The Real Exchange Rate, Innovation and Productivity

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Motivation

- 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; unlike classical trade-policy instruments, RER not constrained by WTO.

Motivation: RER Effects

- Effects of RER depreciation/appreciation far from clear, evidence inconclusive.
- An extensive empirical literature has focused on characterizing the aggregate effects of RER depreciation (Rodrik, 2008 and references therein).
    - RER depreciation promotes economic growth, through its positive impact on the share of tradables relative to the nontradables (Rodrik, 2008)
        - No consensus on the channels: larger aggregate savings, externalities from specialization in tradables,...; other effects.
        - 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.

What we do

- We revisit this important question exploiting **cross-country firm-level** data to overcome these problems.
- Shed light on the **microeconomic channels** through which policies affect the economy.
- Firm-level data allow us to consider changes in the exchange rate as exogenous:
  - We consider RER movements as shifts in the relative price of tradables that operate as demand shocks exogenous to individual firms.
  - Using disaggregated trade-weighted RERs, we can control for country-time fixed effects (aggregate shocks to the manufacturing sector).
  - Alternatively, instrument RER changes with changes in world commodity prices & world capital flows.

Stylized Facts

- In emerging East 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;
  3. higher probability to export.
  4. The positive effects on outcomes are concentrated on exporting firms.
  5. Firms importing intermediates are negatively affected.
- We find no effects for manufacturing firms in industrialized countries and negative effects for firms located in other developing countries (Latin America, Eastern Europe).

Theoretical Model

- We *structurally estimate* a dynamic firm-level model of exporting, importing and R&D investment featuring:
  1. **Market-size effects**: real depreciations raise firm-level demand, thus enhancing the profitability to engage in exporting and R&D.
     - Important to disentangle demand effects of depreciation from true physical productivity growth (requires structural model).
  2. **Imported intermediate goods**: real depreciations increase the cost of importing intermediate inputs, counteracting the positive effect on profitability.
  3. **Financial constraints**: by increasing firms' cash flow, real depreciations relax firms' financial constraints, overcome fixed-cost hurdle for financing R&D.

Theoretical Model (continued)

- Exploit differences in the importance of the 3 channels (due to structural differences in export and import orientation and financial development) across the 3 regions to explain differences in effect of RER on average firm-level outcomes .
- Decompose average effects into physical TFP growth due to R&D; demand effects; import effects.
- Provide counterfactual simulations (effect of temporary depreciations on physical TFP growth and innovation).
- Find that temporary RER movements can have very persistent (positive or negative) effects on TFP growth.

Related literature

- Trade, Innovation, and productivity growth
  - Exports, market size and innovation: Lileeva and Trefler, 2010 (Canada); Bustos, 2011 (Argentina); Aw et al, 2010 (Taiwan); Aghion et al. (France).
  - Imports and innovation: Bloom et al, 2015 (Europe); Autor et al, 2016 (US)
  - Imports and productivity: Halpern et al, 2015 (Hungary)
- Effects of Exchange Rates
  - Effects of large devaluations on emerging markets: Verhoogen, 2008 (Mexico); Gopinath and Neiman, 2014 (Argentina)
  - Effects of RER movements on rich-country firms: Amiti et al, 2012 (Belgium); Berman et al, 2012 (France), Ekholm et al, 2012 (Norway); Fitzgerald and Haller, 2015 (Ireland)
  - Effects of RER aggregate level (Rodrik, 2008)
- Financial Constraints
  - Financial constraints and exports: Manova, 2013
  - Financial constraints exporting and R&D: Gorodnichenko and Schnitzer, 2013 (Eastern Europe)
  - Financial constraints and TFP: Midrigan and Xu, 2014 (S. Korea)

Outline

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

Sample

- **Orbis** (Bureau Van Dijk): 2 CDs + web version
  - Firm-level data of listed and unlisted firms on: sales, materials, capital stock, employees, cash flow, R&D expenditure.
  - Years 2001-2010, $\approx$ 70 developing + 23 industrialized countries.
  - Around 500,000 firms.
- **Worldbase** (Dunn and Brad Street): plant-level export and import status, sales, employment for years 2000, 2005, 2007, 2009 (matched by firm names with Orbis);
- Worldbank **exporter dynamics database**: entry and exit rates into/from exporting.
- Fraction of firms performing R&D: OECD innovation scoreboard.
- Detailed administrative plant-level data: Colombia, France, China, Hungary (export/import intensities).
- **Real exchange rate**: PPP of GDP from Penn World Tables 8.0 (PWT 8.0), export and import-weighted RER constructed by combining PPP with bilateral sectoral export/import shares (3-digit level) from UN COMTRADE database.
- **Other Controls:** real GDP growth rate (PWT 8.0), inflation (IMF GDP deflators)

Reduced-form evidence: RER and firm-level outcomes

- RER is *endogenous* to *aggregate shocks* (e.g. aggregate supply shocks, or aggregate demand shocks – monetary, fiscal policy).
  - RER has large *exogenous* component due to nominal exchange rate – in short and medium run, RER hard to predict with fundamentals.
- Treat RER fluctuations as exogenous demand shocks for individual firms: investigate how *firm-level* outcomes of manufacturing firms are affected by RER movements, $\Rightarrow$ reverse causality unlikely.

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- Treat RER fluctuations as exogenous demand shocks for individual firms: investigate how *firm-level* outcomes of manufacturing firms are affected by RER movements, $\Rightarrow$ reverse causality unlikely.
- Potential *omitted variable bias* (positive aggregate supply (demand) shocks should positively (negatively) correlate with RER.) $\Rightarrow$ control for GDP growth, inflation.
- Alternative 1: use *trade-weighted RERs*:
  - Omitted variable bias: control for country-time fixed effects (aggregate shocks to manufacturing sector).
  - Endogeneity of trade-weighted RER: (i) use pre-sample trade weights; (ii) each of the 163 manufacturing sectors has negligible weight in aggregate price level.
- Alternative 2: *IV* exploiting exogenous fluctuations in world commodity prices interacted with (pre-sample) trade weights and world capital flows interacted with financial account openness.

Changes in aggregate RER and firm-level outcomes

	(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 $prob._{it}$	(6) Δ log export 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

- Results are robust to:
  - IV estimates
  - trade-weighted RERs with country-time FE
  - 3-year changes (annualized)
  - interactions of RER with firm-level trade status

Firm-level export and import participation and intensities by region

	China (emerging East Asia)	Colombia (other developing)	Hungary (other developing)	France (industrialized)
Export prob.	0.26	0.37	0.35	0.23
Import prob.	0.17	0.45	0.39	0.20
Export intensity (conditional)	0.60	0.10	0.10	0.17
Import intensity (conditional)	0.13	0.14	0.24	0.14

Table: Evidence on import and export participation/intensity of manufacturing firms (computed from representative micro data).

- Evidence from Worldbase

R&D, credit constraints and financial development

	(1) R&D prob.$_{it}$	(2) R&D prob.$_{it}$	(3) R&D prob.$_{it}$	(4) 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

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

	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

Summary of stylized facts

- In *emerging East Asia*, RER depreciations $\rightarrow$ *faster growth of: tfpr*, sales, cash flow; a higher R&D Prob.; higher export entry rates.
- In *industrialized countries* and *other developing countries*, RER depreciations have *no* (or negative) *effects* on these outcomes.
- Firms in *emerging East Asia* are *less likely to import* and *less import intensive* and *more export intensive* than firms in other developing countries and industrialized countries;
- Firms' *R&D* choice depends on *cash flow* if financial development is low. Cash flow matters most in other developing economies; has an intermediate effect in emerging East Asia; has no effect in industrialized countries.

Model

- Heterogeneous firms choose whether or not to invest in R&D, which in turn affects their future productivity.
- R&D is an intangible investment: cannot be used as collateral (borrowing constraints).
- Only firms with operating profits larger than the sunk costs involved in 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.
- Small open economy: foreign variables exogenous.

Model: the RER

- 3 sectors: manufacturing (tradable), perfectly competitive outside sector (tradable), non-tradables
- e_t is inverse TFP of outside sector.

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

- RER: $\frac{P_t^*}{P_t} \approx e_t$.
- Interpretation: negative TFP shock to outside sector reduces domestic factor prices and depreciates RER.
- Details

Manufacturing Sector: Preferences, Technologies and Market Environment

- Consumers's 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.
- Infinitely lived monopolistic firms, heterogeneous in terms of log-productivity ω_{it}, each producing a single variety of the manufacturing good with technology:

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

Imports

- Domestic $(X_i t$)and imported (X_{it}^*)intermediates are imperfect substitutes with elasticity ε:

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

- For a firm importing inputs

$$P_{Mt} = P_{Xt} \left[1 + \left(\frac{B^* P_{Xt}}{P_{Xt}^*} \right)^{\varepsilon-1} \right]^{\frac{1}{1-\varepsilon}} = e_t^{-1} \left[1 + \left(A e_t^{-1} \right)^{\varepsilon-1} \right]^{\frac{1}{1-\varepsilon}},$$

- $A \equiv B^* P_{Xt} / P_{Xt}^*$: quality-adjusted relative cost of imported intermediates
- $P_{Mt} = P_{Mt}(e) = P_{Xt} exp\left[-\tilde{a}(e_t)\right]$, where $\tilde{a}(e_t) = (\varepsilon - 1)^{-1} \ln \left[1 + \left(A e_t^{-1} \right)^{\varepsilon-1} \right]$ is the cost reduction from importing: relative price, quality, substitution.
- An increase in $e_t$raises P_{Mt} and reduces domestic firm's profits in domestic and foreign markets.

Demand

- Domestic and foreign demand faced by firm i are

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

- Firms behave as monopolists and charge a constant mark-up over their marginal production costs.
- Firm i's domestic revenue is:

$$R^d_{it} = p^{1-\sigma}_{it} P^{\sigma-1}_{T,t} (P_{T,t} D_{T,t}).$$

- Variable export profits are $\Pi^d_{it} = R^d_{it}/\sigma$.
- e_t potentially affects R^d via marginal costs and by shifting the domestic aggregate price level in manufacturing P_T.
- Both effects are proportional to e_t^{-1} and cancel out, not affecting revenues nor profits for non-importing firms.
- Importing (I) firms: e_t has an additional effect on revenue (and profits) through the price of imported intermediates: A real depreciation reduces revenue and profits of importers.

Exports

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

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

- Variable export profits are $\Pi_{it}^x = R_{it}^x/\sigma$.
- Changes in e_t affect export revenues and profits by impacting a firm's marginal cost. RER depr. reduces domestic factor costs and export prices, domestic firms and increase sales profits in the export market (foreign price level P_T^* is unaffected).
- Effect smaller for exporters that also import (intermediate inputs more expensive).

Exporter and importer status

- Importing and exporting decisions involve per-period fixed costs f_m and f_x. (No one-time sunk entry costs.)
- Each firm's fixed costs are i.i.d. random draws.
- More productive firms self-select into one or both of these activities. The resulting decisions are static choices and complements: each activity raises the gain from the other.
- Firm i chooses one among four different "regimes", which characterize the following per-period profit function:

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

- Firms choosing to export and/or import can always finance the corresponding fixed costs with their profits.

Dynamic R&D choice

- Innovation raises 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 it innovates).
- log-productivity follows stochastic process

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

  $I_{iRD,t-1}$: indicator for innovation in $t-1$. α_2 return to innovation.
- $E(\omega_{it}|I_{iRD} = 1 \quad \forall t) = \frac{\alpha_0+\alpha_2}{1-\alpha_1}$, $E(\omega_{it}|I_{iRD} = 0 \quad \forall t) = \frac{\alpha_0}{1-\alpha_1}$.
- R&D choice dynamic due to both the existence of R&D sunk cost and its impact on productivity, which is persistent.
- Financial constraint: in each period the innovation fixed/sunk cost has to be proportional to current profits.

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

$\theta \in [1, \bar{\theta}]$ quality of financial system.

Dynamic R&D choice II

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

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

- The firm chooses an infinite sequence of R&D decisions $I_{iRD,t}$ that maximizes the value function subject to the financial constraint for R&D.

Estimation

Parameter calibration/estimation strategy consists of several steps:

1. We choose reasonable values for the parameters σ (elasticity of demand) and r (interest rate).
2. 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 model-consistent estimation of the production function (following De Loecker, 2011; Halpern et al, 2015).
3. 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 $\log(e_t)$.
4. Rest of the model's parameters (f_x, f_m, $f_{RD,0}$, f_{RD}, D, D^*, θ, σ_u^2) are estimated by using a simulated method of moment approach that matches model and data parameters.

Parameters to be estimated/calibrated

- Parameters estimated without solving the dynamic model:
  - Output elasticities of inputs: β_l, β_k, β_m.
  - return to R&D: α_2.
  - Stochastic process for log RER: γ_0, γ_1, σ_ν^2

Revenue-based productivity

- Construct revenue-based productivity as:

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

$$E\left(tfpr_{ict} | X_{ict}\right) = \beta_0 + \beta_1 \log e_{ct} + \beta_2 X_{ict}$$

Then

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

- We can show that in the model and simulations $\frac{\partial E\left(tfpr_{ict} | X_{ict}\right)}{\partial \log e_{ct}}$ can be decomposed into:
  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).
- Details:

Solving the dynamic model: 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
			α_1	persistence, productivity
			σ_u	s.d., innovation of productivity
			D	log domestic demand
			D^*	log foreign demand
			A	price-adjusted quality of imported intermediates
			θ	coefficient for credit constraint

- distribution of export (import) fixed cost: f_x (f_m distributed exponential with mean $\bar{f}_x$ ($\bar{f}_m$) and variance $\bar{f}_x^2$ ($\bar{f}_m^2$).
- distribution of R&D sunk cost and fixed cost: $f_{RD,0}$, f_{RD} distributed exponential with mean $\bar{f}_{RD,0}$, $\bar{f}_{RD}$

Estimation procedure

- The parameters are estimated to match a set of moments.
  - Cross-section moments: export, import and R&D participation; export and import intensities; firm-size distribution (mean, s.d.)
  - Dynamic moments: Transitional dynamic of R&D choices, elasticities of TFPR, R&D probabilities w.r.t RER changes.
- For a given set of parameter values, solve the value function (value function iteration) and the policy function.
- Draw the shocks, simulate a set of firms for multiple countries (different realizations of RER) and compute the moments of interest.
- Compare simulated moments with data moments.
- Update the parameters to minimize the distance between data moments and simulated moments.
- Repeat steps until convergence (keeping the draws of the shocks fixed).

Estimated parameters and model fit: emerging East Asia

Parameter	Description	Values	Moments	Data	Model
			(*Cross-sectional moments*)		
f_x	export fixed cost,mean	2,940	R&D probability	0.32	0.31
$f_{RD,0}$	R&D sunkcost, mean	92,100	Export probability	0.26	0.27
f_{RD}	R&D fixed cost, mean	8,700	Export/sales Ratio, mean	0.60	0.59
f_m	import fixed cost, mean	2,952	Import probability	0.17	0.19
A	quality of imported intermediates	0.69	Import/sales ratio	0.13	0.13
D_T	log domestic demand	6.05	Mean firm size (revenue)	7.8	7.2
D_T^*	log foreign demand	6.77	Sd, firm size (revenue)	3.25	2.89
α_1	persistence, productivity	0.84	(*Dynamic moments*)		
σ_u	sd, innovation of productivity	0.43	R&D, continuation prob.	0.82	0.83
θ	credit constraint	15	R&D, start prob.	0.06	0.08
			autocorrelation, TFPR	0.84	0.84
			Elasticity of TFPR (G.O.) w.r.t RER	0.12	0.20
			Elasticity of R&D prob. w.r.t c.f.	0.025	0.042

Estimated parameters and model fit: other developing

Parameter	Description	Values	Moments	Data	Model
			(*Cross-sectional moments*)		
f_x	export fixed cost,mean	135	R&D probability	0.29	0.29
$f_{RD,0}$	R&D sunkcost, mean	75,900	Export probability	0.35	0.36
f_{RD}	R&D fixed cost, mean	11,550	Export/sales Ratio, mean	0.10	0.11
f_m	import fixed cost, mean	498	Import probability	0.39	0.30
A	quality of imported intermediates	0.97	Import/sales ratio	0.24	0.24
D_T	log domestic demand	6.15	Mean firm size (revenue)	7.8	7.25
D_T^*	log foreign demand	4.17	Sd, firm size (revenue)	3.25	2.81
α_1	persistence, productivity	0.85	(*Dynamic moments*)		
σ_u	sd, innovation of productivity	0.43	R&D, continuation prob.	0.82	0.89
θ	credit constraint	11	R&D, start prob.	0.06	0.08
			autocorrelation, TFPR	0.84	0.85
			Elasticity of TFPR (G.O.) w.r.t RER	-0.105	-0.166
			Elasticity of R&D prob. w.r.t c.f.	0.036	0.043

Estimated parameters and model fit: industrialized

Parameter	Description	Values	Moments	Data	Model
			(*Cross-sectional moments*)		
f_x	export fixed cost,mean	720	R&D probability	0.56	0.50
$f_{RD,0}$	R&D sunkcost, mean	115,800	Export probability	0.23	0.24
f_{RD}	R&D fixed cost, mean	9,150	Export/sales Ratio, mean	0.17	0.17
f_m	import fixed cost, mean	2,840	Import probability	0.20	0.21
A	quality of imported intermediates	0.71	Import/sales ratio	0.14	0.14
D_T	log domestic demand	6.10	Mean firm size (revenue)	7.46	7.30
D_T^*	log foreign demand	4.53	Sd, firm size (revenue)	2.94	2.89
α_1	persistence, productivity	0.84	(*Dynamic moments*)		
σ_u	sd, innovation of productivity	0.47	R&D, continuation prob.	0.82	0.89
θ	credit constraint	53	R&D, start prob.	0.06	0.11
			autocorrelation, TFPR	0.84	0.85
			Elasticity of TFPR (G.O.) w.r.t RER	-0.031	-0.022
			Elasticity of R&D prob. w.r.t c.f.	0.006	0.038

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

	Physical productivity	Demand	Imports	Combined
Emerging East Asia	0.013	0.25	-0.06	0.20
Other developing	0.009	0.05	-0.22	-0.16
Industrialized	0.010	0.05	-0.08	-0.02

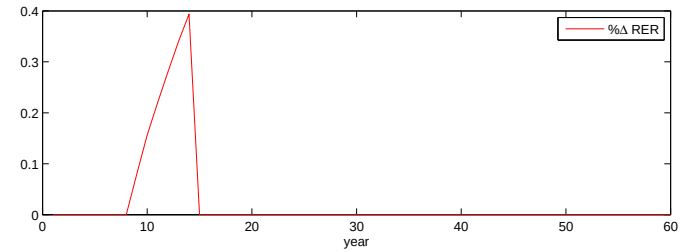
Elasticity of TFPR (G.O) w.r.t RER, by trade status

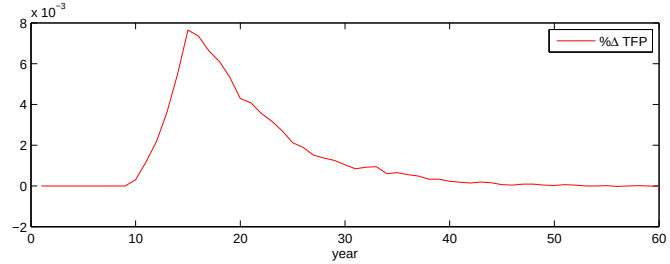
	Export only	Import only	Both	None
Emerging East Asia	0.82	-0.28	0.42	0.07
Other developing	0.06	-0.57	-0.26	-0.07
Industrialized	0.25	-0.44	-0.05	-0.01

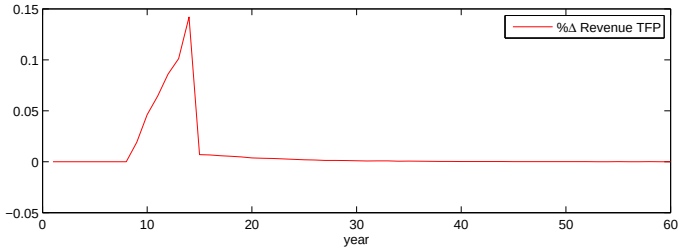
Counterfactual: temporary devaluations

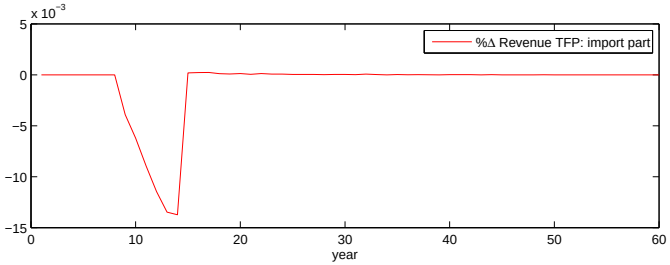
- Yearly depreciation of 8% for five years followed by sudden re-appreciation.
- Depreciation is unanticipated.

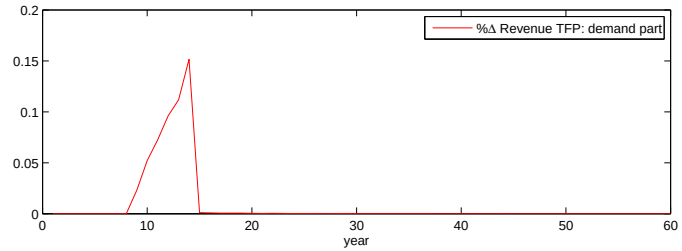
Counterfactual (temporary) devaluation: emerging East Asia



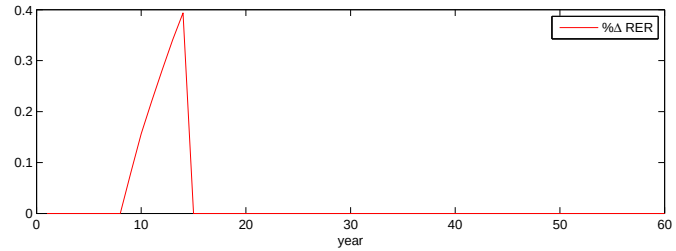


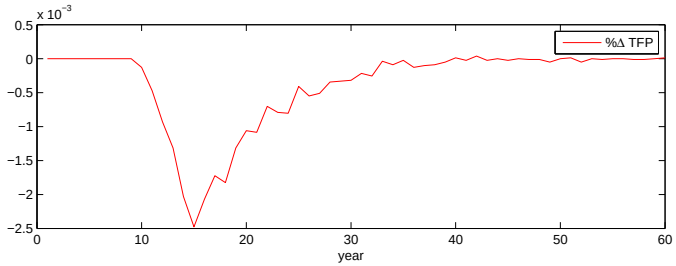


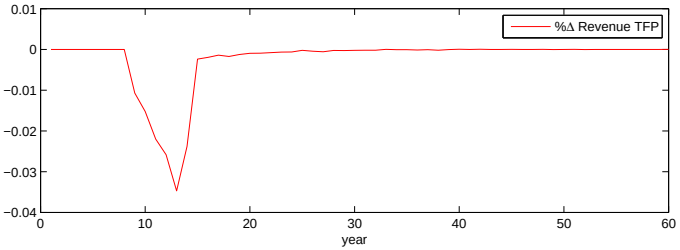


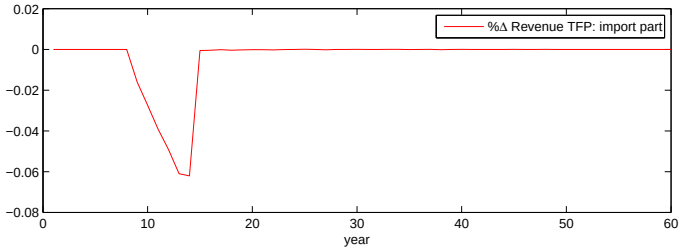


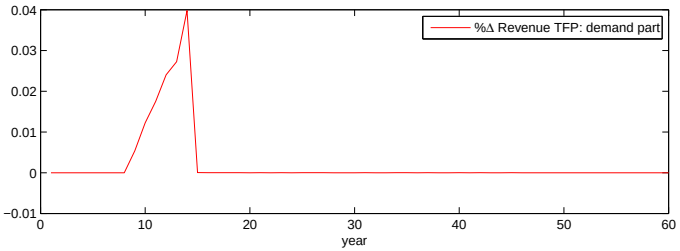
Counterfactual (temporary) devaluation: other developing



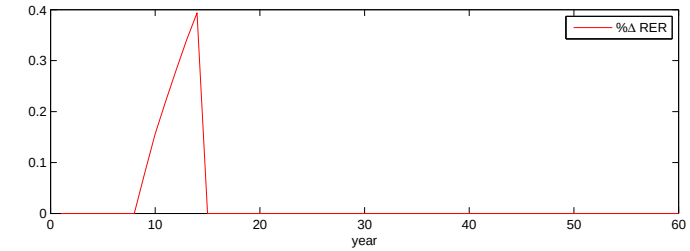


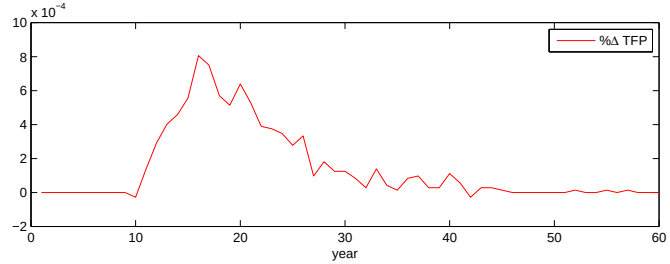


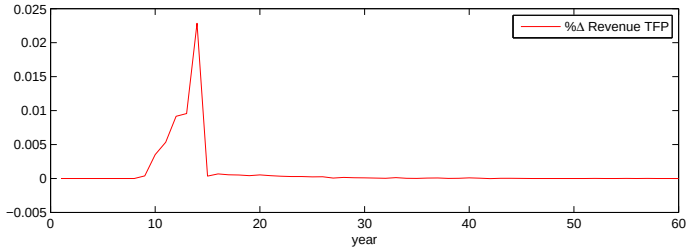


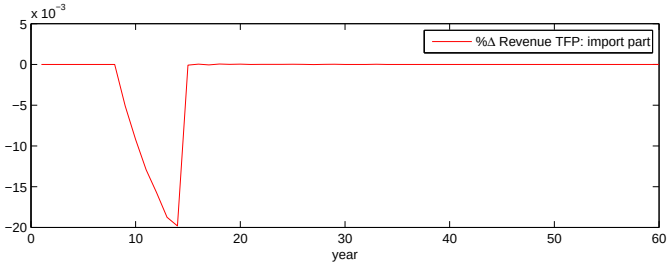


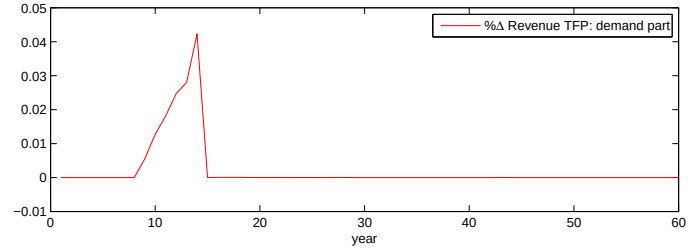
Counterfactual (temporary) devaluation: industrialized











Elasticity of R&D w.r.t RER, decomposition into market size and credit constraints.

	Change in R&D prob.	Market size	Credit constraints
Emerging East Asia	0.039	18%	82%
Other developing	-0.013	40%	60%
Industrialized	0.003	100%	0%

Conclusions

- The effects of RER changes vary across economies according to a number of features: export orientation, imports of intermediates, financial development.
- Explain micro channels of heterogeneous aggregate effects of RER changes across countries.
- Temporary RER changes have very persistent effects on TFP growth and innovation.
- Future work:
  - (Even more) Robustness.
  - Standard errors.

Firm-level export and import propensities by region

	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: Evidence on import and export propensity (Worldbase)

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Changes in trade-weighted RER and firm-level outcomes

$$\Delta \log(Y_{it}) = \beta_0 + \sum_{r \in R} \beta_r^{EXP} \Delta \log(e_{sct}^{EXP}) I_r + \sum_{r \in R} \beta_r^{IMP} \Delta \log(e_{sct}^{IMP}) I_r + \delta_{sc} + \delta_{ct} + u_{ict}, \quad (1)$$

- Export and import-weighted RERs vary at the sector(s)-country(c)-time(t) level.
- δ_{ct}: a country-time-specific fixed effect that controls for any unobserved shock to the manufacturing sector of a given country.
- Cluster standard errors at the country-industry level.

Changes in trade-weighted RER and firm-level outcomes

	(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 $prob._{it}$
$\Delta \log e^{exp}_{sct} \times$	0.827	0.069	0.391	0.751	0.353**
$industrialized_c$	(0.587)	(0.081)	(0.385)	(0.679)	(0.172)
$\Delta \log e^{exp}_{sct} \times$	0.627***	0.212***	0.953***	1.441***	0.041
emerging East $Asia_c$	(0.188)	(0.066)	(0.229)	(0.514)	(0.0535)
$\Delta \log e^{exp}_{sct} \times$	0.0154	0.100	0.222	0.171	0.049
other $developing_c$	(0.239)	(0.078)	(0.395)	(0.487)	(0.381)
$\Delta \log e^{imp}_{sct} \times$	-0.193	6.32E-05	-0.289	-0.557	-0.137
$industrialized_c$	(0.354)	(0.0674)	(0.326)	(0.616)	(0.105)
$\Delta \log e^{imp}_{sct} \times$	0.0507	0.0352	-0.0697	-0.692*	-0.159***
emerging East $Asia_c$	(0.181)	(0.0624)	(0.207)	(0.400)	(0.053)
$\Delta \log e^{imp}_{sct} \times$	-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

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Trade Status

$$\Delta \log(Y_{it}) = \beta_0 + \sum_{T \in e,i,d} \beta_i \Delta \log(e_{ct}) I_T + \beta_2 X_{ct} + \sum_{T \in e,i,d} \beta_T I_T + \delta_{sc} + \delta_t + u_{ict}, \quad (2)$$

- Allow now for different effects of RER for exporters ("e"), importers ("i") and firms that engage in none of these activities ("d").
- 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).

Aggregate RER and Firm Level Outcomes-Trade Participation Status

	(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.$_{it}$
$\Delta \log e^{exp}_{sct} \times$	0.104	0.0204	-.00884	0.032	0.109
domestic$_f$	(0.080)	(0.031)	(0.107)	(0.287)	(0.098)
$\Delta \log e^{exp}_{ct} \times$	0.194***	0.046***	0.0595***	0.340*	0.0945*
exporter$_f$	(0.078)	(0.023)	(0.096)	(0.190)	(0.050)
$\Delta \log e^{exp}_{ct} \times$	0.0373	0.122	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-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

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Changes in trade-weighted RER and firm-level outcomes: 3-year changes

	(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 $prob._{it}$
$\Delta \log e^{exp}_{sct} \times$	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

Changes in RER and firm-level outcomes: IV estimates

	(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 $prob._{it}$
$\Delta \log e_{ct} \times$	-0.0092	-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***
$\text{emerging East Asia}_c$	(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)

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Model: Preferences, Technologies, Market Environment

Representative consumer: a bundle of tradables and non-tradables goods.

$$U_t = g(C_{NT,t}, C_{T,t}) \tag{3}$$

Cobb-Douglas per-period utility; non-tradable sector ($C_{NT,}$), a tradable: numéraire good (D_O) and a manufacturing good (D_T):

$$U_t = \left(\frac{C_{NT,t}}{\alpha_{NT}}\right)^{\alpha_{NT}} \left(\frac{D_{O,t}}{\alpha_O}\right)^{\alpha_O} \left(\frac{D_{T,t}}{\alpha_T}\right)^{\alpha_T}, \tag{4}$$

$\alpha_j \in (0,1)$ for all j, $\sum_j \alpha_j = 1$.

Non-traded and numéraire sectors: perfectly competitive; manufacturing sector: differentiated varieties, monopolistic competition.

Consumption-based price index: $P_t = P_{NT,t}^{\alpha_{NT}} P_{O,t}^{\alpha_O} P_{T,t}^{\alpha_T}$. RER: $\frac{P_t^*}{P_t}$.

Model: Numéraire and Non-traded Sectors

The numéraire good is freely traded and produced with technology

$$Y_O = e^{-1} \left(K_O/\beta_k\right)^{\beta_k} \left(L_O/\beta_l\right)^{\beta_l} \left(X_O/\beta_m\right)^{\beta_m}, \tag{5}$$

$\beta_h > 0$, $\{h = k, l, m\}$, $\sum_h \beta_h = 1$.

e is a shifter inversely related to the sector's productivity:

$$\log(e_t) = \gamma_0 + \gamma_1 \log(e_{t-1}) + \nu_t, \quad \nu_t \sim N(0, \sigma_\nu^2). \tag{6}$$

Equilibrium: all countries produce the numéraire good. Since

$$P_{O,t} = e_t r_t^{\beta_k} w_t^{\beta_l} P_{X_t}^{\beta_m} = e_t f_t = 1; f \equiv r_t^{\beta_k} w_t^{\beta_l} P_{X_t}^{\beta_m} = e^{-1} \tag{7}$$

* an increase in e makes domestic production factors cheaper (real depreciation).

Non-Tradables:

$$Y_{NT} = \left(K_{NT}/\beta_k\right)^{\beta_k} \left(L_{NT}/\beta_l\right)^{\beta_l} \left(X_{NT}/\beta_m\right)^{\beta_m} \tag{8}$$

Non-tradables: Final Consumption or as domestic intermediate input.

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Production function estimation: first stage

- Assuming material input expenditure $\tilde{m}_{it} = \tilde{m}\left(\omega_{it}, k_{it}, D_t, D_t^*, e_t\right)$ strictly increasing in ω_{it}, express ω_{it} as a function of capital k_{it}, material expenditure $\tilde{m}_{it}$ and aggregate demand (D_t, D_t^*, e_t).

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

- where $\tilde{\beta} \equiv \beta \frac{\sigma-1}{\sigma}, \tilde{\omega} \equiv \omega \frac{\sigma-1}{\sigma}$
- $\Phi\left(k_{it}, \tilde{m}_{it}, D_t, D_t^*, e_t\right)$ is approximated using a polynomial:

$$\begin{aligned} \Phi\left(k_{it}, \tilde{m}_{it}, D_t, D_t^*, e_t\right) &= \lambda_0 + \lambda_1 k_{it} + \lambda_2 \tilde{m}_{it} + \lambda_3 k_{it} \tilde{m}_{it} + \lambda_4 k_{it}^2 + \ldots + \lambda_9 \tilde{m}_{it}^3 + \\ &+ \sum_{j=1}^{J} \lambda_j^{EXP} \log(e_{st}^{EXP}) + \sum_{j=1}^{J} \lambda_j^{IMP} \log(e_{st}^{IMP}) + D_{ct} + D_s, \end{aligned}$$

- where D_{ct} and D_s are country-time and sector dummies proxying for aggregate demand shocks.
- $\sum_{j=1}^{J} \lambda_j^{EXP} \log(e_{st}^{EXP})$ and $\sum_{j=1}^{J} \lambda_j^{IMP} \log(e_{st}^{IMP})$ are interactions of sector-specific export and import-weighted RERs with dummies for firm-size bins.

Production function estimation: second stage

- Obtain $\widehat{\beta}_l$ and $\widehat{\Phi}\left(k_{it}, \tilde{m}_{it}, D_t, D_t^*, e_t\right)$ and substitute $\omega_{it} = \alpha_0 + \alpha_1 \omega_{it-1} + \alpha_2 I_{iRD,t-1} + u_{it}$:

$$r_{it} - \widehat{\beta}_l l_{it} = \tilde{\beta}_0 + \tilde{\beta}_k k_{it} + \tilde{\beta}_m \tilde{m}_{it} + \tilde{\alpha}_0 + \tag{9}$$
$$+\alpha_1 \left[\widehat{\Phi}\left(k_{it-1}, \tilde{m}_{it-1}, D_{t-1}, D_{t-1}^*, e_{t-1}\right) - \tilde{\beta}_k k_{it-1} - \tilde{\beta}_m \tilde{m}_{it-1}\right] + \tilde{\alpha}_2 I_{i,RD_{t-1}} + + \tilde{u}_{it} + \varepsilon_{it}.$$

- 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.

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Decomposing expected revenue-based productivity

- expected revenue-based productivity:

$$E(tfptr_{it}) = \left(\frac{\sigma-1}{\sigma}\right) E\left[\beta_0 + \omega_{it} + \varepsilon_{it} + \beta_m \tilde{a}_{it} - \beta_m \log(P_{Xst})\right] + g_{it}\left(D_t, D_t^*, e_t\right) = \tag{10}$$

$$\left(\frac{\sigma-1}{\sigma}\right)\left[\beta_0 + \alpha_0 + \alpha_1 E(\omega_{it-1}) + \alpha_2 E(I_{RD,t-1}) + E(\varepsilon_{it}) + \beta_m E(\tilde{a}_{it}) - \beta_m \log(P_{Xst})\right] + E(g_{it}(D_t, D_t^*, e_t))$$

$$= \left(\frac{\sigma-1}{\sigma}\right)\left[\beta_0 + \alpha_0 + \alpha_1 E(\omega_{it-1}) + \alpha_2 Prob(I_{RD,t-1}=1) + \beta_m Prob(I_{Mt}>0) E(\tilde{a}_{it}|I_{Mt}>0) - \beta_m \log(P_{Xst})\right]$$

$$+ \left[Prob(I_{X,t}=0) E(g_{it}(D_t, D_t^*, e_t)|I_{X,t}=0) + Prob(I_{X,t}=1) E(g_{it}(D_t, D_t^*, e_t)|I_{X,t}=1)\right]$$

- Computing the model counterpart to the reduced-form regression:

$$\frac{\partial E(tfptr_{it})}{\partial \log e_t} = \left(\frac{\sigma-1}{\sigma}\right)\alpha_2 \frac{\partial Prob(I_{RD,t-1}=1)}{\partial \log e_t} \tag{11}$$

$$+ \left(\frac{\sigma-1}{\sigma}\right)\beta_m \left[\frac{\partial Prob(I_{Mt}>0)}{\partial \log e_t} E(\tilde{a}_{it}|I_{Mt}>0) + Prob(I_{Mt}>0)\frac{\partial E(\tilde{a}_{it}|I_{Mt}>0)}{\partial \log e_t}\right]$$

$$+ \left[\frac{\partial Prob(I_{X,t}=0)}{\partial \log e_t} E(g_{it}(D_t, D_t^*, e_t)|I_{X,t}=0) + Prob(I_{X,t}=0)\frac{\partial E(g_{it}(D_t, D_t^*, e_t)|I_{X,t}=0)}{\partial \log e_t}\right]$$

$$+ \left[\frac{\partial Prob(I_{X,t}=1)}{\partial \log e_t} E(g_{it}(D_t, D_t^*, e_t)|I_{X,t}=1) + Prob(I_{X,t}=1)\frac{\partial E(g_{it}(D_t, D_t^*, e_t)|I_{X,t}=1)}{\partial \log e_t}\right]$$

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Table: Production function: coefficient estimates

	(1)	(2)
labor $\tilde{\beta}_l$	0.33621***	0.53342***
	(0.00170)	(0.00245)
capital $\tilde{\beta}_k$	0.09272***	0.20844***
	(0.01782)	(0.01046)
materials $\tilde{\beta}_m$	0.68178***	
	(0.02238)	
R&D return $\tilde{\alpha}_2$	0.07854***	0.03306**
	(0.01306)	(0.01644)
Observations stage 1	1,001,593	1,001,593
Observations stage 2	33,252	49,183
Country-time FE	YES	YES
Sector FE	YES	YES

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Exchange rate process - estimation results

Table: AR (1) $\log(e_{ct})$

	(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

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wbcode	Freq.	Percent	Cum.	wbcode	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