Human Capital, Dynamic Preference and Endogenous Transition form Primitive Agriculture to Industrial Mass Production: Three Stages of Economic Development.

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Abstract

This paper develops an endogenous growth model that captures the historical evolution of preferences, knowledge, technology and output. It develops a human capital-led growth model that generates endogenous transition between three rgimes that have characterized economic development. The economy evolves from an agricultural to traditional manufacturing and then finally to highly automated mass-production stage characterized by increasing returns technology. The model essentially captures the ”pull” view of origins of industrial take off that focuses on the development of new production opportunities in the industrial sector. These new production opportunities evolve because of changing preference pattern with the introduction of new goods. The economy, starting from an agrarian society, consuming and producing only agricultural good is able to take off to a primitive industrial state with sufficiently accumulated human capital followed by a shift in the preferences towards new industrial goods serving fairly new purposes. Again when the knowledge base of the economy becomes strong enough to be embodied into highly automated, standardized, synchronized and continuous technique of production, it enters the stage of mass production (characterized by increasing returns technology) of varieties of new goods that expand the preference set of people. This paper essentially tries to describe the experience of world economy over

the last two hundred years when countries experienced rapid growth in living standards by taking advantage of the scale economies in the production of manufacturing.

1 Introduction

World economies have experienced remarkable increase in living standards over the last two hundred years i.e. in the nineteenth and twentieth centuries, after thousand of years of insignificant change. The origin of such large sustained increase in standard of living in a relatively short span of time is a quest till date. Researchers have identified this phenomenon with the transition of production mode from a primitive, land based agricultural one, subject to diminishing returns to industrial mode showing constant returns to scale in production (Hansen and Prescott, 1999; Laitner, 2000; Love, 1997; Tamura 2002).

Hansen and Prescott (AER, 1999) developed a one good, two sector overlapping generation model. The single commodity can be produced with two different methods. One method uses labor, capital and a fixed factor land and hence subject to diminishing returns. The other method uses only variable inputs labor and capital and exhibits constant returns to scale. Total factor productivities under two techniques grow at two different exogenous rates. Apart from that population is also growing. The economy with low level of technical knowledge and capital produces commodity with agricultural technique. However as technical progress in industrial method takes place continuously, a time comes when it is sufficiently high to make industrial technique profitable at the existing wage and rental rate. Thus both the techniques coexist for some time till capital accumulation becomes sufficiently large in the economy to enable all individuals to operate the more productive industrial technology.

Love (JDE, 1997) and Laitner (RES, 2000) have modeled transition of an economy from only agricultural goods producing state to another state where both agricultural and manufacturing sectors coexist. The channel through which this transition occurs is non-homothetic preference over agricultural and manufacturing goods. Agricultural good is subject to Engel's Law. When technology is not advanced, the economy is basically an agrarian one producing only agricultural good, which is a necessity. However with technological progress as income grows, income elasticity of agricultural good being less than unity, labor is released from this sector to move to manufacturing, the demand for which is also rising. However in all these models transition mechanism work through exogenous technological progress.

Tamura (JEDC, 2002) develops a model of economic and population growth that generates *endogenous* transition between agricultural to industrial production mode. A single commodity can be produced with two methods, one with human capital and a fixed factor land exhibiting diminishing returns while the other requires only human capital. The second method incurs a coordination cost of using intermediate services that is inversely related to the level of human capital. The economy, starting from a low level of human capital specializes in agricultural technique. However over time, human capital grows endogenously as individuals caring about income of their children invests a fraction of their labor time in a linear education production technology. As human capital grows, coordination cost falls and eventually it becomes sufficiently low for industrial technology to become more productive than the primitive one.

However their arguments apparently ignore the historical fact that drastic change in living standards was not associated to just the 'beginning of industrialization'. Much manufacturing had already been taking place in European cities and in the countryside by the middle of the eighteenth century (Joel Mokyr). From the experience of Britain where average standard of living showed little trend upward until 1840s (Mokyr), and twentieth-century Japan and Korea, economies of scale seems to play an important role in it.

The production mode in Britain during 1820s looked quite different compared to 1760s in terms of building parts and machines with increasing accuracy contributing to increased industrial efficiency. During this period industrial technology started to become highly automated, standardized, synchronized and continuous technique of production i.e. mass production.

However these observations immediately leads to the question 'why such mass production technique did not evolve immediately at the time of the beginning of industrialization?' The answer of this question is possibly related to the ability of investors in the industrial sector to overcome certain problems that were beyond their capability in past. One plausible explanation can rely on the extent of market in which new products could be sold. Role of the size of domestic market in development is emphasized by Murphy, Shleifer and Vishny (JPE, 1989). In order to industrialize the existing cottage production mode, firms need to undertake large fixed investment to adopt increasing returns technology. But such an investment by a single firm may not be profitable because of the small size of the market it faces. Thus no firm will be willing to undertake this investment and the economy is trapped in non-industrialized state. The authors discussed several channels such as wage premium paid to the factory workers that can raise labor income and hence demand for all industrial products to make adoption of IRS technology profitable in all sectors. Thus economy moves to the industrialized state. However implications of their model rely on the existing size of the market that can be altered only through some exogenous policy shifts. It does not capture the possibility of evolution of market over time.

In this paper, we try to fill this void. This paper develops an endogenous growth model that captures the historical evolution of preferences, knowledge, technology and output. It develops a human capital-led growth model that generates endogenous transition between three rgimes that have characterized economic development. The economy evolves from an agricultural to traditional manufacturing and then finally to highly automated mass-production stage characterized by increasing returns technology. The model essentially captures the ”pull” view of origins of industrial take off that focuses on the development of new production opportunities in the industrial sector. These new production opportunities evolve because of changing preference pattern with the introduction of new goods. [1]

Bils and Klenow (AER, 2002) quantified the impacts of introduction of new goods on the preference structure. Using US Consumer Expenditure Survey Data (CEX) for the period 1959-1999, they found that new products have played an important role in the substantial shifts in spending. Consumers have been rapidly shifting away from goods that show little variety change, with the shift accelerating in the last twenty years. By ’new goods’ the authors considered a broad category of goods consisting of goods with added features to existing products as well as entirely new products. They found that even controlling for Engel curve and relative price effects, the spending on new goods relative to static ones (whose variety is expanding slowly or not at all) expanded by 1.3% per year.

[1] Stockey (JPE, 1988) modeled dynamic preferences to develop an endogenous growth model where introduction of new and better products is an integral part of the sustained growth process of an economy. The source of growth is accumulation of knowledge through economy wide learning by doing. In his model the inherent characteristics of goods play an important role. As income increases, people consume goods that contain more characteristics, which are costlier to produce relative to goods with lesser characteristics. But in his model even if the characteristics content of a good changes over time, but it serves the same purpose throughout.

Thus it is evident that the preference set is not only changing in terms of composition of goods (as in Stockey) but it is also expanding with new goods serving fairly new purposes compared to the existing ones. In our model the preference structure exhibits this dynamism. While individual's satisfaction is defined in an agrarian society mainly on agricultural goods that fulfill biological needs, over time she starts obtaining utility from goods produced in industries, which are not essential for physiological purpose and later from varieties of goods differentiated by inherent qualities.

In line with the findings of Bils and Klenow, the preference structure in our model is characterized by falling expenditure share on food over time as economy passes through three stages of economic development. Similarly expenditure share on traditional manufacturing good also falls followed by a transition from primitive manufacturing to modern industrial state.[2]

The economy, starting from an agrarian society, consuming and producing only agricultural good is able to take off to a primitive industrial state with sufficiently accumulated human capital followed by a shift in the preferences towards new industrial goods serving fairly new purposes. Again when the knowledge base of the economy becomes strong enough to be embodied into highly automated, standardized, synchronized and continuous technique of production, it enters the stage of mass production (characterized by increasing returns technology) of varieties of new goods that expand the preference set of people.

[2]Bowles (JPE, 1998) discusses evolution of preferences as a result of learned influences on behavior. That is, preferences learned under one set of circumstances became generalized reasons for behavior. However this set of circumstances that constitute institution may vary and as a consequence, preference may evolve over time.

2 Economic Environment

2.1 Preference structure

We start describing the economic environment with preference structure that plays an important role in our model. The economy is populated by a single infinitely lived household. Instantaneous utility of the household is defined over several goods, provided that those goods are available. Household consumes agricultural good, a homogeneous manufacturing product and varieties of differentiated manufacturing products. Agricultural good is a necessity, while manufactures are not. There is a subsistence consumption level of agricultural good.

The utility function of the individual is specified in the following way:

$$u_t = \begin{cases} \ln(c_t^F - c0) & \text{when } Y_t^F > 0, \quad Y_t^M = 0, \quad Y_{it}^A = 0, \quad i = 1, \ldots, n_t \\ \theta_F \ln(c_t^F - c0) + \theta_M \ln(c_t^M + b) & \text{when } Y_t^F > 0, \quad Y_t^M > 0, \quad Y_{it}^A = 0, \quad i = 1, \ldots, n_t \\ \theta_F \ln(c_t^F - c0) + \theta_M \ln[(c_t^M)^\gamma (G_t)^{1-\gamma} + b)] & \text{when } Y_t^F > 0, \quad Y_t^M > 0, \quad Y_{it}^A > 0, \quad i = 1, \ldots, n_t \end{cases}$$

Where c_t^F and c_t^M are the consumption of agricultural and homogeneous manufacturing goods respectively. Moreover G_t is a composite good consisting of n_t differentiated manufacturing products. Production of agricultural, homogeneous manufacturing and differentiated manufacturing goods are respectively denoted by Y_t^F, Y_t^M and $Y_{it}^A, \quad i = 1, \ldots, n_t$. The share of total expenditure spent on agricultural good is θ_F, while that for the manufacturing products as a whole is θ_t^M. Parameter γ denotes the share that homogeneous manufacturing good receives in the expenditure for the class of industrial products as a whole. The rest goes to the composite commodity of differentiated products. And $c0$ is the minimum requirement for agricultural good, while b signifies the manufacturing products are not necessities.

When more than one good are available in the economy, in each period t, household exercises a static optimization problem. In case when economy produces agricultural and homogeneous manufacturing product, in each period, household maximizes $u_t = \theta_F \ln(c_t^F - c0) + \theta_M \ln(c_t^M + b)$ subject to $c_t^F + p_t^M c_t^M = E_t$ where E_t is the total expenditure on two goods in that period and p_t^M is the price of manufacturing in terms of agricultural good . The instantaneous demand functions are $c_t^F = \theta_t^F \tilde{E}_t + c0$ and $c_t^M = \frac{\theta_t^M \tilde{E}_t}{p_t^M} - b$, where $\tilde{E}_t = E_t - c0 + p_t^M b$. Substituting back the demand functions into u_t, indirect utility is derived as

$$v_t = \ln \tilde{E}_t - \theta_M \ln p_t^M + \theta_F \ln \theta_F + \theta_M \ln \theta_M \tag{1}$$

When economy produces agricultural good, homogeneous manufacturing and varieties of differentiated products, household conducts a two-stage budgeting exercise in each period. In the first stage it maximizes a sub-utility function defined on the differentiated products only, which is ,

$$[\sum_{i=1}^{n_t} (c_{it}^A)^{\varepsilon}]^{\frac{1}{\varepsilon}}, \quad \varepsilon < 1$$

subject to

$$\sum_{i=1}^{n} p_{it}^A c_{it}^A = I_t$$

where $p_{it}^A \quad i = 1, ..., n_t$ is the price of ith differentiated good in terms of agricultural good and I_t is the total expenditure on differentiated products in period t. The first stage budgeting gives rise to demand for the ith differentiated product as

$$c_{it}^A = (\frac{p_{it}^A}{P_t})^{-\frac{1}{\varepsilon}} \frac{I_t}{P_t} \tag{2}$$

Here P_t is the composite price of n differentiated products, defined as:

$$[\sum_{i=1}^{n_t} (p_{it}^A)^{-\frac{\varepsilon}{1-\varepsilon}}]^{-\frac{1-\varepsilon}{\varepsilon}} \tag{3}$$

where p_{it} is the individul price of the ith product. And $\frac{I_t}{P_t}$ signifies the composite commodity G_t.

In the second stage, household maximizes $u_t = \theta_F \ln(c_t^F - c0) + \theta_M \ln[(c_t^M)^{\gamma}(G_t)^{1-\gamma} + b)]$ subject to $c_t^F + p_t^M c_t^M + P_t G_t = E_t$. Instantaneous demand functions are respectively

$$c_t^F = \theta_t^F \tilde{E}_t + c0; \tag{4}$$

$$c_t^M = \frac{\theta_t^M \gamma \tilde{E}_t}{p_t^M} - b(\frac{\gamma P_t}{(1-\gamma)p_t^M})^{1-\gamma} \tag{5}$$

$$G_t = \frac{\theta_t^M (1-\gamma)\tilde{E}_t}{P_t} - b(\frac{(1-\gamma)p_t^M}{\gamma P_t})^{\gamma} \tag{6}$$

where $\tilde{E}_t = E_t - c0 + p_t^M b(\frac{\gamma P_t}{(1-\gamma)p_t^M})^{1-\gamma} + P_t b(\frac{(1-\gamma)p_t^M}{\gamma P_t})^{\gamma}$.

Substituting demand functions into the utility function, indirect utility is derived as

$$v_t = \ln \tilde{E}_t - \theta_M \gamma \ln p_t^M - \theta_M (1-\gamma) \ln P_t + \theta_F \ln \theta_F + \theta_M \ln \theta_M \gamma + \theta_M (1-\gamma) \ln \frac{1-\gamma}{\gamma} \tag{7}$$

Household is the supplier of the sole input of production in the economy, namely human capital. It is endowed with one unit of labor time. It allocates $(1 - L_t)$ fraction of time in market activities, while the rest L_t is allocated into a household education production technology. The education production technology is linear and is given by:

$$H_{t+1} = A_H L_t H_t \tag{8}$$

After conducting static optimization, household exercises dynamic optimization by maximizing discounted some of utility subject to lifetime budget constraint and the education production technology.

2.2 Production

The production side of the economy is assumed to be comprised of cost minimizing firms. Agricultural production technology uses effective human capital i.e. human capital adjusted for the labor time available for market activities and a fixed factor land. The land endowment of the economy is normalized to one. The agricultural firm's production function is given by

$$Y_t^F = [EH_{Ft}]^{\gamma_F} \quad \gamma_F < 1 \tag{9}$$

where EH_{Ft} denotes effective human capital employment in this sector.

The production technology of homogeneous manufacturing product exhibits constant returns to scale in effective human capital,

$$Y_t^M = a_m EH_{Mt} \tag{10}$$

where a_m is the unit effective human capital requirement and EH_{Mt} is the effective human capital employment in this sector.

The production technology of each differentiated industrial product exhibits increasing returns to scale. In each period, a firm has to incur some large fixed investment, but within that period, once this investment is made, in order to increase production it has to incur just the variable cost. Let $\overline{EH_A}$ be the required fixed investment in terms of effective human capital and $EH_{Ait}, \quad i = 1, ., n_t$ be the total amount of effective human capital required by the ith firm to operate. Then production function of the ith IRS firm can be specified as

$$Y_{it}^A = a_m \sigma (EH_{Ait} - \overline{EH_A}), \quad i = 1, ., n_t, \quad \sigma > 1 \tag{11}$$

An economy, starting with a very small amount of human capital, which is just sufficient to meet minimum food requirement, initially produces only agricultural good. The economy asymptotically grows at a constant rate as individuals caring about their future income invests a fraction of their labor time (that asymptotically approaches to a constant) in education production technology that exhibits constant returns to scale. Thus the economy endogenously grows over time. Although individuals always prefer to consume two goods to one and three goods to two and so on, initially, they will not demand industrial goods as those are not necessary. The maximum price that consumers will be willing to pay to demand a positive amount of industrial goods will be so low that it will not be profitable for the producers to produce manufacturing good. Thus producers are constrained by lack of market. And the economy remains in agrarian state.

Over time as economy grows, in the preference structure, necessity of food becomes unimportant and individual's willingness to pay for homogeneous industrial good increases. At the existing wage rate, when it equalizes with the minimum price that makes producers to at least cover their unit cost, traditional manufacturing sector that exhibits constant returns to scale opens up, provided that the human capital endowment at that point in time is sufficient to sustain both the sectors. The economy enters the initial stage of industrial state where both agriculture and traditional manufacturing coexist.

Similarly when economy's human capital has grown to a sufficiently high level such that large, fixed investment in the differentiated goods sector becomes possible and consumer's maximum willingness to pay for at least one such differentiated product matches with the producer's price, which is set as a mark up over the marginal cost, the increasing returns technology breaks even. The economy enters to the third phase of industrialization accompanied by substantial sustainable increase in utility. This state is characterized by coexistence of agriculture, traditional manufacturing and varieties of differentiated goods produced with mass production technology.

3 General Equilibrium

The complete general equilibrium analysis combines optimization behavior of consumers and producers taking into account market clearing and full employment conditions. We sequentially characterize general equilibrium for agrarian economy; initial industrialized state and mass production state. Due to the lack of analytical tractability caused by non-homotheticity of preference, we use numerical methods to characterize them.

3.1 Non-industrialized state

Optimizing household chooses consumptionc_t^F; labor time to invest in human capital generation L_t and H_{t+1} in order to Max $\sum_{t=0}^{\infty} \rho^t [\ln(c_t^F - c0)]$, subject to H_0 given; budget constraint

$$c_t^F = W_t(1-L_t)H_t + R_t \tag{12}$$

and education technology given by equation (8).

The agricultural firm whose production technology is specified in (9). Here $EH_{Ft} = (1-L_t)H_{Ft}$, H_{Ft} being the human capital employment in agriculture is a price taking firm in both output and factor markets. It employs human capital such that marginal product of effective human capital equalizes with wage rate, i.e.

$$W_t = \gamma_F [(1-L_t)H_{Ft}]^{\gamma_F - 1} \tag{13}$$

The rest goes to land as rent, i.e.

$$R_t = (1-\gamma_F)[(1-L_t)H_{Ft}]^{\gamma_F} \tag{14}$$

Full employment condition implies

$$H_{Ft} = H_t \tag{15}$$

Apart from that, we have market-clearing condition

$$c_t^F = [(1-L_t)H_{Ft}]^{\gamma_F} \tag{16}$$

The optimization exercise of the household gives rise to Euler equation

$$\frac{(c_{t+1}^F - c0)}{(c_t^F - c0)} = \rho A_H \frac{W_{t+1}}{W_t} \tag{17}$$

This can be rewritten using the wage equation (13) as

$$\gamma_F [(1-L_t)H_{Ft}]^{(\gamma_F-1)} \frac{1}{(c_t^F - c0)} = \rho A_H \frac{1}{(c_{t+1}^F - c0)}$$

$$\left[\gamma_F [(1-L_{t+1})H_{Ft+1}]^{(\gamma_F-1)}(1-L_{t+1}) + [\gamma_F [(1-L_{t+1})H_{Ft+1}]^{(\gamma_F-1)} H_{t+1} \frac{A_H L_{t+1}}{A_H H_{t+1}}\right]$$

The left hand side of the Euler equation measures the loss of utility from lower current period consumption due to a reduction in market time by one unit, which is invested in the education production technology. The right hand side measures the gain in next period utility due to shifting the one unit of market time into human capital generation. The increase in human capital is given by A_H. The first expression within the brace measures utility gain due to additional consumption through an increase in human capital in this period. The second term captures utility gain through increased consumption due to an increase in market time adjusted for net impact of higher human capital and lower labor time investment on education in future.

Using budget constraint (12) and market equilibrium condition (16) and full employment condition (15) along with Euler equation we have

$$\frac{[(1-L_{t+1})H_{t+1}]^{\gamma_F} - c0}{[(1-L_t)H_t]^{\gamma_F} - c0} = \rho A_H \frac{[(1-L_{t+1})H_{t+1}]^{\gamma_F-1}}{[(1-L_t)H_t]^{\gamma_F-1}} \tag{18}$$

This equation along with education production function (8) govern the dynamics of the system.

Because of the complexity of the dynamic equations, we use numerical method, which shows that labor time allocated in education technology slowly increases and asymptotically approaches to a constant value, which is equal to ρ. The growth rate of human capital from a small value increases over time and asymptotically approaches to a value of ρA_H. Similarly growth rate of the agricultural output increases and asymptotically approaches to $(\rho A_H)^{\gamma_F}$.

If there was no minimum consumption of agricultural good, it can be shown that labor time invested in education technology would jump to the constant value of ρ from the beginning and human capital would grow at the rate ρA_H. There would have been no transitional dynamics. But with minimum food requirement, an economy initially endowed with low level of human capital allocates higher fraction of labor time in market activities to maintain the required production than it would have done if there were no minimum consumption. However as human capital and income grows, the magnitude of minimum consumption becomes smaller and smaller relative to income, and household can devote more and more labor time in education generation that also raises growth rate of human capital. Thus non-homotheticity generates transitional dynamics in the system.

3.2 Initial industrialized state

Household maximizes $\sum_{t=0}^{\infty} \rho^t [\ln \tilde{E}_t - \theta_M \ln p_t^M + \theta_F \ln \theta_F + \theta_M \ln \theta_M]$, subject to H_0 given; budget constraint

$$\tilde{E}_t = W_t(1 - L_t)H_t + R_t - c0 + p_t^M b \tag{19}$$

and education technology given by equation (8) with respect to $\tilde{E}_t$, L_t and H_{t+1}.

Optimization behavior gives rise to the Euler equation

$$\frac{\tilde{E}_{t+1}}{\tilde{E}_t} = \rho A_H \frac{W_{t+1}}{W_t} \tag{20}$$

In this stage both agricultural firm and traditional manufacturing firm producing with constant returns to scale (whose technology is specified in (10) operate. Free labor mobility equalizes wage rate across two sectors,

$$\gamma_F [EH_{Ft}]^{\gamma_F - 1} = p_t^M a_m = W_t \tag{21}$$

where EH_{Ft} is the effective human capital allocation in agriculture.

And rental is

$$R_t = (1-\gamma_F)[EH_{Ft}]^{\gamma_F} \tag{22}$$

Goods market clearing conditions are the following

$$\theta_F \tilde{E}_t + c0 = [EH_{Ft}]^{\gamma_F} \tag{23}$$

and

$$\frac{\theta_M \tilde{E}_t}{p_t^M} - b = a_m EH_{Mt} \tag{24}$$

where EH_{Mt} is the effective human capital allocation in traditional manufacturing sector.

Full employment condition is

$$EH_{Ft} + EH_{Mt} = (1-L_t)H_t \tag{25}$$

which says that allocation of effective human capital in two sectors sums up to the total supply of effective human capital.

Making use of equations (19), (23), (24), (21) and (22) in Euler equation (20) and full employment condition (25), we have

$$\frac{[(1-L_{t+1})H_{t+1} + \frac{b}{a_m}] - c0[EH_{Ft+1}]^{1-\gamma_F}}{[(1-L_t)H_t + \frac{b}{a_m}] - c0[EH_{Ft}]^{1-\gamma_F}} = \rho A_H \tag{26}$$

and

$$EH_{Ft} - \left(\frac{c0}{\theta_M + \theta_F \gamma_F}\right)[EH_{Ft}]^{1-\gamma_F} = \left(\frac{\theta_F \gamma_F}{\theta_M + \theta_F \gamma_F}\right)[(1-L_t)H_t + \frac{b}{a_m}] \tag{27}$$

These two dynamic equations along with the education technology (8) govern the dynamics of the system.

The labor time invested in education falls from a high value over time and asymptotically approaches to ρ. Growth rates of human capital and manufacturing output also fall from a high value and asymptotically approach to ρA_H. Growth rate of agriculture increases over time and asymptotically approaches to $(\rho A_H)^{\gamma_F}$.

3.3 Mass production stage

In this stage household maximizes $\sum_{t=0}^{\infty} \rho^t [\ln E_t - \theta_M \gamma \ln p_t^M - \theta_M (1-\gamma) \ln P_t + \theta_F \ln \theta_F + \theta_M \ln \theta_M \gamma + \theta_M (1-\gamma) \ln \frac{1-\gamma}{\gamma}]$, subject to H_0 given; budget constraint

$$\tilde{E_t} = W_t(1-L_t)H_t + R_t - c0 + p_t^M b \left(\frac{\gamma P_t}{(1-\gamma) p_t^M} \right)^{1-\gamma} + P_t b \left(\frac{(1-\gamma) p_t^M}{\gamma P_t} \right)^{\gamma}. \quad (28)$$

and education technology given by equation (8) with respect to $\tilde{E_t}$, L_t and H_{t+1}.

The resulting Euler equation is

$$\frac{\tilde{E_{t+1}}}{\tilde{E_t}} = \rho A_H \frac{W_{t+1}}{W_t} \quad (29)$$

In this stage, agricultural firm, traditional manufacturing and firms producing differentiated products with increasing returns technology operate. Their production technologies are specified in (9), (10) and (11). Agricultural and traditional manufacturing firms are price takers in the product and input markets. Their cost minimization behavior along with free labor mobility equalizes value of marginal products across these sectors, i.e.

$$\gamma_F [EH_{Ft}]^{\gamma_F - 1} = pt^M a_m = W_t \quad (30)$$

where EH_{Ft} is the effective human capital allocation in agriculture.

And rental is

$$R_t = (1-\gamma_F)[EH_{Ft}]^{\gamma_F} \quad (31)$$

The firm producing ith product, $i = 1,.,n_t$ is monopolistically competitive in the product market, but a price taker in the input market. For each additional effective human capital employment, it has to incur the marginal cost W_t. Again it has to pay the wage rate W_t for the fixed investment in terms of effective human capital $\overline{EH_A}$. Moreover It takes into account the demand it faces to maximize profit. Thus the producer of the ith product maximizes

$$p_{it}^A c_{it}^A - W_t E\tilde{H}_{it}^A - W_t \overline{EH_A}$$

where

$$c_{it}^A = (\frac{p_{it}^A}{P_t})^{-\frac{1}{\varepsilon}} G_t;$$

and

$$c_{it}^A = a_m \sigma E\tilde{H}_{it}^A; \quad E\tilde{H}_{it}^A = (EH_{Ait} - \overline{EH_A}) \tag{32}$$

The producer maximizes profit with respect to individual price p_{It}^A taking composite price P_t and wage rate as given. The optimization behaviour of the firm sets price as a mark up over the marginal cost, ie

$$p_{it}^A = \frac{W_t}{a_m \sigma \varepsilon}$$

In a symmetric equilibrium, where all firms face similar technology and same marginal cost, all firms producing differentiated products will charge the same price

$$p_{it}^A = p_t^A = \frac{W_t}{a_m \sigma \varepsilon}, \quad i = 1,.,n_t \tag{33}$$

And the composite price index is

$$P_t = \left(n_t^{-\frac{\varepsilon}{1-\varepsilon}} \right) p_t^A \tag{34}$$

Making use of (2), (6), (33) and (34), we have

$$c_t^A = \frac{(1-\gamma)\theta_M a_m \sigma \varepsilon \tilde{E}_t}{n_t W_t} - b\left(\frac{1-\gamma}{\gamma}\right)^{\gamma} (\sigma\varepsilon)^{\gamma} n_t^{-\frac{1-\gamma(1-\varepsilon)}{\varepsilon}} \tag{35}$$

Goods market clearing conditions are the following

$$\theta_F \tilde{E}_t + c0 = [EH_{Ft}]^{\gamma_F} \tag{36}$$

and

$$\frac{\theta_M \tilde{E}_t}{p_t^M} - b = a_m EH_{Mt} \tag{37}$$

where EH_{Mt} is the effective human capital allocation in traditional manufacturing sector.Since producers of differentiated goods take the demand for them as given, the equilibrium condition in these markets are already satisfied.

Full employment condition is

$$EH_{Ft} + EH_{Mt} + n_t EH_{it}^A + n_t \overline{EH_A} = (1 - L_t)H_t \tag{38}$$

which says that allocations of effective human capital in all three sectors sum up to the total supply of effective human capital.

Zero profit condition determines the number of firms in the market,

$$p_t^A c_t^A - \frac{W_t}{a_m \sigma} c_t^A - W_t \overline{EH_A} = 0 \tag{39}$$

Making use of equations (28), (36), (37), (32), (30) and (31) in Euler equation (29), full employment condition (38) and zero profit condition (39), we have

$$\frac{(1-L_{t+1})H_{t+1} - c0[EH_{Ft+1}]^{1-\gamma_F} + \frac{b}{a_m}(\sigma\varepsilon)^{(\gamma-1)} n_{t+1}^{-\frac{(1-\gamma)(1-\varepsilon)}{\varepsilon}} \left[\left(\frac{1-\gamma}{\gamma}\right)^{\gamma} + \left(\frac{\gamma}{1-\gamma}\right)^{1-\gamma}\right]}{(1-L_t)H_t - c0[EH_{Ft}]^{1-\gamma_F} + \frac{b}{a_m}(\sigma\varepsilon)^{(\gamma-1)} n_t^{-\frac{(1-\gamma)(1-\varepsilon)}{\varepsilon}} \left[\left(\frac{1-\gamma}{\gamma}\right)^{\gamma} + \left(\frac{\gamma}{1-\gamma}\right)^{1-\gamma}\right]} = \rho A_H \tag{40}$$

And

$$EH_{Ft} - \left(\frac{c0\theta_M[(1-\gamma)\varepsilon + \gamma]}{\theta_M + \theta_F\gamma_F}\right)[EH_{Ft}]^{1-\gamma_F} - \frac{b}{a_m}\left(\frac{1-\gamma}{\gamma}\right)^{\gamma}(\sigma\varepsilon)^{(\gamma-1)}\left(\frac{\gamma_F\theta_F[(1-\gamma)\varepsilon+\gamma]}{(\theta_M+\theta_F\gamma_F)(1-\gamma)}\right) n_t^{-\frac{(1-\gamma)(1-\varepsilon)}{\varepsilon}}$$
$$+ n_t\overline{EH_A} = \left(\frac{\gamma_F\theta_F + (1-\gamma)(1-\varepsilon)\theta_M}{\theta_M + \theta_F\gamma_F}\right)(1-L_t)H_t \tag{41}$$

And

$$\left(\frac{c0(1-\gamma)(1-\varepsilon)\theta_M}{\theta_M+\theta_F\gamma_F}\right)[EH_{Ft}]^{1-\gamma_F}+\left(\frac{\theta_F\gamma_F}{\theta_M+\theta_F\gamma_F}\right)(1-\varepsilon)\frac{b}{a_m}\left(\frac{1-\gamma}{\gamma}\right)^{\gamma}(\sigma\varepsilon)^{(\gamma-1)}n_t^{-\frac{(1-\gamma)(1-\varepsilon)}{\varepsilon}}$$
$$+n_t\overline{EH_A}=\left(\frac{(1-\gamma)(1-\varepsilon)\theta_M}{\theta_M+\theta_F\gamma_F}\right)(1-L_t)H_t \tag{42}$$

These three dynamic equations along with the education technology (8) govern the dynamics of the system.

Human capital, manufacturing output and number of firms in the sector producing differentiated goods, that is product varieties grow at a constant rate of ρA_H. Agriculture grows at a rate of $(\rho A_H)^{\gamma_F}$. Household, in each period allocates a constant fraction of labor time ρ in human capital generation.

3.4 Transition from non-industrialized to industrialized state

With a small amount of human capital endowment, the economy is concerned about fulfilling the requirement of agricultural good, which is a necessity. Consumer's maximum willing ness to pay for any industrial good, which is not necessary is too low compared to the minimum price producers should get in order to cover their marginal cost at the existing wage rate. So producers are not able to open up industries as they are constrained by the lack of market for these goods. The economy is in the non-industrialized state, consuming and producing only agricultural good.

However as household cares about its future income, it invests a fraction of their labor time each period and more and more human capital in education production technology that exhibits constant returns to scale. Thus the economy endogenously grows over time. The labor time allocated in education technology slowly increases and asymptotically approaches to a constant value, which is equal to ρ. The growth rate of human capital from a small value increases over time and asymptotically approaches to a value of ρA_H. Similarly growth rate of the agricultural output increases and asymptotically approaches to $(\rho A_H)^{\gamma_F}$. With minimum food requirement, an economy initially endowed with low level of human capital allocates higher fraction of labor time in market activities to maintain the required production than it would have done if there were no minimum consumption. However as human capital and income grows, the magnitude of minimum consumption becomes smaller and smaller relative to income, and household can devote more and more labor time in education generation that also raises growth rate of human capital. Thus non-homotheticity generates transitional dynamics in the system.

In the process, as economy grows, necessity of food becomes more and more irrelevant relative to growing income, the maximum price that consumer will be willing to pay at the existing wage rate to consume a positive amount of industrial good will increase. On the other hand, since human capital is growing, wage rate falls. Thus a time period will eventually come when consumer and producer prices match. In this period market for industrial good has evolved. However from this period onwards, economy will be able to produce only traditional manufacturing with constant returns to scale along with agricultural good, because at this point of time economy has not generated sufficient human capital to meet the fixed investment requirement in the sectors producing goods with increasing returns technology.

The transition condition is defined in the following way: The economy is producing only agricultural good. Let at period T1 consumer and producer prices for consuming and producing positive amount of traditional manufacturing good match. At this period, human capital and labor time investment in education are determined by equations (18) and (8). These are respectively H_{T1} and L_{T1}. Then wage rate is $(1-L_{T1})H_{T1}$. The maximum price at the existing wage rate at which consumer consumes positive amount of traditional manufacturing is derived from budget constraint (19) and using $c_t^M = \frac{\theta_t^M \tilde{E}_t}{p_t^M} - b$ as

$$p_{T1}^{MC} \leq \left(\frac{\theta_M}{\theta_F b}\right)\{[(1-L_{T1})H_{T1}]^{\gamma_F} - c0\}$$

Again producers will produce if price is able to at least cover the marginal cost, i.e.,

$$p_{T1}^{MP} \geq \frac{\gamma_F[(1-L_{T1})H_{T1}]^{\gamma_F - 1}}{a_m}$$

When these two prices match,

$$\left(\frac{\theta_M}{\theta_F b}\right)\{[(1-L_{T1})H_{T1}]^{\gamma_F} - c0\} = \frac{\gamma_F[(1-L_{T1})H_{T1}]^{\gamma_F - 1}}{a_m} \tag{43}$$

This is the condition that determines the time period when market for traditional manufacturing evolves. Now if economy starts producing it, human capital will be allocated efficiently between two sectors, instantly and the economy is on a different dynamic equilibrium path. But to move to that dynamic path where both sectors sustain, economy should have generated enough human capital such that total requirement of effective human capital in two sectors equals the total supply. This can happen at period $T1$ itself, or at some later period $T1'$, such that

$$EH_{FT1'} + EH_{MT1'} = (1-L_{T1'})H_{T1'}; \quad T1' \geq T1 \tag{44}$$

where $EH_{FT1'}$, $L_{T1'}$ and $EH_{MT1'}$ are determined by equations (26), (27) and (24) with $H_0 = H_{T1'}$.

Thus equations (43) and (44) together determines conditions for transition from a non-industrialized state to initial-industrialization state. Numerically we find that such transition occurs after non-industrialized equilibrium reaches the steady state. Such a transition is accompanied by an increase in wage rate as opening of traditional manufacturing drives away labor from manufacturing. More over there is a modest increase in utility due to a shift to the initial-industrialized state from what would have been in the corresponding period if economy remained in the non-industrialized state.

Since transition from agriculture to coexistence of agriculture and traditional manufacturing occurs when agrarian state has reached the long run path, necessity of food in terms of minimum consumption does not play any role in the transition dynamics. However human capital endowment of the economy is not too high in this stage. Thus after opening up of industry, economy has to devote a higher fraction of labor time in education for two sectors to sustain in the future. But as human capital grows it can devote more and more time in market activities. Thus L_t in this state, from a high value falls over time and asymptotically approaches a constant value of ρ. Growth rate of human capital also falls over time from a large value and asymptotically approaches ρA_H.

Similarly market for mass production goods evolves when consumer facing at least one differentiated good wants to pay a price that matches with the price set by the producers as a mark up over marginal cost at the existing wage rate. Suppose, such matching occurs at period $T2$ when economy is in the initial industrialized state. Taking $n_t = 1$ and using (28), (35) and (33), we gave

$$\left(\frac{\theta_M \gamma}{\theta_F b}\right) a_m^{\gamma} \left\{ \frac{\gamma_F [EH_{FT2}]^{(\gamma_F - 1)} [(1 - L_{T2}) H_{T2}] + (1 - \gamma_F) [EH_{FT2}]^{\gamma_F} - c0}{(\gamma_F [EH_{FT2}]^{\gamma_F - 1})^{\gamma}} \right\} = \frac{\gamma_F [EH_{FT2}]^{\gamma_F - 1}}{a_m \sigma \varepsilon} \tag{45}$$

where EH_{FT2}, L_{T2} and H_{T2} are determined by equations (26), (27) and (8) taking $H_0 = H_{T1'}$.

This is the condition that determines the time period when market for mass production evolves. Now if economy starts producing it, human capital will be allocated efficiently between three sectors, instantly and the economy is on a different dynamic equilibrium path. But to move to that dynamic path where both sectors sustain, economy should have generated enough human capital such that total requirement of effective human capital in three sectors equals the total supply. This can happen at period $T2$ itself, or at some later period $T2'$, such that

$$EH_{FT2'} + EH_{MT2'} + n_{T2'} EH^{A}_{iT2'} + n_{T2'} \overline{EH_A} = (1 - L_{T2'}) H_{T2'}, \quad T2' \geq T2 \qquad (46)$$

where $EH_{FT2'}$, $L_{T2'}$, $n_{T2'}$, $EH_{MT2'}$, $EH^{A}_{iT2'}$ are determined by equations (40), (41), (42), (37), (32) and (35) with $H_0 = H_{T2'}$.

Thus equations (45 and (46) together determines conditions for transition from a initial-industrialization state to mass production state. Numerically we find that such transition occurs before initially industrialized equilibrium reaches the steady state. Such a transition is accompanied by a fall in wage rate. More over there is almost doubling of utility due to a shift to the mass production state from what would have been in the corresponding period if economy remained in the initially industrialized state.

Since economy has grown sufficiently so that necessity of agricultural good has become irrelevant and three sectors can be sustained, thus along the dynamic equilibrium path in the mass production stage, human capital from the beginning grows at a rate of ρA_H and household allocate ρ fraction of labor time in education generation in each period.

3.5 Conclusion

This paper develops an endogenous growth model that captures the historical evolution of preferences, knowledge, technology and output. It develops a human capital-led growth model that generates endogenous transition between three rgimes that have characterized economic development. The economy evolves from an agricultural to traditional manufacturing and then finally to highly automated mass-production stage characterized by increasing returns technology. The model essentially captures the ”pull” view of origins of industrial take off that focuses on the development of new production opportunities in the industrial sector. These new production opportunities evolve because of changing preference pattern with the introduction of new goods. The economy, starting from an agrarian society, consuming and producing only agricultural good is able to take off to a primitive industrial state with sufficiently accumulated human capital followed by a shift in the preferences towards new industrial goods serving fairly new purposes. Again when the knowledge base of the economy becomes strong enough to be embodied into highly automated, standardized, synchronized and continuous technique of production, it enters the stage of mass production (characterized by increasing returns technology) of varieties of new goods that expand the preference set of people. This paper essentially tries to describe the experience of world economy over the last two hundred years when countries experienced rapid growth in living standards by taking advantage of the scale economies in the production of manufacturing.

4 Reference

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