The Micro and Macro Productivity of Nations

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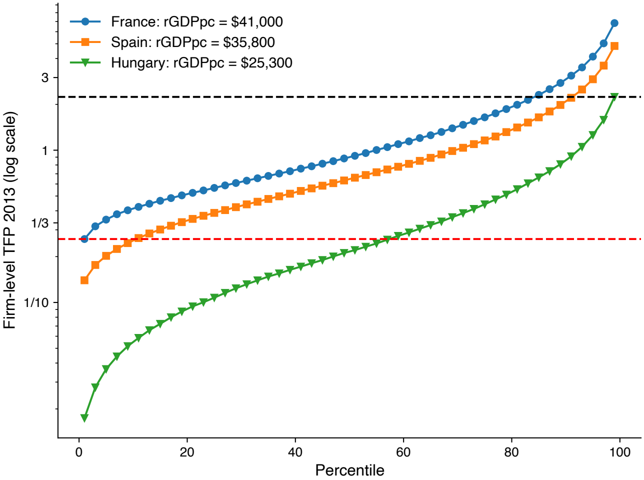
Motivation

- Aggregate productivity at the core of international differences in GDP per capita (Klenow & Rodriguez-Clare 1997, Prescott 1998, Hall & Jones 1999).
- Differences in aggregate productivity linked to distortions in the allocation of resources across firms (Restuccia & Rogerson 2008; Hsieh & Klenow 2009).
- Micro data reveals cross-country differences in the firm-level productivity distribution (Hsieh & Klenow 2009; Gal 2013) that may contribute to aggregate productivity differences.

Firm-level productivity distribution



- About 58% of firms in Hungary with TFP below p1 in France, whereas ≈ 15% of firms in France with higher TFP than p99 in Hungary.

Motivation

- Evidence of higher dispersion in firm-level productivity in less developed countries motivates two questions:
  - How important are the differences in firm-level productivity for cross-country per-capita income?
  - What accounts for the differences in firm-level productivity?
- Our approach links observed firm-level TFP distributions to policies and institutions that misallocate resources across firms.
- Approach motivated by empirical evidence from policy reforms finding substantial effects on selection and technology upgrading from reductions in misallocation (e.g., Pavcnik 02, Bustos 11, Khandelwal et al. 13).

What we do

- Construct comparable firm-level data to document cross-country facts on productivity and measured distortions.
- Develop a model of heterogeneous firms with distortions where firms make entry, operation, and productivity-enhancing investment decisions.
  - Distortions $\Longrightarrow$ firm distribution through operation and investment.
  - Misallocation amplified by firm selection and technology decisions.
  - Characterize bias in measured distortions due to selection and technology.
- Use model to quantify the effects of measured distortions on micro and macro productivity differences across countries.

What we find

- Four facts on cross-country firm-level productivity and distortions.
  - Higher productivity gaps in lower-income countries due to prevalence of low productivity firms.
  - Higher distortions gaps in lower-income countries, mostly due to higher elasticity of distortions to firm-level productivity.
- The quantitative effect of measured distortions.
  - Generated differences in aggregate productivity represent more than half of the variation in cross-country data.
  - Changes in firm-level productivity distribution account for 56% of aggregate losses (1/4 of allocative efficiency).
  - Technology/selection channels both important to account for cross-country data.
  - Measured distortions upward biased, but bias larger in developed countries.

Related literature

- Production heterogeneity and misallocation: Restuccia & Rogerson (2008); Guner, Ventura & Xu (2008); Hsieh & Klenow (2009).
- Technology adoption, producer dynamics, and aggregate productivity: Parente and Prescott (1994); Bhattacharya, Guner & Ventura (2013); Hsieh & Klenow (2014); Bento & Restuccia (2017); Comin & Mestieri (2018); Ayerst (2022); Buera et al. (2023).
- Link of misallocation with selection/technology: Pavcnik (2002), Bustos (2011), Kanderwal et al. (2013), Lagos (2006), Yang (2021), Majerowitz (2023).
- Orbis data: Andrews, Criscuolo & Gal (2015); Poschke (2018); Alviarez, Cravino & Ramondo (2023); Kalemli-Ozcan et al. (2023); Fattal-Jaef (2022).

Outline

- Data and facts.
- Model.
- Calibration.
- Quantitative analysis & results.
- Conclusions.

Data

- Construct firm-level dataset across countries using ORBIS, collected and standardized by Bureau Van Dijk.
- Restrict to countries with >5,000 observations with sufficient data to measure firm-level productivity.
- Focus on 2000-2019, manufacturing firms, trim for extreme values and top and bottom 2% to limit influence of outliers.
- Final dataset contains 37 countries with average 300 thousand firm-year observations.
- Dataset covers wide range of world income: India, Vietnam among poorest; France, Germany among richest.

Variable construction

- Construct model-based measures of firm-level productivity and distortions:

$$\text{TFP}_{i,t} = \frac{y_{i,t}}{n_{i,t}^{\gamma}}, \qquad \text{wedge}_{i,t} = \frac{y_{i,t}}{n_{i,t}}.$$

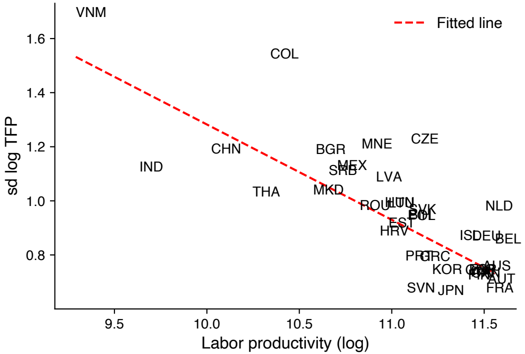
- Output as operating revenue (sales), employment as number of employees.

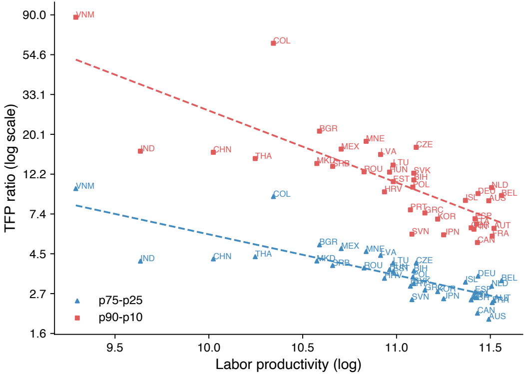
- Controls for country-by-sector-by-year fixed effects.

- Similar results if: (a) include capital as input, (b) use value added as measure of output, (c) CES model, (d) weight observations using national statistics.

EMPIRICS

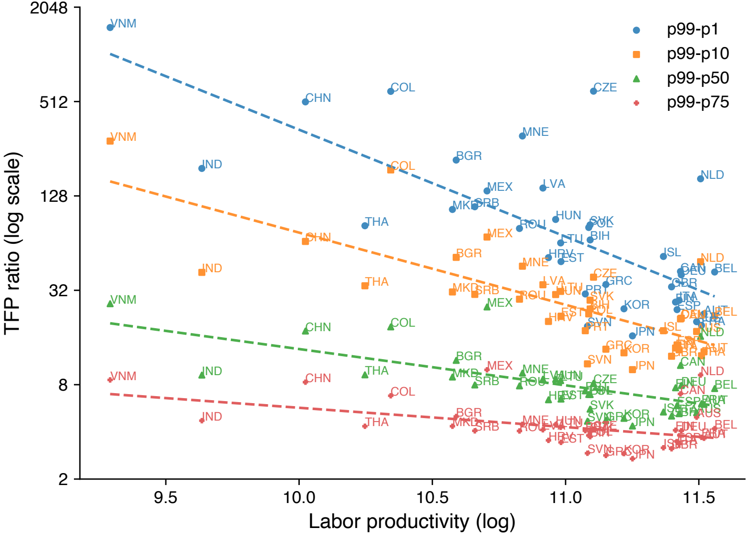
Fact 1: Productivity dispersion tends to be higher in lower income countries





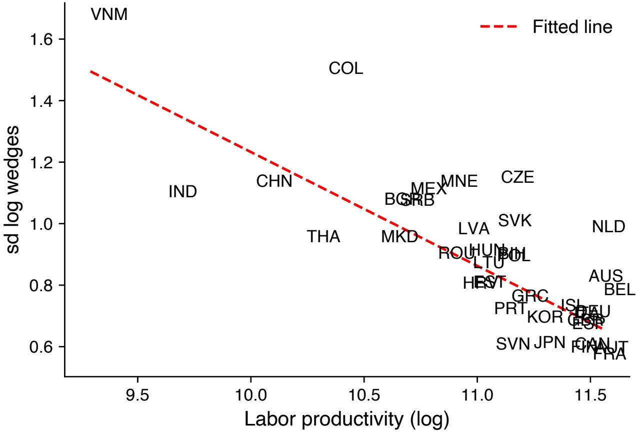
- p90/p10 productivity gap about 7-fold in FRA, 30-fold in VNM.

Fact 2: Productivity fans out in lower income countries

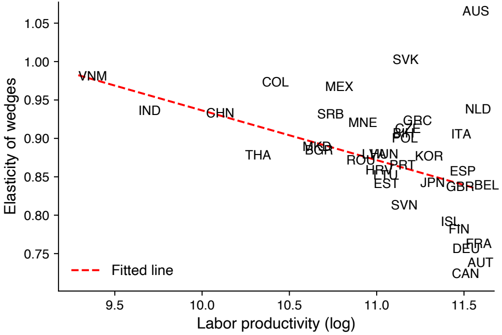


- Higher productivity dispersion driven by differences at bottom of distribution.

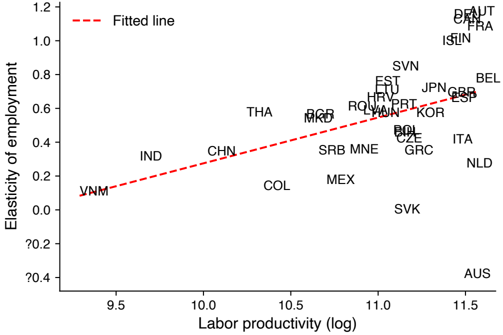
Fact 3: Dispersion in distortions tends to be higher in lower income countries



Fact 4: Measured elasticity of distortions higher in lower income countries



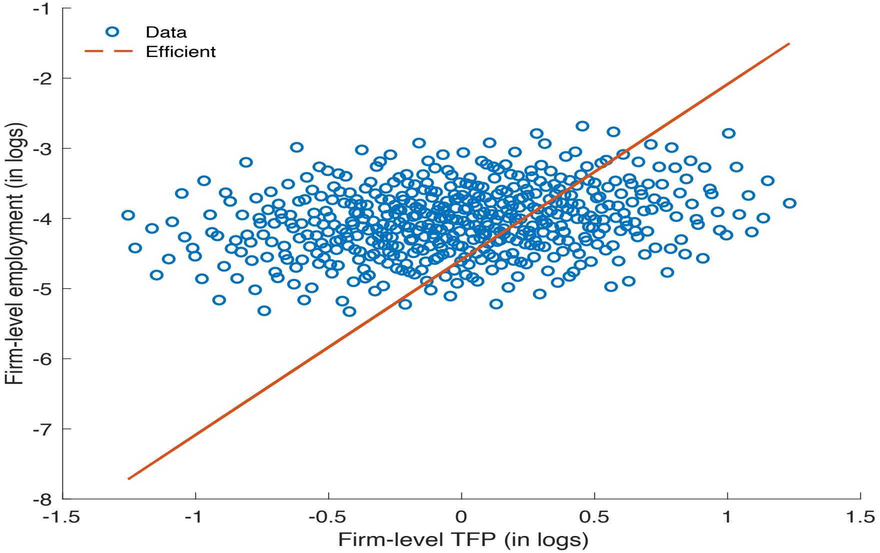
Elasticity of distortions



Elasticity of employment

- Elasticity coefficient from reg. $\log(\text{wedge})$ or $\log(\text{employment})$ on $\log(\text{TFP})$.

Stylized misallocation



MODEL

Model

- Standard model of production heterogeneity with distortions building on Hopenhayn (1992) and Restuccia and Rogerson (2008).
- Framework allows for productivity enhancing investment (technology) and operation decisions by firms (selection).
- Focus on a stationary competitive equilibrium.
- Time is discrete and indexed by $t \in \{1, 2, ..., \infty\}$.
- Representative household, standard preferences on consumption $\log(C)$, one unit of productive time supplied inelastically to firms.

Technology

- At each date, a homogeneous good is produced by firms indexed by i.
- Each firm i employs labor (n_i) to produce output (y_i) following a decreasing-return-to-scale technology:

$$y_i = v_i {z_i}^{1-\gamma} {n_i}^{\gamma}, \qquad \gamma \in (0, 1),$$

where $z_i^{1-\gamma}$ is a permanent productivity component, v_i a random productivity component (e.g. measurement error) with $\mathbb{E}_v v = 1$ realized after production decisions.

- To attain productivity z_i, a firm incurs a productivity investment cost of $\psi \frac{z^\phi}{\chi_i}$ in units of output where χ_i is an innovation ability drawn from iid cdf $G(\chi)$.
- Firm face an operating fixed cost c_f in units of labor every period.

Market structure and distortions

- Competitive economy where households and firms take prices as given.
- Price of output normalized to 1, wage rate denoted by w.
- Firms face idiosyncratic distortions, modeled as a proportional tax τ_i on revenues:
  $$\log(1 - \tau_i(z_i, \epsilon_i)) = (1 - \gamma)[-\rho \log z_i - \log \epsilon_i],$$
  where ρ is the elasticity of distortions with respect to firm TFP and ϵ_i is a random component of distortions drawn from iid cdf $F(\epsilon)$.
- Firms exit at exogenous rate of λ every period.

Incumbent firms

- Incumbent firm characterized by productivity z_i and distortion τ_i chooses labor n_i to maximize per-period profit $\pi(z_i, \tau_i)$:

$$\pi(z_i, \tau_i) = \max_{n \geq 0} \quad \mathbb{E}_v \left[(1 - \tau_i) v z_i^{1-\gamma} n^{1-\gamma} - wn - c_f w \right].$$

  Optimal labor from this problem

$$n(z_i, \tau_i) = (1 - \tau_i)^{\frac{1}{1-\gamma}} z_i \left(\frac{\gamma}{w} \right)^{\frac{1}{1-\gamma}} = \frac{z_i^{1-\rho}}{\epsilon_i} \left(\frac{\gamma}{w} \right)^{\frac{1}{1-\gamma}}.$$

- Per-period profits determine the value of an incumbent firm $W(z_i, \tau_i)$:

$$W(z_i, \tau_i) = \max \left\{ \frac{\pi(z_i, \tau_i)}{1 - R}, 0 \right\}, \quad R = \frac{(1 - \lambda)}{(1 + r)}.$$

Entering firms

- Entering firms draw idiosyncratic innovation ability χ_i and decide level of productivity z at a cost, knowing distortion they face (ρ,ϵ_i):

$$V(\chi_i, \epsilon_i) = \max_{z \geq 0} \left[W(z, \tau(z, \epsilon_i)) - \psi \frac{z^\phi}{\chi_i} \right].$$

Optimal productivity z for an entrant drawing (χ_i, ϵ_i) given by:

$$z(\chi_i, \epsilon_i) = \left(\frac{(1-\rho)\tilde{\Omega}\chi_i}{\psi\phi\epsilon_i} \right)^{\frac{1}{\phi+\rho-1}}, \quad \text{where} \quad \tilde{\Omega} \equiv \frac{\Omega}{1-R}.$$

χ and ϵ affect z in same proportion, depends on elasticity of distortions ρ.

Value of entering

- At the beginning of each period, there is a mass of potential entrants and the value of entry V_e is given by,

$$V_e = \mathbb{E}_{\chi,\epsilon} V(\chi, \epsilon) - c_e w \leq 0.$$

Distribution of firms

- The distribution of firms over productivity levels can be determined from the distribution of firms over innovation ability χ and distortions.
- The law of motion for the distribution of firms $\mu(\chi, \epsilon)$ is,

$$\mu'(\chi, \epsilon) = (1 - \lambda)\mu(\chi, \epsilon) + Eo(\chi, \epsilon)dF(\epsilon)dG(\chi).$$

- In stationary equilibrium,

$$\mu(\chi, \epsilon) = \frac{E}{\lambda} o(\chi, \epsilon)dF(\epsilon)dG(\chi),$$

and the mass (number) of firms is given by

$$N = \int_\chi \int_\epsilon d\mu(\chi, \epsilon) = \frac{E}{\lambda} \int_\chi \int_\epsilon o(\chi, \epsilon)dF(\epsilon)dG(\chi).$$

Stationary equilibrium

A stationary competitive equilibrium comprises a wage w; decision functions for firms: labor demand $n(z, \tau)$, profits $\pi(z, \tau)$, value of incumbent firm $W(z, \tau)$, productivity $z(\chi, \epsilon)$, operating decision $o(\chi, \epsilon)$, net value of firm $V(\chi, \epsilon)$, value of entry V_e, a distribution of firms $\mu(\chi, \epsilon)$, mass of firms N and entrants E; and allocation C for households such that:

(i) Given w, allocation C solves the household's problem.

(ii) Given w, $n(z, \tau)$ solves the incumbent's firm problem, determining $\pi(z, \tau)$ and $W(z, \tau)$.

(iii) Given w, entrants choose $z(\chi, \epsilon)$ and $o(\chi, \epsilon)$ to maximize net value of firm $V(\chi, \epsilon)$.

(iv) Zero profit entry condition $V_e = 0$.

(v) Invariant distribution of firms μ.

(vi) Markets clear.

Model insights

- Measured TFP for firm i given by

$$\text{TFP}_i = \frac{y_i}{n_i^\gamma} = z(\chi_i, \epsilon_i; \rho)^{1-\gamma} v_i.$$

- Technology and selection affect dispersion of TFP, so does mismeasurement.
- Technology: ρ compresses productivity distribution given χ.
- Selection: can increase dispersion of TFP since lees productive firms may operate given distortions, overcoming technology channel a quantitative issue.

QUANTITATIVE ANALYSIS

Calibration

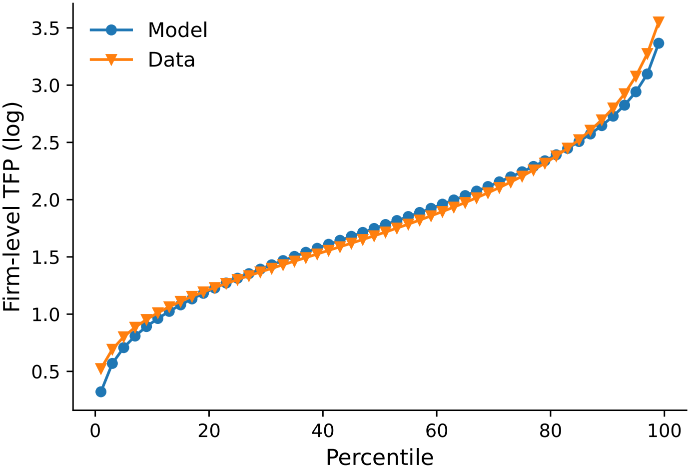
- Strategy: calibrate distorted benchmark economy (BE) to firm-level and aggregate data for France.
- There are 11 parameters to be calibrated.
- 6 parameters normalized or assigned values from outside evidence: $\gamma = 0.8$ (misallocation literature), exit rate $\lambda = 0.1$, real interest rate $r = 0.04$, curvature investment cost function $\phi = 2$, productivity investment cost $\psi = 1$ and entry cost $c_e = 1$.
- Remaining 5 parameters $(\rho, \sigma_\epsilon, \sigma_\chi, \sigma_v, c_f)$ jointly calibrated to match 5 moments from French data: (1) TFP elasticity of distortions, (2) sd log distortions, (3) sd log employment, (4) sd log TFP and (5) average firm size.

Calibration benchmark economy

Parameter	Value	Targeted moments	Model	Data
ρ	0.478	Elasticity of distortions	0.75	0.76
σ_ϵ	1.57	sd log distortions	0.55	0.56
σ_χ	9.94	sd log employment	1.40	1.40
σ_v	0.25	sd log TFP	0.67	0.66
c_f	0.10	Average firm size	14.8	14.9

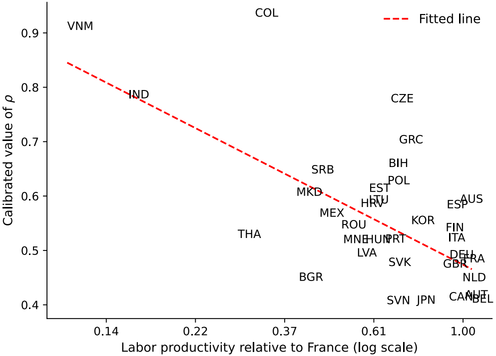
- Calibrated $\rho = 0.478$ implies measured elasticity of distortions 0.75.
- Gap between model parameter and measured elasticity due to strong operation selection of firms.

Firm-level TFP distribution

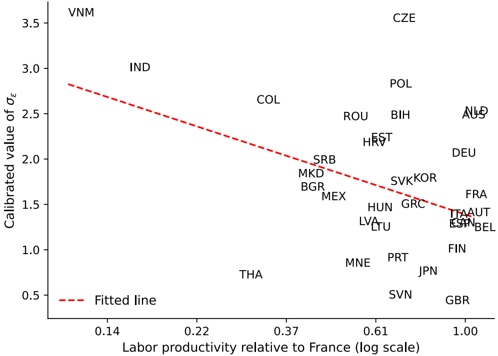


Cross-country calibration

- Repeat the calibration procedure for each country in our dataset.



ρ



σ_ϵ

- Question: **how much of the cross-country data can be accounted for by varying distortions** (ρ, σ_ϵ)**?** Hold σ_χ, σ_v and c_f fixed at the France values.

Cross-country calibration

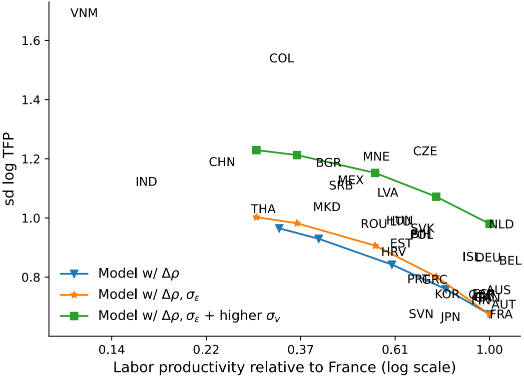
- Vary distortion parameters (ρ, σ_ϵ) based on cross-country calibration:

	BE	Counterfactuals			
ρ	0.478	0.60	0.70	0.80	0.85
σ_ϵ	1.57	1.99	2.33	2.67	2.83

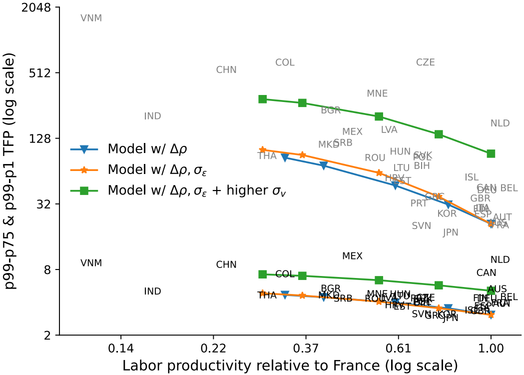
- We also explore a counterfactual with higher $\sigma_v = 0.76$ vs 0.25 in BE.

- We illustrate results in three steps: (1) vary ρ; (2) vary ρ, σ_ϵ; (3) vary ρ, σ_ϵ and higher σ_v.

Firm-level TFP (facts 1 & 2)



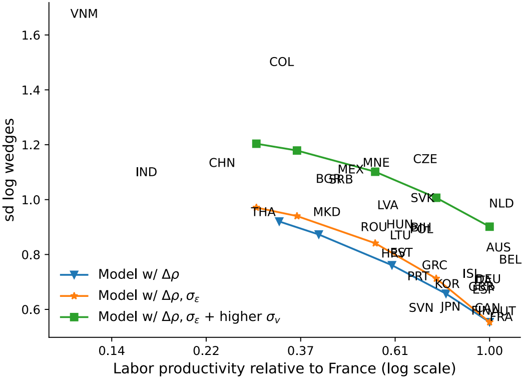
sd log TFP



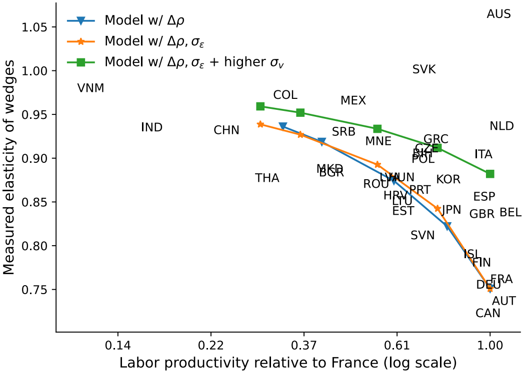
p99-p75 & p99-p1 log TFP

- Model fits data relatively well, bulk of effects from elasticity of distortions ρ.
- Aggregate labor productivity in model $\approx 1/2$ variation cross-country data.

Firm-level distortions (facts 3 & 4)



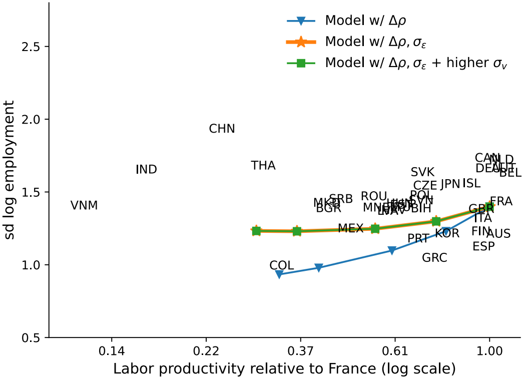
sd log wedges



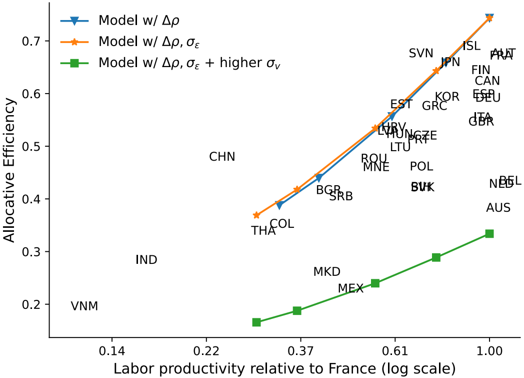
Elasticity of distortions

- Bulk of distortions dispersion from variation in ρ (systematic component).
- Mismeasurement (higher σ_v) represents small component of measured elasticity of distortions in less developed countries.

Other goodness-of-fit moments



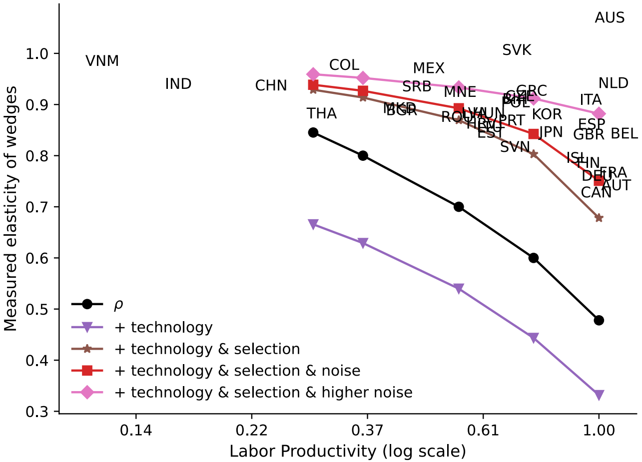
sd log employment



Allocative efficiency (AE)

- Dispersion in firm size driven more by σ_ϵ in less developed countries.
- AE more sensitive to mismeasurement (ex-post productivity dispersion σ_v).

Estimation bias in measured elasticity of distortions



- Measured bias due to transitory productivity v, selection, and technology choice.
- Overall positive bias, but more severe in advanced countries.

Taking stock

- Experiments highlight:
  (a) model can account for key cross-country moments,
  (b) substantial cross-country productivity losses from measured distortions,
  (c) calibrated elasticity of distortions ρ accounts for bulk of cross-country effects.
- Now use model to examine sources of aggregate productivity losses.

Decomposing productivity losses

- How important are different channels for the loss in aggregate productivity?
  - Focus only on variations in ρ.
  - Vary ρ between 0.478 and 0.85, consistent with the cross-country experiments.

Decomposing productivity losses

	Value of ρ	
	0.478	0.85
Aggregate labor productivity	1.00	0.33
Static misallocation contribution (%)	–	*44*
Firm-level productivity contribution (%)	–	*42*
Firm productivity with distortions contribution (%)	–	*14*
Allocative efficiency contribution (%)	–	*58*

- Static misallocation: change distortions with same producers and technologies.
- Changes in firm-level productivity distribution account for 56% of aggregate productivity loss.

Technology versus selection

	Value of ρ	
	0.478	0.85
Technical efficiency	1.00	0.44
Technology contribution (%)	–	*54*
Selection contribution (%)	–	*46*

- Measure impact of selection and technology on technical efficiency (aggregate TFP in the undistorted economy).
- Technology measures change resulting from increased distortions holding set of operating firms constant.
- Technology and selection contribute roughly equal to aggregate productivity loss.

Conclusions

- Documented cross-country differences in firm-level productivity and distortions distributions.
- The productivity costs of distortions extend beyond static misallocation: changes in firm-level productivity distribution account for 56% of aggregate productivity losses, 1/4 of allocative efficiency.
- Measured distortions biased due to technology and selection, but bias higher in advanced countries.
- Future work may examine specific drivers of misallocation for firm dynamics, exploiting within-country institutional contexts or reform episodes to link with technology and selection channels.