The Real Exchange Rate, Innovation and Productivity: A Cross-country Firm-level Analysis*

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Abstract

We use firm-level data for a large set of countries for the period 2001-2010 to evaluate manufacturing firms' responses to changes in the real exchange rate (RER). In East Asian emerging countries, real depreciations are associated with faster growth of firm-level TFP, sales and cash-flow; higher probabilities to engage in R&D and export; higher export intensity; lower probabilities to import intermediate inputs and lower import intensity. We find no or less significant effects for firms from industrialized and other developing countries, which are less export intensive, more import intensive and face less credit constraints. We rationalize these findings by estimating a dynamic firm-level model of exporting, importing and R&D investment in a setup where financial constraints may prevent some firms from financing R&D fixed costs. Real depreciations raise firm-level demand, increasing the profitability to engage in exports and R&D for all firms; however, they raise the cost of importing intermediates. By increasing firms' cash flow, depreciations also relax firms' borrowing constraints, thus enabling more firms to overcome the fixed-cost hurdle for financing R&D. We decompose the effects of RER changes on productivity growth into these different channels and explain cross-country heterogeneity in the effects of RER depreciations in terms of differences in export intensity, import intensity and financial constraints.

JEL Codes: F, O.

Key Words: real exchange rate, firm level data, innovation, productivity, credit constraints

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1 Introduction

The aftermath of the global financial crisis, the expansionary policies implemented therein, and the end of the commodity cycle in emerging markets have renewed the debate on the effects of real exchange rate (RER) movements. Policy-makers in Asia and Latin America have expressed concerns that large capital inflows can bring about the appreciation of their exchange rates and subsequent losses of competitiveness. Similarly, in rich countries, concerns about appreciated exchange rates and their impact on economic activity, mainly in the manufacturing industry, have made recent headlines.

At the aggregate level, for example, there has been much talk about reserve accumulation and capital controls to limit exchange rate appreciations.[1] At the microeconomic level, the idea of governments defining interventionist industrial policies has ceased to be taboo even in the political debate of market-friendly countries. WTO membership forbids many of the classical trade-policy instruments (production and export subsidies, import tariffs and other protectionist measures) used in industrial policies in the past. RER depreciations, while producing effects comparable to those of the combination of import tariffs and export subsidies, are not constrained by the WTO.

On the academic side, however, the empirical evidence on the effects of RER changes is far from conclusive. On the one hand, an extensive empirical literature has attempted to characterize the aggregate effects of RER depreciation (Rodrik, 2008, and references therein) and claims that RER depreciation promotes economic growth through its positive impact on the share of tradables relative to nontradables. Still, evidence on the channels through which this positive effect operates (the individual effects of larger aggregate saving, positive externalities from specializing in tradables, etc.) is elusive and hard to obtain. Moreover, a number of empirical issues (omitted variables, reverse causality, etc.) cast doubts about the accuracy of this macro evidence (see Henry 2008, Woodford, 2008). On the other hand, evidence based on firm-level studies is relatively scarce. Here, data availability for a wide range of countries including emerging economies has been an obvious constraint.

This paper revisits this important question and combines several data sets on cross-country firm-level data to overcome this problem. We study the firm-level effects of medium-term fluctuations in the real exchange rate, thus shedding light on the microeconomic channels through which RER changes affect the economy. The use of firm-level data allows us to exploit the autonomous component driving changes in the exchange rate (see Gourinchas, 1998).[2] This enables us to consider RER movements as shifts in the relative price of tradables that operate as demand shocks which are exogenous to individual firms and to abstract from the underlying sources of aggregate shocks that bring about the RER movements.[3]

We use firm-level data from Orbis (Bureau van Dijk) for around 70 developing and 20 industrialized

[1] See Alfaro, Chari, and Kanczuk (2014), Benigno et al. (2016), Magud, Reinhart, and Rogoff (2011) and references therein for a discussion.

[2] Our analysis, exploiting firm-level data in the manufacturing sector, uses disaggregated trade-weighted exchange rates and controls for country-time fixed effects eliminating spurious correlation due to aggregate shocks to the manufacturing sector. We perform several alternative analyses. See section 2 for details.

[3] For example, Bussière et al., 2015 find that RER movements due to financial inflows have different aggregate growth effects than those due to supply shocks in the manufacturing sector.

countries for the period 2001-2010 to evaluate manufacturing firms' responses to changes in the real exchange rate. We complement the Orbis data with Worldbase (Dun and Bradstreet), which provides plant-level information on export and import activity; and the World Bank's Exporter Dynamics Database, which reports entry and exit rates into exporting computed from representative micro data for a large set of economies.[4]

We find that, for manufacturing firms in East Asian emerging economies, RER depreciations are associated with (i) faster firm-level growth in revenue-based total factor productivity (TFPR), sales and cash flow; (ii) a higher probability to engage in R&D; (iii) and a higher probability to export and faster export growth. By contrast, in Latin American and Eastern European countries the effects of RER depreciations on these outcomes is negative. Similarly, for manufacturing firms from industrialized countries we find also no or much less significant effects of real depreciations.

In the light of this evidence, we construct and structurally estimate a dynamic firm-level model of exporting, importing and R&D investment. The model is based on a number of features. First, it allows for market-size effects: real depreciations increase firm-level demand, thus raising the profitability to engage in exporting and R&D.[5] Second, we model financial constraints: depreciations relax these by increasing firms' cash flow, thus enabling more firms to overcome the fixed-cost hurdle for financing R&D costs. Finally, we also consider the role of imported inputs, as real depreciations increase the cost of importing such goods, thereby counteracting the positive effect on profitability and productivity.[6]

We explain the cross-country variation in the productivity effects of real depreciations with structural differences in terms of export and import probability and intensity and the tightness of financial constraints. Real depreciations have the most positive effects on productivity growth in export-intensive economies where firms are likely to be financially constrained and do not rely much on imported intermediate inputs, and the least positive (or even negative) effects in import-intensive economies with well developed financial markets. Finally, we provide counterfactual simulations to explore the effects of temporary RER depreciations on TFP growth and innovation activity: even short-lived (temporary) real depreciations can trigger sizable impacts on innovation and productivity growth in the long run.

In addition to the literature mentioned above on the real effects of RER, our findings relate to research based on firm-level data that studies the link between trade, innovation, and productivity growth. Regarding the link between exporting and innovation activity, Lileeva and Trefler (2010) find that CUSFTA, the free-trade agreement between Canada and the US of the late eighties, enhanced incentives to innovate and export for Canadian firms. Bustos (2011) obtains similar effects for Argentinian firms from Brazil's tariff reductions. Aw et al. (2014) structurally estimate a dynamic framework

[4]We complement the analysis with evidence from four countries for which we have detailed micro data: China, Colombia, Hungary, France.

[5]In this context, our structural model helps us disentangle the demand effects caused by a real depreciation from true productivity growth.

[6]Our analysis is silent on a number of questions. First, we take RER movements as given and do not attempt to explain how they come about. Second, we do not provide a welfare analysis weighing benefits and costs of RER depreciations. Among the latter, for example, one should consider the costs of reserve accumulation, inflation, financial repression, tensions among countries, etc. (See Woodford (2008) and Henry (2008)).

to study the joint incentive to innovate and export for Taiwanese electronics manufacturers. Aghion et al. (2017) analyze the competition and market size effects associated to trade shocks on innovation. As far as the link between imports and innovation is concerned, Bloom et al. (2015) find that European firms most affected by Chinese competition in their output markets increased their innovation activity. Autor et al. (2016) find instead that rising import competition from China has severely reduced the innovation activity of US firms. None of these papers uses cross-country firm-level data or changes in the RER to identify changes in the incentives for innovation; furthermore, none takes into account the impact of financial constraints or importing of intermediate inputs.[7]

As far as the link between imports and productivity is concerned, Halpern et al (2015) structurally estimate productivity gains from importing foreign intermediates for Hungarian manufacturing firms. This result evokes the findings of Gopinath and Neimann (2014), who find large productivity losses due to reductions in imports at the product and firm level during the Argentine crisis that followed the collapse of the currency board. Large devaluations in emerging markets have also been used to study exporting behavior: Verhoogen (2008) analyzes the behavior of exporting manufacturing firms in Mexico following the 1994 devaluation and finds quality upgrading in response to devaluation.[8]

Firm-level evidence from rich countries suggests a much more muted impact of real exchange rate movements on exports (Berman et al., 2012 for France; Amiti et al, 2014, for Belgium; Fitzgerald and Haller, 2015 for Ireland, among others). Ekholm et al. (2012) even find faster firm-level productivity growth in response to RER appreciation in Norway. This suggests that emerging markets display features that are very different from those of OECD countries. In this regard, the stronger financial frictions emerging markets are subject to and the stronger prevalence of importing of intermediate inputs in OECD countries and Latin America look like a natural point of departure for our theoretical research into the determinants of the effects of RER changes on firm-level behavior.

The relation between financial constraints and trade is explored by Manova (2013). She develops a static model of financial constraints and exporting in which fixed and variable costs of exporting have to be financed with internal cash flows. These financial constraints reduce exports at the extensive and the intensive margin. Gorodnichenko and Schnitzer (2013) also consider innovation activity in this context: they produce a static model in which exports and innovation are complementary activities for financially unconstrained firms, but might become substitutes when financial constraints are binding. They provide some evidence for this with firm-level data for some eastern European countries. Aghion et al. (2012) find that R&D activity becomes procyclical for credit-constrained French firms in sectors dependent on external finance, whereas R&D is countercyclical for non-constrained firms in the same sectors. Finally, Midrigan and Xu (2014) use Korean producer-level data to evaluate the role of financial frictions in determining total factor productivity (TFP): they find that financial frictions distort entry and technology adoption decisions and generate dispersion in the returns to capital across existing

[7]A recent attempt to identify the effects of industrial policy using aggregate data is the cross-country study by Nunn and Trefler (2010). They find that countries with initial tariff structures biased towards skill-intensive manufacturing sectors subsequently grew faster. Their interpretation of this finding is that skill-intensive sectors generate local externalities. Their results suggest large growth effects of industrial policy.

[8]See Burnstein and Gopinath (2014) for an overview of the effects of large devaluations.

producers, and thus productivity losses from misallocation. Our paper shows that RER depreciations enable developing-country firms to access foreign markets, thus relaxing the financial constraints that prevent them from investing in R&D activity.

The rest of the paper is structured as follows. The next section presents reduced-form evidence on the relationship between RER depreciation and a number of firm-level outcomes. This helps us as motivation for the theoretical model we present in Section 3. Sections 4 discuss our estimation strategy, whereas Section 5 presents the data we use and our main estimation results. In Section 6 we use our estimated model to run a number of counterfactual experiments. Section 7 presents some concluding remarks.

2 Reduced-form Empirical Evidence

2.1 Data and Sources

We combine several data sources. We use Orbis (Bureau Van Dijk), which provides data of listed and unlisted firms on sales, materials, capital stock (measured as total fixed assets), cash flow (all measured in domestic currency), employees, and R&D participation.[9] Our sample spans the period 2001-2010: we have an unbalanced annual panel of firms in 76 developing countries and 23 industrialized countries. Data coverage varies a lot across countries and the sample is not necessarily representative in all countries (see Table A-1). We focus on manufacturing firms (US-SIC codes 200-399). The sample is selected according to availability of the data necessary to construct TFP (gross output, materials, capital stock and employees).

The analysis exploits three additional firm-level data sources. Worldbase (Dun and Bradstreet) provides plant-level information on export and import status for the years 2000, 2005, 2007 and 2009 for the same set of countries as Orbis.[10] We matched the data first using the common identifier and then an algorithm to match them based on company names. We use the export and import status in the first year the firm reports this information. The World Bank's Exporter Dynamic Database reports entry/exit rates into/from exporting by country for a large set of industrialized and developing countries computed from underlying Census microdata. Finally, we use information on the fraction of manufacturing firms performing R&D by country from the OECD's innovation scoreboard, which is based on representative survey data.

As far as macro data is concerned, we use the real GDP growth rate from the Penn World Tables 8.0 (PWT 8.0); compute inflation rates from GDP deflators as reported by the IMF; and take information on privat credit/GDP by country from the World Bank's Global Financial Development Database. We define the real exchange rate (RER) as $\log(e_{ct}) = \log(1/P_{ct})$, where P_{ct} is the price level of GDP in PPP (expenditure-based) from PWT 8.0 in country c in year t.[11] This RER is defined relative

[9] A detailed explanation of the datasets we use can be found in the Appendix.

[10] While this dataset is more comprehensive in terms of coverage than Orbis, it only provides basic operational information, such as sales and employment, but it does not include the balance-sheet variables necessary to construct TFP nor information on plants' R&D status.

[11] We obtain similar results using PPP from PWT 7.1. We prefer using version 8.0 since the accuracy of version 7.1

to the U.S. An increase indicates a real depreciation of the currency (making exports cheaper and imports more expensive). We also construct export-weighted and import-weighted country-sector-specific RERs by combining country-level PPP deflators with bilateral sectoral export and import shares at the 3-digit US-SIC level (164 manufacturing sectors) from UN COMTRADE database. We define $\log(e_{sct}^{EXP}) \equiv \sum_{c'} w_{cc's0}^{EXP} \log(P_{c't}/P_{ct})$, where $w_{cc's0}^{EXP}$ is the export share of country c to country c' in sector s in the first period of the sample and $\log(e_{sct}^{IMP}) \equiv \sum_{c'} w_{cc's0}^{IMP} \log(P_{c't}/P_{ct})$, where $w_{cc's0}^{IMP}$ is the import share of country c from country c' in sector s in the first period of the sample. Figure 1 presents the (yearly) time path of the aggregate RER for selected countries over our sample period. RER fluctuations can be quite persistent (e.g. China) and display substantial variation across countries (for export and import-weighted RERs also, across sectors). We exploit this variation to identify the effects of changes in RER on firm-level outcomes.

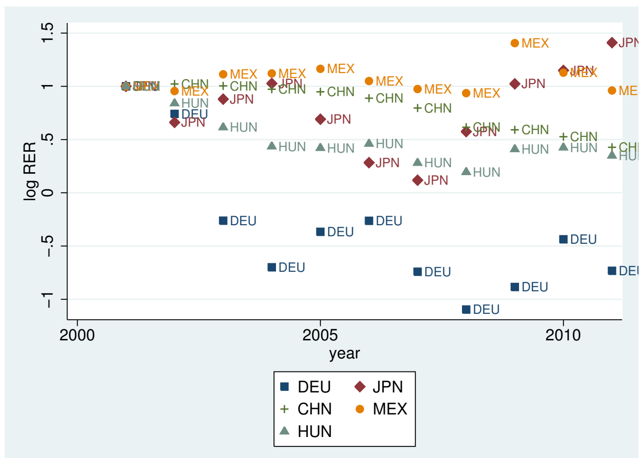


Figure 1: log RER relative to PPP Dollar, normalized to 1 in 2001.

2.2 Firm-level Effects of RER Changes

Since the aggregate RER is the relative price of the foreign vs. domestic aggregate goods basket, endogeneity to aggregate shocks is a concern. However, a large body of empirical work has shown that the RER contains an important autonomous component driven by changes in the nominal exchange rate and that fluctuations in the RER are very hard to predict with fundamentals in the short and medium run (Gourinchas, 1999 and references therein; Corsetti et al. 2014). Our analysis thus considers the exogenous component of RER fluctuations as exogenous demand shocks that impact on firms' export, import and innovation decisions. The fact that we investigate how *firm-level* outcomes of manufacturing firms are affected by RER movements makes reverse causality unlikely. Omitted variable bias is perhaps more of a concern. In particular, positive aggregate supply shocks should be

has recently been questioned (see Feenstra et al, 2015). However, since we use growth rates of RER rather than levels and the measurement problems are related to levels, our results are not affected by them.

positively correlated with the RER, while positive demand shocks should negatively correlate with the RER. Therefore we always control for the aggregate growth rate of the economy. As an alternative, we identify the causal impact of RER fluctuations by using trade-weighted exchange rates. In this case, we can control for country-time fixed effects, which eliminate any spurious correlation due to aggregate shocks to the manufacturing sector. Here we can also dismiss endogeneity concerns due to country-sector-specific shocks: the trade-weighted RERs are constructed using pre-sample trade-weights and each of the 163 manufacturing sectors has negligible weight in a given country's aggregate price level, which is used to construct the RERs. Finally, we also consider an instrumental-variable strategy that exploits exogenous fluctuations in commodity prices and world capital flows. Both higher commodity prices and larger world-level capital flows are likely to be exogenous to domestic shocks and policies and tend to appreciate the RER through their impact on domestic inflation. Moreover, the domestic effects of these external shocks are larger for countries that rely more on commodity trade or have more open financial accounts.

In presenting the results from regressing a number of firm-level variables on the growth rate of the aggregate or trade-weighted RER, we allow the effect of the RER to vary by region: industrialized economies; emerging East Asia; other developing countries. This choice is motivated by our finding that the estimates systematically vary across these regions. First, we run the following regressions at the firm level:

$$\Delta \log(Y_{ict}) = \beta_0 + \sum_{r \in R} \beta_r \Delta \log(e_{ct}) I_r + \beta_2 X_{ct} + \delta_{sc} + \delta_t + u_{ict}, \tag{1}$$

where I_r is a dummy for country c belonging to region r, δ_{sc} is a sector-country fixed effect (controlling for the average growth rate in a given sector-country pair) and δ_t is a time fixed effect. The vector X_{ct} consists of business-cycle controls and includes the real GDP growth rate and the inflation rate. Controlling for inflation corrects for the fact that our dependent variables are measured in nominal value of domestic currency,[12] while we control for real GDP growth because open-economy macro models predict that changes in the real exchange rate are correlated with economic growth. We cluster standard errors at the country level since all firms in a given country are exposed to the same RER shock and RERs are autocorrelated.

We consider five different firm-level dependent variables $\Delta \log(Y_{ict})$: 1) the revenue-based TFP (TFPR) growth rate, constructed from value added; 2) the revenue-based TFP growth rate, constructed from gross output;[13] 3) the growth rate of sales; 4) the growth rate of cash flow; 5) the change of an indicator variable for R&D. (That is, in the case of R&D status we estimate a linear probability model.) We also consider the log entry rate into exporting at the country-time level, defined as the number of new exporters relative to the number of total exporters, from the World Bank's Exporter Dynamics Database.

[12] We use domestic currency values and not dollar values to avoid that nominal exchange-rate changes can have valuation effects.

[13] We construct our TFP measures by adapting the methodology of De Loecker (2013) and Halpern et al. (2015). We explain our approach in detail in Section 4.

Table 1 reports results based on yearly data and aggregate RERs. In industrialized countries, a real depreciation has no significant effect on firm-level TFPR, sales, R&D probabilities and export entry rates, while the impact on cash flow is negative. Instead, in emerging East Asia, a one-percent depreciation of the RER increases value-added TFP growth by 0.24 percent, gross-output TFP growth by 0.12 percent, sales by 0.2 percent, and cash flow by 0.78. The probability of R&D increases by 0.16 percentage points (this effect is not statistically significant though) and the export entry rate increases by 0.55 percentage points. Finally, in the set of other developing economies, real depreciations are associated with significantly slower TFP and sales growth, while there is no significant effect on cash flow, R&D probabilities and export entry.

	(1)	(2)	(3)	(4)	(5)	(6)
	Δ log TFPR$_{VA,it}$	Δ log TFPR$_{GO,it}$	Δ log sales$_{it}$	Δ log c. f.$_{it}$	Δ R&D prob.$_{it}$	Δ log exp. entry rate$_{ct}$
$\Delta \log e_{ct} \times$	0.0196	-0.031	-0.282	-0.319**	-0.168	-0.275
industrialized$_c$	(0.103)	(0.0309)	(0.217)	-0.126	(0.149)	(0.274)
$\Delta \log e_{ct} \times$	0.239***	0.120***	0.195	0.783***	0.166	0.552***
emerging East Asia$_c$	(0.0895)	(0.0198)	(0.216)	-0.114	(0.122)	(0.207)
$\Delta \log e_{ct} \times$	-0.546***	-0.105**	-0.762***	-0.557	0.16	0.063
other developing$_c$	(0.185)	(0.0426)	(0.274)	-0.414	(0.125)	(0.059)
Observations	1,333,986	1,333,986	1,275,606	772,970	148,367	392
R-squared	0.057	0.038	0.103	0.024	0.016	0.107
Country-sector FE	YES	YES	YES	YES	YES	NO
Time FE	YES	YES	YES	YES	YES	YES
Business cycle controls	YES	YES	YES	YES	YES	YES
Cluster	Country	Country	Country	Country	Country	Country

Table 1: The aggregate RER and firm-level outcomes. The dependent variable in columns (1)-(5) is the annual log difference in the following firm-level outcomes computed from Orbis for manufacturing firms for the years 2001-2010: revenue-based TFP computed from value-added (column 1), revenue-based TFP computed from gross output (column 2), nominal sales (column 3), cash flow (column 4), an indicator for R&D status (column 5). The construction of TFP is explained in section 4 of the paper. In column (6) the dependent variable is the log annual change in the export entry rate compute from the Worldbank's export dynamics database. The main explanatory variable of interest is the annual log difference in the real exchange rate from the PWT 8.0 interacted with dummies for: industrialized economy; Emerging East Asia; other developing economy. The regressions also control for the real growth rate of GDP in PPP (from PWT8.0) and the inflation rate (from IMF). Standard errors are clustered at the country level.

In Table A-2 in the Appendix we show that these results are robust and even more pronounced (the effect on R&D becomes statistically significant in emerging East Asia) when instrumenting for RER changes with (i) trade-weighted world commodity prices (using pre-sample trade weights) and (ii) interactions of world gross financial flows with pre-sample values of the Chinn-Ito index for financial account openness.[14] World commodity prices interacted with commodity-country-specific trade weights are strongly negatively correlated with RER changes, in particular for developing countries. The rationale for the second instrument is that world gross financial flows should also be independent of local economic conditions and act as a push factor for the RER, in particular for countries with an

[14] We construct two instruments for the RER. The first one is based on a trade-weighted average of world commodity prices (a fixed set of agricultural commodities, metals, oil). For each country and commodity we compute exports and imports (using trade data from WITS) in the pre-sample year 2000 to construct trade weights. We then compute the instrument as a country-specific trade-weighed average of world commodity prices (using price information from the Worldbank). Our second instrument is based on world capital flows. We compute world capital flows as the sum of equity and debt inflows across countries (from IMF). We then interact this variable (which has only time variation), with the value of the Chinn-Ito index (Chinn and Ito, 2006) for financial openness in the pre-sample year 2000.

open financial account, as measured by the Chinn-Ito index.[15]

Replacing the aggregate RER with export- and import-weighted sector-specific RERs as separate explanatory variables allows us to include country-time fixed effects in the regression and thereby control for aggregate shocks to the manufacturing sector that might be correlated with firm-level outcomes. The regression specification is now:

$$\Delta \log(Y_{ict}) = \beta_0 + \sum_{r \in R} \beta_r^{EXP} \Delta \log(e_{ct}^{EXP}) I_r + \sum_{r \in R} \beta_r^{IMP} \Delta \log(e_{ct}^{IMPp}) I_r + \delta_{sc} + \delta_{ct} + u_{ict}, \quad (2)$$

where δ_{ct} is a country-time-specific fixed effect that controls for any unobserved shock to the manufacturing sector of a given country. We now cluster standard errors at the country-industry level.

Table 2 presents the corresponding results, which share many similarities with those in Table 1. In industrialized countries, a depreciation of the export-weighted RER has no significant effect on value-added and gross-output-based TFP growth, or sales and cash flow growth. By contrast, the R&D probability is significantly positively impacted by the depreciation. A depreciation of the import-weighted RER is associated instead with negative (but insignificant) effects on TFP, sales and cash flow and R&D probabilities. In emerging East Asia instead, a real depreciation of the export-weighted RER is associated with significantly faster TFP, sales and cash flow growth and (insignificantly) higher R&D probabilities, while depreciations of the import-weighted RER have no (TFP and sales) or a negative (cash flow and R&D probabilities) impact on these outcomes. Finally, in the set of other developing countries, real depreciations of the export-weighted RER have an insignificantly positive impact on firm-level outcomes, while real depreciations of the import-weighted RER insignificantly reduce TFP, sales and cash flow growth.

In Appendix Table A-3 we show that our results are not driven by short-term business-cycle fluctuations by reporting regression results with 3-year annualized differences.[16]

2.3 Exports, Imports and Financial Constraints

We now provide direct evidence that the effect of RER changes on firm-level outcomes depends on the firms' trade status. We re-run our regressions of firm-level outcomes on changes in the RER, allowing now for different effects for exporters, importers and firms that engage in none of these activities

[15] Changes in the instruments are strongly negatively correlated with changes in the real exchange rate in the first-stage regressions (not reported). The first-stage multivariate Kleibergen-Paap F-statistic is above 9, which indicates that the instrumental variable estimates might be slightly biased due to a somewhat weak first stages. The overidentication tests, which posit that instruments are exogenous under the null hypothesis, cannot be rejected according to the Hansen statistic.

[16] Results are to be interpreted as average annual changes.To maximize sample coverage we choose 2002, 2005, 2008 and 2010. Overall, we find that in Emerging East Asia export-weighted real depreciations are associated with significantly faster productivity growth, higher probabilities to engage in R&D and larger sales and cash flow, whereas import-weighted real depreciations have no significant impact. This contrasts with the effects in other developing countries, where it is mostly the negative effects of real import-weighted depreciations that matter. Finally, in industrialized countries, positive effects of export-weighted and negative effects of import-weighted real depreciations tend to be less significant, opposite in sign and similar in magnitude.

	(1) Δ log TFPR$_{VA,it}$	(2) Δ log TFPR$_{GO,it}$	(3) Δ log sales$_{it}$	(4) Δ log c. f.$_{it}$	(5) Δ R&D prob.$_{it}$
$\Delta \log e_{sct}^{exp} \times$	0.827	0.069	0.391	0.751	0.353**
industrialized$_c$	(0.587)	(0.081)	(0.385)	(0.679)	(0.172)
$\Delta \log e_{sct}^{exp} \times$	0.627***	0.212***	0.953***	1.441***	0.041
emerging East Asia$_c$	(0.188)	(0.066)	(0.229)	(0.514)	(0.0535)
$\Delta \log e_{sct}^{exp} \times$	0.0154	0.100	0.222	0.171	0.049
other developing$_c$	(0.239)	(0.078)	(0.395)	(0.487)	(0.381)
$\Delta \log e_{sct}^{imp} \times$	-0.193	6.32E-05	-0.289	-0.557	-0.137
industrialized$_c$	(0.354)	(0.0674)	(0.326)	(0.616)	(0.105)
$\Delta \log e_{sct}^{imp} \times$	0.0507	0.0352	-0.0697	-0.692*	-0.159***
emerging East Asia$_c$	(0.181)	(0.0624)	(0.207)	(0.400)	(0.053)
$\Delta \log e_{sct}^{imp} \times$	-0.397	-0.145	-0.330	-0.925	-0.493
other developing$_c$	(0.324)	(0.102)	(0.596)	(0.680)	(0.598)
Observations	1,285,693	1,285,693	1,228,253	746,330	140,048
R-squared	0.054	0.037	0.104	0.025	0.03
Country-time FE	YES	YES	YES	YES	YES
Country-sector FE	YES	YES	YES	YES	YES
Cluster	Country-sector	Country-sector	Country-sector	Country-sector	Country-sector

Table 2: Export-and import-weighted RERs and firm-level outcomes. The dependent variable in columns (1)-(5) is the annual log difference in the following firm-level outcomes computed from Orbis for manufacturing firms for the years 2001-2010: revenue-based TFP computed from value-added (column 1), revenue-based TFP computed from gross output (column 2), nominal sales (column 3), cash flow (column 4), an indicator for R&D status (column 5). The construction of TFP is explained in section 4 of the paper. In column (6) the dependent variable is the log annual change in the export entry rate compute from the Worldbank's export dynamics database. The main explanatory variables of interest are the annual log differences in the export- and import-weighted sector-level real exchange rates computed from PWT 8.0 and bilateral export and import shares at the 3-digit USSIC level (from UN-Comtrade data), interacted with dummies for: industrialized economy; Emerging East Asia; other developing economy. Standard errors are clustered at the country-sector level.

("domestic"). To avoid endogeneity of the trade status, we keep the firms' trade status fixed over the sample period and equal to the trade status in the first period we observe it.

$$\Delta \log(Y_{ict}) = \beta_0 + \sum_{T \in exp,imp,dom} \beta_i \Delta \log(e_{ct}) I_T + \beta_2 X_{ct} + \beta_T I_T + \delta_{sc} + \delta_t + u_{ict}, \tag{3}$$

Table 3 reports the corresponding results. RER depreciations have no significant effect on domestic firms and importers, while they significantly increase TFP, cash flow and R&D propensity for exporters. Appendix Table A-4 repeats these regressions using trade-weighted RER and controlling for country-time fixed effects. Results continue to hold: depreciations of the export-weighted RER have no significant effect on domestic firms, strongly and significantly increase outcomes for exporters and have insignificant negative effects on importers; depreciations of the import-weighted RER instead have no significant effect on firm-level outcomes.

While our firm-level data from Orbis allow to gauge the effect of RER changes on firm-level outcomes by trade status, these data are not comprehensive and not necessarily representative. Moreover, they do not contain information on import and export values. We thus cannot use them to compute regional differences in import and export propensities and intensities. We complement the analysis with evidence on regional differences in export and import intensities and propensities based on representative micro datasets for four countries for which we have detailed administrative plant-level

	(1) Δ log TFPR$_{VA,it}$	(2) Δ log TFPR$_{GO,it}$	(3) Δ log sales$_{it}$	(4) Δ log c. f.$_{it}$	(5) Δ R&D prob.$_{it}$
$\Delta \log e_{ct} \times$	0.104	0.0204	-0.00884	0.032	0.109
domestic$_f$	(0.080)	(0.031)	(0.107)	(0.287)	(0.098)
$\Delta \log e_{ct} \times$	0.194**	0.0469**	0.0595	0.340*	0.0945*
exporter$_f$	(0.078)	(0.023)	(0.096)	(0.190)	(0.050)
$\Delta \log e_{ct} \times$	0.0373	0.0122	0.0347	-0.0379	-0.0181
importer$_f$	(0.035)	(0.010)	(0.036)	(0.105)	(0.059)
Observations	514,971	514,971	485,433	317,395	37,689
R-squared	0.052	0.039	0.097	0.023	0.035
Country-sector FE	YES	YES	YES	YES	YES
Time FE	YES	YES	YES	YES	YES
Business cycle controls	YES	YES	YES	YES	YES
Trade status controls	YES	YES	YES	YES	YES
Cluster	Country	Country	Country	Country	Country

Table 3: The aggregate RER and firm-level outcomes by firm's trade participation status. The dependent variable in columns (1)-(5) is the annual log difference in the following firm-level outcomes computed from Orbis for manufacturing firms for the years 2001-2010: revenue-based TFP computed from value-added (column 1), revenue-based TFP computed from gross output (column 2), nominal sales (column 3), cash flow (column 4), an indicator for R&D status (column 5). The construction of TFP is explained in section 4 of the paper. The main explanatory variable of interest is the annual log difference in the real exchange rate from the PWT 8.0 interacted with firm-level indicators for exporting, importing, no trade participation. The regressions also control for the real growth rate of GDP in PPP (from PWT8.0) and the inflation rate (from IMF). Standard errors are clustered at the country level.

datasets: China, Colombia, Hungary, France.[17]

Table 4 reports import and export probabilities and intensities (imports/sales for importers; exports/sales for exporters). We find that China (representative for emerging East Asia) has a lower import propensity and intensity than the other countries, while Colombia and Hungary (representative for the other developing countries) are very import intensive. At the same time Chinese exporters have a very high export intensity compared to the other countries. Firms in France (representative for industrialized countries) have intermediate export and import propensities and intensities.[18] We find that the effect of RER depreciations on exporters is most positive and highly significant in emerging East Asia, while the effect on importers is most negative in other developing countries (see Table A-5). This is consistent with the evidence that firms in emerging East Asia have a high export intensity and a low import intensity, while the opposite is true for firms in other developing countries.

In order to understand the effect of financial constraints on R&D decisions, we run the following regression:

$$I_{RDit} = \beta_0 + \beta_1 financialdev._c + \beta_2 \log(cashflow)_{it} + \beta_3 \log(cashflow)_{it} \times financialdev._c + \beta_4 X_{ict} + \nu_{it}, \tag{4}$$

[17] The numbers for China have been computed by the authors from representative plant-level data; information for Colombia is from administrative data (we thank Norbert Czinkan for sharing this information with us); data for Hungary are from Halpern et al, 2015; data for France are from Blaum et al, 2015.

[18] Table A-6 provides complementary evidence on regional differences in import and export propensity for the entire set of countries in each region using information from the full Worldbase sample. Since Worldbase data are not necessarily representative for the firm size distribution in each country, we report import and export probabilities by plant-size bin (small ($\leq$ 50 employees), medium (50-200 employees), large ($\geq$ 200 employees) and region. Results from Worldbase confirm that plants in emerging East Asia are much less likely to import than plants in the other regions. Similarly, the export propensity is also somewhat lower in emerging East Asia than in the other regions.

	China	Colombia	Hungary	France
Export prob.	0.26	0.37	0.35	0.23
Import prob.	0.17	0.45	0.39	0.20
Export intensity (conditional)	0.6	0.10	0.10	0.23
Import intensity (conditional)	0.13	0.14	0.24	0.14

Table 4: Evidence on import and export propensity/intensity of manufacturing plants (computed from representative micro data).Data sources: China: computed from administrative data; Colombia: computed from administrative data; Hungary: Halpern et al, 2015; France: Blaum, Lelarge, Peters, 2015.

where I_{it}^{RD} is an indicator that equals one if plant i performs R&D in year t. *log(cash flow)*$_{it}$ is the plant's cash flow (in logs) and *financial dev* is a measure of financial development (private credit/GDP). Credit-constrained firms are more likely to rely on cash flows to finance investment projects. A positive relationship between cash flow and investment therefore suggests the presence of financial constraints. The problem of financial constraints becomes even more important in the context of intangible investments such as R&D, as these are difficult to pledge as collateral. We always include the following set of controls: employment and capital stock (in logs), the inflation rate and the real growth rate of GDP. Depending on the specification, we include different fixed effects (country and sector, country-sector or firm).

We report results for these specifications in Table 5. The coefficient on (log) cash flow, which measures the impact of cash flow on R&D when financial development is zero, is between 0.01 and 0.052 and always highly statistically significant. Moreover, the interaction term between (log) cash flow and financial development is negative and also highly significant: the role of internal cash flow for R&D is smaller when the country has more developed capital markets. Table 6 reports the predicted marginal effects of (log) cash flow for each region. Its impact on R&D is largest for the set of other developing countries (around 0.036), intermediate for emerging East Asia (0.025), and basically zero for industrialized countries. For East-Asian firms, the estimates imply that a one-percent increase in cash flow increases the probability of performing R&D by 0.025 percentage points.

The lack of effects of the RER for industrialized countries and the negative effects for the set of other developing countries (mostly Latin America and Eastern Europe) are plausibly due to the fact that firms in these regions have a smaller export and a larger import intensity and propensity, and face less financial constraints than firms from emerging East Asia. Under these circumstances, the positive effects of a more depreciated RER are smaller and might be compensated by the implied increase in production costs. East Asian firms are instead intensive in exports relative to imports.

2.4 Summary of Stylized Facts

- For exporting firms in emerging East Asia, real depreciations are associated with faster revenue-based productivity growth; faster sales growth; faster growth of cash flow; a higher probability to engage in R&D; higher export entry rates. Positive effects of real depreciations are also present

	(1)	(2)	(3)	(4)
	R&D Prob$_{it}$	R&D Prob$_{it}$	R&D Prob$_{it}$	R&D Prob$_{it}$
financial development$_c$	0.00589***			
	(0.00019)			
log(cash flow)$_{ft}$	0.04385***	0.04824***	0.05209***	0.01549***
	(0.00222)	(0.00284)	(0.00305)	(0.00276)
log(cash flow)$_{ft}\times$	-0.00028***	-0.00028***	-0.00032***	-0.00004***
financial development$_c$	(0.00001)	(0.00002)	(0.00002)	(0.00001)
R-squared	0.250	0.338	0.375	0.790
Observations	117,403	117,394	117,142	108,826
Time FE	YES	YES	YES	YES
Sector FE	NO	YES	NO	NO
Country FE	NO	YES	NO	NO
Sector-country FE	NO	NO	YES	NO
Firm FE	NO	NO	NO	YES
Cluster	Firm	Firm	Firm	Firm

Table 5: R&D sensitivity to cash flow by level of financial development. The dependent variable is an indicator for the firm's R&D status. Explanatory variables are cash flow (in logs), financial development (measured as private credit/GDP) and their interaction. Further controls (not reported): employment, capital (both in logs), the real GDP growth rate (from PWT 8.0) and the inflation rate (from IMF).

	emerging East Asia	other developing	industrialized
credit/GDP	0.84	0.50	1.47
marginal effect of cash flow	0.025	0.036	0.006

Table 6: Marginal effects of cash flow on R&D – estimates by region.

for firms that do not participate in international trade, while there is no significant effect of real depreciations on firm-level outcomes for importers.

- In industrialized countries real depreciations have no significant effects on firm-level outcomes, independently of their trade status.

- In other developing countries (Latin America and Eastern Europe), real depreciations have a significantly negative effect on firm-level outcomes for importers and no significant effect on domestic firms and exporters.

- Firms in emerging East Asia are less likely to import and less import intensive than firms located in other developing countries and in industrialized countries; moreover, firms in emerging East Asia have a higher export intensity than firms in other developing economies and industrialized countries. Firms in located in other developing countries are most likely to import and most import intensive.

- Firms' R&D choice depends on the level of internal cash flow and the more so the less developed local financial markets are. Cash flow matters most for R&D decisions of plants in the set of other developing economies; it has an intermediate impact on R&D in emerging East Asia and does not play a significant role for R&D decisions in industrialized economies.

3 Theoretical Framework

Motivated by this empirical evidence, we build a model with heterogeneous firms that choose whether or not to invest in R&D, which in turn affects their future productivity. Since R&D is an intangible investment that cannot be used as collateral, borrowing constraints here are particularly severe. Only firms with operating profits larger than the fixed/sunk costs involved in R&D activity can finance the corresponding investments. RER fluctuations change cash flows and affect thereby the behavior of firms. Domestic firms self-select into exporting their output and/or importing materials. Foreign firms export into the domestic market. This creates channels through which the exchange rate affects the revenues and profits of the domestic firms potentially impacting on their decision-making regarding R&D.

3.1 Preferences, Technologies and Market Environment

Each country has a representative consumer who consumes a bundle of tradables and non-tradables goods.

$$U_t = g(C_{NT,t}, C_{T,t}) \tag{5}$$

More specifically, we assume Cobb-Douglas per-period utility and, in addition to the non-tradable sector, a tradable sector that consists of a numéraire good and a manufacturing good.

$$U_t = \left(\frac{C_{NT,t}}{\alpha_{NT}}\right)^{\alpha_{NT}} \left(\frac{D_{O,t}}{\alpha_O}\right)^{\alpha_O} \left(\frac{D_{T,t}}{\alpha_T}\right)^{\alpha_T}, \tag{6}$$

$\alpha_j \in (0,1)$ for all j, $\sum_j \alpha_j = 1$. C_{NT}, D_O and D_T denote consumption of, respectively, a non-traded, a numéraire and a manufacturing good, i.e. $C_T \equiv \left(\frac{D_{O,t}}{\alpha_O}\right)^{\alpha_O} \left(\frac{D_{T,t}}{\alpha_T}\right)^{\alpha_T}$; t denotes time. The non-traded and numéraire sectors are perfectly competitive. The manufacturing sector features differentiated varieties produced under monopolistic competition.[19] The consumption-based price index associated to this utility function is $P_t = P_{NT,t}^{\alpha_{NT}} P_{O,t}^{\alpha_O} P_{T,t}^{\alpha_T}$. We take a small-open-economy approach whereby countries face given foreign prices and a given foreign price index P_t^*. Stars denote foreign variables. The RER is defined as $\frac{P_t^*}{P_t}$. Thus, given our assumptions changes in P_t also reflect changes in the real exchange rate. Hence, we will identify P_t with the real exchange rate hereafter.

3.2 Numéraire and Non-traded Sectors

The numéraire good is freely traded and produced with technology

$$Y_O = e^{-1} \left(K_O/\beta_k\right)^{\beta_k} \left(L_O/\beta_l\right)^{\beta_l} \left(X_O/\beta_m\right)^{\beta_m}, \tag{7}$$

[19] We model the manufacturing sector in greater detail below.

$\beta_h > 0$, $\{h = k, l, m\}$, $\sum_h \beta_h = 1$. K_O, L_O, and X_O respectively denote capital, labor and a domestically produced intermediate input employed by the numéraire sector. e is a shifter inversely related to the sector's productivity. We model $\log(e_t)$ as an AR(1) process:

$$\log(e_t) = \gamma_0 + \gamma_1 \log(e_{t-1}) + \nu_t, \quad \nu_t \sim N(0, \sigma_\nu^2). \tag{8}$$

We only consider equilibria in which all countries produce the numéraire good. Since

$$P_{O,t} = e_t r_t^{\beta_k} w_t^{\beta_l} P_{X_t}^{\beta_m} = e_t f_t = 1, \tag{9}$$

$f \equiv r_t^{\beta_k} w_t^{\beta_l} P_{X_t}^{\beta_m} = e^{-1}$: an increase in e makes domestic production factors cheaper. We can therefore think of an increase in e as a real depreciation. The non-traded sector is produced with technology $Y_{NT} = (K_{NT}/\beta_k)^{\beta_k} (L_{NT}/\beta_l)^{\beta_l} (X_{NT}/\beta_m)^{\beta_m}$. We assume that non-tradables can be used for final consumption or as a domestic intermediate input X, which implies $P_{NT,t} = P_{X,t} = e_t^{-1}$.[20] A real depreciation thus increases the relative price of non-tradables. In the appendix we show that $P_t \propto e_t^{-1}$.

3.3 Manufacturing Sector

3.3.1 Preferences, Technologies and Market Environment

There is a continuum of differentiated varieties of manufacturing goods. Consumers have the following preferences over manufacturing varieties i,

$$D_{T,t} = \left(\int_{i \in \Omega_T} d_{it}^{\frac{\sigma-1}{\sigma}} di + \int_{i \in \Omega_T^*} d_{it}^{\frac{\sigma-1}{\sigma}} di \right)^{\frac{\sigma}{\sigma-1}}, \tag{10}$$

where Ω_T and Ω_T^* denote the sets of domestically produced and imported varieties, respectively. We take aggregate variables as exogenous. Since each variety is associated with a different producer, the number of firms equals the number of varieties. There is a fixed number of firms Ω_T. They are infinitely lived and heterogeneous in terms of log-productivity ω_{it}. Each firm produces a single variety of the manufacturing good using technology

$$Y_{it} = \exp(\omega_{it}) K_{it}^{\beta_k} L_{it}^{\beta_l} M_{it}^{\beta_m}. \tag{11}$$

K_i, L_i, and M_i denote the amount of capital, labor and materials, respectively, employed by firm i.

[20] This implies $f = \left(r^{\beta_k} w^{\beta_l}\right)^{1/(1-\beta_m)}$ and $P_X = P_{NT} = f = \left(r^{\beta_k} w^{\beta_l}\right)^{1/(1-\beta_m)} = e^{-1}$: P_{NT}, P_X, and $\left(r^{\beta_k} w^{\beta_l}\right)^{1/(1-\beta_M)}$ move in lockstep.

3.3.2 Imports

We follow Halpern et al. (2015) and assume that manufacturing firms can use domestic and imported intermediates, which are imperfect substitutes with elasticity of substitution ε:

$$M_{it} = \left[(B^* X^*_{it})^{\frac{\varepsilon}{\varepsilon-1}} + X_{it}^{\frac{\varepsilon}{\varepsilon-1}} \right]^{\frac{\varepsilon-1}{\varepsilon}}, \tag{12}$$

where X_i is the quantity of domestically produced intermediates used by firm i and X^*_i is the quantity of imported intermediate inputs. B^* is a quality shifter that allows imported intermediates to be of a different quality. Thus, in case a firm decides to import foreign inputs, the price index of intermediates is given by

$$P_{Mt} = P_X \left[1 + \left(\frac{B^* P_X}{P^*_X} \right)^{\varepsilon-1} \right]^{\frac{1}{1-\varepsilon}} = e^{-1} \left[1 + \left(A e^{-1} \right)^{\varepsilon-1} \right]^{\frac{1}{1-\varepsilon}}, \tag{13}$$

where $A \equiv \frac{B^*}{P^*_X}$ is the quality-adjusted relative cost of imported intermediates. Defining the cost reduction from importing (resulting from a combination of relative price, quality and imperfect substitution) as $\tilde{a}(e) = (\varepsilon - 1)^{-1} \ln \left[1 + \left(A e^{-1} \right)^{\varepsilon-1} \right]$, one can see that cost reductions from importing are increasing in the quality of foreign inputs and decreasing in e. Moreover, it follows that $P_M = P_X exp\left[-\tilde{a}(e)\right]$: an increase in e raises P^*_X/P_X and thus the marginal costs of importing relative to non-importing firms.[21]

Note that material expenditure $\tilde{M} \equiv P_M M$ can be written as $\tilde{M} = P_X exp\left(-\tilde{a}\right) M$. Substituting this into the production function, we get:[22]

$$y_{it} = \beta_0 + \beta_k k_{it} + \beta_l l_{it} + \beta_m \tilde{m}_{it} - \beta_m \log(P_X) + \beta_m \tilde{a}_{it}(e_t) + \omega_{it} + \varepsilon_{it}, \tag{14}$$

Here the term $\beta_m \tilde{a}_{it}(e_t)$ captures the productivity gains from importing intermediates. In case the firm does not import, $P_M = P_X$ and the term $\beta_m \tilde{a}_{it}(e_t)$ disappears from the corresponding expression for the production function.

3.3.3 Demand

Domestic and foreign demand faced by firm i are

$$d_{it} = \left(p_{it}/P_{T,t} \right)^{-\sigma} D_{T,t} \text{ and } d^*_{it} = \left(p_{it}/P^*_{T,t} \right)^{-\sigma} D^*_{T,t}. \tag{15}$$

d_i is the domestic demand faced by firm i; p_i is the domestic price charged by firm i; D_T and D^*_T are demand for the CES aggregate by, respectively, domestic and foreign consumers. The number of foreign firms, Ω^*_T foreign demand D^* and the foreign price level P^*_T are also given. Firms behave as monopolists and charge a constant mark-up over their marginal production costs. Firm i's domestic

[21] We discuss the choice to import inputs below. The price charged by non-importing firms is $p_i\left(\omega_i, e\right) = e^{-1} \frac{\sigma}{\sigma-1} \exp\left(-\omega_i\right)$. Importing firms charge $p_i\left(\omega_i, e\right) = e^{-1} exp\left[-\tilde{a}(e)\right]^{\beta_m} \frac{\sigma}{\sigma-1} \exp\left(-\omega_i\right)$.

[22] We use $z \equiv \log Z$, $Z = K, L, \tilde{M}$.

revenue is

$$R_{it}^{d}=p_{it}^{1-\sigma}P_{T,t}^{\sigma-1}(P_{T,t}D_{T,t}). \tag{16}$$

For non-importing (NI) firms,

$$R_{it}^{d}=\left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma}\exp\left[(\sigma-1)\,\omega_i\right]e_t^{\sigma-1}P_{T,t}^{\sigma-1}(P_{T,t}D_{T,t}). \tag{17}$$

Variable domestic profits are given by $\Pi_{it}^{d}=R_{it}^{d}/\sigma$. Notice that e potentially affects R^{d} by affecting the marginal costs faced by the firm and thereby the price p_i it charges, and by shifting the domestic aggregate price level in manufacturing P_T. Both effects are proportional to e^{-1} and cancel each other out. (See the appendix). Thus, conditional on aggregate expenditure on manufacturing (P_TD_T), e has no effect on R_i^{d} and Π_i^{d}. By contrast, in the case of importing (I) firms, e has an additional effect on revenue (and profits) through the price of imported intermediates:

$$R_{it}^{d}=\left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma}\exp\left[(\sigma-1)\,\omega_i\right]e_t^{\sigma-1}exp\left[-\tilde{a}(e_t)\right]^{(1-\sigma)\beta_m}P_{T,t}^{\sigma-1}(P_{T,t}D_{T,t}). \tag{18}$$

Hence, a real depreciation reduces domestic revenue and profits of importers.

3.3.4 Exports

If a firm with log-productivity level ω_i chooses to export,[23] its export revenue is

$$R_{it}^{x}=p_{it}^{1-\sigma}(P_{T,t}^{*})^{\sigma-1}(P_{T,t}^{*}D_{T,t}^{*}). \tag{19}$$

For non-importing (NI) firms,[24]

$$R_{it}^{x}=\left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma}\exp\left[(\sigma-1)\,\omega_i\right]e_t^{\sigma-1}(P_{T,t}^{*})^{\sigma-1}(P_{T,t}^{*}D_{T,t}^{*}). \tag{20}$$

Variable export profits are $\Pi_{it}^{x}=R_{it}^{x}/\sigma$. Changes in e affect export revenues and profits by impacting on firm's marginal cost. A real depreciation reduces domestic factor costs, makes domestic firms gain market share and increase profits in the export market because the foreign price level P_T^{*} is unaffected by the shift in e. This effect is smaller for exporters that also import, since a real depreciation makes imports of intermediate inputs more expensive, thereby affecting the export profits of importing firms in the opposite direction.

[23]This decision is also discussed below.

[24]As in the case of domestic sales, export revenues and profits of importers and non-importers differ by term $exp\left[-\tilde{a}(e_t)\right]^{(1-\sigma)\beta_m}$.

3.3.5 Exporter and Importer Status

Importing and exporting decisions involve per-period fixed costs f_m and f_x, respectively.[25] Each firm's fixed cost is an iid random draw. More productive firms self-select into one or both of these activities. The resulting decisions are static choices. Moreover, they are complements: each activity raises the gain from the other.

Firm i therefore chooses one among four different "regimes", which characterize the following per-period profit function:

$$\Pi_{it} = \max\left[\Pi_{it}^{(x,m)} - f_x - f_m, \Pi_{it}^{(x,0)} - f_x, \Pi_{it}^{(0,m)} - f_m, \Pi_{it}^{(0,0)}\right], \tag{21}$$

where $\Pi_{it}^{x,m} = \Pi_{it}^{d}\left[\omega_{it}, exp\left[-\tilde{a}\left(e_t\right)\right]\right] + \Pi_{it}^{x}\left[\omega_{it}, e_t, exp\left[-\tilde{a}\left(e_t\right)\right]\right]$ are the profits of a firm that both exports and imports; $\Pi_{it}^{(x,0)} = \Pi_{it}^{d}\left[\omega_{it}\right] + \Pi_{it}^{x}\left[\omega_{it}, e_t\right]$ are the profits of an exporting firm that does not import materials; $\Pi_{it}^{(0,m)} = \Pi_{it}^{d}\left[\omega_{it}, exp\left[-\tilde{a}\left(e_t\right)\right]\right]$ are the profits of an importing non-exporter; and $\Pi_{it}^{(0,0)} = \Pi_{it}^{d}\left[\omega_{it}\right] > 0$ are the profits of a firm that neither exports nor imports. Notice that firms that choose to export and/or import can always finance the corresponding fixed costs with their profits.

3.3.6 Dynamic Choice of R&D

Unlike the static export and import choices, R&D is a dynamic decision with an option value. Innovation increases productivity, but is subject to sunk costs $f_{RD,0}$ in the period the firm starts innovating and fixed costs f_{RD} in other periods in which it innovates. We follow Aw et al. (2011) and assume that log-productivity ω_{it} follows the following Markov process

$$\omega_{it} = \alpha_0 + \alpha_1\omega_{it-1} + \alpha_2 I_{iRD,t-1} + u_{it}, \quad u_{it} \sim N(0, \sigma_u^2), \tag{22}$$

where $I_{iRD,t-1}$ is an indicator variable for innovation in $t-1$ and α_2 is the log-productivity return to innovation. Note that when $|\alpha_1| < 1$ the stochastic process is stationary and the model does not produce any long-run productivity trends. In particular, a plant that always engages in R&D has expected log-productivity $E(\omega_{it}|I_{iRD} = 1 \quad \forall t) = \frac{\alpha_0+\alpha_2}{1-\alpha_1}$, while a plant that never does R&D has expected log-productivity $E(\omega_{it}|I_{iRD} = 1 \quad \forall t) = \frac{\alpha_0}{1-\alpha_1}$. The R&D choice is dynamic due to both the existence of fixed and sunk costs and its impact on productivity, which is persistent.

We model financial constraints by assuming that in each period the sum of all sunk and fixed costs cannot go beyond a proportion θ of current profits:

$$I_{iRD,t}[f_{RD,0}(1 - I_{iRD,t-1}) + f_{RD}I_{iRD,t-1}] \leq \theta\Pi_{it}(\omega_{it}, e_t), \tag{23}$$

Parameter $\theta \in [1, \bar{\theta}]$ reflects the quality of the financial system: the lower θ, the more financially constrained the firms.

[25] Unlike with the R&D decision, we assume no one-time sunk cost is required for either of these two activities.

The current state for plant i in year t is given by the vector $s_{it} = (\omega_{it}, e_t, I_{iRD,t-1})$. The firm's value function is then

$$\begin{aligned} & V_{it}(s_{it}) = \qquad (24) \\ = \quad & \max_{I_{iRD,t}} \Big\{ \Pi_{it}(\omega_{it}, e_t) + \beta E_t V_{it+1}(s_{it+1} | I_{iRD,t} = 1, s_{it}) - I_{iRD,t}[I_{iRD,t-1} f_{RD} - (1 - I_{iRD,t-1}) f_{RD,0}], \\ & \Pi_{it}(\omega_{it}, e_t) + \beta E_t V_{it+1}(s_{it+1} | I_{iRD,t} = 0, s_{it}) \} , \end{aligned}$$

where $\beta = (1+r)^{-1}$ is the plant's discount factor. The plant then chooses an infinite sequence of R&D decisions $I_{iRD,t}$ that maximizes the value function subject to the financial constraint for R&D.

4 Estimation

Our parameter calibration/estimation strategy consists of several steps. First, we choose reasonable values for the parameters θ (credit constraints), σ (elasticity of demand) and r (interest rate). For the moment, we do not investigate the credit-constraint channel and the import channel in the simulations. We thus set the import fixed cost f_m sufficiently large that no firm imports. Moreover, we set θ sufficiently high that no firm is credit constrained.[26]

Second, for a given elasticity of demand σ, parameters α_0, α_1, α_2, which determine the stochastic process for log-productivity, and the output elasticities, β_l, β_k, β_m, are obtained from the estimation of the production function (11). Third, the parameters ruling the stochastic process of the RER (γ_0, γ_1, σ_v^2) are obtained by estimating the AR(1) process specified for $\log(e_t)$ in equation (8).

Finally, the rest of the model's parameters (f_X, $f_{RD,0}$, f_{RD}, D, D^*, σ_u^2)[27] are estimated by using a simulated method of moment approach that matches model and data parameters.[28]

4.1 Production-function Estimation

We follow de Loecker (2011) and Halpern et al. (2015) to recover our firm-level productivity measure. Substituting the demand function (15) into the definition of total revenue, total revenue can be expressed as:[29]

[26] Exploring the role of importing and credit constraints is work in progress.

[27] We assume that firms pick draws for the different fixed costs from a number of exponential distributions with means $\bar{f}_X$, $\bar{f}_{RD,0}$, $\bar{f}_{RD}$, and variances f_X^2,$f_{RD,0}^2$,f_{RD}^2.

[28] We re-estimate the persistence parameter of the log-productivity process α_1 again in the model, as we want to allow for some flexibility in order to match the moments. (The persistence of productivity affects innovation choices.) In the end, however, the two estimates for α_1 are almost identical.

[29] From $d_i = \left(\frac{p_i}{P}\right)^{-\sigma} D$, we get the inverse demand function $p_i = d_i^{\frac{-1}{\sigma}} D^{\frac{1}{\sigma}} P = d_i^{\frac{-1}{\sigma}} \tilde{D}^{\frac{1}{\sigma}}$, where $\tilde{D} \equiv DP^{\sigma}$. Using optimal pricing $p_i = \frac{\sigma}{\sigma-1} MC_i$ it is easy to show that the fraction of domestic sales is given by $\nu_i \equiv \frac{d_i}{d_i + d_i^*} = \frac{P^{\sigma} D}{P^{\sigma} D + e^{\sigma} (P^*)^{\sigma} D^*} \equiv \frac{\tilde{D}}{\tilde{D} + \tilde{D}^*}$. Since $d_i = \nu_i Y_i$ we have that $d_i^{\frac{\sigma-1}{\sigma}} = \nu_i^{\frac{\sigma-1}{\sigma}} Y_i^{\frac{\sigma-1}{\sigma}} = \left(\frac{\tilde{D}}{\tilde{D}+\tilde{D}^*}\right)^{\frac{\sigma-1}{\sigma}} Y_i^{\frac{\sigma-1}{\sigma}}$. We can then write total revenue as $R_i = p_i d_i + p_i^* d_i^* = d_i^{\frac{\sigma-1}{\sigma}} D^{\frac{1}{\sigma}} P + (d_i^*)^{\frac{\sigma-1}{\sigma}} D^{\frac{1}{\sigma}} P^* e = Y_i^{\frac{\sigma-1}{\sigma}} \nu^{\frac{\sigma-1}{\sigma}} D^{\frac{1}{\sigma}} P + Y_i^{\frac{\sigma-1}{\sigma}} (1-\nu)^{\frac{\sigma-1}{\sigma}} (D^*)^{\frac{1}{\sigma}} (P^*) e = Y_i^{\frac{\sigma-1}{\sigma}} \left(\frac{\tilde{D}}{\tilde{D}+\tilde{D}^*}\right)^{\frac{\sigma-1}{\sigma}} \tilde{D}^{\frac{1}{\sigma}} + Y_i^{\frac{\sigma-1}{\sigma}} \left(\frac{\tilde{D}^*}{\tilde{D}+\tilde{D}^*}\right)^{\frac{\sigma-1}{\sigma}} (\tilde{D}^*)^{\frac{1}{\sigma}} = Y_i^{\frac{\sigma-1}{\sigma}} \left[(DP)^{\frac{1}{\sigma}} + (d^*) \left[D^* P^* (e^{\sigma})\right]^{\frac{1}{\sigma}}\right]$.

$$R_{it} = p_{it}d_{it} + p^*_{it}d^*_{it} = (Y_{it})^{\frac{\sigma-1}{\sigma}} \underbrace{[(DP)^{\frac{1}{\sigma}} + I_{ix,t}(D^*_t P^*_t e^\sigma_t)^{\frac{1}{\sigma}}]}_{F_{it}(D_t, D^*_t, e_t)}$$

where Y_{it} is physical output and F_{it} captures the state of aggregate demand, which depends on the RER e_t. F_{it} varies by plant only through I_{ixt}, which is an indicator that equals one if the plant exports and thus allows the plant to also attract foreign demand. Plugging in production function (14) and taking logs,

$$r_{it} = \frac{\sigma-1}{\sigma}\left[\beta_0 + \beta_k k_{it} + \beta_l l_{it} + \beta_m \tilde{m}_{it} - \beta_m \log(P_{Xst}) + \beta_m \tilde{a}_{it}(e_t) + \omega_{it} + \varepsilon_{it}\right] + f_{it}\left(D_t, D^*_t, e_t\right). \tag{25}$$

4.1.1 First Stage

Assuming material input $\tilde{m}_{it} = \tilde{m}\left(\omega_{it}, k_{it}, D_t, D^*_t, e_t\right)$ is strictly increasing in ω_{it}, we can express ω_{it} as a function of capital k_{it}, materials $\tilde{m}_{it}$ and aggregate demand (D_t, D^*_t, e_t):

$$\begin{aligned} r_{it} &= \tilde{\beta}_l l_{it} + \tilde{\beta}_0 + \tilde{\beta}_k k_{it} + \tilde{\beta}_m \tilde{m}_{it} + \tilde{\omega}_{it}\left(k_{it}, \tilde{m}_{it}, D_t, D^*_t, e_t\right) + \beta_m \tilde{a}_{it}(e_t) + \beta_m \log(P_{Xst}) + f_{it}\left(D_t, D^*_t, e_t\right) + \varepsilon_{it} = \\ &= \tilde{\beta}_l l_{it} + \Phi\left(k_{it}, \tilde{m}_{it}, D_t, D^*_t, e_t\right) + \varepsilon_{it}, \end{aligned} \tag{26}$$

where $\tilde{\beta} = \frac{\sigma-1}{\sigma}\beta$ and $\tilde{\omega} = \frac{\sigma-1}{\sigma}\omega$. $\Phi\left(k_{it}, \tilde{m}_{it}, D_t, D^*_t, e_t\right)$ is a function that captures a combination of ω_{it}, the import channel and the demand channel. It is approximated using a flexible polynomial:

$$\begin{aligned} \Phi\left(k_{it}, \tilde{m}_{it}, D_t, D^*_t, e_t\right) &= \lambda_0 + \lambda_1 k_{it} + \lambda_2 \tilde{m}_{it} + \lambda_3 k_{it}\tilde{m}_{it} + \lambda_4 k^2_{it} + ... + \lambda_9 \tilde{m}^3_{it} + \\ &+ \sum_{j=1}^{J} \lambda^{EXP}_j \log(e^{EXP}_{st}) + \sum_{j=1}^{J} \lambda^{IMP}_j \log(e^{IMP}_{st}) + D_{ct} + D_s, \end{aligned} \tag{27}$$

Here, D_{ct} are country-time dummies that proxy for aggregate demand shocks and also correct for the fact that output and inputs are measured in nominal terms and D_s are sector dummies capturing the domestic price of materials. The terms $\sum_{j=1}^{J} \lambda^{EXP}_j \log(e^{EXP}_{st})$ and $\sum_{j=1}^{J} \lambda^{IMP}_j \log(e^{IMP}_{st})$ are interactions of sector-specific export and import-weighted RERs with dummies for firm size bins. They control for the impact of firms' export and import decisions on their demand and productivity. By interacting RERs with dummies for firm size, we allow the impact of RER changes to affect firms differentially depending on their size. OLS estimation of (26) allows us to recover an estimate for the labor coefficient $\widehat{\beta_l}$ and predicted values for $\widehat{\Phi}\left(k_{it}, \tilde{m}_{it}, D_t, D^*_t, e_t\right)$ from the first stage.

4.1.2 Second Stage

In the second stage we obtain consistent estimates for $\tilde{\beta}_k$, $\tilde{\beta}_m$, α_1 and $\tilde{\alpha}_2$. To do this, we plug our estimates $\widehat{\beta_l}$ and $\widehat{\Phi}\left(k_{it}, \tilde{m}_{it}, D_t, D^*_t, e_t\right)$ into the equation resulting from combining the stochastic process for TFP (22) with (26).

$$
\begin{aligned}
& r_{it} - \widehat{\beta}_l l_{it} = \tilde{\beta}_0 + \tilde{\beta}_k k_{it} + \tilde{\beta}_m \tilde{m}_{it} + \tilde{\alpha}_0 + \\
& + \alpha_1 \left[\widehat{\Phi} \left(k_{it-1}, \tilde{m}_{it-1}, D_{t-1}, D_{t-1}^{*}, e_{t-1} \right) - \tilde{\beta}_k k_{it-1} - \tilde{\beta}_m \tilde{m}_{it-1} \right] + \tilde{\alpha}_2 I_{i,RD_{t-1}} + \varepsilon_{it} + \tilde{u}_{it}.
\end{aligned} \tag{28}
$$

Since $E(\tilde{m}_{it}\tilde{u}_{it}) \neq 0$ we need to instrument for $\tilde{m}_{it}$ using the 2-period lag of materials. The moment conditions are given by $E(Z_t'(\varepsilon_t + \tilde{u}_t)) = 0$, where $Z_t = (\tilde{m}_{t-1}, \tilde{m}_{t-2}, k_{t-1}, I_{RD_{t-1}})$. We use a 2-step GMM estimator to obtain consistent estimates of $\tilde{\beta}_k$, $\tilde{\beta}_m$, $\tilde{\alpha}_0$, α_1, and $\tilde{\alpha}_2$. We obtain standard errors using a bootstrap.

Having recovered the parameter estimates, we can now construct revenue-based productivity (TFPR) as

$$
tfpr_{it} \equiv r_{it} - \tilde{\beta}_l l - \tilde{\beta}_k k_{it} - \tilde{\beta}_m m_{it} = \left(\frac{\sigma - 1}{\sigma} \right) [\beta_0 + \omega_{it} + \varepsilon_{it} + \beta_m \tilde{a}_{it} - \beta_m \log P_{Xst}] + f_{it} \left(D_t, D_t^{*}, e_t \right). \tag{29}
$$

Notice that measured revenue-based productivity is a combination of true productivity ω_{it}, import effects on productivity $\beta_m \tilde{a}_{it}(e_t)$ and demand $f_{it}\left(D_t, D_t^{*}, e_t\right)$. We thus need to use our structural model to decompose it into these three effects.

4.2 Decomposing the Productivity Effects of RER Changes

Suppose

$$
E(tfpr_{ict}|X_{ict}) = \beta_0 + \beta_1 \log e_{ct} + \beta_2 X_{ct} + \delta_i + \delta_t \tag{30}
$$

This can be differenced to get rid of δ_i

$$
\Delta tfpr_{ict} = \beta_1 \Delta \log e_{ct} + \beta_2 \Delta X_{ct} + \Delta \delta_t + \Delta u_{ict} \tag{31}
$$

Then

$$
\frac{\partial E(tfpr_{ict}|X_{ict})}{\partial \log e_{ct}} = \beta_1 \tag{32}
$$

is the average elasticity (over the distribution of tfpr) of TFPR with respect to the RER.

In the model we have that

$$
\begin{aligned}
E(tfptr_{it}) &= \left(\frac{\sigma - 1}{\sigma} \right) E\left[\beta_0 + \omega_{it} + \varepsilon_{it} + \beta_m \tilde{a}_{it} - \beta_m \log(P_{Xst})\right] + f_{it}\left(D_t, D_t^{*}, e_t\right) = \\
& \left(\frac{\sigma - 1}{\sigma} \right) [\beta_0 + \alpha_0 + \alpha_1 E(\omega_{it-1}) + \alpha_2 E(I_{RD,t-1}) + E(\varepsilon_{it}) + \beta_m E(\tilde{a}_{it}) - \beta_m \log(P_{Xst})] + E(f_{it}(D_t, D_t^{*}, e_t)) \\
&= \left(\frac{\sigma - 1}{\sigma} \right) [\beta_0 + \alpha_0 + \alpha_1 E(\omega_{it-1}) + \alpha_2 Prob(I_{RD,t-1} = 1) + \beta_m Prob(I_{Mt} > 0) E(\tilde{a}_{it}|I_{Mt} > 0) - \beta_m \log(P_{Xst})] \\
& \quad + [Prob(I_{X,t} = 0) E(f_{it}(D_t, D_t^{*}, e_t)|I_{X,t} = 0) + Prob(I_{X,t} = 1) E(f_{it}(D_t, D_t^{*}, e_t)|I_{X,t} = 1)]
\end{aligned} \tag{33}
$$

Computing the model counterpart to the reduced-form regression:

$$
\begin{aligned}
\frac{\partial E(tfptr_{it})}{\partial \log e_t} = & \underbrace{\left(\frac{\sigma-1}{\sigma}\right)\alpha_2 \frac{\partial Prob(I_{RD,t-1}=1)}{\partial \log e_t}}_{\text{R\&D}} \\
& + \underbrace{\left(\frac{\sigma-1}{\sigma}\right)\beta_m \left[\frac{\partial Prob(I_{Mt}>0)}{\partial \log e_t} E(\tilde{a}_{it}|I_{Mt}>0) + Prob(I_{Mt}>0)\frac{\partial E(\tilde{a}_{it}|I_{Mt}>0)}{\partial \log e_t}\right]}_{\text{imports}} \\
& + \underbrace{\left[\frac{\partial Prob(I_{X,t}=0)}{\partial \log e_t} E(f_{it}(D_t,D_t^*,e_t)|I_{X,t}=0) + Prob(I_{X,t}=0)\frac{\partial E(f_{it}(D_t,D_t^*,e_t)|I_{X,t}=0)}{\partial \log e_t}\right]}_{\text{demand non-exporters}} \\
& + \underbrace{\left[\frac{\partial Prob(I_{X,t}=1)}{\partial \log e_t} E(f_{it}(D_t,D_t^*,e_t)|I_{X,t}=1) + Prob(I_{X,t}=1)\frac{\partial E(f_{it}(D_t,D_t^*,e_t)|I_{X,t}=1)}{\partial \log e_t}\right]}_{\text{demand exporters}}
\end{aligned}
\tag{34}
$$

Here the first line is the productivity effect of RER that operates through the innovation channel. Specifically, this channel combines the 'market size effect' that induces more innovation through a larger net present value of future profits and the 'financial constraints channel', which operates through an increase of current profits and a relaxation of the borrowing constraint. Note that $\frac{\partial Prob(I_{RD,t-1}=1)}{\partial \log e_t} = \frac{1}{\gamma_1}\frac{\partial Prob(I_{RD,t-1}=1)}{\partial \log e_{t-1}}$. This effect combines the market-size effect and the financial constraints channel.

The second line is the importing channel of the RER on productivity. It can be divided into an extensive margin (change in the probability to import weighted with the average import intensity) and an intensive margin (change in import intensity weighted with the average probability to import). This channel, which decreases tfpr, is more important the larger the fraction of importers and the higher the import intensity.

Finally, the third and the fourth lines are the demand channel of the RER. An increases in the RER increases demand both for domestic firms and for exporters. The first term is the change in the probability of serving only the domestic market weighted with average domestic demand and the second term is the average change in demand for firms serving the domestic market weighted with the probability of serving only this market. Similarly, the third and fourth terms capture changes in export probabilities and changes in demand for exporters.

We will use our structural model to decompose the observed average elasticities of TFPR with respect to RER into the different components.

4.3 Model Estimation

Table 7 reports our preferred values for the parameters we calibrate (r, σ, ε and θ) and the list of parameters we need to estimate by matching model and data moments. For emerging East Asia, and the other developing countries, we set the annual real interest rate to 15%, which corresponds to a reasonable value for these economies. For industrialized economies, we choose a real interest rate of 5%. We set the elasticity of demand σ equal to 4, which is a plausible value for this parameter (see

Table 7: Parameters needed

Parameter	Description	Value	Parameter	Description
(*set without solving the dynamic model*)				(*estimated parameters*)
σ	demand elasticity	4	f_x	export fixed cost, mean
ε	subst. elasticity intermediates	4	f_m	import fixed cost, mean
r	interest rate (developing)	0.15	$f_{RD,0}$	R&D sunk cost, mean
r	interest rate (industrialized)	0.05	f_{RD}	R&D fixed cost, mean
θ	coefficient on credit constraint	5	α_1	persistence, productivity
			σ_u	s.d., innovation of productivity
			D	log domestic demand
			D^*	log foreign demand

e.g. Costinot and Rodriguez-Clare, 2015). We set the elasticity of substitution between domestic and imported intermediates equal to 4, which is in the range estimated by Halpern et al. (2015) for Hungarian firms. For the moment we set θ, which determines the level of credit constraints, equal to 5.

The following parameters are estimated within the structural model: the mean export fixed cost f_x, the mean import fixed cost f_m, the mean R&D sunk cost $f_{RD,0}$ and the mean R&D fixed cost f_{RD}. We also estimate within the model the autocorrelation and TFP, α_1 and the standard deviation of the TFP shocks σ_u.[30]

In terms of moments we choose to match in order to identify the model parameters, we distinguish between cross-sectional moments (export probability, import probability, export/sales ratio for exporters, import/sales ratio for importers, R&D probability, mean and standard deviation of the firm size distribution (gross output)) and dynamic moments (continuing and start rate of R&D, elasticities of R&D probability and TFPR with respect to the RER, the autocorrelation of TFPR).

The simulated moments procedure is implemented as follows. For a given set of parameter values, we solve the value function and the corresponding policy function with a value-function iteration procedure: we first draw a set of productivity and RER shocks; we then simulate a set of firms for multiple countries with different realizations of the RER and compute the moments of interest. We compare the simulated and data moments and update the parameter values to minimize the distance between simulated moments and data moments. We iterate these steps (keeping the draws of the shocks fixed) until convergence.

[30] In principle, these parameters can be directly recovered from the TFP estimation, but there we allow for a Markov process which is a bit more general than AR(1). We do this because the estimation works much better when we also allow for a square term in lagged productivity.

5 Estimation Results

5.1 Estimates for RER and TFP Process

Table 8 reports the estimates of both the production-function parameters (equation (11)) and the stochastic process for log-productivity (equation (22)) for the pooled sample (industrialized countries, emerging East Asia, other developing). The estimate for $\tilde{\alpha}_2$ is 0.228 (0.157), which, given a σ of 4, corresponds to a return of R&D of 0.3 (0.2). This seems relatively high but not implausible, in particular when considering the set of developing countries. The coefficients on labor, capital and materials are 0.336, 0.129 and 0.674 and correspond to $\beta_L = 0.448$, $\beta_K = 0.053$ and $\beta_M = 0.899$, which suggests increasing returns to scale. By constrast, the estimates for the value-added-based output elasticities are $\tilde{\beta}_L = 0.533$, and $\tilde{\beta}_K = 0.207$ ($\beta_L = 0.71$ and $\beta_K = 0.28$), suggesting constant returns.

In Table 9 we present results from estimating the AR(1) process for the RER e_t (see equation (8)) using the period 2001-2010 The RER has an autocorrelation coefficient of 0.93. This implies that swings in e_t are very persistent, and can thus potentially have a significant effect on firms' dynamic R&D investment decisions. The R-squared of fitting this process is also 0.93.

Table 8: Production function: coefficient estimates

labor $\tilde{\beta}_l$	0.33621***	0.53342***
	(0.00170)	(0.00245)
capital $\tilde{\beta}_k$	0.09793***	0.20786***
	(0.01976)	(0.01047)
materials $\tilde{\beta}_m$	0.67415***	
	(0.02552)	
R&D return $\tilde{\alpha}_2$	0.22848***	0.15761***
	(0.07306)	(0.03812)
$\log(e^{exp}_{sct})\times$	0.00125	-0.14872***
λ^{exp}_1	(0.02131)	(0.03440)
$\log(e^{exp}_{sct})\times$	0.42624***	0.72894***
λ^{exp}_2	(0.02462)	(0.03941)
$\log(e^{exp}_{sct})\times$	0.34517***	0.75503***
λ^{exp}_3	(0.02741)	(0.04605)
$\log(e^{exp}_{sct})\times$	0.17792***	0.44537***
λ^{exp}_4	(0.06777)	(0.11737)
$\log(e^{imp}_{sct})\times$	-0.07311***	0.10997***
λ^{imp}_1	(0.02015)	(0.03286)
$\log(e^{imp}_{sct})\times$	-0.56088***	-0.83792***
λ^{imp}_2	(0.02471)	(0.03454)
$\log(e^{imp}_{sct})\times$	-0.70016***	-1.14283***
λ^{imp}_3	(0.02682)	(0.04461)
$\log(e^{imp}_{sct})\times$	-0.82707***	-1.24005***
λ^{imp}_4	(0.06633)	(0.11686)
Observations	1,001,593	1,001,593
Country-time FE	YES	YES
Sector FE	YES	YES

Table 9: AR (1) process of log RER

	(1)	(2)
intercept	-0.000472	-0.0315
	(0.0095)	(0.0201)
$\log e_{c,t-1}$	0.930***	0.935***
	(0.015)	(0.015)
Observations	657	657
R-squared	0.931	0.947
s.d. residuals	0.105	0.0924
Cluster	Country	Country
Time dummies	NO	YES

5.2 Estimates of Other Model Parameters

Tables 10-12 report the parameter values estimated using the simulated method of moments procedure for our different sub-samples, [31] as well as a comparison between the data and the simulated models. In general, the model performs very well in terms of fitting both cross-sectional moments and elasticities with respect to RER. For all sub-samples, the only moment for which there is a noticeable difference between data and model is the elasticity of R&D probability with respect to the RER. [32] For the other moments, both cross-sectional (R&D, export and import probabilities, export-to-sales and import-to-sales ratios, firm-size mean and standard deviation) and dynamic (R&D continuation and starting probabilities, the elasticity of TFPR with respect to the RER and the autocorrelation of TFPR), the discrepancies are rather minor.

Regarding the estimated parameter values, the different sub-samples feature important differences. The fixed costs associated to R&D are the largest and they take rather remarkable values in the case of East Asia and other developing countries: they are roughly equivalent to the sales of the firms in the 75th percentile of the corresponding distributions. For industrialized countries these fixed costs are much lower both in levels and relative to the sales percentile. The fixed cost to exporting for East Asia (equivalent to the sales of the 65th percentile) is larger than for other developing (14th percentile) and industrialized (45th percentile) countries. Not surprisingly, the fixed costs to importing are rather high in East Asia (71st percentile) in comparison with other developing (43rd percentile) and industrialized (56th percentile) countries.

The value of parameter A reflecting the quality of imported intermediates has the same value for East Asia and the industrialized countries (0.71), whereas it takes a larger value for other developing countries (0.97). Regarding the demand parameters D and D^*, their most remarkable feature is that D^* is larger than D in the case of East Asia, reflecting the export orientation of firms from these region, whereas D^* is smaller than D for the other two sub-samples. Finally, the parameters ruling the stochastic process of log-productivity ω are comparable across the three subsamples: α_1 and σ_u are in the ballpark of 0.85 and 0.25, respectively.

[31] Standard errors are still to be estimated.

[32] It is true though that the model delivers theoretical moments for this variable that are much closer to zero than the data, whereas the latter are based on estimated elasticities that are not significantly different from zero.

Table 10: Estimated parameters and model fit: emerging East Asia

Parameter	Description	Values	Moments	Data	Model
			(*Cross-sectional moments*)		
f_x	export fixed cost,mean	1,940	R&D probability	0.32	0.32
$f_{RD,0}$	R&D sunkcost, mean	11,000	Export probability	0.26	0.26
f_{RD}	R&D fixed cost, mean	7,300	Export/sales Ratio, mean	0.60	0.59
f_m	import fixed cost, mean	5,642	Import probability	0.17	0.17
A	quality of imported intermediates	0.71	Import/sales ratio	0.13	0.14
D	log domestic demand	4.75	Mean firm size (revenue)	7.8	7.2
D^*	log foreign demand	5.51	Sd, firm size (revenue)	3.25	3.3
α_1	persistence, productivity	0.87	(*Dynamic moments*)		
σ_u	sd, innovation of productivity	0.26	R&D, continuation prob.	0.82	0.86
			R&D, start prob.	0.06	0.06
			Elasticity of R&D probability w.r.t RER	0.166	0.06
			autocorrelation, TFPR	0.936	0.926
			Elasticity of TFPR (G.O.) w.r.t RER	0.12	0.16

In Table 13 we decompose the elasticity of TFPR with respect to RER into its components for each of the regions. For emerging East Asia the overall elasticity is 0.17. This is composed as follows: a 1-percent depreciation leads to a 0.17 percent increase in demand; a 0.05 percent loss in productivity due to importing and a 0.014 increase in physical productivity due to more R&D. Thus, in the short run, even in emerging East Asia physical productivity gains are swamped by productivity losses from importing. However, this result will reverse in the medium run, as we will show below, because productivity gains from R&D are persistent, while productivity losses due to reduced importing are temporary. In the set of other developing countries a 1-percent depreciation is associated with a 0.16 percent loss in TFPR, which is composed of a 0.05 increase in demand, a 0.22 percent loss in productivity due to reduced imports, and a 0.01 percent productivity gain from increased R&D. Finally, the elasticity of TFPR is basically zero in industrialized countries (-0.03) and consists of a 0.05 percent increase in demand, a 0.08 productivity loss due to reduced imports and a 0.008 productivity gain from increased R&D. Thus, our model highlights very different effects of real depreciations on TFPR and its components across regions.

6 Counterfactuals

In this section, we use the estimated model to perform a number of counterfactual exercises: we simulate an unanticipated temporary depreciation of the exchange rate, allowing for a yearly depreciation of 8% for five years with a subsequent appreciation back to the initial level of the RER. All along the

Table 11: Estimated parameters and model fit: other developing countries

Parameter	Description	Values	Moments	Data	Model
			(*Cross-sectional moments*)		
f_x	export fixed cost,mean	95	R&D probability	0.29	0.3
$f_{RD,0}$	R&D sunkcost, mean	25,900	Export probability	0.35	0.35
f_{RD}	R&D fixed cost, mean	15,550	Export/sales Ratio, mean	0.1	0.1
f_m	import fixed cost, mean	498	Import probability	0.39	0.39
A	quality of imported intermediates	0.97	Import/sales ratio	0.34	0.24
D	log domestic demand	5.45	Mean firm size (revenue)	7.8	7.63
D^*	log foreign demand	3.47	Sd, firm size (revenue)	3.25	2.9
α_1	persistence, productivity	0.85	(*Dynamic moments*)		
σ_u	sd, innovation of productivity	0.26	R&D, continuation prob.	0.82	0.85
			R&D, start prob.	0.06	0.06
			Elasticity of R&D probability w.r.t RER	0.16	-0.07
			autocorrelation, TFPR	0.936	0.946
			Elasticity of TFPR (G.O.) w.r.t RER	-0.10	-0.16

Table 12: Estimated parameters and model fit: industrialized countries

Parameter	Description	Values	Moments	Data	Model
			(*Cross-sectional moments*)		
f_x	export fixed cost,mean	920	R&D probability	0.56	0.51
$f_{RD,0}$	R&D sunkcost, mean	5,400	Export probability	0.23	0.23
f_{RD}	R&D fixed cost, mean	2,550	Export/sales Ratio, mean	0.17	0.17
f_m	import fixed cost, mean	2,940	Import probability	0.20	0.21
A	quality of imported intermediates	0.71	Import/sales ratio	0.14	0.14
D	log domestic demand	4.72	Mean firm size (revenue)	7.46	7.66
D^*	log foreign demand	3.2	Sd, firm size (revenue)	2.94	2.97
α_1	persistence, productivity	0.86	(*Dynamic moments*)		
σ_u	sd, innovation of productivity	0.25	R&D, continuation prob.	0.82	0.90
			R&D, start prob.	0.06	0.09
			Elasticity of R&D probability w.r.t RER	-0.168	0.001
			autocorrelation, TFPR	0.936	0.959
			Elasticity of TFPR (G.O.) w.r.t RER	-0.031	-0.025

Table 13: Elasticity of TFPR (G.O) w.r.t RER, Decomposition

	Physical productivity	Demand	Imports	Combined
Emerging East Asia	0.014	0.21	-0.05	0.17
Other developing	0.011	0.05	-0.22	-0.16
Industrialized	0.008	0.05	-0.08	-0.03

exercise, we keep firms' beliefs about the exchange-rate process constant. We do this for the samples of emerging East Asia, other developing countries and industrialized countries.

The top panels of figure 2 plot the simulation results for emerging East Asia. We plot the time paths of the percentage deviations of the exchange rate, revenue TFP and its components from their original steady-state levels. The positive demand effect of the depreciation on demand revenue TFP is quite large relative to the negative effect on import revenue TFP, as expected in a sub-sample of countries with export-intensive firms that import relatively small volumes of intermediate inputs. In this case, the increase in profits due to higher demand for the firms' exports is larger than the decrease in profits due to the fact that intermediate inputs are now more expensive. The resulting net increase in profits leads to R&D investments that trigger an increase in physical productivity. Notice that this increase in physical productivity persists for much longer than the other effects, which are purely transitory. This suggests that temporary exchange rate movements can have very long-lasting effects on productivity growth.

The middle panels of figure 2 plot the results of our simulation for other developing countries. Recall firms in this sub-sample are much more import intensive than East Asian firms. The negative effect of a depreciation on import revenue TFP dominates the positive effect on demand revenue TFP. Similarly, the net effect of the depreciation on firms' profits is negative, inducing them to reduce their investment in R&D with the subsequent decrease in physical productivity. (Again as above, changes in physical productivity are much more long-lasting than those of the other components of revenue TFP.) In contrast with the East-Asian sub-sample, in this case the overall effect of the depreciation on revenue TFP is negative.

Finally, the bottom panels of figure 2 display the simulation results for the industrialized-country case. The pattern of long-lasting changes in physical productivity growth and merely transitory reactions of the other two components of revenue TFP repeats itself once more. The overall effect of the depreciation on revenue TFP growth is positive but tiny in comparison with the magnitudes of our previous two counterfactual exercises. In this case, demand and import revenue TFP growth are of comparable magnitude. The increase in profits induced by a larger volume of exports is compensated by the decrease in profits due to more expensive intermediate-input imports. Since the positive and negative effects of the depreciation on profits roughly cancel each other, R&D investment barely differs from zero: physical TFP growth is positive but very close to zero.

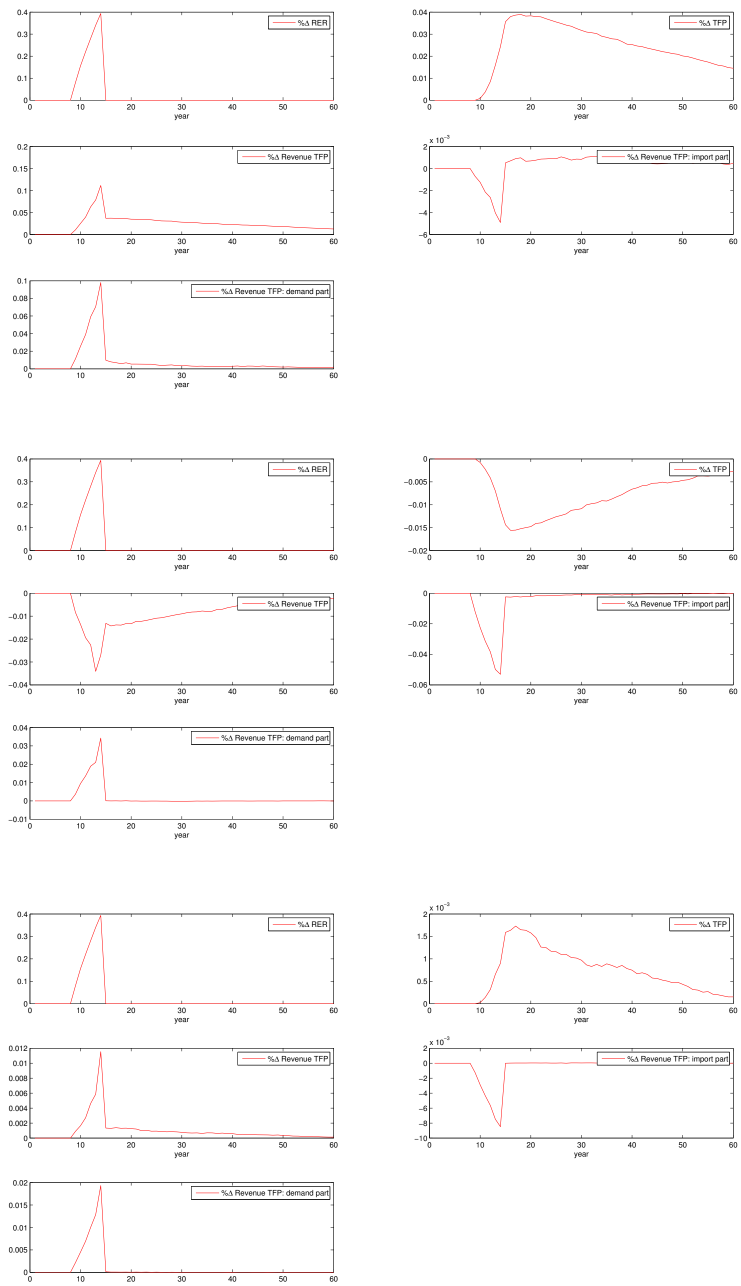
7 The role of financial constraints

[To be completed]

8 Conclusion

[To be written.]

Figure 2: Effect of an unexpected real depreciation on the components of revenue-based TFP by region (emerging Asia (top), other developing (center), industrialized (bottom)).



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Appendix

A-0.1 Aggregate Prices and the Real Exchange Rate

The domestic consumption-based price of the manufacturing CES aggregator is

$$P_T = \left[\int_{i\in\Omega_{T,NI}} p_i^{1-\sigma} di + \int_{i\in\Omega_{T,I}} p_i^{1-\sigma} di + \int_{i\in\Omega_T^*} p_i^{*1-\sigma} di\right]^{\frac{1}{1-\sigma}}. \tag{35}$$

Define the price of imported goods $P_T^* = \left[\int_{i\in\Omega_T^*} p_i^{*1-\sigma} di\right]^{\frac{1}{1-\sigma}}$ and the price of domestic goods

$$P_{TH} = P_{T,NI}\left[1 + \left(\frac{P_{T,I}}{P_{T,NI}}\right)^{1-\sigma}\right]^{\frac{1}{1-\sigma}}, \tag{36}$$

where $P_{T,NI} = e^{-1}\Delta_{T,NI}$ and $P_{T,I} = e^{-1}\left(\frac{P_M}{P_X}\right)^{\beta_m}\Delta_{T,I}$, $\Delta_{T,NI} \equiv \frac{\sigma}{\sigma-1}\left[\int_{i\in\Omega_{T,NI}} \exp\left[\omega_i(\sigma-1)\right] di\right]^{\frac{1}{1-\sigma}}$ and $\Delta_{T,I} \equiv \frac{\sigma}{\sigma-1}\left[\int_{i\in\Omega_{T,I}} \exp\left[\omega_i(\sigma-1)\right] di\right]^{\frac{1}{1-\sigma}}$.

One can express P_T as

$$P_T = \left[P_{TH}^{1-\sigma} + P_T^{*1-\sigma}\right]^{\frac{1}{1-\sigma}} = P_{TH}\left[1 + \left(\frac{P_T^*}{P_{TH}}\right)^{1-\sigma}\right]^{\frac{1}{1-\sigma}} = \tag{37}$$

$$= P_{T,NI}\left[1 + \left(\frac{P_{T,I}}{P_{T,NI}}\right)^{1-\sigma}\right]^{\frac{1}{1-\sigma}}\left[1 + \frac{P_T^{*1-\sigma}}{(P_{T,NI})^{1-\sigma}\left[1 + \left(\frac{P_{T,I}}{P_{T,NI}}\right)^{1-\sigma}\right]}\right]^{\frac{1}{1-\sigma}}.$$

Substituting from the definitions of $P_{T,NI}$, $P_{T,I}$, and P_T^*, imposing $\varepsilon = \sigma$ and manipulating the resulting expression yields $P_T = e^{-1}\Delta_{T,NI}\Gamma^{\frac{1}{1-\sigma}}$, where

$$\Gamma \equiv \left[1 + \left[1 + \left(\frac{e}{A}\right)^{1-\sigma}\right]^{\beta_m}\left(\frac{\Delta_{T,I}}{\Delta_{T,NI}}\right)^{1-\sigma} + \left(\frac{eP_T^*}{\Delta_{T,NI}}\right)^{1-\sigma}\right]. \tag{38}$$

e has a "direct" negative effect on P_T via e^{-1}, and a number of "indirect" effects that operate (1) through the prices of imported final goods, eP_T^*, and intermediate inputs, $\left[1 + \left(Ae^{-1}\right)^{\sigma-1}\right]$, and (2) through the extensive margins of $\Delta_{T,NI}$ and $\Delta_{T,I}$. Changes in ω_i only have lagged effects on P_T, as they operate with a time lag via the innovation process.

Taking logs, $\ln P_T = -\ln(e) + \ln\Delta_{T,NI} + \frac{1}{1-\sigma}\ln\Gamma$. Define $\widetilde{X} = \ln X - \ln\overline{X}$ as the log deviation of variable X from its steady state $\overline{X}$:

$$\widetilde{P}_T = -\widetilde{e} + \widetilde{\Delta}_{T,NI} + \frac{1}{1-\sigma}\widetilde{\Gamma}. \tag{39}$$

Log-linearizing $\Gamma(\cdot)$,

$$\widetilde{\Gamma} \approx (1-\sigma)\left[\frac{\overline{\Gamma}_2 \frac{\beta_m(\overline{e}/A)^{1-\sigma}}{1+(\overline{e}/A)^{1-\sigma}} + \overline{\Gamma}_3}{\overline{\Gamma}}\widetilde{e} + \frac{\overline{\Gamma}_2}{\overline{\Gamma}}\widetilde{\Delta}_{T,I} - \frac{\overline{\Gamma}_2 + \overline{\Gamma}_3}{\overline{\Gamma}}\widetilde{\Delta}_{T,NI}\right], \tag{40}$$

where

$$\begin{aligned}
\overline{\Gamma}_2 &\equiv \left[1+\left(\frac{\overline{e}}{A}\right)^{1-\sigma}\right]^{\beta_m}\left(\frac{\overline{\Delta}_{T,I}}{\overline{\Delta}_{T,NI}}\right)^{1-\sigma}, && (41)\\
\overline{\Gamma}_3 &\equiv \left(\frac{\overline{e}P_T^*}{\overline{\Delta}_{T,NI}}\right)^{1-\sigma}, && (42)\\
\overline{\Gamma} &\equiv 1+\overline{\Gamma}_2+\overline{\Gamma}_3. && (43)
\end{aligned}$$

Plugging back into (39),

$$\widetilde{P}_T \approx -\frac{\left[1+\overline{\Gamma}_2\left(1-\beta_m\frac{(\overline{e}/A)^{1-\sigma}}{1+(\overline{e}/A)^{1-\sigma}}\right)\right]}{\overline{\Gamma}}\widetilde{e} + \frac{1}{\overline{\Gamma}}\widetilde{\Delta}_{T,NI} + \frac{\overline{\Gamma}_2}{\overline{\Gamma}}\widetilde{\Delta}_{T,I}. \tag{44}$$

Notice that the direct effect $-\widetilde{e}$ is of a larger magnitude than the indirect effects. Assuming $\overline{\Gamma}_3$ small, $\widetilde{P}_T \approx -\widetilde{e}$.

Finally, plugging the results obtained above for P_T into aggregate consumption-based price index $P = P_{NT}^{\alpha_{NT}} P_O^{\alpha_O} P_T^{\alpha_T}$ yields

$$\ln P = -(\alpha_{NT}+\alpha_T)\ln e + \alpha_T \ln \Delta_{T,NI} + \alpha_T\frac{1}{1-\sigma}\ln\Gamma. \tag{45}$$

$$\begin{aligned}
\widetilde{P} &= -(\alpha_{NT}+\alpha_T)\widetilde{e} + \alpha_T\widetilde{\Delta}_{T,NI} + \alpha_T\frac{1}{1-\sigma}\widetilde{\Gamma} = && (46)\\
&\approx -\left[\alpha_{NT} + \alpha_T\frac{\left[1+\overline{\Gamma}_2\left(1-\beta_m\frac{(\overline{e}/A)^{1-\sigma}}{1+(\overline{e}/A)^{1-\sigma}}\right)\right]}{\overline{\Gamma}}\right]\widetilde{e} + \alpha_T\frac{1}{\overline{\Gamma}}\widetilde{\Delta}_{T,NI} + \alpha_T\frac{\overline{\Gamma}_2}{\overline{\Gamma}}\widetilde{\Delta}_{T,I}.
\end{aligned}$$

Notice that $\alpha_T\frac{1}{\overline{\Gamma}}$ and $\alpha_T\frac{\overline{\Gamma}_2}{\overline{\Gamma}}$ are each the product of two numbers between zero and one and are therefore close to zero. As for the coefficient of $\widetilde{e}$, it can be approximated by $\alpha_{NT}+\alpha_T$, which is arguably close to 1: $\widetilde{P} \approx -\widetilde{e}$.

A-0.2 Dataset construction

Our main data source for firm-level information is Orbis (Bureau Van Dijk). We combine data from two CDs (2007 and 2014) and the web version of Orbis. Orbis provides firm-level balance sheet data of listed and unlisted firms .

We drop firm-year observations without firm identifiers, company names, information on revenue or sales, total assets, employees and observations with missing accounting units. We replace as missing any negative reported values for sales, revenue, number of employees, total assets, current liabilities, total liabilities, long-term debt, tangible fixed assets, intangible fixed assets, current assets, material costs, R&D expenditure. We convert variables into common units (thousands of current local currency). We compute the capital stock as the sum of tangible fixed assets and intangible fixed assets. We compute value added as revenue minus material costs. We only keep firms with a primary activity in the manufacturing sector (US SIC 1997 codes 200-399).

For those manufacturing firms in Orbis that report revenue, number of employees, capital stock and material costs, we merge by names with the Worldbase datasets for the years 2000, 2005, 2007 2009. Dun & Bradstreet's WorldBase is a database covering millions of public and private companies in more than 200 countries and territories. The unit of observation in Worldbase is the establishment/plant. Among other variables, Worldbase reports for each plant the full name of the company, location information (country, state, city, and street address) basic operational information (sales and employment), and most importantly, information on the plant's trade status (exporting/not exporting/importing/not importing). We use the Jaro-Winckler algorithm to match the datasets by company names. We condition on the firms being located in the same country and then match by names and condition on a match score of at least 93%, which turns out to provide a very good match. For our main analysis we disregard the year information of the trade status to maximize sample coverage. We thus assign a fixed trade status to each firm, giving priority to later years.

We winsorize the data and drop the top and bottom five percent of observations in terms of (log) capital stock, materials, value added, sales, employment in the TFP estimation. After the production function coefficients have been estimated on this restricted sample, we expand sample size and compute TFP also for observations with missing material costs, by proxying for the material cost as (median material share in revenue)$\times$revenue.

Table XXX reports descriptive statistics of firm-level variables.

A-0.3 Additional Figures and Tables

Country	Freq.	Percent	Cum.	Country	Freq.	Percent	Cum
ARG	98	0.01	0.01	KOR	101,252	7.59	95.42
AUS	1,004	0.08	0.08	KWT	33	0	95.43
AUT	5,896	0.44	0.52	LBN	1	0	95.43
BEL	25,903	1.94	2.47	LKA	127	0.01	95.44
BGD	36	0	2.47	LTU	64	0	95.44
BGR	24,105	1.81	4.28	LUX	38	0	95.44
BHR	6	0	4.28	LVA	64	0	95.45
BIH	15,562	1.17	5.44	MAR	15	0	95.45
BOL	32	0	5.45	MEX	153	0.01	95.46
BRA	2,033	0.15	5.6	MKD	73	0.01	95.47
BRB	1	0	5.6	MLT	3	0	95.47
BWA	1	0	5.6	MUS	8	0	95.47
CAN	30	0	5.6	MWI	1	0	95.47
CHE	539	0.04	5.64	MYS	3,210	0.24	95.71
CHL	5	0	5.64	NAM	4	0	95.71
CHN	213,267	15.99	21.63	NGA	168	0.01	95.72
COL	125	0.01	21.64	NLD	4,111	0.31	96.03
CPV	4	0	21.64	NOR	11,227	0.84	96.87
CRI	8	0	21.64	NZL	41	0	96.87
CYP	204	0.02	21.65	OMN	158	0.01	96.88
CZE	5,210	0.39	22.04	PAK	134	0.01	96.9
DEU	100,844	7.56	29.6	PAN	14	0	96.9
DMA	4	0	29.6	PER	151	0.01	96.91
DNK	915	0.07	29.67	PHL	216	0.02	96.92
DOM	6	0	29.67	POL	11,172	0.84	97.76
ECU	18	0	29.67	PRT	137	0.01	97.77
EGY	70	0.01	29.68	PRY	8	0	97.77
ESP	291,233	21.83	51.51	QAT	10	0	97.77
EST	16,555	1.24	52.75	ROU	27	0	97.77
FIN	30,992	2.32	55.07	SAU	33	0	97.78
FJI	3	0	55.07	SGP	1,462	0.11	97.89
FRA	168,760	12.65	67.73	SLV	4	0	97.89
GBR	37,490	2.81	70.54	SRB	3	0	97.89
GHA	4	0	70.54	SVK	9	0	97.89
GRC	24,079	1.8	72.34	SVN	21	0	97.89
GRD	1	0	72.34	SWE	9,262	0.69	98.58
GTM	7	0	72.34	THA	3,676	0.28	98.86
HKG	352	0.03	72.37	TTO	1	0	98.86
HRV	35,877	2.69	75.06	TUN	3	0	98.86
HUN	28	0	75.06	TUR	81	0.01	98.87
IDN	1,056	0.08	75.14	TWN	7,368	0.55	99.42
IND	303	0.02	75.16	TZA	4	0	99.42
IRL	2,120	0.16	75.32	UGA	1	0	99.42
IRN	126	0.01	75.33	UKR	307	0.02	99.44
IRQ	15	0	75.33	URY	5	0	99.44
ISL	25	0	75.33	USA	6,731	0.5	99.95
ISR	696	0.05	75.38	VEN	2	0	99.95
ITA	107,701	8.07	83.46	VNM	528	0.04	99.99
JAM	4	0	83.46	ZAF	174	0.01	100
JOR	229	0.02	83.48	ZMB	8	0	100
JPN	58,097	4.36	87.83	ZWE	3	0	100
KAZ	25	0	87.83				
KEN	13	0	87.83	Total	1,334,023	100	100

Table A-1: Sample Frame

	(1)	(2)	(3)	(4)	(5)
	Δ log TFPR$_{VA,it}$	Δ log TFPR$_{GO,it}$	Δ log sales$_{it}$	Δ log c. f.$_{it}$	Δ R&D prob.$_{it}$
$\Delta \log e_{ct} \times$	-0.0092	-0.054	-0.353	-0.105	-5.169
industrialized$_c$	(0.258)	(0.099)	(0.686)	(0.520)	(5.424)
$\Delta \log e_{ct} \times$	0.286***	0.140***	0.267	0.895***	0.668***
emerging East Asia$_c$	(0.078)	(0.023)	(0.190)	(0.060)	(0.245)
$\Delta \log e_{ct} \times$	-0.922***	-0.337**	-2.114*	-0.906	-4.076
other developing	(0.354)	(0.137)	(1.241)	(0.560)	(2.836)
Observations	1,310,509	1,310,509	1,252,483	758,623	142,093
R-squared	0.011	0.011	0.028	0.014	-0.006
Country-sector FE	YES	YES	YES	YES	YES
Time FE	YES	YES	YES	YES	YES
Business cycle controls	YES	YES	YES	YES	YES
Cluster	Country	Country	Country	Country	Country
Kleibergen-Paap F-Statistic	9.146	9.146	9.919	4.759	8.304
P-value	(0.011)	(0.011)	(0.041)	(0.312)	(0.081)
Hansen	3.333	1.88	3.951	2.625	2.642
P-value	(0.343)	(0.597)	(0.267)	(0.453)	(0.452)

Table A-2: The aggregate RER and firm-level outcomes: IV estimates. The dependent variable in columns (1)-(5) is the annual log difference in the following firm-level outcomes computed from Orbis for manufacturing firms for the years 2001-2010: revenue-based TFP computed from value-added (column 1), revenue-based TFP computed from gross output (column 2), nominal sales (column 3), cash flow (column 4), an indicator for R&D status (column 5). The construction of TFP is explained in section 4 of the paper. The main explanatory variable of interest is the annual log difference in the real exchange rate from the PWT 8.0 interacted with dummies for: industrialized economy; emerging East Asia; other developing economy. The regressions also control for the real growth rate of GDP in PPP (from PWT8.0) and the inflation rate (from IMF). The set of excluded instruments consists of: regional dummies interacted with (i) trade-weighted world commodity prices and (ii) world capital flows interacted with the Chinn-Ito index for financial account openness. Standard errors are clustered at the country level.

	(1)	(2)	(3)	(4)	(5)
	Δ log TFPR$_{VA,it}$	Δ log TFPR$_{GO,it}$	Δ log sales$_{it}$	Δ log c. f.$_{it}$	Δ R&D prob.$_{it}$
$\Delta \log e^{exp}_{sct} \times$	0.540**	0.0471	1.061	-0.241	5.460***
industrialized$_c$	(0.258)	(0.0815)	(0.673)	(1.676)	(1.175)
$\Delta \log e^{exp}_{sct} \times$	0.322**	0.0714	2.841***	3.717**	3.557***
emerging East Asia$_c$	(0.156)	(0.125)	(1.023)	(1.547)	(0.578)
$\Delta \log e^{exp}_{sct} \times$	-0.0838	0.0369	-0.199	-0.493	-1.01
other developing$_c$	(0.123)	(0.113)	(0.861)	(1.188)	(2.073)
$\Delta \log e^{imp}_{sct} \times$	-0.247	0.13	1.891**	-0.342	-2.304**
industrialized$_c$	(0.214)	(0.0837)	(0.745)	(1.42)	(1.023)
$\Delta \log e^{imp}_{sct} \times$	0.0457	-0.109	1.04	0.199	3.234***
emerging East Asia$_c$	(0.149)	(0.119)	(0.918)	(1.451)	(0.739)
$\Delta \log e^{imp}_{sct} \times$	-0.202*	-0.101	-0.658	-1.928*	1.085
other developing$_c$	(0.117)	(0.105)	(0.81)	(1.03)	(2.275)
Observations	298,664	298,570	297,402	195,921	37,983
R-squared	0.085	0.06	0.212	0.115	0.086
Country-sector FE	YES	YES	YES	YES	YES
Time FE	YES	YES	YES	YES	YES
Cluster	Country-sector	Country-sector	Country-sector	Country-sector	Country-sector

Table A-3: Export- and import-weighted RERs and firm-level outcomes – long differences. The dependent variable in columns (1)-(5) is three-year averaged log difference in the following firm-level outcomes computed from Orbis for manufacturing firms for the years 2002, 2005, 2008, 2010: revenue-based TFP computed from value-added (column 1), revenue-based TFP computed from gross output (column 2), nominal sales (column 3), cash flow (column 4), an indicator for R&D status (column 5). The construction of TFP is explained in section 4 of the paper. The main explanatory variables of interest are 3-year-averages of log differences in the export- and import-weighted sector-level real exchange rates computed from PWT 8.0 and bilateral export and import shares at the 3-digit US SIC level (from UN-Comtrade data), interacted with dummies for: industrialized economy; emerging East Asia; other developing economy. The regressions also include business cycle controls: the 3-year-averaged real growth rate of GDP in PPP (from PWT8.0) and the inflation rate (from IMF). Standard errors are clustered at the country-sector level.

	(1)	(2)	(3)	(4)	(5)
	Δ log TFPR$_{VA,it}$	Δ log TFPR$_{GO,it}$	Δ log sales$_{it}$	Δ log c. f.$_{it}$	Δ R&D prob.$_{it}$
$\Delta \log e^{exp}_{sct} \times$	0.0537	0.0234	0.31	0.84	0.11
domestic$_f$	(0.160)	(0.055)	(0.216)	(0.526)	(0.116)
$\Delta \log e^{exp}_{sct} \times$	0.651***	0.219***	0.596***	1.634***	0.278
exporter$_f$	(0.184)	(0.076)	(0.218)	(0.569)	(0.208)
$\Delta \log e^{exp}_{sct} \times$	-0.197	-0.0479	0.304*	0.0599	-0.274
importer$_f$	(0.159)	(0.062)	(0.178)	(0.503)	(0.247)
$\Delta \log e^{imp}_{sct} \times$	0.0471	0.0473	-0.166	-0.472	-0.079
domestic$_f$	(0.125)	(0.042)	(0.180)	(0.459)	(0.089)
$\Delta \log e^{imp}_{sct} \times$	-0.152	-0.0584	-0.193	-0.464	-0.172
exporter$_f$	(0.152)	(0.065)	(0.199)	(0.496)	(0.183)
$\Delta \log e^{imp}_{sct} \times$	0.206	0.0885	-0.0713	-0.0616	0.143
importer$_f$	(0.151)	(0.056)	(0.173)	(0.447)	(0.230)
Observations	505,381	505,381	476,228	311,720	37,419
R-squared	0.057	0.045	0.108	0.026	0.075
Country-sector FE	YES	YES	YES	YES	YES
Country-time FE	YES	YES	YES	YES	YES
Trade status controls	YES	YES	YES	YES	YES
Cluster	Country-sector	Country-sector	Country-sector	Country-sector	Country-sector

Table A-4: Export-and import-weighted RERs and firm-level outcomes by firm's trade status. The dependent variable in columns (1)-(5) is the annual log difference in the following firm-level outcomes computed from Orbis for manufacturing firms for the years 2001-2010: revenue-based TFP computed from value-added (column 1), revenue-based TFP computed from gross output (column 2), nominal sales (column 3), cash flow (column 4), an indicator for R&D status (column 5). The construction of TFP is explained in section 4 of the paper. The main explanatory variables of interest are the annual log differences in the export- and import-weighted sector-level real exchange rates computed from PWT 8.0 and bilateral export and import shares at the 3-digit USSIC level (from UN-Comtrade data), interacted with firm-level indicators for exporting, importing, no trade participation. Standard errors are clustered at the country-sector level.

	(1)	(2)	(3)	(4)	(5)
	Δ log TFPR$_{VA,it}$	Δ log TFPR$_{GO,it}$	Δ log sales$_{it}$	Δ log c. f.$_{it}$	Δ R&D prob.$_{it}$
$\Delta \log e_{ct} \times$	0.0504	-0.016	-0.0739	-0.640***	-0.25
industrialized$_c \times$domestic$_f$	(0.087)	(0.033)	(0.132)	(0.110)	(0.178)
$\Delta \log e_{ct} \times$	0.104	0.00809	-0.0363	-0.14	-0.191
industrialized$_c \times$exporter$_f$	(0.085)	(0.030)	(0.130)	(0.129)	(0.148)
$\Delta \log e_{ct} \times$	0.0681	0.0072	0.00223	-0.143***	-0.0694
industrialized$_c \times$importer$_f$	(0.045)	(0.010)	(0.052)	(0.052)	(0.052)
$\Delta \log e_{ct} \times$	0.285***	0.111***	0.178	0.835***	0.23
emerging East Asia$_c \times$domestic$_f$	(0.082)	(0.027)	(0.141)	(0.117)	(0.146)
$\Delta \log e_{ct} \times$	0.360**	0.0892**	0.231*	0.545**	0.260*
emerging East Asia$_c \times$exporter$_f$	(0.136)	(0.036)	(0.131)	(0.211)	(0.133)
$\Delta \log e_{ct} \times$	-0.0299	0.0284	0.0343	0.0868	0.0328
emerging East Asia$_c \times$importer$_f$	(0.049)	(0.017)	(0.041)	(0.223)	(0.074)
$\Delta \log e_{ct} \times$	-0.193**	-0.0403	-0.359*	-0.143	0.46
other developing$_c \times$domestic$_f$	(0.084)	(0.032)	(0.201)	(0.339)	(0.285)
$\Delta \log e_{ct} \times$	0.114	0.0225	-0.278	0.869***	-0.177
other developing$_c \times$exporter$_f$	(0.096)	(0.026)	(0.226)	(0.225)	(0.257)
$\Delta \log e_{ct} \times$	-0.274***	-0.0561**	-0.0972	-1.116***	0.379
other developing$_c \times$importer$_f$	(0.063)	(0.026)	(0.150)	(0.324)	(0.243)
Observations	514,971	514,971	485,433	317,395	37,689
R-squared	0.053	0.04	0.098	0.024	0.038
Country-sector FE	YES	YES	YES	YES	YES
Time FE	YES	YES	YES	YES	YES
Business cycle controls	YES	YES	YES	YES	YES
Trade status controls	YES	YES	YES	YES	YES
Cluster	Country	Country	Country	Country	Country

Table A-5: The aggregate RER and firm-level outcomes by firm's trade participation status. The dependent variable in columns (1)-(5) is the annual log difference in the following firm-level outcomes computed from Orbis for manufacturing firms for the years 2001-2010: revenue-based TFP computed from value-added (column 1), revenue-based TFP computed from gross output (column 2), nominal sales (column 3), cash flow (column 4), an indicator for R&D status (column 5). The construction of TFP is explained in section 4 of the paper. The main explanatory variable of interest is the annual log difference in the real exchange rate from the PWT 8.0 interacted with firm-level indicators for exporting, importing, no trade participation. The regressions also control for the real growth rate of GDP in PPP (from PWT8.0) and the inflation rate (from IMF). Standard errors are clustered at the country level.

	emerging East Asia	other developing	industrialized
Import prob. (plants $\leq$ 50 emp.)	0.15	0.28	0.12
Import prob. (plants 50-200 emp.)	0.15	0.47	0.28
Import prob. (plants $\geq$ 200 emp.)	0.34	0.64	0.33
Export prob. (plants $\leq$ 50 emp.)	0.15	0.16	0.17
Export prob. (plants 50-200 emp.)	0.16	0.36	0.42
Export prob. (plants $\geq$ 200 emp.)	0.36	0.52	0.57

Table A-6: Evidence on import and export propensity (Worldbase). The table reports import and export probabilities by plant size bin in manufacturing computed from Worldbase data for years 2000, 2005, 2009.