Capital Obsolescence and Agricultural Productivity

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Introduction

- Agricultural productivity growth is key to the development process.
- There are large differences in agricultural productivity across countries

...consider an economy with 1/2 the GDP p/worker of the US

  - *agricultural value added p/worker is 20 times lower than in the US.*
  - *agricultural TFP growth is 4 times lower than in the US.*

Main question

What is the role of capital embodied technology adoption for agricultural productivity?

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- Capital embodied technical change is a key determinant of the price of investment goods. (Solow (1959), Grilliches (1961), Hall (1968), ...)
- We focus on tractors.
  - Detailed equipment's price and characteristics data across high and middle-income countries.
  - Single cross-section, 2014.

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  - Detailed equipment's price and characteristics data across high and middle-income countries.
  - Single cross-section, 2014.

Challenge: Can we identify capital embodied technical change from cross-sectional equipment price data?

Identification

- Price of capital of quality q

$$p_{q,t} = \sum_{s=t}^{T} \phi^{s-t} (F(\textit{efficiency units}_{q,s}, .) \times \textit{return per efficiency unit})$$

Key assumption: quality and quantity are separable.

Gordon (1990), Hulten (1992), Greenwood, et. al. (1997), Cummins & Violante(2002), ...

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- Cross-sectional price profile

$$\ln\left(\frac{p_q}{p_{\bar{q}}}\right) \simeq \text{age}_q \times \ln\left(\frac{\text{depreciation}}{\text{technical change}}\right) + \text{constant}(\bar{q}, \phi)$$

where $\bar{q}$ is the best adopted quality.

This paper

- Novel dataset on second hand prices of agricultural equipment (tractors)
  - construct age-price profiles across 13 countries at different stages of development.
- Study the link between equipment price and quality composition of the capital stock
  - vintage capital growth model,
  - endogenous quality adoption.
- Quantitative exercise
  - identify the growth and level disparities in capital quality,
  - growth and income accounting exercises (1990-2012).

Main findings

1. Empirics:
   - age-price profiles are steeper in more productive countries.
   - the price of a 15 years old piece of equipment is
     - 60 cents on the dollar of a new one in the US.
     - 75 cents on the dollar of a new one in Brazil.
2. Quantitative implications:
   - adoption patterns ...
     - account for 1/4 of productivity growth, on average.
     - account for 1/3 of disparities in output per worker.

Overview

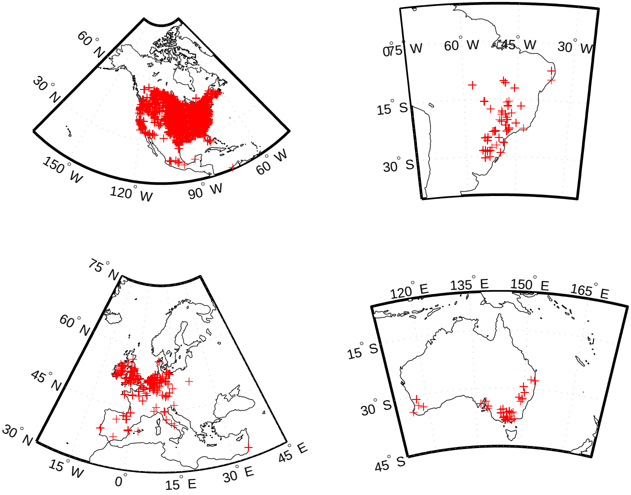
- Price of equipment: empirical evidence.
- Model: inferring quality from cross-sectional data.
- Growth and income accounting exercises.

- Tractor quotes gathered by a mayor publisher of retail and auction data.
- For each tractor sold we observe:
  - price
  - age, model, horsepower, use hours, and location.
- We matched data via geolocation with controls for
  - main crops produced within a 20-mile-wide grid around the sale location (EarthStat).
  - wages of repair workers (OWW by NBER).
- 13 countries at different stages of development:
  - agricultural value added per worker relative to US

    Brazil: 18% France: 77% Canada: 87%

Empirical evidence

Dataset



Age-price profiles

- Hedonic pricing with Box-Cox transform

$$\frac{p_{i,c}^{\theta_1} - 1}{\theta_1} = \gamma_c + \beta_{a,c} a_{i,c} + \frac{X_{i,c}^{\theta_2} - 1}{\theta_2} \beta + \epsilon_{i,c}$$

$p_{i,c}$: price of tractor i sold in county c

γ_c: country-specific intercept

$a_{i,c}$: years since tractor introduced

$X_{i,c}$: tractor's characteristics

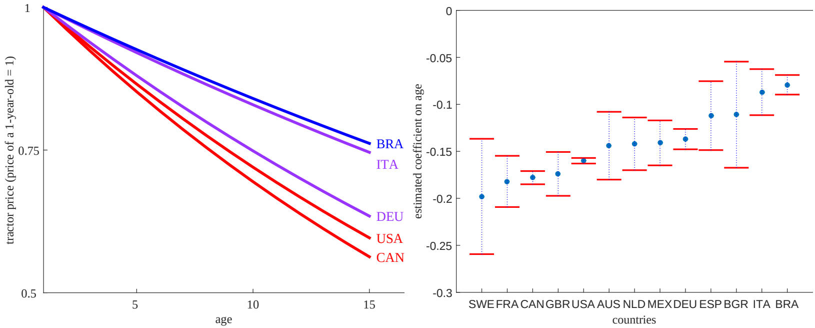
θ_1: shape parameter in pricing

θ_2: shape parameter associated to X

$\beta_{a,c}$ and β: characteristics coefficients

- Maximum likelihood estimation

Age-price profiles



(a) age-price profile

(b) estimated $\hat{\beta}_a$

normalized age-price profile,

$$\frac{\hat{p}_{a,c}}{\hat{p}_{1,c}} = \frac{\left(\hat{\gamma}_c + \hat{\theta}_1 \hat{\beta}_{a,c} a + \hat{\theta}_1 \frac{\bar{X}^{\hat{\theta}_2} - 1}{\hat{\theta}_2} \hat{\beta} + 1\right)^{\frac{1}{\hat{\theta}_1}}}{\hat{p}_{1,c}}$$

Additional controls

Elasticities

Prices

Basic set up

- Continuum of homogeneous farms.
- CRS technology in land, capital and labor.

$$y_t = (\sum_{j \in A_t} q_j k_{j,t})^{\alpha_k} l_t^{\alpha_l} n_t^{\alpha_n}.$$

- Continuum of households, consume and accumulate capital of different vintages.
- Available vintages in the world evolve at rate $\bar{\mu}$.

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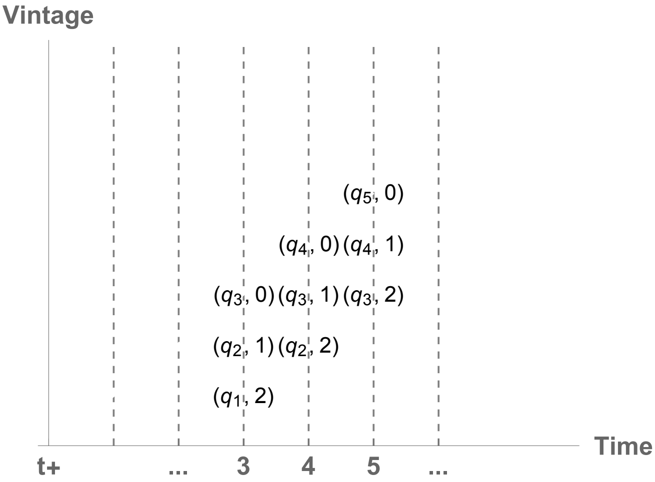
- Continuum of households, consume and accumulate capital of different vintages.
- Available vintages in the world evolve at rate $\bar{\mu}$.
- To adopt a new vintage there is a country specific cost,

$$C(q_j, q_{\bar{j}}, \mu) = \begin{cases} \frac{q_j}{q_{\bar{j}}} \left(\frac{1+\tau}{1+\bar{\mu}} \right) & \text{if } q_j > q_{\bar{j}}, \\ 1 & \text{otherwise.} \end{cases}$$

- Households rent capital to farms in spot markets.

Prices of new and old equipment

Vintage j: (q_j, a_j), a is age



Prices of durables

- The price of a tractor of quality q_j

$$p_{j,t}(0) = \frac{q_j}{q_{\bar{j}_t}} \frac{\hat{\Gamma}_t}{1 - \hat{\psi}}$$

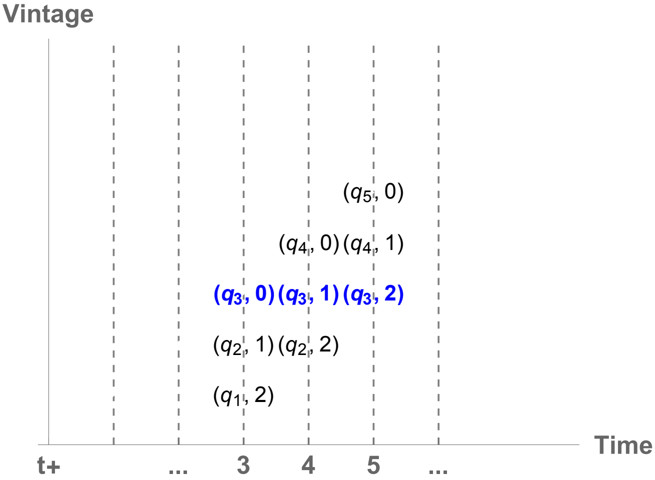
  - Return p/ efficiency unit $\simeq \hat{\Gamma}_t = \alpha_k \frac{y_t}{\widehat{q}\widehat{\delta k}}$
  - Discounting $\hat{\psi} = \omega(\frac{1}{1+\mu})^{1-\alpha_k}$
    where μ is endogenous quality growth.

- Key assumptions:
  - perfect substitutability.
  - separable quality and quantity.

Solow (1959), Lucas (1986), Gordon(1990), Hulten (1992), Greenwood, et.al. (1997).

Prices of new and old equipment

Longitudinal age-price profiles



Prices of new and old equipment

- The price of a new tractor at time t of quality q_j

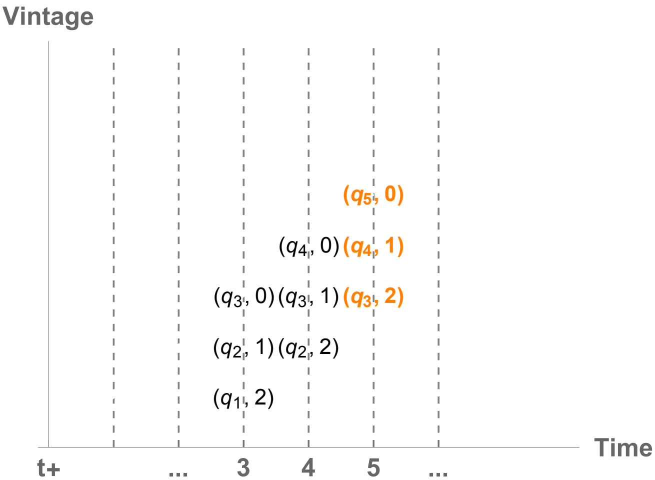
$$p_{j,t}(0) = \frac{q_j}{q_{\bar{j}_t}} \frac{\hat{\Gamma}_t}{1-\hat{\psi}}$$

- The price of the same tractor a years later

$$\ln(p_{\bar{j}_t,t+a}(a)) = age \ln\Big(\underbrace{\frac{(1-\delta)}{(1+\mu)^{1-\alpha_k}}}_{\text{inv. spec. tech. change}} \Big) + \ln(p_{\bar{j}_t,t}(0))$$

Prices of new and old equipment

Cross-sectional age-price profiles



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$$\ln(p_{\bar{j}_t,t+a}(a)) = age \ln\left(\frac{(1-\delta)}{(1+\mu)^{1-\alpha_k}}\right) + \ln(p_{\bar{j}_t,t}(0))$$

- Age-price profiles in a cross-section (+ BGP)

$$ln(p_{\bar{j}_{t-a},t}(a)) = age \ln\left(\frac{(1-\delta)}{(1+\mu)}\right) + \ln(p_{\bar{j}_t,t}(0))$$

Identification

Main relationship for identification

$$\ln p_c \ (age) = age \ \ln\left(\frac{1-\delta_c}{1+\mu_c}\right) + \ln\left(\frac{\Gamma_c}{1-\psi_c}\right)$$

for: $\psi_c = \frac{\omega}{(1+\mu_c)^{1-\alpha_k}} < 1$, and $\Gamma_c \simeq \alpha_{k_c} \frac{y(q_{\bar{j}_t,c})}{(\widehat{q}_c \widehat{\delta}\ \widetilde{k}_c)}$

- Country-specific path of capital quality: μ and $q_{\bar{j}_t}$

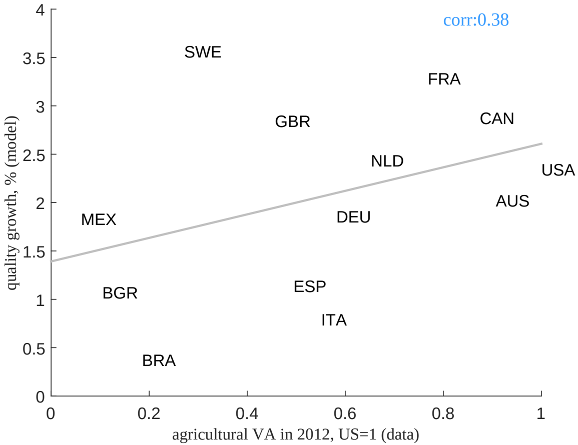
Identification: adoption rate

$$\ln p_{c,i}(age) = age_i \ln\left(\frac{1-\delta_c}{1+\mu_c}\right) + \ln\left(\frac{\Gamma_c}{1-\psi_c}\right) + \gamma\frac{X_i^{\theta}-1}{\theta_2} + \epsilon_i$$

for: $\psi_c = \frac{\omega}{(1+\mu_c)^{1-\alpha_k}} < 1$, and $\Gamma_c \simeq \alpha_{k_c}\frac{y(q_{\bar{j}_t,c})}{(\widehat{q}_c\widehat{\delta}\,\widetilde{k}_c)}$

- Country-specific path of capital quality: μ and $q_{\bar{j}_t}$
- Identify μ given δ_c
    - measure δ_c from the price decay of a synthetic piece of equipment with hours of usage

Inferred quality improvement, μ



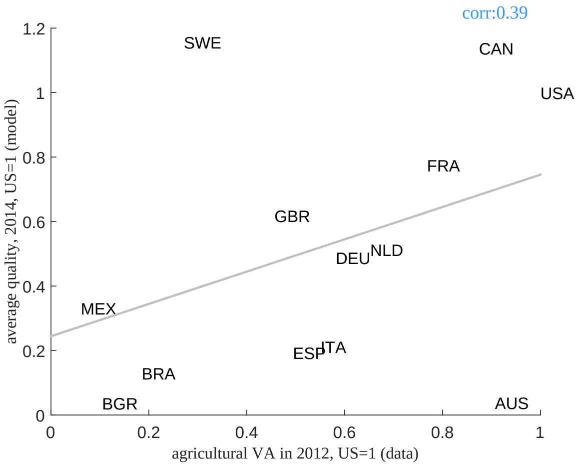
Identification: average quality

$$\ln p_{c,i}(age) = age_i \ln\left(\frac{1-\delta_c}{1+\mu_c}\right) + \ln\left(\frac{\Gamma_c}{1-\psi_c}\right) + \gamma\frac{X_i^{\theta}-1}{\theta_2} + \epsilon_i$$

for: $\psi_c = \frac{\omega}{(1+\mu_c)^{1-\alpha_k}} < 1$, and $\Gamma_c \simeq \alpha_{k_c}\frac{y(q_{\bar{j}_t,c})}{(\widehat{q}_c\widehat{\delta}\,\widetilde{k}_c)}$

- Country-specific path of capital quality: μ and $q_{\bar{j}_t}$
- Identify the top quality $q_{\bar{j}_t}$ given USDA-ERS data for
  - factor shares, α_k, α_l and α_n
  - endowments of land per worker $\widetilde{l}$

Inferred average quality, $q_{\bar{j}_t} \times \hat{q}$



DTL

Model predictions and the data

- Quality improvement as inferred from the equipment price time series (Krusell et.al. (2000)) for the US,

$$\frac{\Delta(\frac{p_{con}}{p_{inv}})}{1-\alpha_k} \simeq 1.2\%, \quad \text{if tractors only } \simeq 2.5\%$$

$$\mu = 2.3\%$$

- Data and model-predicted steady state capital stocks,

$$\rho(k_{data}, k_{model}) = 0.58$$

Stocks

R&D

Accounting exercises

Accounting exercises

What is the role of capital embodied technology adoption for agricultural productivity?

1. Growth accounting exercise
    - cross-country disparities in productivity growth between 1990 and 2012.
    - *on average, capital quality explains 26% of productivity growth*.

details

2. Development accounting exercise
    - cross-country disparities in value added per worker in 2012
    - *capital quality explains 38% of differences in agricultural income per worker*.

details

Conclusion

- We use a cross-section of second-hand prices to identify adoption patterns of capital-embodied technology.

- Age-price profiles are steeper in richer countries.

- Disparities in quality adoption patterns are quantitatively relevant for the path of agricultural productivity.

Conclusion

- We use a cross-section of second-hand prices to identify adoption patterns of capital-embodied technology.

  The same methodology can be applied to other capital goods for which catalog data is available.

- Age-price profiles are steeper in richer countries.

  Characteristics of second hand markets?

- Disparities in quality adoption patterns are quantitatively relevant for the path of agricultural productivity.

  Feedbacks between human capital and capital embodied technology adoption?

Growth accounting

- Growth in TFP:

$$g_{\text{TFP},c} = \alpha_{k,c} g_{q,c} + g_{Res,c}$$

- Fraction of g_{TFP} explained by capital quality

$$\frac{\alpha_{k,c}\mu_{q,c}}{g_{\text{TFP},c}}$$

- Capital quality explains 26% of productivity growth
- Larger role in richer, more capital intensive, countries.
  - 1/3 in US, Canada and France
  - 1/10 in Brazil

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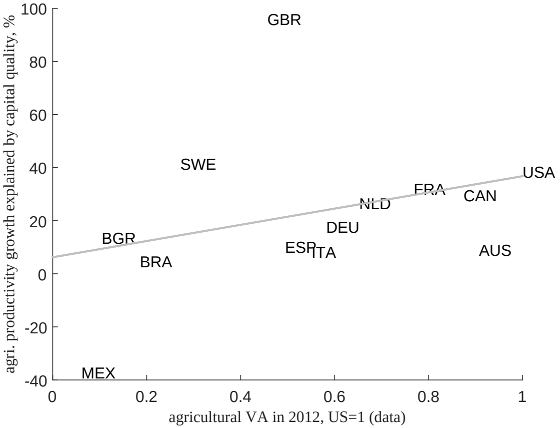
Quality improvement, % of TFP growth



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Development accounting

- How much of the cross-country agricultural income differences are accounted for by ...?

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Development accounting

- How much of the cross-country agricultural income differences are accounted for by ...?
  - Model:

$$S^2(\widetilde{y}_{2012}, \widetilde{y}^d_{2012}) = 87\%$$

$$S^2 = 1 - \frac{(\mathbf{x} - \hat{\mathbf{x}})'(\mathbf{x} - \hat{\mathbf{x}})}{\mathbf{x}'\mathbf{x}}$$

Back

Development accounting

- How much of the cross-country agricultural income differences are accounted for by ...?
  - Model:

$$S^2(\widetilde{y}_{2012}, \widetilde{y}^d_{2012}) = 87\%$$

  - Average capital quality:

$$S^2(\widetilde{y}_{2012}, \widetilde{y}^d_{2012}) - S^2(\widetilde{y}_{2012} | q_{\bar{j}} \widehat{q} = 1), \widetilde{y}^d_{2012}) = 38\%.$$

$$S^2 = 1 - \frac{(\mathbf{x} - \hat{\mathbf{x}})' (\mathbf{x} - \hat{\mathbf{x}})}{\mathbf{x}' \mathbf{x}}$$

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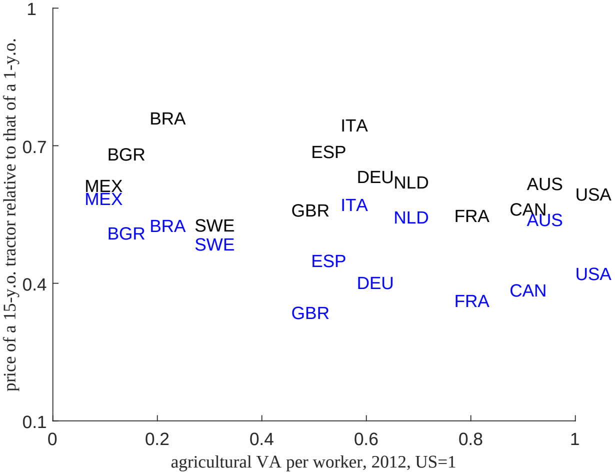
Age-price profiles

Controls for observable characteristics



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Quality level, R&D measures

- Measure of quality: R&D content in imports and local production.

$$\rho(q_{\bar{j}}\hat{q}, q_{R\&D}) = 0.52$$

- Both measures generate analogous ranking of countries by quality.
- Disparities is quality are larger under our benchmark measure.

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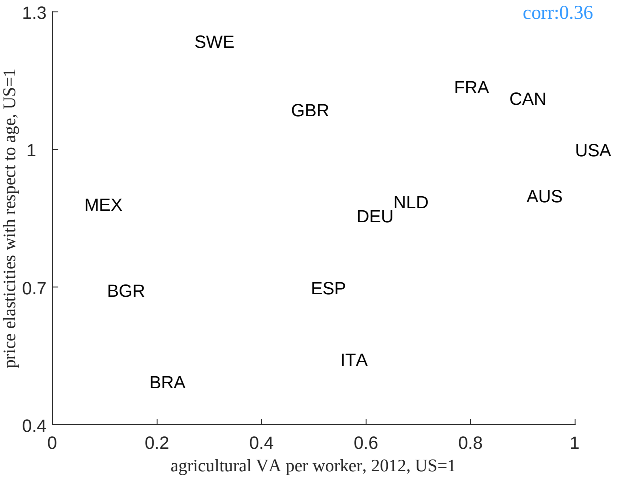
Age-price profiles

Price age elasticity across countries



Relative price, with (black) and without (blue) controls for characteristics

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Notation and basic set up

- CRS technology

$$y_t = (\sum_{j \in A_t} q_j k_{j,t})^{\alpha_k} \overbrace{l_t^{\alpha_l}}^{land} \overbrace{n_t^{\alpha_n}}^{labor}$$

  - $A_t = \left[\underline{j}_t, \bar{j}_t\right]$: set of vintages currently used in production.
  - Capital services for the stock of vintage j at time t.

$$q_j k_{j,t}$$

    - $k_{j,t}$ units of capital of vintage j at time t.
    - q_j quality/efficiency of vintage j.
    - Depreciation rate δ.
    - Vintage retirement rate λ.

  - Costly adoption, $C(\frac{q_j}{q_{\bar{j},t}}, \tau)$ country specific cost τ.

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Along the BGP

- Effective adoption rate in each country is

$$\mu(\tau) = \frac{1+\overline{\mu}}{1+\tau}$$

where $\overline{\mu}$ is the frontier rate.

- Capital services in terms of the best technology adoption $q_{\bar{j}_t}$

$$\sum_{j \in A_t} q_j k_{j,t} = \underbrace{q_{\bar{j}_t} \widehat{\delta}(\delta, \lambda) k}_{\text{Services } \bar{j}_t} \qquad \overbrace{\widehat{q}}^{\text{stock composition}}$$

where $\widehat{\delta}(\delta, \lambda)$ is the effective retirement rate.

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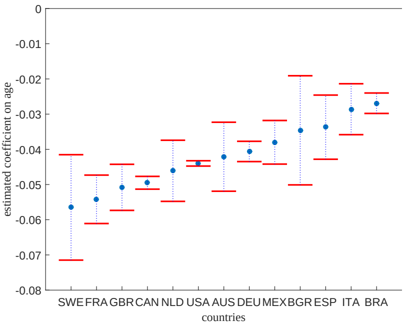
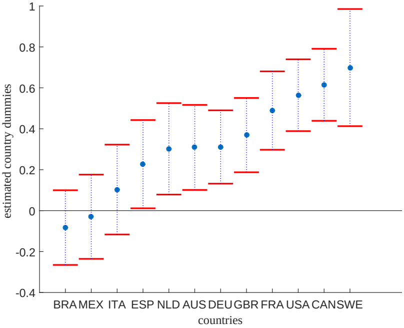
Quantitative exercise

Estimated age-price profiles



Coefficients on age



Country-specific intercepts

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Main relationship for identification

Table: Inferred physical depreciation

	Physical depreciation: δ
AUS	2.35%
BGR	2.62%
BRA	2.59%
CAN	2.20%
ESP	2.40%
FRA	2.31%
GBR	2.40%
DEU	2.40%
ITA	2.28%
MEX	2.48%
NLD	2.32%
SWE	2.26%
USA	2.18%

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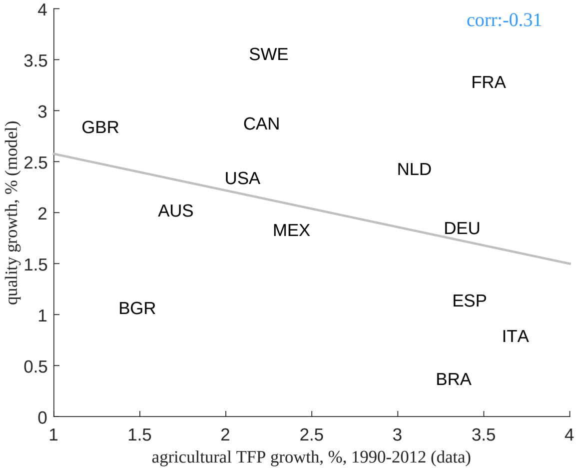
Inferred quality improvement



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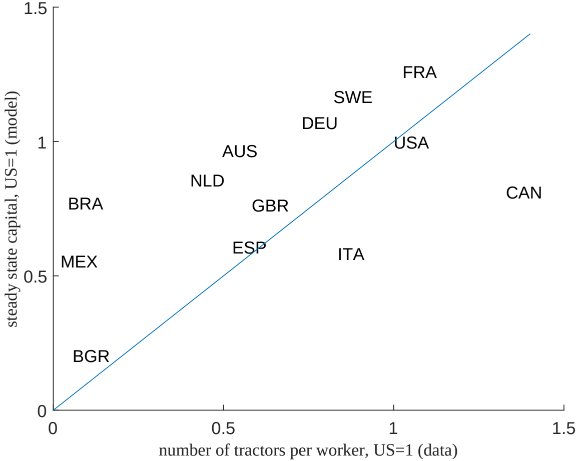
Model predictions and the data

Capital stock



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Quantitative exercise

Production shares

	α_n	α_l	α_k
AUS	18%	68%	14%
BGR	31%	56%	14%
BRA	57%	26%	17%
CAN	72%	4%	24%
ESP	70%	15%	15%
FRA	61%	15%	24%
GBR	32%	31%	37%
DEU	61%	15%	24%
ITA	70%	15%	15%
MEX	24%	42%	34%
NLD	61%	15%	24%
SWE	61%	15%	24%
USA	38%	37%	25%

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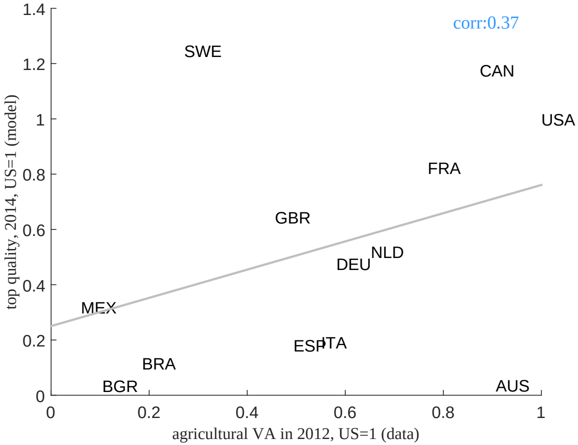
Inferred top quality



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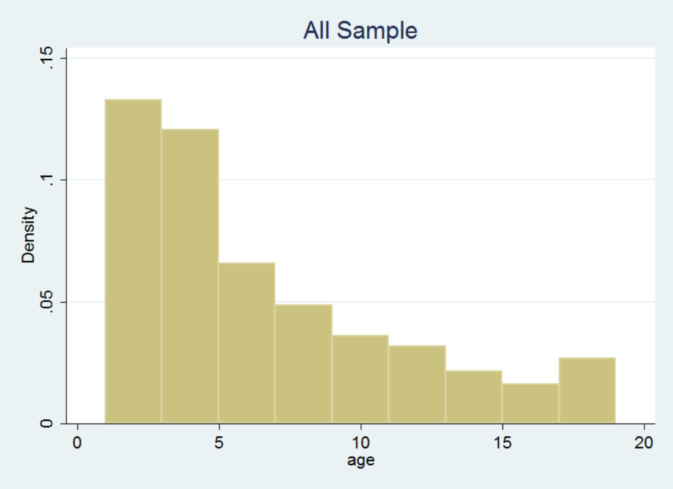
Age distribution



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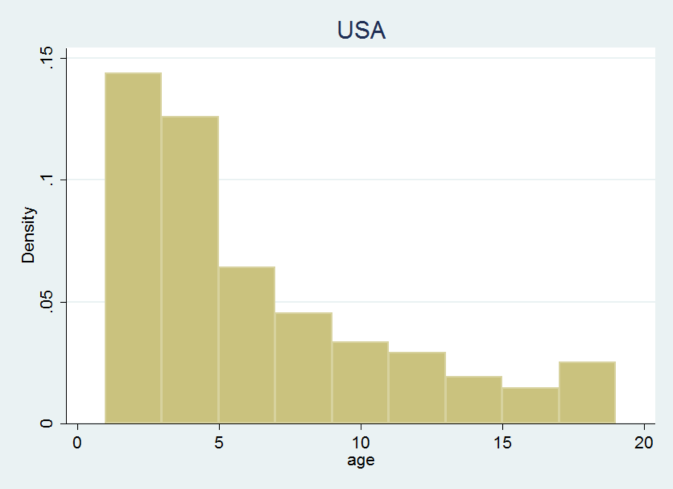

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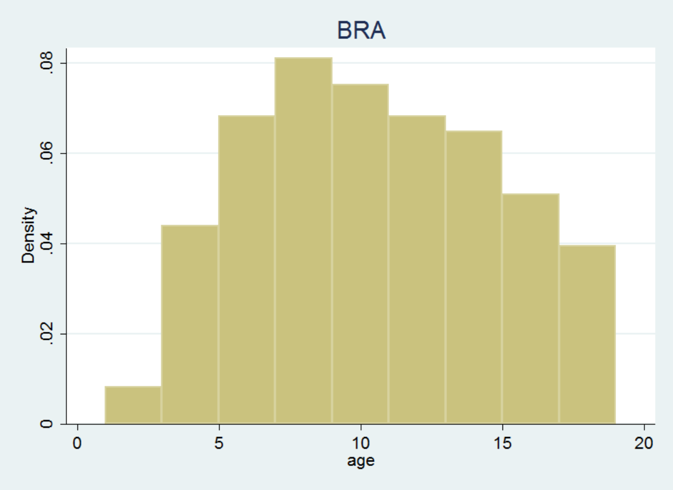

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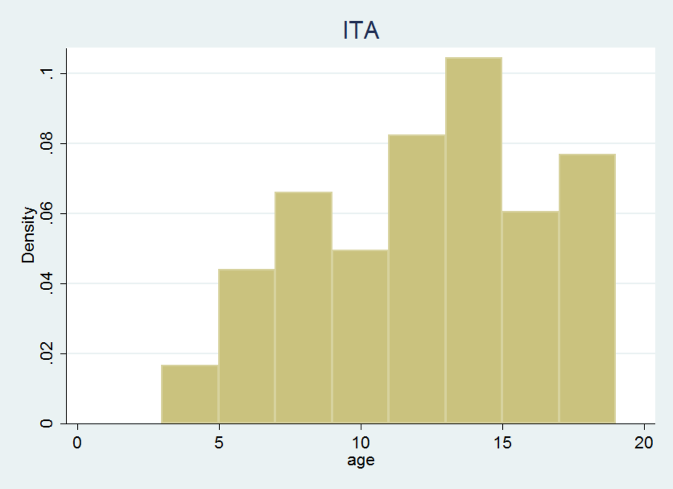

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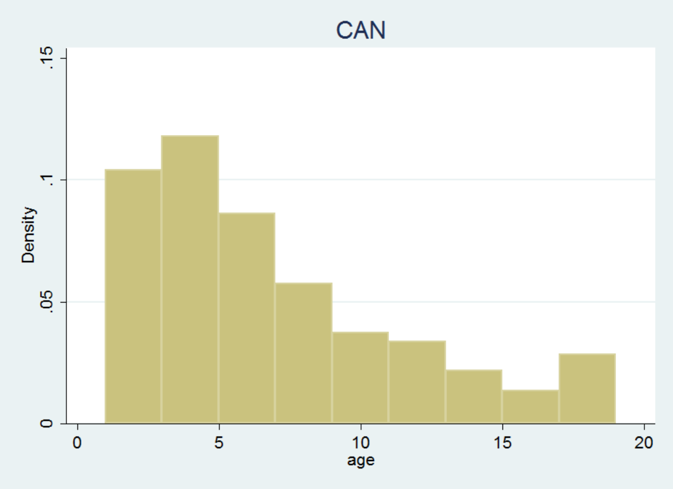

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