Public Policy, Long Run Growth and Economic Transition from Agriculture to Industrial Mass Production

Rudrani Bhattacharya

Thesis submitted to the Indian Statistical Institute in partial fulfilment of the requirements for the award of the degree of Doctor of Philosophy

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Chapter 1

Introduction and Summary of Major Findings

1.1 Background

It has been recognized that the heart of the development process lies on the transformation of an economy from traditional activities in agriculture to industrial activities. As emphasized by Lewis (1954), the movement of labor from primary sector to industry is conducive to the rise of economy's savings and investment rate and thus fostering economic growth. The core of this paradigm is the historically observed rapid growth in today's developed countries associated with expansion of industrial activities.

It is well-documented by now that at least over a few centuries leading up to 1800 AD there was little change in the world living standard in terms of per capita wage, income, output or consumption (Hansen and Prescott, 2002 and Tamura, 2002). Not only that, according to Cameron (1993), the living standard in 1850-Britain was about the same as in the Roman empire era. Subsequent centuries have witnessed a remarkable improvement in the standard of living. During 1800-1996 the per-capita real income in Europe has grown at an annual average rate of 1.8% (Tamura, 2002). During the subsequent 120 years, from 1870 to 1990, these averages are 1.9% for the U.S. and 1.4% for the U.K.

Such transition of growth regimes along with evolution of international income level has been received with increasing interest by scholars in recent years and a strand of literature is building up to describe an endogenous process underlying these phenomena (Love, 1997; Galor and Weil, 2000; Laitner, 2000; Jones, 2001; Galor and Moav, 2002; Hansen and Prescott, 2002; Tamura, 2002).

Among various channels, the key is the transformation of an economy from land based agricultural production mode to industrial activities followed by demographic transition (Hansen and Prescott, 2002 and Tamura, 2002). In agricultural era, land, which is the prime input of production, imposed maximal sustainability condition on the standard of living. Once an economy switches to the modern production technology that uses endogenously growing factors of production, such as physical or human capital, land is no longer important and the economy experiences sustainable growth in income which was not possible earlier given the fixity of land endowment and the growing population.

Again when one examines the evolution of world economies more closely, the following observations stand out as significant and interesting. First, *England was the first country in the world that experienced the transition to modern growth era.* The transition in the English economy took place around the beginning of the nineteenth century when annual productivity growth rose to 1% or more from a rate bellow 1%, prevailing in the eighteenth century (Clark, 2005).

Second, in the *late nineteenth century, the U.S. economy started catching up with the leader in that era, the United Kingdom, and during 1865-1929 the living standard in the U.S. surged persistently and overtook that of U.K.* In 1870, the U.K. per capita GDP was nearly 33% higher than that of the U.S., whereas by 1929, the former had per capita GDP that was 33% lower than that of the latter (Parente and Prescott, 2005). Also as reported in Business Week Online, (2004), while in 1913, the per capita incomes of the U.S. and Britain were roughly the same, by 1950 it was almost 40% higher in the U.S. than in Britain.

The very beginning of the twentieth century in the U.S. was marked by the onset of modern industrial activities characterized by mass production or increasing returns to scale technology.[1] This method of production was fairly established by 1910 and became widely known and more widespread especially after Henry Ford's introduction of Model T in 1913. It brought in dramatic changes in the U.S. industrial structure that was able to produce a wide range of goods at a very low cost. As DeLong (1997) writes, with this "new" production method U.S. became a modern middle-class society consuming varieties of goods such as radios, consumer appliances, automobiles etc. To paraphrase him, "mass production has made the post-World War I United States the richest society the world had ever seen."

Third, the transition from agricultural to industrial activities and the modernization of industries itself in an economy may not be a natural process. Had it occurred naturally, all the economies in the world would have taken off at the same time and eventually modernize their industrial activities at the same pace to achieve the same level of income over time. On the contrary, *the dates of transition to modern growth era and income levels differ across countries considerably.*[2] While the U.S. lagged behind the U.K. in terms of taking off from agriculture to industrial activities, it became the global leader by the second World War through a second stage of transition (mass production) within its industrial organization. The western Europe followed the global leader in the post

[1] According to Parente and Prescott the U.S. acting as a free trade club was one of the major reasons behind its spectacular catching up experiences.

[2] Parente and Prescott, 2005 provides detailed discussion on variation in transition dates across countries.

war period and reduced their income gap with the it (Parente and Prescott).

Moreover, other economies have mixed experiences so far as transition to sustaining growth is concerned. As documented by Parente and Prescott, among the Latin American countries, Mexico's transition process started sometime in 1800-1850, while Brazil entered the era of sustainable growth in 1900. However these countries failed to lower the income gap with the leader (U.S.) in the past hundred years. Again, among the countries in Asia, Japan's transition took place some time, between 1850-1900. In other Asian countries such as South Korea, Taiwan transition started to take place in the mid twentieth century and these countries experienced dramatic increase in income in a relatively short period of time. Income was doubled in these countries in a time horizon that is less than a decade and this incident is known as the *growth miracles.* Increasing returns to scale technology played an important role in the growth performance of these countries as well as the post war Japan (Murphy, Shleifer and Vishny, 1989).

The above observations indicate that the shifts from agricultural to industrial activities and transition within the industrial production structure may not occur naturally as there may exist constraints on the choice of production methods. If costs associated with these constraints are large, adoption of new technologies may not be viable and hence the transition process is hampered. Thus policies may play an important role in eliminating such constraints to facilitate adoption of new methods of production. Hence country-specific policies may play an important role in determining the development trajectory.

It has been found in several studies that firms may face constraints which are imposed as a measure to protect the interests of the factor suppliers to existing production method (Parente and Prescott, 2005). The authors further argue that such constraints stem from specificity of inputs to existing technology or price inelasticity of industry's demand for those inputs. Land is a typical example of an input which is specific to agricultural production process. Thus in many developing countries, adoption of new technologies may face constraints imposed by suppliers of land. In absence of deliberate policy intervention, such constrains are likely to hamper the transition process of the economy.

Indeed, Galor, Moav and Vollrath (2006) observe that the countries which undertook institutional reforms to reduce the power of land-owning class and at the same time adopted policies to facilitate new production method succeeded in reducing the income gap with the leader. They argue that the evidence from Japan, Korea, Russia and Taiwan shows that institutional (land) reforms followed by educational reforms played a significant role in the transition and growth process of these economies.

In Japan, massive land reform process was initiated in 1871 after the Meiji Restoration of 1868. This reform was shortly followed by a series of educational reforms starting in 1872. Similarly South Korea and Taiwan had undertaken land reforms during 1949-53 after the end of Japanese colonization. This period is also marked by educational reforms so that the workforce become technically compatible for the industrial method of production. Similar trend can be found in Russia also where agrarian reforms initiated in 1906 were followed by educational reforms during 1908-12. Galor et al. argue that land reform reduced the influence of the land-owning class in the choice of technique of production and the promotion of human capital generation facilitated adoption of new production methods in these economies.

In contrast, Latin American countries such as Colombia and Mexico which were ahead of the above mentioned economies at the end of the second World War in terms of per capita income started falling behind them in the latter periods of the twentieth century. These Latin American countries are indeed characterized by vast inequality in the distribution of land.

However, in the developing countries where a large segment of the society depends on land, undertaking policy measures promoting industrial activities may turn out as a debatable issue. Indeed, Rodrik (2006) points out "recent economic thinking on policy reforms pays scant attention to structural transformation and industrial development" and pays more importance to correcting economic fundamentals such as macroeconomic stabilization and efficient functioning of markets which are believed to make structural transformation an automatic process.

The above discussed policy issues are becoming increasingly relevant in the developing countries as the surge of globalization in the recent decades has increased the importance of industry in these countries. To quote Rodrik (2006), "In recent decades rapidly growing developing countries have been able to grow much faster than earlier antecedents (Britain during the industrial revolution, the United States during its catch-up with Britain in the late 19th century, or European recovery in the postwar period). The reason for this is that world markets provide near-limitless demand for manufactured exports from developing countries. An expansion of non-tradables is self-limiting, as the domestic terms of trade eventually turns against non-tradables, choking off further investment and growth. And there are natural limits to export-led growth based on primary products, as country after country has discovered. Developing countries exporting manufactured products do not face such limits as long as they can latch on to new activities which face dynamic demand in rich countries markets."

In view of such rapidly changing global scenario, industrialization plays an important role in the long-run development of economies. However broadening the manufacturing base requires effective policy implementation that will direct resources from primary sector to industrial activities. As argued by Rodrik, in the absence of such policies, developing economies in the process of opening to the international trade, will allocate resources to the primary sector in which these countries have comparative advantage. And this process may not be conducive to the long run growth given limited capacity of the primary sector, which depends on fixed endowments of natural resources. This will in turn hamper the transition of these economies to the high growth regime.

The motivation of this thesis is based on the entire realm of issues discussed above and it focusses on two selected topics on the theory of endogenous growth and transition.

1. The first topic focusses on the role of agriculture in the long run growth of a small open economy and implications of public policies in this respect.

2. The second topic deals with endogenous transition of an economy from the primitive agricultural stage to the traditional manufacturing and finally to the modern industrial activities characterized by increasing returns to scale.

The following sections contain a brief discussions on the two essays constituting the thesis.

1.2 Agriculture, Public Input Provision and Growth

The first essay formulates a two-sector endogenous growth model to investigate the role of agriculture in the growth process of an economy, in the context of public infrastructural policy. This work is in line with Matsuyama (1992). In this seminal paper, in contrast to long-standing development literature focussing on the relationship between agriculture and economic development in a static or an exogenous growth framework, he explored the relationship in a dynamic perspective, in which the growth rate is endogenous. The source of growth is learning-by-doing in the industrial sector. He found, contrary to the conventional wisdom, that in a small open economy with a highly productive agricultural sector compared to the rest of the world such that it has comparative advantage in agriculture, the manufacturing sector loses labor over time, its output falls and learning-by-doing slows down, dampening the growth rate of the economy.

My first essay in Chapter 3 focusses on an alternative source of endogenous growth i.e., a tax-financed (non-accumulable) public input used in the production sectors of the economy a la Barro (1990), allowing for such public investment in both manufacturing and agriculture. Numerous studies indicate that public investment as an important source of economic growth and a major catalyst to boost industrial activities (Ram, 1986; Aschauer, 1997; Haque and Kim, 2003; Rodrik and Subramanian, 2004; Bose, Haque and Osborn, 2007). The role of public expenditure in agricultural and rural development has been emphasized by Fan, Zhang and Zhang (2004) and Fan Hazell and Thorat (2000) as well.

This essay contrasts Barro by capturing the notion of sector-specific nature of infrastructure to explore how agricultural development and distribution of public inputs across sectors affect long-run growth and welfare of the economy in a multi-sectoral framework. By doing so, it also attempts to bridge the two classes of empirical literature indicating the contribution of public input either in over all long run growth of the economy, or in the productivity enhancement of a particular sector (manufacturing or agriculture). The main results of this essay are summarized below:

Main Results

(A) In a small open economy, an increase in agricultural productivity, exogenous or policy induced, may have a negative impact on the long-run growth *irrespective* of the pattern of comparative advantage. This is a much stronger result compared to Matsuyama.

Intuitively, an exogenous productivity surge, given employment allocation, raises the total income, tending to increase the provision of the public input. In agriculture, labor productivity increases directly because of productivity gain, as well as due to higher provision of public input. In manufacturing, labor productivity rises only via rise in public input. Return to labor being higher in the former sector, labor moves out of industry, reducing return to capital and hence long run growth rate of the economy.

A policy-induced productivity surge in agriculture via an increase in share of public input in agriculture reduces its share in industry. Labor productivity in the former sector rises, while in the latter it falls. Labor moves out of industry, reducing return to capital and hampering the growth rate of the economy.

(B) Similar to Barro, there exists a tax rate that maximizes the long-run growth rate of the economy.

An increase in tax rate directly reduces the after-tax return on capital and hence growth rate. Again, it raises provision of public input, which tends to raise the return to capital and growth rate. When initial tax rate is low, a small rise in it results in the positive effect to dominate. Hence growth rate rises. For a high value of the tax rate, the negative effect dominates and growth rate falls.

(C) The effects of productivity surge in agriculture (exogenous as well as policy-induced, the latter occurs through increase in share of productive public input in agriculture) and tax rate on the welfare are in general ambiguous. Welfare is defined as the discounted sum of utilities and decomposed into growth and level effects.

However, a numerical exercise based on the parameter values that replicates a few characteristics of Indian sectoral employment data shows that exogenous productivity rise in agriculture is always welfare enhancing, while impacts of tax rate and reallocation of public input across two sectors on welfare crucially depend on the relative employment share in two sectors determined by the level of agricultural TFP and land-endowment of the economy.

Increase in agricultural productivity tends to raise provision of public input that has an initial income enhancing effect, while its impact on the growth rate is negative. Given the parameter values in the numerical analysis, positive level effect outweighs negative growth effect. Thus social welfare increases with exogenous productivity gain in agriculture.

(D) If the economy is endowed with low TFP in agriculture and/or low endowment of land, so that most of the population are employed in manufacturing, welfare has an inverted-U relation with tax rate. Otherwise, social welfare always increases with tax rate.

An increase in tax rate raises provision of public input that enhances income in both sectors. However it reduces the net income having a negative impact on the initial expenditure. The net level effect is thus ambiguous. Growth effect of tax rate is also ambiguous as the growth rate has an inverted-U relation with tax rate.

When TFP in agriculture and/or land endowment are low, positive level effect coupled with positive growth effect tends to raise social welfare due to a small rise in tax rate. Thus social welfare initially increases with tax. With further hike in tax rates, level effect is outweighed by negative growth effect and thus social welfare falls with tax rate.

If agricultural TFP and/or land endowment are high, level effect of tax rate is positive and large and always outweighs the growth effect. Hence social welfare increases with tax rate.

(E) The pattern of changes in social welfare with respect to public input reallocation crucially depends on the productivity of agriculture and endowment of land.

(a) If land-base is large or agricultural productivity is high, social welfare increases with rise in public input share in agriculture.

An increase in share of public input in agriculture reduces its share in industry. Hence its effects on total income and thus on total public input provision are ambiguous. Hence, level effect is ambiguous, too. If the economy is endowed with a highly productive agriculture sector or large amount of land, level effect is positive and large, and always outweighs the negative growth effect. Hence social welfare always rises with increase in share of public input in agriculture.

(b) If land endowment is small, or agricultural productivity is low, social welfare falls with public input share in agriculture.

If land endowment is small, or agricultural productivity is low, level effect of increase in public input share in agriculture is negative. This, coupled with negative growth effect, tends to reduce social welfare.

(c) In between the above two cases, there exists a range of productivity level and a range of land base such that social welfare initially falls and then increases as the share of public input in agriculture increases.

In between these two extreme cases, for some ranges of productivity in agriculture and land base, initially level effect is negative and social welfare falls with increase in public input share in agriculture. However as agricultural productivity endogenously develops through higher and higher share of public input allocated into this sector, level effect becomes positive and starts dominating the growth effect; social welfare starts increasing with the share of public input in agriculture.

(F) Non-homothetic demand pattern gives rise to an interesting pattern of transitional dynamics. During the transitional period, the growth rate of the economy monotonically increases over time.

Initially, with a low level of capital stock, income is low, the savings rate also remains low as the representative household cares about fulfilling the subsistence food requirement. As income grows, minimum level of food requirement becomes increasingly negligible compared to the growing income and hence savings rate increases. Thus growth rate monotonically increases over time.

This implies that any parametric change that has a detrimental effect on the long-run growth, e.g., an increase in agriculture productivity, will have a stronger negative impact on growth in the short run. Put differently, there is an overshooting effect (in the short run) in terms of the growth rate in response to a shock that negatively affects the long run growth rate.

1.3 Advent of Industrial Mass Production: Three Stages of Economic Development

The second essay builds up a human capital-led endogenous growth process that generates *endogenous transition* of an economy from the primitive agricultural stage to an 'early' or traditional industrialized state and finally to advanced industrial state, where traditional manufacturing is characterized by constant returns to scale technology, the advanced stage is marked by mass production or increasing returns technology.

When economy enters the traditional manufacturing stage followed by the first transition, both agriculture and the industries producing goods with constant returns to scale coexist. Finally the model generates a transition within the industrial sector leading to an emergence of a third good by mass production. Compared to the existing literature, the innovation in this essay lies in the second transition-the advent of mass production.

As discussed earlier, the dawn of 'mass production' in the U.S. witnessed in the beginning of the twentieth century (Besanko et. al., 2007) had a significant impact on the U.S. economy. This new method of production involving huge fixed (overhead) costs and low marginal cost was truly a revolution in manufacturing. It brought out a wide spectrum of products at relatively low prices, leading to an impressive increase in the standard of living for all.

It is important to note that Murphy, Shleifer and Vishny (1989) in their famous 'big-push' work has emphasized on the movement from traditional manufacturing characterized by constant-returns to modern manufacturing having increasing returns as the process of industrialization. However, a major difference of this work from theirs is that the latter is a static one and emphasizes how modern manufacturing may become sustainable only when a sufficiently large number of entrepreneurs decide to adopt the increasing-returns technology, whereas this essay provides a dynamic mechanism. It attempts to predict analytically not only the transition from traditional manufacturing to mass production but that from agriculture to traditional manufacturing too.

This essay falls in line with Hansen and Prescott (2002) and Tamura (2002), but unlike them, it considers goods produced in the three different sectors to be different, a feature similar to Love (1997) and Laitner (2000).[3] More specifically, the mass production sector is characterized by monopolistic competition and produces varieties of differentiated products. One novel feature of the model is that the postulated preference structure accompanies and partly facilitates the process of transition-namely that it changes as new goods are introduced. In an agrarian society an individual's utility is defined on agricultural goods that fulfills biological needs, and, over time as the real income grows and industrial goods are introduced, she obtains utility from these goods, which are not essential for physiological purpose. However the preferences are not presumed to change at exogenously specified calender dates, forcing transition. More about the preference structure will be said in Chapter 4.

The theoretical model is calibrated using U.S. data to generate real per capita GDP from 1500 to 1990 AD and the average absolute deviation from the actual time series on U.S. real GDP per capita during the same period is calculated to provide a measure of the model's goodness of fit. In the process, the model endogenously predicts the dates of transition from agriculture to traditional manufacturing and finally to the mass production stage. predicting transition date is novel compared to the existing literature, which either considers the transition date as exogenously given and calibrate the model or generate some qualitative feature of country-specific macroeconomic data. The main

[3]The main features of these papers will be pointed out in Chapter 2.

findings of the essay are summarized as follows:

Main Results

(A) With a sufficiently small human-capital endowment initially, the economy is exclusively concerned with fulfilling the requirement of agricultural good, which is a necessity. At this stage, the consumer's willingness to pay for the industrial good is too low compared to the minimum price that covers the cost of producing this good. The economy thus remains, initially, in a non-industrialized state, consuming and producing only the agriculture good.

(B) Households, caring about their future income, invest in human capital and this causes the real income to grow over time as well as causes the marginal cost of hiring a unit of effective labor to fall. As a result, the consumers' willingness to pay for the industrial good rises, while reduction in the cost of production (due to human capital accumulation) improves the viability of the industrial sector. A time period eventually arrives when the willingness to pay exceeds the minimum producer price for sustaining the traditional manufacturing sector. This sector then opens up and coexists with agriculture.

(C) As the stock of human capital grows further, the fixed cost requirement in producing the mass-production in modern manufacturing good is met and the consumers' willingness to pay for the mass-production good becomes high enough, so that the producers in this sector are able to cover their costs. At that point of time, all three sectors operate in the economy.

(D) The agricultural sector and the real income grow at the same rate in agricultural stage. Given the differences in returns to scale in agriculture and traditional manufacturing, in the second stage the asymptotic growth rate in the manufacturing sector is higher than that in agriculture. The asymptotic growth rate of real income in the latter stage is also higher than that in the former.

(E) When the mass production sector becomes operational, output of different varieties remain fixed, while the number of varieties and the output in the traditional manufacturing sector grow at a common asymptotic growth rate. The asymptotic growth rate of real income in this stage is even higher than that in the previous stage. The intuition is as follows. As the introduction of the mass production sector initiates a shift in preferences toward the non-agricultural goods and these sectors grow at a higher rate than does agriculture, there is an increase in the growth rate of real income. If the effect of variety growth are taken into account, the real income, which can be termed as *variety-augmented real income* grows even at a greater rate.
(F) The simulation exercise predicts the first transition date lying between 1821-1833 and the second at 1904-1905 under different choices of a set of parameter values. The first set of transition dates are well within the historically documented time frame of the first surge of industrial revolution. The second transition dates are also reasonable given evidences of successful launch of mass production technique in various industries in the U.S. during late nineteenth and early twentieth centuries.

The average absolute percentage deviation of real GDP per capita from the actual U.S. time series of the per capita real GDP is around 11.46-13.17%.

1.4 Organization

The thesis is organized as follows. Chapter 2 provides a brief survey of the existing literature in the issues examined in the two above mentioned essays. The two essays are presented in Chapters 3, and 4. Chapter 5 suggests some possible extensions for future research on the topics covered in the thesis.

Chapter 2

Literature Survey

This Chapter provides a selected survey of the literature that relates closely to the two basic issues that will be examined in this thesis.

2.1 Agriculture and Economic Development

The long existing development literature starting from Rosenstein-Rodan (1943), Nurkse (1953) and Lewis (1955) to Murphy, Shleifer and Vishny (1989) and beyond, that explores relationship of agriculture and industrialization is either static or in the tradition of exogenous growth models, focussing on *level effects*, not *growth rate effects*. It stresses the positive linkages between agriculture and industrialization (or modernization). Typically, three channels are recognized.

First, the income elasticity of demand for the agricultural good being less than one, an increase in the agricultural productivity in a closed economy releases labor for manufacturing employment and thus contributes towards 'modernization' and growth of the manufacturing sector. Second, higher income raises the demand for manufacturing products. Third, aggregate savings increase and finance investment in the manufacturing sector.

The seminal paper to formally investigate the relationship between agriculture and economic growth in a dynamic and an *endogenous* process is Matsuyama (1992). His model is reviewed below.

Matsuyama (1992)

It has two sectors, namely, manufacturing (X^M) and agriculture (X^A). Both sectors use labor, which is the only mobile input and normalized to one. The model abstracts from the population growth and the total size of the population is fixed at L. Technologies in *both* sectors are characterized by the diminishing returns to scale.

The production function in the manufacturing sector is given by

$$X_t^M = M_t F_M(n_t) \quad F'_M > 0, \quad F''_M < 0,$$

where n_t denotes fraction of labor employed in manufacturing. The productivity in manufacturing (M) represents knowledge capital, a sector specific input that grows over time through learning-by-doing, although the stock of knowledge at a point of time is given for an individual firm. The knowledge capital accumulates following the learning-by-doing equation,

$$\dot{M}_t = \delta X_t^M, \quad \delta > 0.$$

The production function in agricultural sector is the following:

$$X_t^A = AF_A(1 - n_t), \quad F'_A > 0, \quad F''_A < 0.$$

The agricultural productivity denoted by the parameter A is exogenous or time invariant. It captures technological level, land endowment, climate etc.

The learning-by-doing process in the industry is the source of endogenous growth.

The preference structure reflects Engel's law with respect to the agricultural good which is given by

$$W = \int_0^\infty [\beta \log(c_t^A - c_{\min}^A) + \log c_t^M] e^{-\rho t} dt, \quad c_{\min}^A > 0,$$

where c_t^A and c_t^M are the consumption of agricultural and industrial goods by the representative household and $c_{\min}^A$ is the subsistence level of food consumption.

The basic finding, *contrary to the conventional wisdom, is that agricultural productivity may not be conducive to growth.*[1] *This result depends crucially on the openness of an economy to trade, and the pattern of trade.* A brief discussion on his findings is as follows:

Under the static optimization exercise, the representative household maximizes $u_t = \beta \log(c_t^A - c_{\min}^A) + \log c_t^M, \quad \text{subject to} \quad c_t^A + p_t c_t^M = w_t$ where p_t and w_t are the relative price of manufacturing in terms of agricultural good and wage rate respectively. The static optimization yields the first order condition as $c_t^A - c_{\min}^A = \beta p_t c_t^M$. Adding the first order condition over the entire population yields

$$C_t^A = c_{\min}^A L + \beta p_t C_t^M \tag{2.1}$$

where $C_t^A = c_t^A L$ and $C_t^M = c_t^M L$ are the aggregate consumption of agricultural and manufacturing goods. The free labor mobility condition across sectors implies

$$A F_A'(1 - n_t) = p_t M_t F_M'(n_t). \tag{2.2}$$

Closed Economy

In this framework, the model predicts that *in a closed economy, employment share in manufacturing and food production remain constant over time for a given level of A, while manufacturing output grows at a uniform rate.* Substituting p_t from (2.2) in (2.1), and eliminating C_t^M and C_t^A using the market clearing conditions

$$C_t^M = M_t F_M(n_t), \quad C_t^A = A F_A(1 - n_t) \tag{2.3}$$

[1]He has cited that in the continental Europe, Belgium and Switzerland were first to industrialize, not the land-rich Netherlands. In the US, the North-East industrialized first, not the agriculturally endowed South. More recently, one observes that South Korea and other Asian countries that have grown impressively are not well-known for their agricultural potential.

from equation (2.1) and rearranging, the key relation between labor share in manufacturing and agricultural productivity is derived:

$$F_A(1-n_t) - \beta F'_A(1-n_t)F_M(n_t)/F'_M(n_t) = c^A_{\min}L/A \tag{2.4}$$

It solves for $n^* = n^*(A)$, implying share of labor in manufacturing is constant over time for a given value of agricultural productivity A. From the learning-by-doing equation, manufacturing output grows at a constant rate $\gamma^*_M = \frac{\dot{M}_t}{M_t} = \delta F_M(n^*(A))$.

It then follows from equations (2.1), (2.2) and (2.3), a constant level of food production and consumption for a given value of A,

$$C^{A*} = X^{A*} = c^A_{\min}L + A\beta F'_A(1-n^*(A))F_M(n^*(A))/F'_M(n^*(A)). \tag{2.5}$$

The technology in both sectors having diminishing returns, a simple comparative statics of the expression in (2.4) with respect to A shows $\frac{\partial n^*}{\partial A} > 0$. This in turn implies $\frac{\partial \gamma^*_M}{\partial A} > 0$ and $\frac{\partial C^{A*}}{\partial A} = \frac{\partial X^{A*}}{\partial A} > 0$. Thus, *Employment share in industry, industrial growth rate and food production increase with the agricultural productivity parameter.*

Intuitively, in a closed economy, an increase in A, with income elasticity of food less than one, releases labor to manufacturing. Manufacturing output increases and accelerates the growth rate of this sector as well as the economy's growth rate[2] via learning-by-doing.

Further, *in a closed economy, utility of the representative household rises unambiguously because of productivity surge in agriculture.* This can be shown in the following way: Let M_0 be the initial manufacturing productivity level. Then the consumption and production of manufacturing at t is $C^M_t = X^M_t = M_0 F_M(n^*(A)){\gamma^*_M}^t$. The consumption of agricultural good C^{A*} remains constant for all t given by the expression (2.5). The utility of the representative household consuming $c^A_t = C^A_t/L = C^{A*}/L$ and $c^M_t = C^M_t/L$

[2] In Matsuyama, specifically, the rate of expansion of manufacturing output and that of the overall production possibility frontier in general is referred to as the growth rate of the economy.

amount of food and industrial goods then increases as A rises (following the comparative static results states above).

Agricultural productivity surge directly raises production and consumption of agricultural good, while manufacturing output and consumption increase through the released labor from agriculture leading to a higher level of utility.

Open Economy

Now, consider a small open economy, Home. The productivity level in Home agriculture is A. The initial level of manufacturing productivity in the Home country is M_0. The rest of the world has a different level of agricultural productivity A^R and initial stock of knowledge M_0^R compared to Home. The world economy evolves along the path which is similar to the equilibrium path of a closed economy described above. Its labor share in manufacturing is constant at $n^{R*}(A^R)$.[3] The world manufacturing sector grows at a uniform rate of $\delta F_M(n^{R*}(A^R))$ and the world relative price of manufacturing p_t is determined by the free labor mobility condition of the world,

$$A^R F_A'(1-n^{R*}) = p_t M_t^R F_M'(n^{R*}). \tag{2.6}$$

Given the world relative price of manufacturing in (2.6), Home's labor allocation across sectors is governed by the equation (2.2). Substituting p_t from the former equation in the latter, and rearranging yields the equation determining Home's manufacturing labor share,

$$\frac{F_M'(n_t)}{F_A'(1-n_t)} = \frac{AM_t^R}{A^R M_t}\frac{F_M'(n^{R*})}{F_A'(1-n^{R*})}. \tag{2.7}$$

At $t=0$, the above expression becomes

$$\frac{F_M'(n_0)/F_A'(1-n_0)}{F_M'(n^{R*})/F_A'(1-n^{R*})} = \frac{A/M_0}{A^R/M_0^R} \quad \Rightarrow n_0 \gtreqless n^{R*}, \quad \text{if and only if} \quad A/M_0 \lesseqgtr A^R/M_0^R,$$

given that $F_M'(n)/F_A'(1-n)$ is a decreasing function in n due to diminishing returns

[3] World economy variables are denoted with a superscript R.

technology in both sectors. Intuitively, the home country has a larger manufacturing sector to begin with if it has comparative advantage in industry.

Differentiating (2.7) with respect to time and making use of $\frac{\dot{M}_t}{M_t} = \delta F_M(n_t)$ and $\frac{\dot{M}_t^R}{M_t^R} = \delta F_M(n^{R*})$ yields the dynamic path of labor share in Home manufacturing,

$$\underbrace{\left[\frac{F_A''(1-n_t)}{F_A'(1-n_t)} + \frac{F_M''(n_t)}{F_M'(n_t)}\right]}_{-} \dot{n}_t = \delta \left\{F_M(n^{R*}) - F_M(n_t)\right\}. \tag{2.8}$$

The expression in the square bracket in the left hand side being negative, whether $\dot{n}_t \gtreqless 0$ depends on whether $n_t \gtreqless n^{R*}$. Evaluating (2.8) at $t = 0$ then implies that $\dot{n}_t \gtreqless 0$ if and only if $n_0 \gtreqless n^{R*}$. The latter inequality in turn as discussed above, depends on the pattern of comparative advantage of Home vis a vis the world economy. It has the following implication: *in a small open economy, having comparative advantage in agriculture, manufacturing sector squeezes and the growth rate slows down over time.* Intuitively, in a small open economy, with a highly productive agricultural sector compared to the rest of the world – such that it has comparative advantage in agriculture and hence smaller employment share in industry to begin with compared to the world – over time, the manufacturing sector loses labor. Manufacturing output falls and learning-by-doing slows down, dampening the growth rate of the economy.

Figure 2.1 shows how labor allocation dynamics of the Home country behave depending on its pattern of comparative advantage vis a vis the rest of the world. The horizontal axis of the diagram represents time while along the vertical axis, labor share in Home's industrial sector is measured. If initially, the agricultural productivity relative to that in manufacturing in Home A/M_0 is same as the ratio of these productivity levels in the world economy, A^R/M_0^R, then the employment share in Home manufacturing n_t remains constant at $n_0 = n^{R*}$, where n^{R*} is world's labor share in industry (from equation (2.8) evaluated at $t = 0$). This is depicted by the horizontal line IJ. Now if Home has comparative advantage in agriculture, i.e., $A/M_0 > A^R/M_0^R$, then $n_0 < n^{R*}$, labor

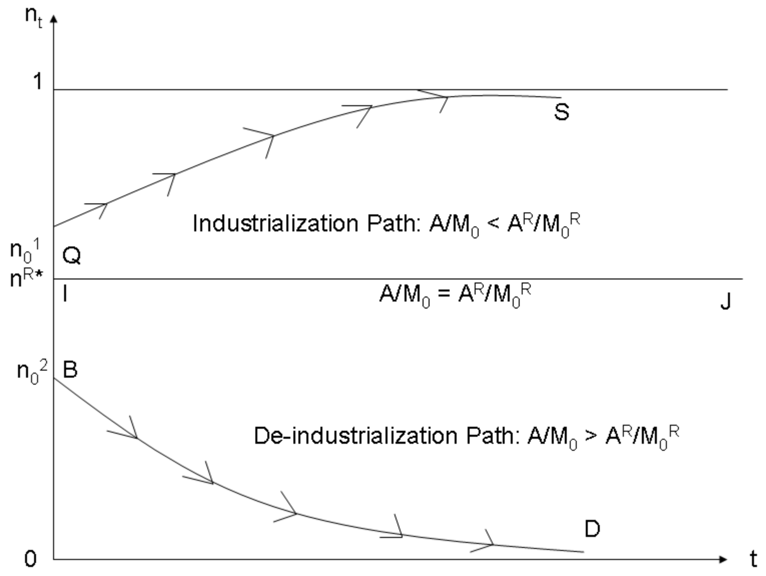

Figure 2.1: Agricultural Productivity and Industrialization

flows out of manufacturing and the economy de-industrializes over time. This path is shown by the line BD. In the opposite case, if the home country has comparative advantage in manufacturing, i.e., $A/M_0 < A^R/M_0^R$, so that $n_0 > n^{R*}$, employment share in industry increases over time and the economy specializes in manufacturing. The line QS depicts this industrialization path.

While productivity surge in agriculture is always welfare enhancing when the economy is closed, the welfare implication of agricultural productivity is ambiguous in a small open economy. This is because in the latter case, growth and level effects work in the opposite directions. More precisely, *Home economy having comparative advantage in industry is better off compared to the rest of the world if discount rate is sufficiently small.* Home attains a higher level of welfare (defined as the discounted sum of utility of the representative household) compared to the rest of the world if the country has comparative disadvantage in agriculture. Labor releases from Home's agricultural sector dampening its output, while industrial output and growth rate of the economy rises. This growth effect outweighs the level effect leading to a higher welfare level compared to the world economy, for a sufficiently small value of the discount rate i.e. if the agents are sufficiently patient. However the home country may not be necessarily worse of if it has comparative advantage in agriculture even if the discount rate is sufficiently small.

Chang, Chen, Hsu (2006)

A major extension of Matsuyama is due to Chang, Chen and Hsu (2006) who introduce the role of productive infrastructure in the manufacturing sector to show that productivity surge in agriculture may contribute to the growth process even for a small open economy.

In the framework of Matsuyama model, Chang et al. bring in the notion of infrastructure (G) that enhances learning-by-doing process in the industry,

$$\dot{M} = H(G_t)X_t^M, \quad H' > 0, \quad H'' < 0. \tag{2.9}$$

Infrastructure is a public input provided by the government and it is financed by proportional income taxes,

$$G_t = \tau(X_t^A + p_t X_t^M) \tag{2.10}$$

where τ denotes tax rate and p_t is the relative price of manufacturing in terms of agricultural good. Following Matsuyama, production functions in agriculture and manufacturing are respectively $X_t^A = AF_A(1 - n_t)$ and $X_t^M = M_t F_M(n_t)$, n_t being the labor share in manufacturing. The total amount of labor is normalized to one.

This extended model *preserves the closed economy findings of Matsuyama, but predicts positive relation between agricultural productivity and long-run growth in a small open economy under certain conditions.*

Given the same preference structure of Matsuyama, equation (2.1) continues to hold in this extended framework. Free labor mobility condition (2.2) holds as well. Using these equations along with the of market clearing conditions $C_t^A = (1 - \tau)X_t^A$ and

$C_t^M = (1-\tau)X_t^M$, the key relation between employment share in industry and the structural parameters such as agricultural productivity A, and tax rate τ is derived:

$$F_A(1-n_t) - \beta F_A'(1-n_t)F_M(n_t)/F_M'(n_t) = \frac{c_{\min}^A L}{A(1-\tau)}. \tag{2.11}$$

It solves for $n^* = n^*(A,\tau)$, implying a constant fraction of labor input in manufacturing over time given agricultural productivity and tax rate. Then, it follows from the labor mobility condition (2.2) and (2.10), a constant level of public input $G^* = G^*(n^*(A,\tau), A, \tau)$. The manufacturing output grows at an uniform rate of $\gamma_M^* = \frac{\dot{M}_t}{M_t} = H[G^*(n^*(A,\tau), A, \tau)]F_M(n^*(A,\tau))$ implied by the equation (2.9). Thus, *in a closed economy, for a given level of agricultural productivity A and tax rate τ, employment share in manufacturing remain unchanged over time, while manufacturing output grows at a constant rate. Allocation of labor across sectors over time implies constant level of food production as well.*

Given diminishing returns to labor in both sectors, a simple comparative statics of the expression in (2.4) with respect to A shows $\frac{\partial n^*}{\partial A} > 0$. Increase in agricultural productivity raises agricultural output, and manufacturing output rises through increase in n^*. As a result, total tax revenue and hence provision of public input G^* also increase. Increase in both n^* and G^* followed by agricultural productivity surge in turn implies $\frac{\partial \gamma_M^*}{\partial A} > 0$. Hence as in Matsuyama, *employment share in manufacturing and industrial growth rate increases with the agricultural productivity parameter A in a closed economy.*

Now consider a small open economy, say, Home. It takes the relative price of manufacturing determined in the world market as given. The world economy evolves along the equilibrium path of a closed economy described above. Its labor share in manufacturing remains constant at $n^{R*} = n^{R*}(A^R, \tau^R)$, given its agricultural productivity level A^R and tax rate τ^R.[4] The industrial sector of the world economy grows at

[4]The rest of the world variables are denoted by the superscript R.

an uniform rate of $H[G^{R*}(n^{R*}(A^R, \tau^R), A^R, \tau^R)]F_M(n^{R*}(A^R, \tau^R))$. The world price of manufacturing is determined by the labor mobility condition of the world economy, $A^R F'_A(1 - n^{R*}) = p_t M_t^R F_M(n^{R*})$.

Substituting p_t from the above expression in Home country's labor mobility condition $AF'_A(1 - n_t) = p_t M_t F_M(n_t)$, yields $AF'_A(1 - n_t) = \frac{A^R F'_A(1-n^{R*})}{M_t^R F_M(n^{R*})} M_t F_M(n_t)$. Differentiating this condition and making use of the learning-by-doing equation (2.9) for both economies gives

$$\left[\frac{F''_A(1 - n_t)}{F'_A(1 - n_t)} + \frac{F''_M(n_t)}{F'_M(n_t)}\right] \dot{n}_t = -\left\{H(G_t)F_M(n_t) - H[G^{R*}(n^{R*}, A^R, \tau^R)]F_M(n^{R*})\right\}. \tag{2.12}$$

The expression in (2.12), evaluated at $t = 0$ says that the fraction of labor input in Home's manufacturing will not change over time, i.e. $\dot{n}_t = 0$ if the initial employment share in industry n_0 is at a critical level n^c, where the critical employment share is such that,

$$H[G(n^c, A, \tau)]F_M(n^c) = H[G^{R*}(n^{R*}(A^R, \tau^R), A^R, \tau^R)]F_M(n^{R*}(A^R, \tau^R)).$$

This solves $n^c = n^c(\tau, A, \tau^R, A^R)$. This threshold size is the share of labor in manufacturing required by the home country such that its rate of learning-by-doing is same with the rest of the world. It depends on the domestic and foreign tax rates and their respective agricultural productivity.

At $t = 0$, if $n_0 \lesseqgtr n^c$ then it follows from (2.12), $\dot{n}_t \lesseqgtr 0$, implying that *if a small open economy starts with an employment share in industry smaller than the threshold level specified above, the economy losses labor out of manufacturing over time. With a bigger manufacturing employment than the threshold to begin with, Home eventually specializes in industry.*

There lies a *stark difference* between Matsuyama and this extended model. In the former, an economy with comparative advantage in agriculture deindustrializes over time. In the latter however, *a highly productive agricultural sector may generate sufficient resources to invest in productive expenditure so that Home's rate of learning by doing is high enough compared to the rest of the world to specialize in industry over time.*

Thus *rise in agricultural productivity may be conducive to long run growth under certain conditions.* Productivity surge in agriculture draws labor out of manufacturing instantaneously lowering learning-by-doing. But more tax revenues are also generated and spent in infrastructure which enhances learning-by-doing. The positive effect is more likely to dominate for higher efficiency in the effect of public spending on knowledge formation.

One important aspect of this extended model is that by raising the tax rate and investing the revenue in infrastructure, it is possible to shift an economy otherwise specializing in agriculture to the industrialization path.

An economy with an initial size of manufacturing sector $n_0 < n^c$, is on the path that eventually specializes in agriculture. However increase in tax rate raises the public input provision and there by the rate of learning-by-doing. Thus the critical size of manufacturing required for Home's rate of learning-by-doing to equalize with that of the world economy falls. If it falls below the current employment share in manufacturing, then the economy shifts to the industrialization path and eventually specializes in manufacturing.

This is shown in Figure 2.2. The horizontal axis represents time, while the vertical axis measures Home's employment share in manufacturing n_t. Suppose initially the domestic tax rate is τ_1 and the corresponding critical value of industrial labor share is n_1^c. At period $t = 0$, the fraction of labor input in manufacturing is $n_0 < n_1^c$. The economy is on the dynamic path BD that eventually leads to specialization in agriculture. Let at period $t = T$, the economy is at point S on the BD curve and the fraction of labor input in manufacturing is n_T. At this period, government increases tax rate to τ_2. The critical value of n corresponding to this higher tax rate is n_2^c which is below n_T. From period T

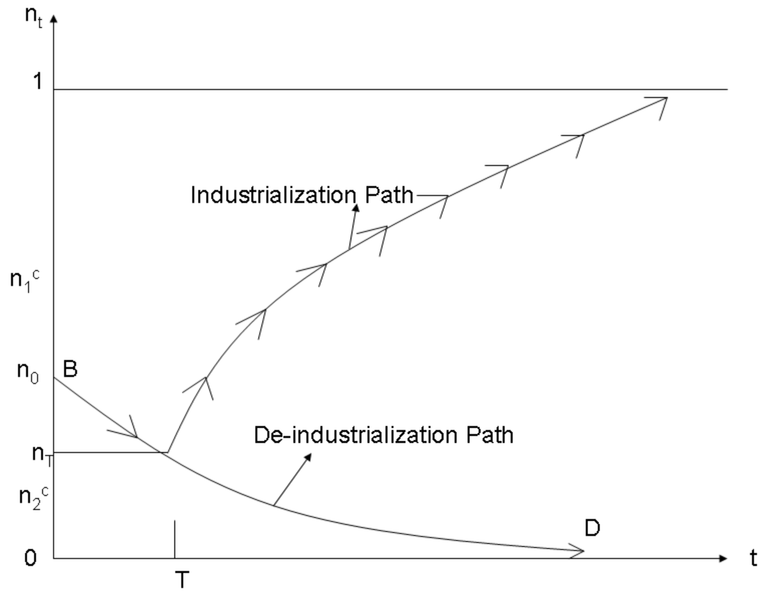

Figure 2.2: Take of from Agriculture to Industrialization

onwards, the economy starts evolving along the path SJ and eventually specializes in industry.

2.2 Public Expenditure and Growth

In both developed and developing countries – especially in the latter – infrastructure is a critical factor in the growth of not only industry *but also* agriculture. Since the thesis contains analysis of agricultural and industrial growth in the presence of infrastructure as a public input, we now briefly discuss some of the existing literature on public expenditure and growth.

2.2.1 A Survey of Theoretical Research

Barro (1990)

It is the seminal paper on this topic. It constructs a model of endogenous growth where the source of growth is the public input (G) in the economy-wide aggregate production function. The other input used by the production technology is capital (K) which is generated through saving out of the after-tax income of the representative households. The following is the economy's production function which is linearly homogeneous in K and G:

$$Y_t = F(K_t, G_t) = K_t f(G_t/K_t) \tag{2.13}$$

There is diminishing returns to individual inputs. The model abstracts from population growth.

Government expenditure is financed through a proportional income tax:

$$G_t = \tau Y_t = \tau K_t f(G_t/K_t) \Rightarrow \quad G_t/K_t = \tau f(G_t/K_t) \Rightarrow \quad G_t/K_t = g(\tau) \tag{2.14}$$

If we substitute this expression of G_t/K_t into the production function (2.13), we obtain that output is proportional to K_t, at any given τ, i.e., the production function is effectively AK.

The representative household maximizes life-time utility $\sum_{t=0}^{\infty} \rho^t (C_t^{1-\sigma} - 1)/(1-\sigma)$, subject to the budget constraint,

$$C_t + K_{t+1} - K_t = (1-\tau)(\pi_t + r_t K_t) \tag{2.15}$$

which says that the sum of consumption C_t and savings $K_{t+1} - K_t$ adds up to the disposable income; π_t is the profit income; r_t is the rental to capital.

The optimization exercise by the representative household yields the Euler equation

$$\left(\frac{C_{t+1}}{C_t}\right)^{\sigma} = \rho[(1-\tau)r_{t+1} + 1]. \tag{2.16}$$

The AK structure of the production function implies that return to capital, being the marginal product of this input is constant for a given tax rate, that is,

$$r_t = f(G_t/K_t) - G_t/K_t f'(G_t/K_t) = f(g(\tau)) - g(\tau)f'(g(\tau)) = r^*(\tau).$$

Then it follows from the Euler equation (2.16) that consumption grows at a constant rate

$$\gamma^* = \{\rho[(1-\tau)r^*(\tau)+1]\}^{1/\sigma}. \tag{2.17}$$

The economy-wide budget constraint $C_t + K_{t+1} - K_t = (1-\tau)Y_t$ can be rewritten in view of (2.14) as $K_{t+1} = [(1-\tau)f(g(\tau))+1]K_t - C_t$. Further rearranging the budget equation yields the dynamic structure of the model in terms of the ratio $\chi = C/K$, given that consumption grows at a uniform rate γ^*, as

$$\frac{1}{\chi_{t+1}} = \frac{[(1-\tau)f(g(\tau))+1]-\chi_t}{\gamma^*\chi_t}. \tag{2.18}$$

In steady state, $\chi_t = \chi^* = [(1-\tau)f(g(\tau)) - \gamma^* + 1]$. Totally differentiating (2.18) and evaluating at $\chi_t = \chi^*$,

$$\left.\frac{d\chi_{t+1}}{d\chi_t}\right|_{\chi^*} = \frac{(1-\tau)f(g(\tau))+1}{\gamma^*} > 1, \quad \text{in view of (2.17).}$$

and given that $r^*(\tau) = f(g(\tau)) - g(\tau)f'(g(\tau))$. There is no initial value of χ_t and thus the above derivative being greater than one implies that, under perfect foresight, χ_t 'jumps' to its steady state instantly. This implies that *consumption, capital and public input grow at an uniform rate γ^* from the beginning and hence there is no transitional dynamics. The AK nature of the production function implies steady state growth.*

In this framework, Barro shows a *non-linear, more specifically, inverted-U shaped relationship between growth rate and tax rate so that a growth-maximizing tax rate exists.* This is shown in Figure 2.3 . The intuition is that an increase in tax rate raises the provision of public input and hence the return to capital. Higher return to capital leads to higher savings and investment. But increase in tax rate reduces disposable income, which has a negative impact on savings and investment. When tax rate is small, the former effect dominates the latter and growth rate increases. When tax rate is sufficiently large, the negative effect becomes dominant and growth rate falls implying the existence of a growth maximizing tax rate.

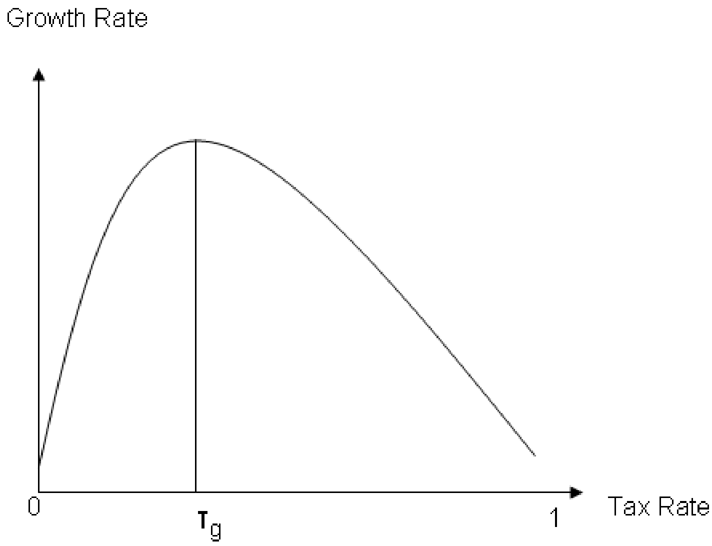

Figure 2.3: Relation of Growth Rate and Tax Rate in Barro Model

Barro analyzes the special case of Cobb-Douglas technology, so that the production function can be written as $Y = K^{\alpha}G^{1-\alpha}$. The growth maximizing condition in this case corresponds to the productive efficiency condition $\frac{\partial Y}{\partial G} = 1$. The latter implies that the marginal benefit of public input equalizes with marginal cost in terms of consumption good. The tax rate satisfying these conditions is the output elasticity of public input, which is $1 - \alpha$.

In addressing the issue of public policy in terms of government's choice of tax rate that maximizes social welfare, Barro shows that in case of Cobb-Douglas technology discussed above, the utility maximizing condition coincides with the growth maximizing condition. Hence, *the growth and utility maximizing tax rates are same when production* *technology is Cobb-Douglas.*

Comparison of the decentralized outcome with that in a command economy reveals that *the growth rate in the market economy is lower than the planned growth rate.*

The social planner maximizes $\sum_{t=0}^{\infty} \rho^t (C_t^{1-\sigma} - 1)/(1-\sigma)$, subject to the resource constraint of the economy $C_t + K_{t+1} - K_t = (1-\tau)Y_t = (1-\tau)K_t f(G_t/K_t)$, and public budget constraint (2.14). Substituting $G_t/K_t = g(\tau)$ from the latter into the production function in the resource constraint of the economy, the optimization yield the Euler equation,

$$\left(\frac{C_{t+1}}{C_t}\right)^{\sigma} = \rho\left[(1-\tau)f(g(\tau)) + 1\right]. \tag{2.19}$$

The dynamics of the model analogous to market economy implies that C, K and G in the command economy grow at a rate,

$$\gamma^P = \{\rho[(1-\tau)f(g(\tau)) + 1]\}^{1/\sigma} \tag{2.20}$$

Comparing (2.17) and (2.20) and given that $r^*(\tau) = f(g(\tau)) - g(\tau)f'(g(\tau))$, it is evident that at any tax rate τ, $\gamma^* < \gamma^P$. Since agents do not internalize the externality implied by the public expenditure and taxation, private marginal return is lower than the social marginal return on capital. Thus decentralized savings rate is lower than that under the command economy.

Differentiating (2.20) with respect to tax rate and using the relation $G_t/K_t = \tau f(G_t/K_t)$ it can be shown that the planned growth rate is maximized when the production efficiency condition is met (irrespective of the form of production function). It has an *important implication for the Cobb-Douglas technology that the tax rates maximizing decentralized and planning growth rates are same for this technology, although decentralized growth rate is lower than the planned rate of growth* (shown in Figure 2.4).

In the *decentralized environment however, the command optimum can be achieved by replacing proportional income tax by lump sum taxation that does not affect the marginal*

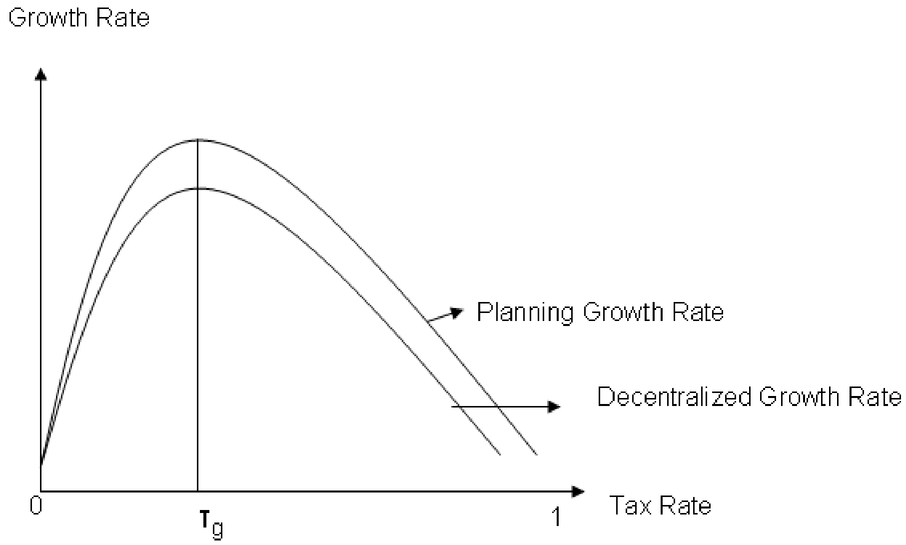

Figure 2.4: Planning and Decentralized growth Rates

return on capital.

2.2.2 Subsequent Papers

The work of Barro motivated a huge strand of literature that explored different aspects of public goods in the growth process of an economy into various directions. Staring form the transitional dynamics in Barro-type model (remember that Barro's model did not have transitional dynamics), the subsequent literature include various aspects such as congestion problem of public goods, role of public spending on long-run growth with finite lived agents and beyond. In this section, some these studies are discussed in brief to bring out the major diversions from Barro and their consequences.

Futagami, Morita and Shibata (1993)

Some infrastructure inputs are flow, while some are stock. Road, irrigation, telecommunication and electrical facilities are the kind of public infrastructure which are stock variables in nature.

Futagami et al. introduces stock of public input in Barro (1990) framework. By specifying public input as a flow variable essentially makes Barro model to belong in the class of AK-growth models which lacks transitional dynamics. These authors are the pioneers to explore the aspects of transitional dynamics in an endogenous growth model where the source of growth is public input.

Public capital (G) accumulates via a proportional tax on income (Y),

$$\frac{dG}{dt} = T = \tau Y, \tag{2.21}$$

where

$$Y = Kf(G/K), \quad f' > 0, \quad f'' < 0. \tag{2.22}$$

Here T denotes total tax revenue, where τ is the proportional tax rate; the variable K signifies capital.

The representative household maximizes lifetime utility derived from consumption (C), which is $\int_0^\infty u(C)e^{-\rho t}dt$, subject to the budget constraint

$$\frac{dK}{dt} = (1-\tau)Kf(G/K) - C. \tag{2.23}$$

Here $u(C)$ is defined as

$$u(C) = (C^{1-\sigma} - 1)/(1-\sigma), \quad \sigma \neq 1,$$

$$= \ln(C), \quad \sigma = 1,$$

The resulting Euler equation of the optimization exercise is,

$$\frac{dC/dt}{C} = \frac{1}{\sigma}[(1-\tau)f(G/K)(1-\eta) - \rho]$$

where η is the elasticity of Y with respect to G, i.e., $\eta = f'G/Y$. The Euler equation, along with the law of motion of public input (2.21) and capital (2.23) reduces to the following dynamic equations in terms of the ratios $x = G/K$ and $y = C/K$, which dictate the dynamics of the economy:

$$\frac{dx/dt}{x} = \frac{dG/dt}{G} - \frac{dK/dt}{K} = \tau f(x)/x - (1-\tau)f(x) + y,$$

$$\frac{dy/dt}{y} = \frac{dC/dt}{C} - \frac{dK/dt}{K} = \frac{1}{\sigma}[(1-\tau)f(x)(1-\eta) - \rho] - (1-\tau)f(x) + y.$$

Setting $\frac{dx/dt}{x} = \frac{dy/dt}{y} = 0$, these dynamic equations solve for the steady state values of x and y. These are x^* and y^*, say. It implies that C, K and G grow at the uniform rate $\gamma^* = \tau f(x^*)/x^*$ (from equation (2.21)) in the *steady state which is a saddle path equilibrium.*

This modified framework preserves *the main result of Barro that there exists a tax rate, which maximizes the steady-state growth rate; if output elasticity of public input is constant, steady-state growth attains a maximum when tax rate equalizes with this elasticity.* In characterizing the transitional dynamics of the model, the authors show that impact of tax rate on the behavior of the dynamic path of the economy essentially depends on whether $\sigma + \eta \gtrless 1$, where σ denotes the inverse of elasticity of intertemporal substitution and η, as discussed earlier is the output elasticity of public input.

In addressing the question of optimal policy, they show that *for the case of constant output elasticity of public input, the tax rate that maximizes welfare is lower than the growth maximizing tax rate (while in Barro, these two tax rates are same). This result is a major deviation from Barro.* This difference arises because if public input affects production as a flow, maximizing the growth rate of capital is equivalent to maximizing the growth rate of consumption and therefore to maximizing the consumption level at each instant of time. Hence overall inter-temporal welfare is maximized. But if public input is a stock, consumption has to be sacrificed to accumulate public capital. Since in the steady state, both private and public capital grows at the same rate, maximizing the growth rate of private capital implies maximizing that of public capital as well, which involves a consumption loss. The central planner internalizes this loss and reduces growth rate by reducing the tax rate to enjoy more consumption.

Dasgupta (1999)

In the literature exploring the role of public infrastructure input as a *stock* variable, Dasgupta (1999) is an important contribution showing that how growth of an economy can be constrained by the growth of infrastructural stock, owned and controlled by the government.[5]

He develops a two-sector growth model with a final good (Y) sector operated by the private firm and the infrastructure (G) sector under control of the government. Infrastructure accumulates using a technology that utilizes privately supplied input–capital (K_g) and the infrastructure services,

$$\frac{dG}{dt} = BK_g^{\beta}G^{1-\beta}. \tag{2.24}$$

This aspect of accumulating public input differs from Futagami et al (1993) because in the latter, public input is accumulated through a proportional tax on the economy-wide income (equation (2.21)).

While infrastructure service is available to the public sector free of cost, purchase of capital is financed by the revenue flows from the sale of infrastructure services to the private sector and the proceeds from tax on capital income:

$$rK_g = p_g G + \tau_K rK, \tag{2.25}$$

where, r is return to capital, p_g is the unit price of public services and τ_K is the proportional tax on capital income.

[5]He cited from the World Bank Development Report (1994) that 1% rise in the stock of infrastructures leads to 1% increase in the real GDP across countries.

Private sector also uses capital (K_y) and infrastructure services as inputs to produce final commodity,

$$Y = AK_y^{\alpha}G^{1-\alpha}$$

The representative household maximizes lifetime utility $W = \int_0^{\infty} e^{-\rho t}\frac{C^{1-\sigma}}{1-\sigma}dt$, subject to the budget constraint saying that total consumption and savings adds up to the after tax capital income, $C + \frac{dK}{dt} = (1 - \tau_K)rK$.

In this framework Dasgupta finds that *the economy is in the steady state when growth rate of the infrastructure stock ($\frac{dG/dt}{G}$) is same as the growth rate of consumption optimally chosen by the representative household ($\frac{dC/dt}{C}$) such that the allocation of capital across sectors (K_g/K_y) satisfies government's budget constraint.* Further, *Unlike Barro, steady state growth rate monotonically falls with tax rate.* Increase in tax rate generates more revenue and hence more infrastructural accumulation, hence growth rate of infrastructure, termed as 'supply rate of growth' rises. The growth rate of consumption which is called 'demand rate of growth' falls due to an increase in tax rate, because higher tax rate reduces disposable income and hence incentive to save. The fall in demand rate of growth is more than the rise in supply rate of growth and hence the steady state growth rate falls as tax rate rises.

The stark difference between Barro and Dasgupta lies in the *comparison of decentralized and planning growth rates. The latter has predicted unlike Barro and others, a higher growth rate under market economy compared to the command economy. In other words, the market will experience "too much growth."* This difference arises because the command economy internalizes social loss due to sacrificing consumption in order to invest in the accumulable resources. As a result, the level of consumption under the command economy is higher that leads to lower investment and growth compared to the market economy.

Barro and Sala-I-Martin (1992)

Barro and Sala-I-Martin (1992) discuss the congestion aspect of public good. They assume the following production function for an individual producer

$$y = Ak(G/K)^{\beta}, \tag{2.26}$$

where y is the output produced by an individual producer using k amount of capital provided by her, G denotes public input and K is the aggregate stock of capital in the economy. Assuming that the total size of population is normalized to one, $k = K$ in equilibrium.

The individual production function exhibits constant returns to private input, k, as long as the government maintains a given state of congestion of the public facilities, i.e., as long as G/K ratio is fixed. In other words, for a given G, the quantity of public services available to a producer declines if other producers raise their levels of input, that leads to a rise in K. It implies that for the individual production to satisfy constant returns to capital supplied by the individual producer, G and K should increase at the same rate.

The important implication of congestion problem is that, *under lump-sum taxation, private return on investment is higher than the social return because an increase in private input by an individual producer reduces facilities available to others. With a proportional tax on income at a rate* $\tau = G/Y$, *the distortion due to congestion is internalized by the individual producer and the private and social returns are equated.* This stands in contrast to Barro and others, where a proportional income tax distorts the marginal return to capital, as individual producers do not internalize the externality of taxation and provision of public input through it. Private return is therefore lower than the social return on investment. In this case, a lump sum taxation equates the private and social returns.

Turnovsky (1997)

Turnovsky (1997) extends the congestion aspect of public good in endogenous growth model by way of introducing the concept of relative congestion. With relative congestion, public input can increase at a slower rate than the total capital stock in the economy and still maintain a fixed level of public services to the individual firm. In this framework, the dynamic behavior of the economy during transition under alternative fiscal policies are investigated.

The production function of an individual firm exhibits constant returns to scale to the capital supplied by the individual producer as long as the ratio of public service available to her and her own capital stock remains constant,

$$y = \alpha k (g/k)^{\beta}, \quad \alpha > 0, \quad 0 < \beta < 1. \tag{2.27}$$

Here y is the output produced by the individual producer who supply k units of capital and g is the services derived by the firm from its use of public capital.

The productive services derived by an individual from government expenditure is defined as

$$g = G(k/K)^{1-\theta}, \quad 0 \leq \theta \leq 1, \tag{2.28}$$

where G and K denote aggregate stock of public and private capital in the economy. The above equation captures the aspect of relative congestion implying that for a given stock of public input, the productive services derived by an individual increases with her own stock of capital relative to the aggregate.

Substituting (2.28) in (2.27) yields

$$y = \alpha \left[\frac{G}{K} \left(\frac{K}{k} \right)^{\theta} \right]^{\beta} k. \tag{2.29}$$

While optimizing in a decentralized economy, the individual firm takes total public input G and the aggregate stock of capital in the above expression as given, although in equilibrium $k = K$ under the assumption that the total population size is normalized to one. With this assumption, the aggregate output turns out to be

$$Y = \alpha \left(\frac{G}{K} \right)^{\beta} K.$$

The social planner considers this aggregate production function while conducting the optimization exercise in the command economy.

Public input accumulates as proportional of the aggregate output

$$\frac{dG}{dt} = \mu Y.$$

This stock property of public input gives rise to the transitional dynamics in the model. The existence of transitional dynamics causes major deviation of Turnovsky from Barro and Sala-I-Martin as in the former, *the decentralized economy replicates the steady state as well as the transitional dynamics of the command economy under a time-varying income tax schedule.* The time-varying tax structure has two components: one is a constant term which equates marginal private and social returns to investment; the other component corrects the time path of tax rate at each point of time depending on the deviation of public to private capital ratio in a decentralized economy at any period t from its steady state value. With such a tax structure, the representative agent tracks the endogenous shadow price of public input as the social planner does in the command economy and thereby the market economy achieves the transitional path of the planned economy.

Further, Turnovsky, in the framework of the command economy preserves the result in Barro (1990) that *long-run growth rate is maximized for $\mu = \beta$, implying that growth-maximizing ratio of public expenditure to income is the output elasticity of public input. However, welfare maximizing value of μ falls short of the growth maximizing value* and this result is similar to Futagami et al (1993).

Mourmouras and Lee (1999) and Kosempel (2004)

Both the studies explore implications for public policy when life-expectancy plays a role in the long run growth rate of the economy. They modified the Barro model with consumers having uncertain lifetime. *While Mourmouras and Lee find the social welfare maximizing tax rate does not vary with life expectancy, Kosempel finds that optimal public policies depend on life expectancy, under the assumption that the representative agent derives utility from public expenditure.*

The household sector in the model is defined as follows. The size of any cohort born at any point in time is normalized to λ. Each representative agent has the probability of death per unit of time equal to λ. The probability that an agent belonging to a cohort born at period i is alive at period t is $e^{\lambda(t-i)}$, where $i \leq t$. The utility at period t of an agent born at time i is defined as

$$U(i,t) = \int_t^\infty u[c(i,v), x(i,v)]e^{-(\rho+\lambda)(t-v)}dv,$$

where $c(i,t)$ is the consumption good and $x(i,t)$ is the public services available to an individual consumer.

The production technology uses capital $K(t)$, labor $L(t)$, (total labor is normalized to one) and government services $G(t)$, where public input and labor are complementary. The production function is defines as

$$Y(t) = M[G(t)L(t)]^\beta K(t)^{1-\beta}.$$

The government imposes a proportional tax τ on income. A fraction τ_X/τ of the tax revenue is used to finance the utility enhancing services to the consumers, while the fraction τ_G/τ is used to cover the cost of productive services provided to firms. The government budget constraints are the following:

$$X(t) = \tau_X Y(t), \quad G(t) = \tau_G Y(t), \quad \tau = \tau_X + \tau_Y,$$

where $X(t)$ denotes the total utility-enhancing services provided by the government, which is the aggregate public services consumed by individuals living in period t. That is, $X(t) = \int_{-\infty}^{t} x(i,t)e^{-\lambda(t-i)}di$.

In this modified Barro model, *the long run growth rate is affected by the change in life expectancy.* A rise in life expectancy captured by a fall in λ increases the propensity to save out of wealth, leading to a higher aggregate savings rate and hence, higher aggregate growth rate.

Moreover, an important implication of the model is that *the effect of an increase in tax rate depends on how the increased tax revenue is allocated between provision of utility-enhancing services and productive services.* Suppose that the government increases income tax rate τ. The increased tax revenue is used to finance the utility-enhancing services, so that τ_X increases. It has a negative impact on growth. Intuitively, in this case, a tax hike reduces after-tax return to capital and hence incentive to save and invest, lowering growth rate.

However if tax rate τ is used to finance the productive expenditure, so that τ_G increases, after-tax return to capital falls. But it increases productivity of capital and hence its effect on growth rate is ambiguous. Further, it is shown that growth rate is maximized when $\tau = \tau_G$=output elasticity of public input (as in Barro's infinite horizon problem) and $\tau_X = 0$. The optimal compositions of public expenditure also differs from the growth maximizing scenario. Social welfare (defined as discounted sum of utility) is maximized if τ_G = output elasticity of public input (as in growth-maximization), and the optimal $\tau_X > 0$.

Finally, a change in life expectancy changes optimal τ_X. The optimal value of τ_X is chosen by the government by equating marginal benefit of utility-enhancing public services to marginal cost. A rise in life expectancy reduces the effective discount rate of an agent, i.e., the agent becomes more patient and his/her propensity to save increases.

Moreover, there is a cost associated with allocation of tax revenue in utility-enhancing services because it shifts resources out of productive expenditure and also financing such expenditure lowers incentive to save. This cost is higher in an economy where agents have higher life expectancy and thus higher incentive to save and grow, compared to the benefit derived out of it. Thus government needs to reduce this cost by reducing τ_X.

2.2.3 A Survey of the Empirical Literature

There are a numerous cross country and panel studies showing that public expenditure, especially infrastructural input provided by the government has a positive and significant effect on sectoral as well as overall economic growth. A brief discussion of some of these studies is provided below.

Ram (1986) empirically investigates the relation between public inputs and growth rate of the economy using the Summer-Heston data set that includes 115 market economies. He considers a theoretical framework where the economy consists of two broad sectors, namely the government and nongovernment sector. The output of the former sector has an externality effect on the output of the latter. Both sectors use labor and capital as inputs. The total output of the economy comprises of outputs in the nongovernment and the government sectors. The total effect of the government size on the growth rate of total output of the economy can be decomposed into two factors: one is due to the intersectoral factor productivity difference and the other is the marginal externality effect of government output.

Ram conducts a cross section analysis and found *public sector output affecting overall growth rate positively and significantly. The result holds irrespective of the sign of sectoral productivity differences. Further the study shows that the positive externality effect of the government size is higher for the period 1970-80 than for 1960-70.*

He also conducts time series analysis covering a full two-decade period of 1960 through 1980 for each of these 115 countries using OLS as well as under the assumption that the disturbance term follows an AR(1) process. *The positive and significant relation between government size and growth rate in general continues to hold for both the specifications.*

Aschauer (2000) made a panel data estimation for the 48 contiguous United States during the decades of the 1970s and 1980s and found that *a one standard deviation increase in public capital stimulates a one-third to one-half standard deviation increase in output per worker.*

Haque and Kim (2003) found *a positive relation between public investment in transportation and communication and economic growth* in a panel framework for fifteen developing countries, during the period 1970-1987.

Rodrik and Subramanian (2004) also found that *public infrastructure positively affecting economic performances in India.*

Bose, Haque and Osborn (2007) examine the growth effects of government expenditure for a panel of thirty developing countries over the decades of 1970s and 1980s. Their findings are that *the share of government capital expenditure affects growth rate positively and significantly. Moreover, a disaggregation of public expenditure reveals that only educational expenditure has a significant positive effect on growth rate of the economy.*

The role of public expenditure in agricultural and rural development has been emphasized by Fan, Zhang and Zhang (2004) and Fan Hazell and Thorat (2000). The former develops a simultaneous equations model to estimate various effects of government expenditure on production and poverty reduction in the rural China through different channels. They found that *public spending on productive investment such as agricultural* R&D, *irrigation, rural education and infrastructure including roads, electricity and telecommunications contribute significantly to agricultural productivity growth.* For instance, during 1978-84 public investment accounted for 12% of agricultural production growth and 45% of poverty reduction. The contribution of public investment in agricultural productivity growth increased to 63% during 1985-2000, which is more than five times its share during the period 1978-84. Further, among different categories of public spending, investment in agricultural R&D has the largest impact on per capita agricultural GDP, while education has the second largest return to it. Government spending on rural infrastructure also contributes significantly to the rural farm and non-farm production growth.

Fan, Hazell and Thorat (2000) obtain similar findings for India. Using a simultaneous equation model, they found, on the basis of pooled time series and cross section data on the state level for 1970-93, that *agricultural research, improved roads, irrigation have contributed significantly to growth in agricultural productivity.* Specifically, government expenditure on roads and R&D has the biggest effects on agricultural productivity and poverty reduction. A 1% increase in R&D expenditure increases TFP by 6% which is 154% larger impact compared to the effect of expenditure on road on the productivity level.

2.3 Economic Transition from Agriculture to Industry

2.3.1 Theoretical Work

The long period of stagnant living standard over a few centuries, leading up to 1800 AD followed by economic growth in the subsequent period is the theme of the so-called 'transition literature.' The seminal papers in this area include Galor and Weil (2000), Jones (2001), Galor and Moav (2002), Hansen and Prescott (2002), Tamura (2002).

Hansen and Prescott (2002)

The transition 'story' of Hansen and Prescott (2002) goes as follows. An economy is initially producing one good with capital, labor and land. This is called the agricultural method or Malthus technology (M), characterized by diminishing returns to capital (K_M) and labor (N_M) due to the presence of land (L_M), a fixed factor,

$$Y_{Mt} = A_{Mt}K_{Mt}^{\phi}N_{Mt}^{\mu}L_{Mt}^{1-\phi-\mu}$$

An alternative technology exists, which is able to produce the same good, using labor and capital only via a constant-returns technology,

$$Y_{St} = A_{St}K_{St}^{\theta}N_{St}^{1-\theta}$$

This is the industrial method or Solow technology.

Total factor productivities of both technologies captured by terms A_M and A_S grow exogenously. Population grows too. Initially, the TFP of the industrial method is so low that only the agricultural method is viable. Population growth rate is assumed to be high enough relative to the TFP growth rate in agriculture, such that the agriculture wage, the capital rental rate and per-capita income are constant. This is the classical Malthusian trap.

Assume that initially the level of accumulated factors is low enough such that the economy produces the agricultural good only. It is shown that *no matter how small the TFP growth rate of the industrial method is, at the agricultural wage and capital rental rate, there* ***will*** *be a finite date when the Solow technology starts to become profitable.* The date of industrial method to become viable is determined by the following condition:

$$A_{St} > \left(\frac{r_K}{\theta}\right)^{\theta}\left(\frac{w}{1-\theta}\right)^{1-\theta}$$

where r_K and w are the rental to capital and wage rate in the Malthusian economy. This condition says that for the industrial sector to break even, this sector should be productive enough to cover the unit cost of production, given the factor prices determined in the ongoing agricultural economy.

By specifying parameter values based on data of the English economy over 1275-1989 (the period 1275-1800 characterizes agricultural stage, while 1800 is identified as the beginning of industrial state), Hansen and Prescott were able to 'generate' transition from agriculture to industry.

Tamura (2002)

Tamura (2002) develops a model of economic and population growth featuring 'endogenous' transition from the agricultural to the industrial production mode. The former uses land (L, fixed) and human capital (H), while the latter only human capital exhibiting constant-returns,

$$y_t^{\text{ag}} = M_{\text{ag}} \left(\frac{L}{N_t^{\text{ag}}} \right)^{\lambda} h_t^{\epsilon(1-\lambda)}, \quad y_t^{\text{ind}} = M_{\text{ind}} h_t,$$

where $y_t^j, j = \text{ag}, \text{ind}$ is the output produced by an individual producer; M_{ag} and M_{ind} are the productivity levels in agriculture and industry, respectively. The term N_t^{ag} denotes population at period t when agricultural method is used.

Unlike in the Hansen-Prescott model, there is no TFP growth in either method. But human capital grows following a linear accumulation technology as agents invest in it taking into consideration the higher income for the future generation,

$$h_{t+1} = A \phi_t h_t \tag{2.30}$$

where A is the productivity parameter in the learning technology and ϕ_t is the fraction of labor time (total labor time is normalized to unity) invested in each child's education.

The model assumes endogenous fertility choice. In an overlapping generation framework, an individual who lives for two periods obtains utility from his adult age consumption (c_t), number of children he bears (n_t) and the average utility of a child that depends on the human capital he receives from his parents, $U(h_t) = \alpha \ln c_t + (1-\alpha) \ln n_t + \beta U(h_{t+1})$. Using $n_t = \frac{N_{t+1}}{N_t}$, N_t being the population at t, the preference at period t can be rewritten recursively as

$$U(h_t) = \sum_{s=t}^{\infty} \beta^{s-t} [\alpha \ln c_s + (1-\alpha) \ln \frac{N_{s+1}}{N_s}] \tag{2.31}$$

The budget constraint of the individual is $c_t = y_t[1 - n_t(\theta + \phi_t)]$, where y_t is the rate of output per unit of time and θ is the fraction of time spent in child-rearing. The budget constraint says that the individual consumes what he earns in the time available after investing in child-rearing and their education. Using (2.30) and $n_t = \frac{N_{t+1}}{N_t}$, the budget constraint can also be rewritten as

$$c_t = y_t \left[1 - \frac{N_{t+1}}{N_t} \left(\theta + \frac{h_{t+1}}{A h_t} \right) \right] \tag{2.32}$$

The crucial assumption of Tamura model is that production is undertaken using the method that maximizes per capita income. Also, all individuals use same method of production and the model abstracts from the transition phase when both methods are used.

In the agricultural stage, individual maximizes (2.31) subject to the budget constraint (2.32) and $y_t = M_{\text{ag}} \left(\frac{L}{N_t^{\text{ag}}} \right)^{\lambda} h_t^{\epsilon(1-\lambda)}$. The optimization exercise yields along the agricultural balanced path, a constant fertility rate $n^{\text{ag}*}$, and a constant fraction of time invested in human capital generation $\phi^{\text{ag}*}$, which are

$$n^{\text{ag}*} = \frac{(1-\alpha)(1-\beta) - \alpha\beta\lambda - \alpha\beta(1-\lambda)\epsilon}{\theta[1 - \beta - \alpha\beta\lambda]}, \tag{2.33}$$

$$\phi^{\text{ag}*} = \frac{\alpha\beta(1-\lambda)\epsilon\theta}{(1-\alpha)(1-\beta) - \alpha\beta\lambda - \alpha\beta(1-\lambda)\epsilon}. \tag{2.34}$$

Similarly in the industrial stage, the individual maximizes (2.31) subject to (2.32) and $y_t = M_{\text{ind}} h_t$. Along the industrial balanced path, fertility rate and time investment in education are respectively,

$$n^{\text{ind}*} = \frac{1-\alpha-\beta}{(1-\beta)\theta}, \tag{2.35}$$

$$\phi^{\text{ind}*} = \frac{\alpha\beta\theta}{1-\alpha-\beta}. \tag{2.36}$$

The natural implication of the model is that *starting with low human capital and agricultural method of production, in finite time the economy switches to the industrial method for a critical level of human capital at which both methods generate same amount of per capita income.*

The transition takes place in the following way: suppose initially, human capital is very low. With diminishing returns to human capital in agricultural method that results in concavity of the production function, agricultural technique dominates when human capital is sufficiently low. This is shown in Figure 2.5. Curve OS represents production function under agricultural technology and the line OP is the industrial production function. At a very low level of human capital, say, H_0, output produced under the agricultural method CD is higher than that under the industrial method BD. Hence at this stage, agricultural technique dominates.

Also, let initial population be N_0^{ag}. The economy is on the agricultural balanced path where population is growing at a rate $n^{\text{ag}*}$ and the growth rate of human capital is $A\phi^{\text{ag}*}$. Suppose at period T, economy generates enough human capital, h_T^{critical} to switch to the industrial mode. In this period, population is $n_T^{\text{ag}} = N_0^{\text{ag}}(n^{\text{ag}*})^T$. The switch occurs when two methods produce same amount of output, so that $M_{\text{ag}}\left(\frac{L}{N_T^{\text{ag}}}\right)^{\lambda}(h_T^{\text{critical}})^{\epsilon(1-\lambda)} = M_{\text{ind}}h_T^{\text{critical}}$. It implies that transition takes place at a finite period T when the critical level of human capital is defined as

$$h_T^{\text{critical}} = \left\{\frac{M_{\text{ag}}}{M_{\text{ind}}}\left(\frac{L}{N_0^{\text{ag}}(n^{\text{ag}*})^T}\right)^{\lambda}\right\}^{\frac{1}{(1-\epsilon(1-\lambda))}}$$

The above condition says that *the switch occurs when average productivities under two methods are same.* Intuitively, the higher the agricultural productivity relative to industry, or the larger the land-endowment per family, the lower will be the incentive to adopt industrial method and hence level of human capital required for the switch to occur will be higher.

Figure 2.5 shows that until economy accumulates H_T^{critical} level of human capital, agricultural production mode with diminishing returns technology prevails; beyond H_T^{critical} industrial method becomes viable.

From the period T onwards, the economy is on the industrial balanced path.

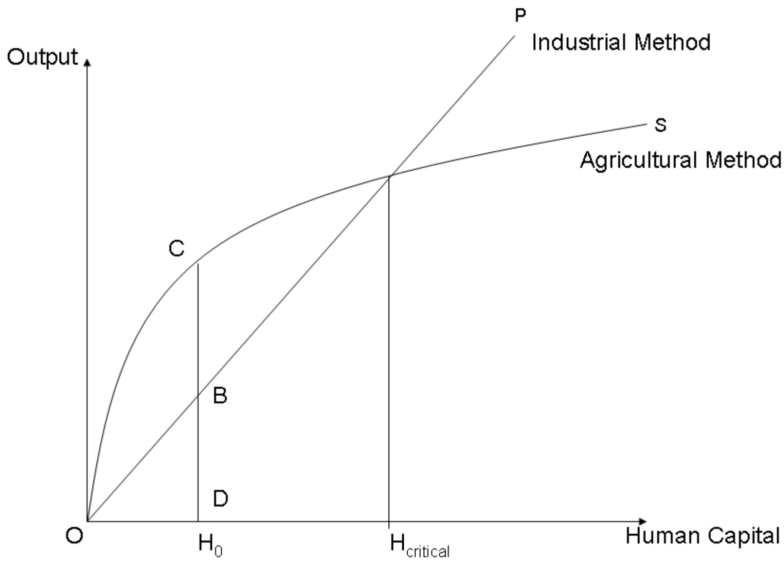

Figure 2.5: Transition from Agriculture to Manufacturing

Tamura's model has other feature like coordination cost of using intermediate services in the industrial method.

Using parameter values averaged over Europe, U.S. and Canada from 200 BC to 1850AD, and from 1850 to 1996, Tamura attempts to replicate per-capita real GDP for the U.S. and population of the three regions together before and after industrialization.[6]

[6]In contrast to these papers in which the transition from agriculture to industry is defined as a change in the method of producing the same good, in an earlier paper, Laitner (2000) treats these two sectors as producing two distinct goods. There is physical capital accumulation, while population and

While Hansen-Prescott and Tamura define transition as a shift from agricultural production mode to industrial production mode, Galor and Weil (2000) and Galor and Moav (2002) depict transition from stagnation to growth through endogenous technical progress. This activity is determined by human quality and knowledge, which are dependent on fertility decisions.

Galor and Weil (2000)

It is a unified growth model to generate historically observed pattern of evolution of population, technology and income over the centuries starting from 500 AD and leading up to the late twentieth century. The model explains ***endogenous*** *transition of an economy through three phases of economic development: Malthusian stagnation, post-Malthusian regime and the modern growth regime. In the first stage, technical progress and population growth are slow and the per capita income is constant. This stage is followed by a phase where rising per capita income is reflected in rapid population growth and finally by the modern growth regime with rapid technical progress, steady per capita income growth and lowering of fertility rate.*

An individual living for two periods allocates his/her endowment of unit labor time in the second period between producing quantity of children n_t, investing in their quality (education) e_t, and in market activities. The production function exhibits CRS in human capital (H) and effective resources, which is a combined factor of land (X) and

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labor productivity grow exogenously. The assumption of hierarchical preferences implies the transition of the economy from agriculture to agriculture-cum-industry.

Love (1997) also considers capital accumulation and these two sectors as producing two goods, together with a non-homothetic utility function having the industrial good as non-essential in consumption. Like agriculture, industrial production is subject to diminishing returns to scale. Transition occurs by an exogenous technology shock to either sector.

technology (A),

$$Y_t = H_t^{\alpha}(A_t X)^{1-\alpha}$$

While human capital accumulation of an individual depends on his/her quality and economy-wide technical progress, the rate of technical progress ($g_{t+1} = \frac{A_{t+1}-A_t}{A_t}$), depends on both the level of education and the size of working population (L). Hence, the human capital accumulation and the rate of technical progress can be written as

$$h_{t+1} = h(e_{t+1}, g_{t+1}), \quad g_{t+1} = g(e_t, L_t)$$

Given this frame work, the demographic transition as well as shift from primitive to modern economic growth occur in the following way: initially, technical progress is slow, causing a low return to human capital and hence people have little incentive to investment in education. With low level of education and therefore, low level of potential income adjusted for labor time available for market activities, individual can maintain the subsistence level of consumption. This is the Malthusian stagnation.

When the population size is sufficiently large, the pace of technical progress increases. This leads to rise in wage rate and the individual becomes capable of maintaining the subsistence consumption by allocating more time towards child- rearing. This is the income effect. Rise in the return to education on the other hand induces people to reallocate the increased income from raising children to invest in their education through substitution effect.

Initially, the income effect dominates and hence population growth rises characterizing the post-Malthusian state. Eventually, the substitution effect starts dominating and fertility declines and level of education increases. Higher education level of the economy on the other hand leads to further technical progress, per capita income grows at a steady rate. The economy enters the modern growth regime.

Galor and Moav (2002)

Galor and Moav extended the above described model by way of introducing heterogeneity of individuals in terms of preference towards quantity and quality (through investing in education) of children. The presence of heterogeneity may give rise to possibility of multiple steady-state equilibria. *Depending on the initial endowment of population whose preference is biased towards the quality of their children ('quality-type') relative to the population ('quantity-type'), they explain **endogenous transition** of the economy from the Malthusian low-level steady state to modern growth regime with sustained per capita income growth and reduction in population growth.*

The individual i's preference structure in the overlapping generation framework is defined as

$$u_t^i = (1-\gamma)\ln c_t^i + \gamma[\ln n_t^i + \beta^i \ln h_{t+1}^i], \quad 0 < \beta < 1$$

where c_t^i is the consumption above a subsistence level $\tilde{c} > 0$ of a type i of generation t, n_t is the number of children, $0 < \beta^i < 1$ is the weight given to offspring's human capital generation. Individuals with higher β will invest more time on child's education compared to child-rearing.

Initially, with a low fraction of population biased towards quality of offsprings, both education level and rate of technological progress are low. As a result, return to human capital is low and investment in education is negligible. The 'quantity-type' population has no incentive to invest in human capital and their income is near the subsistence level. Hence, after spending a sufficient amount of time in market activities to ensure subsistence level of consumption, the time left for child-rearing is just sufficient to generate a fertility rate that replaces the existing population of the 'quantity-type.' This implies a constant level of population. In this stage, per capita income is constant at the subsistence level. This is the well known Malthusian low-level steady-state.

However at the same time, individuals biased towards quality have higher income over the subsistence level. They can devote a lower fraction of time in market activity to ensure the subsistence consumption level and raise the share of time in child-rearing. Hence population of the 'quality-type' individuals increase.

The growing population of 'quality-type' raises level of education in the economy leading to acceleration to technical progress that is followed by rise in economy-wide income level. At this stage, 'quantity-type' population also have higher income above the subsistence level which is spent in increasing the fertility rate. The 'quality-type' reallocates increased resources towards human capital generation contributing to further technical progress. As a result this stage is marked by rising per-capita income and population growth.

Eventually, 'quantity-type' individuals start investing in child's education when return to human capital is sufficiently high. The economy then enters the era of sustained income growth along with reduced fertility rates.

It is important to keep in mind that, barring Jones (2001), an important exception, the transition models outlined above do *not* consider R&D or the production of ideas that generate new goods or new methods of production. Technologies are presumed to be known and the question is when they become viable in a market economy. In contrast, Jones emphasizes on accumulation of ideas, and increasing returns in production technology leading to demographic and growth transition of an economy.

Jones (2001)

In Jones, production of final goods shows increasing returns to accumulable factors, namely, ideas (A) and labor (L), and the fixed factor land (T),

$$Y_t = A_t^{\sigma} L_{Yt}^{\beta} T_t^{1-\beta} \epsilon_t, \quad \sigma > 0, \quad 0 < \beta < 1,$$

where ϵ_t captures an exogenous productivity shock.

New ideas are produced with people working in this sector and the existing stock of knowledge,

$$\Delta A_{t+1} = \delta L_{At}^{\lambda} A_t^{\phi}$$

Production of ideas requires a fraction of final goods to be invested in order to promote innovative activities.

The preference of an individual is defined in terms of consumption c_t and the number of children b_t as

$$u_t(c_t, b_t) = (1-\mu)\frac{(c_t - \bar{c})^{1-\gamma}}{1-\gamma} + \mu\frac{(b_t - \bar{b})^{1-\eta}}{1-\eta},$$

where $\bar{c} > 0$ is the subsistence level of consumption and $\bar{b} \geq 0$ is related to the long run fertility rate. The individual allocates her labor time between market activities and and child-rearing.

The population growth function is the following:

$$\Delta N_{t+1} = b_t N_t - d_t N_t,$$

where N_t is the size of population at period t. The term d_t denotes mortality rate which is defined as a function of consumption relative to the subsistence,

$$d_t(c_t/\bar{c}) = f(c_t/\bar{c} - 1) + \bar{d},$$

where $f(\cdot)$ is some decreasing function such that under certain parametric restrictions this function ensures that everybody in the economy dies if per capita consumption falls to the subsistence level. Moreover the restriction $f(\infty) = 0$ implies that in an economy with infinitely large consumption, the mortality rate is $\bar{d} \geq 0$.

An economy, with the above-stated characteristics, *is initially in a stage where discovery of new ideas is infrequent, both consumption and population rise by the income* *effect. Eventually with increase in production of new ideas, with the assumption of increasing returns to ideas and labor only, the economy experiences a rise in consumption and decline in fertility through the substitution effects. The growth rate of both population and consumption per capita rise initially, followed by decline over time towards their asymptotic balanced growth rate.*

The important parametric condition that makes per capita consumption grow at a positive rate is $\frac{\lambda\sigma}{1-\phi} - (1-\beta) > 0$. Under the assumption that production of ideas exhibits constant returns to scale in labor and the stock of ideas, the above condition reduces to $\sigma + \beta > 1$. Intuitively, the final goods sector should exhibit increasing returns in ideas and the other accumulable factor, labor, holding land fixed. This is a stronger condition that ensures effects of technical progress to outweigh the diminishing returns implied by land.

The intuition behind the transition dynamics is the following: initially, when the population size is small, number of people producing ideas are also small and hence new ideas are discovered infrequently. However, in this stage, any new discovery that leads to increase in return to labor supply has two opposite effects on the optimization process of the individual. The income effect leads to a rise in both consumption and fertility, while the substitution effect works toward consumption away from fertility. Initially, income effects dominates and consumption as well as the size of population rise. Hence, the impact of a new discovery on the per capita consumption is ambiguous.

However, as population increases, more people are engaged in the production of ideas and the rate of accumulation of knowledge rises. The increasing returns effects of ideas and growing labor force dominates over the diminishing returns effects on production implied by the fixed factor, land. Thus consumption increases. Again, in the decision making process of the individual, substitution effect starts dominating and fertility declines. Hence per capita consumption rises.

The economy enters the age of growing per capita income and demographic transition. Falling population growth rate in turn leads to reduction in the rate of innovation as well as the growth rate of per capita consumption which approaches the steady state value in the long run. In the long run, population grows at a rate $1 + \bar{b} - \bar{d} \geq 1$, while consumption and income per capita and wage rate grow at a rate $(1 + \bar{b} - \bar{d})^{[\frac{\lambda\sigma}{1-\phi} - (1-\beta)]}$.

It is important to note that Jones stands apart from all the existing works in the transition literature by capturing the importance of increasing returns to scale in the process of transition of an economy. We highlight this aspect of Jones's work since increasing returns play an important role in transition in the current thesis as well. However the basic difference between Jones and the present work is that in the former, externality of non-rival R&D is the source of increasing returns to scale (IRS) in production of final goods, while in the latter, fixed cost requirements in producing certain industrial goods give rise to IRS technology.

In this context, it is important to note that the seminal 'big-push' work of Murphy, Shleifer and Vishny (1989) also portray "industrialization" as a shift of the production mode within the manufacturing sector. The same manufacturing good can be produced with traditional technology characterized by constant-returns and also using modern technique having increasing returns. *In this framework, modern manufacturing become sustainable only when a sufficiently large number of entrepreneurs/firms decide to adopt the increasing-returns technology. As a result, economy comes out of the low-level equilibrium trap associated with traditional manufacturing to the industrialized equilibrium.*

2.3.2 Cross-Country Difference in Transition Dates and Global Income Divergence

In the recent years the transition literature has been extended towards investigating and explaining cross-country difference in transition dates and pattern of development. Parente and Prescott (2005), Galor and Mountford (2006) and Galor, Moav and Vollrath (2006) are some of the front line papers in this area. The last two studies explore the issue empirically as well.

Parente and Prescott (2005)

Parente and Prescott explain cross-country differences in transition dates in terms of relative efficiencies of the early vis a vis the late starters in the above mentioned Hansen-Prescott framework.

The total factor productivity in the Solow sector has two components: a pure technology component (A_S) and an efficiency component (E_S). Following the Hansen-Prescott analogy of transition to modern production mode, Solow sector opens up when

$$E_S A_{St} > \left(\frac{r_K}{\theta}\right)^{\theta} \left(\frac{w}{1-\theta}\right)^{1-\theta}$$

where r_K and w are return to capital and wage rate determined in the Malthusian economy.

It follows that two countries i and j, with different relative efficiencies will experience transition at two different dates t_i and t_j determined by the condition:

$$E_S^i A_{Sti} = \left(\frac{r_K}{\theta}\right)^{\theta} \left(\frac{w}{1-\theta}\right)^{1-\theta} = E_S^j A_{Stj}$$

Assuming the U.S. as the leader, given the relative efficiency values of the late starters, which include the Latin American countries and the East and South Asian countries, Parente and Prescott model described above is able to generate different transition dates of these different countries. Further, this model is simulated to generate the trajectory of income per capita over a period of 1700-2050 AD of these late starter countries. The model replicates the pattern of evolution of income per capita in these countries. It also predicts the catch up and the growth miracle in the East Asian countries under the assumption of an unexpected increase in relative efficiencies in these countries, particularly around 1957 in Japan.

Galor and Mountford (2006)

Galor and Mountford emphasize on international trade as the key behind global income divergence and demographic transition experienced by the industrialized economies.

Two sets of technologies are available for producing each of agricultural and industrial goods. The old technology in agriculture use unskilled workers (L) and land (X, fixed) and shows diminishing returns; old technology in industry is CRS in unskilled labor,

$$Y_t^{a,O} = a_t^a (L_t^{a,O})^\gamma X^{1-\gamma}; \quad Y_t^{m,O} = a_t^m L_t^{m,O}$$

The new technology in agriculture exhibits CRS in unskilled labor while that in industry is CRS in both skilled (H) and unskilled labor,

$$Y_t^{a,N} = A_t^a L_t^{a,N}; \quad Y_t^{m,N} = A_t^m F(H_t^m, L_t^{m,N})$$

Initially level of new technologies are so low that only old ones prevail. This can be thought as a multi-sector version of Hansen-Prescott idea of dual method of production.

New technologies become viable through human capital generation via individual's optimal allocation of time between market activities and bringing up unskilled and skilled offsprings. The allocation of time between unskilled and skilled offsprings again depends on parents' rational expectation of relative wage rate of skilled and unskilled labor which in turn depends on the economy-wide endogenous technical progress. Technical progress on the other hand depends on the share of skilled labor in total working population.

The theory predicts that *two economies otherwise similar, having different level of technologies will have two different dates of transition. If international trade takes place between them, the early starter will have a comparative advantage in the skill-intensive industrial goods given that technological progress is biased towards industry.*

As argued by the authors, today's industrialized countries had comparative advantage in skill-intensive manufacturing goods while the non-industrialized countries had comparative advantage in unskilled labor-intensive goods. International trade enhanced world demand for skill-intensive goods and hence return to skilled labor that induced individuals to invest in child quality in the developed countries. Investment in education accelerates technical progress, lowers fertility and leads to sustained rise in per capita income in these countries. On the other hand, increase in return to unskilled labor through international trade in the non-industrialized countries induced individuals in these economies to invest in child-rearing that causes high fertility rate, low rate of technical progress, and lower per capita income. As a result standard of living in these two zones diverged giving rise to an asymmetric pattern of development.

The authors have also tested empirically the above predicted propositions using cross country regression analysis. They examine the effect of trade share in GDP on the total fertility rate and human capital accumulation in OECD and non-OECD countries over the period of 1985-1990. The change in years of education of the population above fifteen years has been used as a measure of human capital accumulation. They indeed found that trade share has a positive effect on fertility and a negative effect on human capital accumulation in the non-OECD countries, while the effects are opposite in sign for the OECD countries. The results are statistically significant as well.

Galor, Moav and Vollrath (2006)

Galor, Moav and Vollrath develops a political economy view of cross-country differential in transition dates. According to this view, in a land abundant economy, or in a society with inequality in land holdings, the educational policy can be sub-optimal which hampers the human capital generation. This in turn retards the process of industrialization. Thus differences in institutional structure can give rise to global income divergence. Their work indeed provides a formal analytical framework for the claim put forward by Parente and Prescott that adoption of new production method may face constraints imposed by the input suppliers in the existing method of production.

The basic outline of the model is the following: an economy can produce a single final good using both agricultural and industrial technique. While the former uses land (X), a fixed factor, and labor (L), the latter method of production employs human (H) and physical capital (K),

$$y_t^A = F(X_t, L_t), \quad y_t^M = K_t^{\alpha} H_t^{1-\alpha}, \quad y_t = y_t^A + y_t^M$$

Here, K_t and H_t represent the total stock of physical and human capital at period t in the economy.

In a two-period overlapping generation framework, the human capital of each member of generation t accumulates through public expenditure on education per member of generation t, (e_t),

$$h_{t+1} = h(e_t).$$

Public educational expenditure, e_t is financed by proportional tax on capital transfer received by the member of generation t from the previous generation.

Individuals finance public education system through tax as they care for the income of their offsprings. The tax policy is such that the chosen tax rate maximizes total output produced under the two methods. However, any change in policy regime requires consensus from landlords.

In such a framework, it has been shown that *the total output maximizing tax rate also maximizes return to capital and wage rate and hence minimizes rental on land. The basic intuition is that human capital generation drives labor out of agricultural method to industrial method lowering the return to land.*

If there is inequality in land holdings in the sense that total land endowment is concentrated in the hand of a small segment of the society, then optimal tax policy chosen by the society will be 'no tax policy' and there will be no public investment in education. Thus the economy will be trapped in the low steady state growth path where only agricultural method operates. On the other hand, a society with equal land holdings chooses a positive tax rate optimally and the tax proceeds are invested in human capital formation so that the industrial method can be adopted. Such an economy is on a higher steady state growth path.

Galor, Moav and Vollrath also empirically tested the effect of changes in land inequality on educational investment in different states in the U.S. for the four different years during 1880-1950 with a gap of 20-30 years between each of these four dates. They found that an increase in the rate of change of land inequality has a significant negative effect on the rate of change of educational expenditures which indeed supports the main proposition of the theory.

Chapter 3

Agriculture, Public Input Provision and Growth

3.1 Introduction

This chapter attempts to further our understanding of the role of agriculture in the growth process of an economy, in the context of public infrastructural policy. The long standing development literature, starting from Rosenstein-Rodan (1943), Nurkse (1953) and Lewis (1955) to Murphy, Shleifer and Vishny (1989) and beyond, stresses on positive linkages between agriculture and growth (or modernization) that works mainly through inelastic demand for agricultural goods. The role of agricultural labor productivity in successful launch of industry under the hierarchical preference structure (reflecting extreme form of Engel's law) and income inequality has been emphasized by Eswaran and Kotwal (1993a). In a recent work, Xie (2008) has emphasized on the importance of productivity surge in agriculture in urbanization. These literature captures multi-sectoral interdependence from either static or exogenous growth perspective which is capable of predicting only the level effects of agricultural productivity surge, not its growth rate effect. The seminal paper of Matsuyama (1992) is the pioneer in addressing the *growth rate* aspect of this issue.[1]

As discussed in Chapter 2 Matsuyama investigates the relationship between agriculture and economic growth in an *endogenous growth framework* where the source of growth is learning-by-doing in industry. He finds contrary to the conventional wisdom, under certain conditions, agricultural productivity may not be conducive to growth. Precisely, his findings are that if an economy is closed, an increase in agricultural productivity releases labor to manufacturing under the assumption of less than unitary income elasticity of agricultural good. Inflow of labor in industry increases manufacturing output and accelerates the growth rate of this sector as well as the economy's growth rate via learning-by-doing. But if it is a small open economy with a highly productive agricultural sector compared to the rest of the world such that it has comparative advantage in agriculture, the manufacturing sector loses labor over time, its output falls and learning-by-doing slows down, dampening the growth rate of the economy.[2]

Our analysis emphasizes an alternative source of endogenous growth – i.e. a tax-financed (non-accumulable) public input used in the production sectors of the economy *a la* Barro (1990). The role of agricultural productivity in long run growth and development under alternative engines of growth has also been explored by Eswaran and Kotwal (2001). In an economy, where public investment is the source of growth in agri-

[1]Glomm (1992) has explored how persistent income disparities between country-side and cities due to non-homothetic preference over agricultural and manufacturing goods coupled with sectoral technological differences results in persistent shift of labor force from agriculture, which in turn contributes to urbanization in an endogenous growth framework.

[2]A similar notion is also put forward by Eswaran and Kotwal (1993b). In a static framework, they show that agriculture oriented policy may not be conducive to economic progress in an open economy. More specifically, they showed that primary export-led strategy coupled with price elastic labor supply may hamper the development process by shrinking the production possibility frontier.

culture, while industry experiences innovation-led growth, the authors found similar to Matsuyama, that the positive linkage between agriculture and industry may not hold for an open economy.

We consider public input as the engine of growth in both sectors. The long-standing literature has emphasized the role public input in long run growth (Barro and Sala-I-Martin, 1992; Futagami, Morita and Shibata, 1993; Dasgupta, 1999; Glomm and Ravikumar, 1994; Baier and Glomm, 2001; Turnovsky, 1997, 2004, 2006). This literature mainly emphasizes on the role of publicly provided input such as infrastructures in private production of goods.

There are indeed several empirical studies indicating public investment as an important source of economic growth. These are reviewed in details in Chapter 2. For example, Ram (1986), Haque and Kim (2003), Rodrik and Subramanian (2004) and Bose, Haque and Osborn (2007) found public infrastructural investment affecting overall growth rate positively and significantly. Aschauer (2000) made a panel data estimation for the 48 contiguous states in the United States during the decades of the 1970s and 1980s and found that a one standard deviation increase in public capital stimulates a one-third to one-half standard deviation increase in output per worker, which is quite significant.

Apart from the direct channel of infrastructual services, public investment in other sectors also may play an important role in development and growth. For instance, Glomm and Ravikumar (1993) explore how human capital accumulation by individuals through publicly provided education sector financed by taxes determine the productivity level and growth rate in an endogenous growth framework. Again, Chakraborty (2004) investigates the impact of mortality endogenously determined by public health investment and growth. He shows economies with high mortality tend to invest less in human capital and their growth process is retarded. Thus public health investment that augments health capital and reduces mortality risk plays an important role in determining the investment and growth in an economy.

The current analysis allows for public infrastructural investment in both manufacturing and agriculture. Recall from our review of empirical literature in Chapter 2, that the importance of public expenditure in agricultural and rural development has been explored by Fan Hazell and Thorat (2000) and Fan, Zhang and Zhang (2004). These studies respectively on India and China found significant contribution of public investment in agricultural productivity growth in the late twentieth century. Precisely, Fan, Hazell and Thorat found that agricultural research, improved roads, irrigation- all have contributed significantly to growth in agricultural productivity in India.

Apart from the provision of public input in agriculture, our model has an additional feature that captures the sector-specific nature of public expenditure. For instance, in India, 83% of the public infrastructural investment is comprised of irrigation, electricity, provision of fertilizer etc. (Kumar, Rosegrant and Hazell, 1995), while in industries it is mainly the transport system, telecommunications, expenditures on higher education, etc. In view of this, in our analysis, total tax revenue is divided between financing public inputs specific to agriculture and that to manufacturing. With these features, our model attempts to analyze the consequences of distributional aspect of limited public resources across sectors on long run growth from the perspective of policy choices in developing countries which are resource constrained.

Of course, the ultimate goal of the policy is to ensure a high standard of living and social welfare. In a multi-sectoral framework where sectoral outputs are functions of public input allocated to that sector, the welfare-oriented policy may differ from a purely growth-oriented policy. This demands a rigorous and well-structured theoretical framework for the comparison of growth and welfare oriented policies.[3]

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[3]The issue of welfare decomposition and optimal public expenditure allocation across rural and urban sectors, the inefficiency of practical applicability of such policy due to data and measurement

We attempt to fill this void by developing a two-sector endogenous growth model with public investment in both manufacturing and agriculture. The critical, yet reasonable, assumption is that the public input itself is a manufacturing good, not the agricultural good. In comparison to Matsuyama's model, our model is able to allow not just a costless exogenous increase in agricultural productivity but also a policy-induced enhancement of agricultural productivity. The former refers to an adaptation of new technology, knowledge, organization or institution, whereas the latter is through enhancement of public expenditure share in that sector (given tax rate).

In such a setup, our main result is that in a small open economy, an increase in agricultural productivity, exogenous or policy induced, may have a negative impact on the long-run growth *irrespective of the pattern of comparative advantage.* Hence the 'Matsuyama hypothesis' of *negative relation between agricultural productivity and long-run growth in a small open economy* holds in a stronger fashion. Secondly, similar to Barro, there exists a tax rate that maximizes the long-run growth rate of the economy.

The welfare implication of productivity surge (exogenous as well as policy-induced) in agriculture is in general ambiguous because of its positive level- but negative growth-effects. The effect of change in tax rate on social welfare is ambiguous as well. However, our numerical exercises predicts that an exogenous productivity rise in agriculture is welfare enhancing, except for very high values of the subjective discount factor. These exercises also show that the impacts of tax rate and reallocation of public input across two sectors on welfare crucially depend on the level of agricultural TFP and land-endowment of the economy. Precisely we find that in an economy with very high (low) agricultural productivity and/or land endowment, social welfare (defined as the sum of discounted utilities) increases (decreases) with tax rate and share of public input in agriculture. In between these extreme values of agricultural TFP and land endowment,

problems has been discussed by Lederman and Ortega (2004).

social welfare is inverted-U shaped in tax rate and has a U-shape with share of public input in agriculture.

Our model economy also features an interesting pattern of transitional dynamics. It arises because the income elasticity of the agricultural good is less than one (as it implies non-homothetic preference). Moreover, during the transitional period, the growth rate of the economy monotonically increases over time. This implies that any parametric change that has a detrimental effect on the long-run growth, e.g., an increase in agriculture productivity, will have a stronger negative impact on growth in the short run. Put differently, there is a negative overshooting effect in terms of the growth rate in response to a shock that lowers the long run growth rate.

In order to determine the optimal set of policy instruments (tax rate, distribution of public input across two sectors), the model is calibrated to the Indian data. The orientation of India's development strategy has been a highly debatable issue since the time of independence in the economic and political scenario of the country. The heart of the debate lies in the fact that agriculture had largest share in terms of employment and gross domestic products but at the same time lagging far behind from food sovereignty. In this situation quoting Varshney (1998) "the choice of strategy, however involved a series of fundamental and continuous questions." According to him, these questions precisely include "what place agriculture should have in the larger development strategy, what the resource allocation between industry and agriculture should be, what role the government had to play in agriculture, what means were appropriate if government involvement were essential, and whether landownership patterns had to be changed in order for agriculture to grow."

The above-mentioned questions are intensified even after sixty years, when a mix of strategies focussed on heavy industries and institutional and technical reform in agriculture is not able to reduce agricultural dependence satisfactorily. Thus it is natural to explore model's applicability in assessing and quantifying the long-run growth and welfare implications of agricultural productivity in India. Using our model, we replicate a few characteristics of the Indian economy such as employment share across agriculture and manufacturing sectors. By varying the parameter values representing productivity level and policy instruments, we investigate the growth and welfare effects in this economy and compare between growth and welfare oriented policies.

In conducting the numerical experiments, we quantify (i) growth effect (ii) welfare gains/loss associated with the shift to the optimal policy regime from the existing regime (represented by the benchmark values of policy instruments used in the numerical exercise). Welfare gain/loss is measured by the required percentage change in consumption in the existing regime to achieve the level of utility attained in the optimal policy regime.[4] We also conduct numerical exercise for different values of a set of parameters that generates a different economic structure from the Indian economy. We find that the choice of policy instruments crucially depends, unlike Barro (1990), on the government's objective (whether it is growth oriented or it aims to maximize welfare) as well as the agricultural productivity level and land-endowment of the economy. Moreover, the welfare implications depend on the source of productivity rise and the relative size of the two sectors (agriculture and manufacturing).

The chapter is organized as follows. Section 3.2 describes the basic assumptions and features of the model with homothetic preference structure. The implications of non-homotheticity is explored in section 3.3, which is our model essentially. A numerical exercise is presented in section 3.4, where the chosen parameters are consistent with the Indian economy. Section 3.5 offers concluding remarks.

[4]The purpose of our numerical exercise is in line with Einarsson and Marquis (2001) who quantified impacts of fiscal policy on the post-war U.S. economy with home production sector.

3.2 The Analytical Framework

A small open economy has two sectors: manufacturing (M) and agriculture (F). Both goods are homogeneous. Good F used for consumption only. Good M is multi-purpose. It is consumed, used as the capital good as well as it serves as an infrastructure input in both sectors.

Good M is produced by labor, capital and a public input, while good F is produced by labor, land and the public input. Capital specificity in manufacturing captures in an extreme fashion that this sector is more capital intensive than agriculture. The total supplies of labor and land are fixed, normalized to one. Let G_t denote the total amount of the public input available with the government, μ proportion of which is allocated to sector F and $1-\mu$ to sector M. Denoting capital stock by K_t and labor employment in manufacturing by n_t, we now specify the technologies in the two sectors:

$$F_t = B\mu G_t H_f(1, 1-n_t); \quad M_t = H_m[K_t, (1-\mu)G_t n_t]. \tag{3.1}$$

The functions $H_f(\cdot)$ and $H_m(\cdot)$ are linearly homogeneous and B is the exogenous productivity parameter in sector F. The focus of the analysis is productivity in sector F, not that in manufacturing. Thus the productivity parameter in manufacturing is assumed exogenous and normalized to one. We can express (3.1) as $f_t = B\mu H_f(1, 1-n_t)$ and $m_t = H_m[k_t, (1-\mu)n_t]$, where $f_t \equiv F_t/G_t$, $m_t \equiv M_t/G_t$ and $k_t \equiv K_t/G_t$.

Capital in manufacturing, land in agriculture and labor in both sectors are subject to positive and diminishing returns. Following Barro (1990), the input G used in sector M enhances labor productivity via specialized training facilities for workers, etc., while that in agriculture takes the form of rural development, irrigation, agricultural research etc. that raise the productivity of both labor and land.[5]

[5]Goel (2002) has investigated the impact of infrastructural provision on productivity of the registered manufacturing sector in India during 1965-1999. Her findings are that economic infrastructure

The asymmetry in the way G enters agriculture and manufacturing production function ensures the co-existence of the two sectors and that the economy grows at a constant rate in the steady state. For instance, if public input enters linearly in both sectors, co-existence of both sectors will require labor allocation in both sectors and capital employed in manufacturing to be constant over time. At the same time, growing public input will imply ever increasing growth rate.

On the other hand, if public input enters in a labor-augmenting way, in both sectors, labor will continuously move from agriculture to manufacturing due to diminishing returns to effective labor in the former.

Hence, for the model economy to at a constant positive rate, with co-existing agriculture and manufacturing sectors, it is essential that production functions should exhibit CRS in its accumulable factors. Since manufacturing uses two accumulable factors, namely, private capital and public input, manufacturing production function should exhibit CRS in these two factors. Since agriculture uses only one accumulable factor, public capital, the production function in this sector needs to be characterized by CRS in this factor.

For later purposes, let σ_f and σ_m denote the elasticities of substitution between labor and land in agriculture and between capital and public input-adjusted labor in manufacturing respectively.

Labor moves freely between the sectors, equalizing the values of its marginal products across the two sectors, i.e.,

$$B\mu H_{fn}(1 \underset{-}{-} n_t) = \bar{p}(1-\mu)H_{mn}\left[\frac{(1-\mu)n_t}{\underset{-}{k_t}}\right], \tag{3.2}$$

where $\bar{p}$ is the exogenously given relative price of manufacturing in terms of the agricul-

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that includes five sectors, namely, electricity, banking, irrigation, transport and communications is capital using but labor saving. Also, it is a substitute to capital, while complementary to labor.

ture good, dictated from the world market. For algebraic simplicity, we will, from now on, assume $\bar{p} = 1$. The terms H_{fn} and H_{mn} are the partial of the respective function with respect to the labor input. They are equal to the 'public input adjusted' marginal product of labor in the respective sector, i.e., the ratio of the marginal product of labor to G.

The government imposes a proportional tax rate τ on the total income (including agricultural income). The tax revenues are used to obtain manufacturing goods in the form of a public input, i.e., this input is made out of manufacturing goods only. These assumptions imply

$$\tau(f_t + m_t) = 1 \Leftrightarrow \tau \left\{ B\mu H_f(1, 1 - n_t) + H_m[k_t, (1-\mu)n_t] \right\} = 1. \tag{3.3}$$

Eqs. (3.2)-(3.3) determine the labor allocation variable n_t and the capital/public input ratio, k_t. Notice from (3.2)-(3.3) that n and k are time-independent (or constant), implying m_t and f_t are constant over time. Let $n_t = n^*$, $k_t = k^*$, $m_t = m^*$ and $f_t = f^*$.

Simple comparative statics exercises yield

Proposition 3.1 *(a) An increase in the productivity parameter B in agriculture leads to a decrease in both manufacturing employment and the capital/public input ratio.*
(b) An increase in the share of public input allocated to agriculture has, in general, ambiguous effects on both employment allocation and the capital/public input ratio. However, if the factor elasticity of substitution in manufacturing is greater than or equal to one, manufacturing employment falls (but the effect on the capital/public input ratio still remains ambiguous).
(c) An increase in tax rate reduces the labor allocation in manufacturing and the capital/public input ratio.

The intuitions are as follows: An increase in B, given employment allocation, raises the total income, tending to increase the provision of the public input. In equilibrium, the ratio of capital to public input falls. This reduces the marginal product of labor in manufacturing. The marginal product of labor in agriculture has risen as a result of increase in B. Thus labor moves from manufacturing to agriculture, i.e., n^* falls.

An increase in μ tends to raise the income in sector F but lowers that in sector M. Thus the effects on total income and therefore on the provision of the public input are ambiguous. This implies that k^* may increase or decrease. Moreover, ceteris paribus, an increase in μ increases the marginal product of labor in agriculture but decreases that in manufacturing, thereby leading a decrease in n^*. However, the net effect depends on the change in k^*. Since this effect is ambiguous, the impact of a change in μ on n^* is ambiguous in general.

An increase in tax rate, given stock of capital in that period, reduces ratio of capital to public input. Thus labor productivity per unit of public input in M falls, while that in F remains unchanged. Thus labor moves out of manufacturing. However, higher provision of public input increases productivity of capital in sector M that tends to raise the supply of private capital in that sector. But as n^* has fallen, increase in capital is less than proportional to the increase in public input. Hence k^* falls in equilibrium.

Because n_t, k_t, m_t, and f_t are time-invariant, K_t, G_t and the two sectoral outputs all grow at the same rate. Their growth rate, yet to be solved, defines the growth rate of the economy.

The equilibrium growth rate would depend on the rate of return to capital, the after-tax value of the marginal product of capital in terms of the manufacturing good. It has the expression $r_{kt} = (1-\tau)r_t$, where $r_t = H_{mk}[(1-\mu)n_t/k_t]$. Since n_t and k_t are constant over time, so is r_{kt}, i.e.,

$$r_{kt} = r_k^* = (1-\tau)H_{mk}\underset{-}{\left[\frac{(1-\mu)n^*}{k^*}\right]}. \tag{3.4}$$

As an increase in B lowers both n^* and k^*, (see Proposition 3.1), $dr_k^*/dB \gtreqless 0$

in general. However, as shown in Appendix 1, the employment effect of an increase in B dominates and thus $dr_k^*/dB < 0$ if (i) in both sectors the elasticities of factor substitution are greater than or equal to one and (ii) the share of labor in agriculture is greater than the share of labor in manufacturing – which is very plausible in the context of a developing economy.

An increase in μ, i.e., a decrease in $1-\mu$, directly reduces the ratio of effective labor to capital in manufacturing and thereby tends to lower the rate of return to capital, yet $dr_k^*/d\mu \gtrless 0$. Appendix 1 shows that, under (i) and (ii) again, $dr_k^*/d\mu < 0$. Under these conditions n^* declines unambiguously and to the extent that the ratio $(1-\mu)n^*/k^*$ falls.

An increase in tax rate directly reduces the after-tax return on capital. Again, it reduces both n^* and k^*. Hence, in general, $dr_k^*/d\tau \gtreqless 0$. Appendix 1 shows that r^* has an inverted-U relation with tax rate. An increase in τ raises the ratio $(1-\mu)n^*/k^*$, which has a positive impact on r_k^*. But higher tax rate directly reduces r_k^*. When initial tax rate is low, a small rise in τ results in the positive effect to dominate. Hence r_k^* rises. For a high value of the tax rate, the negative effect dominates and r_k^* falls. Thus,

Proposition 3.2 *The return on capital decreases with B and μ if σ_f, $\sigma_m \geq 1$ and the share of labor in agriculture exceeds that in manufacturing. It has an inverted-U relation with tax rate.*

Next, we specify the demand side of the model economy. For now, we assume that the instantaneous utility function is homothetic, i.e., the income elasticity of both goods is unity. Let this function be $U_t = \delta \ln c_t^M + (1-\delta)\ln c_t^F$, $\delta \in (0,1)$, where c_t^M and c_t^F are consumptions of the manufacturing good and the agriculture good respectively. This implies the individual demand functions: $c_t^M = \delta E_t$ and $c_t^F = (1-\delta)E_t$, where E_t is the total expenditure on the two goods.

Substituting the demand functions into the utility function, we obtain the indirect utility expression: $V_t = \ln E_t$ + Constant. The household sector maximizes $\sum_{t=0}^{\infty} \rho^t V_t$, subject to K_0 given and the budget constraint

$$E_t + K_{t+1} - K_t = (1 - \tau)(w_t + R_t + r_t K_t), \tag{3.5}$$

where ρ the household's discount factor, w_t is the wage rate and R_t the land rent. It is implicit that the rate of capital depreciation is zero. The budget constraint says that the total expenditure plus savings equal the disposable income of the household. The resulting Euler equation is the following:

$$\frac{E_{t+1}}{E_t} = \rho(r_{t+1} + 1) = \rho(r_k^* + 1) \equiv \gamma^*. \tag{3.6}$$

We presume that ρ exceeds a threshold such that $\gamma^* > 1$.

The right-hand side of the budget equation (3.5) can be expressed as $(1-\tau)(F_t+M_t)$. Using this, recalling that k_t, m_t and f_t are constant and utilizing eq. (3.3), we can rewrite this equation as:

$$G_{t+1} = \left(1 + \frac{1-\tau}{k^*\tau}\right) G_t - \frac{E_t}{k^*} \tag{3.7}$$

Eqs. (3.6) and (3.7) spell the dynamics of E_t and G_t. Defining $e_t \equiv E_t/G_t$, these two equations yield

$$e_{t+1} = \frac{\gamma^* e_t}{1 + \frac{(1-\tau)/\tau - e_t}{k^*}}. \tag{3.8}$$

This is one dynamic equation in one variable. In the steady state

$$e_{t+1} = e_t = e^* = \frac{1-\tau}{\tau} - (\gamma^* - 1)k^*. \tag{3.9}$$

It is presumed that τ is not so high such that $e^* > 0$. Totally differentiating (3.8) and evaluating at $e_t = e^*$,

$$\left.\frac{de_{t+1}}{de_t}\right|_{e_t=e^*} = 1 + \frac{e^*}{k^*\gamma^*} > 1. \tag{3.10}$$

There is no initial value of e_t and thus the above derivative being greater than one implies that, under perfect foresight, e_t 'jumps' to its steady state instantly. The economy's growth rate is same as that of E_t, equal to γ^*. There is thus no transitional dynamics.

3.2.1 Growth and Level Effects

Note that γ^* is 1-1 related to r_k^*, the rate of return on capital. Hence the effects of parametric shifts on the economy's growth rate can be summarized as follows.

Proposition 3.3 *An increase in the agricultural productivity parameter B or an increase in the share of public input allocated to agriculture lowers the equilibrium growth rate if $\sigma_f, \sigma_m \geq 1$ and if the share of labor in agriculture is greater than that in manufacturing.*[6] *The long run growth rate initially increases as tax rate rises from a low value, however, it falls with further increase in tax rate.*

The upshot is that, unlike in Matsuyama (1992), (a) both an exogenous and a policy-induced productivity increase in agricultural productivity may have a negative growth effect and (b) this holds irrespective of the pattern of comparative advantage of the small open economy. This is a much stronger prediction compared to Matsuyama. The underlying reason is that higher productivity in the agricultural sector leads to less employment in manufacturing and thereby a lower return to capital.

Turn to the level effect on welfare now, given that the growth effect is negative. Substituting (3.6) recursively into the expression of V_t, the static utility or welfare at time t is given by

$$V_t = \ln E_0 + t \ln \gamma^* + \text{Constant}. \tag{3.11}$$

The first and the second term respectively captures the level effect and the growth effect.

[6]Thus the proposition holds under the standard assumption of Cobb-Douglas technologies, coupled with the above ranking of labor shares in the two sectors.

Since $e_t = e^*$ and $k_t = k^*$, in view of (3.9),

$$E_0 = G_0 e^* = \frac{K_0}{k^*}\left[\frac{1-\tau}{\tau} - (\gamma^* - 1)k^*\right] = K_0\left[\frac{1-\tau}{\tau k^*} - (\gamma^* - 1)\right] \tag{3.12}$$

$$\Rightarrow \frac{\partial E_0}{\partial B} = K_0\left(-\frac{1-\tau}{\tau k^{*2}}\underset{-}{\frac{\partial k^*}{\partial B}} - \underset{-}{\frac{\partial \gamma^*}{\partial B}}\right) > 0. \tag{3.13}$$

Thus the effect of an increase in B on the static level of welfare is positive.[7]

How does an increase in B affect the time path of V_t? From (3.11),

$$\frac{\partial V_t}{\partial B} = \frac{1}{E_0}\underset{+}{\frac{\partial E_0}{\partial B}} + \frac{t}{\gamma^*}\underset{-}{\frac{\partial \gamma^*}{\partial B}}. \tag{3.14}$$

As $t \in (0, \infty)$, there must exist a critical T such that $\partial V_t/\partial B \gtrless 0$ as $t \lessgtr T$. In other words, the growth effect eventually outweighs the level effect. This is illustrated in Figure 3.1. Suppose initially, the agricultural productivity level is B_0. The corresponding one-period welfare is depicted by the curve $V(B_0)$. Now let there be a rise in agricultural productivity to B_1, where $B_1 > B_0$. Due to the positive level effect, initially one-period welfare rises. But eventually because of negative growth effect, at some period, say, T, it falls below $V(B_0)$. This is depicted by the curve $V(B_1)$.

The 'ultimate' welfare question pertains to the change in the discounted sum of welfare. From (3.11),

$$\int_0^\infty V_t dt \equiv W = \frac{\ln E_0}{1-\rho} + \frac{\rho}{(1-\rho)^2}\ln \gamma^* \tag{3.15}$$

$$\Rightarrow \frac{\partial W}{\partial B} = \frac{1}{(1-\rho)E_0}\frac{\partial E_0}{\partial B} + \frac{\rho}{(1-\rho)^2\gamma^*}\frac{\partial \gamma^*}{\partial B} \gtrless 0. \tag{3.16}$$

It is then possible that the discounted sum of welfare may decrease with B. How can a positive productivity shock reduce welfare? The answer lies in a movement from one second-best situation to another. If the public input were financed by a distortion-free

[7]Because of perfect foresight, the initial level effect also partly depends on the equilibrium growth rate.

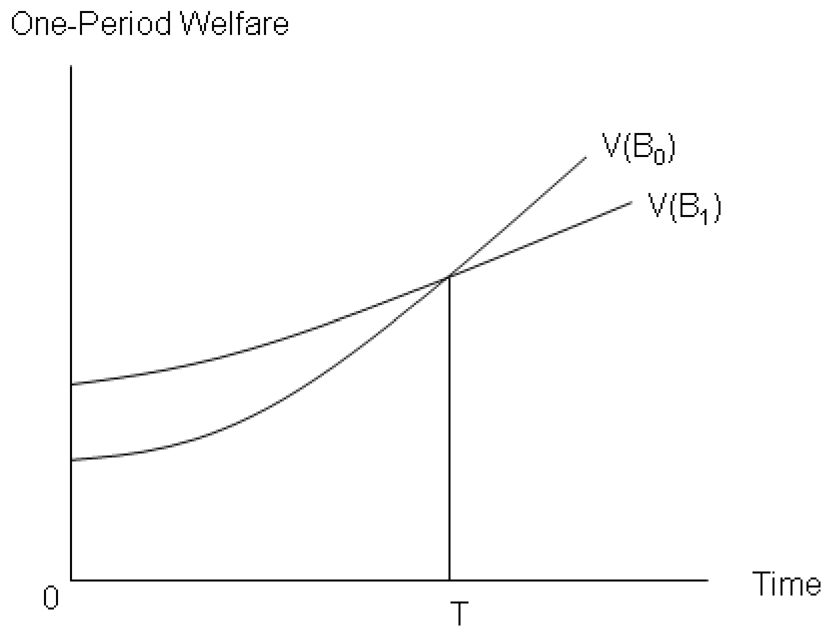

Figure 3.1: An Increase in the Agricultural Productivity Parameter B: Level and Growth Effects on Welfare

lump-sum income tax and this tax as well as its sectoral allocation in the form of public input provision were optimally chosen so as to maximize the discounted sum of social welfare, an increase in the productivity of any sector cannot be welfare-diminishing.[8] However, in the current model, a proportional income tax, τ, is distortionary, and, thus whether τ and μ are exogenous policy parameters or chosen optimally, it is still a second-best situation.

Consider now an increase in μ. Since $\partial k^*/\partial\mu \gtrless 0$, in view of (3.12), $\partial E_0/\partial\mu \gtrless 0$, i.e., the level effect of an increase in μ is ambiguous. Thus the presumption that welfare declines with μ is stronger, compared to an increase in B.

Next, we analyze the impact of tax rate on welfare. It can be shown by using (3.12), that the level effect $\partial E_0/\partial\tau \gtrless 0$. Intuitively, an increase in tax rate enhances income through higher provision of productive input in two sectors, but it reduces after-tax

[8]It can be formally shown by setting up the "planner's problem."

income. Therefore, welfare impact of tax rate is ambiguous.

The above discussions are summarized in the following proposition:

Proposition 3.4 *An exogenous surge in the productivity in agriculture unambiguously enhances initial level of expenditure, while the level effects of an increase in the share of public input in this sector and a rise in tax rate are in general ambiguous. The discounted sum of welfare may increase or decrease with a rise in agricultural productivity (both exogenous and policy-induced) and tax rate.*

3.2.2 Welfare Implication with Optimal Tax Rate and Public Input Share in Manufacturing

Consider a situation where the government chooses τ and μ optimally such that the discounted sum of utility W is maximized. Let $\tau^o(B)$ and $\mu^o(B)$ be the value of τ and μ that solves the maximization problem in terms of the parameter B. Also let $\nu(\tau^o(B), \mu^o(B), B)$ be the maximum value of the welfare function.

The rate of change of welfare with respect to B by virtue of the envelop property becomes

$$\frac{d\nu}{dB} = \left.\frac{\partial W(\tau, \mu, B)}{\partial B}\right|_{\tau^o, \mu^0} \gtrless 0.$$

Thus the discounted sum of welfare may increase or decrease with a rise in agricultural productivity even when τ and μ are optimally chosen.

Making use of eqs. (3.13), (3.16) and expressions for $\hat{k}/\hat{B}$ and $(\hat{n} - \hat{k})/\hat{B}$ from Appendix 1, it can be shown that welfare declines due to an exogenous rise in agricultural productivity if subjective discount factor ρ is sufficiently high such that negative growth effect outweighs the positive level effect. Given the complicated structure of the two-sector dynamic general equilibrium model, a closed form solution of the threshold value of ρ leading to negative welfare effect can not be derived analytically. The threshold value of ρ such that welfare effect is negative can be solved numerically, given other parameter values of the model.

3.3 Non-Homothetic Preferences

A typical feature of the agricultural good that has been highlighted in both static and dynamic models of a developing economy is that the income elasticity of demand for this good is less than unity. In a closed-economy, such non-homothetic preference structure is critical in linking the productivity of the agriculture sector to the expansion of the industrial sector via a demand-induced employment shift toward the latter. This linkage is however absent in a small open economy as the relative price of one good vis-a-vis the other is exogenously given from the world market.

But we shall demonstrate that such a preference structure does affect the growth process of the economy. It is because a change in the static utility function affects the marginal impact of expenditure ('consumption') on the indirect utility and thereby the rate of intertemporal tradeoff between current and future consumption. Specifically, transitional dynamics emerges *because of* this preference structure.

Assume a minimum absolute level of consumption of the agriculture good required for survival, say c^F_{min}. Let the felicity function be a generalization of the earlier one: $U_t = \delta \ln c^M_t + (1-\delta)\ln(c^F_t - c^F_{min})$.

If we define $\tilde{E}_t \equiv E_t - c^F_{min}$, the individual demand functions and the indirect utility have the expressions: $c^M_t = \delta\tilde{E}_t$, $c^F_t - c^F_{min} = (1-\delta)\tilde{E}_t$ and $V_t = \ln \tilde{E}_t +$ Constant. We then express the intertemporal budget constraint as

$$\tilde{E}_t + K_{t+1} - K_t = r_t K_t + w_t + R_t - c^F_{min}. \tag{3.17}$$

The budget equation is a generalization of (3.7):

$$G_{t+1} = \left(1 + \frac{1-\tau}{k^*\tau}\right) G_t - \frac{c^F_{min}}{k^*} - \frac{\tilde{E}_t}{k^*}. \tag{3.18}$$

The intertemporal maximization leads to the Euler equation:

$$\frac{\tilde{E}_{t+1}}{\tilde{E}_t} = \gamma^* \Rightarrow \tilde{E}_t = \tilde{E}_0 \gamma^{*t}. \tag{3.19}$$

Equations (3.18) and (3.19) dictate the dynamics of $\tilde{E}_t$ and G_t. The dynamics is 'solved' through the following lemma, proven in Appendix 2.

Lemma 1 *Under perfect foresight,*

$$\frac{\tilde{E}_t}{G_t - \frac{\tau c^F_{min}}{(1-\tau)}} = \frac{(1-\tau)}{\tau} - (\gamma^* - 1)k^*. \tag{3.20}$$

It is presumed that c^F_{min} is small enough such that the denominator of the ratio on the left-hand side is positive. We have already assumed that τ is small enough so that the r.h.s. (3.20), same as that of (3.9), is positive. Thus $\tilde{E}_t > 0$ for all t. Lemma 1 essentially says that the left-hand side ratio of (3.20) is time invariant. Note that if c^F_{min} were zero, it reduces to E_t/G_t being constant, i.e., there is no transitional dynamics. But given $c^F_{min} > 0$, there is transitional dynamics. For $t = 0$ and noting that $G_0 = K_0/k^*$, (3.20) gives

$$\tilde{E}_0 = \left[\frac{(1-\tau)}{\tau} - (\gamma^* - 1)k^*\right] \left[\frac{K_0}{k^*} - \frac{\tau c^F_{min}}{(1-\tau)}\right]. \tag{3.21}$$

Finally, substituting (3.19) and (3.21) into (3.20),

$$G_t = \frac{\tilde{E}_0 \gamma^{*t}}{(1-\tau)/\tau - (\gamma^* - 1)k^*} + \frac{c^F_{min}}{(1-\tau)/\tau} \tag{3.22}$$

$$\Rightarrow \frac{G_{t+1}}{G_t} \equiv \gamma_G = \frac{\frac{\tau c^F_{min}}{(1-\tau)\gamma^{*t}} + \left[\frac{K_0}{k^*} - \frac{\tau c^F_{min}}{(1-\tau)}\right]\gamma^*}{\frac{\tau c^F_{min}}{(1-\tau)\gamma^{*t}} + \frac{K_0}{k^*} - \frac{\tau c^F_{min}}{(1-\tau)}}.^{9} \tag{3.23}$$

The last equation describes the transitional dynamics. It is interesting that γ_G is monotonically increasing in t. Further, $\lim_{t\to\infty}\gamma_G = \gamma^*$. Thus,

Proposition 3.5 *Over time, the growth rate of the economy increases monotonically and asymptotically approaches γ^*.*

The reason behind the proposition is the following. A change in the static (indirect) utility is inversely proportional to $\tilde{E}_t$, the expenditure on the two goods *net* of the minimum consumption of the agriculture good. Thus, the Euler equation states that the growth rate of $\tilde{E}_t$ is proportional to the rate of return to capital and hence is constant since the rate of return to capital is fixed in the small open economy. This implies that the growth rate of expenditure on two goods, $\tilde{E}_t$ plus a positive constant, must fall over time. Hence the growth rate of savings must increase, implying that the economy's growth rate increases over time.

The long-run growth rate of the economy is independent of the 'non-homotheticity parameter' c^F_{min} however, because its magnitude becomes smaller and smaller relative to income as income grows over time. It is the inelasticity of demand for the agricultural good, which is the *raison de tre* of transitional dynamics in the model economy.

That the growth rate always increases during the transitional phase has the following implication:

Proposition 3.6 *Any parametric change in the economy having a detrimental effect on the growth rate in long run will have a larger (detrimental) impact in the short run.*

[9]Under our assumption of c^F_{min} being small enough so that the denominator of the left-hand side ratio in (3.20) is positive implies

$$\frac{K_0}{k^*} - \frac{\tau c^F_{min}}{(1-\tau)} > 0.$$

For instance, consider an increase in B. Suppose that $\partial\gamma^*/\partial B < 0$ (which holds if $\sigma_f, \sigma_m \geq 1$ and share of labor in agriculture is greater than that in industry). Let, initially, $B = B_0$, and there is an unanticipated permanent increase in B from B_0 to B_1. In terms of Figure 3.2, the long-run growth rate decreases from $\gamma^*(B_0)$ to $\gamma^*(B_1)$. However, since, the growth rate must increase over time, the initial impact on the growth rate at time 0 must be negative and larger in magnitude than the long-run impact. As shown in Figure 3.6, the growth rate initially declines from $\gamma^*(B_0)$ to γ_2. Note that the same applies to an increase in μ, given that $\partial\gamma^*/\partial\mu < 0$.

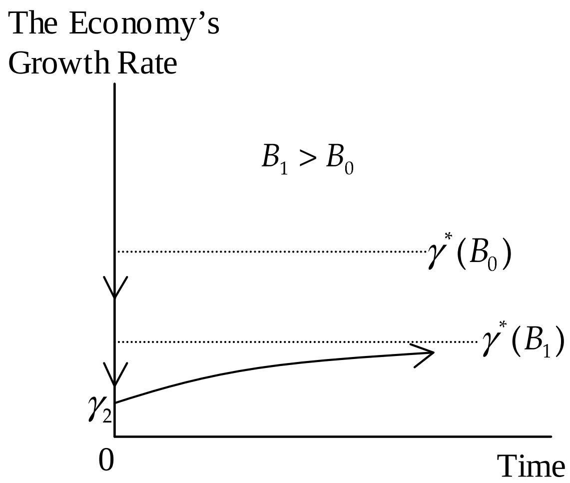

Figure 3.2: Agricultural Productivity Increase and Growth Dynamics

3.4 Quantitative Analysis in the Context of India

As we have already discussed in section 3.1, in an economy like India where around 60% of the population is still dependent on agriculture even after sixty years of heavy industrialization-based development strategy and institutional as well as technical reforms in agriculture, investigating the quantitative aspect of the model based on the Indian economy is of potential interest.

In this section we present a quantitative analysis of the model. We investigate the impact on growth rate and the social welfare function of changes in agricultural productivity and the policy instruments, given other parameter values and specific functional forms of the production functions in the two sectors. Finally, we propose a comparison of optimal choice of policy instruments by the Government with two different objectives of growth-maximization and welfare-maximization.

3.4.1 Functional Forms

Let the production function in the agricultural sector be Cobb-Douglas:

$$F_t = B\mu G_t T^{1-\beta}(1-n_t)^{\beta}. \tag{3.24}$$

Because the endowment of land along with agricultural productivity level in an economy determines the relative size of agriculture and manufacturing in terms of employment and thereby affects the impacts of productivity surge or shifts in policy regime quantitatively, the total land endowment T is not normalized to one in our numerical exercise.

Our analysis is in the context of a small open economy typically characterizing developing economies which are land-based agricultural economies but not necessarily having highly productive agricultural sector. The value of the land endowment plays a role in generating an economic structure for the analysis that is consistent with the characteristics of developing countries.

The technology in the manufacturing sector is also Cobb-Douglas:

$$M_t = K_t^{1-\alpha}[(1-\mu)G_t n_t]^{\alpha}. \tag{3.25}$$

We assume that share of labor in agriculture is higher than that in manufacturing, i.e., $\beta > \alpha$.

Labor mobility condition and budget function of the Government are:

$$\alpha(1-\mu)^{\alpha}k_t^{1-\alpha}n_t^{\alpha-1} = \beta B\mu T^{1-\beta}(1-n_t)^{\beta-1} \tag{3.26}$$

$$\tau[k_t^{1-\alpha}[(1-\mu)n_t]^{\alpha} + B\mu T^{1-\beta}(1-n_t)^{\beta}] = 1. \tag{3.27}$$

These two equations solve for n^* and k^*. The long run growth rate is:

$$\gamma^* = \rho\left[(1-\tau)(1-\alpha)\left(\frac{(1-\mu)n^*}{k^*}\right)^{\alpha} + 1\right], \tag{3.28}$$

which follows from (3.4) and (3.6). Social welfare function is the discounted sum of utility, which is $W = \sum_{t=0}^{\infty} V_t$, where $V_t = \ln \tilde{E}_0 + t\ln\gamma^* + \text{Constant}$, making use of (3.19). Substituting (3.21) in W, social welfare function becomes

$$\begin{aligned} W = \frac{1}{1-\rho}\ln\left[\frac{1-\tau}{\tau} - (\gamma^*-1)k^*\right] \\ +\frac{1}{1-\rho}\ln\left[\frac{K_0}{k^*} - \frac{\tau c_{min}^F}{1-\tau}\right] + \frac{\rho}{(1-\rho)^2}\ln\gamma^* \end{aligned} \tag{3.29}$$

3.4.2 Choice of Parameter Values

Among the model parameters, a subset of them is directly taken from the literature, while the rest are chosen to match a few characteristics of Indian Data. For the reasons discussed in section 3.1, we have chosen India as the benchmark case. However we also vary some of the parameters from the benchmark case to analyze the behavior of economies which are otherwise similar to Indian economy, but have a larger manufacturing sector, in order to have a complete understanding of the model.

The estimates of labor shares in agriculture and manufacturing are taken from Martin and Mitra (2001). Based on the World Bank data on fifty developed and developing countries, their estimate of labor share in agriculture (β) is 0.64 while that for manufacturing (α) is 0.31.

To choose a value for the minimum consumption of food, we follow the World Bank definition of poverty line for under developed countries, which is US $ 1 per day per person or US $ 365 per year (World Bank Development Indicators, 2007). Since in our model, the price of manufacturing relative to agriculture is normalized to one, the value of c^F_{min} in our quantitative analysis is set at 365.

The benchmark value of tax rate τ is chosen to be the average income tax rate in India. The value is 20% according to the India Finance and Industrial Guide, 2007-2008.

The benchmark value of the share of public input in agriculture μ is chosen to be the average value of that variable for Asia (reported in the World Bank seminar on pubic Finance Management, 2007) calculated as follows: the average share of agriculture in GDP in Asia is 34%. Again, the ratio of the share of agricultural spending in total government spending (μ) and the share of agricultural value added in GDP has been reported to be 0.475. Thus the value of μ is calculated to be 0.475 times 0.34, which is 0.1615.

The benchmark value of agricultural productivity level B is normalized to one. As mentioned in the theoretical framework of this model, the productivity level of manufacturing is normalized to one as well. We then examine the impact of percentage change in the agricultural productivity level on labor allocation across two sectors, long run growth and welfare.

We choose the value of land endowment (T), so that given other parameter values, the solution for the share of labor force allocated in agriculture $(1 - n^*)$ matches with the average share of agriculture in total employment in India for 1950-2004 calculated as follows: the value of agricultural employment share has been reported to be 60% in 1999-2000, which is 16% lower than its 1950-51 value (Cahndrashekhar and Ghosh, 2006). Thus interpolated value of $1-n^*$ turns out to be 71%. Again data on employment share in agriculture in India for 1993-2004 are taken from Unni, 2007. The average of these reported values turns out to be 63.5%. Given benchmark value of agricultural productivity, the value of land endowment that generates this employment share of agriculture is 3536.42.

The value of ρ is chosen so that given other parameter values at their benchmark level, net growth rate derived by subtracting 1 from the expression in (3.28) matches with average growth rate of India for 1951-2003, which is 2.64% (Penn World Table 2006). The value of ρ turns out to be 0.8504.

Finally, we need to determine the initial capital stock K_0. We have the expression for initial expenditure less minimum food requirement $\tilde{E}_0$ in (3.21) which is a function of K_0 as well as other parameters. From Penn World Table, 2006, we have average real income of India in terms of $ converted for purchasing power parity for 1950-2003. Subtracting 365 from this gives us a value for $\tilde{E}_0$. Equating this value with the expression of $\tilde{E}_0$, solves for the value of K_0 as $ 2703.5301.

Table 3.1 summarizes parameter values which are common for all numerical examples and benchmark values of B and T.

Table 3.1: Parameter Values Chosen for all Numerical Exercises

β	α	c^F_{min} ($)	τ	μ	B	T	ρ	K_0 ($)
0.64	0.31	365	0.2	0.1615	1	3536.42	0.8504	2703.5301

We explore comparative statics aspects of employment, growth and welfare under different values of B and T which give rise to different economic structures compared to the benchmark case. For instance, given the benchmark value of T, we choose two lower values of agricultural productivity such that the economy, which is otherwise similar to the benchmark case, has a very small agricultural sector in terms of employment. Similarly, we also choose two lower values of land-endowment given agricultural productivity same as the benchmark case so that it allocates a tiny fraction of labor force in agriculture.

The choice of these values are based on the behavior of welfare function with respect to tax rate and share of public input in agriculture. In the next section, intuitions behind different patterns of welfare function under different economic structures are discussed at a length; in this section, we briefly relate the shape of welfare function with different values of B and T for the ease of reference.

Given the benchmark value of land endowment specified in the Table 1, social welfare function has an inverted-U relationship with tax rate, τ, for B falling in the range (0.15, 0.35). It is increasing in tax rate for $B > 0.35$ and a decreasing function of tax for $B < 0.15$. Again, with respect to the share of public input in agriculture, μ, social welfare initially falls and then increases when B falls in the range (0.28, 0.45). It increases with μ for $B > 0.45$, while decreases when $B < 0.28$.

Similarly, given the benchmark value of agricultural productivity, social welfare function is inverted-U shaped with respect to τ for land endowment falling in the range (17, 200). Beyond the upper bound of this range, it is increasing, while it is decreasing for $T < 17$. Again, when land endowment lies in the range (86, 230), social welfare initially falls and then increases with respect to μ. Beyond the upper bound of this range it rises while it falls with μ for an endowment of land $T < 86$.

Our choices of different values for B and T are aimed at exploring optimal policies for various types of economies where social welfare behaves differently with respect to τ and μ depending on values of B and T. For our benchmark value of $B = 1$ and $T = 3536.42$, social welfare is increasing in both τ and μ. In order to explore a situation when economy is industry-based, we choose $B = 0.3$ such that welfare has an inverted-U relation with τ, while it is a U-shaped with respect to μ. Another industrial economy is depicted through the value of $B = 0.25$ where welfare is inverted-U shaped with τ but decreasing in μ.[10]

In order to compare optimal policy choices between the benchmark case that replicates Indian economy and other land-scarce economy, we choose $T = 200$ and $T = 80$. These two values of land endowment generates economies which otherwise having similar characteristics like the benchmark case, employ most of its labor force in manufacturing. For $T = 200$ welfare has an inverted-U relation with τ, while it is U-shaped with respect to μ. At $T = 80$, welfare is inverted-U shaped with respect to τ, but a decreasing function of μ.[11]

Finally we take the lowest value of the land-endowments described above, i.e. $T = 80$ and a sufficiently high value for agricultural productivity ($B = 4$), such that the economy allocates the same fraction of labor force in agriculture as in the benchmark case. We, then examine model behavior under these different parameter choices.
Table 3.2 summarizes different combinations of agricultural productivity level and land endowment that gives rise to economies with different relative sizes of two sectors and the behavior of the social welfare function with respect to tax rate and share of public input in agriculture in that specific economic structure.

[10]Given reference values of τ and μ and T specified in Table 1, $B = 0.15$ is the minimum value of agricultural productivity level such that both agriculture and manufacturing coexist. Hence in our numerical exercise we do not consider a situation of $B < 0.15$ such that social welfare is decreasing in both τ and μ.

[11]Given reference values of τ and μ and B specified in Table 1, at the lower bound of the range of land endowment i.e. $T = 17$, all of economy's labor force is employed in manufacturing. Hence in our numerical exercise we do not consider a situation of $T < 17$ such that social welfare is decreasing in both τ and μ.

Table 3.2: Combinations of B and T

B	T	Structure of the economy	Behavior of W
1	3536.42	Benchmark Case: Large Agriculture	$\uparrow$ w.r.t. τ & μ
0.25	3536.42	Large Manufacturing	Invrt-U with τ, $\downarrow$ with μ
0.3	3536.42	Large Manufacturing	Invrt-U with τ, U with μ
1	80	Large Manufacturing	Invrt-U with τ, $\downarrow$ with μ
1	200	Large Manufacturing	Invrt-U with τ, U with μ
4	80	Large Agriculture	$\uparrow$ w.r.t. τ & μ

3.4.3 Comparative Statics Results

In this section we discuss how the labor allocation across two sectors n^*, ratio of capital to public input k^*, long run growth rate γ^* and social welfare W behave with changes in exogenous productivity surge in agriculture, share of public input in agriculture and tax rate, for all combinations of B and T specified in Table 3.2.

Taking each of the values of B reported in Table 3.2 as the initial level of agricultural TFP, we examine the impact of percentage increase in the productivity level on labor allocation, ratio of capital to public input, growth rate and social welfare. In the numerical exercise, B is increased by 5% up to 100%, that is up to the double of the initial value, if that is permissible given the parameter values and the reference levels of tax rate and share of public input in agriculture. If initial value of B is high, or land endowment is large, then upper bound of the permissible range falls below the double of the initial B. We restrict the increase in B up to 100% of its initial value because it is empirically observed that the total factor productivity in agriculture in all India has increased by 50% during 1970-1994 (Bhattarai and Narayanamurthy, 2003).

The permissible range of share of public input in agriculture, μ is defined as the range where both sectors exist and the value of long run growth rate exceeds one and is determined endogenously given other parameter values and the reference value of tax rate, τ.

The permissible range of tax rate, τ is defined as the range where both sectors exist and the value of long run growth rate exceeds one and is determined endogenously given other parameter values and the reference value of μ.

Our numerical exercise confirms the predictions of the model summarized in Proposition 3.1. We find that *an increase in the productivity parameter in agriculture B reduces labor allocation in manufacturing and the ratio of capital to public input irrespective of structure of the economy in terms of agricultural productivity and land endowment.* The behavior of n^* and k^* with respect to changes in B are shown in Figures 3.3 and 3.4.

An increase in μ reduces labor allocation in manufacturing. Since in our numerical analysis production function are assumed Cobb-Douglas, which implies that the factor elasticity of substitution in manufacturing is equal to one, the negative relation between n^* and μ holds as predicted in the Proposition 3.1(b). The above-mentioned proposition predicts that in general, the effect of change in μ on k^* is ambiguous. Numerically, we find that *the ratio of capital to public input, k^* falls with μ if the economy has a highly productive agricultural sector or it is a land-based economy. If the economy is not agriculture-based, k^* has an inverted-U relation with μ.*

The intuition is as follows. An increase in μ reduces productive public input in M, while that in sector F rises. Labor also moves from industry to agriculture. If agricultural TFP is very high, or the economy has a large land base so that the labor productivity is high, output enhancing effect in F outweighs the negative impact on the sector M output. Hence total income increases, leading to rise in the provision of public input. Supply of capital increases in response to it but at a lower proportion due to fall in labor in M. Hence k^* falls.

If agricultural productivity or land endowment are low, the incremental effect of higher μ in F is outweighed by the negative impact in M. Thus total income falls and that reduces provision of public input in the economy. Although productivity of private input falls, the rate at which supply of private capital falls is lower than fall in public input in M. Hence k^* increases. Eventually, as more and more share of public input is allocated to F so that this sector becomes more productive endogenously, marginal income enhancing effect in F dominates and ultimately k^* falls. As a result, k^* depicts an inverted-U relation with μ, when economy is not an agriculture-based one.

The relationship of n^* and k^* with respect to μ is shown in Figures 3.5 and 3.6. In Figure 3.6, the first graph, that is the benchmark case, is a land based economy, while the last one is four times productive than the benchmark economy. In both cases k^* falls with μ. The other graphs in the figure have either low agricultural productivity or low land-base. For these economies k^* shows inverted-U relationship with μ.

An increase in tax rate reduces the labor allocation in manufacturing and the ratio of capital to public input as predicted in the Proposition 3.1(c). These are depicted in Figures 3.7 and 3.8.

Given the chosen parameter values, the model replicates the pattern of the long run growth rate's behavior in response to agricultural productivity, share of public input in agriculture and tax rate, summarized in the Proposition 3.3. *Long run growth rate falls as the agricultural productivity level and the share of public input in agriculture increase. Growth rate shows an inverted-U relation with respect to tax rate.* These results are depicted in the Figures 3.9, 3.10 and 3.11.

Recall, that the model predicts in general an ambiguous welfare effect of agricultural productivity, share of public input in this sector and tax rate. These results are summarized in the Proposition 3.4. The numerical analysis shows that the welfare effects with respect to the above-stated parametric changes crucially depends on the agricultural productivity level and/or the land endowment of the economy. Next, we discuss these results at length.

Welfare Effect of Agricultural Productivity

Given our choice of the parameter values, an increase in the productivity parameter in agriculture B increases social welfare irrespective of the value of agricultural productivity and land endowment in the economy. Increase in agricultural productivity tends to raise provision of public input that has an income enhancing effect. This positive level effect outweighs negative growth effect for all initial level of agricultural productivity and land endowment, given the other parameter values. Thus social welfare increases with B.

The relationship of social welfare with respect to B is presented in Figure 3.12. Since social welfare is always increasing in B, therefore only four cases are explored. These four cases are: the benchmark economy, economies with lowest level of agricultural productivity, the lowest value of land endowment and the four times productive agriculture and lower land base compared to the benchmark case.

Welfare Effect of Public Input Share in Agriculture

The effect of a change in the share of public input in agriculture on the social welfare is summarized as follows. *If land-base is large or agricultural productivity is high, social welfare increases with μ. If land endowment is small, or agricultural productivity is low, social welfare falls with μ. In between the above two cases, there exists a range of productivity level and a range of land base such that social welfare initially falls with μ and then increases with further rise in it.*

From the discussion above on the impact on k^* of an increase in μ, , we know that if the economy is endowed with a highly productive agriculture or large amount of land, the marginal output enhancing effect of an increase in μ on F outweighs the negative impact on the sector M output. Hence total income increases. The positive level effect outweighs negative growth effect and social welfare increases with μ.

On the other hand if agricultural productivity and land endowment are very low, level effect will be negative, which coupled with negative growth effect reduces social welfare. In between these two extreme cases, for some ranges of productivity in agriculture and land base, initially level effect is negative and social welfare falls with μ. However as agricultural productivity endogenously develops through higher and higher share of public input allocated into F, level effect becomes positive and starts dominating the growth effect; social welfare starts increasing with μ.

Figure 3.13 shows how social welfare behaves with changes in μ for various combinations of agricultural productivity and land endowment specified in Table 3.2.

Welfare Effect of Tax Rate

In an economy with a highly productive agricultural sector or a large land-base, social welfare always increases with tax rate. If agricultural productivity or land-endowment are not high, social welfare has an inverted-U relation with tax rate.

An increase in tax rate raises provision of public input that enhances income in both sectors. However it reduces the net income having a negative impact on the initial expenditure. The net level effect is thus ambiguous. When tax rate is small, the income enhancing effect outweighs the effect of contractionary fiscal policy and the level effect is positive. For low level of tax rate, growth effect is also positive. Thus initially social welfare increases.

Again, according to our specification of production functions, output of sector M is concave with respect to public input, given labor and capital, while it is of constant coefficient type, given labor with respect to public input in sector F. With a highly productive agricultural sector or with large endowment of land, marginal income enhancing effect in F is large and welfare increases at an increasing rate. Thus within the permissible range of tax rate (the upper bound of which is just sufficient to allocate a positive fraction of population in industry), increase in tax rate is always welfare enhancing.

When economy's agricultural sector is not highly productive or it does not have a large land base, marginal income enhancing effect is moderate and welfare increases initially at a decreasing rate. Beyond a certain value of tax rate, contractionary effect becomes dominant and social welfare falls.

Figure 3.14 depicts the relationship of social welfare with tax rate for various structure of the economy.

For instance, our benchmark economy is a land-based one (see Table 3.2). Rise in tax rate is always welfare enhancing for the economy. Similarly, the last graph of Figure 3.14 shows the welfare effect of taxes for an economy that has a smaller land endowment but four times productive agricultural sector compared to the benchmark case. This also has a welfare effect of tax rate similar to the benchmark economy. The other four graphs in Figure 3.14 show how welfare behaves with tax rate for economies which are otherwise similar to the benchmark economy have either less productive agricultural sector or low land base compared to the latter.

3.4.4 Optimal Policy

The main objective of our numerical experiment is to determine the optimal policy chosen by the government in the pursuit of growth and welfare maximization. Technically, the optimal policy implies joint determination of the tax rate and the share of public input in agriculture such that either long run growth or welfare is maximized. The complicated two-sector model structure does not yield analytical solutions. Hence the numerical simulation method is used.

Substituting equation (3.27) in equation (3.26) yields a non-linear equation in n.

Given the values of parameters specified in the Table 3.1, this equation solves for $n = n^*$. The growth/welfare maximizing values of τ and μ are determined in the following two steps. In the first step, the parameters in Table 3.1, except for tax rate are fixed at the reference level specified in the Table 3.1 and Table 3.2 (B and T are set to the values given in this table to explore economies other than the benchmark case). The value of τ is changed within its permissible range and for each of these tax rates, n^* is solved and the corresponding values of growth and welfare are calculated. In the second step, fixing the value of τ corresponding to the maximum level of growth/welfare, μ is varied and the above-stated procedure is followed. These two steps are repeated until the value of μ set in the first step coincides with the growth/welfare maximizing value of μ in the second stage and similarly the value of τ set in the second stage coincides with the growth/welfare maximizing value of τ in the first stage.

The analysis begins with the benchmark economy that replicates India which is a land-based economy that employs over 60% of its population in agriculture. The growth-maximizing and welfare-maximizing tax rates and public input allocation share across sectors are numerically solved within the permissible ranges of these two variables, given other parameter values. Then the effects on growth rate and welfare for this optimal policy instruments in comparison to the current policy regime are quantified. Similar experiments are also conducted for the other types of economies referred to in Table 3.2. The results are reported in Table 3.3 and 3.4.

Table 3.3 summarizes numerical solutions for optimal policies and their impacts on growth and welfare when the government's objective is growth-oriented. The fifth row of the table gives percentage change in growth rate when τ and μ are adjusted optimally from their reference values specified in the second column. The last row gives a measure of changes in social welfare due to changes in policy regimes.

In macroeconomic literature, welfare gain or loss is measured as the percentage

Table 3.3: Optimal Policy: Growth Maximization

	Reference	Optimal Policy					
		$B = 1$ (Benchmark)	$B = 0.25$	$B = 0.3$	$T = 80$	$T = 200$	$B = 4$ And $T = 80$
τ	0.2	0.28	0.3	0.3	0.3	0.3	0.28
μ	0.1615	0.0415	0.1115	0.0915	0.1115	0.0815	0.0415
$\%\Delta\gamma^*$		+ 5.25	+ 1.6	+ 1.92	+ 1.60	+ 2.2	+ 5.4
$\%\Delta W$		- 26.03	+ 18.27	+ 19.81	+ 18.30	+ 19.67	- 28.44

change in steady-state (or balanced growth) consumption in the current policy regime that equates lifetime utility with that in the new policy regime (see Einarsson and Marquis, 2001). Since in this model, the economy is asymptotically growing at a constant rate, there is no steady-state value of consumption. However the expenditure on two goods and public input are growing at the same rate in the long run as that of total expenditure less minimum food consumption and public input. Hence $\tilde{E}/G_t$ in the long run is constant. Thus we define welfare impact as the percentage change in the ratio of $\tilde{E}$ and public input G in the current policy regime that equates lifetime utility with that in the optimal policy regime.[12]

Similarly Table 3.4 summarizes optimal policy choices of the government when the objective is to maximize social welfare.

Growth-Maximizing Policy

The optimal growth maximizing policy for all various types of economies explored is the

[12]Note, that the relative price is exogenously given in the world market.

Table 3.4: Optimal Policy: Welfare Maximization

	Reference	Optimal Policy					
		$B = 1$ (Benchmark)	$B = 0.25$	$B = 0.3$	$T = 80$	$T = 200$	$B = 4$ And $T = 80$
τ	0.2	0.23	0.32	0.38	0.34	0.32	0.2
μ	0.1615	0.2215	0.1015	0.3915	0.4415	0.4015	0.2515
$\%\Delta\gamma^*$		- 7.6	+ 1.7	- 5.6	- 5.89	- 5.3	- 2
$\%\Delta W$		+1003.32	+19.50	+264.14	+93.10	+321.87	+147.69

jointly determined share of public input and tax rate such that agriculture is just able to produce a positive output and the growth rate is maximized. The economy will not allocate all its public resources in manufacturing and specialize in it, given that land is an input specific to the agricultural sector.

Table 3.3 (the first column) shows that in an economy like India with large natural resource base, where more than 60% of the population is engaged in agriculture, this requires a reduction in μ by 12% and an increase in tax rate by 8% from their current value. This leads to an increase in growth rate by 5.25%. However such a policy for this economy leads to a welfare loss of 26.03%.

It is also evident from the last column of Table 3.3 that quantitatively the same optimal growth maximizing policies are applicable for an economy that does not have a large land base but which has a four times productive agricultural sector than the benchmark case and hence more than 60% of its labor force is employed in agriculture. The optimal policy leads to a rise in growth rate by 5.4% and the associated welfare loss is 28.44%.

For the economies with low agricultural productivity or low land base, growth-maximizing policy requires 5-8% reduction in μ and 10% increase in τ from their current level. The resulting increase in growth rate lies between 1.6% and 2.2 % while there is a welfare gain of 18.27-19.67%.

Welfare-maximizing Policy

Optimal policy that maximizes social welfare varies with the structure of the economies. These are summarized as follows:

(a) For an economy with large land base or highly productive agricultural sector, optimal policy is the jointly determined τ and μ which are just sufficient for the manufacturing sector to exist. The entire public resources will not be allocated in agriculture given that capital is an input specific to industry.

For the benchmark case that represents the Indian economy, the optimal policy, shown by the first column of table 3.4 requires a rise in tax rate by 3% and an increase in μ by 6% from their current value. Although this leads to a fall in the growth rate by 7.6% but there is a sharp welfare gain of 1003.32%.

Similarly the last column of Table 3.4 shows that the economy with a very high agricultural productivity, although does not require any change in the tax rate but a rise in μ by 9% is required to maximize welfare. The associated growth effect is -2% while welfare increases by 147.69%.

This optimal policy rule is also applicable for the economy with $T = 200$ among the various cases explored. In this economy the optimally chosen tax rate is 12% higher than its current value, while optimal μ is 24% higher than the current level. Such a policy leads to a sharp fall in growth rate by 5.3% and a large welfare gain of 321.87%.

(b) For an economy with low agricultural productivity or low land base, optimal policy is the jointly determined τ and μ such that the gross growth rate $= \gamma_{Min}$ where γ_{Min} is

the lowest value of $\gamma^* > 1$.

In our numerical analysis, examples of such economies are depicted by $B = 0.3$ and $T = 80$. For these economies, choice of optimal policies requires a tax rate increase by 18% and 14% respectively and an increase in μ by 23% and 28% respectively. Growth rate falls by 5.6% and 5.9% while the welfare gain are 264.14% and 93.10% respectively.

(c) When agricultural productivity is very low, optimal policy is the jointly determined τ *and* μ *such that welfare is maximized and agriculture produces minimum positive amount of output.*

This is depicted by the case of $B = 0.25$. The optimal policy requires a tax rate hike by 12% and a reduction of public input in agriculture by 6%. The associated growth effect is 1.7% and the welfare gain is 19.5%.

It is evident from the numerical simulation results that growth-maximizing policies across all types of economies require a choice of tax rate and share of manufacturing in agriculture such that this sector is just able to produce positive amount of output and the long run growth rate of the economy is maximized.

However in determining the welfare-maximizing policies, the government has to take into account the relative size of the two sectors at the prevailing policy regime. For instance, in a natural resource based economy like India, growth-maximizing and welfare-maximizing policies give rise to completely opposite impacts on the economy. Moreover, the welfare gain under the welfare-maximizing regime is huge compared to the welfare loss under a growth-maximizing regime.

In contrast to that, in an economy with a very low agricultural productivity, both type of policies work in the same direction in terms of their impact on the welfare of the economy relative to the current regime.

3.4.5 Productivity Surge in Agriculture

In this section, we quantify the growth and welfare effects of a productivity surge in agriculture. The results are reported in Table 3.5.

Table 3.5: Productivity Surge in Agriculture

	Productivity Surge in Agriculture			
	$B = 1$	$B = 0.25$	$T = 80$	$B = 4\&T = 80$
$\%\Delta B$	25	100	100	25
$\%\Delta\gamma^*$	-1	-0.9	- 0.9	-1
$\%\Delta W$	+ 64.27	+ 8.42	+ 8.89	71.53

We have explored the percentage increase in B that gives rise to 1% (or close to 1%) drop in the growth rate. For the benchmark case and the economy with four times productive agriculture and lower land base compared to the former, a 25% increase in B leads to 1% fall in the growth rate. welfare gains are 64.27% and 71.53% respectively in these two cases. For the other two cases a doubling of the initial productivity level leads to only 0.9% drop in the growth rate. The associated welfare gains are comparatively low, 8.42% and 8.89%.

3.5 Concluding Remarks

This chapter has developed a two-sector endogenous growth model, following Barro (1990), in which the provision of a government provided input is the source of endogenous growth. Our model predicts a stronger negative growth effect of productivity gain in agriculture in that (a) the productivity increase may be totally exogenous or policy-induced and (b) the negative effect may hold irrespective of the pattern of comparative advantage. The emphasis on agriculture does not however necessarily mean a detrimental growth-development policy, because it may have a positive level-effect.

Moreover, one of the major contribution of our work is to capture the sector-specific nature of public input that provides the government another policy instrument apart from tax rate. This instrument is namely, the allocation function of public input across sectors.

However, the complicated structure of the model implied by the two-sector endogenous growth framework does not yield analytical solutions for the growth and welfare-maximizing values of the policy instruments. Hence, numerical simulation method is used. The model predicts that the choice of values of these public instruments will crucially depend on (unlike Barro) government's objective (whether it is growth oriented or it aims to maximize welfare) and the relative employment share in the two sectors.

In our numerical analysis, the parameters are chosen to mimic a few characteristics of the Indian economy, which resembles with the small open economy outlined by the model. The simulation exercise aims to determine the growth and welfare-maximizing values of tax rate and the share of public input in agriculture. It also attempts to capture the growth effect and the welfare gain or loss associated with shifts in the values of the policy instruments from their reference level to the optimal level.

Precisely, the growth effect captures the percentage change in the growth rate associated with the changes in tax rate and public spending share in agriculture from their respective reference levels to the growth-maximizing values. The welfare gain or loss is measured by the required percentage change in the ratio of total expenditure on two goods to public spending when tax rate and public input share in agriculture are at their reference level, in order to achieve the same level of welfare if those policy instruments would have been at their optimal level.

We find that in a small open economy like India, with large natural resource base, and 60% of the population engaged in agriculture, where on average the income is taxed at a rate of 20% and the average share of agricultural spending in total government spending is 16%, the growth-maximizing policy requires a rise in the tax rate by 8% and a reduction in public input share in agriculture by 12%. This growth-maximizing share of public spending in agriculture is just sufficient to produce a positive level of agricultural output. The economy will not completely specialize in manufacturing because of the existence of agricultural sector-specific input, land. Adoption of growth maximizing policy leads to an increase in growth rate by 5.25% from the average growth rate of 2.64% during 1951-2003. However such a policy for this economy leads to a welfare loss of 26.03%.

To achieve the maximum level of welfare in an economy with the characteristics stated above, a rise in tax rate by 3% and an increase in the share of public spending in agriculture by 6% are required. Although this leads to a fall in the growth rate by 7.6% but there is a sharp welfare gain of 1003.32%. The optimal values of tax rate and public input share in agriculture are such that manufacturing is just able to produce a positive level of output. Again, in this case the economy will not specialize in agriculture, due to the existence of capital, which is an input specific to industry.

The impacts of a productivity surge in agriculture on the growth and welfare of the economy are also explored. We find that a 25% rise in agricultural productivity causes 1% drop in the growth rate and the associated welfare gain is 64.27%.

Finally the growth and welfare effects of policy regime shifts and agricultural productivity surge are explored for the model economies, which are otherwise similar to India, but differ in terms of relative size of agriculture and industry. This completes our understanding of the behavior of the model.

These findings provide us useful insights regarding alternative policy measures and their effects on a small open economy having similar characteristics like India. Our analysis indicates that in such an economy, to achieve the highest possible level of welfare, a policy focussing on the agricultural development is essential. However, such a policy may not be conducive to the long run growth rate of the economy. If the goal is to maximize the growth rate, the economy should allocate its public resources in a way such that industry has the highest employment share.

However, it should be noted that the conflict between growth and welfare effects of agriculture-oriented policies may not exist under certain situations. For instance, in many developing countries such as India, agriculture/rural sector is characterized by either unemployment or under employment. If we take into account these factors, the effect of a productivity surge in agriculture on the growth rate may well be positive. It may also have favorable distributional implications. However this paper makes the point that, absent these considerations, a growth strategy focussing on agriculture may not succeed.

Apart from the central policy question, our model also provides new insights into the dynamics of a macro economy in the presence of non-homothetic preferences. The presence of a minimum consumption level of a good is a factor that gives rise to transitional dynamics. Furthermore, independent of the initial condition (locally), the growth rate increases monotonically over time, approaching a long run value. It has an important implication that any shock to the economy that lowers the long-run growth rate will have a stronger negative growth effect in the short run.

Appendices

Appendix 1

This concerns Proposition 3.2. We show that if elasticity of substitution in both sectors are greater or equal to one and the share of labor in agriculture exceeds that in manufacturing, the return to capital declines unambiguously with an increase in the parameters B and μ. Let θ_{nm} and θ_{nf} denote respectively the share of labor in manufacturing and agriculture, where $\theta_{nf} > \theta_{nm}$. Also let elasticity of substitution in manufacturing and agriculture be σ_m and σ_f respectively; and $\sigma_m, \sigma_f \geq 1$.[13]

Now in the manufacturing sector, the unit cost function is of the form:

$$c_m\left(r, \quad \frac{w_m}{(1-\mu)G}\right), \quad \text{where}$$
$$\frac{\partial c_m}{\partial r} = \frac{K}{M}; \quad \frac{\partial c_m}{\partial \frac{w_m}{(1-\mu)G}} = \frac{(1-\mu)Gn}{M}, \tag{A1}$$

The zero profit condition in the manufacturing sector gives,

$$c_m\left(r, \quad \frac{w_m}{(1-\mu)G}\right) = 1$$

Totally differentiating this, using (A1)and rearranging,

$$(1-\theta_{nm})\hat{r} + \theta_{nm}\left(\hat{w}_m + \frac{\mu}{1-\mu}\hat{\mu} - \hat{G}\right) = 0,$$

where we denote a proportional change by a "hat". This can be rewritten as

$$(1-\theta_{nm})\hat{r} + \theta_{nm}\hat{w}_m = \theta_{nm}\left(\hat{G} - \frac{\mu}{1-\mu}\hat{\mu}\right) \tag{A2}$$

following the definition of the elasticity of substitution, we have,

$$\hat{K} - \widehat{(1-\mu)Gn} = \sigma_m\left[\widehat{\frac{w_m}{(1-\mu)G}} - \hat{r}\right]$$
$$\Rightarrow \sigma_m\hat{r} - \sigma_m\hat{w}_m = \hat{n} - \hat{k} - (1-\sigma_m)\frac{\mu}{1-\mu}\hat{\mu} - \sigma_m\hat{G} \tag{A3}$$

[13] By continuity if elasticities are less than but close to one, then also the results hold

Simultaneously solving (A2) and (A3) for $\hat{w}_m$,

$$\hat{w}_m = \hat{G} + \frac{(1-\theta_{nm})(\hat{k}-\hat{n}) - [\sigma m - (1-\theta_{nm})]\frac{\mu}{1-\mu}\hat{\mu}}{\sigma_m} \tag{A4}$$

In the agricultural sector, the unit cost function is of the form: $c_f(R, w_f)/[B\mu G]$. We have the zero-profit condition, $c_f(R, w_f) = B\mu G$. Totally differentiating it, using Shephard's lemma and rearranging,

$$(1-\theta_{nf})\hat{R} + \theta_{nf}\hat{w}_f = \hat{B} + \hat{\mu} + \hat{G} \tag{A5}$$

By the definition of σ_F,

$$\hat{T} + \frac{n}{1-n}\hat{n} = \sigma_f\left(\hat{w}_f - \hat{R}\right).$$

But $\hat{T} = 0$, as land is fixed. Thus

$$\sigma_f\hat{w}_f - \sigma_f\hat{R} = \frac{n}{1-n}\hat{n}. \tag{A6}$$

Simultaneously solving (A5) and (A6) for $\hat{w}_f$, we have,

$$\hat{w}_f = \hat{G} + \frac{\sigma_f(\hat{B}+\hat{\mu}) + (1-\theta_{nf})\frac{n}{1-n}\hat{n}}{\sigma_f} \tag{A7}$$

The labor mobility equation (3.2) gives $\hat{w}_m = \hat{w}_f$. Thus equating (A4) with (A7) and rearranging, we have

$$(1-\theta_{nm})\hat{k} - \left[\frac{1-\theta_{nm}}{\sigma_m} + \frac{n(1-\theta_{nf})}{(1-n)\sigma_f}\right]\hat{n} = \hat{B} + \left[\frac{1}{1-\mu} - \frac{\mu(1-\theta_{nm})}{(1-\mu)\sigma_m}\right]\hat{\mu} \tag{A8}$$

Now turn to the government's budget equation (3.3). We have

$$\hat{H}_m = (1-\theta_{nm})\hat{k} + \theta_{nm}\left(\hat{n} - \frac{\mu}{1-\mu}\hat{\mu}\right) \tag{A9}$$

$$\widehat{B\mu H_f} = \hat{B} + \hat{\mu} - \theta_{nf}\frac{n}{1-n}\hat{n} \tag{A10}$$

Totally differentiating (3.3), and using (A9) and (A10),

$$\eta\left[(1-\theta_{nm})\hat{k} + \theta_{nm}\left(\hat{n} - \frac{\mu}{1-\mu}\hat{\mu}\right)\right] + (1-\eta)\left[\hat{B} + \hat{\mu} - \theta_{nf}\frac{n}{1-n}\hat{n}\right] = 0,$$

$$\text{where} \quad \eta = \frac{\bar{p}M}{\bar{p}M + F} = \frac{\theta_{nf}n}{\theta_{nf}n + \theta_{nm}(1-n)}$$

$$\Rightarrow \hat{k} = -\frac{\theta_{nm}(1-n)}{n\theta_{nf}(1-\theta_{nm})}\hat{B} + \frac{\theta_{nm}}{n\theta_{nf}(1-\theta_{nm})}\left[\frac{\mu}{1-\mu}\theta_{nf}n - (1-n)\right]\hat{\mu} \tag{A11}$$

This is the solution expression of the change in k. Next, we substitute (A11) into (A8) and solve $\hat{n}$. Using the two solution expressions,

$$\frac{\hat{n}-\hat{k}}{\hat{B}} = \frac{(1-n)\theta_{nm}(1-\theta_{nm})(\frac{1}{\sigma_m}-1) + n\theta_{nm}(1-\theta_{nf})(\frac{1}{\sigma_f}-1)}{n\theta_{nf}(1-\theta_{nm})[\frac{1-\theta_{nm}}{\sigma_m} + \frac{n(1-\theta_{nf})}{(1-n)\sigma_f}]}$$

$$= +\frac{n\left[\theta_{nm}(1-\theta_{nf}) - \theta_{nf}(1-\theta_{nm})\right]}{n\theta_{nf}(1-\theta_{nm})[\frac{1-\theta_{nm}}{\sigma_m} + \frac{n(1-\theta_{nf})}{(1-n)\sigma_f}]} < 0$$

$$\Rightarrow \frac{\hat{r}^*}{\hat{B}} < 0$$

$$\frac{\hat{n}-\hat{k}}{\hat{\mu}} = -\frac{Z}{\frac{1-\theta_{nm}}{\sigma_m} + \frac{n(1-\theta_{nf})}{(1-n)\sigma_f}} < 0 \text{ where,}$$

$$Z \equiv \frac{(1-n)}{n}\theta_{nm}(1-\theta_{nm})(1-\frac{1}{\sigma_m}) + \frac{\mu}{1-\mu}\theta_{nm}\theta_{nf}\left[\frac{1-\theta_{nm}}{\sigma_m} + \frac{1-\theta_{nf}}{\sigma_f}\right]$$
$$+ \frac{\theta_{nf}(1-\theta_{nm})}{1-\mu}\left\{(1-\mu\theta_{nm}) - \frac{\mu(1-\theta_{nm})}{\sigma_m}\right\} - \frac{(1-\theta_{nf})\theta_{nm}}{\sigma_m}$$

$$\Rightarrow \frac{\hat{r}^*}{\hat{\mu}} < 0.$$

Now suppose the government changes tax rate τ while B and μ remains unchanged. Hence $\hat{B} = 0$ and $\hat{\mu} = 0$.

Then (A4) and (A7) along with the labor market equilibrium condition $\hat{w}_m = \hat{w}_f$ give,

$$\left(\frac{1-\theta_{nm}}{\sigma_m}\right)\hat{k} - \left[\frac{1-\theta_{nm}}{\sigma_m} + \left(\frac{1-\theta_{nf}}{\sigma_f}\right)\frac{n}{1-n}\right]\hat{n} = 0. \tag{A12}$$

Totally differentiating (3.3) and making use of (A9) and (A10),

$$\hat{\tau} + \eta(1-\theta_{nm})\hat{k} + \left[\eta\theta_{nm} - (1-\eta)\theta_{nf}\frac{n}{1-n}\right]\hat{n} = 0. \tag{A13}$$

The two equations above solve for

$$\frac{\hat{n}}{\hat{\tau}} = -\frac{\frac{1}{\sigma_m}}{\frac{\eta}{\sigma_m} + \left[\frac{\eta(1-\theta_{nf})}{\sigma_f} - \frac{(1-\eta)\theta_{nf}}{\sigma_m}\right]\frac{n}{1-n}} \tag{A14}$$

and

$$\frac{\hat{k}}{\hat{\tau}} = -\frac{\frac{1-\theta_{nm}}{\sigma_m} + \left(\frac{1-\theta_{nf}}{\sigma_f}\right)\frac{n}{1-n}}{\frac{\eta(1-\theta_{nm})}{\sigma_m} + (1-\theta_{nm})\left[\frac{\eta(1-\theta_{nf})}{\sigma_f} - \frac{(1-\eta)\theta_{nf}}{\sigma_m}\right]\frac{n}{1-n}} \tag{A15}$$

Now, the denominator of (A14) can be rearranged as

$$\frac{\sigma_f(1-\eta)\left[\frac{\eta(1-n)}{1-\eta} - \theta_{nf}n\right] + \eta(1-\theta_{nf})\sigma_m n}{\sigma_m\sigma_f(1-n)}$$

$$= \frac{\sigma_f(1-\eta)\left[\frac{M(1-n)}{F} - \frac{w(1-n)}{F}n\right] + \eta(1-\theta_{nf})\sigma_m n}{\sigma_m\sigma_f(1-n)}$$

$$= \frac{\sigma_f(1-\eta)\left[\frac{(wn+rK)(1-n)}{F} - \frac{w(1-n)}{F}n\right] + \eta(1-\theta_{nf})\sigma_m n}{\sigma_m\sigma_f(1-n)} > 0.$$

Note, that relative price is exogenously fixed and normalized to 1.

Hence $\hat{n}/\hat{\tau} < 0$; $\hat{k}/\hat{\tau} < 0$.

From (A14) and (A15),

$$\frac{\hat{n}-\hat{k}}{\hat{\tau}} = \frac{\left(\frac{1-\theta_{nf}}{\sigma_f}\right)\frac{n}{1-n}}{\frac{\eta(1-\theta_{nm})}{\sigma_m} + (1-\theta_{nm})\left[\frac{\eta(1-\theta_{nf})}{\sigma_f} - \frac{(1-\eta)\theta_{nf}}{\sigma_m}\right]\frac{n}{1-n}} > 0. \tag{A16}$$

Differentiating the after-tax return on capital given in expression (3.4) with respect to tax rate and rearranging,

$$\frac{\hat{r}_k}{\hat{\tau}} = \rho(1-\mu)\frac{n}{r_k k}\left[-\tau + (1-\tau)\underbrace{\left(\frac{\hat{n}-\hat{k}}{\hat{\tau}}\right)}_{+}\right] \gtrless 0.$$

$\Rightarrow Lt_{\tau\to 0}\frac{\hat{r}_k}{\hat{\tau}} > 0; \quad Lt_{\tau\to 1}\frac{\hat{r}_k}{\hat{\tau}} < 0.$

Appendix 2

Lemma 1 is proven here. Define $X_t \equiv \tilde{E}_t/(G_t - u)$, where u will be appropriately chosen. We have, using (3.19),

$$\frac{X_{t+1}}{X_t} = \frac{\tilde{E}_{t+1}}{\tilde{E}_t}\frac{G_t - u}{G_{t+1} - u} = \gamma^* \frac{G_t - u}{G_{t+1} - u}. \tag{A17}$$

Now substract u from both sides of (3.18) and obtain

$$G_{t+1} - u = \left(1 + \frac{1-\tau}{k^*\tau}\right)\left[G_t - \frac{c_{min}^F + uk^*}{k^* + (1-\tau)/\tau}\right] - \frac{\tilde{E}_t}{k^*} \tag{A18}$$

Choose u such that

$$\frac{c_{min}^F + uk^*}{k^* + (1-\tau)/\tau} = u, \quad \text{i.e. } u = \frac{\tau c_{min}^F}{(1-\tau)}. \tag{A19}$$

Then (A18) is expressed as:

$$G_{t+1} - u = \left(1 + \frac{1-\tau}{k^*\tau}\right)(G_t - u) \tag{A20}$$

Substituting (A20) into (A18), we have one dynamic equation in one variable X_t, which is:

$$\frac{1}{X_{t+1}} = \frac{1 + \frac{1-\tau}{k^*\tau} - \frac{X_t}{k^*}}{X_t \gamma^*} \tag{A21}$$

In steady state, $X_{t+1} = X_t = X^*$. From (A21),

$$X^* = \frac{1-\tau}{\tau} - (\gamma^* - 1)k^*.$$

From (A21),

$$\left.\frac{dX_{t+1}}{dX_t}\right|_{X_t = X^*} > 1.$$

Since X_t has no initial value, it implies that, under perfect foresight, $X_t = X^*$, i.e.,

$$\frac{\tilde{E}_t}{G_t - u} = \frac{1-\tau}{\tau} - (\gamma^* - 1)k^*.$$

Substituting the value of u form (A19),

$$\frac{\tilde{E}_t}{G_t - \frac{\tau c_{min}^F}{1-\tau}} = \frac{1-\tau}{\tau} - (\gamma^* - 1)k^*.$$

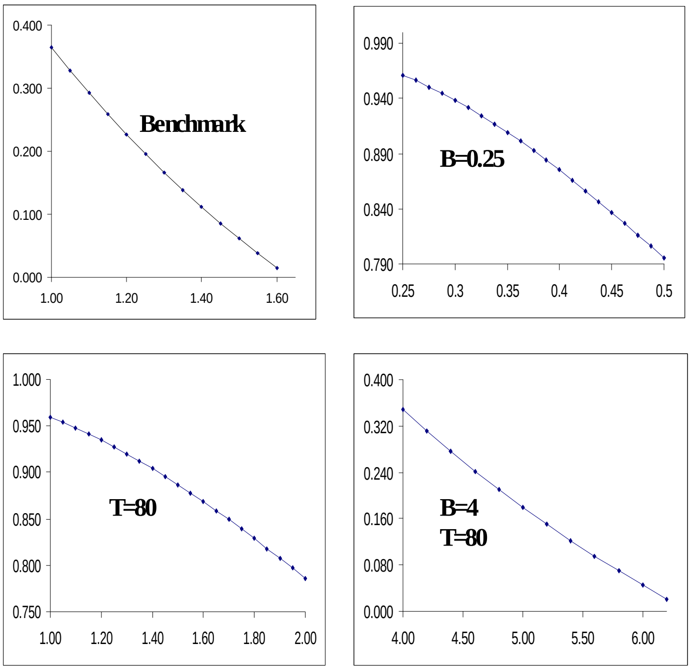

Figure 3.3: Labor Allocation in Manufacturing with respect to Agricultural Productivity

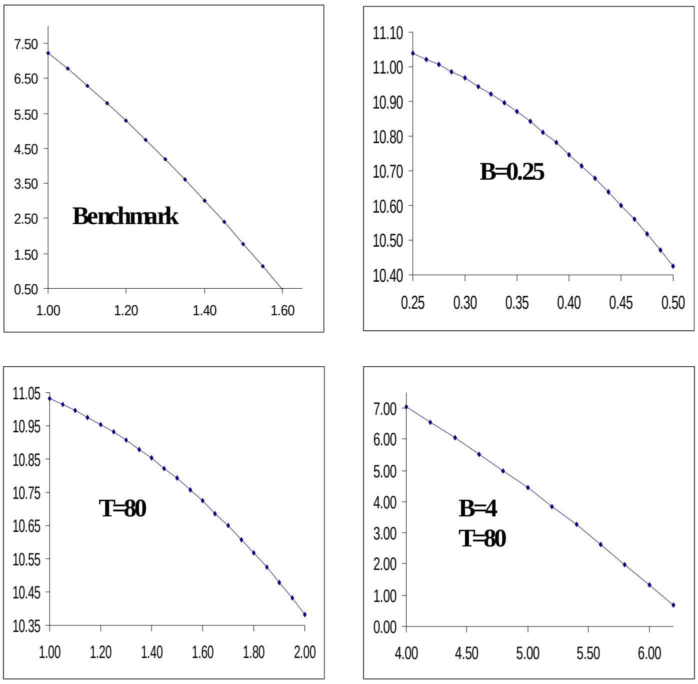

Figure 3.4: Ratio of Capital to Public Input with respect to Agricultural Productivity

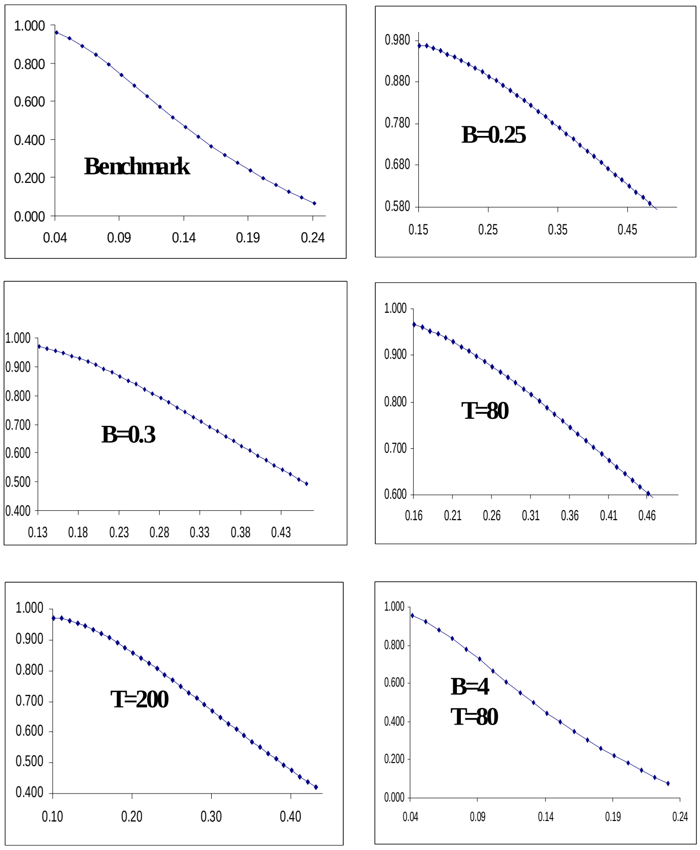

Figure 3.5: Labor Allocation in Manufacturing with respect to Share of Public Input in Agriculture

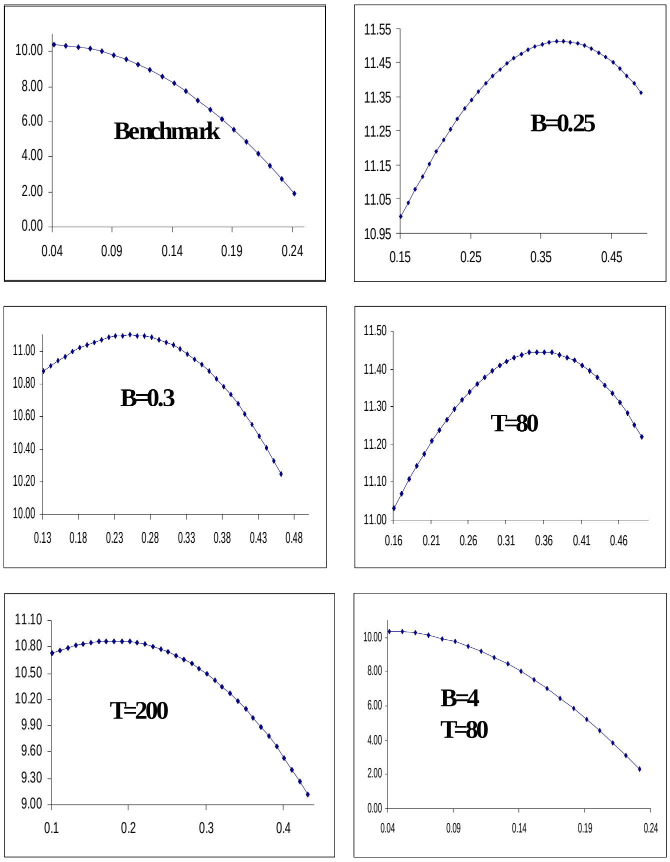

Figure 3.6: Ratio of Capital to Public Input with respect to Share of Public Input in Agriculture

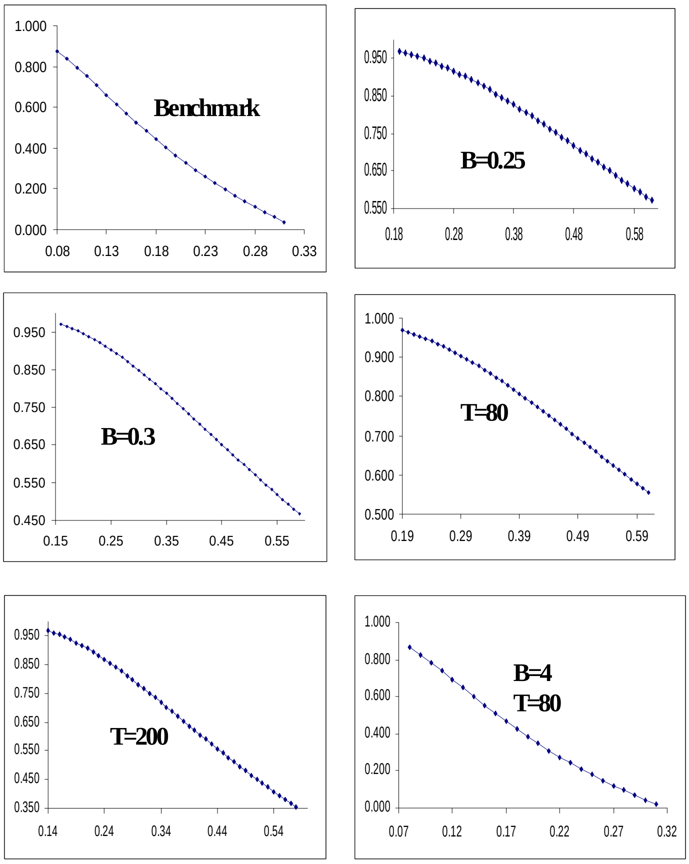

Figure 3.7: Labor Allocation in Manufacturing with respect to Tax rate

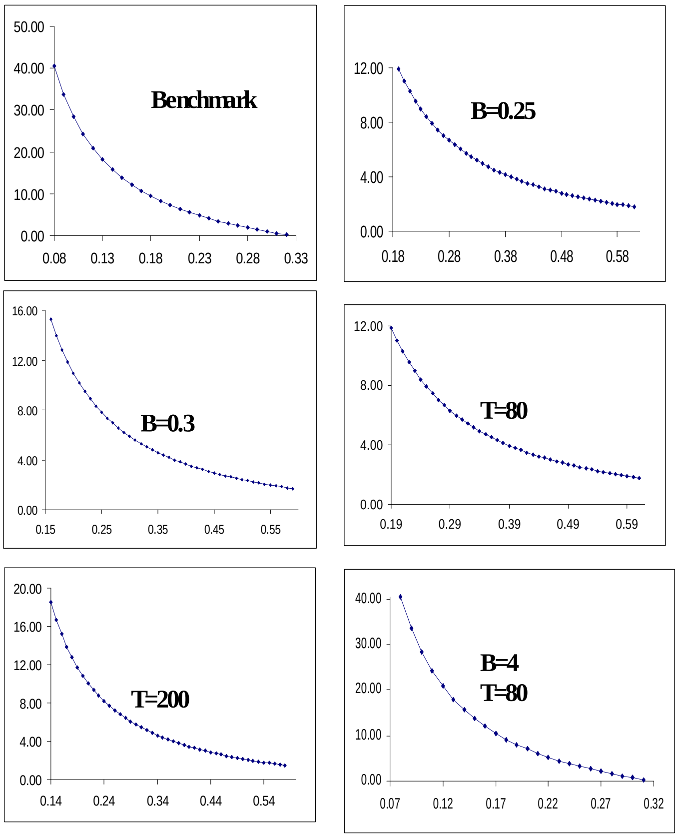

Figure 3.8: Ratio of Capital to Public Input with respect to Tax rate

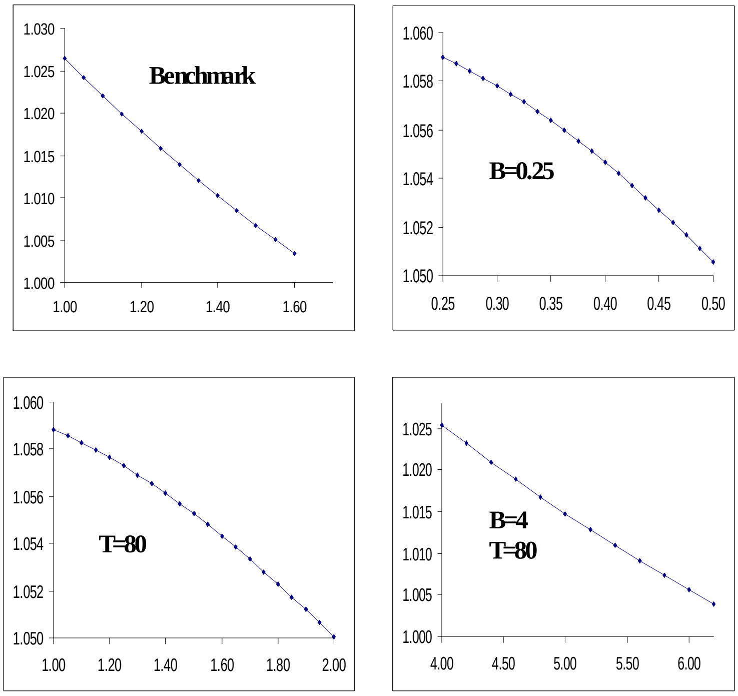

Figure 3.9: Relation between Growth rate and Agricultural Productivity

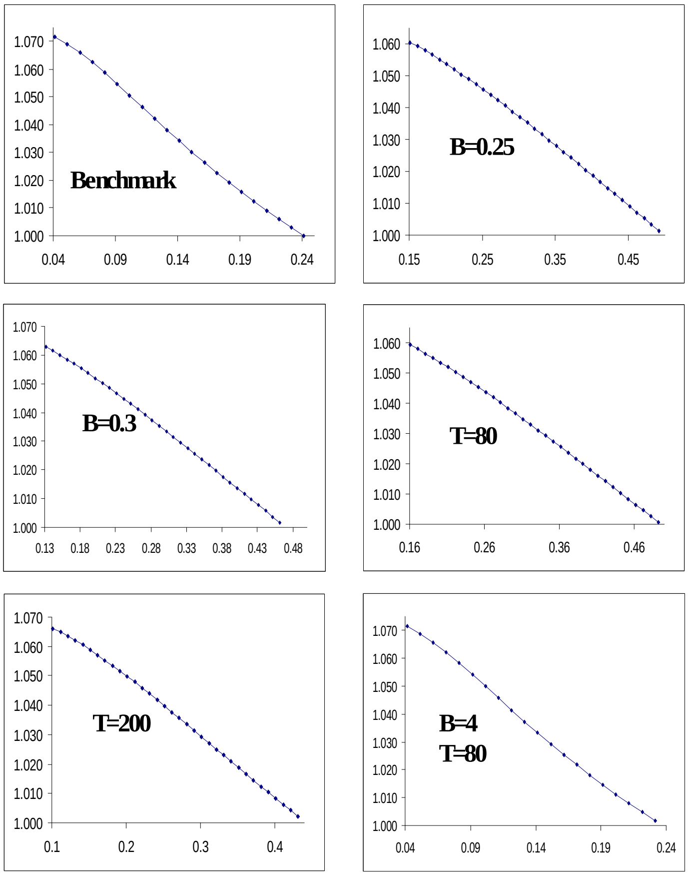

Figure 3.10: Relation between Growth rate and Share of Public Input in Agriculture

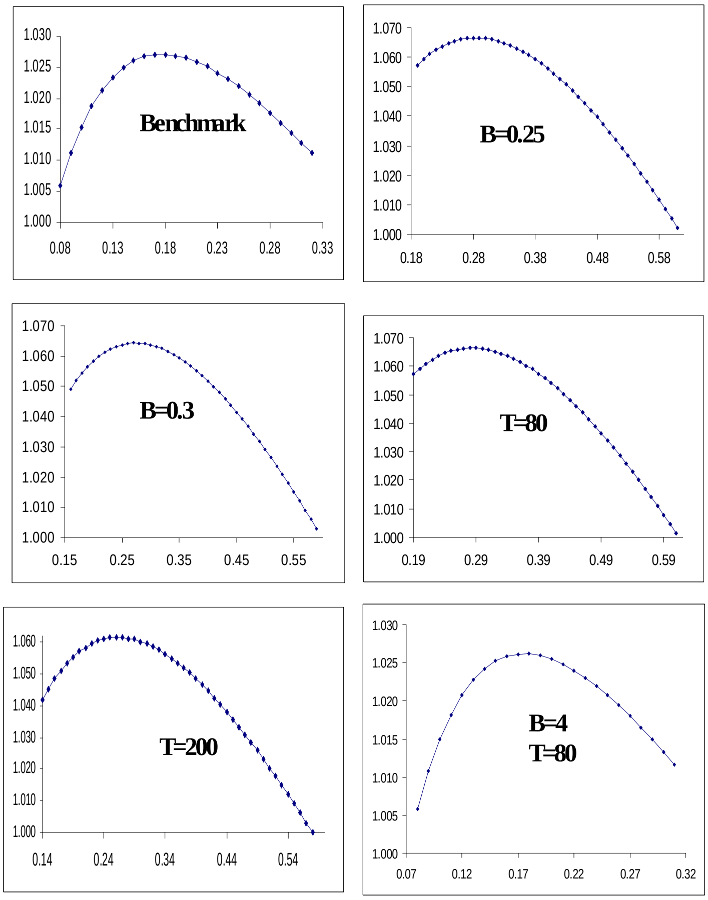

Figure 3.11: Relation between Growth rate and Tax rate

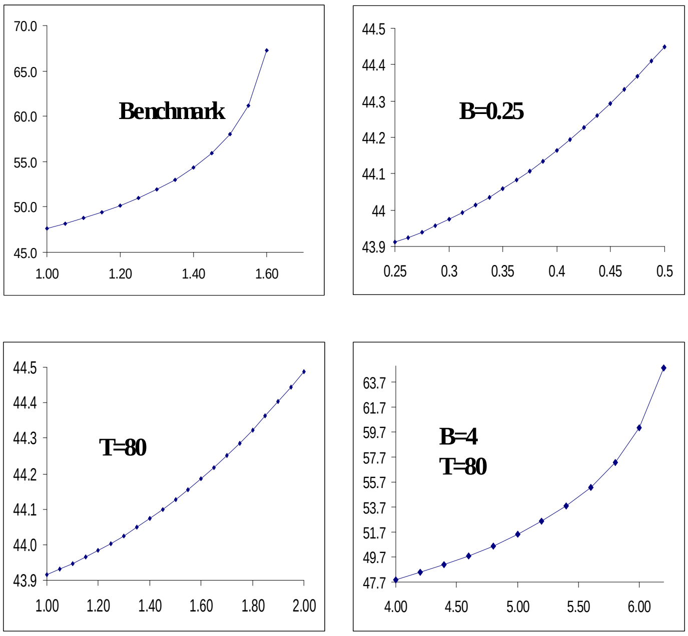

Figure 3.12: Relation between Social Welfare and Agricultural Productivity

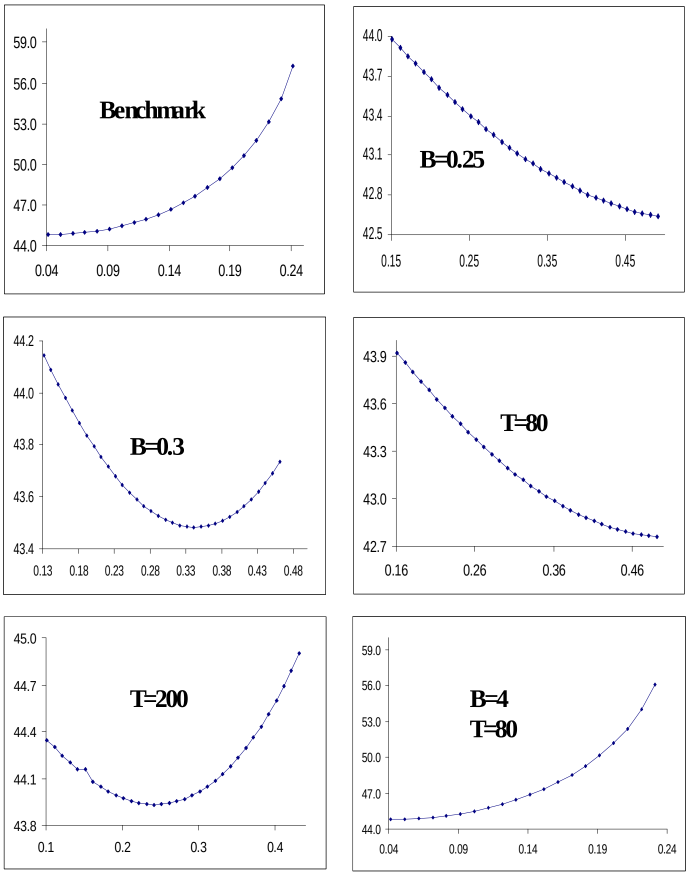

Figure 3.13: Relation between Social Welfare and Share of Public Input in Agriculture

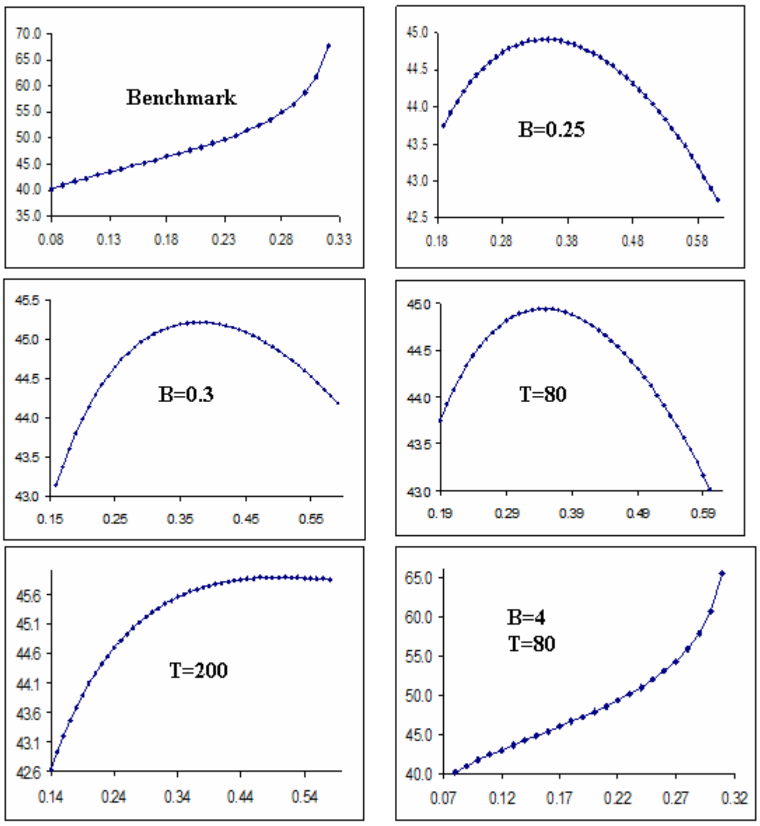

Figure 3.14: Relation between Social Welfare and Tax rate

Chapter 4

Advent of Industrial Mass Production: Three Stages of Economic Development[1]

4.1 Introduction

It is well-known by now that the modern growth process of the world economy had not been triggered off until the beginning of the nineteenth century. It has been observed that over a very long horizon of time, dating back to say, the Roman era and leading up to 1800 AD, world did not experience any significant and sustained upward trend in the per capita income, consumption, wage and output (Cameron, 1993, Hansen and Prescott, 2002 and Tamura, 2002, Parente and Prescott, 2005). Dramatic rise in the standard of living in the world has occurred only over the last centuries. For instance, during 1800-1996 the per-capita real income in Europe has grown at an annual average rate of 1.8% (Tamura, 2002).

[1] This chapter is essentially based on Bhattacharya and Das (2008).

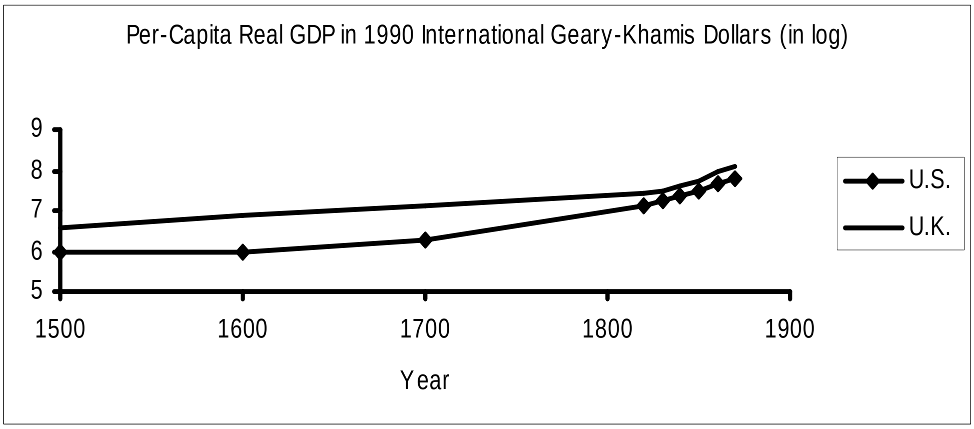

Figure 4.1: Per-Capita Real GDP Trend in U.K. and U.S.: 1500-1870; Source: Maddison (2007)

Figure 4.1 shows the per-capita real GDP trend in the U.S. and U.K. from 1500 to 1870. During 1500-1820 the total growth averaged per year is equal to 0.36% in the U.S. and 0.27% in U.K., whereas over the next fifty years, from 1820 to 1870, the respective averages are 1.3% and 1.2%.[2]

The long period of stagnant living standard followed by economic growth is the theme of the so-called 'transition literature' (Love, 1997; Galor and Weil, 2000; Laitner, 2000; Jones, 2001; Galor and Moav, 2002; Hansen and Prescott, 2002; Tamura, 2002). This literature was surveyed in Chapter 2.

Recall from the review of literature in Chapter 2, both Hansen-Prescott (2002) and Tamura (2002) portray the transition mainly as a movement of the economy from the agricultural method to industrial method of production of the same good. The transition story of Hansen and Prescott is the following. Two alternative methods exist in the economy to produce the same good. The agricultural method, which is referred to as 'Malthus technology' use capital, labor and land. It is characterized by diminishing

[2]During the subsequent 120 years, from 1870 to 1990, these averages are 1.9% for the U.S. and 1.4% for the U.K.

returns to capital and labor due to the use of land, a fixed factor. The industrial method, on the other hand, produces the same good, using labor and capital only via a constant-returns technology. This method is referred to as 'Sollow technology.' Total factor productivities of both technologies and population grow exogenously. Initially, the TFP of the industrial method is so low that only the agricultural method is viable. Population growth rate is assumed to be high enough relative to the TFP grow rate in agriculture, such that the agriculture wage, the capital rental rate and per-capita income are constant. This is the classical Malthusian trap. The model implies that, no matter how small the TFP growth rate of the industrial method is, at the agricultural wage and capital rental rate, there will be a finite date when the Solow technology starts to become profitable.

Tamura features an 'endogenous' transition from agricultural to industrial method in a model of endogenous economic and population growth. The former uses land and human capital and subject to diminishing returns due to the fixed factor land, while the latter uses only human capital exhibiting constant- returns. Unlike in the Hansen-Prescott model, there is no TFP growth in either method. But human capital grows as agents invest in it taking into consideration the higher income for the future generation. While, the dynamic path of the economy leading to transition in Hansen-Prescott is set by the continuous exogenous productivity growth in the industrial sector (agricultural productivity also grow at an exogenous rate), in Tamura, it is the endogenous human capital accumulation that paves the way towards modern growth regime. As discussed in Chapter 2, with a very low level of human capital, agricultural method operates. However, as human capital grows, in finite time the economy switches to the industrial method when average productivity under this method exceeds that under the agricultural technology.

In contrast to these papers where shift in production technique is the agent of transition, Galor and Weil (2000) and Galor and Moav (2002) analyze transition from stagnation to growth through *endogenous* technical progress. This activity is not however a function of the amount of labor hours engaged in R&D as in Jones (2001): it is determined by human quality and knowledge, which are dependent on fertility decisions.[3] Jones (2001) stands apart from the transition models outlined above featuring R&D or the production of ideas and increasing returns in production technology leading to demographic and growth transition of an economy. Apart from Jones, in the above-mentioned transition models, technologies are presumed to be known and the question is when they become viable in a market economy.

The theme of this chapter is positioned in the tradition of Hansen and Prescott (2002) and Tamura (2002). The main idea is to introduce an additional transition from what can be called **traditional manufacturing** based on constant-returns to **modern manufacturing** with increasing returns to scale and mass production. Apart from the new transition introduced, the features of our model are more similar to Tamura's than to Hansen and Prescott's.

It is widely held that the introduction of mass production involving huge fixed (overhead) costs and low marginal cost was truly a revolution in manufacturing – as it brought out a wide spectrum of products at relatively low prices, leading to an impressive increase in the standard of living for all.

Isolated examples of early mass production date back to the mid 19th century in Europe and 1860s in the U.S. (see Hounshell, 1984). And, as laid out lucidly by Besanko et. al. (2007), mass production characterized by automated, standardized, synchronized and continuous techniques of production was already a fairly established method of business organization by 1910. Furthermore, it came to be widely known especially

[3] Galor and Mountford (2006) and Galor, Moav and Vollrath (2006) examine, both theoretically and empirically, the cross-country difference in transition dates and pattern of development.

after Henry Ford's introduction of Model T in 1913.

Figure 4.2 portrays the annual time series of per-capita real GDP of U.S. and U.K. over the period 1870-1990. It is interesting that the per-capita real GDP of U.K. falls below that of U.S. for the first time just around the turn of the 20th century (1903 to be exact). Most noticeable is the persistence of gap between the two series in the entire post-WWII era, which started to develop after 1913. It is an interesting historical coincidence that in that year (when Model T was introduced) the per capita incomes of the U.S. and Britain were roughly the same, whereas by 1950 it was almost 40% higher in the U.S. than in Britain (Business Week Online, 2004).

Indeed, the introduction of mass production in the U.S. has been hailed as one of the main factors behind this dramatic widening of living standards on the two sides of the Atlantic.[4] As documented by DeLong (1997), this "new" production method dramatically transformed the U.S. economy into a modern middle-class society consuming varieties of products; radios, consumer appliances, automobiles are a few examples of such goods. He further writes that mass production has enabled the post-World War I United States to achieve the highest standard of living compared to the rest of the world.[5] According to Piore (2000), "Mass production was the dominant technological paradigm and business model in the United States from the late nineteenth century and continues even today to exercise a strong influence on the way American managers and engineers think about the endeavors in which they are engaged." Whether this production method, also called "fordist mass production" or " fordism" (see Kenny and Florida, 1993), is the dominant method of organizing production today may be debatable, but it is undeniable that it constituted a major change in the form of industrial production.

[4]Business Week Online (2004) cites two other factors hindering the growth of Europe: the world wars and the internal tariff wars among the European nations.

[5]Economies of scale seem to play an important role in the post WWII industrialization of Japan and S. Korea also (Murphy, Shleifer and Vishny, 1989).

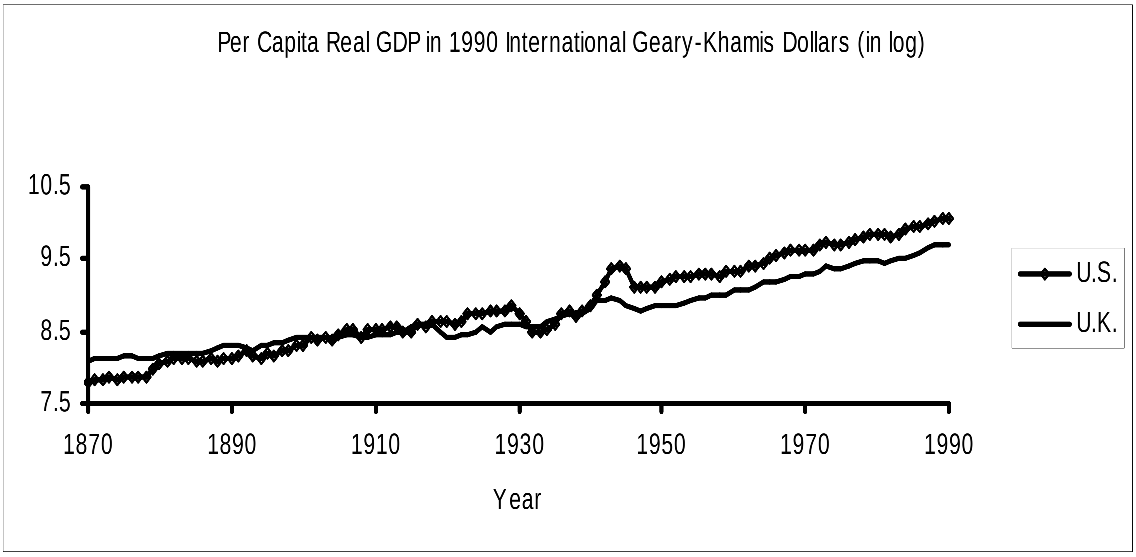

Figure 4.2: Per Capita GDP Trend in U.K. and U.S.: 1870-1990; Source: Maddison (2007)

Because mass production was introduced and commercialized in the U.S. quite successfully it is pertinent to know if, compared to its own past, the average living standard in the U.S. experienced a major shift as mass production began to take root in its economy.

Many econometric studies have attempted to identify structural breaks in the long run time series (over 130 years) of aggregate and per capita macro variables in various countries. With respect to the U.S. real GDP per capita, earlier works identified 1929 or 1930 as the break year, e.g. Ben-David and Papell (1995). Other studies that have allowed more than one break have found 1929/1930 and some year in the 1940s or 1950s as the break years, e.g., Ben-David, Lumsdaine and Papell (2003) and Chen and Zivot (2005). These studies, among others, find a transition from a low- to a high-growth regime associated with the break years.

The above-mentioned studies also examine macro data for other countries and find structural breaks in them too. Furthermore, the timing of the break years has led researchers to attribute such phenomena to severe downturns like the Great Depression or outbreak of a major war, e.g. WW I for the U.K. and WW II for Austria, Denmark and France.

In addition, the literature on economic history sees 1920s in particular as a decade of unprecedented expansion in the U.S. economy, e.g. Weber and Handfield-Jones (1954) and Gordon (2005). These authors ascribe the growth spurt to a shift of power source from coal to electricity, use of internal combustion engines and industrial chemicals etc.

There is a series of recent work that uses cross-section data across countries to investigate growth transitions *in the post WWII era*. For example, Housemann, Pritchett and Rodrik (2005) found growth accelerations to be associated with increases in investment and trade. Accordingly to Jones and Olken (2005), growth reversals are attributed to the growth rate of productivity, not to changes in the pattern of factor accumulation. Jerzmanowski (2006) distinguishes between episodes of stable growth, high growth, stagnation and crises and find that institutional changes and macro policies relating to inflation, trade openness etc. influence such episodes. Cuberes and Jerzmanowski (2007) is an exception, which considers growth starting from 1870. But it does not analyze which factors affect growth reversals: it uncovers patterns around such transitions.

In the analysis of this chapter we abstract from extreme events or shocks as well as technology changes in the energy sector as factors contributing to a permanent shift of the long-run growth rate of an economy. Our analysis focuses on the introduction of the mass production technique as the agent of transition of an industrial economy from traditional manufacturing. We formulate an endogenous growth model, which not only considers this transition but also that from agriculture to traditional manufacturing – both within a unified framework.

Recall that we have already discussed in Chapter 2 that the celebrated 'big-push' work of Murphy, Shleifer and Vishny (1989) does consider "industrialization" as a movement from traditional manufacturing characterized by constant-returns to modern manufacturing having increasing returns. In a comparatively recent work, Wang and Xie (2004) investigates factors determining the transformation from primitive to modern industrial activities characterized by increasing returns technology. They found that low endowment of capital and skilled labor, low level of technology in the modern sector, non-essentiality of those goods in preference structure are some of the major factors which may hinder the transformation of industrial activities.

However, a major difference of the current work from these works is that the latter mentioned works are static ones, whereas ours is a dynamic model, attempting to analytically predict not only the transition from traditional manufacturing to mass production but that from agriculture to traditional manufacturing too. Moreover, Murphy et al. emphasize how modern manufacturing may become sustainable only when a sufficiently large number of entrepreneurs/firms decide to adopt the increasing-returns technology, whereas we consider the accumulation of human capital, which is the source of growth, to a sufficiently high level coupled with some important feature of preference structure (will be discussed next), makes opening of modern industry viable. One major difference between the work of Wang and Xie and ours is that, in the former, externality generated from economy-wide investment in the modern industry that produces homogeneous good is the source of increasing returns in that sector, while in our model, fixed cost requirement of producing differentiated products gives rise to increasing returns to scale.

We postulate a preference structure that accompanies and partly facilitates the process of transition – namely that it changes as new goods are introduced. More specifically, in an agrarian society an individual's utility is defined on agricultural goods that fulfills biological needs, and, over time as the real income grows and industrial goods are introduced, she obtains utility from these goods, which are not essential for physiological purpose. We do *not* presume however that preferences change at exogenously specified calender dates, forcing transition.

Given these features our model generates transition from one to eventually three sectors of production activities. With a sufficiently small human-capital endowment initially, the economy is exclusively concerned with fulfilling the requirement of agricultural good, which is a necessity. At this stage, the consumer's willingness to pay for the industrial good is too low compared to the minimum price that covers the cost of producing this good. The economy thus remains, initially, in a non-industrialized state, consuming and producing only the agriculture good.

Households, caring about their future income, invest in human capital and this causes the real income to grow over time as well as causes the marginal cost of hiring a unit of effective labor to fall. As a result, the consumers' willingness to pay for the industrial good rises, while the viability of the industrial sector improves from the perspective of cost of production. A time period eventually arrives when the willingness to pay exceeds the minimum producer price for sustaining the traditional manufacturing sector. This sector then begins to operate side by side with agriculture. As the stock of human capital grows further, the fixed cost requirement in producing the mass-production in modern manufacturing good is met and the consumers' willingness to pay for the mass-production good becomes high enough, so that the producers in this sector are able to cover their costs. At that point of time, all three sectors become operational.

Note thus that the growth of human capital in our 'story' is similar to the role of TFP growth in the Hansen-Prescott model. Moreover the notion of endogenous structural changes through changing composition of aggregate consumer demand is similar in line with Zweimuller (2008). He formulates an endogenous growth model where structural changes occur as new goods are continuously introduced via endogenous innovation and consumption evolves along a hierarchy of wants so that each of these new goods starting as a luxury becomes a necessity as the consumer gets satiated with each new product.

While the primary objective of this analysis is to develop a growth scenario with two endogenous transitions - particularly the one from traditional manufacturing to mass production - with each accompanied by a higher long-run growth rate, we subject our model to calibrate in reference to the per capita real income growth in the U.S. economy, and, 'predict, so-to-speak, the two transition dates/years. The model yields the first transition to have occurred around 1820s and the second circa 1900, which are consistent with historical accounts.

In what follows in section 4.2 the general features of our model are introduced. Section 4.3 describes the general equilibrium of the economy in each phase of its development, outlines the dynamics and introduces the transition conditions. The procedures for the calibration exercise and the results are reported in section 4.4. Section 4.5 concludes this chapter.

4.2 General Features of the Model

4.2.1 Production and Market structure

The model abstracts from both population growth (whether exogenous, or endogenous through fertility decisions) and physical capital accumulation. The driving force of growth in this model is human capital. Empirical evidence suggests that human capital can be a prime engine of long run growth. For instance, Dinopoulos and Thompson (1996) find evidence of human capital-led endogenous growth based on a sample of countries provided by Mankiw, Romer and Weil (1992). But instead of allowing for a separate sector producing education or training, household production of human capital is assumed. In every period, a household is endowed with one unit of labor time. A fraction of it $(1-L_t)$ is allocated to market activities and the rest to a linear learning-activity that enhances human capital (equivalently, skill in terms of a general-purpose input in production). This holds even when the economy is producing the agriculture good only. There are surveys and econometric studies, showing a positive effect of education on farm household's (net) income in developed countries. For instance, Huffman (2001) finds that experience or acquiring skills by specializing in a particular type of work has a positive impact on farm wage. He obtains similar finding for many developing countries.

Denoting the total stock of human capital at time t as H_t,

$$H_{t+1} = a_H L_t H_t, \tag{A1}$$

where a_H is the technology coefficient in producing human capital.

In what follows, H_{jt} denotes the employment of human capital (labor in effective units) in sector j, $j = F,\ M,\ S$, standing respectively for the agriculture sector (producing food), the traditional manufacturing and the mass production sector.

The food production function satisfies constant-returns in land and labor, along with diminishing returns to each input. Let the land endowment be normalized to one and the technology be given by

$$Y_t^F = H_{Ft}^{\gamma}, \quad \gamma < 1. \tag{A2a}$$

Because land is sector-specific, production bears a decreasing-returns relationship with respect to the labor input, and, in this sense it is a 'decreasing-returns' sector.

When it comes to existence, sector M produces a homogeneous product via a constant-returns technology:

$$Y_t^M = a_M H_{Mt}. \tag{A2b}$$

Here a_M denotes the technology coefficient in this sector. The markets for goods F and M are perfectly competitive.

The mass production sector produces a variety of products (brands) when it becomes sustainable. Mass production refers to a technology that involves a large fixed cost but presumably a very low marginal cost. It is an increasing-returns technology. The production function of the ith firm producing variety i is given as

$$Y_{it}^{S} = \max\{a_S(H_{Sit} - \bar{h}), 0\}, \quad \bar{h} > 0. \tag{A2c}$$

The parameter $\bar{h}$ reflects fixed cost and a_S is the efficiency parameter. We further require a strictly positive lower bound on $\bar{h}$, which will be introduced later. The market for this good is monopolistically competitive.[6]

In each sector the entry/exit process of firms is assumed to be instantaneous, costless and simultaneous. We do not consider coordination problems.

Our transition model and those which are related to our paper do not consider R&D or industrial learning per se that gives rise to the postulated production functions. Pre-existence of such knowledge is presumed and the issue is regarding when they are successfully introduced to the market.[7] More precisely, it is assumed that the technical knowledge of producing good M (or good S) is known by some period, which is not far later than the introduction of good F (or good M) – such that its introduction to the market is not (exogenously) delayed by the unavailability of technology.

However, this is *different* from saying that technologies of good M and good S appear 'on the horizon' sequentially, so that these goods are introduced to the market sequentially. It will be argued in section 4.3.5 that good S becomes viable only after good M (under some conditions), even if the technologies of the two goods were known at the same time.

[6]Because of increasing returns, it is necessary that this sector be imperfectly competitive. For analytical tractability only we assume monopolistic competition. In principle, one could, for example, assume that sector S is oligopolistic and produces a homogeneous good.

[7]For instance, as mentioned in the Introduction, there were instances of mass production around the mid-19th century, but they did not become viable until much later.

4.2.2 Preferences and the Household Optimization Problem

Preferences satisfy two salient features. First, good F is a necessity, while the two manufacturing goods are not. Second, any preference for a manufacturing good (M or S) arises only when it is produced (and 'seen' by households). In other words, the utility function itself changes when new goods are introduced. We consider this natural. For example, it is hard to imagine that a 19th century household would be able to even potentially define its preferences for a washing machine, a computer or a cell phone.

There is indeed empirical evidence supporting that preferences change as new goods are introduced. Bils and Klenow (2002), for example, have quantified the impacts of introduction of new goods on the preference structure, by using U.S. Consumer Expenditure Survey Data (CEX) for the period 1959-1999. They have found that as new products arrive in the market, consumer spending shifts rapidly and substantially toward the new goods. 'New goods' mean products which are either entirely new or have added features to existing products. Controlling for Engel-curve and relative price effects, the spending on new goods relative to 'static' ones expands by 1.3% annually.[8]

As said earlier, we assume a fixed population size. For convenience, we normalize it to unity. The utility function is the following.

$$u_t = \begin{cases} u_t^F = \ln c_t^F \text{ if } Y_t^M = 0,\ Y_{it}^S = 0 \\ u_t^M = (1-\theta_M)\ln c_t^F + \theta_M \ln\left(c_t^M + b\right) \text{ if } Y_t^M > 0,\ Y_{it}^S = 0 \\ u_t^S = (1-\theta_M\delta)\ln c_t^F + \theta_M\delta \ln\left[(c_t^M)^{\varphi}(G_t)^{1-\varphi} + b)\right] \text{ if } Y_t^M \text{ and } Y_{it}^S > 0, \end{cases} \tag{A3}$$

where $b > 0$, $\delta > 1$ and $\theta_M,\ \theta_M\delta,\ \varphi \in (0,1)$. Recall that, Y's refer to production of a good. Further, c_t^F and c_t^M are the consumption of good F and good M respectively and

[8]There are other approaches that model changing pattern of consumer preferences. For instance, in Stokey (1988), as income grows, consumers' preference shifts towards goods with more characteristics. Bowles (1998) discusses the evolution of preferences as a result of learned influences on behavior.

G_t is a composite good consisting of differentiated varieties of good S. It is defined as

$$G_t \equiv \left[\int_0^{n_t} (c_{it}^S)^\epsilon di \right]^{\frac{1}{\epsilon}}, \quad \epsilon < 1. \tag{A4}$$

In (A4), c_{it}^S denotes consumption of the ith variety, $1/(1-\epsilon)$ is the elasticity of substitution between any two varieties and n_t the total number of varieties.

When only good F is available, a household spends its entire income on it, and, as good M becomes available, the share of total spending on this good falls.[9] In the mass production stage, the share of expenditure on good F is even less, captured by the parameter δ. Within the manufacturing-goods basket, the parameter φ is the expenditure share of good M. The parameter b captures non-essentiality of manufacturing products in preference.

The following remarks are in order.

1. The domain of c_t^F is assumed to be $[1, \infty)$, so that the (sub-)utility from consuming the good F is non-negative. It is then implicit that there is a minimum consumption level of good F equal to 1. But there is no such minimum consumption requirement for the industrial good and we assume $c_t^M \in \bar{R}_+$. Further, we normalize b to unity, so that the sub-utility from consuming the industrial good approaches zero as c_t^M approaches zero. All these assumptions imply that the total utility during any phase of development is always non-negative, so that discounted utility (for any future period) is less than the undiscounted utility.

2. Note that in the traditional-manufacturing stage, if $c_t^M \to 0$, then $u_t^M \to (1 - \theta_M) \ln c_t^F$, which is less than u_t^F for any given level of c_t^F. Similarly, if $G_t \to 0$, $u_t^S \to (1 - \delta\theta_M) \ln c_t^F$ and this is less than u_t^M. These properties capture an element of addiction towards new goods in that when they are available in the market but

[9]The specification of utility from goods F and M is similar to the utility function assumed by Love (1997).

not consumed, there is a sense of deprivation. For instance, all else the same, utility without an automobile or email facility in an automobile or internet era is not same as utility prior to the respective era when these goods were not available in the market.

3. While such a characterization is sufficient for our analysis – and we believe that it captures some very realistic aspects of change in preferences – it is not necessary. For example, if we specify $u^F = (1-\theta_M)\ln c_t^F$, then $\lim_{c_t^M \to 0} u^M = u^F$ for any given c_t^F. However, there exists no such transformation which makes utility continuous across traditional manufacturing and the mass-production stage for any amounts consumed. But, an appropriate additive constant can be included into u^S so that for a particular parametric economy, utility is continuous at equilibrium quantities consumed across stages of development. Such an additive constant does not influence decisions at the margin. As we shall see later, transition dates are solved by invoking marginal conditions in the respective forthcoming stage.

4. Indeed, the assumption of shifting preferences is not required, if one were to solve the entire model numerically. We could specify a single utility function with two non-essentiality parameters associated with goods M and S, e.g., $u_t = (1-\theta_M\delta)\ln c_t^F + \theta_M\delta\ln[(c_t^M)^{\varphi}(\eta+G_t)^{1-\varphi}+b]$. Our assumption of changing preferences is motivated by empiricism as well as for the sake of analytical tractability.

We now consider the household's optimization problem. If two or more goods are available in the economy, in each period the household solves a static and a dynamic problem. The static problem is the following.

When goods F and M are only available, u_t^M is maximized, subject to $c_t^F + p_t^M c_t^M = E_t$, E_t being the total expenditure on two goods in period t and p_t^M the price of good M in terms of good F, the numeraire good. The instantaneous demand functions and the indirect utility expressions are

$$c_t^F = (1-\theta_M)\tilde{E}_t; \quad c_t^M = \theta_M \frac{\tilde{E}_t}{p_t^M} - 1 \quad \text{where } \tilde{E}_t = E_t + p_t^M, \tag{A5}$$

$$v_t^M = \ln \tilde{E}_t - \theta_M \ln p_t^M + (1-\theta_M)\ln(1-\theta_M) + \theta_M \ln \theta_M. \tag{A6}$$

To the extent that the manufactured good is not essential in consumption, expenditure on food bears a proportional relationship to a level ($\tilde{E}_t$), which is *higher* than the total expenditure on all goods consumed. We call this the "food-adjusted expenditure."

When all three goods are available, the static problem is equivalent to a two-stage budgeting exercise. In the first stage the sub-utility function (A4) is maximized subject to $\int_0^{n_t} p_{it}^S c_{it}^S di = I_t$, where p_{it}^S is the price of ith brand and I_t the total expenditure on good S. This gives rise to the (standard) demand function of the ith differentiated brand:

$$c_{it}^S = \left(\frac{p_{it}^S}{P_t}\right)^{-\frac{1}{1-\epsilon}} \frac{I_t}{P_t}, \text{ where } P_t \equiv \left[\int_0^{n_t} (p_{it}^S)^{-\frac{\epsilon}{1-\epsilon}} di\right]^{-\frac{1-\epsilon}{\epsilon}}. \tag{A7}$$

Here P_t is the composite price of the differentiated brands. In the second stage, the household maximizes u_t^S subject to $c_t^F + p_t^M c_t^M + P_t G_t = E_t$. The problem yields the following demand functions and the indirect utility function:

$$c_t^F = (1-\delta\theta_M)\breve{E}_t; \quad c_t^M = \frac{\theta_M \delta\varphi \breve{E}_t}{p_t^M} - \left[\frac{\varphi P_t}{(1-\varphi)p_t^M}\right]^{1-\varphi} \tag{A8}$$

$$G_t = \frac{\delta\theta_M(1-\varphi)\breve{E}_t}{P_t} - \left[\frac{(1-\varphi)p_t^M}{\varphi P_t}\right]^{\varphi} \text{where } \breve{E}_t = E_t + \frac{(p_t^M)^{\varphi} P_t^{1-\varphi}}{\varphi^{\varphi}(1-\varphi)^{1-\varphi}}, \tag{A9}$$

$$v_t^S = \ln \breve{E}_t - \theta_M \delta\varphi \ln p_t^M - \delta\theta_M(1-\varphi)\left[\ln p_t^S - \frac{1-\epsilon}{\epsilon}\ln n_t\right]$$
$$+(1-\delta\theta_M)\ln(1-\delta\theta_M) + \delta\theta_M \ln(\delta\theta_M\varphi) + \theta_M\delta(1-\varphi)\ln\frac{1-\varphi}{\varphi}. \tag{A10}$$

Here $\breve{E}_t$ is the food-adjusted expenditure.

It will be established later that the economy evolves, at finite dates, from agriculture to agriculture-cum-traditional manufacturing and finally to the state where all three goods are produced and consumed. Let these dates be T^* and T^{**} respectively. The dynamic problem facing the representative household is the following. Denoting the discount factor by ρ (< 1), under perfect foresight it is assumed to maximize

$$\sum_{t=0}^{T^*-1} \rho^t \ln c_t^F + \sum_{t=T^*}^{T^{**}-1} \rho^t v_t^M + \sum_{t=T^{**}}^{\infty} \rho^t v_t^S,$$

subject to the learning technology (A1) and the respective budget constraint:

$$\bar{W}_t(1 - L_t)H_t + R_t - c_t^F \geq 0 \text{ for } t \in [0, T^* - 1]$$

$$\bar{W}_t(1 - L_t)H_t + R_t - (\tilde{E}_t - p_t^M) \geq 0 \text{ for } t \in [T^*, T^{**} - 1]$$

$$\bar{W}_t(1 - L_t)H_t + R_t - \left[\breve{E}_t - \frac{(p_t^M)^\varphi P_t^{1-\varphi}}{\varphi^\varphi(1-\varphi)^{1-\varphi}}\right] \geq 0 \text{ for } t \geq T^{**},$$

where we have made use of the relationships between the household's expenditure E_t on the one hand and the food-adjusted expenditure ($\tilde{E}_t$ or $\breve{E}_t$) on the other. Here $\bar{W}_t$ is the highest wage rate across sectors at time t and R_t is the land-rental income.[10] It is assumed further that $\rho a_H > 1$, which ensures a positive growth rate. Note that the log-linear indirect utility functions, in all three phases, satisfy constant intertemporal elasticity of substitution (equal to one) with respect to the food-adjusted expenditure.

The choice variables are $\{c_t^F\}$, $\{\tilde{E}_t\}$, $\{\breve{E}_t\}$ in the respective time intervals, $\{L_t\}_0^\infty$ and $\{H_t\}_1^\infty$. Note that H_t is the state variable, whereas the rest are control variables. There is one initial condition: H_0 is given. The dynamic problem leads to the following Euler

[10] The atomistic household expects to sell any arbitrary amount of his labor time to its higher bidder across sectors. Of course, in Phase F, there is production in the agriculture sector only and thus $\bar{W}_t$ is the wage rate in this sector.

equations:

$$\frac{c_{t+1}^F}{c_t^F} = \rho a_H \frac{\bar{W}_{t+1}}{\bar{W}_t} \text{ for } t \in [0, T^* - 2] \tag{A11a}$$

$$\frac{\tilde{E}_{T^*}}{c_{T^*-1}^F} = \rho a_H \frac{\bar{W}_{T^*}}{\bar{W}_{T^*-1}} \tag{A11b}$$

$$\frac{\tilde{E}_{t+1}}{\tilde{E}_t} = \rho a_H \frac{\bar{W}_{t+1}}{\bar{W}_t} \text{ for } t \in [T^*, T^{**} - 2] \tag{A11c}$$

$$\frac{\breve{E}_{T^{**}}}{\tilde{E}_{T^{**}-1}} = \rho a_H \frac{\bar{W}_{T^{**}}}{\bar{W}_{T^{**}-1}} \tag{A11d}$$

$$\frac{\breve{E}_{t+1}}{\breve{E}_t} = \rho a_H \frac{\bar{W}_{t+1}}{\bar{W}_t} \text{ for } t \geq T^{**}.^{11} \tag{A11e}$$

These equations imply a simple, yet central, property of the model economy which holds irrespective of which phase it is passing through. That is, the ratio of 'food-adjusted expenditure' (i.e. c_t^F, $\tilde{E}_t$ or $\breve{E}_t$) to the wage rate has a balanced growth path, with a gross growth rate equal to ρa_H. This balanced growth feature results from the indirect utility functions satisfying constant intertemporal elasticity of substitution and the learning technology being linear in labor time invested.[12] As we shall see, it implies that the agriculture sector grows at a constant rate through all phases. But it *does not* imply that other sectors or the real income in Phases M and S have balanced growth paths.

Let us define

$$\chi_t^F \equiv \frac{c_t^F}{\bar{W}_t}; \quad \chi_t^M \equiv \frac{\tilde{E}_t}{\bar{W}_t}; \quad \chi_t^S \equiv \frac{\breve{E}_t}{\bar{W}_t},$$

each of which grows at the rate ρa_H in the respective phase. In general, let $g_{xt} \equiv x_{t+1}/x_t$ denote the (gross) growth rate of any variable x. Thus

$$g_{\chi^F} = g_{\chi^M} = g_{\chi^S} = \rho a_H. \tag{A12}$$

[11]Appendix 3 details the derivation of these conditions.

[12]See, for example, Barro and Sala-i-Martin (2004, Chapter 2) on this.

4.3 General Equilibrium

Solving the model essentially involves separately characterizing the general equilibrium of the one-sector, the two-sector, the three-sector economy and then connecting them endogenously. In Phases M and S, we assume perfect labor mobility across sectors. This implies that in equilibrium the wage rate will be equalized across sectors, i.e., $\bar{W}_t \equiv W_t$, the common wage rate in the economy. For notational simplicity, we shall henceforth use W_t instead of $\bar{W}_t$.

Transition dates are determined by the respective industry viability conditions as well as Euler equations at the time of transition ((A11b) and (A11d)). It is presumed that a household's roles as a consumer and a producer are decentralized. Absent any dynamic trade off facing an entrepreneur in introducing the technology of either producing good M or good S, free accessibility of technology and free entry and exit, the producers objective boils down to maximizing one-period profit.

4.3.1 The Agrarian Economy

Under perfect competition in the agricultural sector, wage and land-rental expressions are:

$$W_t = \gamma H_{Ft}^{-(1-\gamma)}; \quad R_t = (1-\gamma) H_{Ft}^{\gamma}. \tag{A13}$$

Note that, given diminishing returns with respect to each input and constant-returns with respect to labor and land, the land-rental rate, equal to lands marginal product, increases with labor input.

Here and onwards $\bar{H}_t \equiv (1 - L_t)H_t$ denotes the total amount of human capital at time t devoted to market activity. Since there is only one sector of production, $H_{Ft} = \bar{H}_t$ in Phase F.

We next observe that

$$\chi_t^F \equiv \frac{c_t^F}{W_t} = \frac{Y_t^F}{W_t} = \frac{H_{Ft}^{\gamma}}{\gamma H_{Ft}^{-(1-\gamma)}} = \frac{\bar{H}_t}{\gamma}. \tag{A14}$$

Since $g_{\chi^F} = \rho a_H$, it follows that $g_{\bar{H}t} = \rho a_H$. This implies:

Proposition 4.1 *In Phase F, agricultural production and real income grow at the rate of* $(\rho a_H)^{\gamma}$.

Under perfect foresight, its initial value, L_0, depends on the entire time path of the economy through various phases. Its determination as well as the dynamics of L_t will be discussed fully in section 4.3.3. For now, given L_0, $\bar{H}_0$ equals $(1 - L_0)H_0$, where H_0, the initial endowment of human capital, is known or pre-determined. Then $\bar{H}_t$ obeys $\bar{H}_0(\rho a_H)^t$ in phase F. The dynamics of agricultural output follows from the production function.

4.3.2 Agriculture and Traditional Manufacturing

Given that production takes place in two sectors, $H_{Ft}+H_{Mt} = \bar{H}_t$ and free labor mobility equalizes wage rate across these sectors, i.e.,

$$\gamma H_{Ft}^{\gamma-1} = p_t^M a_M = W_t, \tag{A15}$$

where the last equality is the zero-profit condition in sector M. The land-rental expression remains equal to:

$$R_t = (1 - \gamma)H_{Ft}^{\gamma} \tag{A16}$$

In view of (A5), the goods market clearing condition is given by:

$$(1 - \theta_M)\tilde{E}_t = H_{Ft}^{\gamma}. \tag{A17}$$

At any time t, the total expenditure on the two goods, E_t, equals the total income, which is the sum of the wage and rental incomes. Using (A15), this leads to $\tilde{E}_t =$

$W_t\bar{H}_t + R_t + p_t^M = H_{Ft}^{\gamma-1}\left[\gamma\bar{H}_t + (1-\gamma)H_{Ft} + \frac{\gamma}{a_M}\right]$. Substituting this into (A17) yields a unique solution of H_{Ft}, given $\bar{H}_t$, equal to

$$H_{Ft} = \frac{\gamma(1-\theta_M)(\bar{H}_t + 1/a_M)}{\theta_M + \gamma(1-\theta_M)}. \tag{A18}$$

Hence, a static or within-period equilibrium exists and it is unique. The full-employment condition, $H_{Ft} + H_{Mt} = \bar{H}_t$ determines H_{Mt}. Next, writing (A17) as $(1-\theta_M)\tilde{E}_t = W_t H_{Ft}/\gamma$, and making use of (A18), we also obtain

$$\chi_t^M \equiv \frac{\tilde{E}_t}{W_t} = \frac{H_{Ft}}{\gamma(1-\theta_M)} = \frac{\bar{H}_t + 1/a_M}{\theta_M + \gamma(1-\theta_M)}. \tag{A19}$$

Assume for now that T^*, the beginning date of Phase M is known. Section 4.3.5 analyzes its determination and the solution of $\bar{H}_{T^*}$.

Dynamics in Phase M

We first substitute $p_t^M = W_t/a_M$ into the demand function for good M given in (A5), and next use $c_t^M = Y_t^M$, the market-clearing condition for this good, to obtain $\chi_t^M = \frac{Y_t^M+1}{\theta_M a_M}$. This equation, together with (A19) implies

$$\rho a_H = \frac{H_{Ft+1}}{H_{Ft}} = \frac{a_M\bar{H}_{t+1}+1}{a_M\bar{H}_t+1} = \frac{Y_{t+1}^M+1}{Y_t^M+1}. \tag{A20}$$

since $g_{\chi^M} = \rho a_H$.

Thus employment in agriculture continues to grow at the rate ρa_H, implying the agriculture output growth rate equal to $g_{Ft}^Y = (\rho a_H)^\gamma$, where the superscript Y denotes the respective output. We also obtain $g_{\bar{H}t} > \rho a_H$ and $g_{Mt}^Y > \rho a_H$, the latter implying that the traditional manufacturing sector grows faster than the agricultural sector. The lack of balanced growth results from the non-homotheticity of preferences as well as the difference in returns to scale between the two sectors.

It follows from eqs. (A20) that both $g_{\bar{H}t}$ and g_{Mt}^Y monotonically decline over time 'approaching' the rate ρa_H. This can be shown in the following way: from (A20), we can express $\bar{H}_{t+1}/\bar{H}_t = \rho a_H + (\rho a_H - 1)/(a_M \bar{H}_t)$. As $\bar{H}_t$ increases with time, the r.h.s. falls over time approaching ρa_H. The same method of proof also applies to the dynamics of g^Y_{Mt}. It is important to note that this is not same as the asymptotic growth rate since Phase M is not terminal. Good M being non-essential in consumption, the income elasticity of demand for it is greater than one. Positive growth implies that good M becomes less inessential over time and thus the income elasticity falls over time. This implies a decline in the growth rate of sector M over time.

Next, we focus on the growth rate of real income. The Cobb-Douglas part of the utility specification gives rise to a price index in terms of good F, equal to $(p^M_t)^{\theta_M}$. (Recall that the price of good F is normalized to one.) We can thus define real income as $I_t = E_t/(p^M_t)^{\theta_M}$. Using (A5), (A15) and (A17), it can be expressed as:

$$I_t = (a_M)^{\theta_M} \left(\chi^M_t - \frac{1}{a_M} \right) \gamma^{1-\theta_M} H_{Ft}^{-(1-\gamma)(1-\theta_M)}. \tag{A21}$$

As both χ^M_t and H_{Ft} grow at ρa_H, the growth rate of real income $g_{It} > (\rho a_H)^{\gamma+(1-\gamma)\theta_M}$. Further, since that $g_{\chi^M} = \rho a_H$, we can write,

$$g_{It} \equiv \frac{I_{t+1}}{I_t} = \left[\frac{(\rho a_H - 1) a_M \chi^M_t}{a_M \chi^M_t - 1} + 1 \right] (\rho a_H)^{-(1-\gamma)(1-\theta_M)}.$$

The term in the square bracket falls and approaches ρa_H as χ_{Mt} rises over time, implying g_{It} declines, approaching $(\rho a_M)^{\gamma+(1-\gamma)(1-\theta_M)}$.

In summary we have

Proposition 4.2 *In Phase M*

(a) The agricultural sector continues to grow at the rate of $(\rho a_H)^{\gamma}$.

(b) The traditional manufacturing sector grows at a rate higher than ρa_H and this rate decreases over time approaching toward ρa_H.

(c) The growth rate of real income exceeds but monotonically declines over time approaching toward $(\rho a_H)^{\gamma+\theta_M(1-\gamma)}$, which, in turn, is higher than its growth rate in Phase F.

Part (c) is of particular interest as it says that the growth rate of standard of living is higher in Phase M. This follows from the introduction of sector M, which is a constant-returns-technology sector.

While our emphasis is on long-term growth and how it jumps as the economy traverses from one phase to the next, it is worth noting that at the time of transition the growth rate may not increase. It is possible that the real income even falls. This is because the composition of the consumption basket and therefore the price index are different. The new real income depends partly on the new preference parameters and the relative price of the newly introduced good. The latter would depend on the productivity parameter of the new sector as well. It is thus possible that the change in composition of the price index more than offsets the positive effect of human capital accumulation on real income, leading to an initial decline in real income. This applies during the transition of the economy from Phase M to Phase S as well.

4.3.3 Agriculture, Traditional Manufacturing and Mass Production

As production takes place in three sectors, we have $H_{Ft} + H_{Mt} + H_{St} = H_t$. The free labor mobility condition (A15) continues to hold, and, the market-clearing condition for the agriculture good is analogous to that in Phase M:

$$(1 - \delta\theta_M)\breve{E}_t = H_{Ft}^{\gamma}. \qquad \text{(A22)}$$

In sector S, firm i faces marginal cost of production equal to W_t/a_S. Taking into account the demand function given in (A7) and that a particular firm treats P_t (the composite price of good S) and W_t as given, profit maximization implies the familiar mark-up rule:

$$p_{it}^{S} = \frac{W_t}{a_S \epsilon}. \qquad \text{(A23)}$$

In symmetric equilibrium, $p_{it}^S = p_t^S$, $c_{it}^S = c_t^S$. Thus, from (A7) and (A9):

$$P_t = n_t^{-\frac{1-\epsilon}{\epsilon}} p_t^S; \quad G_t = n_t^{\frac{1}{\epsilon}} c_t^S. \tag{A24}$$

It turns out to be convenient – as well as illustrative – to express the static three-sector model in terms of profits made in sector S at any given n_t, and then utilize the zero-profit condition in sector S to solve n_t and hence the model. Towards this end, let us define

$$\alpha \equiv \frac{(1-\epsilon)(1-\varphi)}{\epsilon}; \quad \xi \equiv \frac{1}{a_M^{\varphi}(a_S\epsilon)^{1-\varphi}\varphi^{\varphi}(1-\varphi)^{1-\varphi}}.$$

As shown in Appendix 4,

$$A\frac{\pi_t}{n_t W_t} = B(\bar{H}_t) - Z(n_t; \bar{h}), \text{ where} \tag{A25}$$

$$A \equiv \frac{(\varphi+\epsilon-\varphi\epsilon)\delta\theta_M + \gamma(1-\theta_M\delta)}{(1-\epsilon)[\delta\theta_M + \gamma(1-\delta\theta_M)]}; \quad \underset{+}{B}(\bar{H}_t) \equiv \frac{(1-\varphi)\theta_M\delta\bar{H}_t}{\delta\theta_M + \gamma(1-\delta\theta_M)}$$

$$Z(\underset{\pm}{n_t}; \underset{+}{\bar{h}}) \equiv \frac{\gamma\xi(1-\varphi)(1-\delta\theta_M)n_t^{-\alpha}}{\delta\theta_M + \gamma(1-\delta\theta_M)} + \frac{n_t\bar{h}}{1-\epsilon}.$$

Eq. (A25) implies $\pi_t \gtreqless 0$ as $Z(n_t; \bar{h}) \lesseqgtr B(\bar{H}_t)$. Thus

$$Z(n_t; \bar{h}) = B(\bar{H}_t) \tag{A26}$$

spells the zero-profit condition in sector S. It has one variable n_t, and, in principle, solves the static three-sector model.

Notice that the function $Z(\cdot)$ is U-shaped with respect to n_t, as shown in Figure 4.3. Hence a solution exists, i.e., the mass production sector becomes viable if and only if $\bar{H}_t$ exceeds a threshold. This is because the technology of good S requires a minimum (positive) amount of labor ($\bar{h}$ per firm) in order to produce any arbitrarily small amount. Equating $\min_n Z(n_t; \bar{h})$ to $B(\bar{H}_t)$ gives the threshold equal to

$$\bar{H}^{**} = \frac{1+\alpha}{\delta\theta_M} \cdot [\gamma\xi(1-\delta\theta_M)]^{\frac{1}{1+\alpha}} \cdot \left\{\frac{\bar{h}[\delta\theta_M + \gamma(1-\delta\theta_M)]}{\alpha(1-\varphi)(1-\epsilon)}\right\}^{\frac{\alpha}{1+\alpha}}. \tag{A27}$$

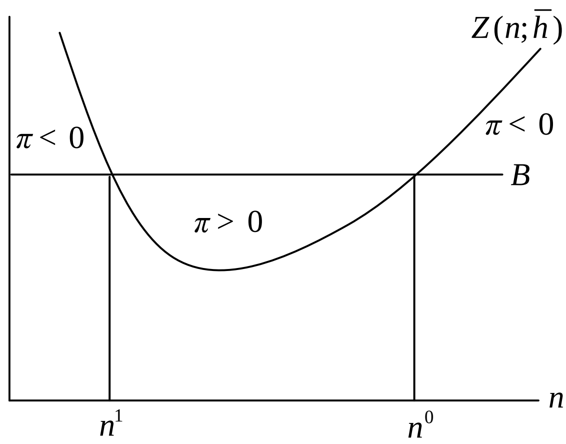

Figure 4.3: Solution of n_t

Furthermore, as seen in Figure 4.3, given that a solution exists, there are precisely two of them for $\bar{H}_t > \bar{H}^{**}$. The multiplicity of equilibria arises due to income elasticity of demand for good S being greater than one. On the one hand, an increase in n_t tends to reduce the quantity demanded for any particular variety and thereby reduce profits earned by any particular firm. It is a substitution effect. On the other hand, an increase in n_t also means an increase in the number of firms in sector S, which tends to increase the economy-wide demand for labor and thereby increase real income. Hence there is a positive income effect on quantity demanded for any variety or hence on profit earned by a single firm in sector S. If the income elasticity is greater than one, this income effect may outweigh the substitution effect. The two equilibria correspond to the overall positive or negative effect of an increase on n_t on profit earned by a single firm. We see however the equilibrium on the right (left) arm of the $Z(n; \cdot)$ curve is stable (unstable) in the sense that $d\pi/dn <\ (>)\ 0$ around a point such as n^0 (n^1).

We use this stability criterion and disregard the solution along the declining part of $Z(n_t; \cdot)$, and interpret that along the rising portion (such as n^0) to be the market-determined number of firms or varieties. Accordingly, eq. (A26) implicitly yields $n_t = n(H_t),\ n' > 0$, which is intuitive.

Further exploring the static three-sector model, note that, by using the mark-up condition, the zero-profit condition yields a constant value of a firm's output over time, equal to $c_t^S = \bar{h}a_S\epsilon/(1-\epsilon)$. This is a well-known feature of the Dixit-Stiglitz kind of a monopolistically competitive model. The total industry output in sector S equal to $\bar{c}^S n_t$.

In both sectors, the respective price is proportional to the wage rate (although the proportions are different). Thus p_t^S/p_t^M is constant, equal to $a_M/(a_S\epsilon)$. Homothetic preference within the manufacturing-goods basket then implies that the ratio of outputs in sectors M and S is constant. This ratio together with the solution of output in sector S determines the output in sector M. The respective employment of labor in sectors M and S is then determined from the production functions and the number of firms in sector S. In turn, the full-employment condition solves the employment and thus output in the agricultural sector.

The Euler equation (A11d), written as $\chi_{T^{**}}^S = \rho a_H \chi_{T^{**}-1}^M$ links $\bar{H}_{T^{**}}$, the initial-period human capital used in market activity in Phase S, to its counterpart in Phase M. Specifically, substituting $\pi_t = 0$ into (A5),

$$\chi_t^S = \frac{\psi(\bar{H}_t)}{\delta\theta_M + \gamma(1-\delta\theta_M)}, \text{ where } \psi(\bar{H}_t) \equiv \bar{H}_t + \xi[n(\bar{H}_t)]^{-\alpha} \ . \qquad \text{(A28)}$$

Using this equation, (A19) and that χ_t^M grows at the rate ρa_H, we write $\chi_{T^{**}}^S = \rho a_H \chi_{T^{**}-1}^M$ as

$$\psi(\bar{H}_{T^{**}}) = \frac{\delta\theta_M + \gamma(1-\delta\theta_M)}{\theta_M + \gamma(1-\theta_M)} \left(\bar{H}_{T^*} + \frac{1}{a_M}\right) (\rho a_H)^{T^{**}-T^*}, \qquad \text{(A29)}$$

which implicitly solves $\bar{H}_{T^{**}}$, given $\bar{H}_{T^*}$.[13]

[13]Of course, the transition date T^{**} itself must be such that $\bar{H}_{T^{**}}$ does not fall short of the critical level $\bar{H}^{**}$. We will examine this condition more specifically in section 4.3.5.

Dynamics in Phase S

We first substitute $\pi_t = 0$ into (A6) and obtain

$$\chi_t^S = \frac{\xi n_t^{-\alpha} + \frac{\bar{h}}{(1-\varphi)(1-\epsilon)} n_t}{\delta \theta_M}. \tag{A30}$$

Since $g_{\chi^S} = \rho a_H$, eqs. (A28) and (A30) imply

$$\rho a_H = \frac{\psi(\bar{H}_{t+1})}{\psi(\bar{H}_t)} = \frac{\xi n_{t+1}^{-\alpha} + \frac{\bar{h}}{(1-\varphi)(1-\epsilon)} n_{t+1}}{\xi n_t^{-\alpha} + \frac{\bar{h}}{(1-\varphi)(1-\epsilon)} n_t}. \tag{A31}$$

These equations govern the dynamics of $\bar{H}_t$ and n_t. It is established in Appendix 5 that $\bar{H}_t$ and n_t increase over time and their dynamic paths are unique. We see from (A31) that the growth rates of both $\bar{H}_t$ and n_t are higher than ρa_H.

The agriculture sector continues to grow at $(\rho a_H)^\gamma$.[14] As argued earlier, the ratio of outputs in the two manufacturing sectors is constant. Hence both manufacturing sectors grow at the same rate even though in one of the sectors the technology is constant-returns and in the other it is increasing-returns. Moreover, since c_t^S is constant over time, this growth rate must be equal to that of n_t. Hence $g_{nt} = g_{Mt}^Y = g_{St}^Y > \rho a_H > g_{Ft}^Y$.

The Cobb-Douglas part of the utility specification in which the Dixit-Stiglitz function is nested gives us the overall price index in terms of good F as $(p_t^M)^{\delta\theta_M\varphi}(p_t^S)^{\delta\theta_M(1-\varphi)}$. We thus define real income as

$$I_t \equiv \frac{E_t}{(p_t^M)^{\delta\theta_M\varphi}(p_t^S)^{\delta\theta_M(1-\varphi)}} = \frac{a_M^{\delta\theta_M\varphi}(a_S\epsilon)^{\delta\theta_M(1-\varphi)}(\chi_t^S - \xi n_t^{-\alpha})}{H_{Ft}^{(1-\gamma)(1-\delta\theta_M)}}, \tag{A32}$$

where we have made use of (A9), (A15), (A23) and (A24). Thus, the growth rate of real income,

$$g_{It} = \frac{\chi_{t+1}^S - \xi n_{t+1}^{-\alpha}}{\chi_t^S - \xi n_t^{-\alpha}} (\rho a_H)^{-(1-\gamma)(1-\delta\theta_M)} > (\rho a_H)^{\gamma+\delta(1-\gamma)\theta_M} > (\rho a_H)^{\gamma+(1-\gamma)\theta_M}, \tag{A33}$$

by utilizing that both χ_t^S and H_{Ft} grow at the rate ρa_H and that $\delta > 1$.

[14] From (A22), χ_t^S is proportional to H_{Ft}. Since χ_t^S grows at ρa_H, so does H_{Ft}.

Furthermore, if the number of varieties produced in sector S is valued in the utility function, its growth must constitute an additional source of rise in the standard of living. Indeed, there is a huge literature in industrial organization and international trade, dating back to Dixit and Stiglitz (1977), which presumes that an increase in the number of varieties is a source of welfare gain. Xie (1998) also emphasizes the role of expanding varieties of consumer goods in long run growth and determination of the trade pattern of an economy. Dinopoulos and Thompson (1998) finds variety expansion as a component of long run growth in an endogenous growth framework where the growth is driven by the endogenous frequency of innovation. In our model, the utility function itself suggests an expression for 'variety-augmented real income', equal to

$$I_t^v = \frac{E_t}{(p_t^M)^{\delta\theta_M\varphi}(P_t)^{\delta\theta_M(1-\varphi)}} = {n_t}^{\alpha\delta\theta_M} I_t, \tag{A34}$$

where P_t, as given in (A24), is equal to $n_t^{-(1-\epsilon)/\epsilon} p_t^S$. As n_t grows, I_t^v grows even faster than I_t.

Note that the economy grows but remains for ever in Phase S. As $t \to \infty$, $g_{nt} = g_{Mt}^Y = g_{St}^Y$ approach ρa_H. The growth rates of real income and variety-augmented real income respectively approach $(\rho a_H)^{\gamma+(1-\gamma)\delta\theta_M}$ and $(\rho a_H)^{\alpha\delta\theta_M+\gamma+(1-\gamma)\delta\theta_M}$; these rates exceed the approaching growth rate of real income in Phase M due to the shift in preferences away from agriculture (implied by $\delta > 1$).

However, as in Phase M, the respective growth rates decline over time in Phase S (proved in Appendix 6). This happens as manufactured goods become less inessential and the income elasticity of demand for them falls gradually over time approaching unity.

It is worth commenting that we use the term "asymptotic" rather than "steady state", because there is no steady state growth possibility for the manufacturing sector in Phase M or Phase S in the sense that there exists no configuration of $\bar{H}_t$ at any

t, which returns the same growth rate period after period. Indeed, the growth rate is different between *any* two periods in Phases M and S.

We now turn to the dynamics of L_t. From the learning equation (A1):

$$\Delta L_t \equiv L_{t+1} - L_t = (1 - L_t)\left(1 - \frac{1}{L_t}\frac{g_{\bar{H}t}}{a_H}\right). \tag{A35}$$

Hence, as $t \to \infty$ and $g_{\bar{H}t} \to \rho a_H$, $\Delta L_t = (1 - L_t)(L_t - \rho)/L_t$ spells the asymptotic dynamics of L_t. We see that $L_{t+1} \gtrless L_t$ as $L_t \gtrless \rho$. That is, if L_t is not asymptotic to ρ, it approaches either 1 or 0, implying either zero income or zero stock of human capital for the next period. Under prefect foresight, these possibilities are obviously ruled out, and thus $\lim_{t\to\infty} L_t \to \rho$; that is, the proportion of time invested in learning equals the time discount factor.

In summary,

Proposition 4.3 *In Phase S,*

(a) The agricultural sector grows at $(\rho a_H)^\gamma$.

(b) Both manufacturing sectors as well as the number of varieties in sector S grow at a common rate higher than ρa_H *and become asymptotic to this rate.*

(c) The real income grows at a rate higher than and becomes asymptotic to $(\rho a_H)^{\gamma+(1-\gamma)\delta\theta_M}$, *which is greater than its approaching growth rate in Phase M.*

(d) The 'variety-augmented real income' grows even at a greater rate.

(e) The proportion of labor time invested in learning is asymptotic to the discount factor ρ.

Intuitively, as the introduction of the mass production sector initiates a change in preferences toward the non-agricultural goods (which works like the Engel's Law) and these sectors grow at a higher rate than does agriculture, there is an increase in the growth rate of real income. A positive growth rate of the number of varieties available is a further source of enhancement of real income growth.

Phase S is akin to an infinite-horizon Ramsey economy. Its initial history is given by initial level of total human capital $H_{T^{**}}$ (not $\bar{H}_{T^{**}} = (1 - L_{T^{**}})H_{T^{**}}$, which is the amount of human capital engaged in market activity). The question remains as to how rational agents choose $L_{T^{**}}$ and how L_t evolves over time and becomes asymptotic to ρ.

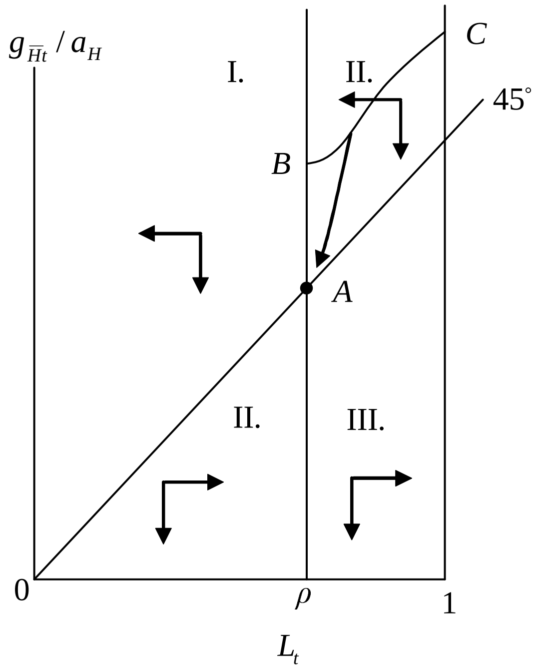

Figure 4.4: Dynamics of L_t in Phase S

From eq. (A35), $\Delta L_t \gtreqless 0$ as $g_{\bar{H}t}/a_H \lesseqgtr L_t$. Figure 4.4 depicts this in the $(L_t,\ g_{\bar{H}t}/a_H)$ space. By construction, $\Delta L_t \gtrless 0$ below and above 45° line respectively. This explains the directions of horizontal arrows. We already know that $g_{\bar{H}t}$ declines over time. Hence all vertical arrows point downward. We also know that $g_{\bar{H}t}/a_H$ and, under perfect foresight, L_t, both become asymptotic to ρ, i.e. both move so as to get arbitrarily close to the point A on the 45° line. It is straightforward to see that the perfect foresight path lies in the region II. Accordingly, throughout Phase S, L_t is greater than ρ, falls monotonically and becomes asymptotic to ρ.

In view of (A31), $g_{\bar{H}t}$ equals $\psi^{-1}[\rho a_H \psi(\bar{H}_t)]/\bar{H}_t \equiv \Omega(\bar{H}_t)$, a function of $\bar{H}_t$. Since

$g_{\bar{H}t}$ declines monotonically with time and $\bar{H}_t$ increases over time, it follows that $g_{\bar{H}t}$ decreases with $\bar{H}_t$, i.e., $\Omega'(\bar{H}_t) < 0$. At the initial period, T^{**}, we have $g_{\bar{H}t}|_{t=T^{**}} = \Omega[(1 - L_{T^{**}})\bar{H}_{T^{**}}]$. Since $\Omega'(\cdot) < 0$, for any given value of $\bar{H}_0$, there is thus a positive schedule between $g_{\bar{H}t}|_{t=T^{**}}/a_H$ and $L_{T^{**}}$. This schedule is marked BC in Figure 4.4. The dynamic system of the economy in Phase S originates from that point on BC such that both $g_{\bar{H}t}/a_H$ and L_t become asymptotic to ρ. Given the direction of arrows, Figure 4.4 is indicative that the perfect foresight path is unique, consistent with a unique value or solution of $L_{T^{**}}$. A formal proof of the uniqueness of the perfect foresight path is provided in Appendix 6.

4.3.4 Overall Dynamics

Provided that at time 0, the economy is in Phase F and H_0 is known historically, any particular value of L_0 yields a specific value of $\bar{H}_0$. Once $\bar{H}_0$ is known, the entire path of $\bar{H}_t$ and hence that of $g_{\bar{H}t}$ are determined, *independent* of future values of L_t. Given $\{g_{\bar{H}t}\}_0^\infty$, $\{L_t\}_1^\infty$ is obtained from eq. (A35). However, L_t may or may not become asymptotic to ρ. Corresponding to H_0, that value of L_0 such that (A35) leads to L_t being asymptotic to ρ is the prefect-foresight solution of L_0.[15]

It is proved in Appendix 6 that, $L_t > \rho$ in phases F and M also. In view of (A35), this implies that in Phase F in which $g_{\bar{H}t} = \rho a_H$, L_t increases monotonically. Whether the path of L_t in Phase M is monotonic is unclear however.

4.3.5 Transition-Date Sequence and Conditions

Since good F is the essential good and the manufacturing goods are not, at sufficiently low levels of human capital only good F will be produced in equilibrium.

[15] This constitutes the basis of solving the dynamics of the model in our simulation exercise.

In section 4.2 we have discussed at length the rationale behind our assumption of shifting preferences. Relative to u^F, we can interpret u^M as the *newer self.* Likewise, relative to u^M, u^S defines the newer self. We make the (forward-looking) assumption that it is the preference of the newer self, which facilitates the advent of industrial goods in the economy. As the stock of human capital and per capita real income grow over time, the newer self's willingness to pay for good M or good S rises enough so as to make the production of these goods viable. Since the preferences of the newer self governs the respective equilibrium, this assumption is *equivalent to* saying that good M (respectively good S) will be introduced at the earliest period when in the two-sector model (respectively in the three-sector model), the output of good M (respectively good S) becomes positive. Because preferences are such that no old good becomes perfectly substituted by some other, once a sector opens it will not close as long as the economy experiences a positive rate of growth.

We now formally develop the respective transition conditions. For simplicity, we shall call the new self's willingness to pay as the consumer's willingness to pay.

Phase F to Phase M

Assume for now that the economy can move from Phase F to Phase M, not directly to Phase S. This transition occurs when the minimum level of $\bar{H}_t$ that can sustain sector M is attained. The condition for the transition is that the consumer price at an arbitrarily small amount of consumption of good M, say p_t^{MC}, is able to cover the unit cost of producing this good, i.e., $p_t^{MC} \geq W_t/a_M$.

As human capital (effective labor supply) accumulates, W_t, the reward to a unit of labor, tends to fall but total earnings increase and by income effect the willingness to pay for good M, same as p_t^{MC}, tends to increase. Hence the *ratio* of p_t^{MC} to W_t rises over time. It follows that the transition condition is met and sector M opens only when $\bar{H}_t$

attains a threshold, say $\bar{H}^*$, such that $p_t^{MC} = W_t/a_M$. The expression of $\bar{H}^*$ is derived below.

From (A5), zero consumption of good M is equivalent to

$$\theta_M \tilde{E}_t = p_t^{MC}.$$

Using $E_t = W_t \bar{H}_t + R_t$, the expression of R_t given in (A13), the relation $\tilde{E}_t = E_t + p_t^M$, the goods-market clearing condition (A17) and substituting p_t^{MC} for p_t^M, we obtain

$$\tilde{E}_t = \frac{W_t \bar{H}_t + p_t^{MC}}{1-(1-\gamma)(1-\theta_M)}.$$

Solving the last two equations simultaneously yields

$$\frac{p_t^{MC}}{W_t} = \frac{\theta_M \bar{H}_t}{\gamma(1-\theta_M)},$$

which is increasing in $\bar{H}_t$. The minimum level of $\bar{H}_t$ required for sector M to open, $\bar{H}^*$ is the solution of $\bar{H}_t$ when $p_t^{MC} = W_t/a_M$. Thus

$$\bar{H}^* = \frac{\gamma(1-\theta_M)}{\theta_M a_M}. \tag{A36}$$

Next, in view of (A14), $\chi_{T^*-1}^F = \bar{H}_{T^*-1}/\gamma = \bar{H}_0(\rho a_H)^{T^*-1}/\gamma$, and from (A19), $\bar{H}_{T^*} = \chi_{T^*}^M[\theta_M + \gamma(1-\theta_M)] - 1/a_M$. Using these, the Euler equation (A11b), written as $\chi_{T^*}^M = \rho a_H \chi_{T^*-1}^F$, yields

$$\bar{H}_{T^*} = \frac{\rho a_H[\theta_M + \gamma(1-\theta_M)]}{\gamma}\bar{H}_0(\rho a_H)^{T^*-1} - \frac{1}{a_M}.$$

This leads to solution of the opening date for sector M, equal to the earliest date at which $\bar{H}_{T^*} \geq \bar{H}^*$:

$$T^* = \min\left\{ t \,\middle|\, \frac{\rho a_H[\theta_M + \gamma(1-\theta_M)]}{\gamma}\bar{H}_0(\rho a_H)^{t-1} - \frac{1}{a_M} \geq \bar{H}^* \equiv \frac{\gamma(1-\theta_M)}{\theta_M a_M} \right\}. \tag{A37}$$

Phase M to Phase S

This transition occurs when it is possible for a positive measure of monopolistically competitive firms to earn zero (normal) profits, along with the outputs in the remaining two sectors being non-negative.

Turning back to our analysis of static general equilibrium with three sectors, we observe that these conditions are met when $\bar{H}_t \geq H^{**}$, where the latter is defined in defined in (A27). Before this threshold is attained, the market size is not big enough and hence the scale economies are not large enough for firms in sector S to break even. Fixed costs being the source of scale economies, an equivalent way of looking at it is that unless the market size is above a threshold, the amount produced by a single firm will be too small to cover the fixed cost.

Notice that, apart from the fixed cost parameter $\bar{h}$, other technology parameters such as a_M and a_S appear in the expression of $\bar{H}^{**}$ (through ξ). Intuitively, higher values of technical efficiency parameters a_M and a_S tends to push down W_t, the cost of one unit of effective labor, and a higher value of the preference shift parameter δ tends to push up the consumer price for the basket of manufactured goods. Hence, they all imply the viability of sector S at a lower value of $\bar{H}^{**}$ and thus an earlier opening date for Phase S. On the other hand, a higher value of the fixed-cost parameter $\bar{h}$ implies a higher value of $\bar{H}^{**}$ and therefore a later opening date for Phase S.

In general, $\bar{H}^{**} \gtreqless \bar{H}^{*}$. That is, without further restrictions, the economy may jump from Phase F to Phase S directly. It is because non-essentiality of consumption holds for entire basket of manufactured goods (captured by the parameter b, which we have normalized to one). There is no differential degree of non-essentiality between good M and good S.

We assume that $\bar{h}$ is above a threshold, such that $\bar{H}^{**} > \bar{H}^{*}$, i.e., Phase S follows

Phase M. This condition can be written explicitly as

$$\bar{h} > h_0, \text{ where } h_0 \equiv \frac{\alpha\gamma(1-\varphi)(1-\epsilon)}{\delta\theta_M + \gamma(1-\delta\theta_M)} \cdot \left[\frac{\delta(1-\theta_M)}{(1+\alpha)a_M}\right]^{\frac{1+\alpha}{\alpha}} \cdot \frac{1}{[\xi(1-\delta\theta_M)]^{\frac{1}{\alpha}}}. \quad \text{(A38)}$$

Recall that T^{**} denotes the date of the opening of sector S and we already have an implicit solution of $\bar{H}_{T^{**}}$ in (A29) as a function of time. Using this

$$T^{**} = \min \ \left\{t | \, \psi^{-1} \left[\left\{ \frac{\delta\theta_M + \gamma(1-\delta\theta_M)}{\theta_M + \gamma(1-\theta_M)} \right\} \left(\bar{H}_{T^*} + \frac{1}{a_M} \right) (\rho a_H)^{t-T^*} \right] \geq \bar{H}^{**} \right\}. \quad \text{(A39)}$$

It is worth noting that although the preference shift parameter δ is a determinant of the date of this transition, it is not qualitatively important: even if $\delta = 1$, there is a solution of T^{**}.[16]

4.4 Calibration and Sensitivity Analysis

Because mass production was commercially successful in the U.S. first and unlike the developed countries in Europe, it was not devastated by the World Wars, it is natural to assess how far the model is able to replicate the experience of the U.S. in terms of per capita real income growth.

As can be seen from Figure 4.1, the per capita real GDP of the U.S. varied little prior to 1600AD and since this date has shown a positive trend. Our analysis is designed to explain the growth segment, not the preceding stagnation. We choose 1500AD as the starting date of our analysis, a century ahead of the beginning of the positive-per-capita growth era.

[16] The condition $\delta > 1$ ensures that the asymptotic growth rate in Phase S exceeds the approaching growth rate of real income in Phase M.

4.4.1 Choice of Parameter Values

Among the model parameters, some are directly taken from the literature, while others are chosen so as to replicate a few data points of the U.S. economy.

The discount factor ρ is set, equivalent to approximately 4% annual discount rate (as in Einarsson and Marquis, 2001). In our model human capital grows in the long run (in the third stage) at the rate ρa_H, which is the long-run growth rate of the manufacturing sector in the third stage. Given ρ, the value of a_H was chosen such that ρa_H matches the growth rate of the U.S. manufacturing output per worker during the period 1950-2000, equal to 2% annually (Forbes, 2004). The parameter γ in the agricultural production function is set to make the growth rate in the agricultural stage $(\rho a_H)^\gamma$ consistent with the growth rate of U.S. GDP per capita during 1500-1820, equal to 0.34% (Maddison, 2004).

The share of expenditure on food prior to 1800 is taken from Clark (2007) while Caplow, Hicks and Wattenberg (2001) report its value for 1901 and 1997. The average of the figures for 1800 and 1901 is equal to 0.625. Accordingly, we choose $\theta_M = 1 - 0.625 = 0.375$.

In Phase S the share of food in the total expenditure approaches $1 - \delta\theta_M$. We equate it to 0.33, which is the simple average of expenditure shares of food in 1901 and 1997, as given in Caplow, Hicks and Wattenberg (2001). Thus $\delta\theta_M = 1 - 0.33 = 0.67$. Given $\theta_M = 0.375$, $\delta = 1.79$. The parameter ϵ is taken equal to 0.7, based on Wu and Zhang (2000).

There is no near-direct estimate available for φ, the expenditure allocation parameter within the category of industrial goods. We choose $\varphi = 0.5$, the midpoint between 0 and 1. Alternatively, the average share of consumer durables in total expenditure in the U.S. over 1944-53 as well as 1990 has been estimated at 0.37 (Juster and Lipsey, 1967 and Lipsey 1998). Presuming that such goods belong to sector S since they typically involve huge fixed cost of production, the value 0.37 may be assumed to represent the expenditure share of all goods in this sector. In our model, $\delta\theta_M(1-\varphi)$ is the expression of this share in the long run. Equating it to 0.37 and using the values of θ_M and δ, we also arrive at $\varphi = 0.5$.

Finally, the initial value of human capital adjusted for labor time available for market activities $\bar{H}_0$ is chosen such that the agricultural output at the starting date 0 matches the U.S. real GDP (measured in the scale of thousand 1990 International Geary-Khamis dollars) in 1500 AD; doing so yields $\bar{H}_0 = 0.00456$. These parameter values are summarized in Table 1 for ease of reference.

Table 4.1: Parameter Values Chosen for all Simulations

ρ	a_H	γ	θ_M	δ	ϵ	φ	$\bar{H}_0$
0.96	1.0625	0.17	0.375	1.79	0.7	0.5	0.00456

There are three remaining parameters: a_M, a_S and $\bar{h}$. The productivity parameter a_M is chosen by matching the predicted per capita real income with the actual per capita real GDP (measured in the scale of thousand 1990 International Geary-Khamis dollars) of a selected year in Phase M. We consider two alternative years, namely, 1870 and 1880 – which are 'far' after when the first surge of industrial activity is believed to have occurred and before mass production became commercialized.

Similarly, the parameter a_S was chosen such that the simulated figure of per capita income matches the actual for a selected year in Phase S. We alternatively choose 1950 and 1960.[17] These choices are motivated by that our model is not purported to explain

[17] It may be noted that Tamura (2002) chose parametric values such that the simulated figures for 1850 and 1996 matched the actual per capita U.S. real GDP in those years – and 1850 was chosen as the year of transition from agriculture to industry. Another such example is Todo and Miyamoto

per se the post WWII growth experience of the developed countries till date.

The fixed-cost parameter $\bar{h}$ is implicitly determined by normalizing the minimum output (that a firm produces after meeting fixed cost) to unity, so that net output to be sold in the market is non-negative (see, for example Devereux, Head and Lapham, 1996). It yields $\bar{h}a_S = 1$. This schedule and the relation matching simulated value of per capita income to the actual in 1950 or 1960 simultaneously determine a_S and $\bar{h}$.

Table 2 lists the values of a_M, a_S and $\bar{h}$ corresponding to various pairings of one year selected from $\{1870, 1880\}$ and another from $\{1950, 1960\}$.

4.4.2 Results

The main objective of our simulations exercise is two-fold: (a) to predict the transition dates and (b) to show the goodness of fit of the simulated per-capita real GDP series with the actual time series.[18] In particular, predicting the transition dates, we believe, is novel compared to the existing literature. For instance, in Hansen and Prescott (2002), the simulated series of wage, population and rentals before and after the transition show qualitative similarity with the actual time series of these variables, but inferring the date

(2002), who developed a R&D based endogenous growth model with costly international knowledge diffusion and calibrated their model for seventeen advanced economies in order to explore existence of scale effect in per capita income growth. In attempting to predict the number of people in the R&D sector in the post-war U.S., they chose the parameter values such that the simulated number of people in R&D sector in U.S. in a given pre-war year matches with the actual.

This practice does not necessarily bias the simulated series to the actual series on the average, since, in principle, the average distance between an actual series and a simulated one without any such matching may very well be less than that between the actual and a simulated series that matches the actual data at some selected dates.

[18] Note that the price deflator used in generating the theoretical time series is different over the phases, reflecting the change in preferences. But this is not an issue, since the actual time series of real variables use price deflators that change over time as the pattern of expenditure changes.

Table 4.2: 'Predicting' Transition Dates and % Deviation from Actual (U.S. Per Capita Real GDP)

Matching real per-Capita GDP at	Other Parameter Values			Transition Date: Phase F to Phase M	Transition Date: Phase M to Phase S	Average % Deviation
	a_M	a_S	$\bar{h}$			
A. 1870 & 1950	0.137	0.093	10.75	1833	1904	11.46
B. 1870 & 1960	0.137	0.091	10.99	1833	1905	11.57
C. 1880 & 1950	0.175	0.07	14.29	1821	1905	13.17
D. 1880 & 1960	0.175	0.07	14.29	1821	1905	13.17

or year of transition from agriculture to industry is not an objective. In Tamura (2002), the transition date is fixed at 1850, while the model is used to replicate the per-capita real GDP and population before and after this date.

Numerically solving the dynamics of the model including deriving the transition dates is fairly straightforward. Given $\bar{H}_0$ and the parameter values, the dynamics of $\bar{H}_t$ through Phases A and M follow eqs.(A14) and (A19). In the process, the first transition date is solved by using (A37). The dynamics of other variables are solved from that of $\bar{H}_t$.

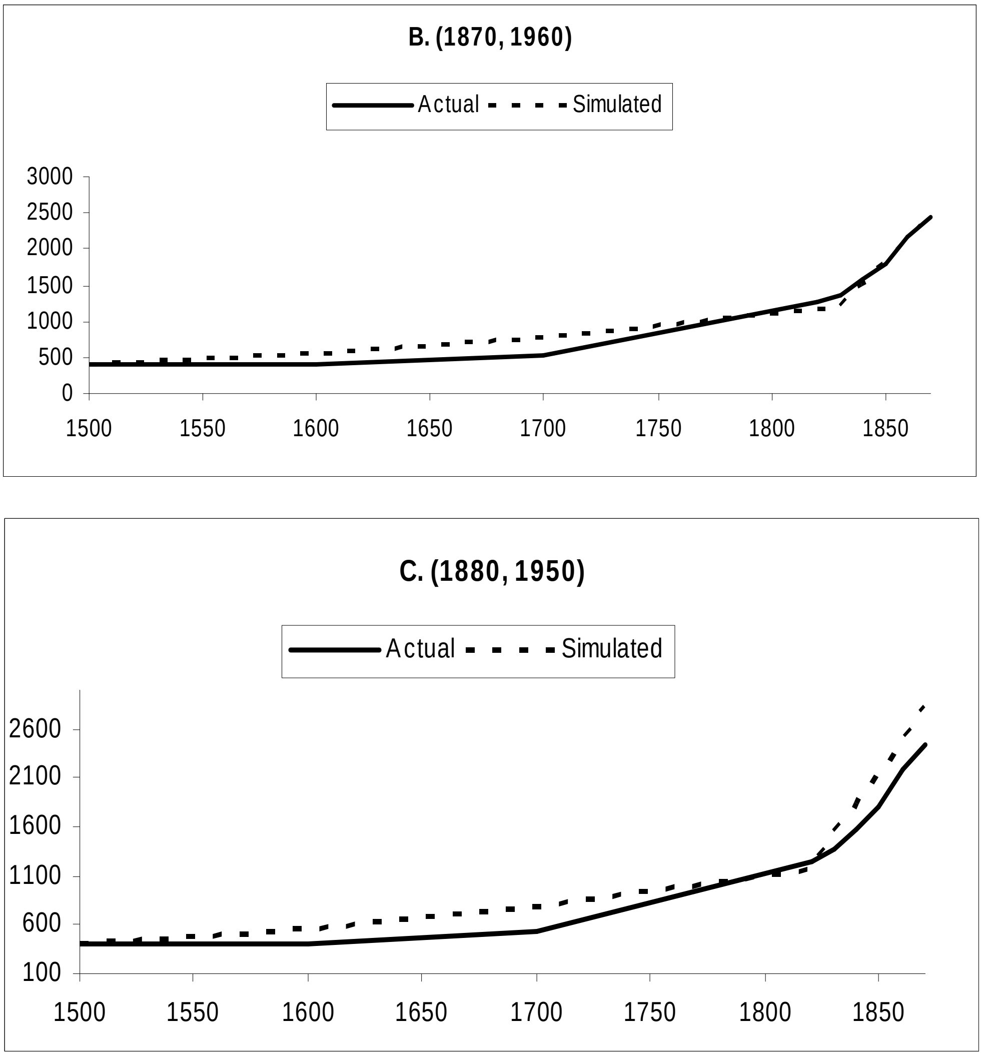

Figure 4.5: Per Capita Real GDP in 1990 International Geary-Khamis Dollars over 1500-1870

Solving the second transition date is a bit more complicated. The dynamics of $\bar{H}_t$ in Phase S, stated in (A31), contains the variable n_t. Eq. (A26), being non-linear, does not yield a closed-form solution of n_t in terms of $\bar{H}_t$. Hence there is no single closed-form equation describing the dynamics of $\bar{H}_t$. Using the dynamic equation (A19) in phase M, we simultaneously solve the Euler condition (A11d) and eq. (A26) by iteration until $\bar{H}_t$ begins to exceeds to the critical value $\bar{H}^{**}$. This amounts to solving eq. (A39) and determines the second transition date, T^{**} as well as $\bar{H}_{T^{**}}$.[19]

Given $\bar{H}_{T^{**}}$ and $n_{T^{**}}$, eqs. (A31) are iterated to solve $\bar{H}_t$ and n_t for subsequent periods in Phase S. The solutions of the dynamics of other variables follow.

Once the entire path of $\bar{H}_t$ is determined, that of $g_{\bar{H}t}$ computed. We choose a value for L_0 in the interval $(\rho, 1)$, iterate eq. (A35) by using the series $\{g_{\bar{H}t}\}$ and check if L_t diverges away from or converges toward ρ. By trial, we compute that (unique) value of L_0 such that $L_t \to \rho$. This is the perfect-foresight solution of L_0 and the entire path of L_t.

Table 4.2 reports the results of our simulation. The model predicts the first transition – from agriculture to industry – between 1821 and 1833, which is well within the historically accepted period of this transition. The second transition dates are close to the year 1900. Although Ford's use of mass production technique in producing model T cars in 1913 is considered a land-mark event and the adoption of this technique in American manufacturing continued well into the 1920s, mass production enterprises began to form successfully around and even before 1900 for the manufacture of tobacco products, matches, detergents, photographic film, metal-making etc.; a prominent example is Andrew Carnegie's use of the Bessemer method of producing steel by the turn of the century (Kaplan, 1984; Boyce, 1989). Hence the model's prediction of the second transition date seems to be within what may be called the initial wave of the commercialization of the

[19]The latter may exceed $\bar{H}^{**}$ since time is discrete.

mass production method.

Consider the last column of Table 4.2. The average absolute percentage deviation of the simulated series from the actual remains within in the range of 11.46 to 13.17%.[20]

Figures 4.5 and 4.6 illustrate the simulated paths relative to the actual time series of per-capita real GDP of the U.S. for cases B and C listed in Table 4.2. (The graphs for other cases are quite similar.) The former shows it over the period 1500 to 1870, which includes the transition from Phase F to Phase M. The latter depicts those for the period from 1870 to 1990. It is of some interest to note that at the time of the second transition there is a fall in the level of real GDP in the simulated series. As discussed earlier at the end of section 4.3.2, this can very well happen, since the price-index function is different for each phase.[21]

Figures 4.5 and 4.6 also show predicted time paths assuming no transition to mass production. Clearly, introducing mass production delivers a better goodness-of-fit.

However, we do notice that while our mass-production model is an improvement from one without it, it still under-predicts the actual movement of real per capita GDP in the most recent decades. This is indicative that other factors or structural changes must be taken into account if the objective is to better predict the relatively more recent experience. We shall comment further on this in the concluding section.

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[20] In calculating these averages we used the data points for the years 1500, 1600, 1700, 1820 and the beginning years of all following decades (e.g. 1830, 1840 etc.) up to 1990. Tamura (2002) provides the % deviation with respect to his simulated model for only eleven selected years over the interval 1500 to 1996. Hence his averages are not comparable to ours.

[21] Ceteris paribus, if we were, for instance, to choose a sufficiently high value of the productivity parameter of a_S so that the relative price of the new good S is sufficiently low, then real GDP in the simulated series would not have declined.

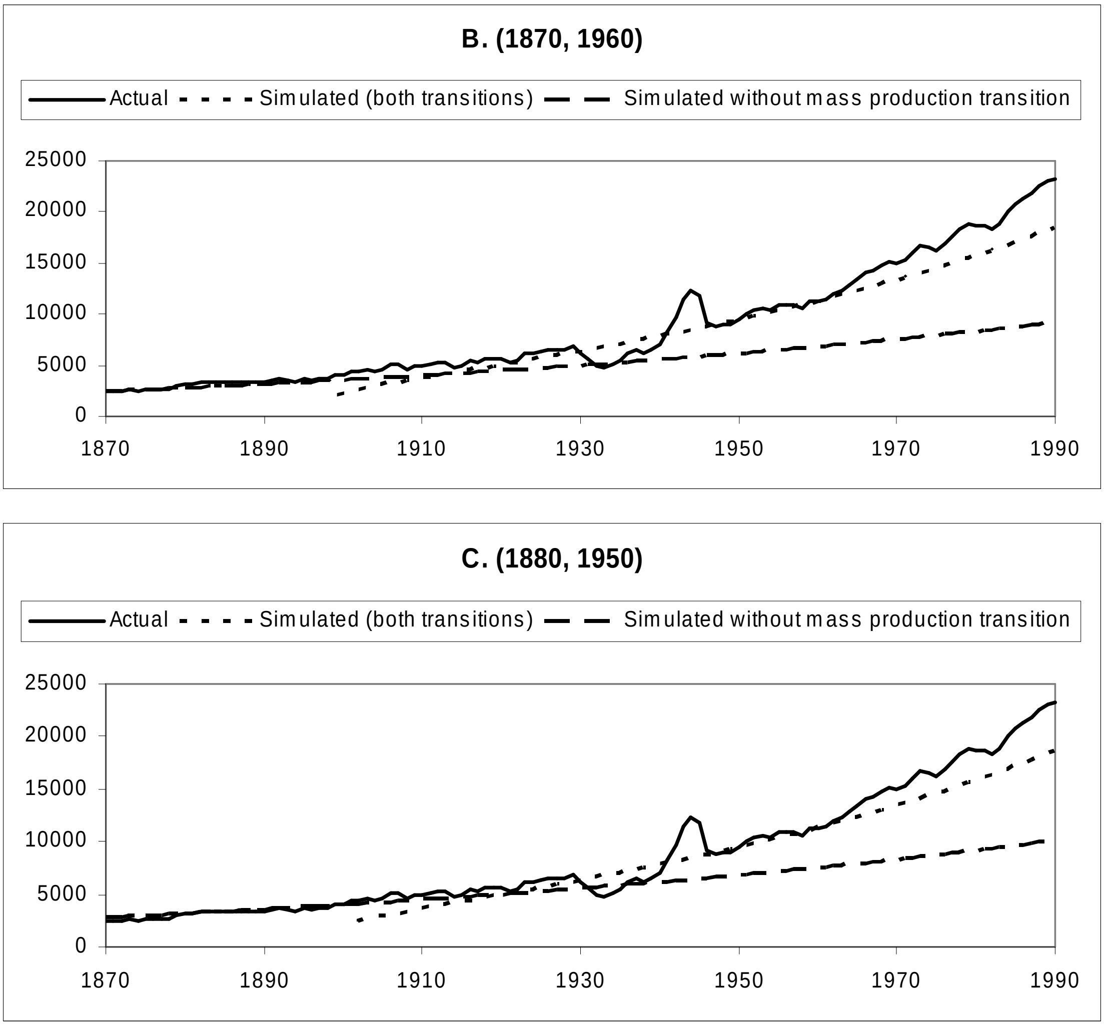

Figure 4.6: Per Capita Real GDP in 1990 International Geary-Khamis Dollars over 1870-1990

4.4.3 Sensitivity Analysis

We now fix one of the calibrated models and consider variations of several parameters, one at a time. A priori, we select the case D as our benchmark. Table 4.3 provide the summary of results.

The first column lists the parameter and the magnitude of variation considered (around its value given in Table 4.1). As one can see, the transition dates as well as the overall goodness-of-fit are highly sensitive to the value of a_H, and, furthermore, the sensitiveness varies with the direction of the variation of the parameter a_H. Increasing it even by 0.5% hastens both transitions by more than sixty years, while lowering it by the same percentage delays each transition by more than a century. Such ultra-sensitiveness results from it being a growth parameter.[22]

Transition dates are not so sensitive with respect to changes in other parameters (except ρ), since they only exert level effects. Increasing (decreasing) the share of labor in agriculture (γ) by 20% delays (hastens) both transitions by a decade. A higher (lower) value of θ_M by 20% hastens (delays) both the transitions by almost a decade.

An increase (a decrease) in δ, the parameter signifying the rise in the long-run expenditure share of manufacturing as a whole in Phase S by 20% does not change the first transition date from the benchmark case, while the second transition date is hastened (delayed) by about a decade.

[22]Over centuries of time periods, a very small variation in it results in a relatively large cumulative effect on $\bar{H}_t$. Furthermore, a_H is *not* a determinant of the critical level of $\bar{H}$, which ushers any of the two transitions. For example, a 1% increase in a_H implies nearly a nineteen hundred per cent increase in the growth factor $(\rho a_H)^t$ over 300 years (as $(1.01)^{300} = 19.79$) and thus hastens the transition dates by several decades.

In Tamura (2002), human capital also grows via a linear learning technology, and, for the same reason, raising (lowering) the productivity parameter by 2.5% hastens (delays) the industrial revolution almost by 250 years relative to the break year of 1850 in his model.

Table 4.3: Sensitivity Analysis

Parameter: (% change)		Av. Deviation %	1st Transition Date	2nd Transition Date
$a_H : \pm 0.5$	Higher	347.57	1756	1824
	Lower	60.29	1929	2042
$\gamma : \pm 20$	Higher	13.34	1830	1914
	Lower	21.54	1810	1894
$\theta_M : \pm 20$	Higher	25.35	1812	1896
	Lower	21.52	1832	1916
$\delta : \pm 20$	Higher	19.38	1821	1897
	Lower	20.42	1821	1915
$\varphi : \pm 20$	Higher	14.17	1821	1897
	Lower	16.41	1821	1910
$\epsilon : \pm 20$	Higher	13.61	1821	1891
	Lower	13.85	1821	1916

Raising (lowering) in φ, the expenditure allocation parameter within the category of industrial goods in favor of traditional (mass-production) manufacturing delays (hastens) the second transition by a few years, while the first transition date does not change.

The parameter of substitution among the varieties in the basket of good S, ϵ, was varied as well. An increase (a decrease) in it by 20% hastens (delays) the second transition date by more than a decade.

Interestingly, the average deviations increase with different variations considered, but overall remain moderate (except for those of a_H).

Finally, it may be noted that while the actual per capita real GDP figures for particular years were used to primarily estimate the coefficients of the production functions in sector M and S, this choice partly influences the determination of transition dates. A sensitivity check was done especially for the second transition. Relative to the benchmark case in which the post WWII matching year chosen was 1960 and the derived date of the second transition was 1905, we tried 1970 and 1980. The respective dates came out to be 1897 and 1894. Thus, the model is fairly resilient in generating the introduction of mass production around the turn of the twentieth century.

4.5 Concluding Remarks

While the existing literature on the transition of developed countries has focused on the transformation of economies from being agricultural to industrial, the current analysis has introduced a second transition: from traditional manufacturing to modern manufacturing characterized by increasing returns. This is different from the Murphy-Shleifer-Vishny's big-push model in three aspects: (a) ours is a dynamic and a growth model, (b) it incorporates two transitions and (c) both transitions are endogenous.

In our model the source of growth lies in the accumulation of human capital. We have also introduced preference change as new goods are introduced (but there is no exogenous change in preferences dependent on time). Non-essentiality of industrial goods in the preference implies that traditional manufacturing become viable only after the agrarian economy lasts for some time. The viability of the mass production sector lagging that of traditional manufacturing stems from a sufficiently threshold level of the fixed-cost component in the mass production technology.

Each transition is associated with a jump in the long-run growth rate of real income. In particular, the second transition entails, besides an increase in the growth rate of real income, a positive growth in the number of varieties available and this is a further source of growth of utility.

We have also carried out calibration exercises, aiming to mimic the time series of per-capita real GDP of the U.S. (for nearly 500 years, starting from the year 1500). Of particular interest is the predicted year of each transition. As Table 4.2 shows, across the four calibrations, the first transition is dated between 1821 and 1833 – very much within the range of decades (1800 to 1850) considered to mark the beginning of the industrial stage of economies in Western Europe and the U.S. The transition to mass production dates in the vicinity of 1900. This is also consistent with historical accounts (see, for example, Besanko et. al., 2007, among others).

However, our analysis does not model transition as a process over time: it occurs as a one-shot shift in regime. As a matter of fact, the incorporation of mass production techniques into the mainstream of American industry took decades – starting from successful commercialization in sectors like steel, aluminum, chemicals etc. already by the beginning of the twentieth century to what may be called an entrenchment of "Fordism" by 1920s. Future analysis must consider transition as a phase in itself, which, in particular, will have the potential to explain the rise in the growth rate of standard of living in the U.S. around 1920s – which our model does not generate. Nonetheless, we regard our model as a step toward looking into alternative and more enriched depictions of growth and transition involving mass production.

We must mention that our analysis is not designed to explain or accommodate various factors or structural changes underlying the rapid growth experience of developed countries after World War II. The central idea of this analysis is to demonstrate a simple mechanism behind how, over a long course of time, an economy may pass from an agrarian state with decreasing-returns technology to an industrial state with constant-returns and then from that to mass production characterized by increasing-returns.

For instance, the rise of the service sector is a major post WWII phenomenon in the world economy; see Buera and Kaboski (2006). In their opinion this is the "greatest transformation of the structure of production since the Industrial Revolution." Kenny and Florida (1993) have argued that the Japanese method of blending innovation with production has become a "revolutionary method" of organizing production. They see this as a "fundamental supersession and potential successor to mass production fordism." It is also arguable that the recent surge of IT sectors and IT products have fundamentally changed technology and our consumption pattern.

Last but not least at all, like Murphy, Schleifer and Vishny (1989), our analysis throughout assumes a closed economy. International trade and investment, outsourcing etc. must be taken into account in explaining real income movements and growth/transition experience of developing countries in particular. A natural extension in the context of transition in an open economy will be to explore how transition may induce a dynamic pattern in the international trade in a framework similar to Dinopoulos and Wooton (1989).

Appendices

Appendix 3: Household's Dynamic Optimization Problem and Euler Equations

We set up the Lagrangian:

$$\begin{aligned}\mathcal{L} = &\sum_{t=0}^{T^*-1} \rho^t \ln c_t^F + \sum_{t=T^*}^{T^{**}-1} \rho^t v_t^M + \sum_{t=T^{**}}^{\infty} \rho^t v_t^S \\ &+ \sum_{t=0}^{\infty} \kappa_t (a_H L_t H_t - H_{t+1}) + \sum_{t=0}^{T^*-1} \lambda_t^F [W_t(1-L_t)H_t + R_t - c_t^F] \\ &+ \sum_{t=T^*}^{T^{**}-1} \lambda_t^M [W_t(1-L_t)H_t + R_t - (\tilde{E}_t - p_t^M)] \\ &+ \sum_{t=T^{**}}^{\infty} \lambda_t^S \left\{ W_t(1-L_t)H_t + R_t - \left[\breve{E}_t - \frac{(p_t^M)^{\varphi} P_t^{1-\varphi}}{\varphi^{\varphi}(1-\varphi)^{1-\varphi}} \right] \right\}\end{aligned}$$

The first-order conditions are:

$$\begin{aligned}\frac{\rho^t}{c_t^F} &= \lambda_t^F, \text{ for } t \in [0, T^*-1] \\ \frac{\rho^t}{\tilde{E}_t} &= \lambda_t^M, \text{ for } t \in [T^*, T^{**}-1] \\ \frac{\rho^t}{\breve{E}_t} &= \lambda_t^S, \text{ for } t \geq T^{**}\end{aligned} \tag{A1}$$

$$a_H \kappa_t = \begin{cases} \lambda_t^F W_t & \text{for } t \in [0, T^*-1] \\ \lambda_t^M W_t & \text{for } t \in [T^*, T^{**}-1] \\ \lambda_t^S W_t & \text{for } t \geq T^{**} \end{cases} \tag{A2}$$

$$\kappa_{t-1} = \begin{cases} \kappa_t a_H L_t + \lambda_t^F W_t (1-L_t) \text{ for } t \in [1, T^*-1] \\ \kappa_t a_H L_t + \lambda_t^M W_t (1-L_t) \text{ for } t \in [T^*, T^{**}-1] \\ \kappa_t a_H L_t + \lambda_t^S W_t (1-L_t) \text{ for } t \geq T^{**}. \end{cases} \tag{A3}$$

Combining (A2) and (A3),

$$a_H\kappa_0 = \lambda_0^F W_0$$

$$a_H\kappa_t = \kappa_{t-1} = \begin{cases} \lambda_t^F W_t \text{ for } t \in [1, T^* - 1] \\ \lambda_t^M W_t \text{ for } t \in [T^*, T^{**} - 1] \\ \lambda_t^S W_t \text{ for } t \geq T^{**}. \end{cases} \tag{A4}$$

Eliminating the multipliers from the above equations gives the Euler equations in the text.

Appendix 4: Derivation of Eq. (A25)

By utilizing (A8), (A9), (A15) and (A24), we obtain the following expressions for the quantities demanded of good M and any particular variety of good S:

$$c_t^M = \varphi a_M(\delta\theta_M \chi_t^S - \xi n_t^{-\alpha}); \quad c_t^S = \frac{(1-\varphi)a_S\epsilon}{n_t}\left(\delta\theta_M \chi_t^S - \xi n_t^{-\alpha}\right),$$

where, recall that $\chi_t^S = \breve{E}_t/W_t$. Using the mark-up rule, the above expression of c_t^S and that $\pi_t = (p_t^S - W_t/a_S)c_t^S - W_t\bar{h}$, we obtain

$$\frac{\pi_t}{W_t} = \frac{(1-\varphi)(1-\epsilon)}{n_t}\left(\delta\theta_M \chi_t^S - \xi n_t^{-\alpha}\right) - \bar{h}. \tag{A5}$$

Next, by definition,

$$\frac{E_t}{W_t} = \bar{H}_t + n_t\frac{\pi_t}{W_t} + (1-\gamma)\frac{H_{Ft}^\gamma}{W_t}.$$

Substitute the above expression as well as (A15), (A22) and the expression of p_t^S in (A24) in $\breve{E}_t$ given in (A9) and obtain

$$\chi_t^S = \bar{H}_t + n_t\frac{\pi_t}{W_t} + (1-\gamma)\frac{H_{Ft}^\gamma}{W_t} + \xi n_t^{-\alpha}.$$

In turn, substitute this into the market-clearing condition (A22) expressed as $\chi_t^S = H_{Ft}^\gamma/[W_t(1-\delta\theta_M)]$ and eliminate H_{Ft}^γ/W_t. This yields

$$\chi_t^S = \frac{\bar{H}_t + n_t\frac{\pi_t}{W_t} + \xi n_t^{-\alpha}}{\delta\theta_M + \gamma(1-\delta\theta_M)}, \tag{A6}$$

which is a restatement of the market-clearing condition (A22).

Solving eqs. (A5) and (A6) simultaneously for π_t/W_t and χ_t^S yields eq. (A25).

Appendix 5: Dynamics of $\bar{H}_t$ and n_t in Phase S

Consider the function $n(\bar{H}_t)$. Totally differentiating (A26),

$$\frac{dn_t}{d\bar{H}_t} = \frac{(1-\varphi)\delta\theta_M}{[\delta\theta_M + \gamma(1-\delta\theta_M)]\left\{\frac{\bar{h}}{1-\epsilon} - \alpha C[n(H_t)]^{-(1+\alpha)}\right\}}, \text{ where } C \equiv \frac{\gamma\xi(1-\varphi)(1-\delta\theta_M)}{\delta\theta_M + \gamma(1-\delta\theta_M)}.$$

Recall that $\psi(\bar{H}_t) \equiv \bar{H}_t + \xi[n(\bar{H}_t)]^{-\alpha}$. Using the above expression, we get

$$\psi'(\bar{H}_t) = \frac{\frac{\bar{h}}{1-\epsilon} - \alpha\xi(1-\varphi)[n(H_t)]^{-(1+\alpha)}}{[\delta\theta_M + \gamma(1-\delta\theta_M)]\left\{\frac{\bar{h}}{1-\epsilon} - \alpha C[n(H_t)]^{-(1+\alpha)}\right\}}.$$

At $\bar{H}_t$ greater than but arbitrarily close to $\bar{H}^{**}$, the minimum level of human capital for market activity that can sustain three sectors, we have

$$\frac{\bar{h}}{1-\epsilon} - \alpha C[n(H_t)]^{-(1+\alpha)} \simeq 0$$
$$\Rightarrow \frac{\bar{h}}{1-\epsilon} - \alpha\xi(1-\varphi)[n(H_t)]^{-(1+\alpha)} < 0, \text{ since } C < \xi(1-\varphi)$$
$$\Rightarrow \psi'(\bar{H}_t) < 0.$$

However, since n_t monotonically increases with $\bar{H}_t$ without bound, there must exist a critical value of $\bar{H}_t$, say $\bar{H}'$, such that

$$\psi'(\bar{H}_t) > 0 \text{ for } \bar{H}_t \geq \bar{H}'. \tag{A7}$$

Thus, as shown in Figure 4.7, $\psi(\bar{H}_t)$ function is U-shaped.

Suppose that sector S opens up at $t = T$ and let $\bar{H}_T = \bar{H}^{**}$. Then, $\bar{H}_{T+1}$ is determined where the $\psi(\bar{H}_t)$ curve intersects the line $\rho a_H \psi(\bar{H}^{**})$, since, in view of (A31) in the text, $\psi(\bar{H}_t)$ grows at the rate ρa_H. From Figure 4.7, $\bar{H}_{T+1} > \bar{H}' > \bar{H}_T = \bar{H}^{**}$. Thereafter, in view of (A7) and that $\psi(\bar{H}_t)$ monotonically increases over time, it follows

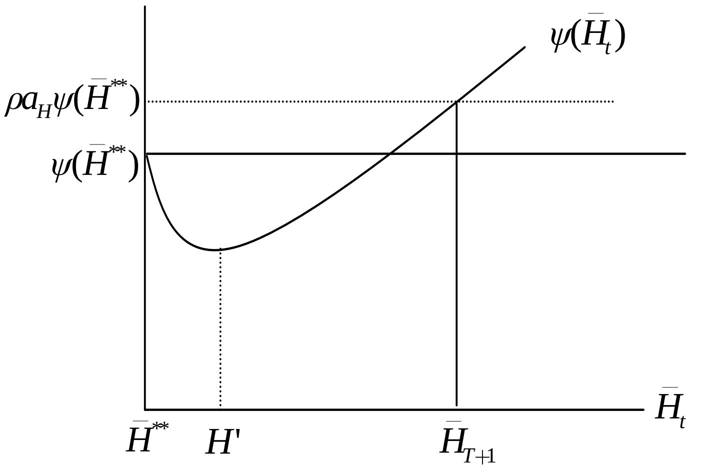

Figure 4.7: The ψ Function

that $\bar{H}_t$ increases over time and its dynamic path is unique. As $\bar{H}_t$ and n_t are one-to-one related, n_t also increases monotonically over time and its dynamic path is unique.[23]

Appendix 6: Proof that $g_{\bar{H}_t}$, g_{nt}, g_{It} and $g_{I^v t}$ Decline Over Time in Phase S

From (A31), we have

$$\frac{n_{t+1} + \beta n_{t+1}^{-\alpha}}{n_t + \beta n_t^{-\alpha}} = \rho a_H, \text{ where } \beta \equiv \frac{\xi(1-\varphi)(1-\epsilon)}{\bar{h}}.$$

Rearranging it, we obtain

$$g_{nt} = \rho a_H + \frac{\beta}{n_t^{1+\alpha}} \left(\rho a_H - \frac{1}{g_{nt}^{\alpha}} \right)$$

$$\text{or } g_{nt} - \rho a_H - \frac{\beta}{n_t^{1+\alpha}} \left(\rho a_H - \frac{1}{g_{nt}^{\alpha}} \right) \equiv \Gamma(g_{nt}, \underset{+}{n_t}) = 0. \tag{A8}$$

Note that $\Gamma(1, n_t) < 0$, $\lim_{g_{nt} \to \infty} \Gamma(g_{nt}, n_t) = \infty$ and $\partial^2 \Gamma / \partial (g_{nt})^2 < 0$. Together, these conditions imply, by virtue of continuity of the function Γ, that $\Gamma(g_{nt}, n_t) = 0$ has one

[23]If $\bar{H}_T$ is greater than $\bar{H}^{**}$ (which is possible as time is discrete), the same results hold as long as a_H is high enough such that $\rho a_H \{\bar{H}_T + \xi[n(\bar{H}_T)]^{-\alpha}\} \geq \bar{H}^{**} + \xi[n(\bar{H}^{**})]^{-\alpha}$.

and only one solution of g_{nt} for any given n_t, and at that value of g_{nt}, $\partial\Gamma/\partial g_{nt} > 0$. Hence (A8) yields $dg_{nt}/dn_t < 0$. This implies that as t increases and n_t increases, g_{nt} falls.

From (A31) once again, we have

$$\frac{\bar{H}_{t+1} + \xi n_{t+1}^{-\alpha}}{\bar{H}_t + \xi n_t^{-\alpha}} = \rho a_H,$$

which we rearrange as

$$g_{\bar{H}t} = \rho a_H + \frac{\xi}{\bar{H}_t n_t^{\alpha}} \left(\rho a_H - \frac{1}{g_{nt}^{\alpha}}\right). \tag{A9}$$

As time increases, (a) $\bar{H}_t n_t^{\alpha}$ increases, and, (b) as just proved, g_{nt} declines. Hence the r.h.s. of (A9) decreases unambiguously, implying that $g_{\bar{H}t}$ falls over time.

Next, from the expression of g_{It}, given in (A33), it decreases with t if and only if $(1-k_{t+1})/(1-k_t)$ declines with t, i.e., for any t,

$$\frac{1-k_{t+2}}{1-k_{t+1}} < \frac{1-k_{t+1}}{1-k_t}, \text{ where } k_t \equiv 1/(\chi_t^S n_t)^{\alpha}\ . \tag{A10}$$

We have g_{kt} increasing with t since g_{nt} falls with t and χ_t^S grows at a constant rate. Thus, $g_{kt+1} > g_{kt}$. Using this,

$$\begin{aligned}
&(1-k_{t+2})(1-k_t) - (1-k_{t+1})^2 \\
&= (1-g_{kt+1}{\cdot}g_{kt}k_t)(1-k_t) - (1-g_{kt}k_t)^2 \\
&< (1-g_{kt}^2 k_t)(1-k_t) - (1-g_{kt}k_t)^2 \\
&= -(1-g_{kt})^2 k_t < 0 \\
&\Rightarrow (1-k_{t+2})(1-k_t) - (1-k_{t+1})^2 < 0 \\
&\Rightarrow \text{(A10) holds}
\end{aligned}$$

and hence g_{It} declines with t. From (A34), it is evident that $g_{I^v t}$ falls over time since both g_{nt} and g_{It} decrease over time.

Uniqueness of the Perfect Foresight Path in Phase S and the Proof that $L_t > \rho$ in all Three Phases

Note that (A35) implies

$$\frac{\partial(L_{t+1} - L_t)}{\partial L_t} = \frac{1}{L_t^2} \cdot \frac{g_{\bar{H}t}}{a_H} - 1 > 0, \tag{A11}$$

since $L_t < 1$ and in region II $g_{Ht}/a_H > L_t$, and,

$$\frac{\partial(L_{t+1} - L_t)}{\partial g_{\bar{H}t}} > 0. \tag{A12}$$

Assume to the contrary that there are two time paths of $\{L_t^A\}$ and $\{L_t^B\}$ in region II, both asymptotic to ρ. Without loss of generality suppose that at some t (possibly at T^{**}), $L_t^A > L_t^B$. Since at any given H_t, a higher L_t implies a higher $g_{\bar{H}t}$, (A11) and (A12) together imply that $L_{t+1}^A - L_t^A > L_{t+1}^B - L_t^B$, or, $L_{t+1}^A - L_{t+1}^B > L_t^A - L_t^B$. Hence as time progresses, $|L_t^A - L_t^B|$ increases and thus both series cannot be asymptotic to the same value, a contradiction. Hence the perfect foresight path must be unique.

It is already seen in Figure 4.4 that $L_t > \rho$ in phase S. Suppose, $L_t \leq \rho$ at some t in either Phase F or M. Then eq. (A35) implies

$$L_{t+1} \leq 1 - \left(\frac{1}{\rho} - 1\right) \frac{g_{\bar{H}t}}{a_H} \leq 1 - \left(\frac{1}{\rho} - 1\right) \rho = \rho,$$

since $g_{\bar{H}t} \geq \rho a_H$ for all t. Hence, for all subsequent t, $L_t \leq \rho$, which contradicts that $L_t > \rho$ in Phase S.

Chapter 5

Suggestions for Future Research

This thesis, essentially, has presented two essays. They relate to selected topics in public policy and endogenous growth, as well as long run transition of an economy. More specifically, it has analyzed (a) the role of agriculture in public spending-led long run growth in a small open economy and implications of public policies for its growth and welfare (b) endogenous transition of an economy from primitive agriculture to industrial mass production.

Rather than summarizing the results obtained, this concluding chapter indicates some paths towards future research in each of these two topics.

5.1 Role of Agriculture in Long-run Growth

5.1.1 Agro-Industry and Implications for Development and Growth

The existing literature largely assumes that the sole linkage between agriculture and industry is the common pool of labor, from which this factor of production is allocated across the two sectors. However another important linkage between these two sectors occurs through the so-called agro-industries. These industry-processes transform agricultural raw materials into differentiated consumable products e.g., dairy products, processed food etc.

A typical feature of this industry is that the input suppliers, producers, processors and supermarkets are integrated. While, it is a common production structure in north-west Europe and parts of the USA, it has also become a widely observed phenomenon in agri-business in many of the countries of the Asia-Pacific region such as Indonesia, Malaysia, Philippines (World Bank, 2001, FAO, 2002). More specifically, large final goods producing firms are integrated backwards with the small competitive input suppliers (Love and Burton, 1999). The main reason behind such integration is to ensure the quality of input. Perry (1978) and McGee and Basset (1976) analyze the effects of a *monopsonist integrating backward in a competitive input market.*

Moreover, in a small open economy, such arrangements insulates agricultural input suppliers and the industrial buyers from volatility of agricultural prices in the world market (Jensen, Kehrberg, and Thomas, 1962). Hence, the consequences of agricultural productivity surge on industry which is integrated with the former to ensure quality of inputs or to avoid the uncertainty regarding input prices and its implication for the long run performance of the economy is a potential research question.

5.1.2 The Role of Agriculture in Industrial Agglomeration and Long-run Growth

The linkages between agriculture and industry may also arise from a decreasing-cost *industry's dependence on rural unskilled labor.* Such linkages are explored in the 'agglomeration literature' (Puga, 1999; Fujita and Thisse, 2002; Forslid and Ottaviano, 2003; picard and Zeng, 2005). An extension of our model could be a merge of two-sector endogenous growth model with the agglomeration literature. A natural and an important research agenda will be to explore the *effects of agricultural productivity surge on long run growth of the economy and the spacial concentration of industry* in a framework developed by Picard et al (2005), where industry is dependent on the local agricultural sector for the supply of unskilled labor, while skilled labor (an input), specific to industry is perfectly mobile.

Yet, another interesting question in the above context worth exploring could be, how improvement of public infrastructure facilitates unskilled labor mobility affecting the economic growth and development pattern in terms of industrial concentration in line with Martin (1999).

5.2 Transition Via Rise of Service Sector

In the concluding remarks of Chapter 4, I had mentioned about the rise of the service sector, a major post WWII phenomenon in the world economy. A potentially fruitful area for future research would be to recognize the service sector and analyze how this sector's share in GDP has increased over time and become higher than that of manufacturing in many countries by now.

Services play a dominant role not only in the post war economic activities of the OECD economies, but also in transformation of production structure and trade patterns in emerging economies like India and China.

In explaining the role of services in both developed and low income countries *demand-side factors* have been emphasized in the literature (Balassa, 1964; Samuelson, 1964; Bhagwati, 1984, 1985; and Panagariya, 1988). The most important paper in the literature is a recent piece of Buera and Kaboski, (2006). They have developed a model to explain the increasing share of the services reflecting both rising relative price and rising relative quantity of services to manufacturing. Their model captures certain distinct features such as transformation of this sector from low-skilled to highly skill-intensive activities and finally, a shift from market provision to home production of services with economic growth. Buera et al. also focus on the demand side linkage of services and economic growth.

A brief discussion of their model follows. The preferences of agents are defined over a set of heterogeneous services and agents satiate these desires sequentially. As labor productivity grows at an exogenous constant rate and income rises, the consumption set expands to more luxury services which are the complex ones, which are produced by specialized skilled workers. Initially services are provided through market production that exhibits increasing returns to scale in intermediate input used in the production of services. However as income rises, given a constant disutility of public consumption, service are produced at home using intermediate and durable goods. Moreover, the acquisition of any particular skill involves fixed cost, and hence agents choose to acquire skill that is specific to a particular service. The agents work as highly productive skilled workers for a particular service on the market, but are less skilled in the broad range of services potentially produced at home. As income rises, the service sector expands, the demand for specialized skill increases, investment and returns to skill increase, and the composition of the service sector shifts toward skill-intensive services. The rise of service sector takes place, when incomes are high enough for agents to demand skill-intensive services.

Apart from the demand-side factors, the other most important aspects of service sector relate to the supply-side linkage of this sector and economic development. Specifically, it focus on the relationship of services to the production structure of economies, particularly the relationship of the service sector to manufacturing (Francois and Reinert, 1996). Eswaran and Kotwal (2002) unify both the demand and supply-side linkages. In a static framework, the authors develop a model where a composite of differentiated services enter the utility function as well as production of manufacturing goods. In a small open economy with comparative advantage in agriculture, positive exogenous shock in income expands demand for services and increase in the number of differentiated services reduce the effective cost of manufacturing goods, thereby making industrial production viable. Hence service sector plays an important role in transforming the comparative advantage and thus production structure of an economy.

Exploring the supply-side aspects - meaning that services are used as important input of production of goods and services (for instance, financial services are essential inputs in industrial production) will be a potentially fruitful research agenda. By modelling this feature in an appropriate dynamic framework, it can be attempted to replicate the growth and transformation of an economy through industry-service linkages by developing a human capital-led endogenous growth model where different stages of industrial production uses differentiated services as inputs. Moreover production of different services involves different levels of fixed cost in terms of human capital. Thus production of more complex goods requires, more complex services that in turn need higher level of human capital. Thus an economy can not reach certain stage of development until sufficient human capital is generated to produce certain services which are essential for producing new and more complex goods compared to the previous stage of development.

Again, the type services demanded by the household and the production sectors may differ. For instance, while financial services are used by both sectors, managerial services are mainly used as input in production, where as educational, health services are typically demanded by the households. Hence incorporating the differences in the category of services demanded by households and producers to analyze the dynamic behavior of the economy is another potential research agenda.

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