Business Cycles during Structural Change: Arthur Lewis' Theory from a Neoclassical Perspective

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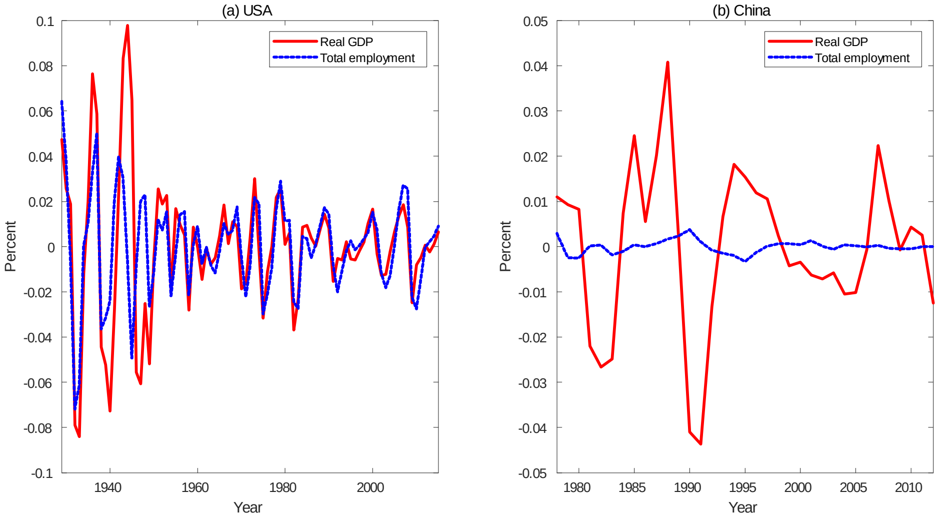
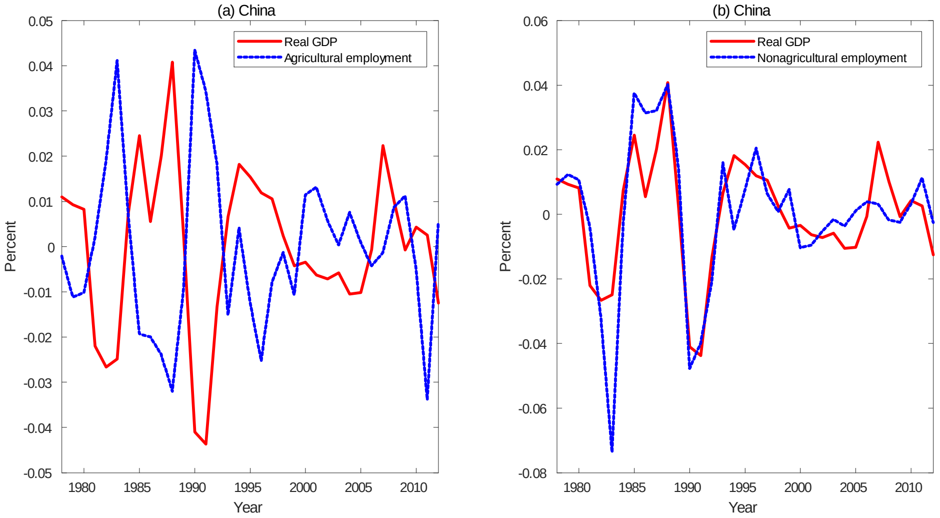
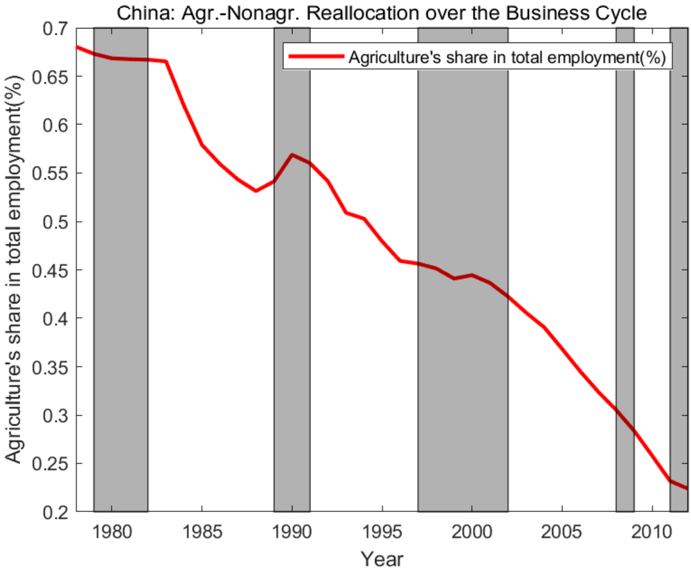
US (left) &China (right): GDP vs. Total Employment



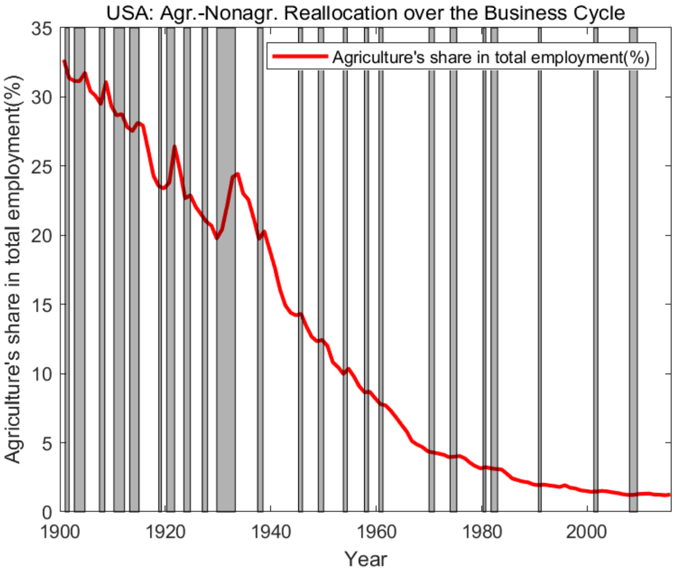
China: GDP vs. Agric. empl & Non-Agric. empl



China: Agr-NonAgr Reallocation over the Business Cycle



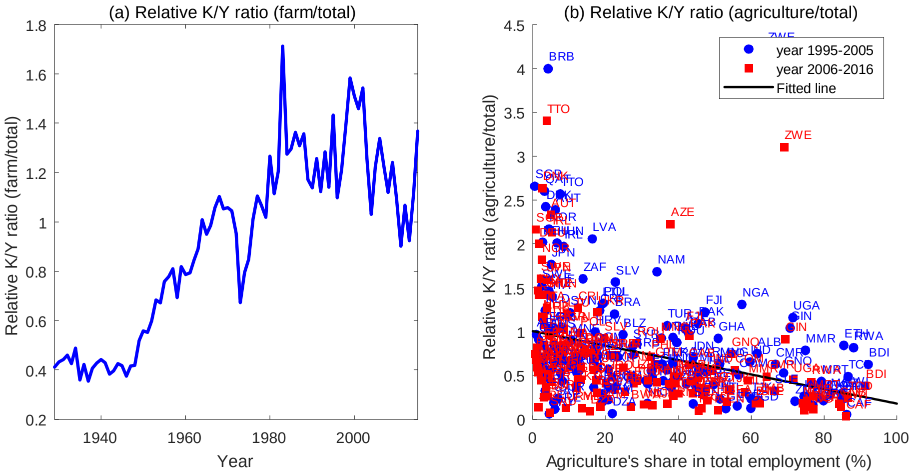
US: Agr-NonAgr Reallocation over the Business Cycle



Purpose of the Paper

- Unified theory of business cycles and structural transformation
- Structural transformation:
  1. Reallocation of labor away of Agr as capital accumulates
  2. Modernization of Agr: As workers leave Agr,
     labor productivity gap NonAgr-vs-Agr $\downarrow$ and labor share in Agr $\downarrow$
- Business cycles change during structural change. Poor countries have:
  1. Acyclical and smooth labor supply
  2. Strong labor reallocation between Agr and NonAgr
  3. Labor productivity in Agr $\uparrow$ in booms (also relative to NonAgr)
- Goals:
  1. Propose a theory quantitatively consistent with both structural transformation and business cycles
  2. Match China-US (and cross-country) patterns
  3. Novel framework to analyze fluctuations during transition

Modernization of Agriculture: KY ratio

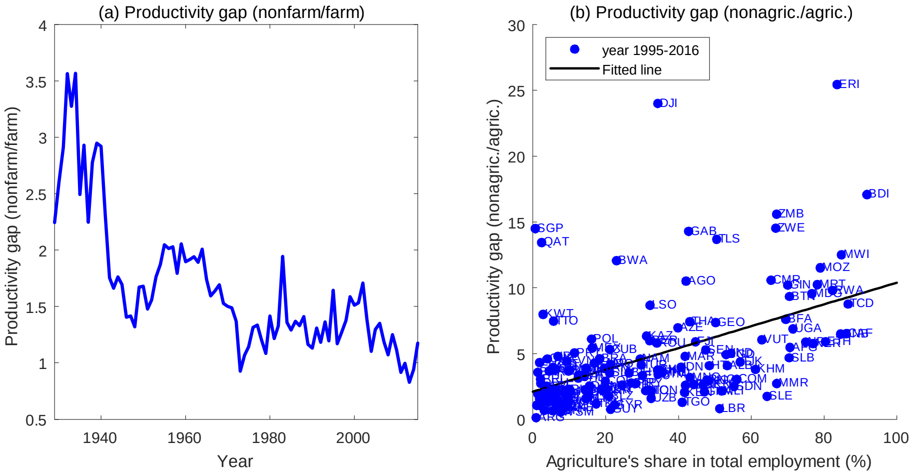


Labor Productivity Gap

- Define Productivity Gap as the ratio of the Average Productivity of Labor (APL) in NonAgr vs. Agr

$$\text{Prod. Gap} \equiv \frac{\text{Value Added per Worker in NonAgr}}{\text{Value Added per Worker in Agr}}$$

Modernization of Agric.: Productivity Gap



Business Cycle Over Structural Change

- Modernization is accompanied by transformations in the nature of business cycle fluctuations.
- Consider HP Filtered or First-Differenced data:

	Large Agriculture (poor country)	Small Agriculture (rich country)
Employment-GDP correlation	acyclical	procyclical
corr(agr. empl.,nonagr empl.)	negative	≈ 0
Labor productivity gap	countercyclical	acyclical

- US time-series and US-China contrasting evidence in line will cross-country evidence.

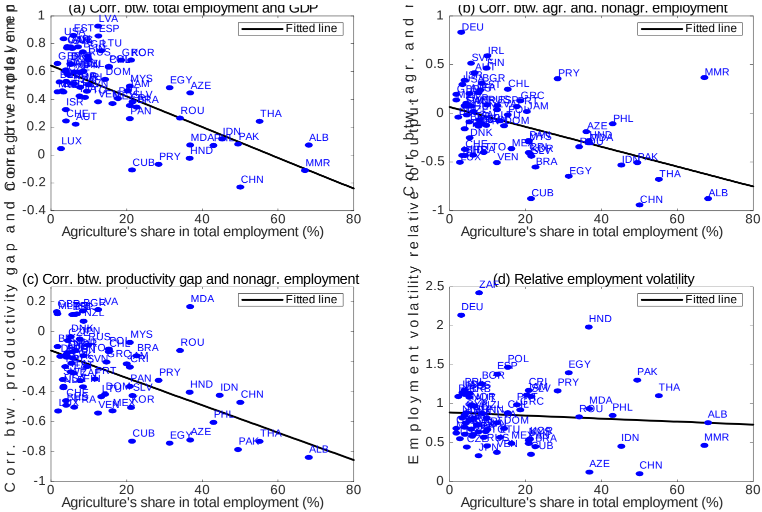


Figure: X-axis: avg. agr. empl. share. Y-axis: (a) corr. empl.-GDP; (b) corr. nonag-ag employment; (c) cyclicality APL ratio; (d) rel. empl. volatility.

DO WE NEED A NEW THEORY?

Theory: Why Hansen-Prescott Does Not Work

- Consider a two-sector neoclassical benchmark
  - cf. Hansen and Prescott (2002)
- Cobb-Douglas production function in each sector

$$Y^M = Z^M \times \left(K^M\right)^{1-\alpha} \left(L^M\right)^{\alpha} \text{ and } Y^G = Z^G \times \left(K^G\right)^{1-\beta} \left(L^G\right)^{\beta}$$

which implies constant factor shares:

$$\frac{wL^M}{P^M Y^M} = \alpha \text{ and } \frac{wL^G}{P^G Y^G} = \beta$$

- So, the productivity gap is

$$\frac{P^M Y^M}{L^M} / \frac{P^G Y^G}{L^G} = \frac{\beta}{\alpha}$$

- Counterfactual!

Our Model: Traditional vs. Modern Agr Sector

- Introduce business cycles in a transition model *à la* Acemoglu-Guerreri (2008) with Agr and NonAgr sector.
- Structural transformation is driven by two forces:
  - exogenous differential technical progress,
  - endogenous capital deepening.
- Extend Acemoglu-Guerreri to incorporate a "rural Lewis sector."
- Agr goods are produced using two different technologies
  1. Modern (neoclassical) sector using labor, capital, and land;
  2. Traditional sector with no capital.

Literature

- Structural Changes
  - Baumol (1967), Kongsamut, Rebelo and Xie (2001), Ngai and Pissarides (2007; 2008), Acemoglu and Guerrieri (2008)
  - Alvarez-Cuadrado and Poschke (2011), Herrendorf, Rogerson and Valentinyi (2013, 2015), Alvarez-Cuadrado et al (2017)
- Business Cycle
  - Cross-country: Rogerson (1991), Da-Rocha and Restuccia (2006), Aguiar and Gopinath (2007)
  - Zhang, Rozelle, and Huang (2001), Brandt and Zhu (2000; 2001), Yao and Zhu (2017)
- Development
  - Lewis (1954); Harris and Todaro (1970); Hansen-Prescott (2002); Parente, Rogerson, and Wright (2000); Gollin, Lagakos, and Waugh (2014)

THE MODEL

Production: Final Good

- The final good is produced competitively
- It combines Agr and NonAgr goods, with elast. of subst. ε

$$Y = F\left(Y^G, Y^M\right) = \left[\gamma\left(Y^G\right)^{\frac{\varepsilon-1}{\varepsilon}} + (1-\gamma)\left(Y^M\right)^{\frac{\varepsilon-1}{\varepsilon}}\right]^{\frac{\varepsilon}{\varepsilon-1}}.$$

- Can be interpreted as a preference aggregator.
- Extension: nonhomothetic (Stone Geary) preferences:
  - Agr good as "necessity" in consumption.
- Study both $\varepsilon > 1$ and $\varepsilon < 1$
  - (although estimation suggests $\varepsilon > 1$)

Production: NonAgr and Agr Sector

- Production Function in NonAgr sector:

$$Y^M = \left(K^M\right)^{1-\alpha} \left(Z^M N^M\right)^{\alpha}$$

- Agr is produced in two ways: modern (AM) and traditional (S) technology with an elasticity of substitution $\omega > 1$:

$$Y^G = \left[\left(Y^{AM}\right)^{\frac{\omega-1}{\omega}} + \left(Y^S\right)^{\frac{\omega-1}{\omega}}\right]^{\frac{\omega}{\omega-1}},$$

where

$$\begin{aligned} Y^{AM} &= \left(K^{AM}\right)^{1-\beta} \left(Z^{AM} N^{AM}\right)^{\beta}, \\ Y^S &= Z^S N^S. \end{aligned}$$

  - Assume $\beta > \alpha$ (M more capital intensive than AM)
  - Later (estimation): allow land in agriculture

TFP Growth and Urban-Rural Wedge

- TFP grows at a constant rate in each sector
- Only one friction:
  - an exogenous time-invariant wedge (a "tax" on nonagr employment) that keeps marginal productivity higher in urban than in rural sector;
  - stand-in for a variety of institutional frictions inducing rural overpopulation;
  - does not matter for the theory, matters for quantitative results.

Social Planner's Problem

- The Recursive Competitive Equilibrium is equivalent to the solution to the following distorted social planner's problem

$$\max_{K^M, K^{AM}, N^M, N^{AM}, N^S, c} \int_0^\infty e^{-(\rho - n)t} \times \log\left(c_t\right) \, dt$$

subject to the resource constraints

$$\begin{aligned}
\dot{K}_t &= F\left(Y_t^M, Y_t^G\right) - \delta K_t - cN_t - \tau \bar{W}_t N_t^M + Tr_t, \\
K_t &= K_t^M + K_t^{AM}, \\
N_t &= N_t^M + N_t^{AM} + N_t^S,
\end{aligned}$$

given exogenous law of motions for TFPs, and initial conditions.

- We later augment it with endogenous labor supply and shocks.

Static Equilibrium

- Static efficiency: equate MPL and MPK across sectors.
- Let:

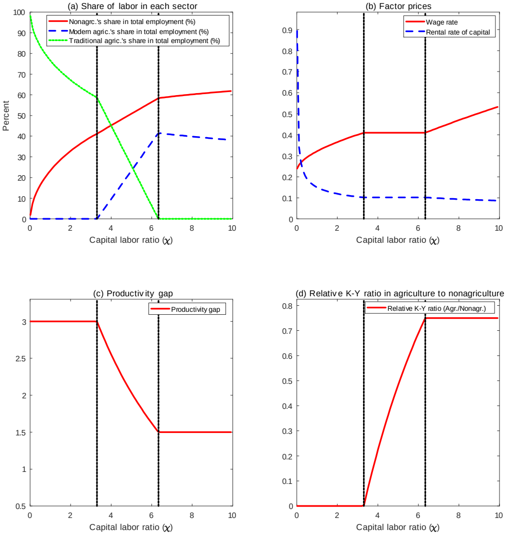
$$\chi \equiv \frac{K}{L} \text{ (endogenous state variable)}$$
$$\kappa \equiv K^M / K \text{ (share of capital in Nonagr)}$$
$$\upsilon \equiv \frac{\left(Y^{AM}\right)^{\frac{\omega-1}{\omega}}}{\left(Y^{AM}\right)^{\frac{\omega-1}{\omega}} + \left(Y^S\right)^{\frac{\omega-1}{\omega}}} \text{ (Agr modernization).}$$

- $\kappa(\chi, \mathbf{Z})$ and $\upsilon(\chi, \mathbf{Z})$ are sufficient for characterization
  - pin down employment in the three sectors.
- RESULT: for ω *close* to $\varepsilon > 1$: $\partial\kappa/\partial\chi > 0$ and $\partial\upsilon/\partial\chi > 0$

Static Equilibrium (Lewis)

- Monotone dynamics is not a robust feature.
- Consider a "Lewis model" ($\omega \to \infty$ and $\varepsilon > 1$) driven by capital accumulation.
- Three stages of economic growth:
  1. Early Lewis: no modern agriculture ($\upsilon = 0, \kappa = 1$);
  2. Advanced Lewis: modernization of agriculture ($\upsilon \uparrow, \kappa \downarrow, N^S \downarrow$).
  3. Neoclassical: demise of agriculture ($\kappa \uparrow$ and $\kappa \to 1$) and further modernization of agriculture ($\upsilon \to 1$).

Static Equilibrium (Lewis)



Asymptotic Balanced Growth Path (ABGP)

- Sufficient conditions: suppose $\omega > 1$ and

$$\varepsilon > 1, \qquad g^M \geq g^{AM} \geq g^S.$$

[or, alternatively, $\varepsilon < 1$ and $g^{AM} \geq g^M \geq g^S$]

- ... then the dynamic equilibrium converges to unique ABGP where

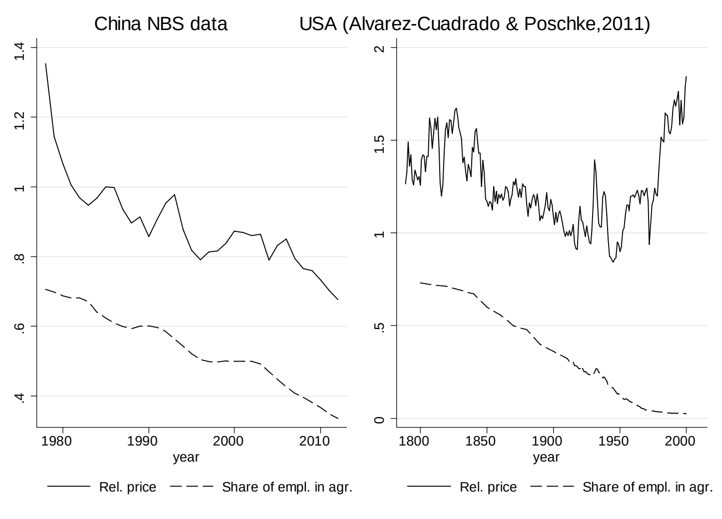
$$\begin{aligned} \kappa_t &\to 1, \qquad \upsilon \to 1, \\ \frac{\dot{c}_t}{c_t} &\to g^M, \qquad \frac{\dot{\chi}_t}{\chi_t} \to g^M. \end{aligned}$$

- Note: labor and capital accumulation in agriculture can be positive in the ABGP, but it goes to zero as a share of total GDP.

Elasticity of Substitution btw. Agr/Nonagr Goods

- What should we believe about elasticities ω and ε?
- $\omega > 1$ seems plausible (in Lewis, $\omega \rightarrow \infty$).
- What about ε ?
  - Herrendorf et al. (2013), Comin et al. (2018), etc. argue $\varepsilon < 1$
  - Foster and Rosenzweig (2004), Moscona (2018) argue $\varepsilon > 1$

Relative price (non-agr./agr.) vs. agricultural employment share: CHINA vs. USA



QUANTITATIVE ANALYSIS

Quantitative Model

- Discrete time.
- Persistent shocks to the three TFPs.
- Endogenous labor supply (pref. for leisure).
- Land in (modern) agriculture.
- First estimate the deterministic model to match structural change.
- Then, estimate stochastic processes for TFPs.
- Finally, simulate the stochastic model
  and compare business cycle statistics.

Model Estimation: SMM (for China)

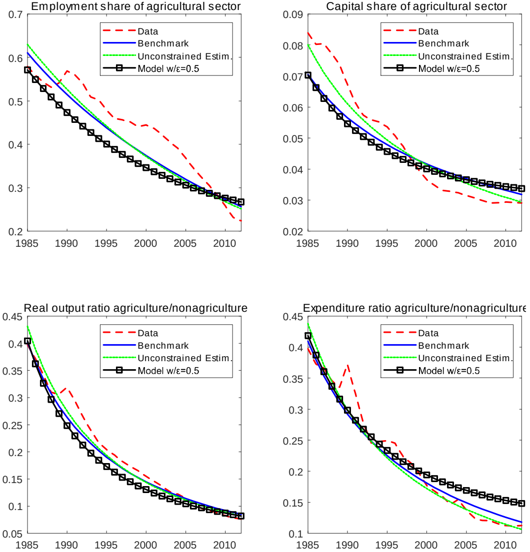
- 8 parameters are calibrated outside the model
  - $n = 1.4\%, \delta = 5\%, (1+\rho)^{-1} = 0.96, \alpha = 0.50, Y_{1985} = 1, \tau = 0.64, \theta = 0.76, g_M = 6.4\%$
- 10 parameters are estimated by SMM to match 19 moments (China 1985-2012):
  - (i) the share of agricultural employment in total employment;
  - (ii) the share of capital in agriculture relative to the total capital stock;
  - (iii) the ratio of real output in agriculture to total GDP;
  - (iv) the relative value added share of agriculture, evaluated at current prices (i.e., the expenditure share of agricultural goods);
  - (v) the capital/output ratio;
  - (vi) theproductivity gap between agriculture and nonagriculture (adjusted for rural-urban wage differences).

Estimated Parameters (SMM)

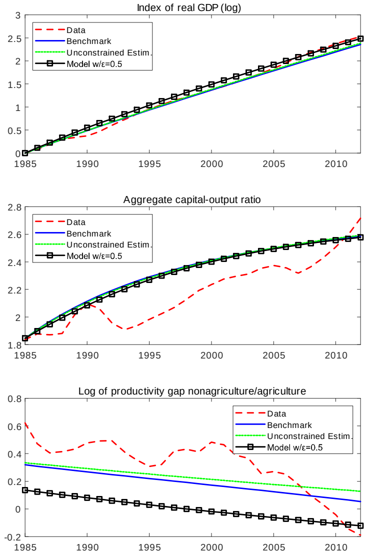
	Estimated Parameters	Benchmark $\varepsilon \le \omega$	Robustness Unconstrained Estim.	$\varepsilon = 0.5$
$\bar{c}$	Subsist. level in food cons.	–	–	0.133
ε	ES btw agric. and nonagric. cons.	4.07	6.70	0.50
ω	ES btw modern and trad. agr.	4.07	1.40	1.28
γ	weight on agric. goods	0.52	0.58	0.0018
$1-\beta-\beta_T$	capital's income share in modern agr.	0.21	0.21	0.18
β	labor's income share in modern-agric.	0.17	0.35	0.16
$\frac{g^G}{\beta+\beta_T}$	TFP growth rate in total agric.	6.0%	6.2%	5.7%
g^S	TFP growth rate in trad. sector	4.7%	1.3%	0.5%
Z^S_{1985}	initial TFP level in trad. agr.	1.74	1.97	0.39
Z^{AM}_{1985}	initial TFP level in modern-agr.	0.92	1.29	0.38
Z^M_{1985}	initial TFP level in nonagr.	2.62	2.84	1.39
	J-statistic	0.808	0.491	1.008

Table: Estimated parameters.

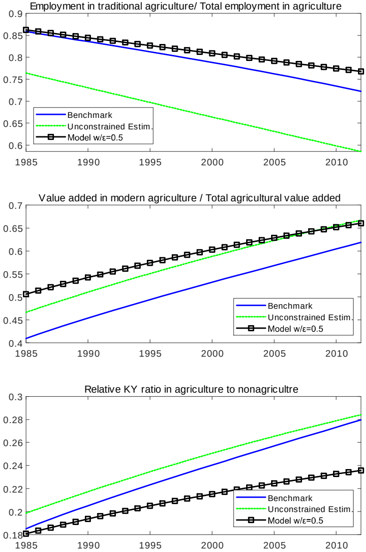
Model Fit 1: Decline of Agricultural Sector



Model Fit 2: GDP growth, Prod. Gap, K/Y Ratio



Trajectories: Traditional Agr Share in Agr



QUANTITATIVE ANALYSIS: BUSINESS CYCLE DURING STRUCTURAL CHANGE

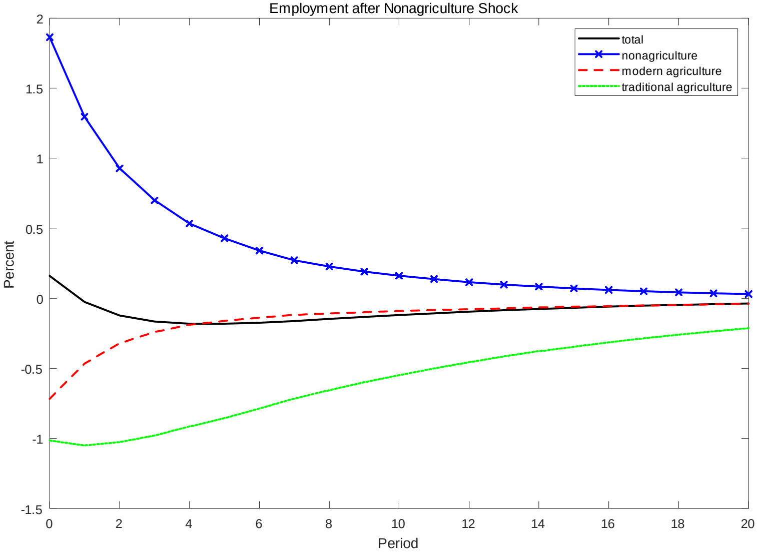
Estimate joint TFP process

- Observed sectoral TFP sequence $\tilde{z}_t^j = \log\left(Z_t^j\right) - \log\left(Z_t^j\right)$ where $\bar{Z}_t^j$ is the deterministic trend for $j \in \{M, AM, S\}$
- $\tilde{z}_t^j$ consists of two parts: the true TFP level z_t^j and an i.i.d. measurement error ζ_t^j
- z_t^j follows an autoregressive VAR(1) process, $z_t^j = \phi^j z_{t-1}^j + \epsilon_t^j$

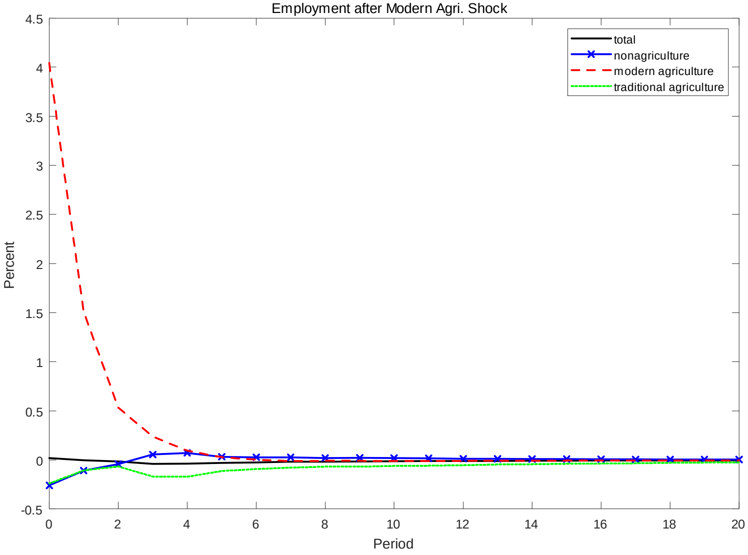
$j =$	ϕ^j	$\sigma\left(\varepsilon_t^j\right)$	$\sigma\left(\zeta_t^j\right)$	$corr\left(\varepsilon_t^j, \varepsilon_t^M\right)$	$corr\left(\varepsilon_t^j, \varepsilon_t^{AM}\right)$	$corr\left(\varepsilon_t^j, \varepsilon_t^S\right)$
			Case A: Benchmark			
M	0.70	0.0182	6.0e-04	1	0.631	-0.389
AM	0.51	0.0489	0.0042	0.631	1	-0.745
S	0.51	0.0480	0.0295	-0.389	-0.745	1

Table: The estimated TFP process

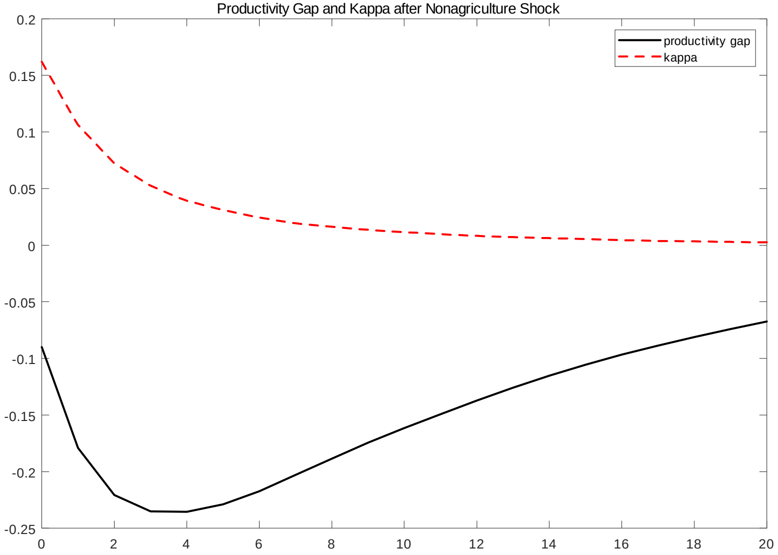
Impulse-Resp. of Employment to NonAgr TFP Shock



Imp.-Resp. of Employment to Modern Agr TFP Shock



Imp.-Resp. of Prod. Gap to Nonagr TFP Shock



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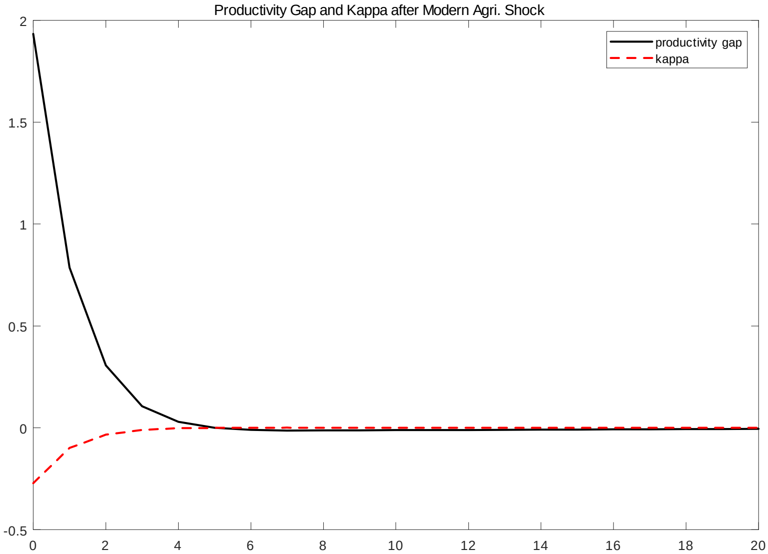

Business Cycle Statistics: China data vs. model

	c	i	y^G	y^M	$\frac{P^G y^G}{P}$	$\frac{P^M y^M}{P}$	$\frac{APL^G}{APL^M}$	n^G	n^M	n
	A. China, 1985-2012							$std(y) = 1.7\%$		
$\frac{std(x)}{std(y)}$	0.99	3.53	0.40	1.21	1.64	1.34	2.17	1.00	1.04	0.10
$corr(x, y)$	0.70	0.65	-0.11	0.99	0.06	0.95	-0.48	-0.78	0.83	-0.23
$corr(x, n^G)$	-0.67	-0.61	0.10	-0.79	-0.01	-0.76	0.62	1.00	-0.93	0.18
$corr\left(x, n^M\right)$	0.64	0.65	-0.14	0.85	0.01	0.82	-0.65	-0.93	1.00	-0.01
	B. Benchmark							$std(y) = 1.3\%$		
$\frac{std(x)}{std(y)}$	0.24	2.50	2.09	1.43	1.53	1.30	2.58	3.28	1.52	0.51
$corr(x, y)$	0.75	0.99	-0.29	0.94	-0.15	0.96	-0.58	-0.56	0.74	-0.08
$corr\left(x, n^G\right)$	-0.31	-0.56	0.86	-0.74	0.80	-0.71	0.96	1	-0.90	0.81
$corr\left(x, n^M\right)$	0.42	0.75	-0.79	0.91	-0.70	0.89	-0.87	-0.90	1	-0.68

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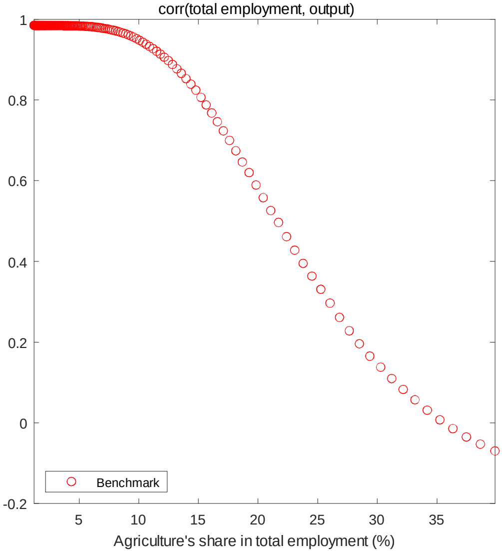
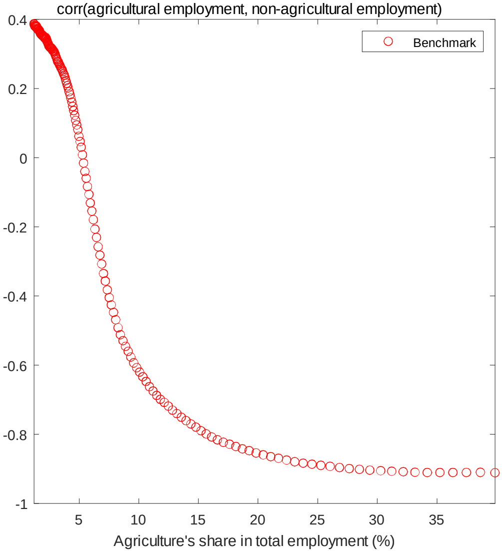
Employment: From Acyclical to Procyclical

Richer countries (lower share of employment in agriculture) to the left



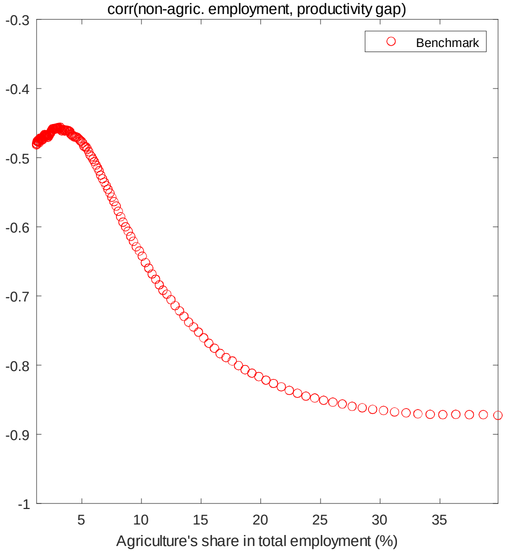
Employment Agr-NonAgr Turns Less (Neg.) Correlated

Richer countries (lower share of employment in agriculture) to the left



Prod Gap (Nonag/Ag) Becomes Less Countercyclical

Richer countries (lower share of employment in agriculture) to the left



Robustness analysis

- Modify TFP process for traditional sector
  - assume same persistence, $\phi^S = \phi^{AM}$
  - common shock to entire agric. sector
- Capital adjustment costs
- Cobb-Douglas preferences ($\varepsilon = 1$ and large subsistence level in food)

Conclusion

- We document how business cycle features changes throughout development
    - China vs. US
    - A cross section of countries
- Provide unified theoretical framework to account for business cycles and structural change
- Estimate model to match structural transformation in China
    - Model is broadly consistent with business cycle properties of China
- As productivity grows and capital accumulates, business cycles become more similar to those of the US

ADDITIONAL MATERIAL

Literature

- Business cycles in developing countries
  - Sectoral comovement
    - Hornstein and Praschnik (1997), Horvath (2000), Boldrin et. al. (2001), Kim and Kim (2006)
  - Cross-country business cycle differences
    - Rogerson (1991): movement out of Agriculture in the US has been concentrated during upturns in economic activity, whereas the movement of workers out of manufacturing has been concentrated during downturns.
    - Da-Rocha and Restuccia (2006) focus on the role of Agriculture. We provide new evidence and a model with structural change
    - Aguiar and Gopinath (2007): emphasize trend shocks
  - China:
    - Zhang, Rozelle, and Huang (2001); in the early 1990's the layoffs increased and hiring slowed. Those who lost their jobs returned to the Agricultural sector.
    - Brandt and Zhu (2000; 2001),
      Yao and Zhu (2017)

Literature (cont.)

- Structural change
  - Driving force: differential technical change and capital deepening Baumol (1967), Kongsamut, Rebelo and Xie (2001), Ngai and Pissarides (2007; 2008), Acemoglu and Guerrieri (2008)
  - China: Cheremukhin et. al. (2015),
- Dual labor market:
  - Lewis (1954), Harris and Todaro (1970)

Deterministic Dynamic Systems (Constant h)

- In absence of shocks, the deterministic equilibrium is characterized by the following systems of differential equations w.r.t. $(c, \upsilon^A, \kappa^M, \chi)$ where

$$\kappa^M \equiv \frac{K^M}{K}, \upsilon^A \equiv \frac{\varsigma\left(Y^{AM}\right)^{\frac{\omega-1}{\omega}}}{\left(Y^A\right)^{\frac{\omega-1}{\omega}}}, \chi \equiv \frac{K}{N},$$

$$\begin{aligned} \frac{\dot{c}}{c} &= \frac{1}{1+\theta(\sigma-1)} \times \left[\begin{array}{c} \eta_t^{\frac{1}{\varepsilon}} (1-\gamma)(1-\alpha_M) \times \\ \left(\kappa_t^M\right)^{-\alpha_M} \left(Z_t^M \upsilon_t^M\right)^{\alpha_M} \chi_t^{-\alpha_M} - \delta - \rho \end{array} \right] \\ \frac{\dot{\chi}_t}{\chi_t} &= \eta_t \left(Z_t^M\right)^{\alpha_M} \left(\kappa_t^M\right)^{1-\alpha_M} \left(\upsilon_t^M\right)^{\alpha_M} \chi_t^{-\alpha_M} - \delta - c\chi_t^{-1} - n, \end{aligned}$$

Deterministic Dynamic Systems (Constant h)

$$\frac{\dot{\kappa}_t^M}{\kappa_t^M} = \left(1-\kappa_t^M\right) \frac{\begin{pmatrix} \left(\alpha_M\ g^M - \alpha_A g^A + \left(\alpha_A - \alpha_M\right) \frac{\dot{\chi}_t}{\chi_t}\right) + \\ \left(\frac{1}{\omega-1} - \frac{\left(\alpha_A-\alpha_M\right)\left(1-\nu_t^M\right)}{\alpha_A\ \upsilon^A+1-\upsilon_t^A}\right) \frac{\dot{\upsilon}_t^A}{\upsilon_t^A} \end{pmatrix}}{\frac{1}{\varepsilon-1} + \left(\alpha_A - \alpha_M\right)\left(\kappa_t^M - \nu_t^M\right)},$$

$$\frac{\dot{\upsilon}_t^A}{\upsilon_t^A} = \frac{\left(1-\upsilon_t^A\right)\left(\alpha_A\ g^A - g^S + \left(1-\alpha_A\right)\left(\frac{\dot{\chi}_t}{\chi_t} - \frac{\dot{\kappa}_t^M}{\kappa_t^M}\frac{\kappa_t^M-\nu_t^M}{1-\kappa_t^M}\right)\right)}{\frac{1}{\omega-1} + \frac{\left(1-\upsilon_t^A\right)\left(1-\alpha_A\right)\left(1-\nu_t^M\right)}{\alpha_A\ \upsilon_t^A+1-\upsilon_t^A}},$$

$$\frac{Z_t^M}{Z_t^M} = g^M,\ \frac{Z_t^A}{Z_t^A} = g^A,\ \frac{Z_t^S}{Z_t^S} = g^S,$$

Deterministic Dynamic Systems (Constant h)

...where

$$\eta_t \equiv (1-\gamma)^{\frac{\varepsilon}{\varepsilon-1}} \left(1 + \frac{1-\alpha_M}{1-\alpha_A}\frac{1-\kappa_t^M}{\kappa_t^M}\frac{1}{\upsilon_t^A}\right)^{\frac{\varepsilon}{\varepsilon-1}},$$

$$\nu_t^M = \left(1 + \frac{1-\kappa_t^M}{\kappa_t^M}\frac{1-\alpha_M}{1-\alpha_A}\left(\frac{\alpha_A}{\alpha_M} + \frac{1}{\alpha_M}\frac{1-\upsilon_t^A}{\upsilon_t^A}\right)\right)^{-1},$$

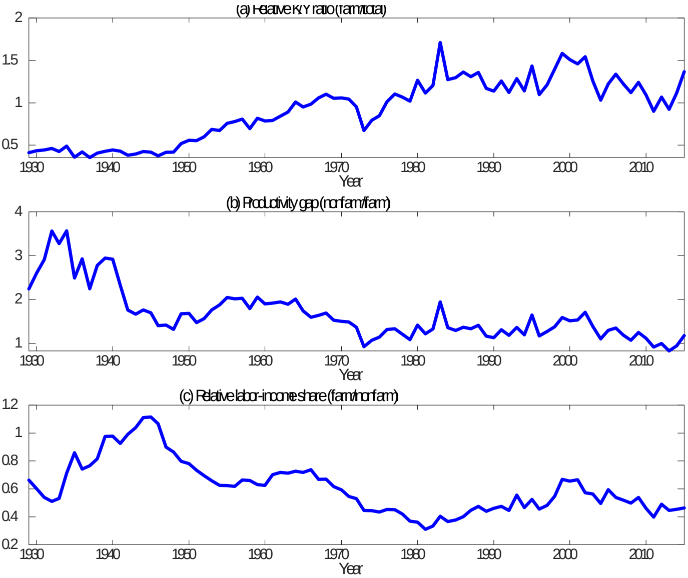
$$\nu_t^A = \frac{1}{1-\tau}\frac{1-\kappa_t^M}{\kappa_t^M}\frac{1-\alpha_M}{1-\alpha_A}\frac{\alpha_A}{\alpha_M}\nu_t^M.$$

Business Cycle Statistics: China data vs. model

Table: Business Cycle Statistics: Model vs Data

FIRST DIFF				$x =$				
HOMOTH	c	i	$\frac{P^G y^G}{P}$	$\frac{P^M y^M}{P}$	PrGap	n^G	n^M	n
	A. FD- Filtered China Data: $std\,(y) = 2.4\%$							
$\frac{std(x)}{std(y)}$	1.27	3.34	1.82	1.31	2.32	1.00	0.76	0.30
$corr\,(x, y)$	0.57	0.63	0.12	0.93	-0.09	-0.57	0.66	-0.25
$corr\left(x, n^G\right)$	-0.74	-0.34	-0.38	-0.38	0.35	1.00	-0.50	0.71
$corr\left(x, n^M\right)$	0.32	0.37	0.40	0.53	-0.52	-0.50	1	0.19
	B. FD- Filtered Model, $std\,(y) = 2.6\%$							
$\frac{std(x)}{std(y)}$	0.30	2.36	1.11	1.25	0.72	1.10	1.27	0.49
$corr\,(x, y)$	0.80	0.99	0.24	0.95	-0.42	-0.30	0.69	0.18
$corr\left(x, n^G\right)$	-0.22	-0.27	0.80	-0.51	0.79	1	-0.78	0.75
$corr\left(x, n^M\right)$	0.55	0.66	-0.40	0.88	-0.81	-0.78	1	-0.52

Labor's Income Share in non-farm/farm sector



Rel. Price of non-farm/farm output in the US

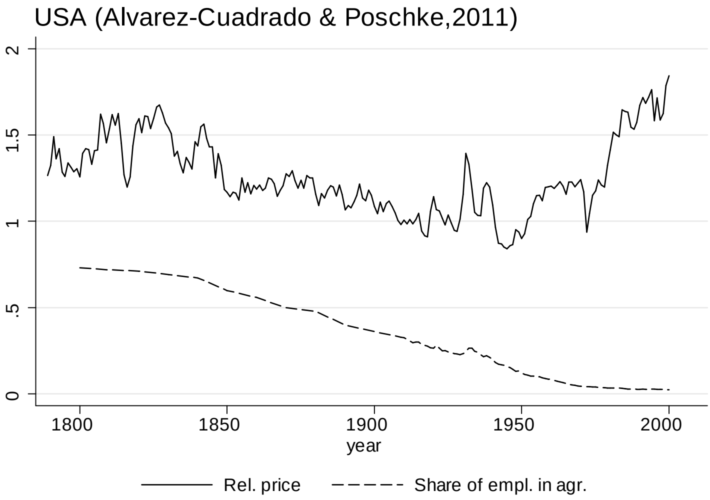
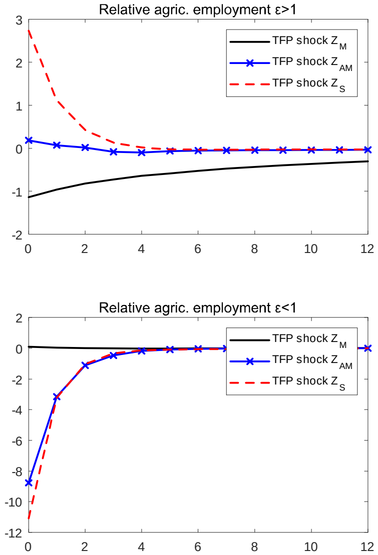


Figure: The Figure is from the Figure 1 in Alvarez-Cuadrado and Poschke (2011).

Impulse Response to Agriculture TFP Shock

- Consider increase in agricultural TFP: $Z^{AM} \uparrow$ and $Z^{S} \uparrow$
- $\varepsilon > 1$: shock $Z^{AM} \uparrow$ and $Z^{S} \uparrow$ *reverses* structural change: $N^{M} \downarrow$ (workers go from manufacturing to agriculture when agriculture becomes more productive)
- $\varepsilon < 1$: shock $Z^{AM} \uparrow$ or $Z^{S} \uparrow$ *accelerates* structural change: $N^{M} \uparrow$ (workers leave countryside and move to manufacturing when agriculture becomes more productive)

TFP Shock & Structural Change: High vs. Low epsilon



Rel. Price of non-farm/farm output in CHINA

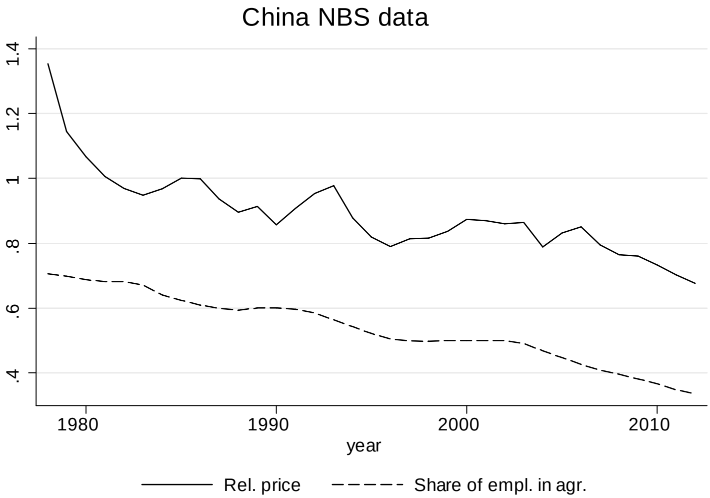


Figure: The Figure plots the share of employment in agriculture and the relative

Rel. Price of non-farm/farm output in Other Countries

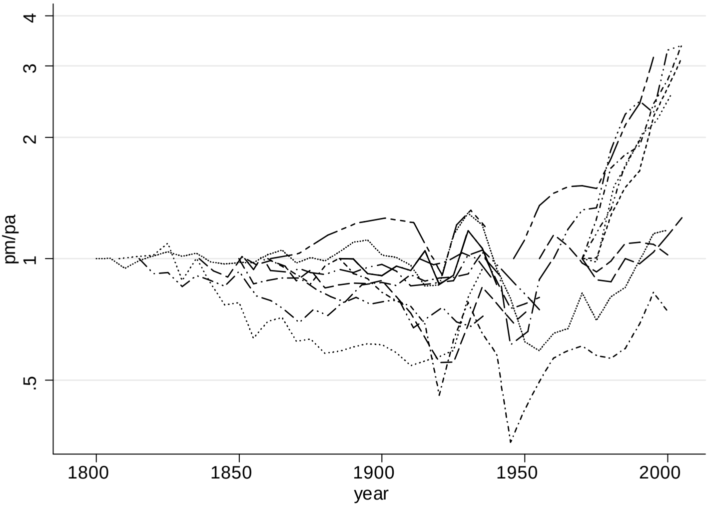


Figure: The Figure is from the Left panel of Figure 4 in Alvarez-Cuadrado and

Rel. Price of non-farm/farm output (Pre-WWII)

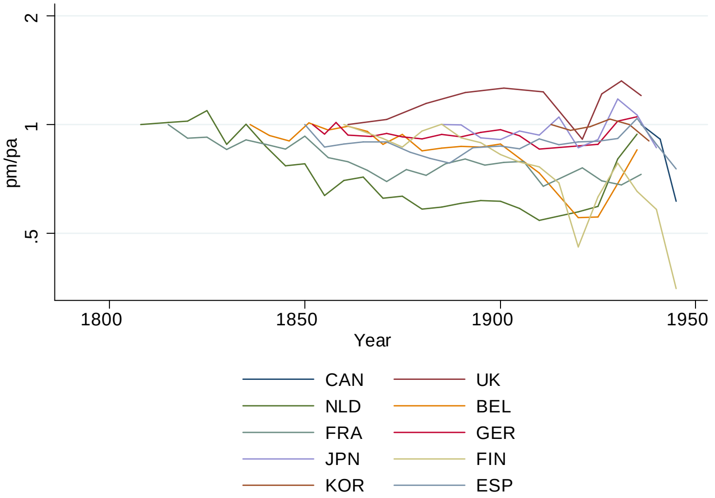


Figure: The Figure is based on the Left panel of Figure 4 in Alvarez-Cuadrado