TECHnological Factor Productivity

Diego Comin with Xavier Cirera, and Marcio Cruz

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Motivation

- Open up an establishment, and zoom into each business function
- Observe **what technologies** are used to conduct the main tasks involved in the function and out of these which is **most widely used**.
- This information is relevant to study many fundamental questions
  1. How far are establishments from the frontier?
  2. Are there significant **differences in technology across the business functions** of **an** establishment?
  3. **Why?**
  4. Aggregate the BF-level technologies into a establishment index of technology: **TECHFP**
  5. What dimensions of technological landscape are more relevant for TECHFP?
  6. How much of the cross-establishment **dispersion in productivity** can be accounted for by the variation in TECHFP?

Firm Adoption of Technology (FAT)

- New dataset (FAT) that covers representative sample of establishments in 10 countries: Korea, Poland, Brazil, India, Vietnam, Bangladesh, Senegal, Kenya, Ghana, Burkina Faso.
- **The Grid**:
  - A two-dimensional structure that lists business functions and technologies.
  - Covers 7 general business functions (relevant for all) and 58 sector-specific functions (11 big sectors + Other manufacturing).
  - For each of them: 4-7 technologies (total 303 technologies)
  - Can be ranked from least to most sophisticated
  - Relevant for establishments in all sectors and countries

The GRID

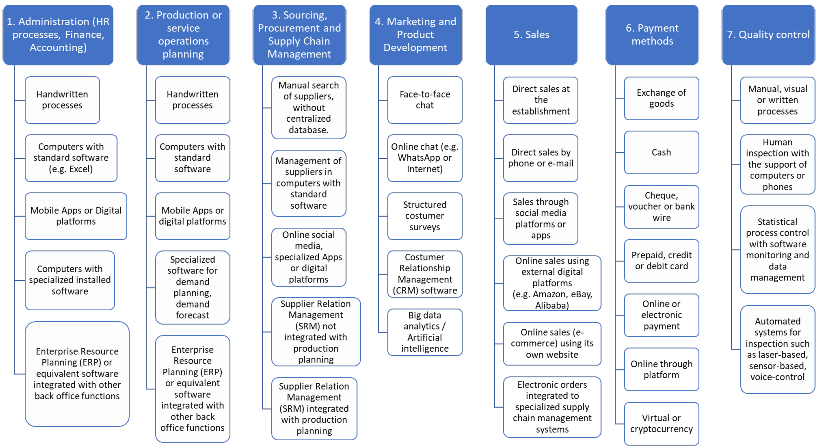


Figure 1: General Business Functions and Their Technologies

Grid for food processing ⏩ skip slide

Survey

- Sampling frame: Representative sample stratified at the sector, establishment size and region.
- Cover 12,636 establishments.
- Ex-post quality checks skip slide
- Technology questions:
  - Do you use technology X in the BF?
  - Of the technologies that you use in the BF, which one is the most widely used?

Technology sophistication measure

- Technologies in a BF can be ranked based on their sophistication.
  - Capacity to conduct more tasks, of greater complexity with greater accuracy.
- Let $r_{f,j}$ be the sophistication of a given technology, $r_{f,j} \in 1, 2, ..., R_f$
- Relative rank $\hat{r}_{f,j} = \frac{r_{f,j}-1}{R_f-1}$
- $MOST_{f,j} = 1 + 4 * \hat{r}_{f,j}^{MOST}$
- $MAX_{f,j} = 1 + 4 * \hat{r}_{f,j}^{MAX}$

Describing Technology Sophistication

	Mean	SD	p10	p50	p90	Skewness	Kurtosis
MOST_{fj}	1.77	1.02	1.00	1.67	3.67	1.47	4.56
MAX_{fj}	2.39	1.28	1.00	2.00	4.33	0.59	2.17
MOST_{j}	1.79	0.61	1.10	1.71	2.64	0.92	3.67
MAX_{j}	2.41	0.82	1.43	2.28	3.58	0.61	2.86

Technology sophistication and establishment characteristics ⏩ skip slide

Technology differences across business functions

$$S_{f,j,c} = \alpha_j + \beta_{f,c} + u_{f,j,c}$$

	(1) MAX	(2) MOST
Var(S_{fjc})	1.64	1.05
Var(α_{fc})	0.42	0.31
Var(α_j)	0.48	0.22
Var($u_{f,j,c}$)	0.66	0.47
Contribution WVAR	40%	45%

Distribution of WVAR across establishments skip slide

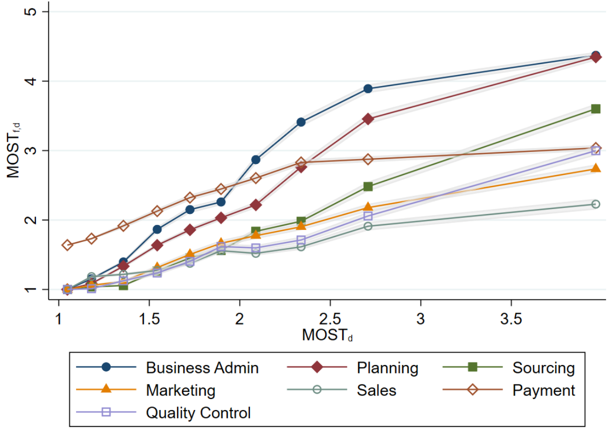
Correlates of WVAR across establishments skip slide

Why is WVAR so high?

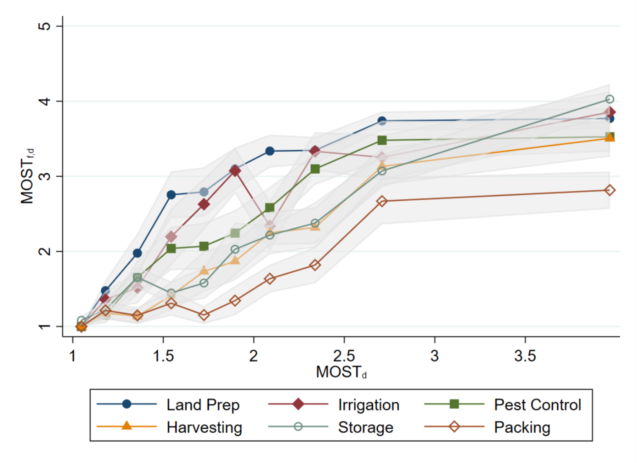
$$S_{f,j} = \alpha_f + \varepsilon_f * S_j + v_{f,j}$$

The technology curve

$$S_{f,j} = \alpha_f + \varepsilon_f * S_j + v_{f,j}$$



Technology Curve, SSBF Agriculture



Stability across countries ⏩ skip slide

A micro-foundation of the technology curve

- Establishments choose a vector of technology sophistication $s_{f,j}$ across functions, to maximize $\Pi_j(a_j) - \sum_{f=1}^{N_f} C_j C_{f,X} e^{s_{f,j}}$

  subject to

$$e^{a_j} = \left[\sum_{f=1}^{N_f} \underbrace{\left(\Omega_f^{\frac{1}{\sigma}} e^{\frac{(\varepsilon_f - (1-\sigma)) a_j}{\sigma}} \right)}_{\widetilde{\omega}_f(a_j)} e^{\frac{\sigma-1}{\sigma} s_{f,j}} \right]^{\frac{\sigma}{\sigma-1}} .$$

- a_j is TECHnological Factor Productivity.
- Non-homothetic CES aggregator. If $\varepsilon_f = (1-\sigma)$, becomes homothetic.
- ε_f technology-elasticity of function f
- Controls how does the importance of the function $\widetilde{\omega}_f$ change with a_j.
- σ elasticity of substitution across technologies in different BFs

Optimal technology sophistication

$$s_{f,j} = \kappa_j + \kappa_f + \varepsilon_f * a_j - \sigma ln(C_{f,X})$$ ⏩ skip slide

$$WVar_j = a_j^2 Var(\varepsilon_f) + \sigma^2 Var(ln(C_{f,X})) - 2a_j\sigma Cov(\varepsilon_f, ln(C_{f,X}))$$

- If $Var(\varepsilon_f) > 0$, $WVar_j$ increases with a_j (heterogeneity of the Mg. value of sophistication across BFs)
- If $Var(ln(C_{f,X})) > 0$, heterogeneity in Mg. cost

Estimation Strategy

- Optimal adoption:

$$s_{f,j} = \kappa_j + \kappa_f + \varepsilon_f * a_j + \beta_f * X_j + v_{f,j}$$

  This is a mixed model.

- Follow Aguiar and Bils (2015) 2-step approach to estimate slope of Engel curves and household expenditure in the CEX.
  1. Proxy a_j by $a_j = \alpha * \overline{a}_j + u_j$, where u_j is classical error.
  2. Obtain estimate of ε_f from regression replacing a_j by $\overline{a}_j$
  3. Estimate using $\widehat{\varepsilon}_f$ as regressor. This provides estimates of $\widehat{\kappa}_j$, $\widehat{a}_j$, and their VCV.

- $\widehat{\varepsilon}_f$ and $\widehat{a}_j$ are unbiased estimates of ε_f and a_j up to a constant scaling factor.

- Details ⏩ skip slide

Analysis of estimates

	Mean	SD	P90/P10
$\widehat{\varepsilon}_f$	0.82	0.4	4.32

- Is $Var(\widehat{\varepsilon}_f)$ due to non-homotheticities or to differences in technology across BFs? skip slide
- $Var(\widehat{\varepsilon}_f * \widehat{a}_j)/WVAR = 43\%$
- How much do we lose by using standard technology measures vs. $\widehat{a}_j$? skip slide
- What establishment characteristics correlate with attributes of technology landscape predict $\widehat{a}_j$? skip slide
- What fraction of cross-establishemnt dispersion in productivity can be accounted for $\widehat{a}_j$? skip slide

Conclusions

- Study technology inside the establishment
- New data
  - Comprehensive direct measures of technologies used
  - Unit of observation is BF/establishment
- New questions and findings
  - Large differences in technology sophistication across the business functions of a establishment
  - The technology curve
- New models
- Estimate of technology curves and TECHFP
- Estimates justify the use of comprehensive measurement of technology at the BF level
- TechFP is strongly correlated with establishment productivity and accounts for 15% of cross-establishment variation

Appendix

Business functions and technologies

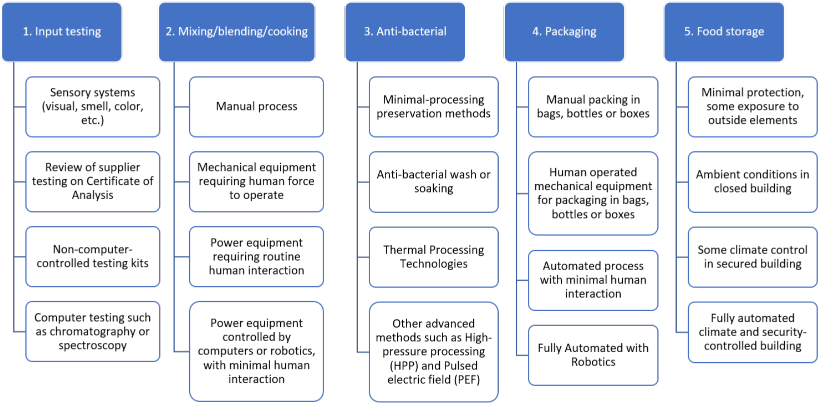


Figure 2: Sector Specific Business Functions and Technologies in Food Processing

back

Technology sophistication and establishment characteristics

VARIABLES	(1) $MOST_j$	(2) MAX_j
Medium	0.21***	0.35***
	(0.01)	(0.01)
Large	0.51***	0.80***
	(0.02)	(0.02)
Age 6 to 10	0.02	-0.02
	(0.01)	(0.02)
Age 11 to 15	0.05***	0.01
	(0.01)	(0.02)
Age 16+	0.04***	0.01
	(0.01)	(0.02)
Multi-establishment	0.14***	0.37***
	(0.01)	(0.02)
Foreign owned	0.18***	0.36***
	(0.02)	(0.03)
Exporter	0.20***	0.33***
	(0.01)	(0.02)
Observations	12,408	12,408
R-squared	0.45	0.41

back

Ex-post checks on bias and measurement error

1. Non-response bias
    - High average (unit) response rate of 49%
    - Reweight
    - No significant difference between establishments in response sample and in groups that proxy for non-response
2. Enumerator bias
    - Study significance of enumerators dummies on firm sophistication
3. Respondent bias
    - Parallel pilot in Kenya, where we re-question firms on the technologies used in a random set of business functions.
    - 73% of answers are the same in both interviews.
    - Compare reported values of firm characteristics and some technology data with other surveys and observe strong correlations with administrative data.

back

Distribution of Within-establishment Variance

Variable	Mean	SD	p10	p90
Wvar(MAX)	0.74	0.55	0.22	1.51
Wvar(MOST)	0.54	0.55	0.04	1.30

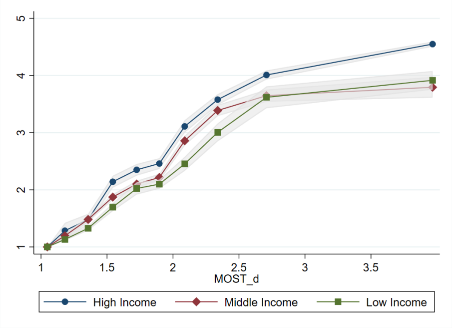
back

Correlates of WVAR across establishments

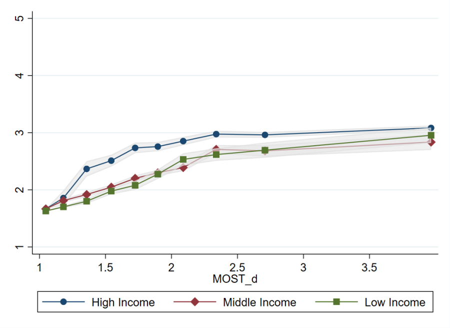
VARIABLES	(1) WVar(MAX)	(2) WVar(MOST)
S_j	1.31***	1.24***
	(0.03)	(0.03)
S_j^2	-0.18***	-0.15***
	(0.01)	(0.01)
Medium	0.01	-0.02***
	(0.01)	(0.01)
Large	0.10***	0.01
	(0.02)	(0.02)
Age 6 to 10	-0.03**	0.01
	(0.01)	(0.01)
Age 11 to 15	-0.05***	-0.01
	(0.01)	(0.01)
Age 16+	-0.04***	0.02**
	(0.01)	(0.01)
Multi-establishments	-0.02**	-0.03***
	(0.01)	(0.01)
Foreign owned	-0.02	-0.04**
	(0.02)	(0.02)
Exporters	-0.03**	-0.02*
	(0.01)	(0.01)
Number of BF	0.00	0.01***
	(0.00)	(0.00)
Country	1-digit FE	Yes
Yes		
Observations	12,169	12,172
R^2	0.33	0.49

back

Technology Curves across countries



(a) Business Administration



(b) Payment

back

Technology Curves across countries

$$\sum_f \sum_c \sum_d \omega_{f,c,d}(S_{f,c,d} - S_d)^2 =$$

$$\underbrace{\sum_f \sum_c \sum_d \omega_{f,c,d}(S_{f,c,d} - S_{f,d})^2}_{\text{Cross-country}} + \underbrace{\sum_f \sum_d \omega_{f,d}(S_{f,d} - S_d)^2}_{\text{Cross-function}}$$

- The cross-function component of the variance in the technology curve accounts for 89% of the variance.

back

Expression a_j

a_j is given by:

$$\sum_{f=1}^{N_f} \Omega_f e^{\varepsilon_f a_j} \left(\frac{C_{f,X} C_j \overline{\varepsilon}_j}{\Pi_j'(a_j)\sigma} \right)^{1-\sigma} \left(\frac{1-\sigma}{\sigma} \right)^{\sigma} = 1.$$

back

Estimation details

- $s_{f,j} = \frac{1}{2}\left(MAX_{f,j} + MOST_{f,j}\right)$
- $\bar{a}_j = s_j + \varrho * \sqrt{WVar_j}$, which is a first order approximation to a_j around the average level of sophistication in each business function.

back

Variation in slope of tech curves

- Is $Var(\widehat{\varepsilon}_f)$ due to non-homotheticities or to differences in technology across BFs?

1. Study heterogeneity in slope of technology curves across sectors, for functions that are relevant in multiple sectors (i.e., have same technologies in grid): Fabrication, GBFs
   - $Max(\widehat{\varepsilon}_f^{GBF}) - Min(\widehat{\varepsilon}_f^{GBF}) = 0.89$
   - Avg $MAX_s(\widehat{\varepsilon}_{f,s}^{GBF}) - Min_s(\widehat{\varepsilon}_{f,s}^{GBF})$ across functions $=$0.78.

2. Model with function-specific technical change (γ_f)
   - Heterogeneity in slope can be due to heterogeneity in γ_f.
   - Functions with higher γ_f have flatter technology curves
   - As $Var(\widetilde{\kappa}_j)$ tends to 0, variance in slopes is entirely driven by non-homotheticties.

back

TechFP and technology measures

	$\widehat{a}_j$					
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
$Computer_j$	0.94***					
s_j^{BA}		0.51***				
s_j^{PAY}			0.3***			
s_j				.98***		
$\sqrt{WVar_j}$				.17***		
MAX_j					0.42***	
$MOST_j$					0.65***	
s_j^{GBF}						.99***
s_j^{SSBF}						.03***
Observations	10,812	10,833	10,986	11,114	11,114	10,958
R^2	0.29	0.69	0.07	0.74	0.74	0.81

back

TechFP and establishment characteristics

VARIABLES	$\widehat{a}_j$
h_j	0.005***
Management	0.17***
Multi-establishment	0.29***
Multinational	0.21***
Exporter	0.25***
6 to 10 years	-0.01
11 to 15 years	0.01
16+ years	0.01*
Observations	10,320
R-squared	0.485
Country, sector FE	YES

back

Technology and productivity

	Value added per worker			
VARIABLES	(1)	(2)	(3)	(4)
k_j	0.304***	0.287***	0.286***	0.283***
h_j	0.005***	0.003**	0.003**	0.003**
$\widehat{a}_j$		0.306***		0.26***
$\widehat{a}_j * AGRI$			0.79***	
$\widehat{a}_j * MAN$			0.36***	
$\widehat{a}_j * SER$			0.27***	
Computer				0.011
Management				0.087***
Observations	6,8389	6,839	6,839	6,812
R^2	0.48	0.5	0.5	0.5

back