

The Real Exchange Rate, Innovation and Productivity

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February 2018

- Aftermath of Global Financial Crisis: renewed the debate of the effects of real exchange rate (RER) movements.
 - Massive inflows to emerging markets (quantitative easing): Policymakers from emerging markets concerned about loss of competitiveness.
 - Rich countries: recent concerns about appreciated exchange rates and their impact on manufacturing.

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 - Rich countries: recent concerns about appreciated exchange rates and their impact on manufacturing.
- Revived interest in different policies:
 - Macro: reserve accumulation and capital controls to limit exchange rate appreciations (Alfaro, Chari, Kanczuk, 2015).
 - Micro: production and export subsidies, tariffs/industrial policy (Barattieri, Cacciatore and Ghironi, 2017); unlike classical trade-policy instruments, RER not constrained by WTO

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 - Empirical issues: omitted variables, reverse causality, etc. (Woodford, 2008, Henry, 2008).
- Firm-level studies are relatively scarce, data availability for emerging markets being an obvious constraint.

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- We investigate the effects of RER movements on firm productivity exploiting **cross-country firm-level** data.
 - ① Comprehensive compilation of firm-level data: economic activity, trade status, R&D, etc.
- We document empirical evidence on the heterogeneous effects of RER movements on average firm-level outcomes across three regions.
 - In emerging Asia, for manufacturing firms, RER depreciations associated with:
 - ① faster firm-level TFP (revenue-based), sales and cash flow growth;
 - ② higher probability to engage in R&D and export;
 - ③ The positive effects on outcomes are concentrated on exporting firms.
 - ④ Firms importing intermediates are negatively affected.
 - There are on average negative effects for firms located in other emerging economies (Latin America, Eastern Europe).
 - We find no significant effects for manufacturing firms in industrialized countries.

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 - 2 **Imported intermediate goods.**
 - 3 **R&D investment subject to financial constraints.**
- Decompose average TFPR effects: physical TFP growth due to R&D; demand effects; import effects.
 - Quantify the importance of market-size effect and financial constraint on R&D and TFP growth.

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- Conduct counterfactual simulations of temporary depreciations and appreciations.
- Temporary RER movements can have persistent (positive or negative) effects on TFP growth through innovation.
- Asymmetric and non-linear impact depreciations/appreciations
 - Export and import orientations; substitution between domestic and intermediate inputs
 - Hysteresis due to sunk costs R&D; credit constraints.


- Our analysis is silent on:
 - How the RER appreciation/depreciation came about.
 - Welfare analysis; Costs of reserve accumulation, inflation, financial repression, tensions among countries, etc. (Woodford, 2008; Henry, 2008).

- Introduction
 - Related Literature
- Reduced-form Empirical Evidence
- Theoretical Model
- Estimation Strategy
- Estimation Results
- Counterfactual Experiments


Sample: Manufacturing Firms

- **Orbis** (Bureau Van Dijk): 2 CDs + web version
 - Firm-level data of listed and unlisted firms: sales, materials, capital stock, employees, cash flow, R&D expenditure.
 - Years 2001-2010, \approx 70 dev. + 23 indust. countries, \approx 500,000 firms.
- **Worldbase** (Dunn and Brad Street): plant-level export and import status, sales, employment for years 2000, 2005, 2007, 2009 (matched with Orbis); 
- Detailed **administrative plant-level data**: Colombia, France, China, Hungary (export/import participation and intensities).
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- Other data:
 - Fraction of firms performing R&D: OECD innovation scoreboard.
 - **Other Controls**: real GDP growth (PWT 8.0), inflation (IMF GDP deflators)
 - (Robustness:) **Currency composition of debt**: World Bank Enterprise survey, Salomão and Valera (2007); IADB Firms' Balance Sheet project.

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 - RER has large *exogenous* component due to nominal exchange rate (Gourcinhas, 1999); RER hard to predict short- medium-run.
- Individual firms: treat aggregate RER fluctuations as exogenous demand shocks \Rightarrow reverse causality unlikely.
- Potential *omitted variable bias* (positive aggregate supply (demand) shocks should positively (negatively) correlate with RER) \Rightarrow control for GDP growth, inflation.

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- Potential *omitted variable bias* (positive aggregate supply (demand) shocks should positively (negatively) correlate with RER) \Rightarrow control for GDP growth, inflation.
- *Strategy I*: Trade-weighted RERs:
 - Omitted variable bias: control for country-time fixed effects (aggregate shocks to manuf. sector); country-sector-time FE.
 - Endogeneity of trade-weighted RER: (i) use pre-sample trade weights; (ii) each of the 163 manufacturing sectors: negligible weight in aggregate price level.
- *Strategy II*: IV exploiting (i) exogenous fluctuations in world commodity prices interacted with (pre-sample) trade weights; (ii) world capital flows interacted with financial account openness.

Reduced-form evidence: RER and firm-level outcomes

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

- Dependent variable (firm(i)-time(t)-level):
 - 1 revenue-based TFP (TFPR) growth rate, from value added;
 - 2 revenue-based TFP growth rate, from gross output;
 - 3 sales growth rate;
 - 4 cash flow growth rate;
 - 5 change of an indicator variable for R&D (linear probability model.);
 - 6 growth rate of entry rate into exporting at the country-time level (new exporters/total exporters).
- Aggregate RER varies at the country(c)-time(t) level.
- I_r dummy for country c belonging to region r ; δ_{sc} : sector-country fixed effect; δ_t : time fixed effect; vector X_{ct} : business-cycle controls (real GDP growth rate and the inflation rate).
- Cluster standard errors at the country level.

Changes in aggregate RER and firm-level outcomes

	(1)	(2)	(3)	(4)	(5)	(6)
	$\Delta \log \text{TFPR}_{VA,it}$	$\Delta \log \text{TFPR}_{GO,it}$	$\Delta \log \text{sales}_{it}$	$\Delta \log c. f._{it}$	$\Delta \text{R\&D prob.}_{it}$	$\Delta \log \text{export entry rate}_{ct}$
$\Delta \log e_{ct} \times$ emerging East Asia _c	0.239*** (0.0895)	0.120*** (0.0198)	0.195 (0.216)	0.783*** (0.114)	0.191* (0.095)	0.552*** (0.207)
$\Delta \log e_{ct} \times$ other emerging _c	-0.546*** (0.185)	-0.105** (0.0426)	-0.762*** (0.274)	-0.557 (0.414)	0.16 (0.125)	0.063 (0.059)
$\Delta \log e_{ct} \times$ industrialized _c	0.0196 (0.103)	-0.031 (0.0309)	-0.282 (0.217)	-0.319** (0.126)	-0.168 (0.149)	-0.275 (0.274)
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

- Results are robust to:

- trade-weighted RERs with country-time FE
- excluding years of global financial crisis
- 3-year changes (annualized)
- IV estimates

Firm-level export and import participation and intensities by region

	China (emerging East Asia)	Colombia (other emerging)	Hungary (other emerging)	France (industrialized)
Export prob.	0.26	0.27	0.35	0.23
Import prob.	0.17	0.45	0.39	0.20
Avg. export intensity (exporters)	0.60	0.10	0.10	0.17
Avg. import intensity (importers)	0.13	0.14	0.24	0.14

Table: Import and export part./intensity of manuf. firms (from micro data).

- Similar evidence by region using the World Bank's Enterprise Survey (no industr.).
- Similar evidence by region from D&B World Base.
- Analysis by plant-size bins (small, medium, large).

$$\Delta \log(Y_{ic,t}) = \beta_0 + \sum_{r \in R} \sum_{T \in \{exp, imp\}} \beta_{Tr} \Delta \log(e_{c,t}) I_T I_r + \sum_{r \in R} \sum_{T \in \{exp, imp\}} I_T I_r + \delta_{cst} + u_{ic,t}$$

- Interact effect of RER with firm-level trade status (exporter, importer; multinational):
 - Include country-sector-time FE (δ_{cst}).
- To avoid endogeneity of the trade status, we keep the firms' trade status fixed over the sample period (equal to the trade status in the first period we observe it).

Table: Aggregate RER and firm-level outcomes by firm's trade status

	(1)	(2)	(3)	(4)	(5)
	$\Delta \log \text{TFPR}_{VA,it}$	$\Delta \log \text{TFPR}_{GO,it}$	$\Delta \log \text{sales}_{it}$	$\Delta \log c. f_{it}$	$\Delta \text{R\&D prob.}_{it}$
$\Delta \log e_{ct} \times$	0.197**	0.030	0.135***	0.243***	0.065***
emerging Asia _c × exporter _f	(0.075)	(0.019)	(0.036)	(0.035)	(0.011)
$\Delta \log e_{ct} \times$	-0.157***	-0.016**	-0.099***	-0.123**	-0.101***
emerging Asia _c × importer _f	(0.041)	(0.008)	(0.024)	(0.049)	(0.012)
$\Delta \log e_{ct} \times$	-0.005	0.019	-0.088***	-0.096	-0.049*
emerging Asia _c × multinational _f	(0.045)	(0.019)	(0.015)	(0.059)	(0.024)
$\Delta \log e_{ct} \times$	0.394**	0.087**	0.333***	1.162***	0.167***
other emerging _c × exporter _f	(0.159)	(0.036)	(0.079)	(0.281)	(0.029)
$\Delta \log e_{ct} \times$	-0.251	-0.074	0.005	-0.803***	-0.119
other emerging _c × importer _f	(0.177)	(0.046)	(0.102)	(0.203)	(0.072)
$\Delta \log e_{ct} \times$	-0.027	-0.083**	0.382	0.502*	0.036
other emerging _c × multinational _f	(0.127)	(0.040)	(0.248)	(0.292)	(0.024)
Observations	511,061	511,061	481,733	313,856	35,151
R-squared	0.094	0.076	0.16	0.063	0.116
Country-sector-time FE	YES	YES	YES	YES	YES
Firm status controls	YES	YES	YES	YES	YES
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- Industrialized: smaller/insignificant.

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- Industrialized: smaller/insignificant.
- Additional Results: Financial constraints and R&D; Foreign Borrowing.

Summary of stylized facts

- Firms in emerging Asia: real depreciations are associated with faster revenue-based productivity growth, faster sales growth, faster growth of cash flow, higher probability to engage in R&D, and higher export entry rates.
- Other emerging markets (Latin America and Eastern Europe): real depreciations have a significantly negative effect on firm-level outcomes.
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- Firms' R&D choice depends on the level of cash flow; the more so the less developed local financial markets are.
- Firms in other emerging economies are most exposed to foreign currency borrowing, followed by firms from emerging Asia. Exporters borrow a larger share in foreign currency compared to other firms.

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- Firms choose whether to invest in R&D; affects their future productivity
 - $\omega_{it} = \alpha_0 + \alpha_1 \omega_{it-1} + \alpha_2 I_{iRD,t-1} + u_{it}$;
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 - Only firms with operating profits larger than the sunk costs can finance it.
 - Firms can borrow a share θ of current profits;
- RER fluctuations change cash flow and affect thereby the behavior of firms, follow an AR(1) process; $\log(e_t) = \gamma_0 + \gamma_1 \log(e_{t-1}) + \nu_t$.

Model: Setup (cont.)

- Consumers' preferences over manufacturing varieties i :

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

- Ω_T and Ω_T^* : sets of domestically produced and imported varieties.
- Firms self-select into exporting their output and/or importing materials; per-period fixed costs f_m and f_x , i.i.d. random draws.
- Domestic (X_{it}) and imported (X_{it}^*) intermediates: imperfect substitutes, $\varepsilon > 1$:

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

- $A \equiv B^* / P_{Xt}^*$: quality-adjusted relative cost of imported intermediates (RER, quality, and imperfect substitution.)

Summary: Timing Decisions

- 1 Observe $s_{i,t} = (\omega_{i,t}, e_t, I_{iRD,t-1}, \Pi_{i,t-1})$.
- 2 Observe the realizations of $f_{ix,t}$ and $f_{im,t}$.
- 3 Choose variables inputs $(M_{i,t}, L_{i,t}, K_{i,t})$, export status $I_{ix,t}$ and import status $I_{im,t}$.
- 4 Make R&D decision $I_{iRD,t}$.
- 5 Observe realization of additional productivity shock $\epsilon_{i,t}$.
- 6 Produce output $Y_{i,t}$ and sell according to demand.

Revenue-based productivity

- Construct revenue-based productivity as:




$$tfpr_{it} \equiv r_{it} - \tilde{\beta}_l l - \tilde{\beta}_k k_{it} - \tilde{\beta}_m m_{it} = [\tilde{\beta}_0 + \tilde{\omega}_{it} + \tilde{\varepsilon}_{it} + \tilde{\beta}_m \tilde{a}_{it} - \tilde{\beta}_m \log P_{Xst}] + g_{it}(D_{T,t}, D_{T,t}^*, e_t).$$

- In the model $\frac{\partial \mathbb{E}(tfpr_{i,t})}{\partial \log e_t}$ can be decomposed as:

$$\beta_1 \equiv \frac{\partial \mathbb{E}(tfpr_{i,t})}{\partial \log e_t} = \underbrace{\tilde{a}_2 \frac{\partial \text{Prob}(I_{iRD,t-1} = 1)}{\partial \log e_t}}_{\text{innovation}} + \underbrace{\tilde{\beta}_m \frac{\partial \mathbb{E}(\tilde{a}_{i,t})}{\partial \log e_t}}_{\text{imports}} + \underbrace{\frac{\partial \mathbb{E}(g_{i,t}(D_{T,t}, D_{T,t}^*, e_t))}{\partial \log e_t}}_{\text{demand}}$$



- 1 Innovation channel: market size effect + financial constraints effect.
- 2 Importing channel: extensive (prob to import) and intensive margin (import intensity).
- 3 Change in demand: domestic market and exporters (extensive and intensive).

Parameter calibration/estimation strategy consists of several steps:

- 1 Calibrate parameters σ (elasticity of demand; 4), ε (subst. elasticity of intermediates; 4) and r (interest rate; 0.05-industrialized and 0.15-emerging).
- 2 For a given elasticity of demand σ , parameters $\alpha_0, \alpha_1, \alpha_2$, (stochastic process for log-productivity), and output elasticities, $\beta_l, \beta_k, \beta_m$: obtained from model-consistent estimation of the production function (following De Loecker, 2011; Halpern et al, 2015).
 - Estimation procedure;  Parameter estimates 
- 3 The parameters ruling the stochastic process of the RER ($\gamma_0, \gamma_1, \sigma_v^2$): obtained by estimating the AR(1) process specified for $\log(e_t)$.
 - Parameter estimates 
- 4 Rest of the model's parameters ($f_x, f_m, f_{RD,0}, f_{RD}, D, D^*, \theta, \sigma_u^2$): estimated by using an indirect inference approach that matches model and data statistics.

Estimated parameters and model fit: emerging Asia

Parameter	Description	Values (S.E.)	Moments	Data	Model
(*Cross-sectional moments*)					
f_x	log export fixed cost, mean	7.98 (0.01) (11th pctile of exporters' sales)	R&D probability	0.25	0.19
$f_{RD,0}$	log R&D sunkcost, mean	13.38 (1.63) (17.6 pct. of avg. R&D benefit)	Export probability	0.26	0.26
f_{RD}	log R&D fixed cost, mean	9.06 (1.25) (0.24 pct. of avg. R&D benefit)	Export/sales Ratio, mean	0.60	0.64
f_m	import fixed cost, mean	7.99 (0.04) (5th pctile of importers' sales)	Import probability	0.17	0.19
A	quality of imported intermediates	0.72 (0.01)	Import/sales ratio	0.17	0.19
D_T	log domestic demand	5.56 (0.01)	Mean firm size (log revenue)	6.6	6.7
D_T^s	log foreign demand	6.53 (0.01)	Sd, firm size (log revenue)	3.23	3.19
(*Dynamic moments*)					
α_1	persistence, productivity	0.86 (0.003)	R&D, continuation prob.	0.90	0.86
σ_u	sd, innovation of productivity	0.44 (0.006)	R&D, start prob.	0.06	0.04
θ	credit constraint	15 (23.97)	autocorrelation, TFPR	0.91	0.86
			Elasticity of TFPR (G.O.) w.r.t RER	0.12	0.21
			Elasticity of R&D prob. w.r.t c.f.	0.025	0.032

- Estimated parameters: Other Emerging Economies 
- Estimated parameters: Industrialized 

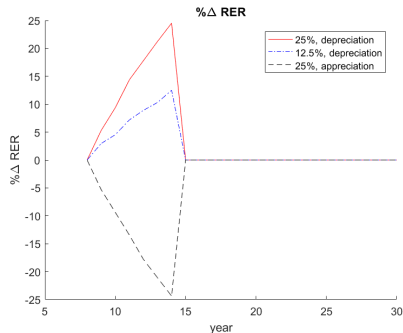
Elasticity of TFPR w.r.t RER, Decomposition

	Innovation (R&D)	Imports	Demand	Total Elasticity
Emerging Asia	0.013	-0.055	0.266	0.21
Other emerging	0.009	-0.207	0.051	-0.15
Industrialized	0.013	-0.069	0.051	-0.01

Counterfactual: temporary depreciations/appreciations

- Yearly depreciation of 5% for five years followed by sudden re-appreciation.
- Depreciation/appreciation is unanticipated.
- Other cases: Yearly depreciation of 2.5%; appreciation 5% for five years followed by sudden re-appreciation.

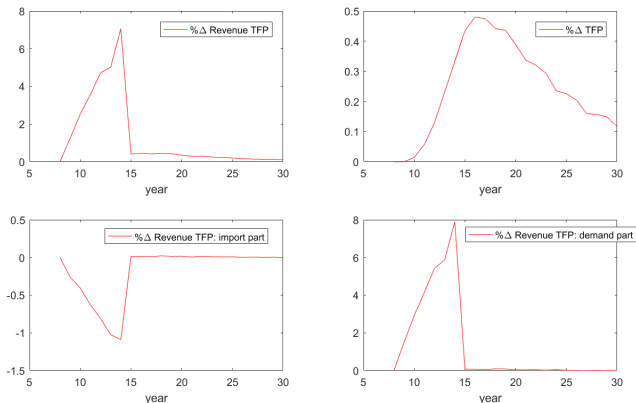
Figure: Unexpected real depreciation (25%, 12.5%) and real appreciation (25%).



Counterfactual: temporary depreciations-Asia

- Yearly depreciation of 5% for five years (unanticipated)

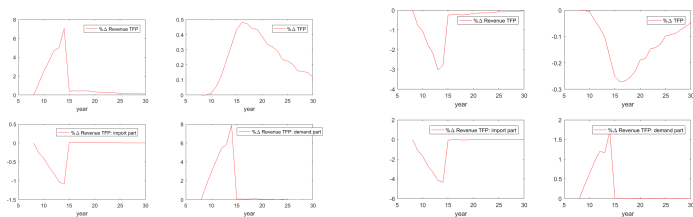
Figure: Unexpected real depreciation (25%).



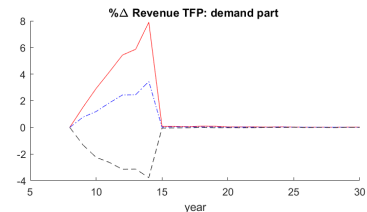
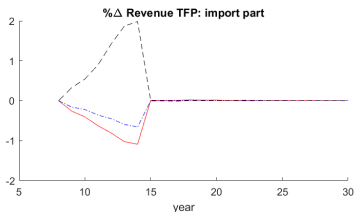
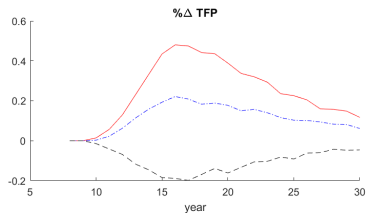
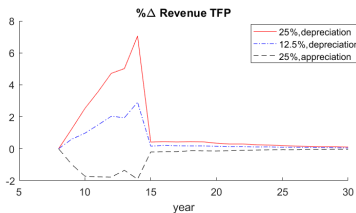
Counterfactual: temporary depreciations-Other Emerging

- Yearly depreciation of 5% for five years (unanticipated)

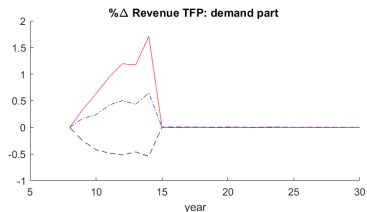
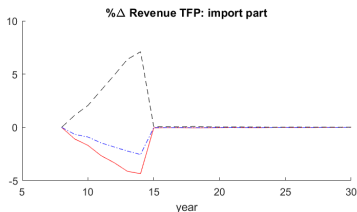
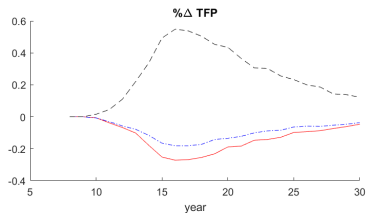
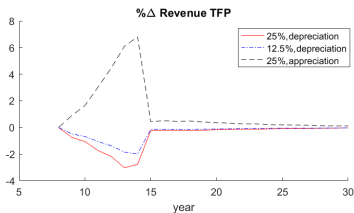
Figure: Unexpected real depreciation (25%).




Counterfactual (temporary) depreciation/appreciation: emerging East Asia



Counterfactual (temporary) depreciation/appreciation: other emerging economies



Additional Results and Robustness checks

- RER and firm level outcomes: depreciations and appreciations
- Foreign-currency borrowing 
- Non-Targeted moments
- Elasticity of demand
- Interest rate
- Return to R&D

- The effects of RER changes on firm-level outcomes vary across economies according to a number of features: export orientation, dependence on imports of intermediates, financial development.
- Explain micro channels of heterogeneous aggregate effects of RER changes on firm-level outcomes across countries.
- Temporary RER changes have very persistent effects on TFP growth and innovation.
- RER changes effects: asymmetric, non-linear.

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- Future Work: (Even more) Robustness/Counterfactuals

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- Future Work: (Even more) Robustness/Counterfactuals
- Services
- Implications for policy

