Why England? Demographic Factors, Structural Change and Physical Capital Accumulation during the Industrial Revolution

Nico Voigtländer and Joachim Voth

Universitat Pompeu Fabra

Recent models of industrialization	Insights from economic history
Radical discontinuity	Slow transition (100 years+)
Supply-driven	Structural change important
Bigger is better (numerous models)	Little evidence that size of population or absolute size of GDP matters
Emphasis on modelling ONE transition over time	Focus on cross-sectional differences in timing
Some models (Becker et al., Lucas) emphasize that IR = increase in returns to human capital	Skill premia flat Human capital accumulation minimal before 1850

Our Approach

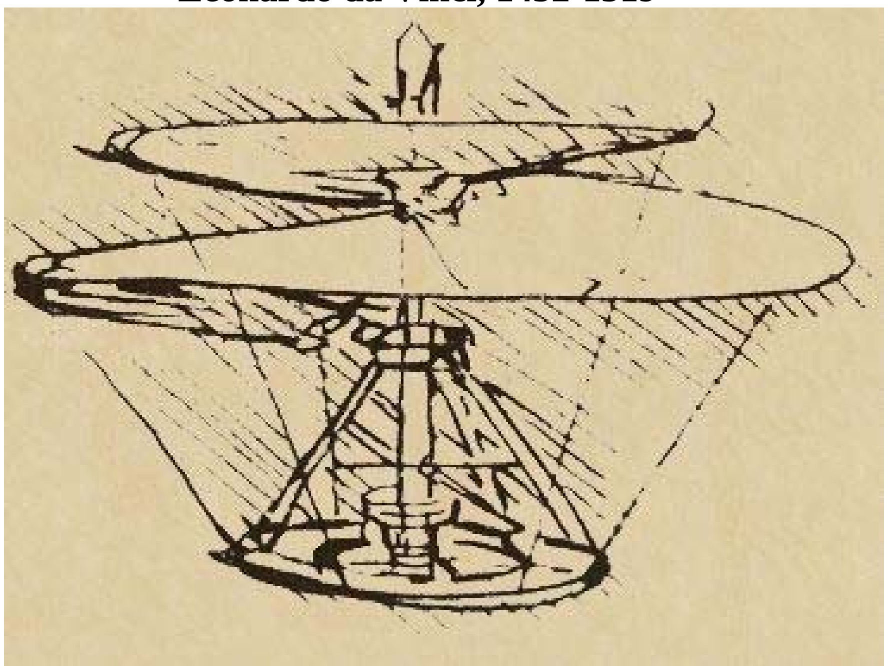
- We provide a model of industrialization where
  - Structural change is driven by Stone-Geary preferences in a 2-sector model
  - A stream of microinventions instead of education drives (endogenous) TFP growth (modelled through an externality to capital)
  - Stochastic fluctuations of agricultural productivity influence the timing of IR
  - Starting incomes matter (determined by demographic regime)
- Emphasis on structural change
  - Demand is key element for adoption of modern technology: Stone-Geary preferences with 2 sectors
  - Positive externality from capital accumulation – stream of microinventions
- Probabilistic nature of the Industrial Revolution
  - Shocks to pre-industrial agriculture drive income-fluctuations
- Calibration with the available data from Britain
  - Similar to Stokey (2001), Lagerlöf (2006)

Main Results

- Explain the slow, but accelerating growth during IR
  - Initially, income growth translates into population growth, but also into a higher aggregate capital stock
  - Demographic regime crucial for the escape from Malthusian trap
  - Income support for the poor much less important
  - Structural change favors capital-intensive industry sectors
- Failed industrialization due to negative shocks following high-income periods or short duration of positive shocks
- Above 90% probability that England‘s labor share in manufacturing exceeds 40% in 1850
- Chance plays a major role for the extent of industrialization in England
- France could also have industrialized by 1850, but with lower growth and lower manufacturing shares; China is likely to stagnate acc. to our calibrations.

Ideas vs. Micro-inventions

Leonardo da Vinci, 1452-1519



20th Century

In Britain, [...] the private sector on its own generated the technological breakthroughs and, more importantly, adapted and improved these breakthroughs through a continuous stream of small, anonymous "microinventions" which cumulatively accounted for the gains in productivity. [Mokyr, 1995]

Literature

- Unified growth theory:
  - Transition driven by exogenous TFP growth in modern sector and fixed land supply in agriculture [Hansen and Prescott (2002)]
  - Endogenous quality/quantity tradeoff based on the speed of technological change → Virtuous circle: higher human capital raises technological progress, which in turn raises the value of human capital [Galor and Moav (2000); Galor and Weil (2000); Jones (2001)]
- Unanswered issues:
  - Human capital (education) initially not crucial [Clark 2003]
  - Structural change, not fast TFP growth is key
  - No sudden take-off, instead slow, sustained growth [Crafts and Harley (1992)]
  - Probabilistic nature of IR: failed industrializations
  - Could other countries (France, China) have industrialized before England?

Historical Background

- England 1750-1850
  - Very slow growth over centuries (about 0.15% p.a.) before the IR
  - Output growth during IR initially slow, probably concentrated in only a few sectors; TFP growth rates also low but accelerating.
  - Many production methods not skill-using but skill-saving
  - Human capital (measured by literacy) increases slightly, from low levels, only after 1860 rapid gains
  - Labor share in agriculture falls rapidly
  - Capital share probably increases (growth of Y higher than of wL). Rise in K, K/L.

Trend Growth in England

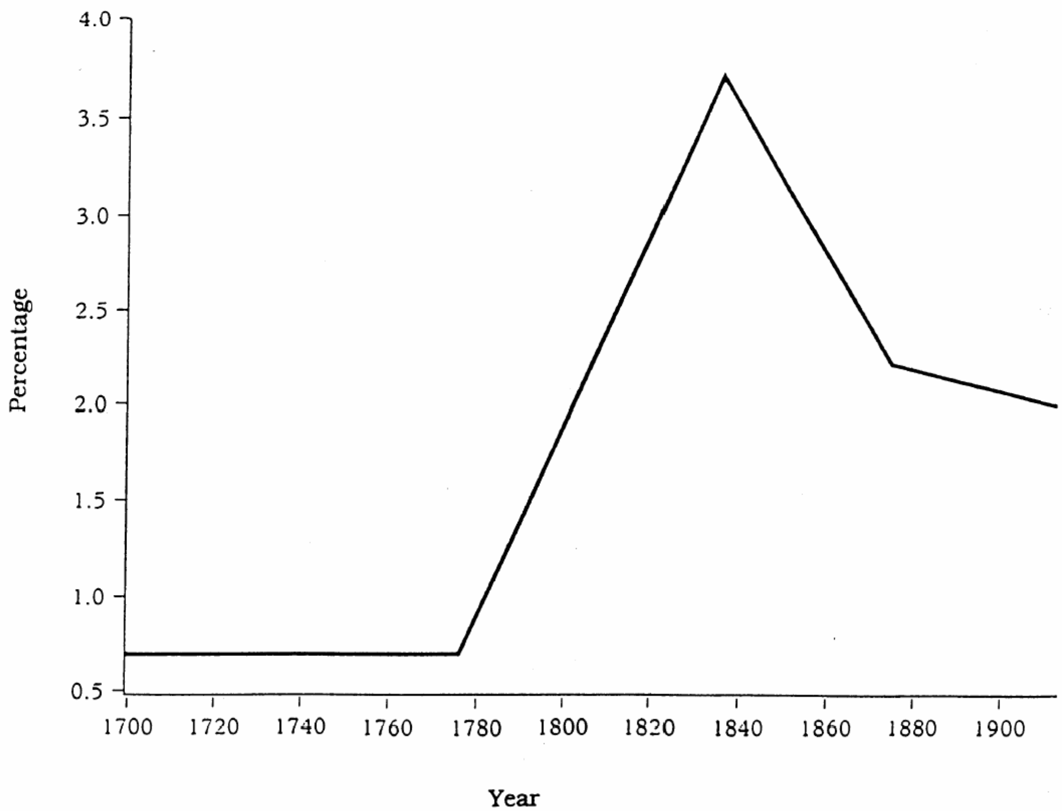


FIGURE 1

TREND GROWTH IN INDUSTRIAL PRODUCTION

Source: Crafts, JEH 1995

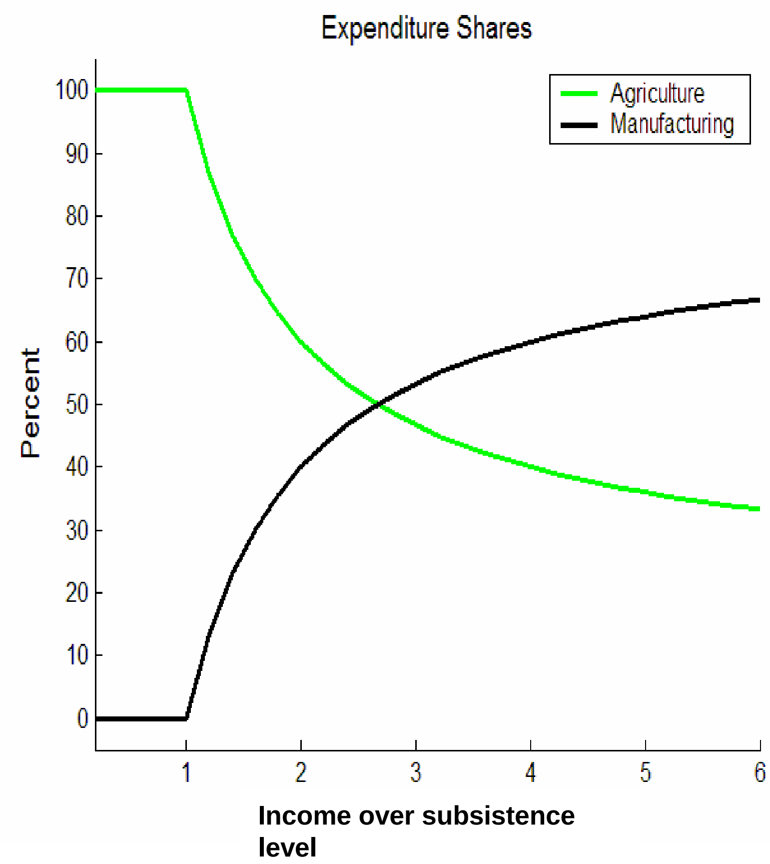
The Model – Consumption

- Population: N
- Two goods: Agriculture and manufacturing
- Stone-Geary preferences:

$$C = (c_A - \underline{c})^{\alpha} c_M^{1-\alpha}$$

- Intertemporal utility:

$$U(C_t) = \frac{C_t^{1-\psi} - 1}{1-\psi}, \quad \psi \geq 1$$



The Model – Final Good Producers

- Factors: Land (L), Labor (N), Capital Varieties [v(j)]
- Perfect competition, continuum [0,1] of firms
- Agriculture:

$$Y_A = A_{A,t}\left[\int_0^J \nu_A(j)^{\frac{1}{1+\varepsilon}} dj\right]^{\phi(1+\varepsilon)} N_A^{\mu} L^{1-\phi-\mu}$$

where $j \in [0, J]$ are capital varieties

- Manufacturing:

$$Y_M = A_M\left[\int_0^J \nu_M(j)^{\frac{1}{1+\varepsilon}} dj\right]^{\eta(1+\varepsilon)} N_M^{1-\eta}$$

The Model – Capital Producers

- Capital Variety Production:

$$\nu(\tilde{j}) = A_J \left[\int_0^J \nu_{\tilde{j}}(j)^{\frac{1}{1+\epsilon}} dj \right]^{\eta(1+\epsilon)} N_{\tilde{j}}^{1-\eta} \quad - \quad F$$

where F is a fixed cost of variety production

Representation with Aggregate Externality

- Under symmetry and $F = \varepsilon$ the model simplifies:
- Agriculture:

$$Y_A = A_{A,t} K^{\phi\varepsilon} K_A^{\phi} N_A^{\mu} L^{1-\phi-\mu}$$

- Manufacturing:

$$Y_M = A_M K^{\eta\varepsilon} K_M^{\eta} N_M^{1-\eta}$$

[Produces capital varieties and manufacturing consumption goods]

Solving the Model

- Standard FOC for consumption and production:
  - $$\frac{p_A(c_A - \underline{c})}{p_M c_M} = \frac{\alpha}{1-\alpha}$$
  - $R_{K,A} = R_{K,M} = R_K$
  - $w_A = w_M = w$
- Goods and labor market clearing
- Consumption and savings from intertemporal optimization:

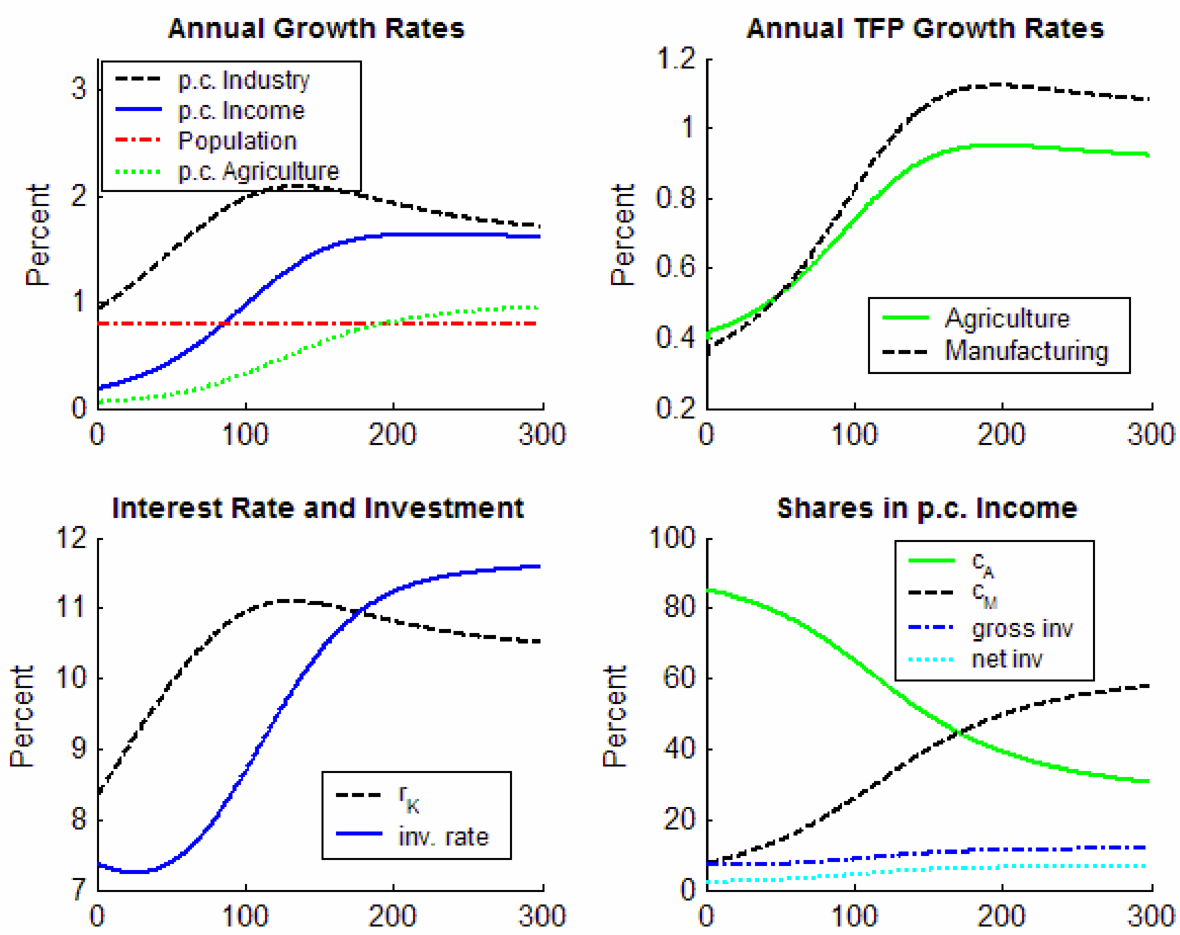
$$\left(\frac{1}{e_t - p_A \underline{c}}\right)^{\psi} = \frac{\beta}{g(c_t)} E\left[\left(\frac{p_{M,t+1}}{p_{M,t}}\right)^{\psi(1-\alpha)+\alpha} \left(\frac{1}{e_{t+1} - p_A \underline{c}}\right)^{\psi} (R_{K,t+1} + 1 - \delta)\right]$$

where e_t : expenditure

- LoM of the capital stock:

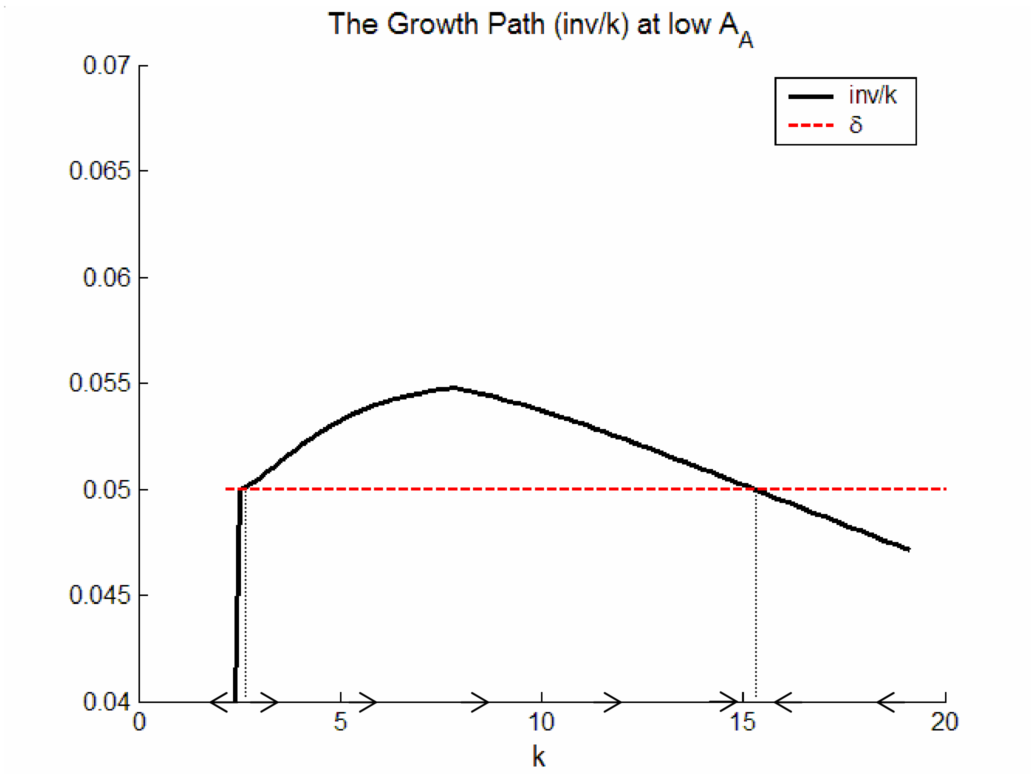
$$K_{t+1} = (1-\delta) K_t + Y_t - E_t$$

Basic Results with *Constant* Population Growth



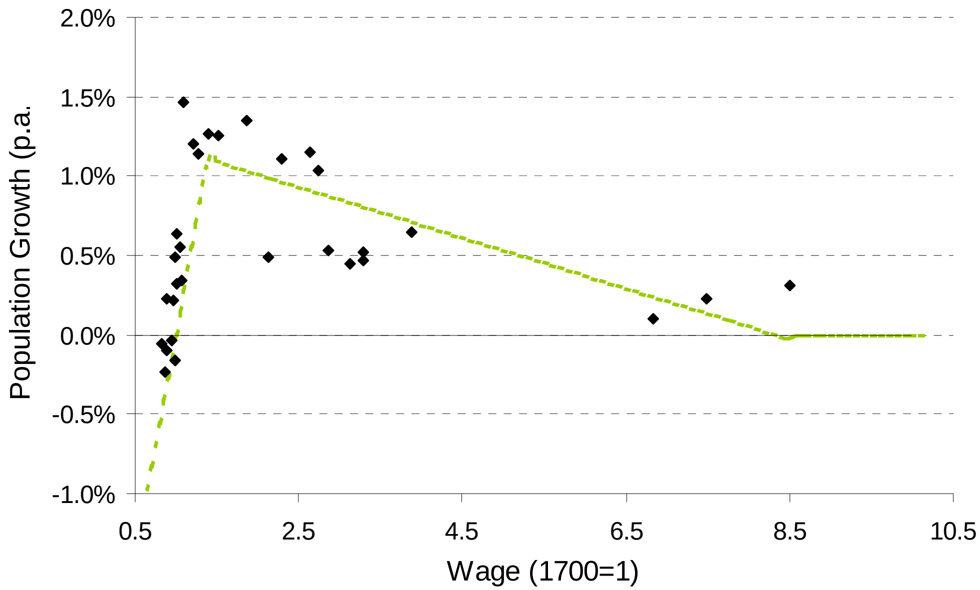
Transitional Dynamics w/o Population Growth

- Steady State: $\bar{y} - \bar{e} = \delta \bar{k}$



Population Dynamics – Preventive Check

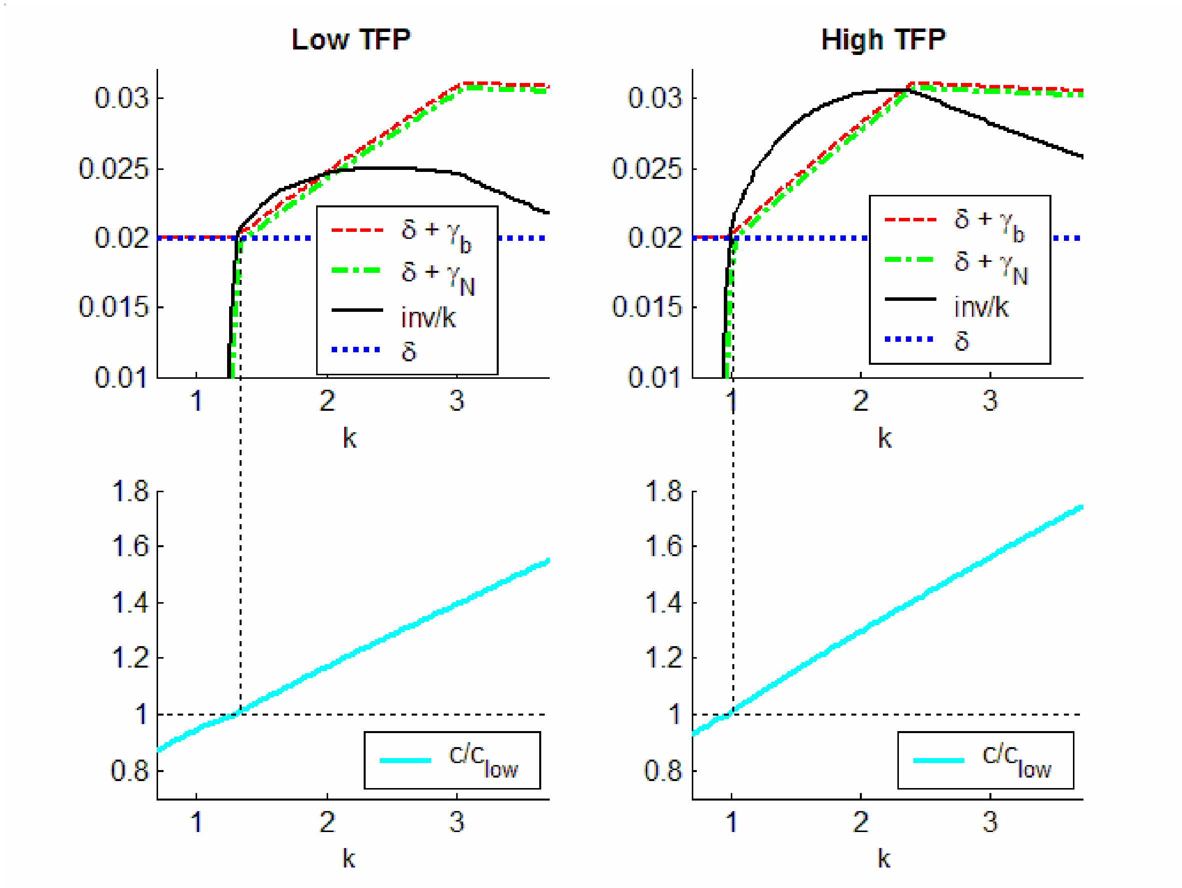
- Similar to Hansen and Prescott (2002), but adjusted for British population growth data:



- Net birth rate: $\gamma_b = g_b\left(c_t / \underline{c}\right) - 1$
- Survival rate: $g_s = \min(c_t / \underline{c}\,,\ 1)$
- Net population growth: $\gamma_N = \mathrm{g_b} g_s - 1$

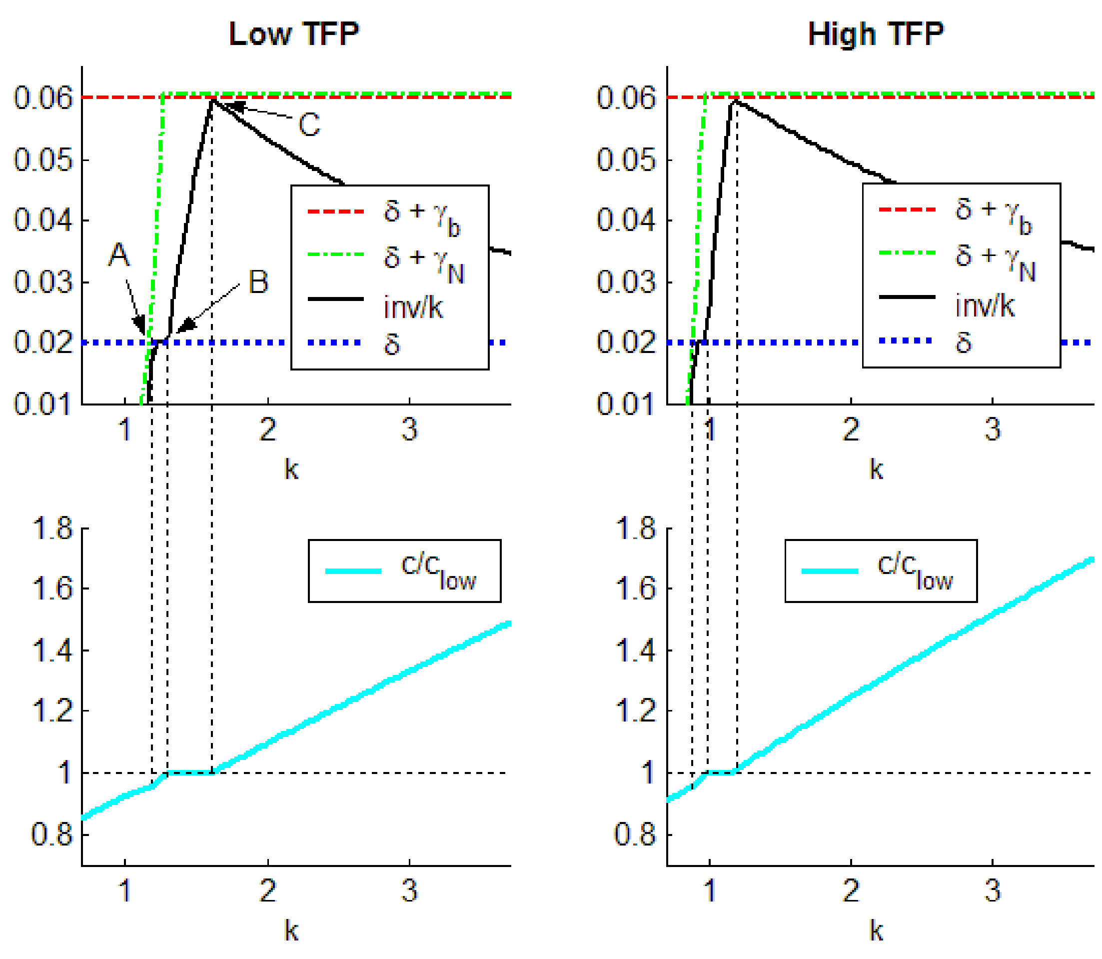
The Role of Population Growth – England

- Steady State: $\frac{\bar{y}-\bar{e}}{p_K} \equiv \overline{\text{inv}} = [\gamma_N + \delta]\bar{k} \quad \Rightarrow \quad \boxed{\frac{\overline{\text{inv}}}{\bar{k}} = \gamma_N + \delta}$

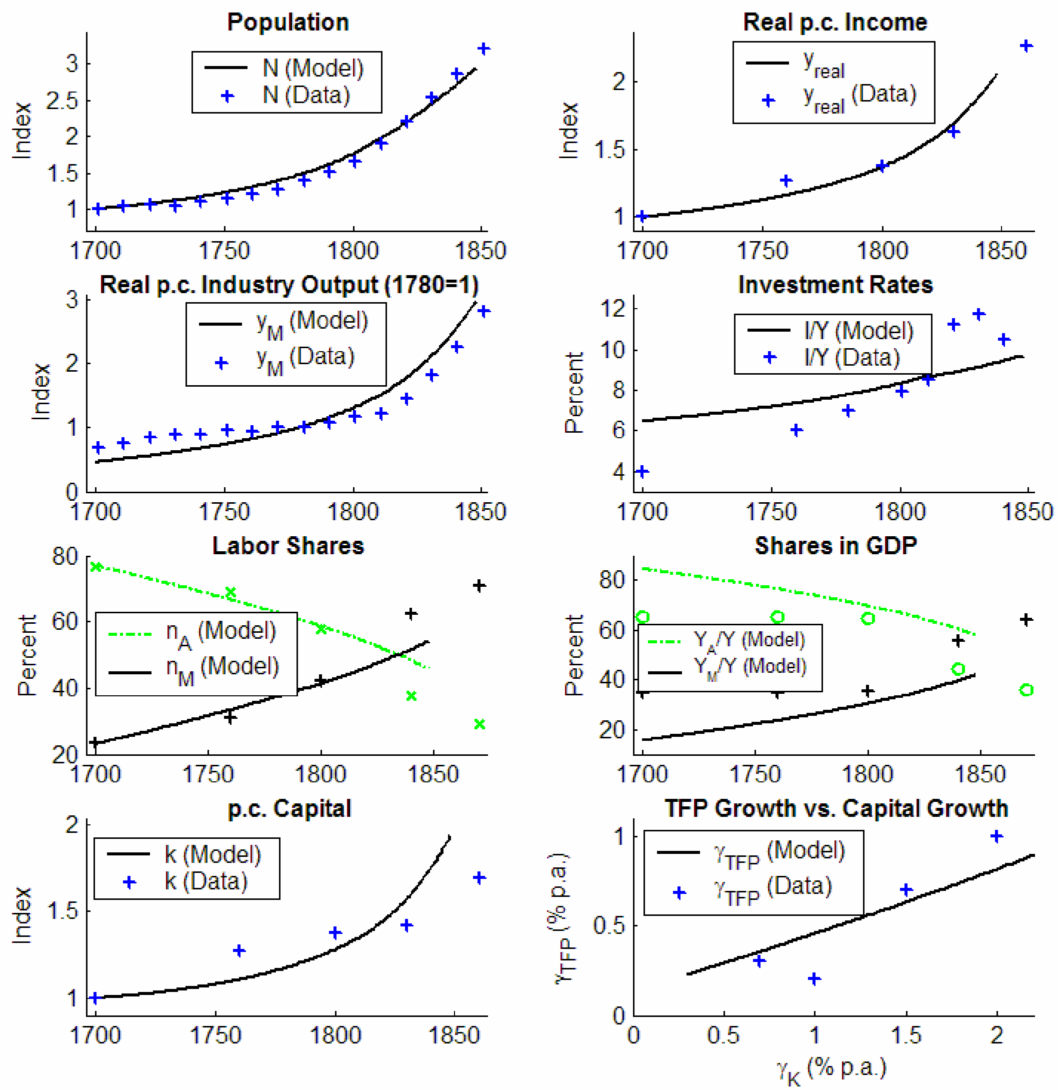


Population Growth – Positive Check: China

- Net birth: $\gamma_b =$ constant

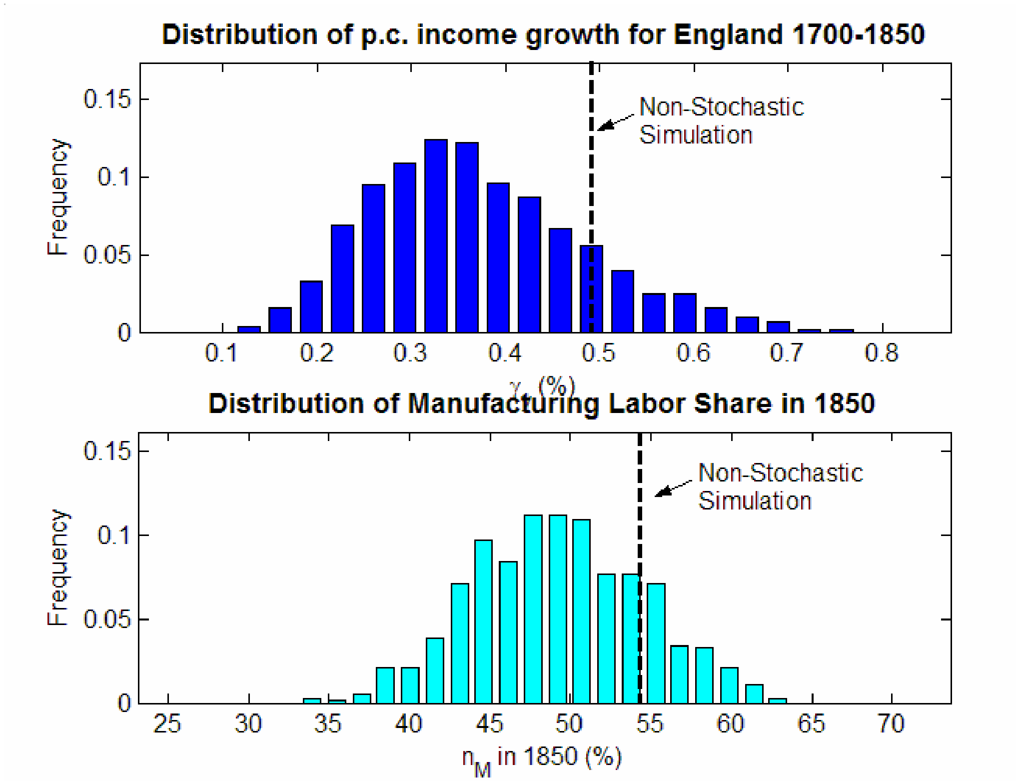


Simulation Fit to Actual Data



Probabilistic Experiment

- Use baseline model with calibrated shocks to agricultural productivity
- Simulation for 1700-1850



Historical Comparative Data and International Calibrations

Table 4: Income, Urbanization and Population Growth in other Countries

	p.c. income (in 1990 Geary-Khamis dollars)		Population growth (% p.a.)		Urban Shares (%)		N_M/N* (%)
Year	1700	1820	1700-1820	1820-1850	1700	1800	1700
England	1250	1706	0.76**	0.83	13.3	20.3	23
France	910	1135	0.31	0.51	9.2	8.8	16
China	600	600	0.85	0.26	6.0	3.8	10

Sources: Maddison (2003) for p.c. income and population growth; Vries (1984) and Rozman (1973) for urban shares.

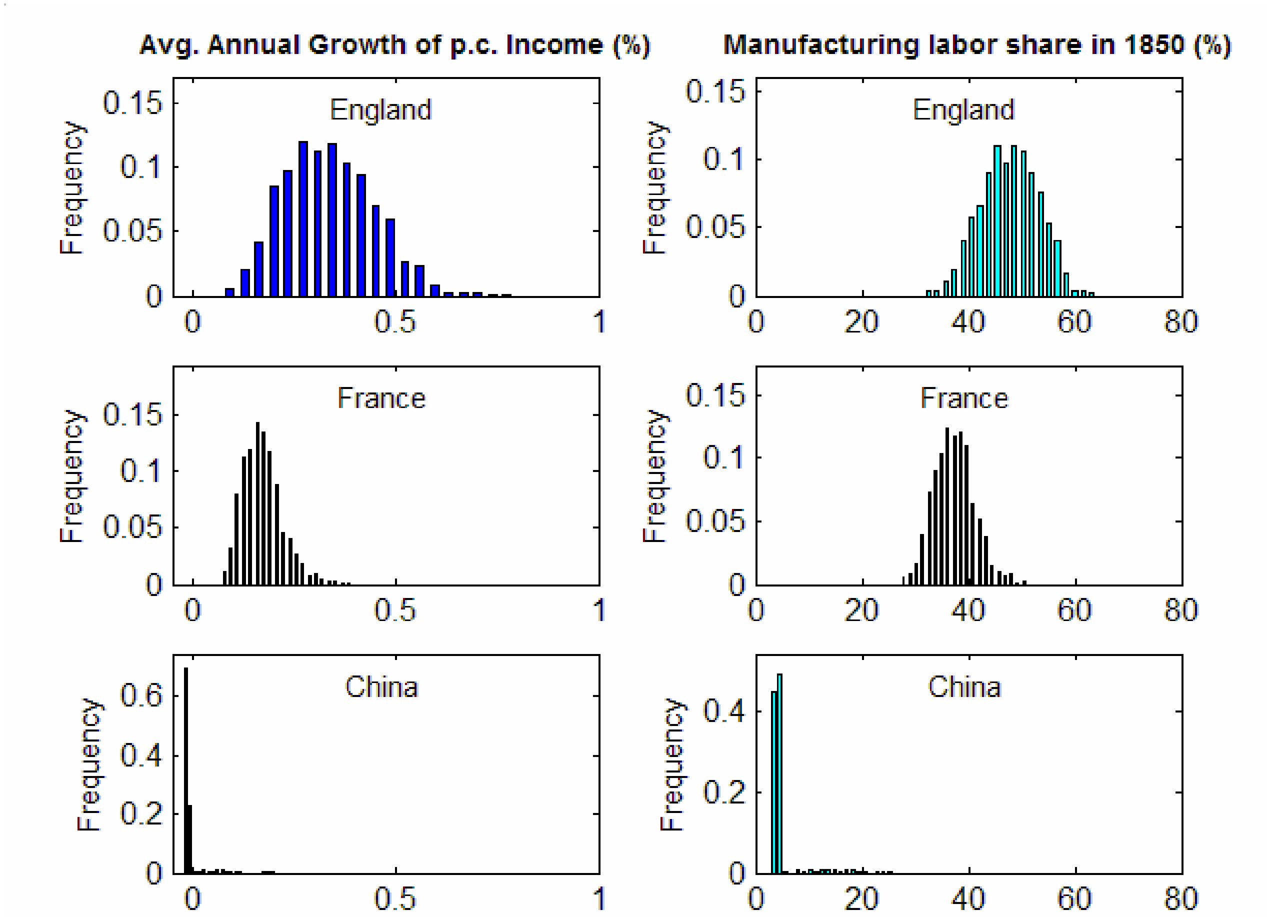
*Manufacturing Labor Share. For England: Calculated from Crafts (1985), leaving out services. For France and China: Author's calculation based on urban shares.

**1701-1751: 0.25%, from Wrigley and Schofield (1981)

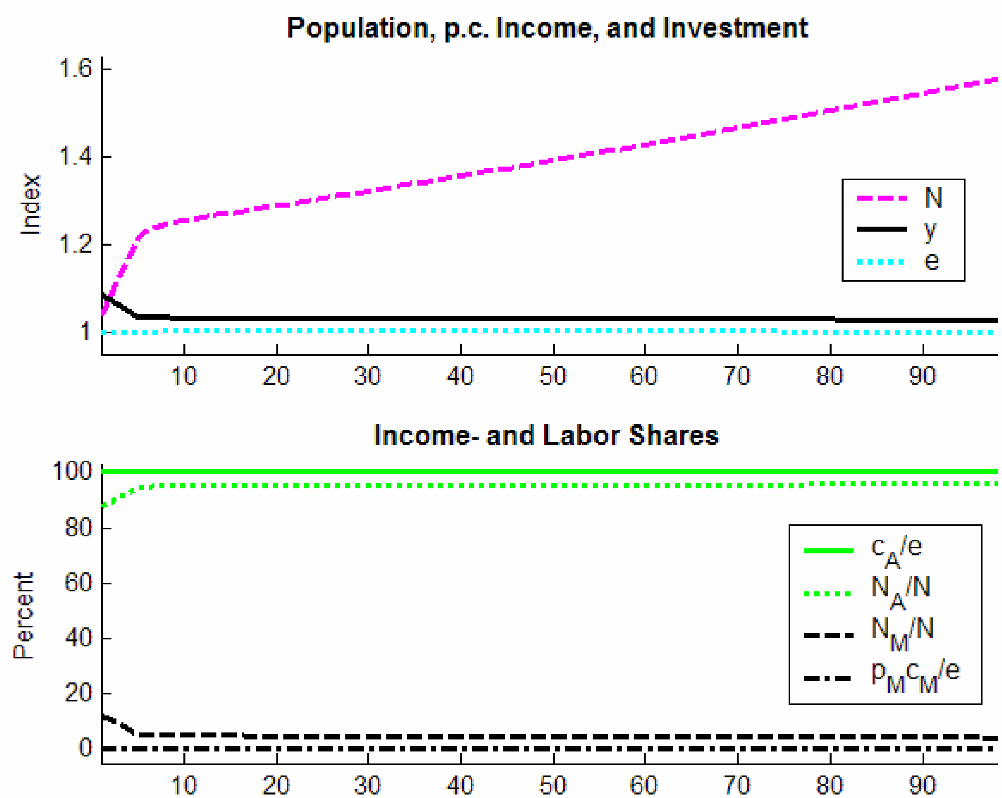
Table 5: Calibration of Initial Conditions in Cross-Country Simulations

	$\frac{N_A}{N}$	γ_b	γ_N	$\frac{c}{\underline{c}}$	$\frac{c_A}{e}$	$\frac{Y_A}{Y}$
England	0.77	0.29%	0.29%	1.106	0.901	0.846
France	0.84	0.32%	0.32%	1.046	0.953	0.895
China	0.92	4.0%	0.80%	0.969	1.000	0.948

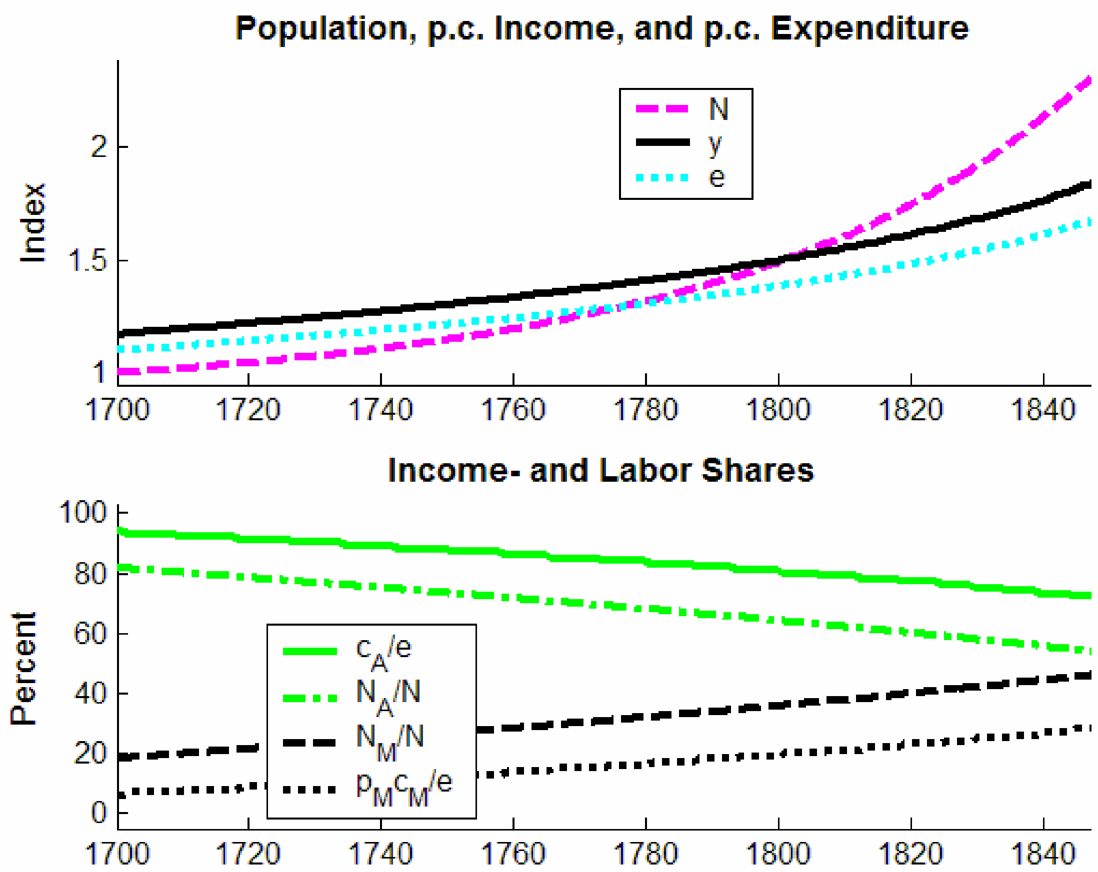
Comparative Results



Counterfactual I: England in 1700 with Chinese Demography



Counterfactual II: China in 1700 with English demography



Conclusions

- A simple 2-sector model can capture key dynamics of transition from Malthusian stagnation to growth
- Aggregate externatities explain the slow, accelerating growth rates observed in England
- Stone-Geary preferences allow us to model the shift out of agriculture
- Probabilistic nature of take-off captured → important role
- Population dynamics are key component – European marriage pattern

backup

Calibration (I)

Parameters

$\alpha = 0.3$ -- share of agriculture in (developed) consumption

$\phi = 0.25$ -- capital share in agriculture

$\mu = 0.4$ -- labor share in agriculture

$\eta = 0.35$ -- capital share in manufacturing

$\underline{c} = 1$ -- minimum consumption requirement in agriculture

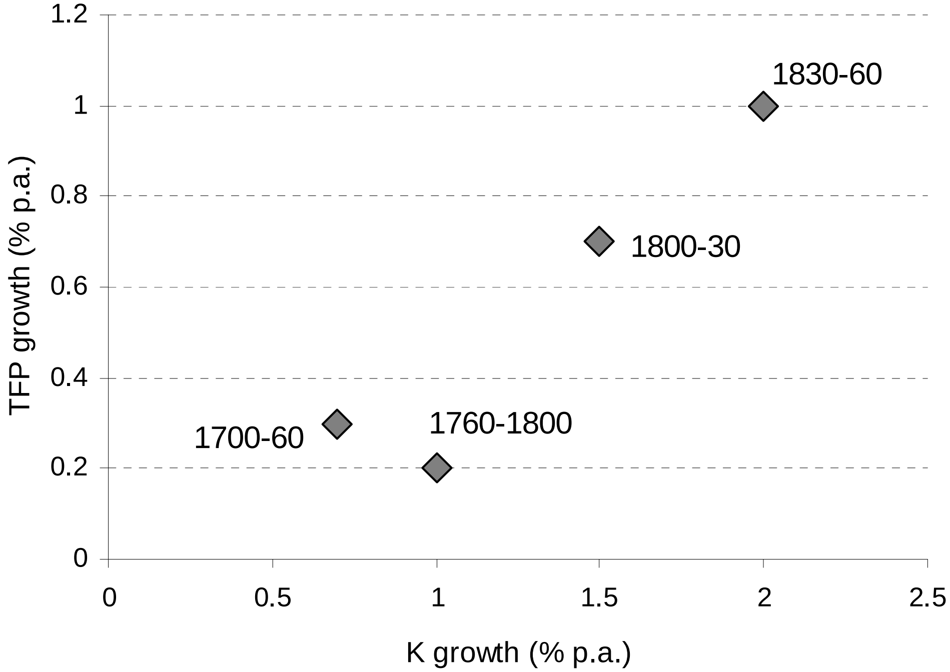
$\delta = 0.02$ -- capital depreciation

$\beta = 0.93$ -- intertemporal rate of time preference

Calibration (II)

- Aggregate Externality:

$$TFP_M = A_M K^{\eta\varepsilon} \quad \Rightarrow \quad \frac{\dot{TFP}_M}{TFP_M} = \eta\varepsilon \frac{\dot{K}}{K}$$



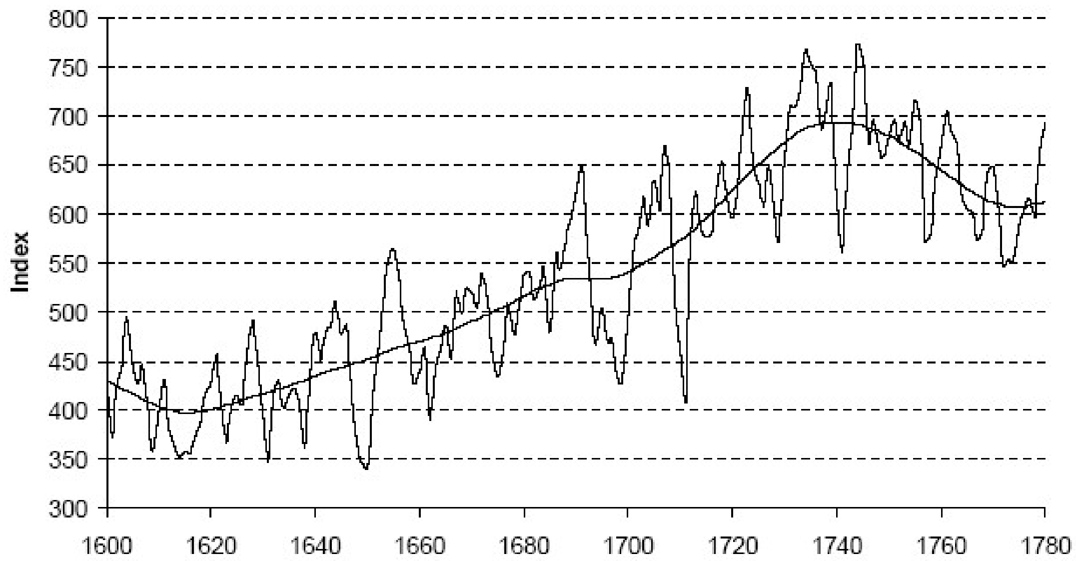
weighted LS (1700-1860):

$$\hat{\eta\varepsilon} = 0.44 \quad (0.06), \text{ no constant}$$

$$\Rightarrow \hat{\varepsilon} = \frac{0.44}{\eta} = 1.25$$

Calibration (III)

- Shocks to income
  - Real wage index for England 1600-1780 and HP-filtered trend [Wrigley and Schofield (1997)]



$\Longrightarrow$ $\theta = 0.60$ (t=10.31), $\sigma_{\varepsilon} = 0.075$

Simulation Results: England 1700 - 1850