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

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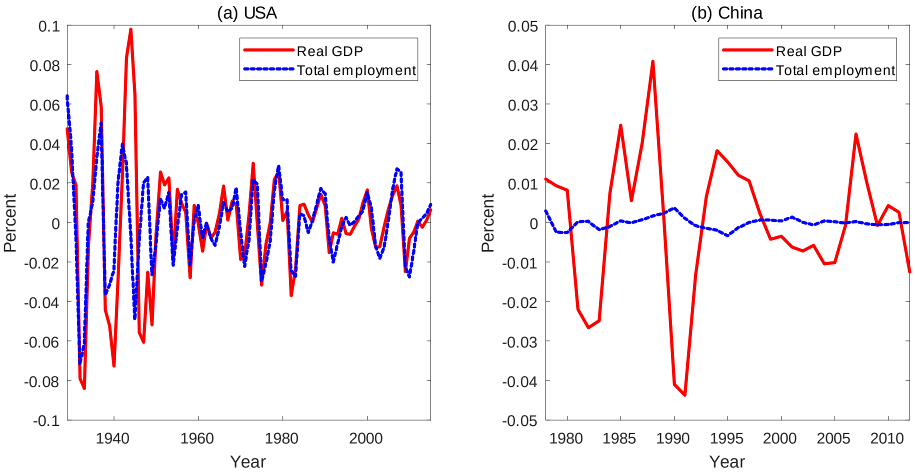
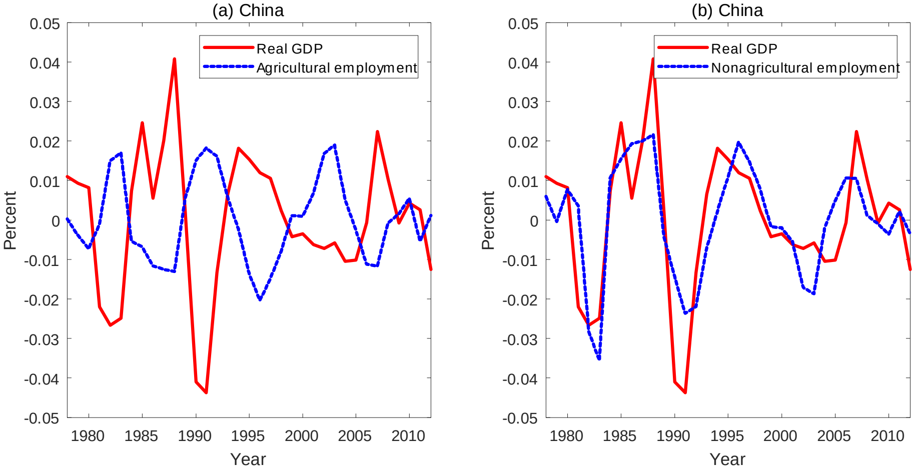
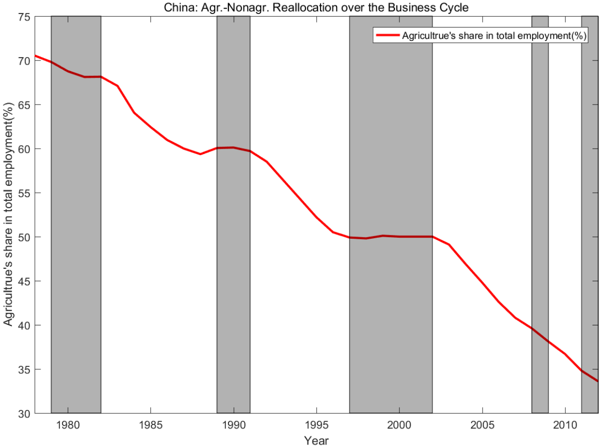
US (left) &China (right): GDP vs. Total Employment



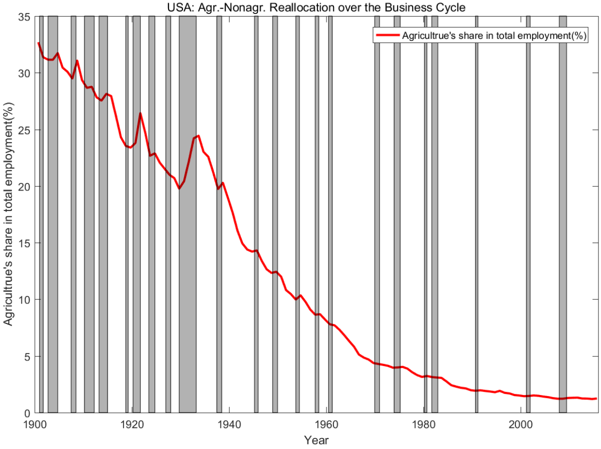
China: GDP vs. Agric. empl & Non-Agric. empl



China: Agr-NonAgr Reallocation over the Business Cycle



US: Agr-NonAgr Reallocation over the Business Cycle



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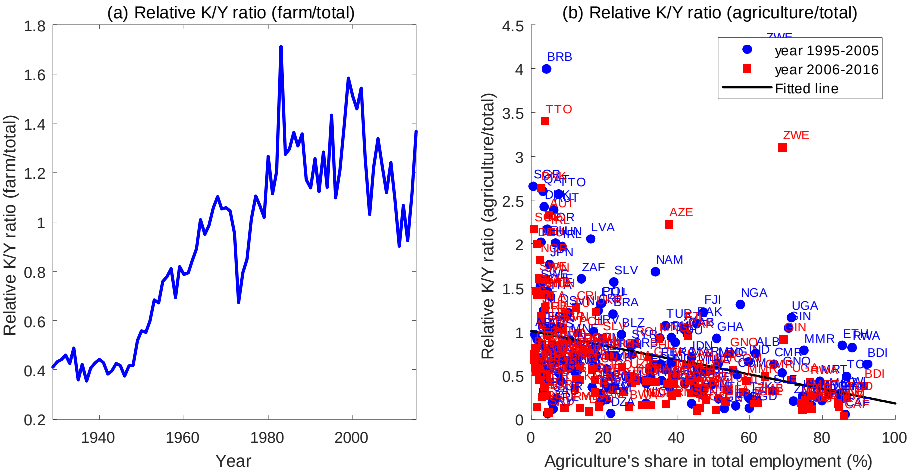
  3. Novel framework to analyze fluctuations "far from steady state"

STYLIZED FACTS: STRUCTURAL CHANGE

Modernization of Agriculture: KY ratio

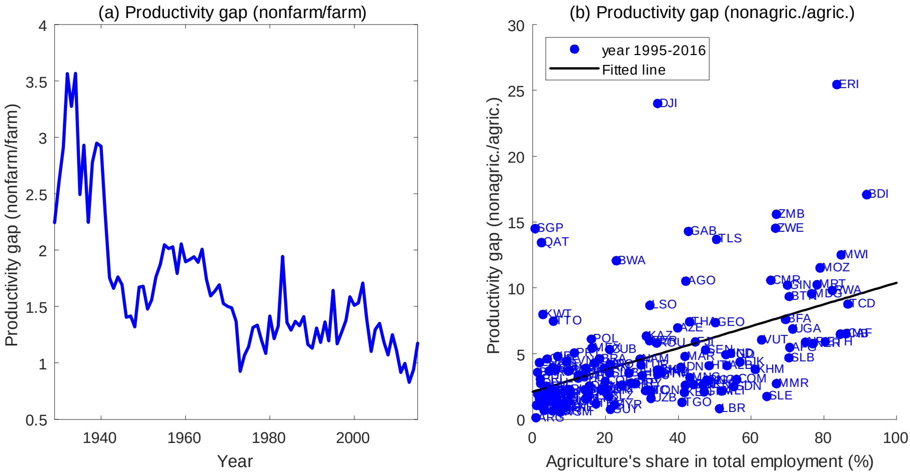


Labor Productivity Gap

- 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



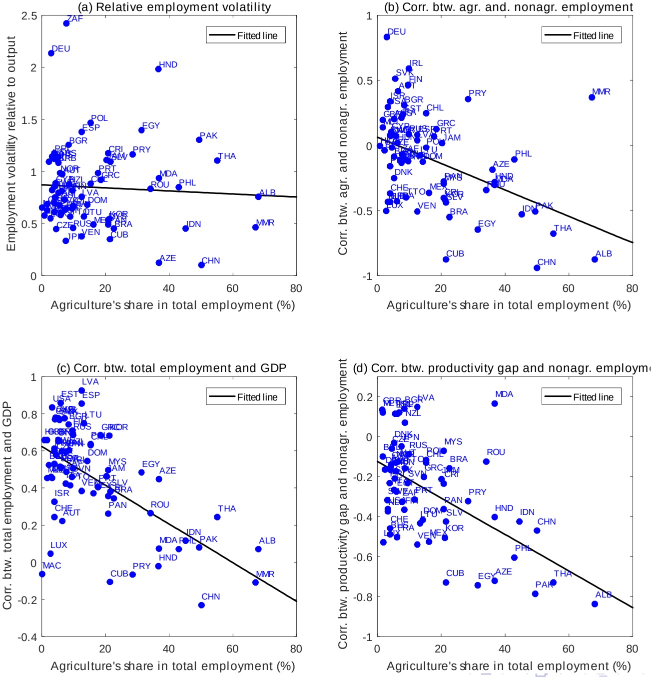
STYLIZED FACTS: BUSINESS CYCLE

Business Cycle Over Structural Change

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

	Large Agriculture (poor country)	Small Agriculture (rich country)
relative volatility empl.-GDP	low	high
corr(agr. empl.,nonagr empl.)	negative	≈ 0
corr total employment-GDP	low	high
labor prod. gap	countercyclical	acyclical
relative volatility cons.-GDP	high	low

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


(a) Relative employment volatility
Employment volatility relative to output
Agriculture's share in total employment (%)
Fitted line
(b) Corr. btw. agr. and. nonagr. employment
Corr. btw. agr. and nonagr. employment
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(c) Corr. btw. total employment and GDP
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(d) Corr. btw. productivity gap and nonagr. employm
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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

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

- Counterfactual predication: constant productivity gap.

Theory: Why Hansen-Prescott Does Not Work

- Cobb Douglas implies constant factor shares:

$$\begin{aligned}\frac{wL^M}{P^M Y^M} &= \alpha \text{ and } \frac{wL^G}{P^G Y^G} = \beta \\ &\Rightarrow \\ \frac{P^M Y^M}{L^M} &= \frac{w}{\alpha} \text{ and } \frac{P^G Y^G}{L^G} = \frac{w}{\beta}\end{aligned}$$

- So, the productivity gap is

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

- 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 is a "necessity".
- Our estimates suggest $\varepsilon > 1$ (discussed later).

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 $\omega > 1$:

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

where

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

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

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

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

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

Static Equilibrium

- Equalization of MPL and MPK across sectors.
- Let:

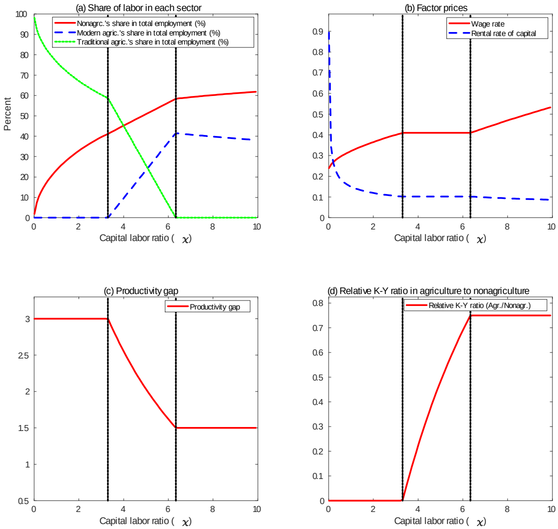
$$\chi \equiv \frac{K}{L} \text{ (endogenous state variable)}$$
$$\kappa \equiv K^M / K \text{ (share of capital in Nonagr)}$$
$$\upsilon \equiv \frac{\varsigma \left(Y^{AM}\right)^{\frac{\omega-1}{\omega}}}{\varsigma (Y^{AM})^{\frac{\omega-1}{\omega}} + (1-\varsigma)(Y^S)^{\frac{\omega-1}{\omega}}}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

- $\kappa(\chi, \mathbf{Z})$ 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" ($\omega \to \infty$) 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)

- Suppose (sufficient conditions!!)

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

- Then, the dynamic equilibrium converges to a unique ABGP where

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

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

ELASTICITIES OF SUBSTITUTION

Elasticity of Substitution btw. Agr/Nonagr Goods

- The results hinge on the assumption $\omega > 1$ and $\varepsilon > 1$.
- Large ω is plausible (in Lewis, $\omega \to \infty$).
- What about ε ?
- Some earlier studies argue $\varepsilon < 1$...

Elasticity of Substitution btw. Agr/Nonagr Goods

- Recall production function

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

- Profit maximization of final producers imply:

$$\frac{P_t^G Y_t^G}{P_t^M Y_t^M} = \frac{\gamma}{1-\gamma}\left(\frac{Y_t^G}{Y_t^M}\right)^{\frac{\varepsilon-1}{\varepsilon}}$$

- A relationship between relative expenditure and (real) output.

Elasticity of Subs§titution btw. Agr/Nonagr Goods

- Takes log on both sides

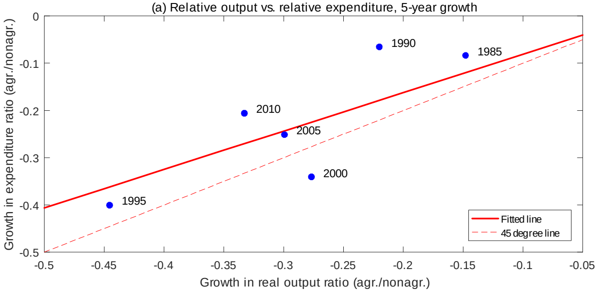
$$\ln\left(\frac{P_t^G Y_t^G}{P_t^M Y_t^M}\right) = \ln\left(\frac{\gamma}{1-\gamma}\right) + \frac{\varepsilon - 1}{\varepsilon}\ln\left(\frac{Y_t^G}{Y_t^M}\right).$$

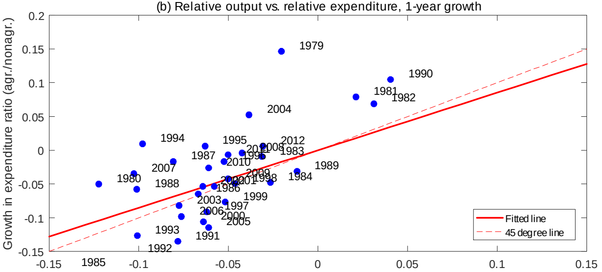
- Take the first difference

$$\Delta\ln\left(\frac{P_t^G Y_t^G}{P_t^M Y_t^M}\right) = \frac{\varepsilon - 1}{\varepsilon}\Delta\ln\left(\frac{Y_t^G}{Y_t^M}\right),$$

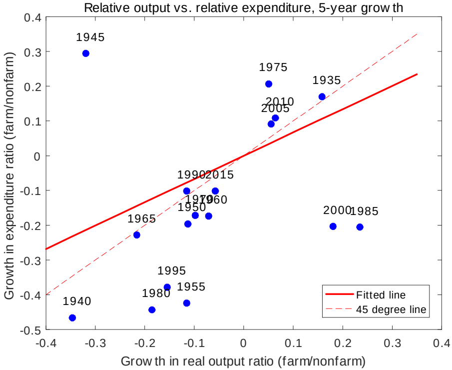
  - $\varepsilon > 1$ iff $\Delta\ln\left(\frac{Y_t^G}{Y_t^M}\right)$ has positive coefficient in simple OLS

Elasticity of Substitution btw. Agr/Nonagr Goods: China





Elasticity of Substitution btw. Agr/Nonagr Goods: USA



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

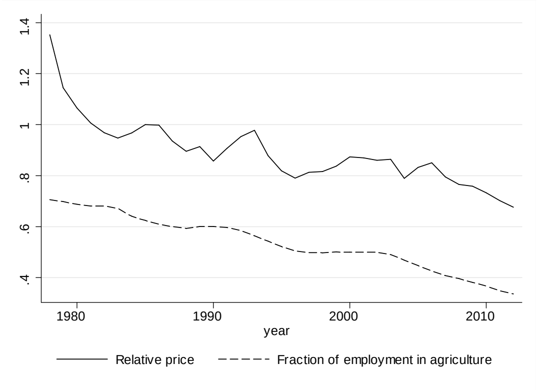


Figure:

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

Figure: Source: Figure 1 in Alvarez-Cuadrado and Poschke (2011, AEJ Macro).

Productivity Gap and LIS Ratio

- We show that the Productivity Gap is

$$\frac{APL^M}{APL^G} = \frac{1}{1-\tau}\frac{\overbrace{1-\upsilon\left(1-\beta\right)}^{\text{labor's income share in Agr sector}}}{\underbrace{\alpha}_{\text{labor's income share in NonAgr sector}}}$$

  where υ is the output share of ModernAgr in Agr. and APL is avg. product of labor.
- Since υ increases and $\lim_{t\to\infty}\upsilon = 1$, the productivity gap falls over time, converging to

$$\lim_{t\to\infty}\frac{APL_t^M}{APL_t^G} = \frac{1}{1-\tau}\frac{\beta}{\alpha}$$

- Note: τ is the exogenous wedge.

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)

- 5 parameters are calibrated outside the model
  - $n = 1.5\%, \delta = 5\%, (1+\rho)^{-1} = 0.96, \alpha = 0.50$, $Y_{1985} = 1$
- 14 parameters are estimated by SMM
  to match 226 moments (China 1985-2012):
  - Capital stock (in current price) share in agr. sector
  - Employment share in agr. sector
  - Aggregate GDP growth and K/Y ratio
  - Productivity Gap during 1985-2012
  - Ratio of (real) agr to total output
  - Expenditure share in agr products
  - Hours worked in the long run (1/3)

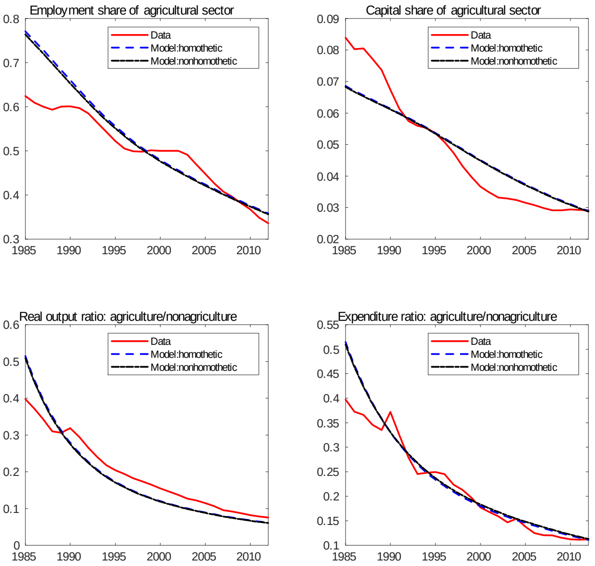
Estimated Parameters (SMM)

	Estimated Parameter	Homoth	NonHom	NoTargPG
$\bar{C}^G/Y$	Subsistence level Agr	**0**	**0.05**	**0.05**
ε	ES btw Nonagr and Agr	**3.60**	**3.36**	**4.00**
ω	ES btw Modern and Trad. Agr	**9.00**	**9.00**	**8.22**
τ	labor wedge	0.76	0.75	0.73
θ	pref. weight on consumption	0.73	0.73	0.71
γ	weight on Agr output	0.61	0.60	0.54
ς	weight on Modern Agr output	0.40	0.39	0.50
ξ	capital inc. share in Modern Agr	0.14	0.13	0.21
β	labor inc. share in Modern Agr	0.61	0.60	0.68
g^M	TFP growth rate Nonagr	6.5%	6.5%	6.5%
g^{AM}	TFP growth rate Modern Agr	6.1%	6.1%	5.9%
g^S	TFP growth rate Trad Agr	0.9%	0.9%	1.0%
Z^M_{1985}	initial TFP level Nonagr	4.33	4.45	3.42
Z^{AM}_{1985}	initial TFP level Modern Agr	2.26	2.25	2.42
Z^S_{1985}	initial TFP level Trad Agr	1.23	1.18	1.35

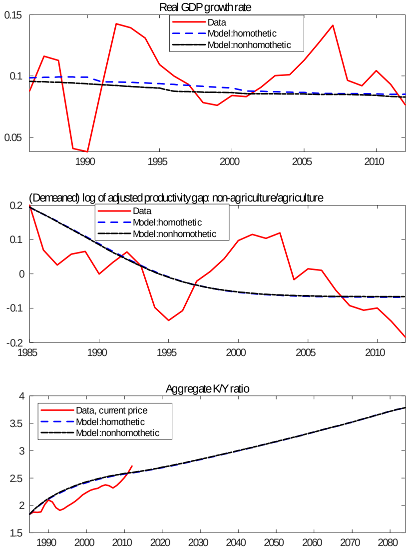
Elasticity of substitution $\varepsilon > 1$

QUANTITATIVE ANALYSIS: FITTING STRUCTURAL CHANGE

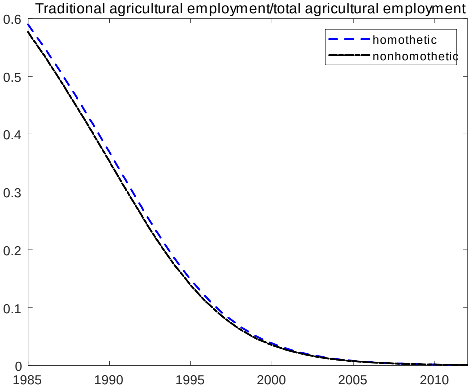
Model Fit 1: Decline of Agricultural Sector



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

- TFP has cyclical and trend components: $\ln Z_t^j = (1 + g^j) + z_t^j$
- Cyclical component is simple VAR(1),

$$\begin{bmatrix} z_{t+1}^M \\ z_{t+1}^{AM} \\ z_{t+1}^S \end{bmatrix} = \begin{bmatrix} \phi^M & 0 & 0 \\ 0 & \phi^{AM} & 0 \\ 0 & 0 & \phi^S \end{bmatrix} \cdot \begin{bmatrix} z_t^M \\ z_t^{AM} \\ z_t^S \end{bmatrix} + \epsilon_t,$$

- Estimates of persistence: $\hat{\phi}^M = 0.63$, $\hat{\phi}^{AM} = 0.9$, and $\hat{\phi}^S = 0.42$
- Implied volatility of innovations: $\sigma\left(\epsilon_t^M\right) = 0.042$, $\sigma\left(\epsilon_t^{AM}\right) = 0.036$, and $\sigma\left(\epsilon_t^S\right) = 0.053$

Business Cycle Statistics: China data vs. model

Table: Business Cycle Statistics: Model vs Data

HP FILTER / HOMOTH.	c	i	$\frac{P^G y^G}{P}$	$\frac{P^M y^M}{P}$	PrGap	n^G	n^M	n
A. HP-filtered China Data: $std(y) = 1.7\%$								
$\frac{std(x)}{std(y)}$	0.99	3.53	1.63	1.34	2.04	0.64	0.73	0.10
$corr(x, y)$	0.70	0.65	0.06	0.95	-0.17	-0.69	0.73	-0.23
$corr(x, n^G)$	-0.60	-0.31	-0.37	-0.55	0.48	1.00	-0.94	0.48
$corr(x, n^M)$	0.60	0.37	0.41	0.57	-0.54	-0.94	1.00	0.04
B. HP-filtered Model, $std(y) = 1.6\%$								
$\frac{std(x)}{std(y)}$	0.27	2.39	1.09	1.18	0.62	1.03	1.07	0.42
$corr(x, y)$	0.81	0.99	0.30	0.97	-0.38	-0.25	0.73	0.43
$corr(x, n^G)$	-0.08	-0.25	0.78	-0.43	0.72	1	-0.75	0.69
$corr(x, n^M)$	0.45	0.75	-0.31	0.87	-0.74	-0.75	1	-0.21

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$corr(x,y)$	0.70	0.65	0.06	0.95	-0.17	-0.69	0.73	-0.23
$corr\left(x,n^G\right)$	-0.60	-0.31	-0.37	-0.55	0.48	1.00	-0.94	0.48
$corr\left(x,n^M\right)$	0.60	0.37	0.41	0.57	-0.54	-0.94	1.00	0.04
B. HP-filtered Model, $std(y) = 1.6\%$								
$\frac{std(x)}{std(y)}$	0.27	2.39	1.09	1.18	0.62	1.03	1.07	0.42
$corr(x,y)$	0.81	0.99	0.30	0.97	-0.38	-0.25	0.73	0.43
$corr\left(x,n^G\right)$	-0.08	-0.25	0.78	-0.43	0.72	1	-0.75	0.69
$corr\left(x,n^M\right)$	0.45	0.75	-0.31	0.87	-0.74	-0.75	1	-0.21

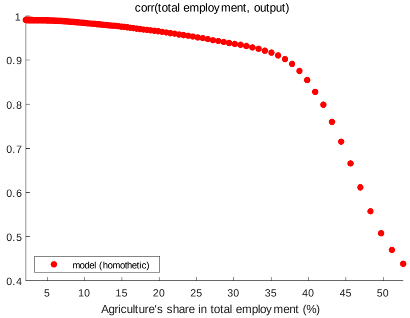
Business Cycle Statistics: China data vs. model

Table: Business Cycle Statistics: Model vs Data

HP FILTER	$x =$							
HOMOTH.	c	i	$\frac{P^G y^G}{P}$	$\frac{P^M y^M}{P}$	PrGap	n^G	n^M	n
	A. HP-filtered China Data: $std(y) = 1.7\%$							
$\frac{std(x)}{std(y)}$	0.99	3.53	1.63	1.34	2.04	0.64	0.73	0.10
$corr(x, y)$	0.70	0.65	0.06	0.95	-0.17	-0.69	0.73	-0.23
$corr\left(x, n^G\right)$	-0.60	-0.31	-0.37	-0.55	0.48	1.00	-0.94	0.48
$corr\left(x, n^M\right)$	0.60	0.37	0.41	0.57	-0.54	-0.94	1.00	0.04
	B. HP-filtered Model, $std(y) = 1.6\%$							
$\frac{std(x)}{std(y)}$	0.27	2.39	1.09	1.18	0.62	1.03	1.07	0.42
$corr(x, y)$	0.81	0.99	0.30	0.97	-0.38	-0.25	0.73	0.43
$corr\left(x, n^G\right)$	-0.08	-0.25	0.78	-0.43	0.72	1	-0.75	0.69
$corr\left(x, n^M\right)$	0.45	0.75	-0.31	0.87	-0.74	-0.75	1	-0.21

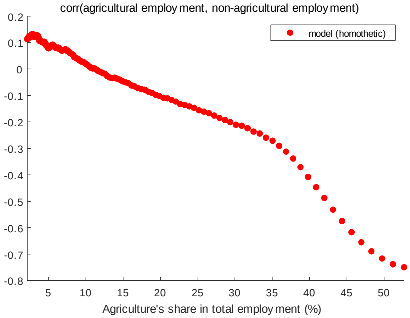
Employment: From Acyclical to Procyclical

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



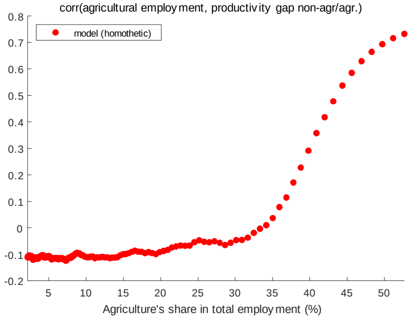
Employment Agr-NonAgr Turns Less (Neg.) Correlated

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

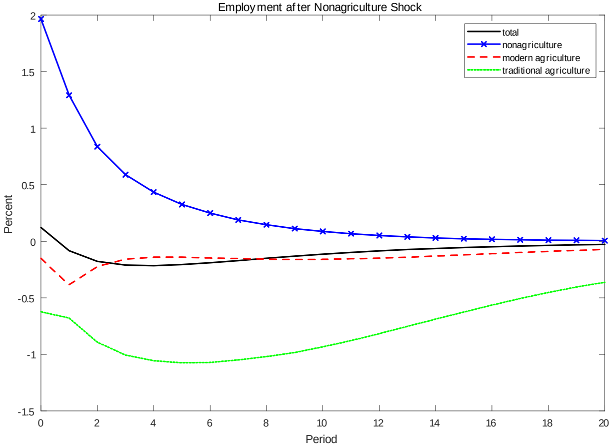


Prod Gap (Nonag/Ag) Becomes Less Countercyclical

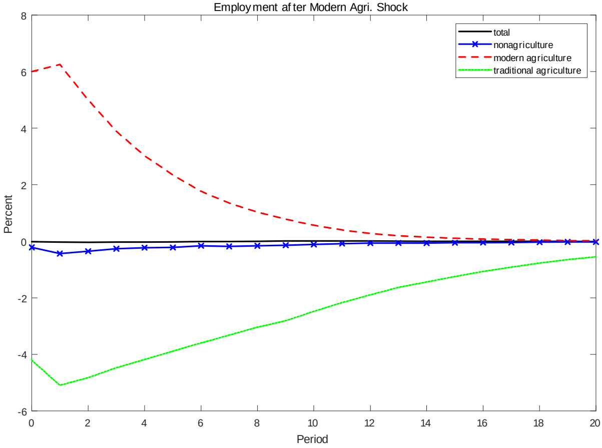
Richer countries (lower share of employment in agriculture) to the left



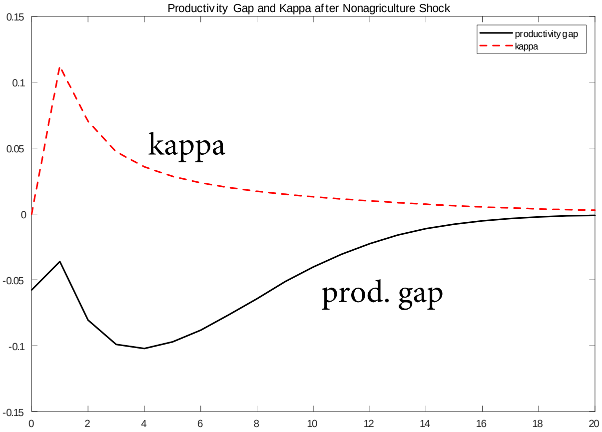
Imp.-Resp. of Employment to NonAgr TFP Shock



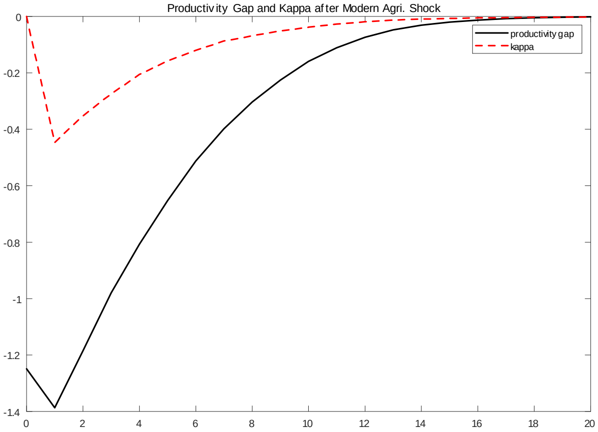
Imp.-Resp. of Employment to Modern Agr TFP Shock



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



Imp.-Resp. of Prod. Gap to Modern Agr TFP Shock



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
- We provide a unified theoretical framework to account for business cycles and structural change
- We estimate the model to match the structural transformation in China
  - The model is broadly consistent with the 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. $\left(c, \upsilon^A, \kappa^M, \chi\right)$ where

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

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

Deterministic Dynamic Systems (Constant h)

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

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

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

Deterministic Dynamic Systems (Constant h)

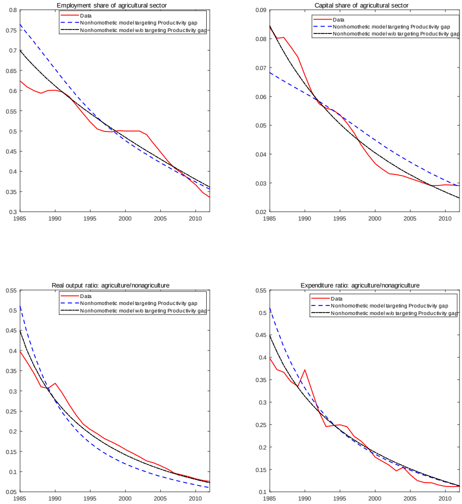
...where

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

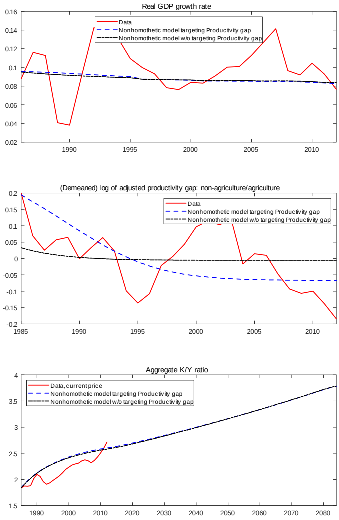
$$\nu_t^M = \left(1 + \frac{1-\kappa_t^M}{\kappa_t^M} \frac{1-\alpha_M}{1-\alpha_A} \left(\frac{\alpha_A}{\alpha_M} + \frac{1}{\alpha_M} \frac{1-\upsilon_t^A}{\upsilon_t^A}\right)\right)^{-1},$$

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

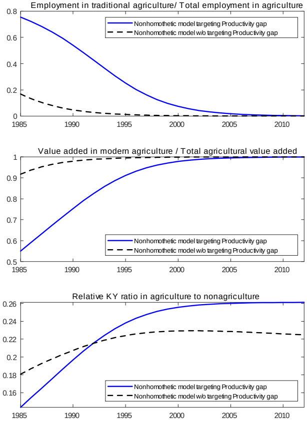
Comparing Two Versions of Non-homothetic Model



Comparing Two Versions of Non-homothetic Model



Comparing Two Versions of Non-homothetic Mode



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: $std\left(y\right) = 2.4\%$								
$\frac{std(x)}{std(y)}$	1.27	3.34	1.82	1.31	2.32	1.00	0.76	0.30
$corr\left(x, y\right)$	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, $std\left(y\right) = 2.6\%$								
$\frac{std(x)}{std(y)}$	0.30	2.36	1.11	1.25	0.72	1.10	1.27	0.49
$corr\left(x, y\right)$	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

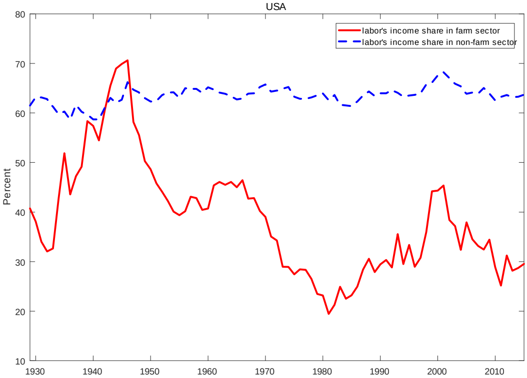


Figure: The Figure plots the labor's income share in farm/non-farm sectors in the USA. The labor's income share is defined as the compensation of employees divided by the value-added output minus proprietor's income. Source: Compensation of employees by farm/non-farm come from NIPA Table 6.2A, 6.2B, 6.2C, and 6.2D. Proprietor's income by farm/non-farm come from NIPA Table 1.12. The value-added output by farm/non-farm come from the NIPA Table 1.3.5.

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

Figure: The Figure is from the Figure 1 in Alvarez-Cuadrado and Poschke (2011, AEJ Macro). It plots the share of employment in agriculture and the relative price of manufactures to agricultural goods in the US 1790/1800-2000. Note that the value-added price index is not available for such a long period, they use producer prices and wholesale prices of all commodities versus farm products in the US.

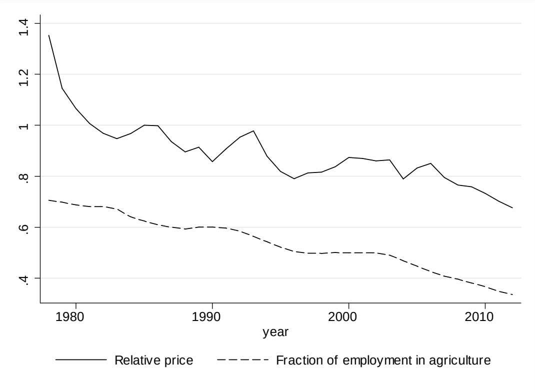


Figure: The Figure plots the share of employment in agriculture and the relative price of non-agricultural goods to agricultural goods in CHINA 1978-2012. The relative price is calculated as non-agr. output deflator divided by the agr. output deflator.

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

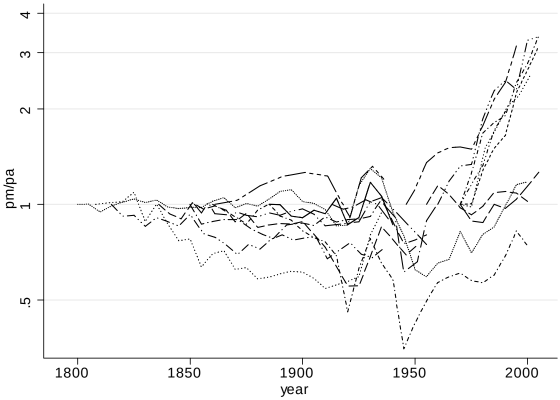


Figure: The Figure is from the Left panel of Figure 4 in Alvarez-Cuadrado and Poschke (2011, AEJ Macro). Countries include CAN, UK, NLD, BEL, FRA, GER, JPN, FIN, KOR, ESP.

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

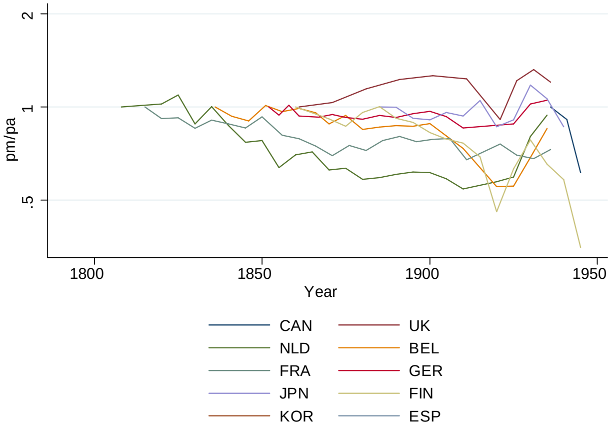


Figure: The Figure is based on the Left panel of Figure 4 in Alvarez-Cuadrado and Poschke (2011, AEJ Macro). Countries include CAN, UK, NLD, BEL, FRA, GER, JPN, FIN, KOR, ESP.