misc. manufactures	89	7.1	8.1	12.8%
Average	-	7.4	7.9	13.8%

Notes: Entries are short industry descriptions, SITC codes (revision 3), estimated σ_s, estimated θ_s, and the geometric averages of the estimated $\frac{\triangle b_{is}}{b_{is}} = \widehat{b}_{is} \square 1$ over all years.

TABLE 7: Welfare Gains from China's Productivity Growth

	China	World	Rest of World	Share Rest of World
1995	14.4%	0.91%	0.018%	2.0%
1996	14.9%	0.79%	0.025%	3.1%
1997	15.4%	0.79%	0.039%	4.9%
1998	15.5%	1.06%	0.025%	2.4%
1999	15.7%	1.12%	0.025%	2.3%
2000	15.8%	1.25%	0.034%	2.7%
2001	15.5%	1.31%	0.043%	3.3%
2002	15.4%	1.47%	0.054%	3.7%
2003	15.1%	1.56%	0.064%	4.1%
2004	14.9%	1.66%	0.092%	5.5%
2005	14.9%	2.13%	0.061%	2.8%
2006	14.3%	2.47%	0.076%	3.1%
2007	14.1%	2.88%	0.075%	2.6%
1995-2007	520.5%	21.18%	0.634%	3.0%

Notes: Entries are predicted welfare changes from productivity growth in China. World welfare gain is average welfare gain in the world weighted by each country's output share. Rest of World refers to countries other than China. 1995-2007 welfare gain (last row) is cumulative welfare gain from 1995 to 2007.

TABLE 8: Decomposition of Welfare Gains from China's Productivity Growth

	Welfare	≈	Terms-of-trade	+	Home market	=	Sum
United States	0.38%		1.20%		-0.59%		0.61%
Argentina	0.09%		0.34%		-0.21%		0.13%
Brazil	0.18%		0.28%		-0.10%		0.18%
Canada	-0.06%		0.69%		-0.65%		0.04%
France	-1.13%		1.10%		-2.05%		-0.95%
Germany	0.50%		0.64%		-0.18%		0.46%
India	0.55%		0.51%		0.03%		0.54%
Italy	0.11%		0.52%		-0.63%		-0.11%
Japan	1.30%		0.40%		0.99%		1.39%
Mexico	0.24%		0.82%		-0.51%		0.31%
Russia	-1.23%		1.12%		-1.91%		-0.79%
United Kingdom	0.04%		0.64%		-0.50%		0.14%
Africa	-0.25%		0.44%		-0.50%		-0.06%
Other Asia	3.64%		1.34%		2.61%		3.95%
Other Europe	0.27%		0.53%		-0.20%		0.33%
Other Latin America	0.07%		0.29%		-0.15%		0.14%
Average	0.29%		0.68%		-0.28%		0.40%

Notes: Entries are cumulative effects from 1995 to 2007 from China's productivity growth. Column 1 gives net welfare gain following equation (10), columns 2-3 the terms-of-trade effects and home market effects following equation (11), and column 4 the sum of columns 2-3. We have no trade data for Russia until 1996 so that all entries for Russia refer to the years 1996 to 2007 only.

TABLE 9: Decomposition of Terms-of-Trade Effects from China's Productivity Growth

	Terms-of-trade	=	Bilateral	+	Multilateral
United States	1.20%		1.18%		0.02%
Argentina	0.34%		0.32%		0.02%
Brazil	0.28%		0.33%		-0.05%
Canada	0.69%		0.62%		0.07%
France	1.10%		0.61%		0.49%
Germany	0.64%		0.71%		-0.07%
India	0.51%		0.55%		-0.04%
Italy	0.52%		0.26%		0.26%
Japan	0.40%		0.48%		-0.08%
Mexico	0.82%		0.86%		-0.04%
Russia	1.12%		0.01%		1.11%
United Kingdom	0.64%		0.59%		0.05%
Africa	0.44%		0.37%		0.07%
Other Asia	1.34%		1.40%		-0.06%
Other Europe	0.53%		0.59%		-0.06%
Other Latin America	0.29%		0.29%		0.00%
Average	0.68%		0.57%		0.11%

Notes: Entries are cumulative effects from 1995 to 2007 from China's productivity growth. Column 1 gives the terms-of-trade effect following equation (11). Columns 2 and 3 decompose this into the bilateral terms-of-trade effect vis-a-vis China and the multilateral terms-of-trade effect vis-a-vis all countries other than China. We have no trade data for Russia until 1996 so that all entries for Russia refer to the years 1996 to 2007 only.

7 Figures

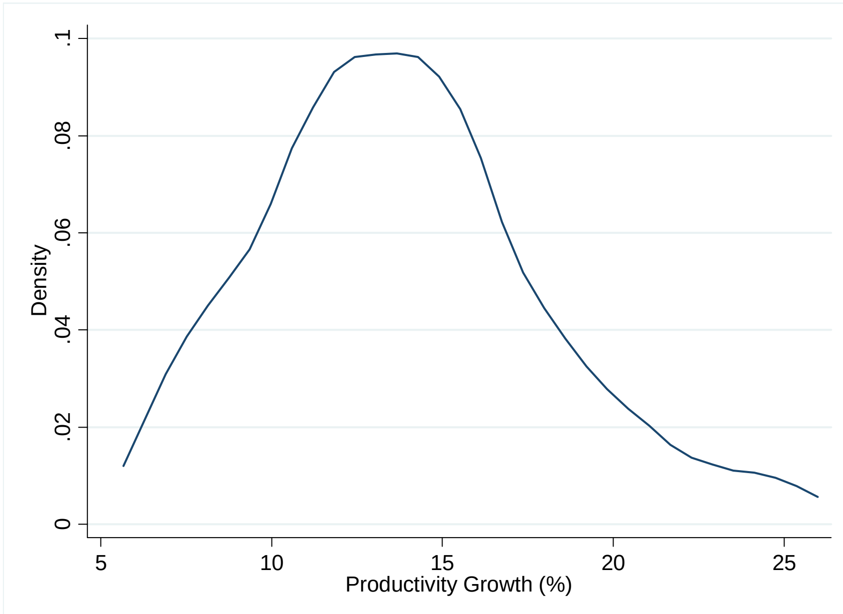

Figure 1: Distribution of productivity growth across manufacturing industries in China

Notes: This is a kernel density plot of the geometric average of the estimated annual productivity growth rates from 1995 to 2007 across manufacturing industries in China.

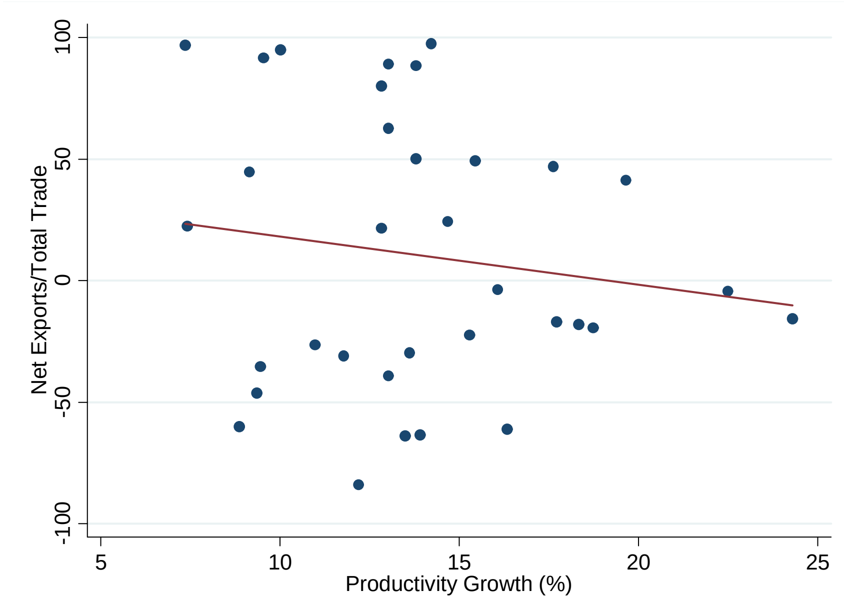

Figure 2: Industry productivity growth and industry net exports in China

Notes: This figure plots the relationship between industry productivity growth and normalized industry net exports in China. Productivity growth is computed as in Figure 1. Industry net exports are computed as the simple average of industry net exports from 1995-2007. Total trade is computed as the simple average of the sum of exports and imports from 1995-2007. The line is a linear regression line.

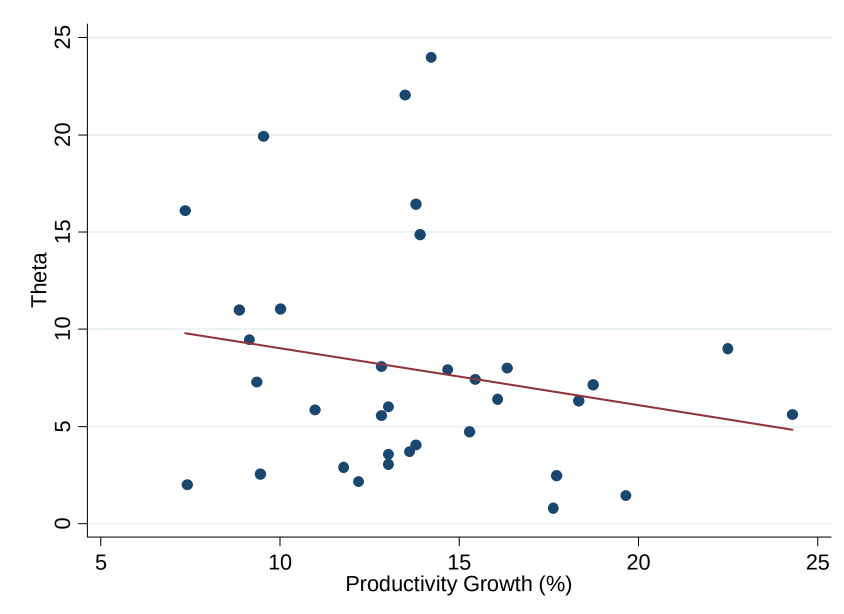

Figure 3: Industry productivity growth and industry trade elasticities in China

Notes: This figure plots the relationship between industry productivity growth and industry trade elasticities in China. Productivity growth is computed as in Figure 1. The line is a linear regression line.

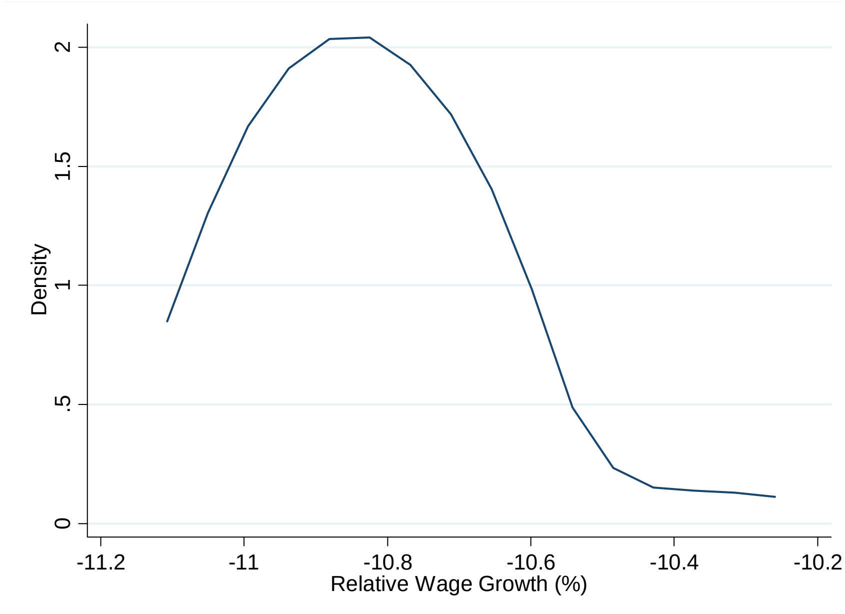

Figure 4: Distribution of predicted changes in wages relative to China's wage

Notes: This is a kernel density plot of the simple average of the predicted annual changes in wages relative to China's wage from 1995 to 2007 across China's trading partners.

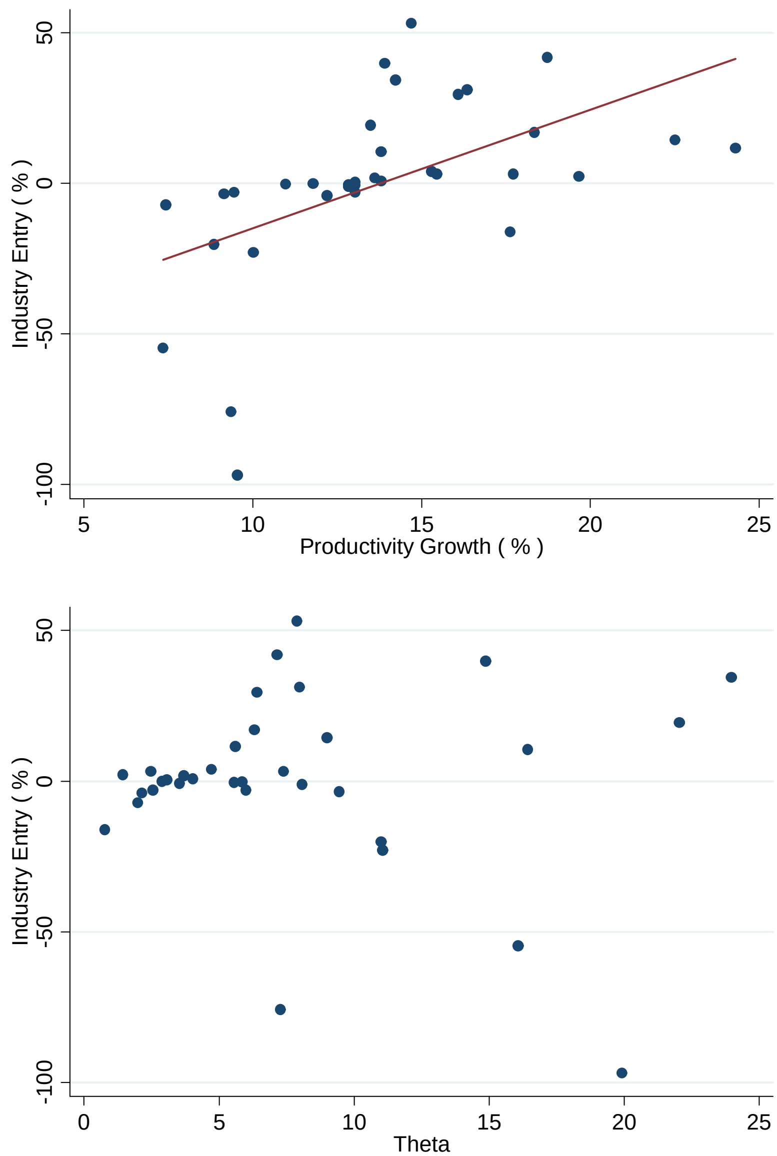

Figure 5: Industry entry and industry productivity growth/trade elasticities in China

Notes: The upper panel plots the relationship between industry productivity growth and industry entry in China. The lower panels plots the relationship between industry trade elasticities and industry entry in China. Productivity growth is computed as in Figure 1. Industry entry is computed as the simple average of the predicted annual changes in the number of industry entrants from 1995-2007. The line is a linear regression line.