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Spillover Effects of Exchange Rates: A Study of the Renminbi

Aaditya Mattoo, Prachi Mishra, and Arvind Subramanian

Abstract

This paper estimates the impact of China's exchange rate changes on exports of competitor countries in third markets, which we call the "spillover effect." We use recent theory to develop an identification strategy in which competition between China and its developing country competitors in specific products and destinations plays a key role. We exploit the variation—afforded by disaggregated trade data—across exporters, importers, product, and time to estimate this spillover effect. We find robust evidence of a statistically and quantitatively significant spillover effect. Our estimates suggest that, on average, a 10 percent appreciation of China's real exchange rate boosts a developing country's exports of a typical 4-digit Harmonized System (HS) product category to third markets by about 1.5 to 2 percent. The magnitude of the spillover effect varies systematically with product characteristics as implied by theory.

Keywords: exchange rates, exports, China, spillover

JEL codes: F13, F14, O53

Aaditya Mattoo works with the Development Economics Research Group, World Bank. Email: amattoo@worldbank.org. **Prachi Mishra** works in the Research Department of the International Monetary Fund. Email: pmishra@imf.org. **Arvind Subramanian** is an economist at the Peterson Institute for International Economics. Email: asubramanian@piie.com.

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Peterson Institute for International Economics

1750 Massachusetts Avenue, NW Washington, DC 20036-1903
Tel: (202) 328-9000 Fax: (202) 659-3225 www.piie.com

INTRODUCTION

Studying the effects of exchange rates is a hardy perennial of international macroeconomics. But nearly all the empirical research is focused on the impact of exchange rate changes on the country experiencing or undertaking them.[1] There is less evidence quantifying the effect of exchange rate movements on the exports of competitor countries, a classic case of spillover that in its adverse manifestation is dubbed the "beggar-thy-neighbor" effect.

This paper examines the spillover effect of movements in China's exchange rate on exports of other developing countries in third country markets. The Chinese currency provides a suitable opportunity to study the spillover dimension for three reasons. China, by virtue of being the world's largest exporter of goods, is likely to have quantitatively more significant competitive consequences for other countries than nearly any other exporter. Second, China is also a highly diversified exporter so that it potentially competes with a broad range of countries and across the product spectrum. Finally, reflecting China's dominant size and encompassing scope, its exchange rate policy has been one of the most controversial aspects of international macroeconomics during the 2000s. More recently, it has been in the spotlight because of the consequences of a possibly undervalued renminbi on demand and output in industrial countries, experiencing high unemployment and excess capacity.

The spillover effect is estimated with the help of highly disaggregated trade data which facilitates the use of a novel methodology to exploit the variation across exporters, importers, products, and time. We use disaggregated trade data at the 6-digit level spanning 124 developing country exporters and 57 large importers over the period 2000–08. Our empirical approach is motivated by an analytical framework that we develop based on Feenstra, Obstfeld, and Russ (2011). The framework suggests an identification strategy that relies on the following reasoning: The more a country competes with China in a third market, the more a given depreciation of the renminbi is likely to hurt its exports in that market. We develop indices of competition between China and its competing exporting countries at the exporter-importer-product level to implement this strategy. The empirical specification, with a battery of very general fixed effects that control for all observable and unobservable importer-exporter-product, importer-exporter-time, exporter-product-time, and importer-product-time varying characteristics, helps us overcome to a large extent the problems of omitted variables that plague estimation of trade-exchange rate equations using aggregated data. Moreover, our estimates are less susceptible to reverse causality concerns, as exports, measured at a disaggregated level are

1. This is generally true of the older, voluminous literature on the trade consequences of exchange rates (Goldstein and Khan (1985) provide a survey and other contributions include Hooper, Johnson, and Marquez (2000) and Thursby and Thursby (1987)). It is also true of the more recent micro-literature on trade and exchange rates (Dekle and Ryoo (2007); Das, Roberts, and Tybout (2001); Forbes (2002); Berman, Martin, and Mayer (2012)). It is also a characteristic of the recent literature on the growth consequences of exchange rates (Dooley, Folkerts-Landau, and Garber (2003); Rodrik (2008); and Johnson, Ostry, and Subramanian (2010)).

unlikely to affect a macroeconomic variable like the exchange rate—more so when the latter is the exchange rate of another country, China.[2]

We find robust evidence for the existence of a statistically and economically significant spillover effect. In particular, exports to third markets of countries with a greater degree of competition with China tend to rise and fall significantly more as the renminbi appreciates and depreciates. Our estimates suggest that a 10 percent appreciation of the renminbi increases a developing country's exports at the product-level on average by about 1.5 to 2 percent. For high indices of competition, the increase could be as large as 6 percent. The results imply that going forward, an appreciation of the renminbi could provide a substantial boost to developing country exports. Our spillover estimates are robust to a variety of statistical tests, to alternative measures of exchange rates, to alternative disaggregation of the trade data, and also across exporting and importing regions. They are also robust to incorporating the effect of competition from countries (other than China) whose currencies move with the renminbi.

We also find that the magnitude of the spillover effect is consistent with the predictions from the analytical framework. For example, as implied by theory, the spillover effect is greater for homogenous products with greater substitution possibilities than differentiated products. Further, the spillover effect is attenuated for products that rely more on foreign inputs (and hence have a lower degree of Chinese domestic value added).

A few recent studies examine the effects of China's export performance on other Asian countries but do not focus on exchange rates (Hanson and Robertson 2008, Eichengreen, Rhee, and Tong 2004, and Ahearne et al 2003; the latter two use an augmented gravity framework and find some evidence of Chinese exports crowding out other Asian exports). A few other papers examine the impact of exchange rate changes but on variables other than trade.[3] For example, Eichengreen and Tong (2011) have recently estimated the effect of renminbi revaluation on stock market valuations of foreign firms.[4] There is no study so far on the effect of exchange rate changes on exports of other countries, even though this has been a central international concern going back to Robinson (1947) and the experience of the competitive devaluations prior to and during the Great Depression.

ANALYTICAL FRAMEWORK

In order to develop an analytical framework for our empirical exercise, we use the model in Feenstra, Obstfeld, and Russ (2011). The setting is as follows. There are j countries, and g different goods. Each country produces a range of distinct varieties of each good. There is a constant elasticity of substitution (η) consumption index for the representative consumer in country j. Goods are differentiated not only by their

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2. See Engel (2009) for a discussion of how hard it is econometrically to separate out the effect of exchange rates on trade.
3. Yet another strand in the China-related literature has been to explain the determinants of China's real exchange rate (Wei and Zhang 2011).
4. Eichengreen and Tong (2011) find that renminbi appreciation has a positive effect on stock prices of firms in sectors competing with China, which is consistent with the findings in this paper.

characteristics, also by their country of origin (Armington assumption), with a constant elasticity of substitution between domestically produced and foreign varieties of good g (ω_g), and a constant elasticity of substitution between different varieties of good g originating in different exporters (σ_g). The same elasticity applies to different varieties of good g produced domestically.

Feenstra, Obstfeld, and Russ (2011) show that we can express country j's imports from country i (equivalent to exports of country i to country j) of a particular good g, defined at the Harmonized System (HS) 6-digit level, V_g^{ij}, as follows (equation 11 in their paper).

$$(1)\quad V_g^{ij} = \left[\kappa_g^{ij}\left(\frac{P_g^{ij}}{P_g^{Fj}}\right)^{1-\sigma_g}\right] * \left[\left(1-\beta_g^{j}\right) * \left(\frac{P_g^{Fj}}{P_g^{j}}\right)^{1-\omega_g}\right] * \left[\alpha_g^{j}\left(\frac{P_g^{j}}{P^{j}}\right)^{1-\eta}\right] P_j C_j$$

That is, the proportion import demand (V_g^{ij}) of total consumption in $P_j C_j$, depends on three sets of components:[5]

- the preference weight consumers in j attach to imports of good g from country i, κ_g^{ij}; the price of g imports by j from i, P_g^{ij}, relative to the price index of all g imports, P_g^{Fj}; and the elasticity of substitution between imported varieties of g, σ_g;
- the preference weight consumers in j attach to domestically produced units of good g, β_g^j; the price index of all g imports by j, P_g^{Fj}, relative to the domestic price of good g, P_g^j; and the elasticity of substitution between the home and foreign varieties of good g, ω_g;
- the preference weight consumers in j attach to consumption of the g good, α_g^j; the price index of the g good, P_g^j, relative to the price index of all goods in j, P^j; and the elasticity of substitution between different goods, η.

We first establish the effect of a change in China's exchange rate changes vis-à-vis country j, E^{cj}, on country j's imports of a particular good g from country i, V_g^{ij}—what we define as the "spillover effect." We can express this as a chain effect, consisting of the effects of: the change in the Chinese exchange rate on the price of the Chinese good, the change in the price of the Chinese good on the foreign price index, and the change in the foreign price index on demand for good g from country i:

$$(2)\qquad \frac{\partial \ln V_g^{ij}}{\partial \ln E^{cj}} = \frac{\partial \ln P_g^{cj}}{\partial E^{cj}} * \frac{\partial \ln P_g^{Fj}}{\partial \ln P_g^{cj}} * \frac{\partial \ln V_g^{ij}}{\partial \ln P_g^{Fj}}$$

Now consider each term in the chain starting from the third term. Taking logs of equation 1 and differentiating with respect to P_g^{Fj} under the assumption that a change in P_g^{Fj} has a negligible effect on the aggregate price index for good g in country j (P_g^j), we get:[6]

5. Note that we use imports and exports interchangeably throughout this paper, based on the simple identity that imports of a country A from another country, say, B are exactly the exports of B to A. In the empirical section, we use data reported by importing countries, which is generally regarded as more reliable than export data.

(3) $$\frac{\partial \ln V_g^{ij}}{\partial \ln P_g^{Fj}} = \sigma_g - \omega_g$$

This implies that the elasticity of demand for imports of good g from country i with respect to the foreign price index is simply the difference between the elasticity of substitution between imported varieties of g, σ_g, and the elasticity of substitution between home and foreign varieties, ω_g.

From Feenstra, Obstfeld, and Russ (2011), we have the price index for imported goods, P_g^{Fj}, (their equation 5):

(4) $$P_g^{Fj} = \left[\sum_{\substack{i=1 \\ i\neq j}}^{J} \kappa_g^{ij} \left(P_g^{ij}\right)^{1-\sigma_g}\right]^{\frac{1}{1-\sigma_g}}$$

Taking logs, differentiating with respect to the price of the Chinese good g in the j market, P_g^{cj}, and simplifying, we get:

(5) $$\frac{\partial \ln P_g^{Fj}}{\partial \ln P_g^{cj}} = \frac{\kappa^{cj}(P^{cj})^{1-\sigma_g}}{\sum_{\substack{i=1 \\ i\neq j}}^{J} \kappa_g^{ij}(P_g^{ij})^{1-\sigma_g}} = s_g^{cj}$$

This implies that the elasticity of the foreign price index for good g with respect to the price of the Chinese good g is equal to the expenditure on the Chinese good as a share of expenditure on all imports of g, s_g^{cj}.

We assume that the price of the Chinese good in the j market, P_g^{cj}, depends on the price in China, P_g^c, the exchange rate, E^{cj} (defined in renminbi/importer currency), and an exponent which captures the extent of product-specific exchange rate pass-through from prices in China to j, μ_g^{cj}.

(6) $$P_g^{cj} = P_g^c (1/E^{cj})^{\mu_g^{cj}}$$

Differentiating with respect to the exchange rate, E^{cj}, we have:

(7) $$\frac{\partial \ln P_g^{cj}}{\partial \ln E^{cj}} = -\mu_g^{cj}$$

Substituting from equations 3, 5, and 7 in equation 2, we get:

(8) $$\frac{\partial \ln V_g^{ij}}{\partial \ln E^{cj}} = -(\sigma_g - \omega_g) s_g^{cj} \mu_g^{cj}$$

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6. This is an innocuous assumption from the empirical perspective because any additional terms—for example aggregate destination-specific prices—will be absorbed in the very general fixed effects.

Equation 8 implies that a change in the Chinese exchange rate will have a non-zero effect on import demand for good g only if (1) the elasticity of substitution across imported varieties is different from that between imported and domestic varieties, (2) Chinese share in total imports of that good is strictly positive, and (3) the exchange rate pass-through is non-zero.[7]

Given our assumption regarding the symmetric elasticity of substitution between imported varieties, σ_g, the effect of a change in China's exchange rate changes vis-à-vis country j, E^{cj}, on country j's imports of a good g from country i, V_g^{ij}, does not depend on any exporter attribute. This makes equation 8 less amenable to empirical analysis. For example, if in order to test the prediction in equation 8, we were to regress the import demand at the exporter-importer-product level on the Chinese exchange rate vis-à-vis the importing country, we would not be able to include destination country fixed effects. We could, of course, strive to include all the relevant destination country attributes explicitly, but the effect of the exchange rate would not be estimated precisely because we would inevitably fail to control for certain unobserved sources of variation at the destination country (or destination-year) level.

One way to have such more general controls is to introduce more variation—for example, across exporters—in the right hand side of equation 8. This would allow importer demand at the exporter-importer-product level to be regressed on a term that had all three sources of variation, which in turn would allow the inclusion of general fixed effects in the regression. To find such variation across exporters, we consider country j's imports, V_p^{ij}, from country i of a particular bundle of goods p, defined at a higher level of aggregation. In our empirical analysis, we use trade data at the HS 6-digit level. Therefore g is defined at the HS 6-digit level. Country j's imports of p (at, say, the HS 4-digit level) can be expressed as:

$$V_p^{ij} = \sum_{g=1}^{G} V_g^{ij} \tag{9}$$

G denotes the number of HS 6-digit lines in the product category p. Taking logs and differentiating with respect to the exchange rate, E^{cj} and simplifying we get[8]

$$\frac{\partial \ln V_p^{ij}}{\partial \ln E^{cj}} = -\sum_{g=1}^{G} \left(\frac{V_g^{ij}}{\sum_g V_g^{ij}}\right) s_g^{cj} \mu_g^{cj} (\sigma_g - \omega_g) \tag{10}$$

This equation is intuitive because it captures the interplay between two ingredients that together determine the spillover effect of China's exchange rate: the first is the relative importance of China as a source of imports of a good in the importing country, s_g^{cj}; the second is the relative importance of that good $\left(\frac{V_g^{ij}}{\sum_g V_g^{ij}}\right)$ in the exports of the competitor country. More formally, the elasticity of, say, Brazil's exports to j at

7. Note that in Broda and Weinstein (2006), $\sigma_g = \omega_g$, i.e., the elasticities of substitution between imported varieties equals the elasticity of substitution between home and foreign varieties. In our framework, if $\sigma_g = \omega_g$, in response to a renminbi depreciation, consumers in country j reduce their demand for varieties of good g produced at home and hence there is no spillover effect.

8. See the appendix for the intermediate steps in deriving equation 10.

the HS 4-digit category with respect to China's exchange rate vis-à-vis j is related to the weighted average of China's share in total imports in each constituent 6-digit category which Brazil exports, where the weights are Brazil's exports in the corresponding 6-digit category as a share of its total exports in the 4-digit category.

Further, we also assume that the elasticities of substitution and the pass-through are constant for all 6-digit lines within the relevant 4-digit category, i.e., $\mu_g^{Cj} = \mu_p^{Cj}$, $\sigma_g - \omega_g = \sigma_p - \omega_p$. Then equation 10 can be rewritten to give us an expression for the spillover effect, $\frac{\partial \ln V_p^{ij}}{\partial \ln E^{cj}}$,

$$(11) \qquad \frac{\partial \ln V_p^{ij}}{\partial \ln E^{cj}} = I_{ijp}^V * [-\mu_p^{Cj} * (\sigma_p - \omega_p)]$$

where $I_{ijp}^V = \sum_{g=1}^{G} [(\frac{V_g^{ij}}{V_p^{ij}}) * s_g^{Cj}]$ is what we call the value-based index of competition (VBI) with China for good g exported from i to j. For example, if the HS 4-digit category, shirts, consisted of only two items, cotton shirts and non-cotton shirts, then our measure is simply the share of China in country j's imports of each type of shirt, weighted by the importance of each type of shirt in country i's shirt exports to j. Equation 11 suggests that the elasticity of exports of a typical product to the importing country depends on: the index of competition; the two elasticities of substitution, σ and ω; and the extent of pass-through, μ.

Under some additional symmetry assumptions, we can also compute an alternative index of competition where we rely on the overlap between China's exports and those of country i, at the extensive margin. We first assume that for each 6-digit category that i exports to j within a 4-digit category, it exports the same amount. If i exports N_p^{ij} 6-digit categories in the relevant 4-digit category to j, then the first term in equation 10 simplifies to $1 / N_p^{ij}$. Next assume that in each 6 digit category within the relevant 4-digit category where i exports to j, China exports either a fixed share, s_p^{Cj} or nothing. $s_g^{Cj} = s_p^{Cj}$ for $N_{p,Ch}^{ij}$ lines or zero otherwise. Then summing the second ratio over the relevant 6 digit lines gives us $s_p^{Cj} * N_{p,Ch}^{ij}$. As above, we also assume that the elasticities of substitution and the pass-through are constant for all 6-digit lines within the relevant four digit category, i.e., $\mu_g^{Cj} = \mu_p^{Cj}$, $\sigma_g - \omega_g = \sigma_p - \omega_p$.

So that in this special case, equation 11 can be written as:

$$(12) \qquad \frac{\partial \ln V_p^{ij}}{\partial \ln E^{cj}} = I_{ijp}^C * [-s_p^{Cj} * \mu_p^{Cj} * (\sigma_p - \omega_p)]$$

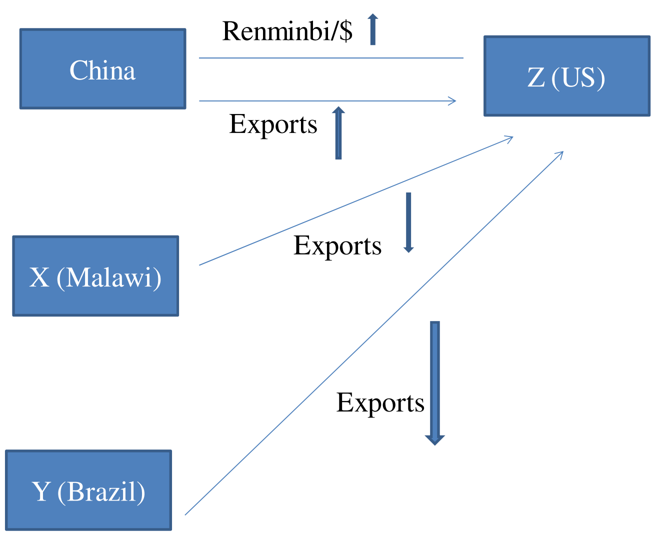
where $I_{ijp}^C = \frac{N_{p,Ch}^{ij}}{N_p^{ij}}$ is what we call the "count-based index" (CBI) of competition. The notion of competition in the CBI is based on whether or not China and its competitor commonly export a particular good (the extensive margin), and unlike the VBI, ignores the magnitudes of exports.

ESTIMATION STRATEGY

Equations 11 and 12 motivate the estimation of the spillover effect. They imply two key predictions which we can take to the data: (1) spillover effect is less than or equal to zero and (2) the magnitude of this effect depends on the index of competition between China and its competing exporters. Higher is the degree of competition, larger is the magnitude of the spillover effect.

Our identification strategy relies on the following intuition. Take two countries, Malawi and Brazil. Assume that Brazil faces a greater degree of competition with China in the US market for a particular product. When the renminbi depreciates vis-à-vis the US dollar, exports from Brazil to the United States for that product will fall more than exports from Malawi to the United States (figure 1).

Figure1 Identification strategy



Source: Author's calculations.

This identification strategy yields the following estimating equation:

$$(13) \qquad \ln V_{ijpt} = \beta I_{ijp} * \ln E_{jt} + v_{jpt} + s_{ipt} + \gamma_{ijt} + \theta_{ijp} + \epsilon_{ijpt}$$

where V_{ijpt} is the value of exports of HS 4-digit product p from country i to country j. E_{jt} is the Chinese exchange rate vis-à-vis j measured in renminbi per unit of j's currency. I_{ijp} is an index of competition between Chinese exports and those of its competitors as described in the analytical section. Note that the index does not have a time subscript which we explain below. The interaction term combines the exchange rate between China and the importing country (say the renminbi-dollar exchange rate) and the index of competition between the exporter and China in the importing country.

Econometrically, an advantage of the formulation in equation 13 is that we can control for a wide range of omitted variables through a set of very general fixed effects. In fact, in our core estimations, we employ all three-way combinations of importer, exporter, product, and time fixed effects. The term v_{jpt} captures any importer, product, and time varying characteristics: One example would be fiscal support for the car industry in the United States. Similarly, the term s_{ipt} captures any exporter, product, and time-varying characteristics; for example, a productivity shock in Bangladesh that helped textile exports. Note that these fixed effects also encompass all country-time shocks both on the importer and exporter side such as the business cycle in each country. The term γ_{ijt} captures any bilateral time-varying determinants of exports: for example, currency unions, and exchange rate pegs against particular currencies. The term θ_{ijp} captures bilateral product-specific characteristics: for example, all pre-existing preferential trade agreements that have product-specific tariffs and other barriers. The only factors that are not controlled for are policies of the importing country that vary by source country and product and time (for example, changes over time in product-specific preferential tariffs).[9] Finally, it is worth noting that our estimation strategy also controls for any possible effect on competitor countries stemming from productivity or other developments in China, whether exogenous or induced by exchange rates: If these are time-varying and product-specific, they will be absorbed in the s_{ipt} and v_{jpt} fixed effects.

Furthermore, our estimating equation is less susceptible to reverse causality from exports to exchange rates for two reasons: Our dependent variable, disaggregated exports, is less likely to affect a macroeconomic variable like the exchange rate; moreover, the latter is the exchange rate of another country. What about reverse causality from the exports to the index of competition? Our count-based index, while derived from theory under symmetry assumptions, has the empirical virtue of being based on the extensive margin and not being measured in value terms; hence being less related to the left hand side variable and less afflicted by reverse causality problem. Our value-based index is potentially more vulnerable to the reverse causality problem because it is expressed in values, like the dependent variable. To minimize such endogeneity concerns, we compute both indices for the initial period of the sample (i.e., for the year 2000).

DATA

We focus on the period 2000–08, during which concerns about China's exchange rate policy have been most debated. For this period, we compile disaggregated data on bilateral exports from the UN Comtrade database. We collect data reported by the importing countries, which is generally regarded as more reliable than data on exports (i.e., exports from i to j are measured by imports of j from i). The data are for roughly 6000 non-oil HS 6-digit lines covering 900 4-digit products. We cover the 57 major importing countries (making sure that we include all countries that together accounted for over 95 percent of total exports of developing countries) and 124 developing country exporters which are potentially in competition with China (summary statistics are provided in appendix table 1 and the list of importing and exporting countries covered in appendix table 2).[10] The list of developing countries is based on World Bank country classification, and is comprised of all low and middle income countries (2010 GNI per capita of $12,275 or less).

9. The lack of a comprehensive database on trade policies at the importer-exporter-product-time level makes it difficult to control for such effects.
10. In principle, we could include all exporting countries in our sample. We choose to restrict the analysis to developing country exporters, largely due to computational constraints. However, this restricted choice also stems from the fact that

The trade data are reported in current US dollars, and are deflated by the US Consumer Price Index (CPI). We recognize that ideally we would use bilateral price indices to deflate trade between different country pairs but such bilateral deflators are not available. However, the presence of the very general fixed effects has the consequence also of implicitly deflating the trade data. The data are implicitly deflated by prices that vary by importer, product, and time; by importer, product, and exporter; and by exporter, product, and time. They are, however, not deflated by prices that vary along all four dimensions (importer, exporter, product, and time).

Exchange rate data are from the International Monetary Fund's (IMF's) International Financial Statistics (IFS) database. In the theoretical framework, the key price that determines the transmission mechanism of exchange rate changes is the price in the importing market charged by Chinese exporters. Equation 6 suggests that this price is determined by the domestic price of the good in China, the China-importer bilateral exchange rate and the pass-through. Since we parameterize the pass-through, the relevant changes to focus on are those stemming from changes in domestic prices in China and the exchange rate. Hence, our bilateral exchange rate is deflated by China's CPI.

Before we present the econometric results, it is worth looking at some basic data. Figure 2 plots China's average index of competition (where the average is over all exporters and products). The index is measured in two ways consistent with the discussion in the analytical section. Both the VBI and the CBI rise over time, consistent with China becoming a bigger and more diverse exporter. The CBI shows in particular that by 2008, on average, China occupied nearly all the product space of other developing country exporters. Figures 3a and 3b plot the same indices but disaggregated by region. These charts show that China's overlap with all regions has risen steadily over time, with the level of the overlap greatest with other exporters in Asia (over 95 percent in 2008 for the CBI), and least with Europe and Central Asia.

RESULTS

Main Findings and Robustness

All results are presented for both variations of our competition index. In table 1, we present the baseline results. Our core sample has nearly 3.6 million observations. Columns 1 through 4 use the value-based index while columns 5 through 8 use the count-based index. In both cases, the number of fixed effects progressively increase across the specifications, with a comprehensive set of fixed effects in columns 4 and 8, making the specification a very demanding one. These will constitute our core specifications. All regressions are clustered at the importer-exporter-product level.

We find that the coefficient on the interaction term between the Chinese exchange rate and the index of competition is consistently negative and significant at the 1 percent confidence level. In other words, a depreciation of the Chinese exchange rate vis-à-vis, say, the dollar, is associated with a greater reduction in a

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developing countries compete more with China than industrial countries do: The average index of competition between the former set and China is about 0.4 and 0.9, respectively for the value-based and count-based indices of competition. The corresponding numbers for industrial countries are 0.1 and 0.7, respectively.

developing country's exports of a particular product to the United States, the more that country is in competition with China in that product in the United States.

We subject this core specification to a series of robustness checks in table 2 through table 6. In table 2, column 1, we drop outliers, defined as the top and bottom 1 percentile of observations. The key coefficient is negative and statistically significant with the magnitudes close to those for the larger core sample. In column 2 through column 4, we cluster the standard errors at the exporter-importer-year, exporter-product-year, and importer-product year levels, and the statistical significance of the coefficients remain unchanged.[11]

Our core specification uses annual data. To test whether the results hold for the medium run, we use a long difference approach suggested by Acemoglu and Johnson (2007). Thus, in column 5, we use observations only for 2000 and 2008 and find that the results remain similar to the baseline, with the magnitude of the interaction coefficient increasing by a little. In columns 6 and 7, to make sure that the results are not driven by the choice of year for measuring the index of competition, we measure the index for the years 2001 and 2002, respectively. In column 8, we use an alternative measure of competition—the export similarity index due to Finger and Kreinin (1979).[12] Thus, for a wide range of robustness tests, the core results remain unaltered, both in the sense that the coefficients are stable and consistently significant at the 1 percent confidence level.

In table 3, we test for robustness to alternative measures of the exchange rate variable. In our analytical framework, we assumed that the price of Chinese goods in the importing country market is determined by a simple relationship between domestic prices in China and exchange rate pass-through. Based on the framework, in our core specifications we deflate the nominal bilateral exchange rate (between China and the

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11. Clustering the standard errors at a higher level of aggregation (importer-exporter, importer-product, or exporter-product) also does not alter the significance of our findings.

12. The Finger-Kreinin index can be expressed as: $FK_{ijpt} = \Sigma g \min[\frac{X_{ijgt}}{\sum_g X_{ijgt}}, \frac{X_{Cjgt}}{\sum_g X_{Cjgt}}]$

where $\frac{X_{ijgt}}{\sum_g X_{ijgt}}$ = Share of product g in total exports from i to j at the 4 - digit level

$\frac{X_{Cjgt}}{\sum_g X_{Cjgt}}$ = Share of product g in total exports from China to j at the 4 - digit level.

The results are also robust to using the alternative formulation of the Finger-Kreinin Index defined as

$$FK_{ijpt} = 1 - \frac{1}{2}\sum_g \left|\frac{X_{ijgt}}{\sum_g X_{ijgt}} - \frac{X_{Cjgt}}{\sum_g X_{Cjgt}}\right|$$

and the weighted Finger-Krenin Index defined as

$$WFK_{ijpt} = \sum_g \frac{X_{ijgt}}{\sum_k X_{ijgt}} * [1 - \frac{X_{ijgt} - X_{Cjgt}}{X_{ijgt} + X_{Cjgt}}]$$

importing country) by Chinese prices. The implicit assumption here is that Chinese producers take account of changes in the bilateral exchange rate and average domestic inflation to determine export prices. However, there could be alternative ways Chinese producers and exporters determine their destination-specific export prices. Chinese producers could be influenced just by the nominal bilateral exchange rate (E_{jt}) or by the real bilateral exchange rate ($E_{jt} * P_{jt}/P_t^C$), with P_{jt} and P_t^C denoting prices in importing country and China respectively. The specifications corresponding to these two ways of measuring the exchange rate are in columns 1 and 2 (for the VBI) and columns 6 and 7 (for the CBI). In both cases, the results are robust, although the magnitudes decline relative to the core specification.

Yet other models of pricing behavior could involve Chinese producers looking at changes in their multilateral competitiveness in determining destination-specific export prices. In this case, the relevant exchange rate is not destination specific but a multilateral one that is identical across all importers (ME_t) where ME stands for China's multilateral exchange rate and hence without a j subscript).[13] We reestimate the core regression to cater to these possibilities by using the IMF's effective exchange rate as the relevant measure with the nominal rate in columns 3 and 8, and the real rate in columns 4 and 9. Again, the coefficients are correctly signed and significant at the 1 percent confidence level. Interestingly, these coefficients are substantially greater than for the core specification.

In all these specifications, exchange rates are measured as the relative price of two different currencies. An alternative way of measuring real exchange rates—sometimes called the internal real exchange rate—is as the relative price of tradables to non-tradables within a country. This exchange rate is available from the Penn World Tables from the series that measures the price level of GDP.[14] In columns 5 and 10, we use this measure of China's real exchange rate. Again, we find that the coefficient on the interaction term is significant at the 1 percent level, and is greater in magnitude than in the core specification.[15]

One potential omitted variable issue arises in regard to our core specification. Our finding that the typical developing country's exports are adversely affected when China's currency depreciates has not yet addressed an important question: What if other countries respond to China's depreciation by devaluing their own currencies? In table 4, we control for this possibility. Among the developing countries which are the top exporters, we identify those whose currencies are most closely correlated with that of China (in real terms) during the period 2000–08.[16] We interact the exchange rates of each of these countries with the respective

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13. Note that in this case, the exchange rate varies across time and the index varies across importer, exporter, and product so that the interaction term exploits the variation across all four dimensions.
14. A higher price level is associated with a higher price of non-tradables and hence signifies an appreciation of the real exchange rate (see Rogoff 1996). This exchange rate variable, like the IMF's nominal and effective exchange rate series, is a multilateral variable, and hence varies only by time and not across importers.
15. Note that an increase in all the effective exchange rate measures in columns 3 through 5, and 8 through 10 denotes an appreciation (unlike in columns 1 and 2, and 6 and 7, and our baseline exchange rate measures in tables 1 and 2). Hence, a positive coefficient on the interaction terms in these columns is consistent with our main findings.
16. We include the top 10 exporters (after China) based on total exports between 2000 and 2008. Developing countries' index of competition with other non-significant exporters is likely to be much smaller, and hence exchange rate movements in these countries is less likely to displace exports of other developing countries.

index of competition of each with the exporting country, where the index is defined as analogous to that of China in equations 11 and 12.

In columns 1 and 4, we include countries whose exchange rates have a correlation coefficient relative to the renminbi that is greater than 0.7. So we add two additional regressors to the core specification. In each case, the regressor is the interaction between the country's exchange rate and that country's index of competition. In columns 2 and 5, we repeat this procedure to include countries whose correlation coefficients with the renminbi are more than 0.4. In columns 3 and 6, the threshold correlation coefficient is 0.3. For presentational reasons, we only show the impact on the main coefficient of interest, namely that relating to China. This coefficient remains significant at the 1 percent confidence level, although it is slightly reduced in magnitude. Overall, these results suggest that our main finding related to the spillover effect of the Chinese exchange rate remains strong and robust to inclusion of possible omitted variables. Thus, exporters competing with China suffer because of a renminbi depreciation and not (or not just) because they are adversely affected by the depreciation of currencies that closely track the renminbi.

An interesting related finding is that we do find statistically significant and negative coefficients on the interaction terms for the other countries (not shown). Therefore, the spillover effect we estimate is not specific to China, and is more general. Unsurprisingly, the indices of competition are much lower for all the other countries. Therefore, the magnitude of the spillover effect which is given by the coefficient multiplied by the index is much smaller for the other countries than for China.[17]

In table 5, we test for robustness across exporters, defined in geographic terms. We split the sample into four regions and find that the results hold across all. The coefficients on the China spillover effect are greater for Asia than for sub-Saharan Africa but it is difficult to say whether these differences are due to the fact of supply conditions in the exporting region or due to differences in the product composition of their exports and/or their geographic destination.[18]

In table 6, we check if the results are robust to the degree of product disaggregation. In the core specification, the data are at the HS 4-digit level. In table 6, we use data at the HS 2-digit level. The indices of competition are measured by aggregating across 6-digit lines within the 2-digit category. The sample size shrinks from over 3.6 million to about 860,000 observations. But the interaction term remains negative and significant.

Overall, the results in table 1 through table 6 confirm the predictions from the analytical framework. The elasticity of developing country exports with respect to Chinese exchange rate is consistently and robustly negative. Further, this elasticity depends on the index of competition: A given depreciation of the renminbi is associated with a bigger reduction in developing country exports the higher this index.

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17. See the Results section for detailed discussion on the magnitudes of the coefficients.

18. The differences are also statistically significant (based on a estimating a stacked specification with triple interaction terms with regional dummies). We find some suggestive evidence that the differences between Asia and sub-Saharan Africa, for example, may be due to the fact that the latters' exports tend to be less homogenous than those of Asia. We also tested for robustness across importers, defined in terms of advanced and other countries, and the results hold for each category of importers.

Spillover Effect and Product Characteristics

Equations 11 and 12 suggest that the spillover effect should vary according to two product attributes: elasticity of substitution (σ_p) between different imported varieties and exchange rate pass through (μ_p). Higher the values of σ_p and $\mu_{p,}$ the larger should be the spillover effect.

First, we analyze how the spillover effect varies by the degree of substitution between products. We partition the data into homogenous (i.e., those with a greater degree of substitutability) and differentiated products based on Rauch's (1999) classification.[19] As shown in table 7, columns 1, 2, 4, and 5, we find that the coefficients on the interaction between the index of competition and exchange rates are higher in magnitude for homogenous products vis-à-vis differentiated ones. Columns 3 and 6 confirm that the differences between the coefficients for the two types of goods are statistically significant. The differences are substantial: For the count-based and value-based indices, the coefficients on homogenous goods are about 20 and 40 percent greater, respectively, than for differentiated goods.

Second, we explore how the spillover effect is related to a likely determinant of Chinese exchange rate pass-through—the imported intermediate content of Chinese exports. One of the key features of Chinese manufacturing exports has been the extent to which they have relied on foreign intermediate inputs. The greater the reliance on foreign inputs (lower the domestic value added), the more an exchange rate depreciation will increase input costs and hence dampen the competitive advantage from a depreciation. In other words, a greater reliance on foreign inputs is analytically analogous to a lower pass-through, which theory predicts will dampen the spillover effect. We test this proposition in the data. We use the classification in Koopman, Wang, and Wei (forthcoming) to divide our data into two samples: those characterized by a high degree of foreign inputs and those with a low degree.[20]

In table 8 we estimate our core specification for each of these samples. We find that, consistent with theory, our spillover effect is in fact dampened for products with a high degree of foreign inputs (compare columns 2 versus 1, and 5 versus 4). Columns 3 and 6 confirm that the differences between the two samples are statistically different: The coefficient on the core interaction term is about 13 percent greater (in absolute value) for the sample with the lower degree of foreign intermediate inputs in the case of the value-based index and 10 percent greater for the count-based index.[21]

19. Note that Rauch's classification is available at the Standard International Trade Classification (SITC) 4-digit; we concord it to HS 6-digit level using standard concordance tables, and then partition the data into homogenous and differentiated using Rauch's liberal classification (reference priced goods are included in the homogenous category). We then aggregate the data to the HS 4-digit level.

20. The classification of sectors by domestic value added is restricted to manufacturing, and is based on International Standard Industrial Classification (ISIC) data which we concorded with HS 4-digit data.

21. The same result holds for an alternative classification by share of processing exports (with high domestic value added products being those with low share of processing) due to Koopman, Wang, and Wei (forthcoming).

Discussion of Magnitudes

Recall that the spillover effect we estimate in equation 13 is given by:

$$\frac{\partial \ln V_{ijpt}}{\partial \ln E_{jt}} = I_{ijp} * \beta$$

Our estimations identify β which we can multiply by the relevant value of the index of competition to obtain the average spillover effect. The range of estimates for different combinations of the two indices of competition and estimates of β are shown in table 9. For the baseline estimate of our elasticity (columns 4 and 8 in table 1) and for the median index of competition, we get a total spillover effect of –0.14 and –0.20 for the value- and count-based indices respectively. The estimates imply that a 10 percent depreciation/appreciation of the renminbi is associated with a reduction/increase in developing country exports at the product level to a third market of about 1.5 to 2 percent.

For countries that are in the 90th percentile in terms of competition with China, the range of baseline estimates increases to 2 to 3 percent for the two indices. If we use the higher values of β corresponding to multilateral measure of exchange rates, for example (column 5 in table 3), the magnitude of the estimates increases substantially. For the indices of competition in the 90th percentile, the spillover effect could be as high as 6 percent for a 10 percent change in the renminbi.[22]

How do our empirical estimates compare with those suggested by the analytical framework? Equations 11 and 12 yield theoretical magnitudes for the spillover effect. From the existing literature, we can obtain estimated values for each of the parameters. Of course, there is wide variation in each of these, but some ball-park estimates are the following: $\sigma=3$, $\omega=1$, $\mu=0.4$ and $s=0.4$. The estimates of σ (the elasticity of substitution between imported goods, or the micro-Armington elasticity) and ω (the elasticity of substitution between domestic and imported goods, or the macro-Armington elasticity) are based on Feenstra, Obstfeld, and Russ (2011). The pass-through coefficient (μ) is an average of the estimates from Campa and Goldberg (2005) for industrial countries and the estimates of Gopinath, Itskhoki, and Rigobon (2011) for the United States.[23] The average share of China, s, in the markets of each of the importing countries is obtained from our data.

Combining these estimates with the average value of the index of competition for the value (I^V_{ijp}) and count-based (I^C_{ijp}) indices from our data (of 0.4 and 0.9, respectively), yield a magnitude of the third-market

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22. Note that even using the estimates from table 4, where we control for movements in other currencies, the spillover effect of China's exchange rate movements is in the range of 1 to 2 percent. We also conduct another exercise where we assume that a movement in the renminbi is followed by movements in other correlated currencies. Based on our estimates from table 4, the overall spillover effect of movements in all these currencies is also in the range of 1 to 2 percent. This is due to the fact that spillover effect of other currencies is much smaller in magnitude than China's. Although the coefficients on the interaction terms are similar, the indices of competition are much smaller for the other countries. These results are available upon request.
23. Goldberg and Knetter (1997) and Goldberg and Hellerstein (2008) also provide evidence on pass-through and its decline over time. Xing (2010) looks specifically at pass-through of Chinese exchange rates to import prices in the United States and Japan, and estimates pass-through coefficients of 0.23 and 0.56 for the United States and Japan respectively.

effect of –0.32 for the value-based index and –0.29 for the count-based index. Therefore, theory appears to predict a spillover effect of about 0.3. For the count-based index, the theoretical and our baseline empirical estimates (–0.2) are not far apart. For the value-based index, our baseline empirical estimates are below those derived from theory (0.14 versus 0.32). There are two possible explanations. Residual measurement errors would impart a natural attenuation bias to the econometric estimates. Second, the values of the elasticity of substitution that we use to derive the theoretical prediction are based on Feenstra, Obstfeld, and Russ (2011), who estimate the elasticity for goods at a level of disaggregation close to the HS 10-digit level. Our data on the other hand are at HS 4-digit so that the relevant elasticity for our purpose could be well below the value of three that we use here.[24] Such a lower value would bring our empirical estimates closer to those based on theory.

Overall, the baseline estimates in this paper suggest that a 10 percent depreciation/appreciation in the renminbi exchange rate vis-à-vis an importing country decreases/increases on average developing country exports by about 1.5 to 2 percent. Given the 30 percent *appreciation* of China's real exchange rate vis-à-vis the US dollar over 2000–08, our findings suggest that this could have been associated with about a 4.5 to 6 percent increase in the typical developing country's exports to the United States, with much greater effects for countries in closer competition with China.

CONCLUSION

To our knowledge, this paper is the first attempt to quantify the effect of exchange rate changes on the exports of competitor countries to third markets—the spillover effect—that both exploits the rich variation afforded by disaggregated trade data and does so in a manner that is motivated by and consistent with theory. We study the case of China and find that its exchange rate changes can have significant and robust spillover effects.

These findings may have important policy implications for developing countries and for the multilateral system if exchange rate movements (or the lack thereof) stem from policy actions. Since we have found that the resulting spillover effects are significant, one country's policies can then potentially have substantial export implications for other countries.

Importantly, we would emphasize that this paper identifies precisely, and in a robust way, a very specific mechanism of influence from exchange rates to trade (the spillover effect of Chinese exchange rate movements on exports of competitor countries to third markets). There could be other beneficial effects on developing country exports to China which we do not measure. For example, a depreciation of the renminbi could increase developing country exports of raw materials and intermediate goods to China to be used in the production of China's exports to third countries. Similarly, if China's depreciation boosts its own growth, that could increase its demand for all goods and services, which could also lead to greater developing country

24. Broda and Weinstein (2006) argue that with more disaggregated data, one is likely to find higher estimates of the elasticity of substitution.

exports. Thus, the effect of China's exchange rate on overall exports of other countries remains an open question. Finally, we have not directly estimated any effects of China's exchange rate movements on its own exports. Further research is needed to precisely identify all these other effects.

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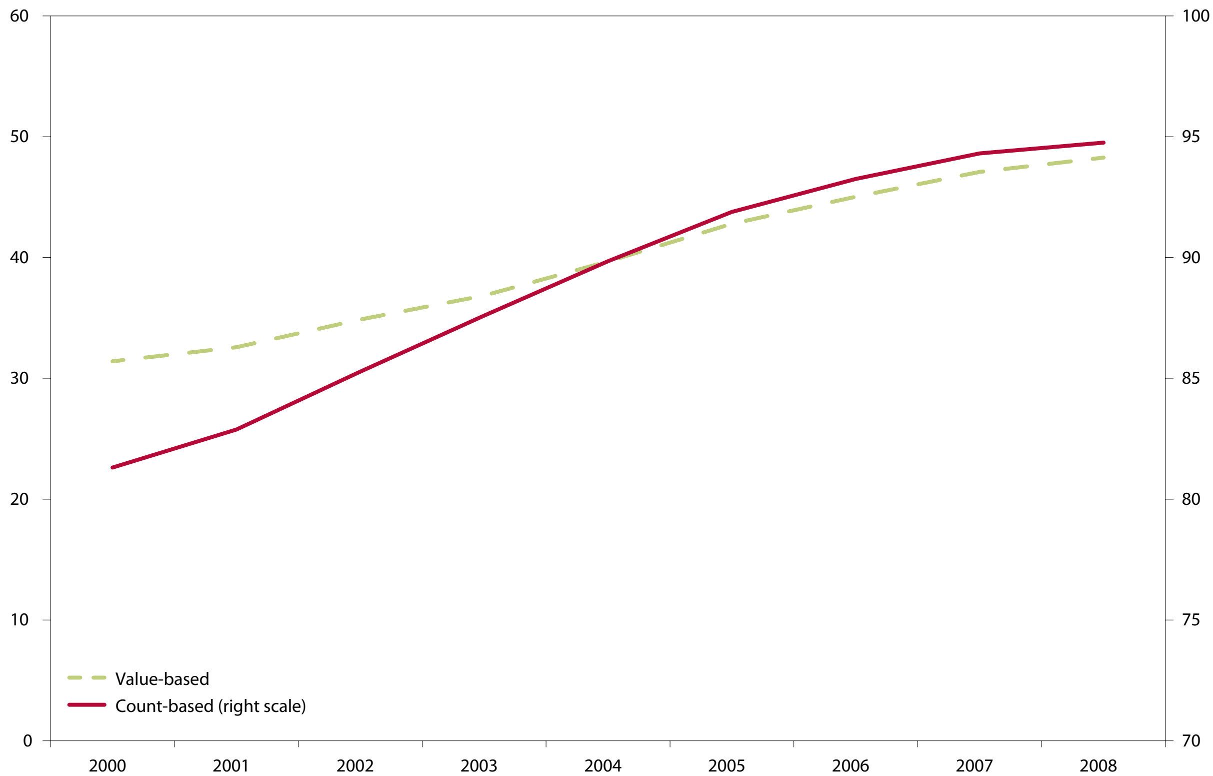
Figure 2 Average index of competition



Source: Author's calculations.

Figure 3a Value-based index of competition: by region of exporter

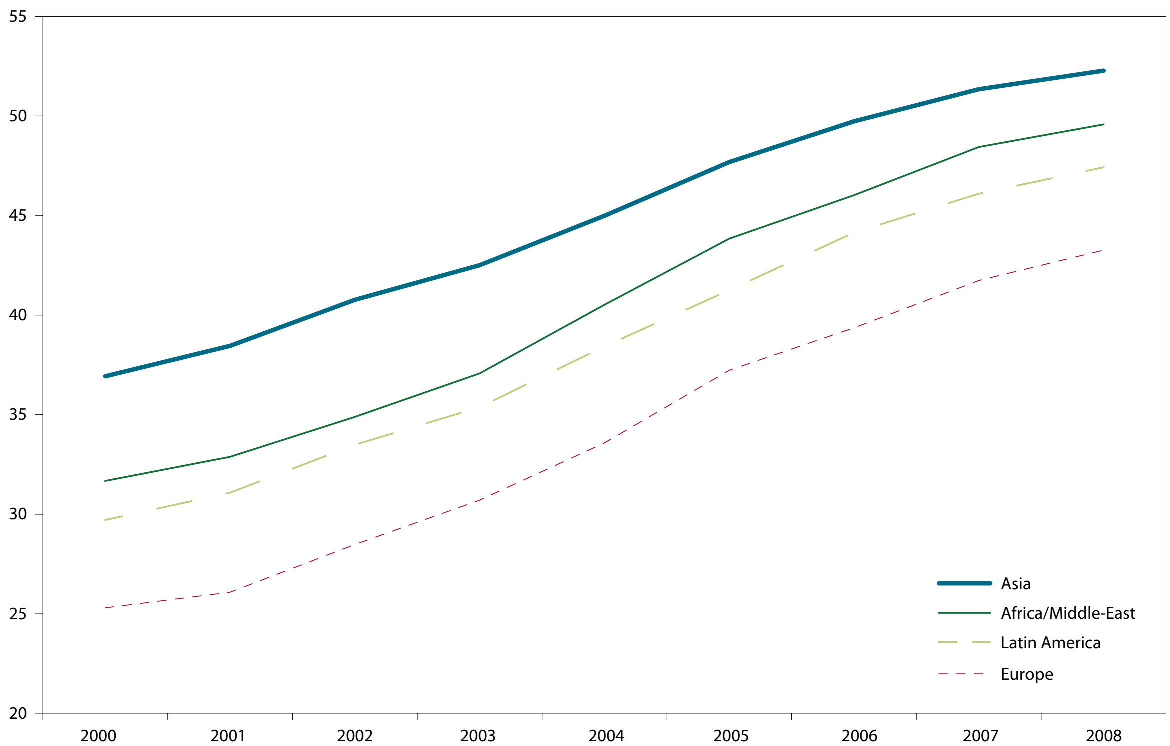
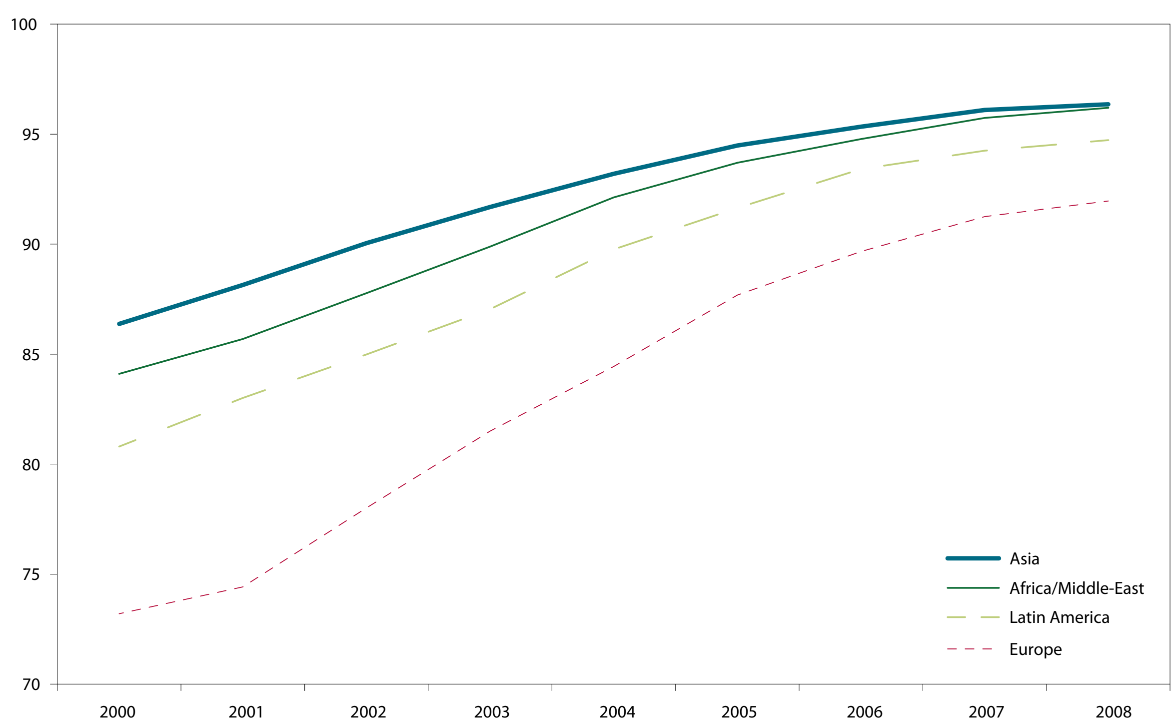


Figure 3b Count-based index of competition: by region of exporter



Source: Author's calculations.

Table 1 Exports from developing countries and Chinese exchange rates: baseline specification

Dependent variable = log(exports) at (exporter, importer, 4-digit product, year) level								
	Value-based index of competition				**Count-based index of competition**			
	[1]	**[2]**	**[3]**	**[4]**	**[5]**	**[6]**	**[7]**	**[8]**
Index of competition with China*log(exchange rate of importer with respect to China)	–0.178*** [0.002]	–0.227*** [0.001]	–0.128*** [0.001]	–0.352*** [0.004]	–0.250*** [0.001]	–0.234*** [0.001]	–0.158*** [0.001]	–0.222*** [0.002]
Number of observations (N)	3,586,936	3,586,936	3,586,936	3,586,936	3,586,936	3,586,936	3,586,936	3,586,936
Fixed effects								
exporter*importer*product	N	N	N	Y	N	N	N	Y
exporter*importer*time	N	N	Y	Y	N	N	Y	Y
exporter*product*time	N	Y	Y	Y	N	Y	Y	Y
importer*product*time	N	Y	Y	Y	N	Y	Y	Y

Notes: Exchange rate of importer with respect to China is measured as renminbi/importer currency, deflated by the Chinese Consumer Price Index (CPI). The index of competition in columns 1 through 4 is defined as the summation over all 6-digit products within the 4-digit category of the following: share of China in overall imports of a 6-digit product multiplied by the share of the 6-digit product in total 4-digit exports from the exporter to the importer. The index of competition with China in columns 5 through 8, is defined at the 4-digit product level, and is equal to the share of 6-digit products within a 4-digit category that country *i* exports to country *j*, that China also exports to *j*. The index of competition in all the columns is measured in the year 2000. The regression sample includes years from 2000–08. Standard errors denoted in parentheses are clustered at the importer*exporter*product level. ***, **, and * denote statistical significance at the 1, 5, and 10 percent level respectively.

Source: Author's calculations.

Table 2 Robustness

	Dependent variable = log(exports) at (exporter, importer, 4–digit product, year) level							
	[1] Drop outliers	**[2] Cluster export*import*year**	**[3] Cluster export*product*year**	**[4] Cluster import*product*year**	**[5] Long–difference (2000, 2008)**	**[6] Index of competition —2001**	**[7] Index of competition—2002**	**[8] Finger–Krenin Index**
Value–based index of competition								
Index of competition with China*log(exchange rate of importer with respect to China)	−0.370*** [0.005]	−0.352*** [0.001]	−0.352*** [0.003]	−0.352*** [0.003]	−0.416*** [0.038]	−0.326*** [0.004]	−0.311*** [0.004]	−0.385*** [0.003]
Count–based index of competition								
Index of competition with China*log(exchange rate of importer with respect to China)	−0.192*** [0.002]	−0.222*** [0.001]	−0.222*** [0.001]	−0.222*** [0.001]	−0.208*** [0.017]	−0.387*** [0.002]	−0.417*** [0.003]	
Number of observations (N)	3,479,214	3,586,936	3,586,936	3,586,936	788,775	3,586,936	3,586,936	3,586,936

Notes: See notes to table 1 for definitions of the value–based and count–based index of competition. Exchange rate of importer with respect to China is measured as renminbi/importer currency, deflated by the Chinese Consumer Price Index (CPI). In column 1, the top and bottom fifth percentile of the observations are dropped. In columns 2 through 4, we make alternative assumptions on clustering the standard errors. In column 5, we restrict the sample to two years—2000 and 2008. In columns 6 and 7, the index of competition is measured in 2001 and 2002 respectively. In Column 8, we use the Finger–Krenin index of export similarity. The index of competition except in columns 6 and 7 is measured in the year 2000. The regression sample (except column 5) includes years from 2000–08. All regressions include exporter*importer*time, exporter*product*time, importer*product time, and exporter*importer*product fixed effects. Standard errors denoted in parentheses are clustered at the importer*exporter*product level (except in columns 3 through 5) . ***, **, and * denote statistical significance at the 1, 5, and 10 percent level respectively.

Source: Author's calculations.

Table 3 Robustness to alternative exchange rate measures

Dependent variable = log(exports) at (exporter, importer, 4-digit product, year) level					
	Value-based index of competition				
	[1] Nominal exchange rate	**[2] Real exchange rate (deflated by relative prices)**	**[3] Nominal effective exchange rate**	**[4] Real effective exchange rate**	**[5] Real effective exchange rate (PWT)**
Index of competition with China*log(exchange rate of importer with respect to China)	–0.150*** [0.009]	–0.245*** [0.009]	0.576*** [0.006]	0.545*** [0.006]	0.681*** [0.007]
Number of observations (N)	3,586,936	3,586,936	3,602,228	3,602,228	3,602,228
	Count-based index of competition				
	[6] Nominal exchange rate	**[7] Real exchange rate (deflated by relative prices)**	**[8] Nominal effective exchange rate**	**[9] Real effective exchange rate**	**[10] Real effective exchange rate (PWT)**
Index of competition with China*log(exchange rate of importer with respect to China)	–0.133*** [0.004]	–0.214*** [0.004]	0.346*** [0.003]	0.356*** [0.002]	0.398*** [0.003]
Number of observations (N)	3,586,936	3,586,936	3,602,228	3,602,228	3,602,228

Notes: See notes to table 1 for definitions of the value-based and count-based index of competition. In columns 1 and 5, nominal exchange rate of importer with respect to China is measured as renminbi/importer currency. In columns 2 and 6, real exchange rate of importer with respect to China is measured as renminbi/importer currency, deflated by the Chinese CPI relative to importer CPI. In columns [3] and [7], nominal effective exchange rate of China (2005=100) from the International Monetary Fund (IMF) is used. In columns 4 and 8, real effective exchange rate of China (2005=100) from the IMF is used. Note that an increase in the real and nominal effective exchange rates denotes an appreciation. In columns 5 and 10, the measure of the real exchange rate is the price level of GDP (series p) from the Penn World Tables (PWT; version 7), which is the ratio of GDP at market exchange rates to GDP at purchasing power parity exchange rates. The price level is expressed relative to that of the United States. An increase in the price level denotes an appreciation of the real exchange rate. The regression sample in all regressions includes years from 2000–08. All regressions include exporter*importer*time, exporter*product*time, importer*product time, and exporter*importer*product fixed effects. Standard errors denoted in parentheses are clustered at the importer*exporter*product level. ***, **, and * denote statistical significance at the 1, 5, and 10 percent level respectively.

Source: Author's calculations.

Table 4 Robustness to omitted variables

Dependent variable = log(exports) at (exporter, importer, 4-digit product, year) level							
	Value-based index of competition				Count-based index of competition		
	[1]	[2]	[3]		[4]	[5]	[6]
Index of competition with China*log(exchange rate of importer with respect to China)	–0.253*** [0.005]	–0.211*** [0.006]	–0.172*** [0.008]		–0.163*** [0.005]	–0.224*** [0.006]	–0.242*** [0.008]
Number of observations (N)	3,141,707	2,697,281	2,248,111		3,141,707	2,697,281	2,248,111
Controls							
Index of competition with other country*log(exchange rate of importer with respect to that country)							
Malaysia, Poland (correlation >= 0.7)	Y	Y	Y		Y	Y	Y
Mexico, Thailand (correlation>=0.4)	N	Y	Y		N	Y	Y
Brazil, India (correlation>=0.3)	N	N	Y		N	N	Y
Fixed effects							
exporter*importer*product	Y	Y	Y	Y	Y	Y	Y
exporter*importer*time	Y	Y	Y	Y	Y	Y	Y
exporter*product*time	Y	Y	Y	Y	Y	Y	Y
importer*product*time	Y	Y	Y	Y	Y	Y	Y

Notes: The control countries are among the top ten exporters in the world, whose real effective exchange rates are highly correlated with the Chinese. Exchange rate of importer with respect to, for example, China is measured as renminbi/importer currency, deflated by the Chinese Consumer Price Index (CPI). The exchange rate of importer with respect to other countries is also measured in a similar way. The index of competition in columns 1 through 3 is defined as the summation over all 6-digit products within the 4-digit category of the following: share of China, Malaysia, South Africa, etc. in overall imports of a 6-digit product multiplied by the share of the 6-digit product in total 4-digit exports from the exporter to the importer. The index of competition with China, Malaysia, South Africa, etc. in columns 4 through 6, is defined at the 4-digit product level, and is equal to the share of 6-digit products within a 4-digit category that country *i* exports to country *j*, that China, Malaysia, and South Africa also exports to *j*. The index of competition in all the columns is measured in the year 2000. The regression sample includes years from 2000–08. Standard errors denoted in parentheses are clustered at the importer*exporter*product level. ***, **, and * denote statistical significance at the 1, 5, and 10 percent level respectively.

Source: Author's calculations.

Table 5 Robustness by region of exporter

	Dependent variable = log(exports) at (exporter, importer, 4-digit product, year) level							
	Value-based index				Count-based index			
	Asia	Europe	LAC	MENA+SSA	Asia	Europe	LAC	MENA+SSA
Index of competition with China*log(exchange rate of importer with respect to China)	–0.467***	–0.433***	–0.297***	–0.116***	–0.288***	–0.258***	–0.192***	–0.139***
	[0.008]	[0.011]	[0.012]	[0.015]	[0.004]	[0.005]	[0.005]	[0.007]
Number of observations (N)	1,234,019	997,174	750,565	436,403	1,234,019	997,174	750,565	436,403

Notes: The region of the exporter is defined based on the World Bank country classification. See notes to table 1 for definitions of the value-based and count-based index of competition. Exchange rate of importer with respect to China is measured as renminbi/importer currency, deflated by the Chinese Consumer Price Index (CPI). The index of competition in all the columns is measured in the year 2000. The regression sample includes years from 2000–08. LAC denotes Latin America and the Caribbean; MENA denotes the Middle East and North Africa; SSA denotes sub-Saharan Africa. All regressions include exporter*importer*time, exporter*product*time, importer*product time, and exporter*importer*product fixed effects. Standard errors denoted in parentheses are clustered at the importer*exporter*product level. ***, **, and * denote statistical significance at the 1, 5, and 10 percent level respectively.

Source: Author's calculations.

Table 6 Robustness to degree of product aggregation (HS 2-digit level)

Dependent variable = log(exports) at (exporter, importer, 2-digit product, year) level								
	Value-based index				Value-based index			
	[1]	[3]	[4]	[5]	[1]	[3]	[4]	[5]
Index of competition with China*log(exchange rate of importer with respect to China)	–0.131*** [0.002]	–0.084*** [0.002]	–0.009*** [0.002]	–0.306*** [0.006]	–0.293*** [0.001]	–0.206*** [0.001]	–0.113*** [0.001]	–0.268*** [0.003]
Number of observations (N)	861,487	861,487	861,487	861,487	861,487	861,487	861,487	861,487
Fixed effects								
exporter*importer*product	N	N	N	Y	N	N	N	Y
exporter*importer*time	N	N	Y	Y	N	N	Y	Y
exporter*product*time	N	Y	Y	Y	N	Y	Y	Y
importer*product*time	N	Y	Y	Y	N	Y	Y	Y

HS = Harmonized System

Notes: Exchange rate of importer with respect to China is measured as renminbi/importer currency, deflated by the Chinese Consumer Price Index (CPI). The index of competition in columns 1 through 4 is defined as the summation over all 6-digit products within the 2-digit category of the following: share of China in overall imports of a 6-digit product multiplied by the share of the 6-digit product in total 2-digit exports from the exporter to the importer. The index of competition with China in columns 5 through 8, is defined at the 2-digit product level, and is equal to the share of 6-digit products within a 2-digit category that country *i* exports to country *j*, that China also exports to *j*. The index of competition in all the columns is measured in the year 2000. The regression sample includes years from 2000–08. Standard errors denoted in parentheses are clustered at the importer*exporter*product level. ***, **, and * denote statistical significance at the 1, 5, and 10 percent level respectively.

Source: Author's calculations.

Table 7 Products distinguished by degree of differentiation

Dependent variable = log(exports) at (exporter, importer, 4-digit product, year) level						
	Value-based index			Count-based index		
	Homogenous [1]	Differentiated [2]	Interaction [3]	Homogenous [4]	Differentiated [5]	Interaction [6]
Index of competition with China*log(exchange rate of importer with respect to China)	–0.339*** [0.010]	–0.312*** [0.004]	–0.101*** [0.002]	–0.240*** [0.004]	–0.205*** [0.002]	–0.176*** [0.001]
Index of competition with China*log(exchange rate of importer with respect to China)*Dummy for homogenous			–0.040*** [0.003]			–0.046*** [0.002]
Number of observations (N)	981,310	2,679,680	1,326,035	981,310	2,679,680	1,326,035

Notes: Goods are classified into homogeneous or differentiated according to Rauch's liberal classification at 6-digit level. Exchange rate of importer with respect to China is measured as renminbi/importer currency, deflated by the Chinese Consumer Price Index (CPI). The index of competition in all the columns is measured in the year 2000. The regression sample includes years from 2000–08. All regressions include exporter*importer*time, exporter*product*time, importer*product time, and exporter*importer*product fixed effects. Standard errors denoted in parentheses are clustered at the importer*exporter*product level. ***, **, and * denote statistical significance at the 1, 5, and 10 percent level respectively.

Source: Author's calculations.

Table 8 Products distinguished by domestic value added

Dependent variable = log(exports) at (exporter, importer, 4-digit product, year) level						
	Value-based index			Count-based index		
	High domestic value added [1]	Low domestic value added [2]	Interaction [3]	High domestic value added [5]	Low domestic value added [6]	Interaction [7]
Index of competition with China*log(exchange rate of importer with respect to China)	–0.329*** [0.005]	–0.285*** [0.005]	–0.283*** [0.007]	–0.236*** [0.002]	–0.191*** [0.003]	–0.170*** [0.004]
Index of competition with China*log(exchange rate of importer with respect to China)*Dummy for high domestic value added			–0.125*** [0.013]			–0.100*** [0.006]
Number of observations (N)	1,511,450	1,830,310	3,341,760	1,738,687	1,848,249	3,341,760

Notes: Regressions are restricted to manufacturing only. The data on share of domestic value added for products in the manufacturing sector is from Koopman, Wang, and Wei (forthcoming). Goods are classified into high- and low-value added categories based on values above and below the median. See notes to table 1 for definitions of the value-based and count-based index of competition. Exchange rate of importer with respect to China is measured as renminbi/importer currency, deflated by the Chinese Consumer Price Index (CPI). The index of competition in all the columns is measured in the year 2000. The regression sample includes years from 2000–08. All regressions include exporter*importer*time, exporter*product*time, importer*product time, and exporter*importer*product fixed effects. Standard errors denoted in parentheses are clustered at the importer*exporter*product level. ***, **, and * denote statistical significance at the 1, 5, and 10 percent level respectively.

Source: Author's calculations.

Table 9 Range of estimated spillover effect of a 10 percent depreciation of Chinese exchange rate

	Value-based index			Count-based index		
Beta coefficients →	Baseline	Minimum	Maximum	Baseline	Minimum	Maximum
Percentile of the index of competition ↓						
10	–0.01	–0.00	–0.01	0.00	0.00	0.00
50	–1.30	–0.47	–2.52	–1.99	–1.39	–3.74
90	–3.12	–1.13	–6.03	–2.22	–1.55	–4.17

Notes: For the value-based index, the baseline, minimum, and maximum values of the estimated coefficients correspond to column 4, table 1; column 3, table 1; and column 5, table 3 respectively. For the count-based index, the baseline, minimum and maximum values of the estimated coefficients correspond to column 8, table 1; column 4, table 4; and column 7, table 2 respectively.

Source: Author's calculations.

APPENDIX

Steps in the Derivation of Equation 10

From equation 9,

$$\frac{\partial lnV_p^{ij}}{\partial lnE^{Cj}} = \frac{\partial \ln(\sum_{g=1}^{G} V_g^{ij})}{\partial lnE^{Cj}}$$

Applying the formula: $dlny = dy/y$

$$\frac{\partial lnV_p^{ij}}{\partial lnE^{Cj}} = \frac{1}{\sum_{g=1}^{G} V_g^{ij}} \frac{\partial(\sum_{g=1}^{G} V_g^{ij})}{\partial lnE^{Cj}}$$

Applying the identity: $\left(\frac{d\sum y}{dx} = \sum \frac{dy}{dx}\right)$

$$\frac{\partial lnV_p^{ij}}{\partial lnE^{Cj}} = \frac{1}{\sum_{g=1}^{G} V_g^{ij}} \sum_{g=1}^{G} \frac{\partial V_g^{ij}}{\partial lnE^{Cj}}$$

Further, applying the formula: $\frac{\partial y}{\partial lnx} = y \frac{\partial lny}{\partial lnx}$

$$\frac{\partial lnV_p^{ij}}{\partial lnE^{Cj}} = \frac{1}{\sum_{g=1}^{G} V_g^{ij}} \sum_{g=1}^{G} V_g^{ij} \frac{\partial lnV_g^{ij}}{\partial lnE^{Cj}}$$

Substituting for $\frac{\partial lnV_g^{ij}}{\partial lnE^{Cj}}$ from equation 8

$$\frac{\partial lnV_p^{ij}}{\partial lnE^{Cj}} = \frac{1}{\sum_{g=1}^{G} V_g^{ij}} \sum_{g=1}^{G} V_g^{ij}[-(\sigma_g - \omega_g)s_g^{cj}\mu_g^{cj}] = -\sum_{g=1}^{G} \frac{V_g^{ij}}{\sum_{g=1}^{G} V_g^{ij}} [(\sigma_g - \omega_g)s_g^{cj}\mu_g^{cj}]$$

This is equation 10 in the paper.

Table A1 Summary Statistics

Variable	Observations	Mean	Standard deviation	Minimum	Maximum
Nominal Exports (1,000 US dollars)	3,586,936	2,009.797	39,531.450	0.001	1.590E+7
Log (real exports, deflated by US CPI)	3,586,936	–1.485	3.134	–11.611	12.100
Index of competition with China (structural measure)	3,586,936	0.408	0.325	0.000	1.000
Index of competition with China (count–based measure)	3,586,936	0.898	0.282	0.000	1.000
Nominal exchange rate (renminbi/importer currency)	3,586,936	2.614	3.332	0.000	15.222
Log (renminbi/importer currency exchange rate, deflated by Chinese CPI)	3,586,936	–5.892	2.426	–13.247	–2.632

CPI = Consumer Price Index

Source: Author's calculations.

Table A2 List of countries

Exporting countries		Importing countries
Afghanistan	Macedonia, FYR	Algeria
Albania	Madagascar	Argentina
American Samoa	Malawi	Australia
Argentina	Malaysia	Austria
Armenia	Maldives	Belarus
Bangladesh	Mali	Belgium
Belarus	Marshall Islands	Brazil
Belize	Mauritania	Canada
Benin	Mauritius	Chile
Bhutan	Mexico	Colombia
Bolivia	Micronesia, Fed. Sts.	Czech Republic
Bosnia and Herzegovina	Moldova	Denmark
Botswana	Mongolia	Egypt, Arab Rep.
Brazil	Montenegro	Finland
Bulgaria	Morocco	France
Burkina Faso	Mozambique	Germany
Burundi	Myanmar	Greece
Cambodia	Namibia	Hong Kong, China
Cameroon	Nepal	Hungary
Cape Verde	Nicaragua	India
Central African Republic	Niger	Indonesia
Chile	Pakistan	Ireland
Colombia	Palau	Israel
Comoros	Panama	Italy
Congo, Dem. Rep.	Papua New Guinea	Japan
Costa Rica	Paraguay	Kazakhstan
Cote d'Ivoire	Peru	Korea, Rep.
Cuba	Philippines	Malaysia
Djibouti	Poland	Mexico
Dominica	Romania	Morocco
Dominican Republic	Russian Federation	Netherlands
Ecuador	Rwanda	New Zealand
Egypt, Arab Rep.	Samoa	Nigeria
El Salvador	Sao Tome and Principe	Norway
Eritrea	Senegal	Pakistan
Ethiopia (excludes Eritrea)	Seychelles	Philippines
Fiji	Sierra Leone	Poland
Gabon	Solomon Islands	Portugal
Gambia, The	Somalia	Qatar
Georgia	South Africa	Romania
Ghana	Sri Lanka	Russian Federation

(continued on next page)

Table A2 List of countries *(continued)*

Exporting countries		Importing countries
Grenada	St. Kitts and Nevis	Saudi Arabia
Guatemala	St. Lucia	Singapore
Guinea	St. Vincent and the Grenadines	Slovak Republic
Guinea-Bissau	Suriname	South Africa
Guyana	Swaziland	Spain
Haiti	Syrian Arab Republic	Sweden
Honduras	Tajikistan	Switzerland
India	Tanzania	Taiwan, China
Indonesia	Thailand	Thailand
Jamaica	Togo	Turkey
Jordan	Tonga	Ukraine
Kazakhstan	Tunisia	United Arab Emirates
Kenya	Turkey	United Kingdom
Kiribati	Uganda	United States
Kyrgyz Republic	Ukraine	Venezuela
Lao PDR	Uruguay	Vietnam
Latvia	Uzbekistan	
Lebanon	Vanuatu	
Lesotho	Vietnam	
Liberia	Zambia	
Lithuania	Zimbabwe	

Source: Author's calculations.