

S-SHAPED TRANSITION AND CATAPULT EFFECTS*

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Abstract

Among the rich economies of the world today, per capita output levels had typically diverged before converging to the per capita output level of the frontier economy. Since frontier economies have grown at stable rates, non-frontier economies display an S-shape aggregate transition path. Along this transition, there are "catapult effects": longer episodes of divergence are associated with faster subsequent rates of convergence to the frontier. In this paper, we construct and quantitatively assess a model of S-shaped transition with catapult effects. Deviations in per capita output from frontier economy levels are endogenous, while conventional growth accounting would classify these deviations as TFP differences.

Keywords S-shaped transition; catapult effects; TFP.

JEL Classification O11, O41, O57.

I Introduction

During the post war period, the levels of per capita output among the rich economies of the world displayed a remarkable convergence. This compelling fact has motivated the construction of aggregate models which can explain the growth dynamics of these economies. Lead by the post war data, such models feature (i) constant growth rates for frontier economies and (ii) falling growth rates for economies converging to the frontier economy levels of per capita output.

When we apply these features to longer time series beginning from the time of the Industrial Revolution, the assumption of constant growth rates in frontier economies is

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robust. However, the transition path to the frontier displays *rising* then falling growth rates which implies an S-shaped transition path for log per capita output. Specifically, we observe *divergence* in log per capita output relative to frontier economies, before convergence. The contribution of this paper is to construct and quantitatively assess a model of S-shaped transition.¹

Figure 1 shows the paths of log per capita output between 1820-2000 for countries with per capita output over \$12000 in 1998 (in 1990 US\$).² The log linear path of development in frontier economies such as the UK or US, clearly contrasts from the S-shaped paths of non-frontier economies, such as Korea or Japan. Figure 1 also reveals that among economies undergoing S-shaped transition, a longer period of divergence in log per capita income relative to the frontier, is associated with a faster subsequent rate of convergence. For the same economies, Figure 2 shows the number of years it takes for an economy to increase its per capita output from \$2000 to \$12000 is a falling (and remarkably linear) function of the first year it reached a per capita output level of \$2000.³ We label this the "catapult effect", which is an empirical target of our model.

In conventional growth or development accounting exercises, time series and cross-sectional differences in per capita output which are not accounted for by years of schooling, physical capital stocks, and labor force participation rates are labelled TFP differences. In our model, such unaccounted deviations in per capita output from the frontier economy levels are *endogenous*. In this sense, we provide a theory of TFP differences.

We consider a dual economy which makes a gradual compositional change from activities with zero labor productivity growth, the "traditional sector", to activities with positive exogenous labor productivity growth, the "modern sector". Despite the productivity growth differences, the two sectors coexist and aggregate productivity can remain

¹Phillips and Sul (2005) also document the S-shaped aggregate growth path for OECD economies since 1870, and for the economies in the PWT since 1960.

²Data from Maddison (2001). UAE is not included since it is an oil producing country. Luxemburg and Iceland are not included due to lack of data.

³Parente and Prescott (1994) show a similar figure for the number of years to go from \$2000 to \$4000 in 1990 US\$.

stagnant for a long while due to the presence of adjustment costs.

These adjustment costs are summarized by two assumptions (a) sector specific experience and (b) complementarity between labor and experience. The complementarity between labor and sector-specific experience implies that entry into the modern sector by young agents who supply labor, is limited by the stock of old agents who supply experience. Meanwhile, today's young entrants in turn determine tomorrow's stock of experience, and so on.

The speed and slope of transition to the steady state (where modern sector technology is used exclusively) depend on the initial distribution of experience across sectors. Despite a sustained productivity growth in the modern sector, aggregate output can remain stagnant for a long while, and then accelerates before decelerating, generating an S-shaped transition path.

Countries with a lower initial share of experience in the modern sector will remain stagnant for longer since it takes time for a significant share of workers to move into the modern sector. However, over time the incentives to move into the modern sector are greater as the productivity growth of the modern sector accumulates. Once a significant mass of the labor force is in the modern sector, the transition of the labor force to the modern sector begins to occur very rapidly. Intuitively, this generates the catapult effect.

In the quantitative analysis, we treat the Industrial Revolution as an unexpected arrival of exogenous productivity growth in the modern sector. We calibrate the model such that economies with different initial shares of experience in the modern sector are in steady states before the Industrial Revolution, and analyze their transition paths to the new steady state following the Industrial Revolution. For each economy we calibrate initial experience shares using non-agricultural labor shares as a proxy for the modern labor share in the data. We then assess whether the simulated paths of sectoral labor force transition and per capita output conform with cross country data over the period from 1820-2000. This analysis requires us to map simulated paths of labor efficiency (related to TFP) into implied paths of per capita output. We construct a method for evaluating

the long term TFP elasticity of per capita output using cross country time series data, and compare with existing results which have used cross sectional data from the US.

The paper is organized as follows. Section II reviews the related literature. Section III introduces the model. Section IV discusses the calibration procedure. Section V discusses the simulation results. Section VI concludes.

II Literature

The theoretical contribution of this research is to show that combining labor-experience complementarity and dual economy transition generates S-shaped aggregate growth dynamics. Chari and Hopenhayn (1991) consider the role of technology-specific labor-experience complementarity in a steady state framework (linear aggregate growth). In a multi-sector economy, Kremer and Thomson (1998) show when labor and *skill* are complements (where the level of skill is a decision variable), the aggregate transition path to steady states must be concave. We show when labor and *experience* are complements, the transition path will be convex before becoming concave in a dual economy, generating the S-shaped transition key to the analysis. The empirical contribution of this paper is that (to the best of our knowledge) this is a first attempt at applying mechanisms of labor-experience complementarity to account for levels and dynamics of cross country inequality.⁴

Klenow and Rodríguez-Clare (1997) and Caselli (2005) show that adding *aggregate* experience in measuring human capital plays virtually no role in accounting for cross-country income differences. Our model suggests that the relevant state variable is the *distribution* of sector-specific experience rather than aggregate experience. Incorporating this will reduce the size of TFP in growth and development accounting.

The importance of transition to modern economic growth is emphasized by Kuznets (1966), Lucas (2000) and Galor (2005) among others. A large literature has analyzed

⁴A recent paper by Beaudry and Francois (2005) shows theoretically how labor experience complementarities can also generate multiple steady states in a multi sector model.

why economies can differ in the timing of their transitions. Recent contributions include Gollin, Parente and Rogerson (2002), Restuccia, Yang and Zhu (2003), Lucas (2004), Ngai (2004), and Galor (2005).⁵ They explain the different timing of transitions by exogenous productivity differences in the modern sector across countries, exogenous productivity differences in the agricultural sector across countries combined with barriers to international trade, or externalities in factor accumulation which induce multiple equilibria. We agree these are important features of data. We show how a framework without these features can still account for the varied transition dynamics across economies.

In a companion paper, Jeong and Kim (2006), we confirm using individual earnings data for Thailand for 1976-1996 that detailed occupational categories can be partitioned into zero and positive labor productivity growth activities. Our estimates of technology parameters confirm the presence of sector specific labor-experience complementarity.⁶ The current model differs from that paper in that we allow experience to accumulate across generations. Allowing for this improves the quantitative performance of the model in explaining cross country growth outcomes.

III Model

Consider a two-period overlapping generations economy with constant cohort population normalized to 1. Lifetime preferences are

$$(1) \quad u = c_1 + \beta c_2, \quad \beta \in (0, 1),$$

where β is a discount factor. From the linear preferences, the equilibrium interest factor is $R = \frac{1}{\beta}$. The lifetime budget constraint is given by

$$(2) \quad c_1 + \beta c_2 = y_1 + \beta y_2.$$

⁵The nature of transition studied varies from (i) traditional to modern, (ii) agriculture to non-agriculture, (iii) rural to urban.

⁶In our related work Jeong, Kim and Manovskii (2006), we also confirm the presence of labor experience complementarity for the US. Modelling the US as a one sector economy where modern transition is complete, we find the complementarity plays an important role in explaining wage dynamics observed in the PSID.

A homogenous good is produced in either the traditional sector or the modern sector. The efficiency units of labor $LY_{k,t}$ in sector k at date t is a constant returns to scale function of raw labor $L_{k,t}$ and sector-specific experience $E_{k,t}$, ($k = T$ for traditional sector and M for modern sector) such that

$$(3) \quad LY_{T,t} = G(L_{T,t}, E_{T,t}),$$

$$(4) \quad LY_{M,t} = \gamma^t XF(L_{M,t}, E_{M,t}).$$

The key identifying assumption of the modern sector is there exists sustained exogenous growth in labor productivity, i.e. $\gamma > 1$, which is absent in traditional sector.⁷ X is a parameter governing the relative productivity level between the two sectors. Aggregate efficiency units of labor LY_t at date t is

$$(5) \quad LY_t = LY_{T,t} + LY_{M,t}.$$

In each sector, labor and experience complement each other, that is

$$(6) \quad G_{L_{T,t}E_{T,t}} \geq 0 \text{ and } F_{L_{M,t}E_{M,t}} \geq 0.$$

Young agents supply one unit of raw labor either to the traditional sector or to the modern sector. Once old, they acquire and supply experience specific to the sector they work in when young. We assume the experience acquired by old agents can be *disembodied* in the following sense. Old agents transfer their experience to the next generation through "firms" who supply this experience in production even after the old agents have passed away. We attempt to capture the idea that experience can improve output over generations even when the agents who first acquired this experience have retired. Allowing this mechanism improves the quantitative performance of the model.⁸

Let N_t and M_t denote the measures of young agents who enter the traditional and modern sectors respectively in period t . That means $L_{T,t} = N_t$ and $L_{M,t} = M_t$. Let λ

⁷The parameter γ represents the exogenous growth factor in the real value of output from either advances in production techniques or due to demand effects, which we do not distinguish.

⁸Sector-specific complementarity alone, without this intergenerational transfer, still generates the key qualitative features such as S-shaped transition and the catapult effect. Such a model is developed in Jeong and Kim (2006).

be the depreciation factor of experience across generations (which is common between sectors), and S_k the finite number of future generations for which current experience affects output in sector k .⁹

The resource constraints are

$$(7) \quad \begin{aligned} 1 &= N_t + M_t \\ E_{T,t} &= \sum_{s=0}^{S_T} N_{t-s-1} \lambda^s, \quad E_{M,t} = \sum_{s=0}^{S_M} M_{t-s-1} \lambda^s \end{aligned}$$

Note that $N_t = 1 - M_t$ and the state of the economy in period t is $\mathbf{M}_t \equiv \{M_j\}_{j=t-1-\max\{S_T, S_M\}}^{t-1}$. The initial state \mathbf{M}_0 is given.

We consider a decentralized economy where firms hire young and old workers from competitive labor markets, and offer workers wages equal to marginal products. Specifically, each period, the firm pays young workers their marginal product of labor and old workers their marginal product of experience for the contribution to current output. Firms also pay today's old workers the marginal product of their experience for the contribution to future output (subject to discount factor λ) over an additional S_k periods. We define the difference between current output and total payments of firms to young and old workers as “dividend”. Firms earn dividends accruing from the marginal products of accumulated experience from previous generations.

In the following analysis, we consider a parsimonious version of the model where there is no complementarity between labor and experience in the traditional sector. Under this assumption, the marginal product of labor (denoted by w_T) and the marginal product of experience (denoted by e_T) in traditional sector are constant over time since G becomes a linear function of labor and experience. For a young agent entering the traditional sector, the present value of lifetime earnings is the sum of (i) the marginal product of labor when young w_T , (ii) the discounted marginal product of experience when old βe_T plus (iii) the discounted marginal product of his experience in future periods after he leaves the labor

⁹ $S_k = 0$ implies the experience of current old agents in sector k does not transfer to future generations.

market $\beta e_T \sum_{s=1}^{S_T} (\beta\lambda)^s$. This lifetime earnings is

$$(8) \quad \Gamma \equiv w_T + \beta e_T \sum_{s=0}^{S_T} (\beta\lambda)^s.$$

This is constant across generations and over time.

The present value of the lifetime earnings in modern sector can be characterized as follows. Defining $f\left(\frac{L_{M,t}}{E_{M,t}}\right) \equiv \frac{F(L_{M,t}, E_{M,t})}{E_{M,t}}$, the marginal product of labor is $\gamma^t X f'\left(\frac{L_{M,t}}{E_{M,t}}\right)$ and the marginal product of experience is $\gamma^t X \left[f\left(\frac{L_{M,t}}{E_{M,t}}\right) - f'\left(\frac{L_{M,t}}{E_{M,t}}\right) \frac{L_{M,t}}{E_{M,t}} \right]$ in modern sector. We define $\pi\left(\frac{L_{M,t}}{E_{M,t}}\right) \equiv \left[f\left(\frac{L_{M,t}}{E_{M,t}}\right) - f'\left(\frac{L_{M,t}}{E_{M,t}}\right) \frac{L_{M,t}}{E_{M,t}} \right]$. Complementarity of labor and experience in equation (6) implies f' decreases in $\frac{L_{M,t}}{E_{M,t}}$ while π increases in $\frac{L_{M,t}}{E_{M,t}}$.

For a young agent entering the modern sector in period t , the present value lifetime earnings is the sum of (i) the marginal product of labor when young $\gamma^t X f'\left(\frac{L_{M,t}}{E_{M,t}}\right)$, (ii) the discounted marginal product of experience when old $\gamma^{t+1} X \beta \pi\left(\frac{L_{M,t+1}}{E_{M,t+1}}\right)$, plus (iii) the discounted marginal product of his experience in future periods after he leaves the labor market $\gamma^{t+1} X \beta \sum_{s=1}^{S_M} (\beta\lambda\gamma)^s \pi\left(\frac{L_{M,t+1+s}}{E_{M,t+1+s}}\right)$. This lifetime earnings is

$$(9) \quad \gamma^t X \left[f'\left(\frac{L_{M,t}}{E_{M,t}}\right) + \beta\gamma \sum_{s=0}^{S_M} (\beta\lambda\gamma)^s \pi\left(\frac{L_{M,t+1+s}}{E_{M,t+1+s}}\right) \right].$$

In each sector, the value of firms consists of the discounted stream of future dividends. Recall the dividend is defined as the difference between current output and total payments of firms to young and old workers. The dividend $d_{T,t}$ for traditional firms at date t is

$$(10) \quad d_{T,t} \equiv e_T E_{T,t} - N_{t-1} \sum_{s=0}^{S_T} (\beta\lambda)^s e_T.$$

The dividend $d_{M,t}$ for modern firms at date t is

$$(11) \quad d_{M,t} \equiv \gamma^t X \left[\pi\left(\frac{L_{M,t}}{E_{M,t}}\right) E_{M,t} - M_{t-1} \sum_{s=0}^{S_M} (\beta\lambda\gamma)^s \pi\left(\frac{L_{M,t-1+s}}{E_{M,t-1+s}}\right) \right].$$

The value of firms in each sector at date t is

$$(12) \quad V_T(\mathbf{M}_t) = d_{T,t} + \beta V_T(\mathbf{M}_{t+1}), \text{ for traditional sector,}$$

$$(13) \quad V_{M,t}(\mathbf{M}_t) = d_{M,t} + \beta V_{M,t+1}(\mathbf{M}_{t+1}), \text{ for modern sector.}$$

In the modern sector, unlike the traditional sector, the value function depends on time due to the presence of exogenous productivity growth. In this two-period overlapping-generations economy, old agents own the firms. In the asset market, old agents sell firms to young agents after realizing dividends. Note if there is no intergenerational experience transfer (if $S_T = S_M = 0$), the value of firms in each sector is zero.

We do not model the economy before the "Industrial Revolution" which is our initial period. The Industrial Revolution is defined as an unexpected event where exogenous productivity growth first occurred in the modern sector. Before this event, we assume economies were in an initial steady state where traditional and modern sectors coexist, and the share of cohort entry into the modern sector $M_{-i} = M_0$ is constant for all $i \geq 0$. The latter implies the labor-experience ratio $\frac{L_{k,t}}{E_{k,t}}$ is constant at $\Lambda_k \equiv \sum_{s=0}^{S_k} \lambda^s$ for each sector k , at the initial steady state.

Define X_{IR} as relative productivity level that is consistent with the coexistence of the two sectors in the initial steady state such that

$$(14) \quad \Gamma \equiv X_{IR} \left[f' \left(\frac{1}{\Lambda_M} \right) + \beta \sum_{s=0}^{S_M} (\beta\lambda)^s \pi \left(\frac{1}{\Lambda_M} \right) \right].$$

This condition states that young agents are indifferent between entering the traditional or modern sectors in the initial steady state, and hence, the modern share of employment is indeterminate. Thus, economies can have different modern shares in initial steady states before the Industrial Revolution. For our empirical analysis, we date the Industrial Revolution at calendar year 1820.

A competitive equilibrium consists of a sequence of modern sector cohort shares $\{M_t\}_{t=0}^{\infty}$, such that in every period t ,

- (i) agents earn wages equal to their marginal product,*
- (ii) given interest factor R , agents choose which sector to work, and how much to consume each period to maximize their lifetime utility (1) subject to budget constraint (2), at wages and dividends implied by equations (8) to (13),*

- (iii) firms maximize value, and dividends are distributed to shareholders,
- (iv) resource constraints (7) are satisfied, and
- (v) asset markets clear.

In equilibrium, ex ante identical young agents in period t choose which sector to work in by comparing the sectoral lifetime earnings in (8) and (9).¹⁰ If young agents coexist in both sectors in period t , then $M_t \in (0, 1)$, and the lifetime earnings equalize across sectors. Then participation constraints during transition are

$$(15) \quad \Gamma = \gamma^t X \left[f' \left(\frac{M_t}{E_{M,t}} \right) + \beta \gamma \sum_{s=0}^{S_M} (\beta \lambda \gamma)^s \pi \left(\frac{M_{t+1+s}}{E_{M,t+1+s}} \right) \right].$$

Once young agents exclusively enter the modern sector at some specific endogenous date τ , the terminal participation constraints hold such that

$$\Gamma \leq \gamma^t X \left[f' \left(\frac{1}{E_{M,t}} \right) + \beta \gamma \sum_{s=0}^{S_M} (\beta \lambda \gamma)^s \pi \left(\frac{1}{E_{M,t+1+s}} \right) \right], \quad \forall t \geq \tau.$$

Transition is complete when the experience level first reaches its steady state level Λ_M in period $\tau + 1 + S_M$.

To solve for the equilibrium, we first guess τ starting from $\tau = 0$, and using the participation constraints solve for $M_t \in (0, 1) \forall t < \tau$, which is consistent with the initial state \mathbf{M}_0 . We then verify whether the terminal participation constraints hold. If $\tau \neq 0$, we try $\tau = 1$ and so on.¹¹

IV Calibration

Efficiency units of labor in the traditional sector are assumed to take the form

$$G(L_{T,t}, E_{T,t}) = (L_{T,t} + E_{T,t}).$$

¹⁰There is additional source of income from asset transactions, i.e., from dividends and the buying and selling of firms. These transactions are independent of working sector and hence not enter the lifetime income comparison in determining the sectoral labor supply choice.

¹¹Jeong and Kim (2006) characterize the equilibrium and prove uniqueness for the case where $S_T = S_M = 0$, i.e. no intergenerational transmission of experience.

This implies $w_T = e_T = 1$. The marginal productivity of labor equals the marginal productivity of experience in the traditional sector, and we measure output such that the marginal product of labor is unity. We further assume there is no intergenerational experience transfer in the traditional sector, i.e. $S_T = 0$.

Efficiency units of labor in the modern sector take the CES form

$$F(L_{M,t}, E_{M,t}) = (\alpha L_{M,t}^\mu + (1 - \alpha) E_{M,t}^\mu)^{\frac{1}{\mu}}.$$

We set $S_M = 2$, so modern experience is transferred over two generations subject to discount factor λ .

We define *labor efficiency* A_t such that

$$(16) \quad A_t \equiv \frac{G(L_{T,t}, E_{T,t}) + \gamma^t X F(L_{M,t}, E_{M,t})}{L_{T,t} + L_{M,t}}.$$

IV.1 Labor Efficiency Elasticity

Simulation of the model makes predictions on the path of labor efficiency A_t . Since we only observe historical data on per capita output $y_{i,t}$, we need a method of converting changes in A_t into changes in $y_{i,t}$. We outline this procedure and its justification here.

The aggregate production function of country i at date t is

$$(17) \quad Y_{i,t} = (A_{i,t} L_{i,t} h_{i,t})^\theta K_{i,t}^{1-\theta},$$

where $Y_{i,t}$ denotes total output, $A_{i,t}$ labor efficiency, $L_{i,t}$ the labor force, $h_{i,t}$ the human capital per worker from schooling, $K_{i,t}$ the physical capital stock, and θ the labor share. We construct a series of labor efficiency levels $\{A_{i,t}\}_{t=t_0}^T$ from the data $\{Y_{i,t}, L_{i,t}, h_{i,t}, K_{i,t}\}_{t=t_0}^T$ according to the aggregate production function in (17). We use PWT 6.1 data from 1960-1996 for $Y_{i,t}$, $L_{i,t}$ and $K_{i,t}$. The human capital $h_{i,t}$ from schooling is computed using the Barro-Lee (2001) educational attainment data, and following the imputation method of Hall and Jones (1999). We take $\theta = \frac{2}{3}$ as common across countries. The index of total factor productivity $TFP_{i,t} = A_{i,t}^\theta$. Full details of data construction are in the Appendix.

Let $k_{i,t}$ denote per worker capital stock, and $p_{i,t}$ the labor force participation rate (labor force size divided by population size). The growth rate of per capita output $y_{i,t}$ is then

$$(18) \quad \frac{\dot{y}_{i,t}}{y_{i,t}} = \theta \frac{\dot{A}_{i,t}}{A_{i,t}} + \theta \frac{\dot{h}_{i,t}}{h_{i,t}} + (1 - \theta) \frac{\dot{k}_{i,t}}{k_{i,t}} + \frac{\dot{p}_{i,t}}{p_{i,t}}$$

At annual frequencies, this is an accounting identity since the labor efficiency levels are constructed as residuals for each year from equation (17). However, at frequencies longer than a year, the relationship between per capita output growth and labor efficiency growth is no longer an identity. This is because in the long-run, factor accumulation and labor force participation respond to labor efficiency.

Figure 3 compares the relationship between $\frac{\dot{y}_{i,t}}{y_{i,t}}$ and $\frac{\dot{A}_{i,t}}{A_{i,t}}$ at the annual frequency and the relationship at the 36-year frequency for our sample countries during the 1960-1996 period.¹² The slope and intercept of this linear relationship vary by time frame. The slope becomes steeper and the intercept becomes closer to zero, the longer the frequency. We confirmed that these two trends are also evident at intermediate frequencies of 10-years and 20-years. This suggests that over longer time frames, factor accumulation and labor force participation are indeed correlated with the labor efficiency, implying the long run relationship $\frac{\dot{y}_{i,t}}{y_{i,t}}$ and $\frac{\dot{A}_{i,t}}{A_{i,t}}$ has intercept zero.¹³

Given these findings, we assume the following long-run relationship between per capita output and labor efficiency

$$(19) \quad y_{i,t} = A_{i,t}^\eta.$$

This specification implicitly assumes that in the long run, all changes in per capita output are driven (directly and indirectly) by changes in labor efficiency. The parameter η corresponds to the *labor efficiency elasticity of per capita output*. The TFP elasticity of per capita output is given by $\frac{\eta}{\theta}$.

¹²The 36-yearly data is calculated between 1960 and 1996, which is the longest time frame feasible for most countries in the PWT 6.1 data. Our sample countries are the same as Figure 1.

¹³Given the East Asian productivity growth debate, we also replaced the labor efficiency growth for Singapore, Taiwan, Hong Kong, and South Korea, using Hsieh's (2000) dual TFP estimates and labor shares. This makes the linear relationship between labor efficiency and per capita output more evident.

We estimate η from a linear regression of $\frac{\dot{y}_{i,t}}{y_{i,t}}$ on $\frac{\dot{A}_{i,t}}{A_{i,t}}$ assuming no constant, using the 36-year frequency data. Our benchmark estimate is $\hat{\eta} = 1.7$, with a standard error of 0.16. The adjusted R^2 is 0.83. We find this benchmark estimate is robust to alternative specifications and measurement of labor efficiency growth.¹⁴

The estimate of $\hat{\eta} = 1.7$ implies the TFP elasticity of per capita output is 2.6 at an aggregate labor earnings share of $\theta = \frac{2}{3}$. This is similar to the TFP elasticity of 2.8 obtained by Erosa, Koreshkova and Restuccia (2006). Manuelli and Seshadri (2005) obtain a substantially higher TFP elasticity of 8. These existing estimates are obtained by calibrating the human capital production function using cross-sectional earnings data for the US. We obtain our estimate using the long run cross-country growth relationship. Our estimate of $\hat{\eta} = 1.7$ implies an income gap of factor of 20 is consistent with a labor efficiency gap of factor of 5.8.

IV.2 Data proxy for modern sector labor share

Data on the partition of the economy into modern and traditional sectors are available neither from national income and products accounts nor from nationally representative micro surveys. We proxy modern sector labor shares by the non-agricultural labor force share. Because modern technologies are used in agriculture and traditional technologies are used in non-agriculture, the use of this proxy must be considered with caution. Farming high-yield varieties of wheat and rice during the Green Revolution in India, farming

¹⁴In our benchmark growth accounting, we imputed $h_{i,t}$ following Hall and Jones (1999), where the returns to schooling vary by the level of schooling, but the schedule of returns to schooling is common across countries. Klenow and Rodriguez-Claire (1997) allow the returns to schooling to vary across countries although the country-specific returns to schooling is constant over the level of schooling. We fixed the labor share at $\frac{2}{3}$ common across countries in our benchmark growth accounting. Caselli and Feyrer (2005), based on the data in Bernanke and Gurkaynak (2001) and Gollin (2002), reports country-specific labor shares. The constructed labor productivity measure depends on the specification. Thus, we allow the returns to schooling and the labor share to vary across countries and re-estimate η . Allowing country-specific returns to schooling as in Klenow and Rodriguez-Claire (1997), we get the estimate of η at 1.62 with a standard error of 0.17 and adjusted R^2 of 0.80. Allowing country-specific labor shares as in Caselli and Feyrer (2005), we get the estimate of η at 1.63 with a standard error of 0.18 and adjusted R^2 of 0.77.

Using Hsieh's (2000) dual TFP estimates and labor shares for East Asian countries, we estimate η at 1.69 with a standard error of 0.11 and adjusted R^2 of 0.91. Hsieh's (2000) dual TFP estimates depend on which rates of returns to capital investment is used. We take average of these in the estimation.

of some specific fruits such as pineapple in Ghana (see Conley and Udry, 2005), or shrimp farming in Thailand (see Jeong and Kim, 2006) are good examples of agricultural activities that belong to modern sector. On the other hand, some manufacturing and service activities such as metal processing by blacksmith or street vendor sales may well belong to traditional sector. That is, the biases of using non-agriculture labor share to represent modern sector labor share go both ways, cancelling each other, and hence the overall bias may not be large.

The non-agriculture labor share is likely to *overestimate* the modern labor share (mainly due to the presence of the traditional service activities) for the developing countries. This gap may become larger as the countries are poorer since the share of traditional sector in manufacturing and services may well be larger in poor countries. For the rich economies, however, agriculture is likely to be a modern sector and the non-agriculture labor share is likely to *underestimate* the modern labor share. To avoid these systematic errors, we do not use the non-agricultural labor share data when this share exceeds 90% or falls below 10%. The results indicate that the movements of non-agriculture labor share over time can be explained very well by those of predicted modern labor share in simulation.

In Jeong and Kim (2006), we were able to identify the partition of the economy into modern versus traditional sectors using individual earnings and occupational category data for Thailand between 1976-1996. Specifically, we identified a partition of occupational categories such that one set of occupations had no exogenous productivity growth and another had high and stable productivity growth. While this method conforms directly with the identification of sector, data limitations do not allow us to use this strategy for the present cross country analysis. However, our results from that research consistently suggest that using the non-agricultural labor share is a good proxy for the modern labor share. Despite the coexistence of traditional and modern sectors in agriculture and non-agriculture, we found that the traditional sector is prevalent in agriculture and the modern sector is prevalent for non-agriculture.

IV.3 Parameter selection

The parameters of the model are matched to fit the time series of per capita output and non-agricultural labor share for the US from 1820-2000, and the experience premium and dividend ratio for the US in 2000.¹⁵

Each period of the model corresponds to 30 years in the data. The Industrial Revolution is assumed to occur between 1820 and 1850 and is represented as the arrival of sustained exogenous increases in the productivity of the modern sector at factor γ from 1850 onwards. Thus $t = 0$ for 1820, and $t = 6$ for 2000. We assume agents treat the Industrial Revolution as unexpected, but from 1850 onwards they are fully aware of the future stream of productivity increases in the modern sector.

Initial experience shares are steady state experience shares, so the stock of modern sector experience in 1820 is given by, $E_{M,0} = \Lambda_M M_0$. The initial modern labor share for the US is $M_{0,US}$. The six parameters of the model are $(\beta, \mu, \gamma, \alpha, \lambda, X_{IR})$.

Once modern transition is complete, an economy reaches a new steady state where everyone works in the modern sector. The implied modern sector experience premium (ratio of earnings of old to young) in this state is given by¹⁶

$$(20) \quad EP^{ss} = \frac{(1 - \alpha)}{\alpha} (1 + \lambda + \lambda^2)^{\mu-1} (1 + \beta\gamma\lambda + (\beta\gamma\lambda)^2).$$

Assuming the US to have completed modern transition by the mid 20th century (which we verify using the simulation), we set parameters to be consistent with this ratio for the US data. Heckman, Lochner and Todd (2003) report the estimates of the US experience premium using a Mincerian specification for the 1940-1990 period using the Census data.¹⁷ We compute the implied experience-earnings profiles and take the ratio of average earnings of experience group of 0-9 to the average earnings of experience group of 30-39 as a measure of experience premium for EP^{ss} . The ratios in the data are 3.21, 3.32, 3.75, 3.84, 3.15,

¹⁵Our choice of the US as the benchmark economy is motivated by quality of historical and current data.

¹⁶Once transition is complete $L_{M,t} = 1, E_{M,t} = (1 + \lambda + \lambda^2)$. Applying our CES specification to $\frac{E_E}{E_L} (1 + \beta\gamma\lambda + (\beta\gamma\lambda)^2)$, we get this formula.

¹⁷See Table A1 in the Appendix for the estimates.

and 3.21 for the Census years of 1940, 1950, 1960, 1970, 1980, and 1990, respectively. We take the average of these values 3.4 for EP^{ss} in equation (20).

In the new steady state where modern transition is complete, the ratio of dividend to labor earnings is given by¹⁸

$$(21) \quad DR^{ss} = \frac{EP^{ss} \left(\frac{(1+\lambda+\lambda^2)}{(1+\beta\gamma\lambda+(\beta\gamma\lambda)^2)} - 1 \right)}{EP^{ss} + (1 + \lambda + \lambda^2)}.$$

We set parameters which are consistent with this ratio for the US today. To calibrate DR^{ss} , we use the National Income and Products Accounts (NIPA) data from the US Bureau of Economic Analysis (BEA) that reports various dividends data as well as personal income data.¹⁹ The average ratio of the total dividends to the normalized labor earnings is 0.22. Using domestic dividends, this ratio becomes 0.18. We take the average value 0.20 for DR^{ss} in equation (21).

The parameter selection procedure is as follows. We first fix values for $(\beta_0, \mu_0, \gamma_0)$ and solve for α and λ from the earnings equations (21) and (20) such that $\alpha_0 = \alpha(\beta_0, \mu_0, \gamma_0)$, and $\lambda_0 = \lambda(\beta_0, \mu_0, \gamma_0)$. Given parameters $(\beta_0, \mu_0, \alpha_0, \lambda_0)$, we solve for X_{IR} that satisfies the initial steady-state condition (14) such that

$$X_0 = X_{IR}(\beta_0, \mu_0, \alpha(\beta_0, \mu_0, \gamma_0), \lambda(\beta_0, \mu_0, \gamma_0)) \equiv X(\beta_0, \mu_0, \gamma_0).$$

Next, we choose $(\beta_0, \mu_0, \gamma_0)$ that best match the transition paths of modern sector labor share and the per capita output of US for the 1820-2000 period, using a root-mean-squared-error (RMSE) criterion at the given initial modern labor share for the US,

¹⁸The dividend and labor earnings in the modern sector are defined in equations (4) and (11). Applying our CES specification for $F(L_{M,t}, E_{M,t})$ to (4) and (11), we get this formula.

¹⁹We take total compensation to employees, which includes wages and salary disbursement and supplemental compensation such as employer contribution to employee pension and insurance funds, as our labor earnings measure. Then, we normalize this earnings data by the per worker human capital from schooling $h_{i,t}$, which is not in the model but in the data. There are two main categories of dividends data, “domestic” and “rest of world.” The “rest of world” dividends measure the earnings of U.S. residents remitted by their unincorporated foreign affiliates. We compute the dividends ratios using both total dividends and domestic dividends. Table A2 in Appendix A reports the raw data.

$\hat{M}_{US,0}$.²⁰ That is

$$(22) \quad (\beta, \mu, \gamma) = \arg \min_{(\beta_0, \mu_0, \gamma_0)} \left\{ \sum_{t=0}^6 \left[\frac{M_t^s - M_{US,t}}{M_{US,t}} \right]^2 + \left[\frac{y_t^s - y_{US,t}}{y_{US,t}} \right]^2 \right\}^{\frac{1}{2}}.$$

$\{M_t^s\}_{t=0}^6$ and $\{y_t^s\}_{t=0}^6$ are the paths of modern sector labor share and the log per capita output simulated from the model at the parameters $(\gamma, X_0, \beta_0, \lambda_0, \alpha_0, \mu_0)$, and at the initial modern labor share of US $\hat{M}_{US,0}$. $\{M_t^{US}\}_{t=0}^6$ and $\{y_t^{US}\}_{t=0}^6$ are the actual paths of modern sector labor share and the per capita output of US for the 1820-2000 period. Per capita output data are obtained from Maddison (2001). Non-agricultural labor shares are obtained from Mitchell (2003).

The initial modern share for the US is set at $\hat{M}_{US,0} = 0.33$. Applying the above calibration procedure, the benchmark parameter values chosen are reported in Table I. $\gamma = 1.24$ implies an annual growth factor of 1.007. $\beta = 0.05$ implies an annual discount factor of 0.904. $\lambda = 0.24$ implies an annual discount factor of 0.954.

TABLE I. Benchmark Parameter Values

Parameter	γ	β	μ	α	λ	X_{IR}
Value	1.24	0.05	-1.50	0.14	0.24	3.85

V Simulation

At the chosen parameters, we simulated the paths of per capita output and modern labor share for hypothetical economies differentiated only by their initial modern labor share in 1820. Figure 4 shows that economies with lower initial modern shares are poorer in 1820, and their per capita output levels remain stagnant for longer, the lower the initial share. The simulated labor efficiency is converted to per capita output according to (19) at $\hat{\eta} = 1.7$. The documented pattern of S-shaped transition and catapult effect are evident in the simulation. In 1820, a simulated economy with 50% labor share in the modern sector is 2.4 times richer than an economy with 1% labor share in the modern sector.

²⁰The actual $\hat{M}_{US,0} = 0.3$. We adjust $\hat{M}_{US,0}$ in the range (0.25, 0.35) that best generates the dynamic path of the US modern labor share.

In 2000, that economy is 17.2 times richer. Figure 5 shows that S-shaped transition and catapult effects are also evident for the modern labor shares.

A key feature of cross country inequality displayed in Figure 4 is that the magnitude of divergence of per capita output is amplified at low levels of initial modern labor share. For instance, the maximum gap in log per capita output along the transition path between two economies with initial shares of 0.5 and 0.1 is much smaller than the maximum gap between two economies with initial shares of 0.1 and 0.01. This feature goes a long way in explaining why the gap in ratios of per capita output observed between Japan and Korea during the 1970s was never observed between the UK and US, despite larger absolute differences in modern labor shares (as proxied by non-agricultural labor share) between the UK and US.

The general point to make here is that economies with low initial modern shares (say below 0.1) look very similar in terms of per capita output and economic structure in 1820. However, small differences in the initial modern shares can translate into big differences in per capita output along the transition path. Comparing Figure 4 with Figure 1 (which use the same scale and normalization) we see that the model is able to generate dynamics of per capita output which fit well the evolution of cross country inequality in the data.

Using the information in Figure 4, we can assess the model's performance in capturing the catapult effect documented in Figure 2. For economies differentiated by their initial modern labor shares, Table II shows the first year that simulated per capita output reaches \$2000 versus the simulated number of years for per capita output to grow from \$2000 to \$12000. Comparing these numbers with the plot of Figure 2, the model does a remarkable job in matching the pattern and magnitude of the catapult effect. The model suggests that the miracle economies of the future will be ever more spectacular: an economy reaching the per capita output level \$2000 in 1977 is predicted to grow six fold in 39 years!²¹

TABLE II. First year \$2000 reached versus years taken to reach \$12000

²¹The US economy is simulated with initial modern share of 0.33. We equate the per capita income of this simulated economy with that of the US in 1820. This implies a per capita output level of \$2000 corresponds to 0.46 and \$12000 corresponds to 2.26 of the log scale in Figure 4.

First year	1843	1873	1902	1935	1960	1977
Years taken	93	83	69	55	48	39

Figure 6 documents the dynamics of the non-agricultural labor share in the data for the same countries as Figure 1. Comparing Figure 5 with Figure 6, the model captures the overall dynamics of the modern share in the data, proxied by non-agricultural labor share.

Using the parameter values calibrated from the US time series, we assess the ability of the model to predict the dynamics of non-agricultural labor share and per capita output for other economies. For each economy, we calibrate an initial modern labor share in 1820 consistent with the path of non-agricultural labor share during the years for which data is observed. Then for each economy we simulate the dynamics of per capita output from 1820 onwards and compare with data.

Note the calibrated parameter $X = X_{IR}$ from (14), ensures the lifetime earnings are equalized between sectors in 1820. However, due to discounting when the earnings profile of workers in the modern sector is steeper than the traditional sector, the per capita output is higher in economies with higher modern labor shares.

For most countries there is no data for non-agricultural labor shares in 1820. We choose the initial modern labor share for country i , $\hat{M}_{i,0}$, that best matches the transition paths of modern sector labor share using the root-mean-squared-error criterion. That is

$$\hat{M}_{i,0} = \arg \min \left\{ \sum_{t=0}^6 \left[\frac{M_t^s - M_{i,t}}{M_{i,t}} \right]^2 \right\}^{\frac{1}{2}} .$$

Table III summarizes the calibrated initial modern labor shares used in simulation of the UK, US, Japan and Korea. The model succeeds in replicating the long term path of sectoral transition and per capita output observed in the data. Figure 7 displays the fit between the observed non-agricultural labor shares and the simulated modern labor shares. The patterns of transition of labor share out of agriculture follow the patterns of S-shaped transition and catapult effects we simulate for the patterns of modern sector labor share.

TABLE III. Calibrated initial modern labor shares $\hat{M}_{i,0}$

Country	UK	US	Japan	Korea
Initial share	0.7	0.33	0.13	0.05

At the simulated modern labor shares for each country, Figure 8a and 8b compares the simulated per capita output and data for the UK, US, Japan, and Korea. The overtaking of the UK by the US, and the underperformance of Japan and Korea in the 1940s and 1950s attributed to episodes of war cannot be simulated. However, the general path of modern labor share and per capita output are simulated well by the model.

V.1 Poor Countries

While our primary motivation is to model the transition dynamics of currently rich economies where we observe a remarkable convergence in per capita output levels, our model is applicable to other economies which have yet to converge. Figure 9 shows the dynamics of per capita output for economies with per capita output under \$12000 in 1998 and per capita output data dating back to 1913 or earlier in Maddison (2001). Among these economies, the stagnation in per capita output seems longer, and divergence seems more evident. Figure 10 shows the dynamics of the non-agricultural labor share for the subset of these economies using data from Mitchell (2003). Overall, the path of non-agricultural labor share conform well with the simulated dynamics of modern sector labor share shown in Figure 5.

As examples of poor economies where the model performs weakly and strongly, Figures 11 and 12 illustrate the performance of the model in simulating the dynamics of Argentina and China. They represent the richest and poorest country from this "poor country sample". Calibrating the initial modern labor share of $\hat{M}_{Argentina,0} = 0.18$ for Argentina and $\hat{M}_{China,0} = 0.03$ for China, the model matches the observed non-agricultural labor share dynamics well, as shown in Figure 11.²²

For Argentina, the simulation is unable to capture the convergence in per capita output to a level close to the US by 1910, followed by a divergence in per capita output

²²Chinese labor force share data from China Statistical Yearbook.

(particularly after 1970), as shown in Figure 12. Factors outside the model (such as favorable terms of trade and aggressive tariff and import substitution policy) may account for these deviations from the simulated trend.

For China, while per capita output levels are over-predicted during the historically turbulent years from 1940-1980, the model matches well the levels between 1820-1910 and from 1980 onwards. The simulation predicts that per capita output in China will reach 58% of the per capita output of the US in 2030, and 90% in 2060.

Guided by theory, we use data on agricultural labor shares in a different way from the existing literature. This measure acts as a proxy for the distribution of sector specific experience. For the simulated economies in Figure 4, Figure 13 shows how the relationship between simulated traditional sector labor shares and simulated per capita output evolves over time. As time passes, the difference in log per capita outputs widen for a given difference in traditional labor shares. Figure 14 shows the current cross country relationship between agricultural labor shares and per worker output levels for 85 countries collected by the FAO in 1990. To facilitate comparison with Figure 13, the per capita output in Figure 13 and GDP per worker in Figure 14 has been equated for the US in 2000. A comparison of the two figures reveals the predicted relationship in the model for the year 2000 fits the log linear pattern and slope of the data very well. Thus, if we follow the prescription of the model and adjust for human capital quality according to the composition of labor across traditional and modern sectors (where we use agricultural labor share as proxy for traditional labor share), the degree of TFP differences measured in growth accounting will be substantially reduced.

V.2 Sensitivity analysis

We vary each of the parameters (β, μ, γ) and initial modern labor share for the US $M_{US,0}$ at $\pm 50\%$ from their benchmark values reported in Table I, and compare the resulting RMSE defined in (22) with the benchmark outcome. The parameters (α, λ) are then given by equations (21) and (20) as before. These results are reported in Table IV. The

calibration of the model to the US is robust to these variations in (β, μ) , while variations in γ and $M_{US,0}$ can lead to substantial deviations from the US data.

TABLE IV. Robustness of parameters

Parameter	<i>Benchmark</i>	$\pm\beta$	$\pm\mu$	$\pm\gamma$	$\pm M_{US,0}$
Range parameter		(0.25, 0.75)	(-0.75, -2.25)	(1.12, 1.36)	(0.17, 0.50)
Range RMSE	0.50	(0.56, 0.53)	(0.63, 0.62)	(1.19, 2.61)	(1.33, 1.13)

The labor efficiency elasticity of per capita output η is not a parameter of the model, but is an important parameter in the quantitative analysis is. A higher η implies smaller differences in $A_{i,t}$ can account for the observed differences in per capita output from (19). As discussed above, our estimate of η is somewhat smaller than other estimates in the literature. We conducted the simulation using a higher value of labor efficiency elasticity $\eta = 3$ (TFP elasticity of 4.5). The calibrated parameter set is $\beta = 0.20, \mu = -2, \gamma = 1.09$. $\beta = 0.20$ implies an annual discount factor of 0.948 which is closer to conventional estimates.²³

VI Conclusion

We constructed and quantitatively assessed a model of S-shaped transition with catapult effects. Using the non-agricultural labor share as proxy for the modern sector labor share, we showed that the model accounts well for the dynamics of per capita output and modern labor share, particularly among the group of today’s rich economies. Our main message is that an important aspect of the quality of human capital is its composition in terms of modern versus traditional sector experience. Incorporating this into growth accounting (both in cross section and time series) will reduce the size of TFP differences.

Previous studies have documented the low productivity of workers in agriculture relative to other sectors in developing countries, and have been puzzled by why such countries devote so much of their labor force to this relatively unproductive sector. Our model suggests the presence of sector-specific complementarity between labor and experience can solve this puzzle.

²³The implied $\alpha = 0.11, \lambda = 0.28$.

This paper illustrates the path of transition and specifically the timing of takeoffs in aggregate output are functions of historical endowments. Policies which speed up transition to the modern sector encourage growth by bringing forward the timing of transition, but the impact may not be observed for many years later when the take-off of aggregate output occurs. However, the success of the model in replicating the transition dynamics of the currently rich economies suggest that for these economies, the historical endowment of experience in 1820, rather than policy, has dictated the main contours of their development paths.

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A Appendix

A.1 Cross-country Data

We use PWT 6.1 data to construct the cross-country per capita output and labor productivity for the period 1950-2000. The time period that maximizes the sample country is 1960-1996, which is used for our estimation of η . The measured variables are constructed as follows. The per capita output (RGDPL or RGDPCH) and per worker output (RGDPWOK) are directly observed from PWT data. We also observe investment rate data (KI, measured in percent), population data (POP, measured in 1000 people). Capital stock is constructed following standard perpetual inventory method. We first recover the investment amount I_t such that

$$I_t = \text{RGDPL} * (\text{POP} * 1000) * (\text{KI} / 100).$$

Initial capital stock is constructed assuming constant growth rate of investment around the initial period such that

$$K_0 = \frac{I_0}{(g + \delta)},$$

where g is the geometric average growth rate of investment between 1960 and 1970, δ the depreciation rate of physical capital stock set at 0.06, and I_0 the initial investment level. Given this initial capital stock K_0 , the physical capital stock is constructed by the simple law of motion

$$K_{t+1} = I_t + (1 - \delta)K_t.$$

The labor force L_t is constructed such that

$$L_t = \text{RGDPCH} * (\text{POP} * 1000) / \text{RGDPWOK},$$

which gives us the per worker capital stock $k_t = \frac{K_t}{L_t}$.

We construct the per worker human capital data h_t from schooling s_t such that

$$h_t = \exp[\phi(s_t)],$$

where $\phi(s_t)$ is the returns to schooling schedule. Klenow and Rodriguez-Claire (1997) assume $\phi(s_t) = r_s t$ following Mincer (1974). Hall and Jones (1999) assume a piecewise linear schedule for ϕ such that

$$\begin{aligned}\phi(s) &= 0.134 * s, \quad \text{if } s \leq 4 \\ &= 0.134 * 4 + 0.101 * (s - 4), \quad \text{if } 4 < s \leq 8 \\ &= 0.134 * 4 + 0.101 * 4 + 0.068 * (s - 8), \quad \text{if } 8 < s\end{aligned}$$

Due to the abundance of studies on Mincerian earnings equations for each country, we can allow country-specific returns schooling r_i using the method and the data in Klenow and Rodriguez-Claire (1997). The nonlinear schedule of returns to schooling in Hall and Jones (1999) is more general than Klenow and Rodriguez-Claire (1997) but there few estimates available for this nonlinear schedule and hence we use the same schedule above across countries when we adopt Hall and Jones (1999) method. The schooling data are obtained from Barro and Lee (2001).

We assume the aggregate production function takes the simple Cobb-Douglas form

$$Y_t = (A_t L_t h_t)^\theta K_t^{1-\theta}$$

and TFP_t is measured as

$$TFP_t = A_t^\theta = \frac{y_t}{h_t^\theta k_t^{1-\theta}}.$$

A.2 US Experience Premium

Table A1 reports the estimates of experience premium in US using the Census data (for white males sample), reproduced from Table 2 in Heckman, Lochner and Todd (2003). Our measure of experience premium EP^{ss} is obtained using these estimates (standard errors are in parentheses).

TABLE A1. Estimated Coefficients in Mincerian Earnings Regression for US

Year	1940	1950	1960	1970	1980	1990
Experience	0.0904 (0.0005)	0.1074 (0.0006)	0.1156 (0.0003)	0.1323 (0.0002)	0.1255 (0.0001)	0.1301 (0.0001)
Experience ²	-0.0013 (0.0000)	-0.0017 (0.0000)	-0.0018 (0.0000)	-0.0022 (0.0000)	-0.0022 (0.0000)	-0.0023 (0.0000)

A.3 US Dividend Ratio

Table A2 reports the total employee compensation, total dividends paid, domestic dividends paid from the NIPA data from Bureau of Economic Analysis of the US Department of Commerce, and human capital per worker from schooling following Hall and Jones (1999) for the 1960-2000 period. Our measure of dividends ratio to labor earnings DP^{ss} is obtained using these data.

TABLE A2. National Earnings and Dividends for US (in Billions of US\$)

Year	Total Compensation	Total Dividends	Domestic Dividends	Human Capital
1960	296.4	19.2	16.8	2.68
1961	305.3	20.4	17.5	2.70
1962	327.1	22.2	19.0	2.72
1963	345.2	23.5	20.2	2.74
1964	370.7	26.4	22.6	2.76
1965	399.5	29.3	25.2	2.79
1966	442.7	29.2	25.5	2.81
1967	475.1	30.4	26.4	2.83
1968	524.3	33.2	29.0	2.85
1969	577.6	34.8	30.0	2.87
1970	617.2	35.3	30.2	2.89
1971	658.3	37.5	31.4	2.90
1972	725.1	40.9	34.4	2.91
1973	811.3	49.0	40.5	2.92
1974	890.7	59.7	48.1	2.93
1975	949.0	51.9	43.3	2.93
1976	1059.2	64.5	52.8	3.01
1977	1180.4	74.7	60.5	3.08
1978	1335.8	81.3	66.6	3.16
1979	1501.0	97.0	77.1	3.25
1980	1651.8	107.5	86.0	3.34
1981	1825.7	115.8	95.0	3.33
1982	1925.9	124.9	101.1	3.32
1983	2043.0	128.3	108.8	3.31
1984	2255.4	137.6	117.9	3.30
1985	2424.9	143.4	122.4	3.29
1986	2570.1	156.8	128.9	3.31
1987	2750.2	162.2	134.3	3.32
1988	2967.2	205.7	160.6	3.33
1989	3145.2	236.3	188.4	3.35
1990	3338.2	247.5	203.8	3.36
1991	3445.3	253.7	212.2	3.37
1992	3651.2	266.5	221.9	3.38
1993	3794.9	282.1	242.7	3.38
1994	3979.6	327.1	268.4	3.39
1995	4177.0	361.3	302.9	3.40
1996	4386.9	425.4	356.4	3.40
1997	4664.6	484.5	401.1	3.41
1998	5020.1	513.3	429.8	3.41
1999	5352.0	516.7	424.1	3.41
2000	5782.7	566.7	480.4	3.42

Figures

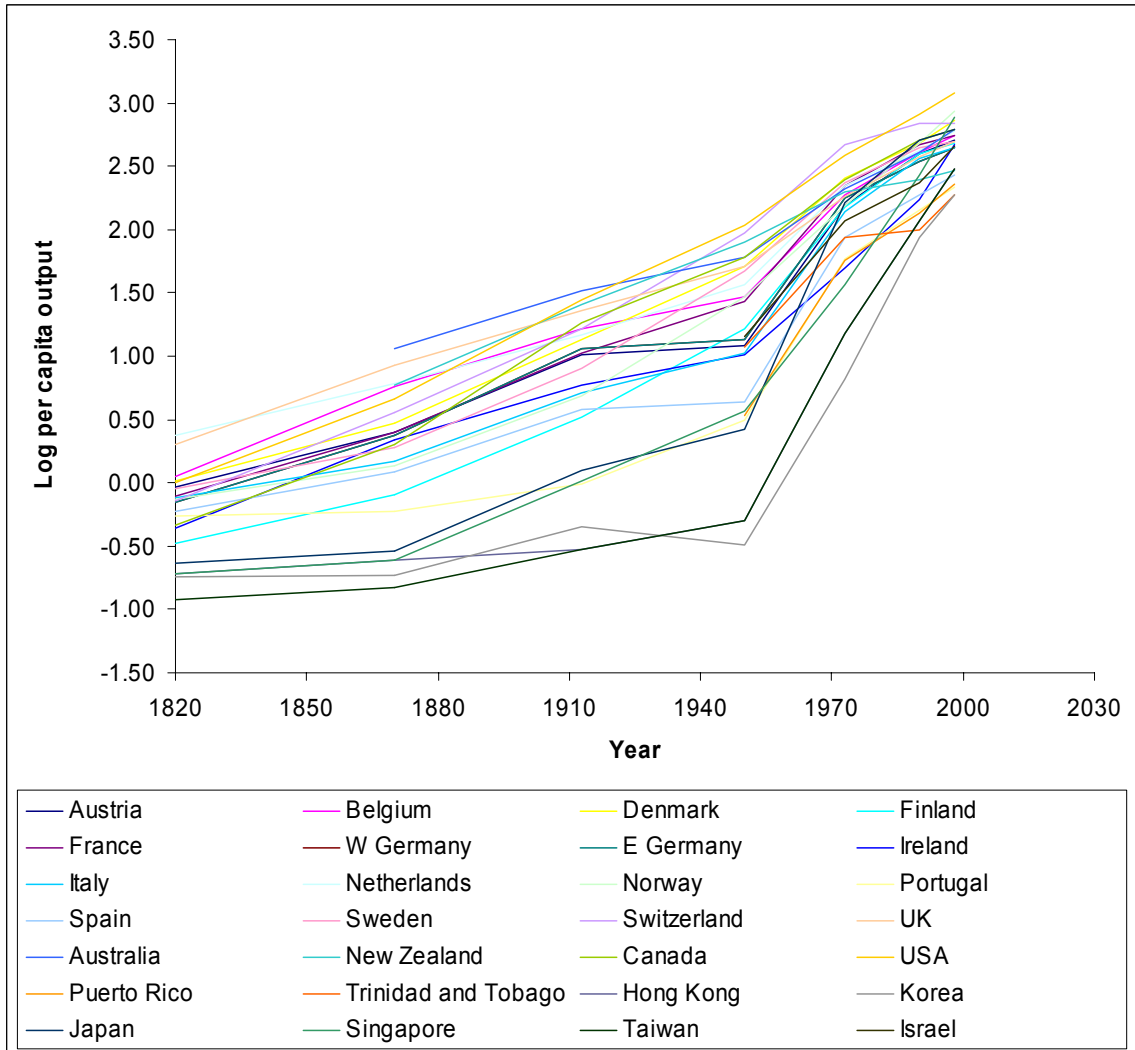


Figure 1. Log Per Capita Output Normalized by US 1820 Level

Countries with real GDP per capita over \$12000 in 1998 in 1990 dollars. Source: Maddison (2001)

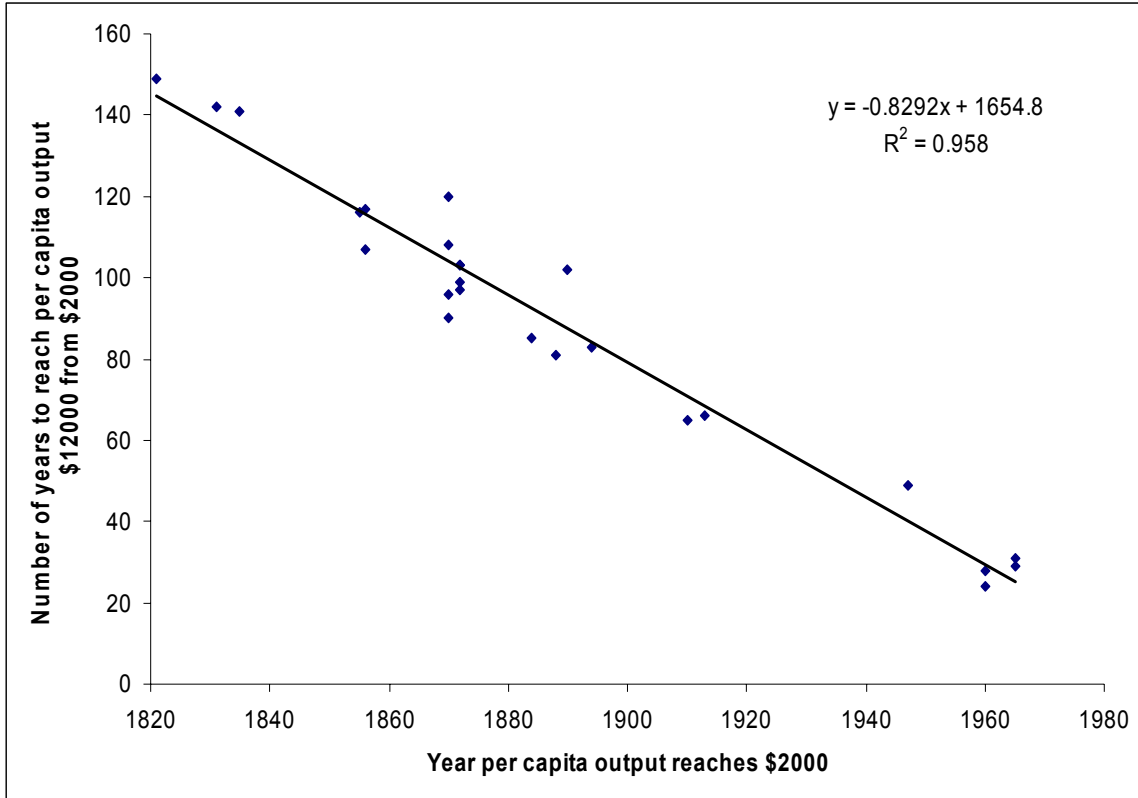


Figure 2. Catapult Effect

Countries with real GDP per capita over \$12000 in 1998 in 1990 dollars. Source: Maddison (2001)

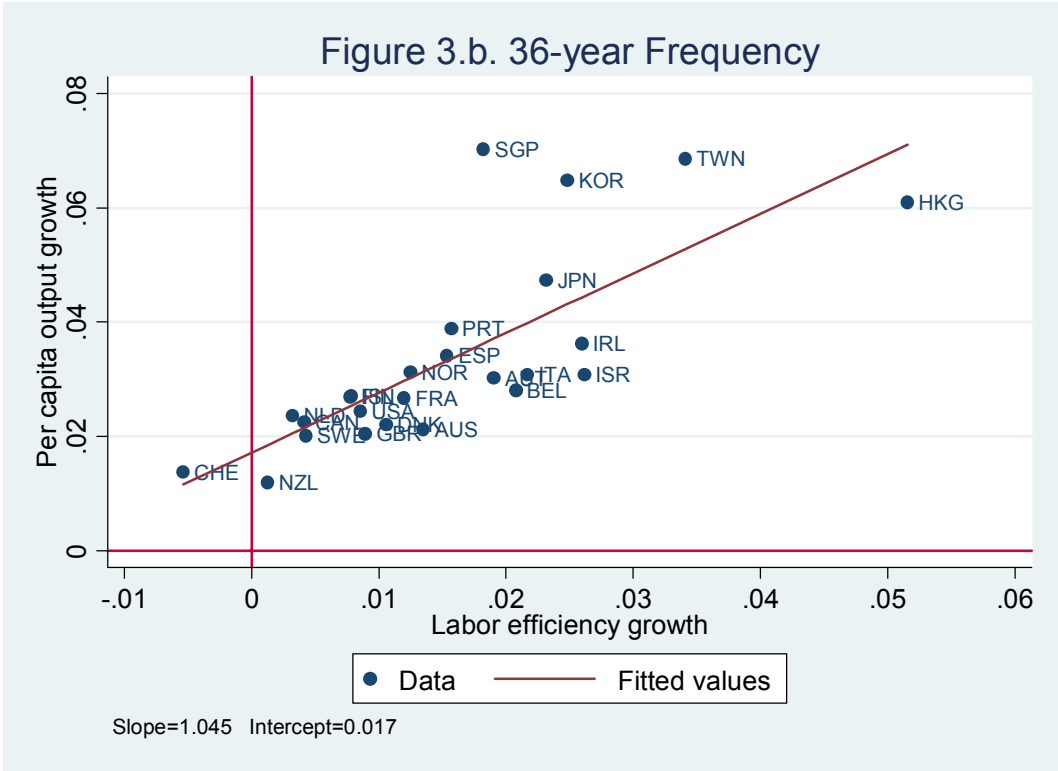
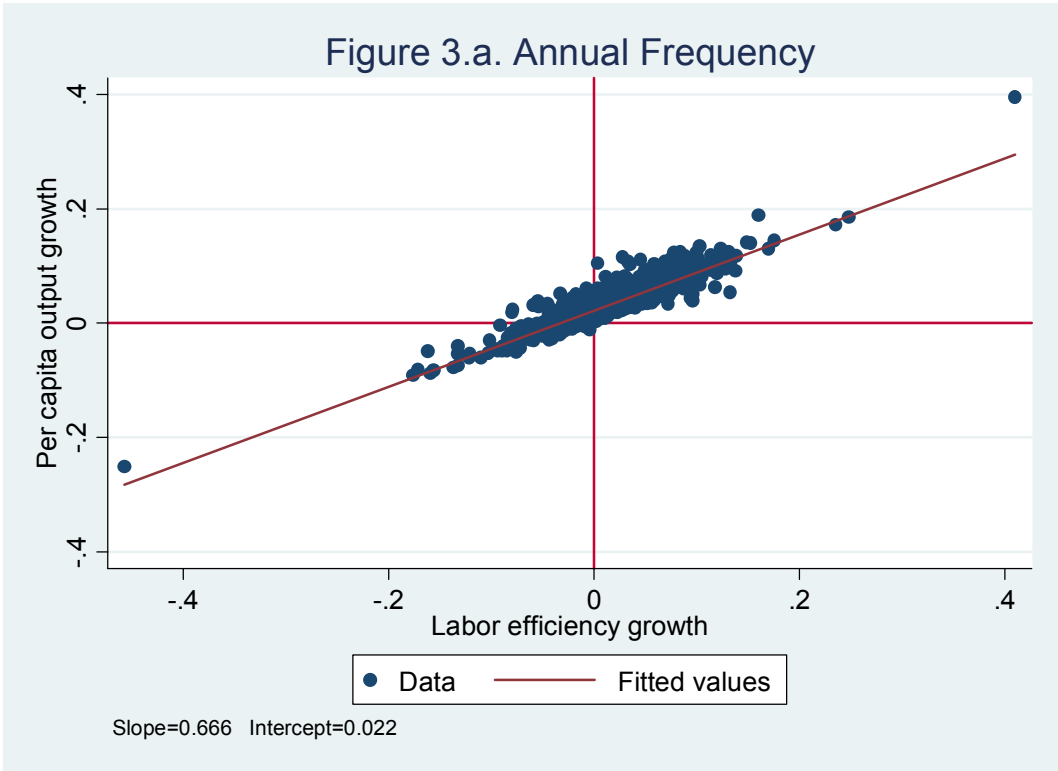


Figure 3. Labor efficiency elasticity of per capita output

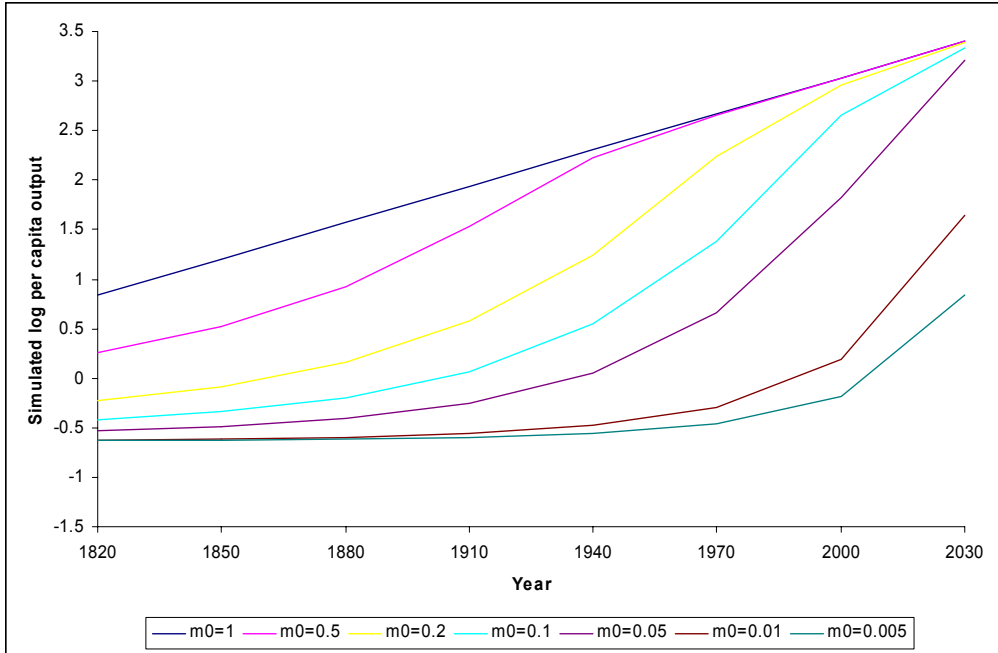


Figure 4. Simulated Log Per Capita Output Normalized by UK 1820 Level
Various initial modern sector labor force shares.

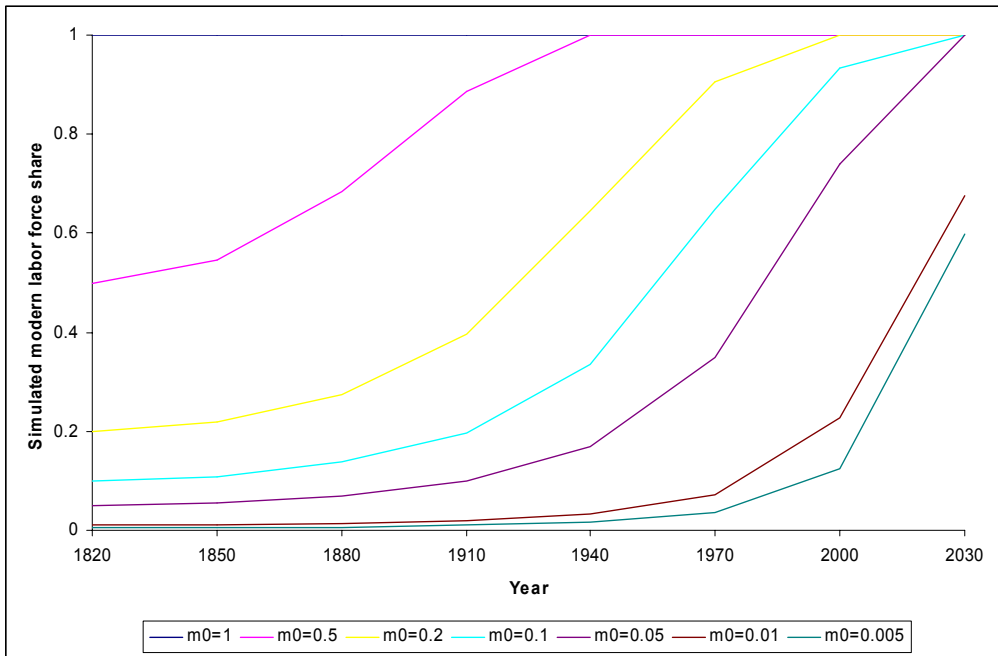


Figure 5. Simulated Modern Labor Share
Various initial modern sector labor force shares.

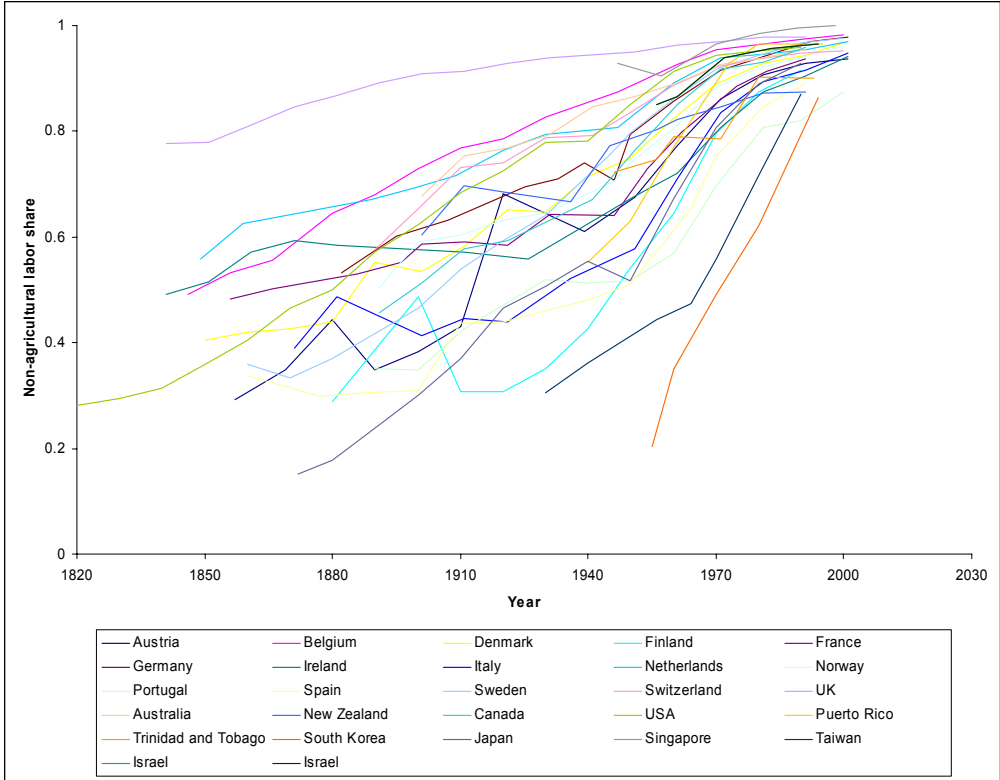


Figure 6. Non-agricultural Labor Share for rich economies

Source: Mitchell (2003).

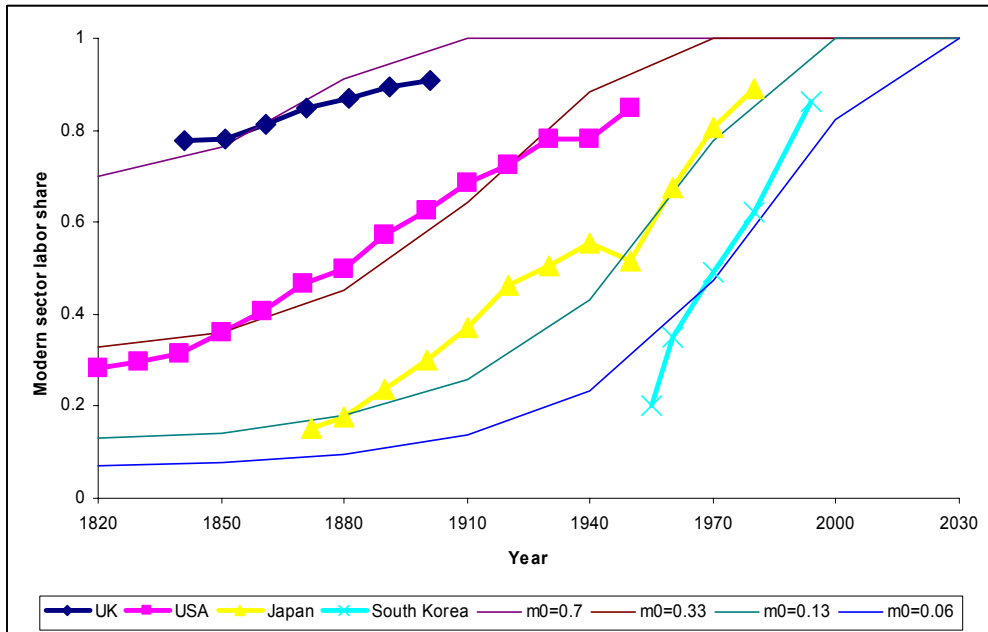


Figure 7. Comparison of Modern Labor Share: simulation versus data.

Smooth lines are simulation.

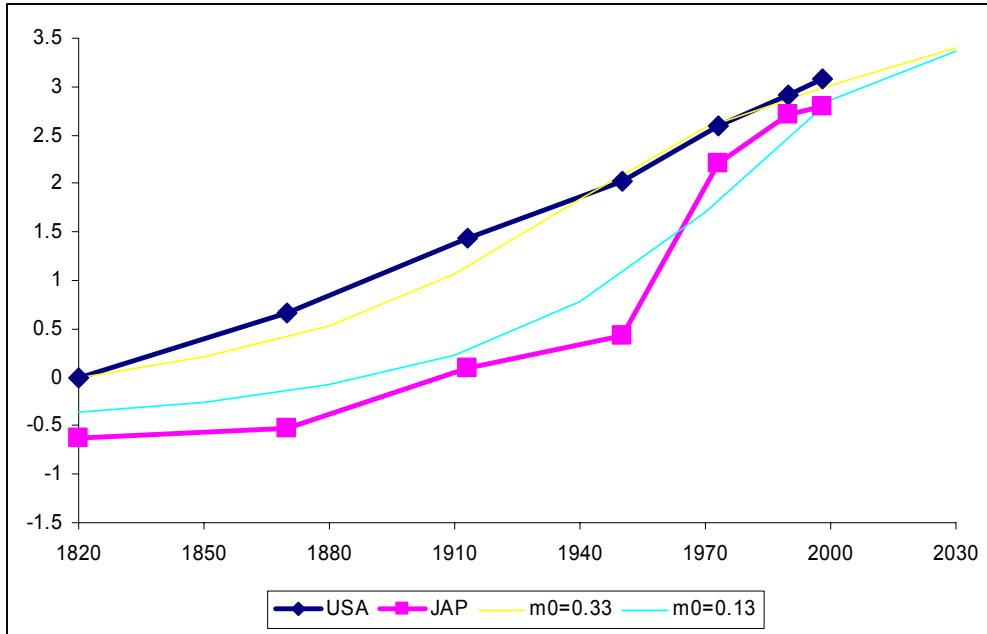


Figure 8a. Comparison of Log Per Capita Output for US and Japan: simulation versus data.

Smooth lines are simulation.

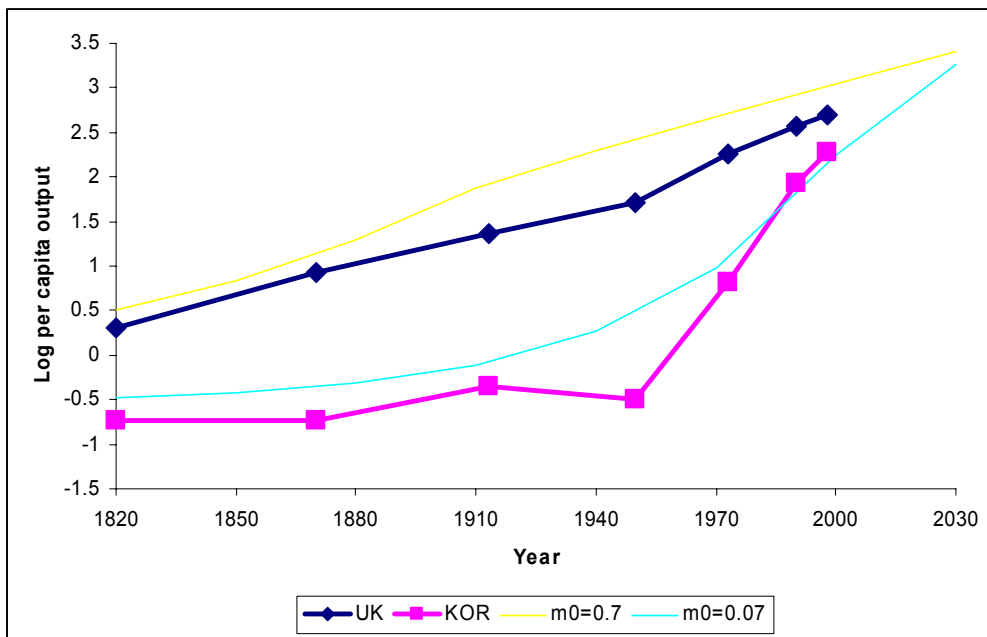


Figure 8b. Comparison of Log Per Capita Output for UK and Korea: simulation versus data.

Smooth lines are simulation.

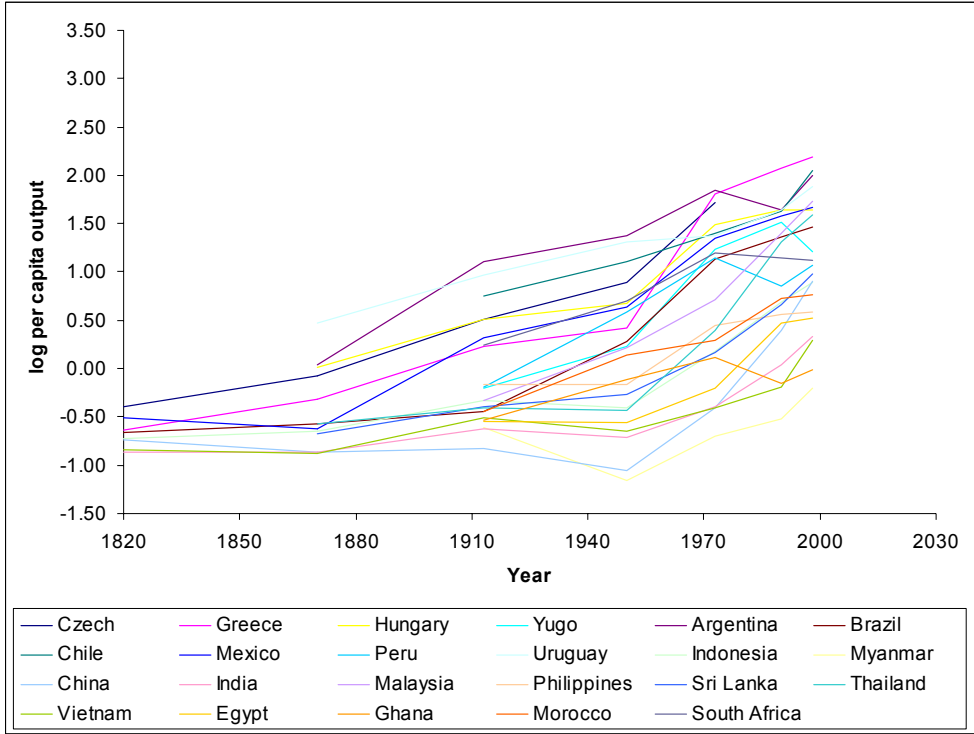


Figure 9. Log Per Capita Output of Poor Countries Normalized to US 1820 Level
 Countries with per capita output under \$12000 in 1998, and per capita output series beginning in 1913 or earlier. Source: Maddison (2001).

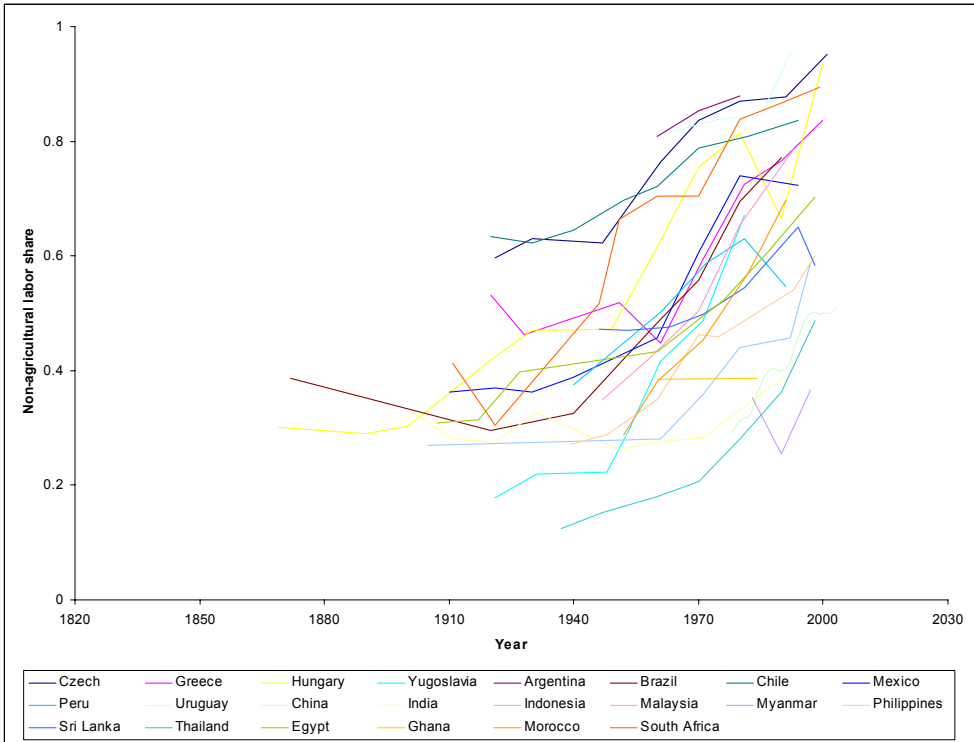


Figure 10. Non-agricultural Labor Share of Poor Countries
 Countries with per capita output under \$12000 in 1998, and per capita output series beginning in 1913 or earlier. Source: Maddison (2001) and Chinese Statistical Yearbook for China.

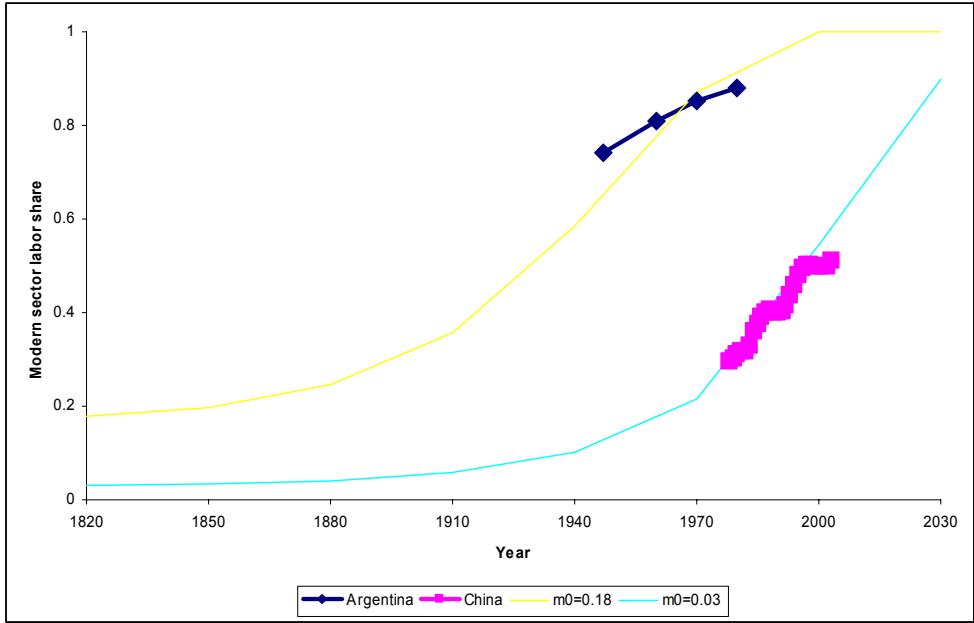


Figure 11. Comparison of Modern Labor Share for Argentina and China: simulation versus data.
Smooth lines are simulation.

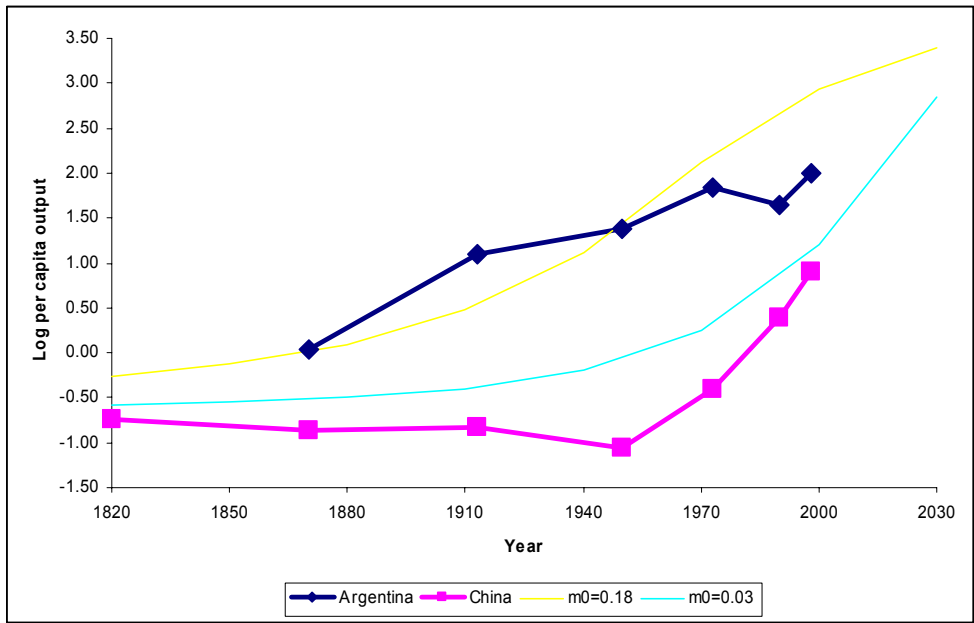


Figure 12. Comparison of Log Per Capita Output for Argentina and China: simulation versus data.
Smooth lines are simulation.

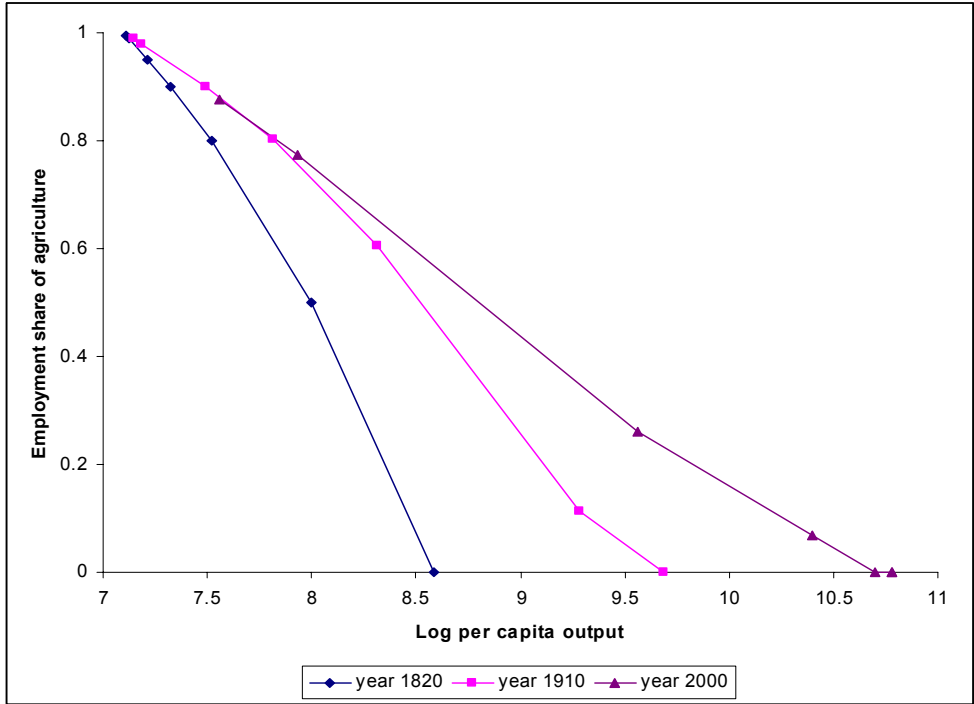


Figure 13. Simulated Traditional Labor Share versus Log Per Capita Output.

For US, simulated log per capita output and actual log per worker output are equated for 2000. In 2000, US has simulated agricultural employment share of zero.

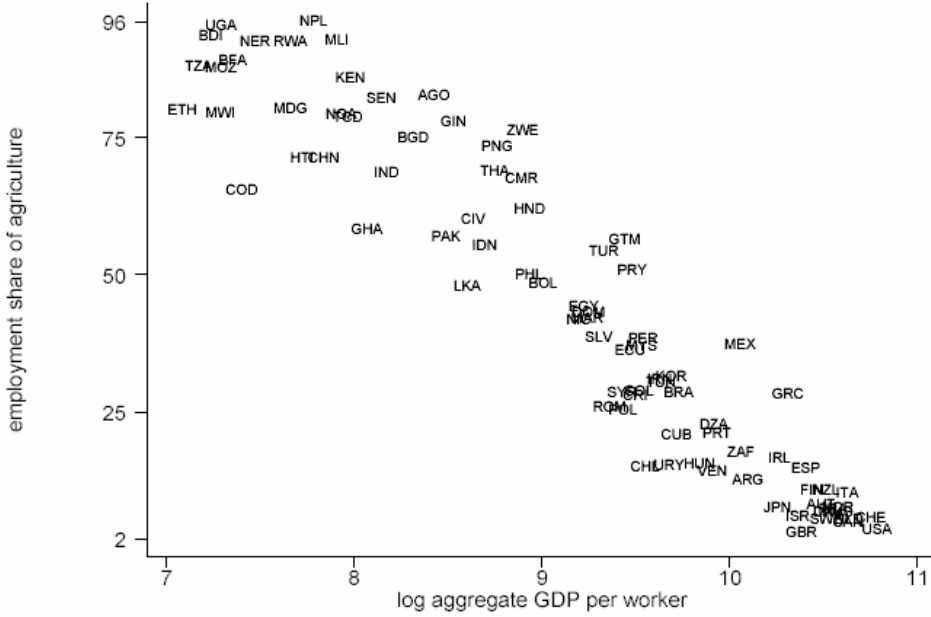


Figure 14. Agricultural Labor Share versus Log Per Worker Output

Source: Restuccia, Yang and Zhu (2003).