A Unified Theory of the Evolution of International Income Levels

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ABSTRACT: This paper develops a theory of the evolution of international income levels. In particular, it augments the Hansen-Prescott theory of economic development with the Parente-Prescott theory of relative efficiencies and shows that the unified theory accounts for the evolution of international income levels over the last millennium. The essence of this unified theory is that a country starts to experience sustained increases in its living standard when production efficiency reaches a critical point. Countries reach this critical level of efficiency at different dates not because they have access to different stocks of knowledge, but rather because they differ in the amount of society-imposed constraints on the technology choices of their citizenry.

1. Introduction

Over the last decade, a fairly complete picture of the evolution of international income levels has emerged. Figure 1 plots the path of gross domestic product (GDP) per capita for four major regions of the world relative to the leader going back to 1700 using data from Maddison (1995). In 1700, the living standard of the richest country was less than three times the living standard of the poorest country.[1] This is the nature of the disparity prior to 1700 as well, as no single country experienced sustained increases in its living standard over the pre-1700 period. After 1700, huge differences in international

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[1] Bairoch (1993) estimates this difference in 1700 to be smaller than a factor of two.

incomes emerged, as some countries experienced sustained and large increases in their living standards well before others.

England was the first country to develop, that is, to realize sustained increases in per capita income. The exact date at which England began to develop is subject to debate. Some historians such as Bairoch (1993) place this date at around 1700. Western European countries and countries that were ethnic offshoots of England began to develop shortly thereafter. At first, the increases in income experienced by these early developers were irregular and modest in size. For example, Bairoch (1993) reports that it took England nearly 100 years to double its income from its 1750 level. However, after the start of the twentieth century, these increases have been larger and relatively regular with income doubling every 35 years in these countries—a phenomenon Kuznets (1966) labels *modern economic growth*.

Countries located in other regions of the world started the development process later in time. For these countries, the gap in income with the leader continued to widen prior to the time they started modern economic growth. For Latin America, the beginning of the twentieth century is the approximate start of modern economic growth. For Asia, the middle of the twentieth century is the approximate start of modern economic growth. For Africa, modern economic growth has yet to start: although per capita income has increased in nearly every African country since 1960, the increases have been modest and irregular in the period that has followed. Because of these later starting dates, the disparity in international income levels increased to their current-day levels.

Some countries and regions have dramatically reduced their income gap with the leader subsequent to starting modern economic growth. For example, in the postwar period, Western Europe has managed to eliminate much of its income gap with the United States, the leader since 1890. Asia is another region that has been catching up with the leader in the postwar period. The catch-up in Asia, in fact, has been dramatic because of the growth miracle countries of Japan, South Korea, and Taiwan that doubled their income in a decade or less. Latin America, in contrast, is an example of a region that has not eliminated its gap with the leader since starting modern economic growth. Latin American per capita income has remained at roughly 25 percent of the leader for the last 100 years.

A theory of the evolution of international income levels must account for these facts. The theory must generate an initial period with living standards at the pre-1700 level followed by a long transition period to modern economic growth. The theory must generate different starting dates for the transition to modern economic growth across countries. Namely, it must identify some factor or set of factors that differs across countries and that delays the start of the transition by as much as two centuries. The theory must also account for the sizable and persistent differences in living standards that characterize the experience of countries that have been experiencing modern economic growth for as long as 100 years. Finally, the theory must be consistent with *growth miracles,* namely, the large increases in relative income experienced by some initially poor countries in a relatively short period of time after 1950.

There are well-tested theories of some of these phenomena, but not a comprehensive theory that accounts for all of them. This paper unifies these well-tested theories and examines whether the unified theory can account for all of these phenomena.[2] A well-tested theory of the first phenomenon, the pattern of an initial period of stagnant living standards followed by a transition to modern economic growth, is provided by Hansen and Prescott (2002). The Hansen and Prescott theory is a combination of two long-standing and successful theories: the classical theory of the pre-1700 period and the neoclassical theory of the post-1900 period.

The classical economists, in particular, Malthus (1797) and Ricardo (1817), developed a theory that accounts well for the constant living standard that characterized the pre-1700 era. The main feature of this theory is an aggregate production function characterized by fixed factors, the most important of which is land. According to this theory, increases in knowledge lead to increases in output that are completely offset by increases in population. As a result, living standards do not increase. Economists have also had for a long time a good theory of modern economic growth that has characterized the United States and much of Western Europe since 1900. Solow (1970) developed his growth model specifically to account for this post-1900 pattern of growth. The main feature of this theory is also an aggregate production function, but one with no fixed factor of production. According to this theory, improvements in technology that lead to more

[2] Ngai (2000) provides a unification of these theories along the lines of this paper.

output being produced with the same resources are not offset by increases in population. As a result, living standards rise.

Hansen and Prescott (2002) unify the classical and modern growth theories by allowing people to use both the traditional production function and the modern production function. They show that when total factor productivity (TFP) associated with the modern production function reaches a critical level, the economy moves resources out of the traditional sector and into the modern sector. This is the date at which the transition begins. The transition is found to last a long period, roughly a century. The model thus gives rise to a pattern of economic development characterized by a long initial period of economic stagnation, followed by a long transition, followed by modern economic growth, as observed in Western Europe and its offshoots.

The Hansen and Prescott theory is not a theory of the evolution of international income levels because it does not address the issues of different starting dates of the transition to modern economic growth, sizeable income differences for countries experiencing modern economic growth, and growth miracles. Some factor that differs across countries must be added to the Hansen and Prescott theory to make it a theory of the evolution of international income levels.

Parente and Prescott (2000) develop a theory that accounts for the sizable differences in living standards for countries experiencing modern economic growth and that accounts for growth miracles. More specifically, they develop a theory of a country-specific TFP and then introduce this factor into a model in which only the modern production function is available. Their theory of country-specific TFP, which they refer to as a *theory of relative efficiency*, is based on policy differences. More specifically, the theory shows how various policies that constrain choices of technology and work practices at the level of the production unit determine the aggregate efficiency at which a country uses its resources in production. The development of a theory of relative efficiencies is essential. Despite the fact that there is ample empirical evidence that countries differ in relative efficiencies, a theory of international income levels that takes countries' TFPs as exogenous is sterile, because it offers no policy guidance.

In this paper, we augment the Hansen and Prescott theory of economic development with the Parente and Prescott (2000) theory of relative efficiencies and show that the resulting unified theory is a theory of the evolution of international income levels. In this unified theory, a country begins its transition to modern economic growth when the efficiency with which it uses resources in the production of goods and services in the modern sector reaches a critical point. Countries reach this critical level of efficiency at different dates not because they have access to different stocks of knowledge, but rather because they differ in the amount of society-imposed constraints on the technology choices of their citizenry. We show that plausible differences in efficiencies delay the start of the transition to modern economic growth by more than two centuries, as observed in the data. Additionally, we show that the augmented model accounts well for the growth miracles that a number of countries experienced subsequent to 1950. Changes in a country's institutions that result in large increases in the efficiency with which resources can be used in production give rise to growth miracles. Thus, the unified theory accounts for the way international income levels have evolved.

The paper is organized as follows. Section 2 starts with a review of the classical theory of the pre-1700 income level followed by a review of the neoclassical growth theory of modern economic growth. It then concludes with a review of how Hansen and Prescott (2002) combine these two theories into a single theory of economic development. Section 3 deals with the second component of the theory, namely, differences in efficiencies. It reviews the Parente and Prescott (2000) theory of relative efficiencies. Section 4 develops the unified theory of international income levels. In Section 4, a model based on the unified theory is developed and calibrated to the U.K. and U.S. development experiences over the last three centuries. The calibrated model is used to examine the effect of differences in efficiencies across countries on the start of the transition to modern economic growth and the effect of an increase in a country's efficiency on the subsequent path of its per capita GDP. Section 5 examines the development experiences of individual countries and groups of countries over the last three centuries within the context of the theory. Section 6 concludes the paper.

2. A Theory of Economic Development

In this section, we present the theory of economic development put forth by Hansen and Prescott (2002). We do this in three stages. First, we describe the classical component of that theory and derive its equilibrium properties. Next, we describe the modern growth component of that theory, and also derive its equilibrium properties. The last stage merges these two components and, in doing so, presents the Hansen and Prescott model of economic development.

Figure 2 describes the general pattern of economic development. More specifically, Figure 2 reports per capita income of the leader country dating back to 2000 B.C. Up until 1700, the living standard in the leader country, or any other country for that matter, displayed no secular increase. These living standards were significantly above the subsistence level. In 1688, for example, the poorest quarter of the population in England—the paupers and the cottagers—survived on a consumption level that was roughly one-fourth the national average.[3] A few societies, such as the Roman Empire in the first century, the Arab Caliphates in the tenth century, China in the eleventh century, and India in the seventeenth century realized some increase in their per capita income. However, these increases were not sustained. After 1700, per capita income in England started to increase. Over the next 150 years, these increases in the leader country were modest in size and irregular. However, since 1900, these increases have been larger and fairly regular, with per capita income doubling roughly every 35 years.

Technology was not stagnant over any part of this time period. Economic historians have documented a steady flow of technological innovations in this 2000 B.C. to A.D. 1700 period.[4] Yet these innovations prior to 1700 did not translate into increased living standards. Instead they translated into increased population: as total output increased, the population adjusted so as to maintain a constant level of per capita output. After 1700, these innovations did translate into increases in living standards.

[3] See Maddison (1991, p. 10) and Bairoch (1993, pp. 101–108).

[4] See Mokyr (1990) for a review of this literature.

2A. Classical Theory: The Pre-1700 Era

Classical economists, most notably Malthus and Ricardo, devised a theory that accounts well for the constant level of per capita income that characterized the pre-1700 era. The theory predicts a trade-off between living standards and population size. This trade-off exists because population growth is an increasing function of per capita consumption and because there is an important fixed factor of production, namely, land. A key implication of this theory is that there is a constant standard of living to which the economy adjusts. The theory predicts that increases in the stock of usable knowledge, which could translate into increases in living standards, instead translate into an increase in population.

Malthus' theory of population is a biological one rather than an economic one. According to his theory, fertility rises and mortality falls as consumption increases. Being classical, the model has no utility theory and so agents have no decision over the number of children they have. Recently a number of authors, including Tamura (1988), Becker, Murphy, and Tamura (1990), Doepke (2000), Galor and Weil (2000), and Lucas (2002), have generated Malthus-like population dynamics in a neoclassical model with household utility defined over consumption of goods and number of children. These models follow Becker (1960) by having a trade-off between quality and quantity of children.

We take an alternative approach, one that has society determining the size of its population through its institutions and policies. We likewise add household preferences to the classical theory of production. However, we define household preferences only over household consumption and not the quantity of children. Consequently, in this societal theory of population growth, the quantity of children is treated as exogenous from the standpoint of the household.

The reason we take this societal approach to population growth is twofold. First, there is no tested theory of population dynamics, and once modern economic growth begins, demographics play a secondary role in development. Second, and more important, the approach reflects the view that groups of individuals, namely, societies, have had a much larger say in deciding how many children a family has than the family itself.

Societies have instituted and continue to institute policies that give them their desired population size. Often the policies of society are not what individual families want. In modern China, for example, a law effectively limits many households to one child. By contrast, Iran in the 1980s wanted a higher population and so implemented subsidies to encourage people to have more children. After achieving its objective, the government stopped these subsidies in the 1990s and began to subsidize contraceptives. India today, wanting a lower population growth rate, has set up family planning programs in many regions. In all these cases, the effects of policy upon demographics are dramatic. Even in poor and rural Indian villages, which did not experience any increase in human capital or income, policy has led to a dramatic decline in population growth rates.

Why did society choose population size prior to 1700 so as to maintain the same constant living standard? The answer relates to the fact that land was an essential input to the production process in the pre-1700 era. In particular, as a valuable resource, land was subject to expropriation by outsiders. Prior to modern times, a small group of people with large amounts of quality-adjusted land and therefore a high income standard could not defend this land from outside expropriators. For this reason, there was a maximal sustainable living standard. Society set up social institutions that controlled population so as to maintain the highest possible living standard consistent with the ability to defend itself from outside expropriators. Once an economy switches to the modern production technology, land is no longer an important input, so its defense is not an issue. At the stage when the modern production technology dominates, society sets up its social institutions that it sees as maximizing living standards subject to a constraint that a society perpetuates itself.

For the purpose at hand it is not essential that we model society's choices of institutions that affect fertility choices. Instead, it is sufficient to treat the growth rate of population in a simple mechanical way, namely, as a function of average consumption. In order to reflect society's choices, it must display two properties. First, the function must have a large slope, in the neighborhood of the pre-1700 consumption level. Second, for high levels of average consumption, the slope of the function must be near zero. The first property is only relevant for the theory of the pre-1700 era. The second property is only relevant for the theory of the post-1900 period. This is the approach that we take in this chapter.

With this in mind, we now proceed with a neoclassical formulation of the classical theory of constant living standards. There is a single good in the model that can be used for either consumption or investment purposes. The good is produced with a constant returns to scale technology that uses capital, labor, and land. An infinitely lived household owns the economy's land and capital and rents them to firms in the economy. Land is fixed and does not depreciate. The household is made up of many members, each of whom is endowed with one unit of time. The household uses its capital, labor, and land income for consumption and investment purposes. The growth rate of population is a function of average consumption of household members. A household member's utility in the period is defined over the member's consumption in the period. The household's objective is to maximize the sum of each member's utility. The details of the economy are described as follows.

Technology

The classical theory of production is given by a Cobb-Douglas technology,

$$Y_{Mt} = A_{Mt}\ K_{Mt}^{\phi} N_{Mt}^{\mu} L_{Mt}^{1-\phi-\mu}. \tag{2.1}$$

In equation (2.1), Y_{Mt} is output, K_{Mt} is capital, N_{Mt} is labor, and L_{Mt} is land in period t. A_{Mt} is a total factor productivity (TFP) parameter, ϕ is the capital share parameter, and μ is the labor share parameter. The Cobb-Douglas assumption implies unit elasticity of substitution.[5] We allow for exogenous growth in TFP. More specifically, we assume that technology grows at the exogenous rate of γ_M; that is, $A_{Mt} = (1+\gamma_M)^t$. This assumption reflects the fact that technological change was evident from 2000 B.C.[6]

Output can be used for either consumption or investment purposes. The resource constraint for the economy is given by

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[5] The precise value of the elasticity of substitution between land and the other factors is not important provided that it is not greater than one. The evidence is that throughout most of history the substitution of these other factors for land was limited and, if anything, this elasticity of substitution was less than one. The unit elasticity assumption is made because it simplifies the analysis.

[6] We follow Hansen and Prescott's convention of using the letter M to index variables associated with the classical production function.

(2.2) $$C_t + X_t = Y_{Mt},$$

where C_t denotes total consumption and X_t denotes total investment.

Preferences

Household preferences are added to the classical theory of production as follows. Period utility of each household member is defined over the member's consumption of the final good. We assume a log utility function, because it is in the class of utility functions that is consistent with a constant-growth equilibrium and because empirically it is consistent with a wide variety of micro and macro observations. Household utility in each period is the sum of each individual member's utility in the period. Strict concavity of individual household members' preferences implies that the household's utility is maximized by giving equal consumption to each member. For this reason, the discounted stream of utility of the household is just

(2.3) $$\sum_{t=0}^{\infty} \beta^t N_t \log(c_t),$$

where β is the time discount factor, c_t is consumption of a household member, and N_t is household size.

As is evident from equation (2.3), we are using a dynastic construct. This is in contrast to Hansen and Prescott (2002), who use a two-period overlapping generations construct. We adopt an infinitely lived household framework rather than the two-period overlapping generations framework for two reasons. First and foremost, the empirical counterpart of a period is a year, while in the two-period overlapping generations construct, the empirical counterpart of a period is 35 years. Thirty-five years is simply too long a period for examining the model's ability to account for the large increases in output realized in a short period of time after 1950 by countries such as Japan and South Korea and for the long transition to modern economic growth.

Second, the size of the effect associated with differences in savings rates on an economy's steady-state per capita output level depends importantly on the construct that is used. The level effects are in fact larger with the dynastic construct. This is important for judging whether differences in savings rates can account for the large differences in transition dates as well as the large differences in incomes that continue to exist between economies that have started modern economic growth. Thus, if plausible differences in savings rates cannot give rise to 200-year delays in development in the dynastic construct, then it follows that some factor other than savings rates accounts for the pattern of development.[7] This is the conclusion of the quantitative exercises undertaken by Parente and Prescott (2000). The choice of construct is not important, however, in assessing the plausibility of other factors such as efficiency, as reflected in TFP, differences: the size of the level effects is the same regardless of whether the dynastic or overlapping generations construct is employed.

Endowments

Each member of the household is endowed with one unit of time, which the member can supply to firms in the economy to earn wage income. The household is also endowed with the economy's stock of land and capital, which the household rents to firms in the economy. Land in the economy is fixed in supply: it cannot be produced, and it does not depreciate. Without loss of generality, the total quantity of land in the economy is normalized to one. Since land has no alternative use aside from production, the input to production in each period is one. Capital is assumed to depreciate and evolves according to the following law of motion:

(2.4) $$K_{t+1} = (1-\delta)K_t + X_t ,$$

where δ is the depreciation rate.

Population Dynamics

As mentioned earlier, because we take a societal approach to population size, we model population growth as a function of the average consumption level of household members. More specifically, we assume that the number of agents born into a household in period t + 1 depends on the average consumption level of household members from period t. Let N_t denote the number of household members in period t, and let c_t denote their average consumption level. Then,

[7] See Hendricks (forthcoming) for a more detailed explanation of this phenomenon.

(2.5) $$N_{t+1} = g(c_t)N_t \, .$$

The function g is the growth factor of population from one period to the next. The classical prediction of a stable living standard at the pre-1700 level, $c_{M,}$ requires that the function g have a sufficiently large and positive slope at c_M and that $g(c_M)$ = $(1+\gamma_M)^{1/(1-\phi-\mu)}$. This c_M is the maximal living standard consistent with a society being able to defend its land.

Equilibrium Properties

For such a population growth function, there is a steady-state equilibrium with a constant living standard c_M and a population growth rate equal to $(1+\gamma_M)^{1/(1-\phi-\mu)} - 1$. This constant living standard satisfies $g(c_M) = (1+\gamma_M)^{1/(1-\phi-\mu)}$. Were the living standard to rise above c_M, say, because of plague or drought, population increase would exceed technical advances and the living standard would then fall until it returned to c_M. If for some reason c were below c_M, the population growth factor would be less than the one needed to maintain the living standard, and the living standard would increase until it was again c_M. Along the steady-state equilibrium path, aggregate output, capital, consumption, and the rental rate of land all grow at the rate of the population. Per capita variables as well as the rental price of labor and capital are all constant. Increases in technology in this model simply translate into a higher population rather than higher living standards. This is precisely the pattern of development observed prior to 1700.

2B. Modern Growth Theory: The Post-1900 Era

The classical theory accounts well for the pattern of economic development up to 1700. However, it does not account for the increase in living standards that occurred after 1900. Since about 1900, the growth rate has been roughly constant, with a doubling of per capita output every 35 years. Modern growth theory, in contrast, does. We now turn to that theory.

Besides the roughly constant rate of growth achieved by developed countries over the last century and a half, a number of other features of post-1900 growth in the United

Kingdom and some other countries are noted by Kaldor (1957). These additional modern economic growth facts are roughly that the consumption and investment shares of output are constant, the share of income paid to capital is constant, the capital-to-output ratio is constant, and the real return to capital is constant.

Modern growth theory accounts well for these modern growth facts. Quantitatively, the steady-state equilibrium of the economy mimics the long-run observations of the United Kingdom and the United States. This is no surprise: Solow (1970) developed the theory with these facts in mind. A key feature of that theory is a Cobb-Douglas production function that includes no fixed factor of production and that is subject to constant exogenous technological change. More specifically, the production technology for the composite good that can be used for either consumption or investment purposes is given by

(2.6) $$Y_{St} = A_{St}\ K_{St}^{\theta}\ N_{St}^{1-\theta}\ .$$

In equation (2.6), Y_{St} is output, K_{St} is capital, and N_{St} is labor in period t. The parameter θ is capital's share, and the parameter A_{St} is TFP. TFP grows exogenously at the constant, geometric rate γ_S. As can be seen, the critical difference between the classical and modern growth production functions is that the modern growth function does not include the fixed factor input land.[8]

Because the final objective of this section is to merge the classical theory and the modern growth theory into a single model, we maintain the same assumptions regarding preferences, endowments, and population dynamics as in the preceding subsection. The household in the model rents capital to firms and supplies labor. It uses its capital and labor income to buy consumption for household members and to augment the household's stock of capital.

In contrast to the classical theory, population growth in the modern theory does not have any consequences for the growth rate of per capita variables in the long run. The choice of the population growth function is therefore unimportant in this respect. The standard

[8] Again, we follow Hansen and Prescott's convention of using *S* to index variables associated with the modern growth production function.

procedure is to assume a population growth function $g(c)$ that is constant over the range of sufficiently high living standards associated with the modern growth era. Population thus grows at a constant exponential rate.

Clearly, population cannot grow at an exponential rate forever. At some population level, natural resources would become a constraining factor. If population were ever to reach this level, it would be unreasonable to abstract from land as a factor of production. But societies control their population so that it never reaches this level. Indeed, reproduction rates have fallen dramatically in the last 50 years, so much in the rich countries, in fact, that these countries must increase their fertility rates to maintain their population size in the long run. This suggests a population growth function that asymptotically approaches one. This is an additional property we impose on the population growth function in the analysis that follows.

In the case where the population growth function is a constant, per capita output, consumption, and capital all increase at the rate $(1+\gamma_S)^{1/(1-\theta)}$ along the equilibrium constant growth path. The rental price of labor also grows at this rate. The rental price of capital, in contrast, is constant. Capital's share of income is also constant and equal to θ, as is consumption's share and investment's share of output. As can be seen, the growth rate of the economy's living standard is independent of the economy's population growth rate: the only thing that matters is the exogenous growth rate of technological change. The population growth rate does have a level effect, but it is small. Thus, unlike in the model of the pre-1700 era, the population growth function in the model of the post-1900 era has only a minor role.

2C. The Combined Theory

The classical theory accounts well for the constant living standard that characterizes the pre-1700 era, and the modern growth theory accounts well for the doubling of living standards every 35 years that characterizes the post-1900 experience of most of the currently rich, large, industrialized countries. In the period in between, living standards increased in these countries, but at a slower and far more irregular rate compared to the post-1900 period.

We seek a theory of this development process, namely, a theory that generates a long period of stagnant living standards up to 1700, followed by a long transition, followed by modern economic growth. Given the success of the classical theory and the modern growth theory in accounting for the pre-1700 and post-1900 eras, the logical step, and the one taken by Hansen and Prescott (2002), is to merge the two theories by permitting both technologies to be used in both periods. We now present the combined theory of Hansen and Prescott, and we use that theory to organize and interpret the development path of the leading industrialized country over the 1700–2000 period.

In the combined theory of Hansen and Prescott (2002), output in any period can be produced using the traditional and/or the modern growth production functions. Both technologies, therefore, are available for firms to use in all periods.[9] Capital and labor are not specific to either production function. In light of these assumptions, the aggregate resource constraint for the combined model economy is

(2.7) $$N_t c_t + X_t \leq Y_{Mt} + Y_{St} = Y_t ,$$

the capital rental market clearing constraint is

(2.8) $$K_t = K_{Mt} + K_{St} ,$$

and the labor market clearing condition is

(2.9) $$N_t = N_{Mt} + N_{St} .$$

Household preferences continue to be given by equation (2.3). Additionally, the population growth function continues to be given by equation (2.5), and it displays the properties that the function has a large slope in the neighborhood of the pre-1700 consumption level and a slope near zero for large levels of consumption.

In their combined theory, Hansen and Prescott assume that the rate of TFP for the classical production function and the rate of TFP for the modern economic growth

[9] The maximum output that can be produced if both technologies are available is characterized by a standard aggregate production function $Y_t = A_t\, F(K_t, L_t, N_t)$. By *standard* we mean that it is weakly increasing and concave, homogenous of degree one, and continuous. Even though both the Malthus and the Solow production functions are Cobb-Douglas technologies, the function F is not Cobb-Douglas.

production function are each constant over time. We deviate from Hansen and Prescott on this dimension. Although we maintain their assumption that the rate of TFP growth associated with the traditional technology is constant, we assume that the rate of TFP growth associated with the modern growth technology increases over time, converging asymptotically to the modern growth rate. We make this alternative assumption in light of the historical evidence on technological change and the empirical counterparts of the two production functions.

The empirical counterpart of the classical production function is a traditional technology for producing goods and services that is most commonly associated with the family farm. A key feature of this production technology is that it is based on the use of land in the production of hand tools and organic energy sources. For this technology, the historical record shows gradual improvements in these methods over the last 2,000 years at a roughly constant rate change.[10] The empirical counterpart of the modern growth production function is a modern technology that is most commonly associated with the factory.[11] A key feature of this technology is that it uses machines driven by inanimate sources of energy. For this technology, the historical record suggests modest growth in the eighteenth century, followed by much higher growth in the nineteenth and twentieth centuries. Consequently, a more plausible assumption is that the growth of TFP associated with the modern production function increased slowly after 1700 and converged to the rate associated with the modern growth era shortly after 1900.

We emphasize that traditional production occurs in household production units with most of the resources being allocated to producing household consumption and only a limited amount to trade. There was little scope for people working in these sectors to develop more efficient production methods. Rapid increases in productivity occurred only when goods developed in the industrial sector were introduced in farming. The reaper and the tractor dramatically increased productivity on farms. Insecticides and

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[10] The exception to this constant rate of growth might be the Green Revolution in the middle of the twentieth century, where the introduction of new seed varieties resulted in large increases in farm yields associated with traditional farming methods.

[11] The distinction between technologies is, thus, not along the lines of agriculture and manufactures. In this classification, modern agriculture with its use of synthetic fertilizers and tractors is associated with the modern growth production function.

fertilizers also contributed to productivity, as did the development of hybrid corn and new seeds. This is all well-documented by Johnson (2000).

An economy that starts out using only the traditional production function will eventually use the modern one. To see this, suppose that it were never profitable for firms to use the modern production function. Then the economy's equilibrium path would converge to the steady state of the pre-1700-only model. The steady state of that model is characterized by constant rental prices for capital and labor, r_M and w_M. Capital and labor are not specific to any one technology. Thus, a firm that first considers using the modern production function can hire any amount of capital and labor at the factor rental prices r_{Mt} and w_{Mt}. Profit maximization implies that a firm will not choose to operate the modern growth technology if

(2.10) $$A_{St} < \left(\frac{r_{Mt}}{\theta}\right)^{\theta}\left(\frac{w_{Mt}}{1-\theta}\right)^{1-\theta}.$$

This inequality must be violated at some date. Asymptotically, the rental prices would approach constant values if only the classical production function were operated, and so the right-hand side of (2.10) is bounded. The left-hand side is unbounded because TFP in the modern function grows forever at a rate bounded uniformly away from zero. The inequality given by (2.10), therefore, must be eventually violated. At the date when TFP in the modern production function surpasses the critical level given by the right-hand side of (2.10), the economy will start using the modern growth production function. This marks the beginning of the Industrial Revolution. This result is independent of the size differences in the growth rates of TFP associated with the traditional and modern production functions.

Over the transition, more and more capital and labor will be moved to the modern production sector. The rental price of labor will show a secular rise. The traditional production function will, however, continue to be operated, though its share of output will decline to zero over time, because of the assumptions that land is used only in traditional production and that its supply is inelastic.

We now use the combined theory to organize and interpret the development path of the industrial leader over the 1700–2000 period. The empirical counterpart of a period is a year. The initial period of the model is identified with the year 1675. We attribute the stagnation of the leader prior to 1700 to a low level of TFP associated with the modern production function to warrant use of the modern production function. We attribute the start of economic growth of the leader in 1700 to growth in TFP associated with the modern production function so that its level exceeds the critical value given by equation (2.10). Lastly, we attribute the rising rate of growth of per capita output of the leader from 1700 to 1900 to greater use of the modern production function and the rising rate of growth of TFP.

We proceed to parameterize the model. The model is calibrated so that the economy starts to use the modern production function around the year 1700. Following Hansen and Prescott, the model is calibrated so that the steady state of the classical-only model (subsection 2A) matches pre-1700 observations and the steady state of the modern growth-only model (subsection 2B) matches the post-1900 growth experience of the United States.

In the calibration, we deviate from Hansen and Prescott along two dimensions. First, we calibrate the population growth function so that it matches Maddison's (1995) estimates for U.K. population growth rates over subperiods of the 1675–1990 period. Given our theory of population growth, it is more appropriate to use the time series data from a particular country to restrict the population growth function for that country rather than cross-section data as Hansen and Prescott do. Second, we calibrate the annual growth rate of TFP for the modern production function so that it remains at the traditional rate up until 1700, increases linearly to one-half of its modern growth rate in 1825, and then increases linearly to its modern growth rate in 1925.

Following Hansen and Prescott, we pick the initial capital stock and the initial population so that if only the traditional production function were available, the equilibrium would correspond to the steady state of the pre-1700 model and there would be no incentive to operate the modern production function if it were available. This ensures that in period 0 only the traditional production function is operated and that there is a period of constant living standards.

Table 1 lists the values for each of the model parameters and provides comments where appropriate. The population growth rate function implied by the U.K. population growth data used in the computation is depicted in Figure 3.

For the parameterized model economy, it takes 150 years before 95 percent of the economy's output is produced in the modern sector. Figures 4–6 depict the model economy's development path along a number of other dimensions. Figure 4 compares period *t* per capita output relative to 1700 per capita output for the model economy and the industrial leader as reported by Maddison (1995, Tables 1.1 and C.12). According to the model, an economy that begins the transition in 1700 will be approximately 28 times richer in 1990 as it was in 1700. Figure 5 depicts the growth rate of per capita output for the model economy over the 1700–2000 period. The growth rate of per capita output is slow at the onset of the transition, less than 1 percent per year on average. One hundred years later, the growth rate is near the modern growth rate of 2 percent per year. This pattern is primarily a consequence of the assumption that TFP growth for the modern technology increases slowly over the 1700–1990 period. Figure 6 depicts the path of the rental prices of capital and labor over the 1700–2000 period. As can be seen, the real wage rate increases steadily once the transition begins. The real interest rate, in contrast, shows very little secular change over three centuries. These latter predictions conform well to the pattern of development associated with England, the United States, and other early developers.

Table 1. Restricted Parameter Values

Parameter	Value	Comment
γ_M–growth rate of TFP for traditional production	.0009	Consistent with pre-1700 world population average annual growth rate of .003
ϕ–capital share in traditional production	.10	
μ–labor share in traditional production	.60	Chosen so that labor's share does not vary with the level of development as reported by Gollin (2002)
A_{M0}–initial TFP for traditional production	1.0	Normalization
δ–depreciation rate	.06	Consistent with U.S. capital stock and investment rate since 1900
γ_S–asymptotic TFP growth rate for modern production	.012	2 percent rate of growth of per capita GDP in modern growth era
θ–capital's share in modern production	.40	U.S. physical capital's share of output
A_{S0}–initial TFP for modern production	.53	1700 starting date given initial period for model is 1675
β–subjective time discount factor	.97	Consistent with real rate of interest between 4 and 5 percent in modern growth era

The predictions of the model are not sensitive to the value of the capital share parameter in the modern growth production function. This is an important result, because the magnitude of the capital share with a broad definition of capital that includes intangible as well as tangible capital could well be greater than the 0.40 share value used in the above exercise. The paths of per capita GDP, its growth rate, and rental prices are nearly identical to those shown in Figures 4–6 for alternative values of the capital share in the modern production function. The transition still takes a long time. For a capital share as high as 0.70, 140 years elapse before 95 percent of the economy's capital is produced using the modern production function.

3. A Theory of Relative Efficiencies

The Hansen and Prescott theory of economic development reviewed in Section 2 is not a theory of the evolution of international income levels. It does not address the issue of why modern economic growth started at different dates in different countries. India, for example, began modern economic growth nearly 200 years later than did the United Kingdom. As a result, India's income level relative to the leader fell from 50 percent in 1770 to only 5 percent in 1970. Neither does the theory address the issue of why some countries that have been experiencing modern economic growth for a century have failed to narrow the income gap with the industrial leader. Latin America, for example has remained at roughly 25 percent the U.S. income level since the second half of the nineteenth century when modern economic growth began there. The theory does not address the issue of why some countries in the 1950–2000 period have been able to substantially narrow the income gap with the industrial leader. These countries include Italy, Japan, Korea, Spain, and Taiwan, and all of which experienced a growth miracle. Some factor that differs across countries must be added to the Hansen and Prescott theory to make it a theory of the evolution of international income levels.

One might be led to introduce differences in TFP associated with the modern production to the model, because the Hansen and Prescott theory of development predicts that per capita income in a country starts to increase once TFP in the modern sector reaches a critical level. Moreover, there is ample evidence that countries (at least those experiencing modern economic growth) differ along this dimension.[12] Although it would be easy to introduce such differences into the Hansen and Prescott theory, it would not be useful, as long as country-specific TFP differences are treated exogenously. Absent a theory of the country-specific TFP component, the theory of the evolution of international income levels is sterile because it offers no policy guidance. What is needed is a policy-based theory of why TFP differs across countries at a point in time.

Parente and Prescott (2000) develop a theory of TFP that attributes differences in TFP to country-specific policies that both directly and indirectly constrain the choice of production units. Their theory of TFP is more appropriately called a *theory of relative efficiencies*. This is because Parente and Prescott (2000) decompose a country's TFP into the product of two components. The first component is a pure knowledge or technology component, denoted by *A*. The second is an efficiency component, denoted

[12] See, for example, Klenow and Rodriguez-Clare (1997), Hall and Jones (1999), and Hendricks (2002).

by *E*. In the context of the Hansen and Prescott model, the modern growth production function is

(3.1) $$Y_{St} = E_S A_{St} K_{St}^{\theta} N_{St}^{1-\theta}.$$

The technology component of TFP, A_{St}, is common across countries. It is the same across countries because the stock of productive knowledge that is available for a country to use does not differ across countries.[13] The efficiency component differs across countries as the result of differences in economic policies and institutions. Here we consider the case in which a country's economic policies and institutions do not change, so E_s is not subscripted by *t*. The efficiency component is a number in the (0,1] interval. An efficiency level less than one implies that a country operates inside the production possibilities frontier, whereas an efficiency level equal to one implies that a country operates on the production possibility frontier. Differences in efficiency, therefore, imply differences in TFP.

Relative efficiencies at a point in time, and not absolute efficiencies, can be determined using the production function and the data on quantities of the inputs and the output. Thus, it is not possible to determine if any country has an efficiency level equal to one, although we tend to doubt that this is the case. Changes in relative efficiencies of a given country can also be determined conditional on an assumption on the behavior of the technology component of TFP such as that it grows at some constant rate.

We now present the Parente and Prescott (2000) theory of relative efficiencies. To keep the analysis manageable, we present the theory of relative efficiencies in the context of an economy in which only the modern production function is available. The theory constitutes a theory of the aggregate production function when there are constraints at the production unit level. In light of this, we first review the theory underlying the aggregate production function. We then show how policy constraints give rise to an aggregate production function with a different efficiency level. We follow this by providing estimates of cross-country relative efficiencies associated with the modern production function using the mapping from policy to aggregate efficiency derived in

[13] Much of the stock of productive knowledge is public information, and even proprietary information can be accessed by a country through licensing agreements or foreign direct investment.

this section with estimates of the costs imposed by a country-specific policy. Finally, we conclude this section with a discussion of why constraints on the behavior of the production units exist.

The Aggregate Production Function

Before developing the mapping from policy to aggregate efficiency, we briefly review the theory of the aggregate production function associated with modern growth. The theory underlying the aggregate production function is as follows. In each period, there is a set of plant technologies *B*. A plant technology $b \in B$ is a triplet that gives the plant's output y_b and its capital and labor inputs, k_b and n_b. A plan $\{\lambda_b\}$ specifies the measure of every type of plant operated. The aggregate production function, that is, the maximum *Y* that can be produced given aggregate inputs *K* and *N*, is

(3.2) $$Y = F(K,N) = \max_{\lambda \geq 0} \sum_b \lambda_b y_b$$

subject to the two resource constraints

(3.3) $$\sum_b \lambda_b k_b \leq K$$

(3.4) $$\sum_b \lambda_b n_b \leq N .$$

Assuming that this program has a solution, which it will under reasonable economic conditions, the aggregate production function will be weakly increasing, weakly concave, homogeneous of degree one, and continuous.

Empirically, the Cobb-Douglas aggregate production function is the one consistent with the post-1850 modern economic growth era. The question then is, What set of technologies *B* gives rise to the Cobb-Douglas aggregate production function? One such set is the set of plant technologies defined by

(3.5) $$y \leq d(n)k^{\theta} .$$

The function $d(n)$ is an increasing and continuous function of the labor input. Assuming that $n^* = \arg\max d(n)\, n^{\theta-1}$ exists, the aggregate production function is

(3.6) $$Y = A\, K^{\theta} N^{1-\theta},$$

where $A = \max d(n)\, n^{\theta-1}$. With the assumption that the function d increases over time, the expression A will increase over time.

Consequences of Constraints for Aggregate Efficiency

Next, consider the plant production technology with constraints imposed on it. We consider two types of policy. The first type constrains how a particular plant technology can be operated. The second type constrains the choice of the production units that can be operated. For sure, a number of other types of policy have a similar effect, but they are not considered by Parente and Prescott (2000).[14]

The first type constrains how a given technology is operated. A policy that gives rise to this type of constraint is a work rule, which dictates the minimum number of workers or machines needed to operate a plant technology. In particular, suppose constraints are such that the input to a $b = (k,n,y)$ type plant must be $\phi_K k_b$ and $\phi_N n_b$ for all plant types where ϕ_K and ϕ_N exceed one. This implies that a particular technology, if operated, must be operated with excessive capital and labor. With these constraints, the aggregate production function is

(3.7) $$Y = \phi_N^{\theta-1}\phi_K^{-\theta} A \ K^{\theta} N^{1-\theta} = E_S\, A \ K^{\theta} N^{1-\theta},$$

where $E_S \equiv \phi_K^{-\theta}\phi_N^{\theta-1}$. This is the aggregate production function used in Section 2. If the nature of the constraints were to double the capital and labor requirements, then the efficiency measure would be one-half. If the nature of constraints is to quadruple both the capital and labor requirements, then the efficiency measure would be one-fourth.

The second type of policy constrains the choice of the production units that can be operated. This type of constraint can map into the efficiency parameter of an aggregate production with a composite capital stock made up of both physical and intangible components. Any policy that serves to increase the amount of resources the production unit must spend in order to adopt a better technology is a constraint of this nature. Such policies and practices take the form of regulation, bribes, and even severance packages to factor suppliers whose services are eliminated or reduced when a switch to a more

[14] For example, Schmitz (2001) suggests a mapping of government subsidies to state-owned enterprises and aggregate efficiency.

productive technology is made. In some instances, the policy is in the form of a law that specifically prohibits the use of a particular technology. The empirical evidence suggests that this second type of constraint is more prevalent than the first.[15]

Following Parente and Prescott (2000), let the output of a quality *b* plant be given by the following equation:

(3.8) $$y_t = b\, k_{Pt}^{\theta_P} [\min(n_t, \bar{n})]^{\theta_n} \qquad \bar{n} > 0, \quad \theta_P < 1.$$

With this technology, a minimum number of workers, $\bar{n}$, is required to operate a plant. The variable k_P denotes the physical capital input. The subscript *P* is introduced in order to differentiate physical capital from intangible capital. There are no increasing returns to scale in the economy, because if the inputs of the economy are doubled, the number of plants doubles.[16]

A plant's quality is a choice variable. To improve its quality, resources are needed. This resource cost is the product of two components. The first component is technological in nature and reflects the cost in the absence of constraints. The second component, denoted by ϕ_I, reflects the constraint itself. The function that gives the required resources a plant must expend to advance its quality from *b* to *b′* is

(3.9) $$x_{bb'} = \phi_I \int_b^{b'} \left(\frac{s}{W_t} \right)^{\alpha} ds.$$

W_t is the stock of pure knowledge in the world in period *t*. Its growth rate is exogenous and equal to γ_W. Thus,

(3.10) $$W_{t+1} = W_0 (1+\gamma_W)^t.$$

Integrating (3.9) yields

$$x_{It} = \phi_I \frac{b_{t+1}^{\alpha+1} - b_t^{\alpha+1}}{W_0^{\alpha}(1+\gamma)^{\alpha t}(1+\alpha)}.$$

Let

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[15] See Parente and Prescott (2000) for a survey of this evidence.

[16] See Hornstein and Prescott (1993) for a detailed coverage of this technology.

$$k_{It} = \frac{\phi_I b_t^{\alpha+1}}{W_0^{\alpha}(1+\gamma)^{\alpha(t-1)}(1+\alpha)}.$$

The plant technology is specified by

(3.11) $$y_t = \mu \phi^{-\theta_I} (1+\gamma)^t k_{It}^{\theta_I} k_{Pt}^{\theta_P} [\min(\bar{n}, n_t)]^{1-\theta_n} ,$$

with

(3.12) $$k_{It+1} = (1-\delta_I) k_{It} + x_{It} ,$$

where δ_I and μ are functions of α, γ, ϕ_I, and W_0 and $\theta_I = 1 - \theta_P - \theta_n$. The variable k_{It} has the interpretation of the plant's intangible capital stock, as it is the value of the plant's past investments in quality improvements. The sum of θ_I and θ_P is strictly less than one, so there is an optimal plant size.

Aggregating over plants implies the following equilibrium aggregate production relation:

(3.13) $$Y_t = E_S A_0 (1+\gamma_S)^t K_{It}^{\theta_I} K_{Pt}^{\theta_P} N_t^{1-\theta_P-\theta_I} ,$$

with $E_S \equiv \phi^{-\theta_Z}$. The laws of motion for the aggregate capital stocks are

(3.14) $$K_{I,t+1} = (1-\delta_I) K_{It} + X_{It}$$

(3.15) $$K_{P,t+1} = (1-\delta_P) K_{Pt} + X_{Pt} .$$

Now if the intangible capital stock has the same depreciation rate as physical capital, then the aggregate production relation with two capital stocks given by (3.13) maps into an aggregate production function with one capital stock and a large value for the capital share.[17] More specifically, the capital share in the one-capital-stock model, θ, is the sum of θ_I and θ_P. The relations between the two capital stocks, K_I and K_P, and the composite capital stock, K, are

(3.16) $$K_{It} = \frac{\theta_I}{\theta} K_t$$

(3.17) $$K_{Pt} = \frac{\theta_P}{\theta} K_t .$$

[17] This requires an assumption that there is an additional resource cost associated with maintaining the plant's current quality. Such a cost could reflect, among other things, training for young workers who replace old workers retiring in the previous period.

In the experiments that follow, this effectively is the underlying aggregate production function for the modern sector in the combined development theory of Hansen and Prescott when we consider capital share values greater than 0.40.[18]

Estimates of Aggregate Relative Efficiency

The mappings developed in the preceding subsection allow us to impute the aggregate relative efficiency associated with the modern production function for various constraints. In general, the size of the effect of the constraint on a country's aggregate efficiency depends on the factor input affected by the constraint and on that input's share in the production function. In the special case where the constraints affect all inputs equally, that is, $\phi = \phi_n = \phi_I = \phi_P$, the individual factor shares are unimportant and the efficiency level of a country is just $E_s = \phi$. Hence, the implied difference in relative efficiencies is equal to the implied cost differences of policy. Thus, if the cost difference in policies between two countries is a factor of five, the implied factor difference in aggregate relative efficiency is also five.

Are factor differences in relative efficiency greater than five reasonable? Obviously, it is not possible to answer this question definitively without a comprehensive international study of the total costs of the constraints imposed by society. Some estimates of the cost differences associated with some country-specific policies do exist. Studies that estimate the costs of certain policies of individual countries that affect the technology and work practice choices of the production units located there do find that these costs vary systematically with income levels, with large differences existing between rich and poor countries. These studies suggest that factor differences in relative efficiencies could be easily as great as five.

For example, Djankov et al. (2002) calculate the costs associated with the legal requirements in 75 countries that an entrepreneur must meet in order to start a business. They find that the number of procedures required to start up a firm varies from a low of

[18] We say *effectively* because there are two technical issues in the combined theory when capital is broadly defined. First, if intangible capital is not an input into the traditional production function, then the economy will need to make some investments specifically in intangible capital prior to switching to the modern production function. Second, after the transition, as new plants open, they will have a lower technology level compared to older plants.

2 in Canada to a high of 20 in Bolivia and that the minimum official time required to complete these procedures ranges from a low of 2 days in Canada to a high of 174 days in Mozambique. These costs do not reflect any unofficial costs involved with starting a firm, such as bribes, or bureaucratic delays. Because these official cost measures are positively correlated with indexes that incorporate measures of bribes, the true difference in start-up costs between low-cost and high-cost countries is surely even larger than those reported in the study.

Reasons for Constraints

The evidence strongly suggests that production units in poor countries are severely constrained in their choices, and the costs associated with these constraints are large. This prompts the question, Why does a society impose these constraints? A large number of studies, some of which are surveyed in Parente and Prescott (2000), suggest that constraints typically are imposed on firms in order to protect the interests of factor suppliers to the current production process. These groups stand to lose in the form of reduced earnings if new technology is introduced. These losses occur because either the input they supply is specialized with respect to the current production process or the monopoly power granted to them over the supply of a particular input is eroded.[19]

4. A Unified Theory of the Evolution of International Incomes

In this section we unify the Parente and Prescott (2000) theory of relative efficiencies and the Hansen and Prescott (2002) theory of development. The unified theory is then used to organize and interpret the evolution of international income levels. We unify the Parente and Prescott (2000) theory and the Hansen and Prescott theory as follows. We assume that technological increases in both sectors result from growth in world knowledge. Consequently, the technology component of TFP in each production function is the same across countries at any point in time. The paths for the technology components of TFP are determined as in subsection 2C by requiring that the leader

[19] Parente and Prescott (1999) show in a model with no capital how a monopoly right granted to factor suppliers can significantly lower a country's efficiency. Herrendorf and Teixeira (2003) extend this model to include physical capital and show that these monopoly rights have even larger effects on a country's efficiency.

country with an efficiency parameter in the modern sector set to one start its transition to modern economic growth in 1700. We then introduce differences in this efficiency parameter across countries. Given a country's relative efficiency parameter and the common path of the technology components of the TFPs, we compute the equilibrium path of the economy.

As mentioned in Section 3, we doubt than any country has or had an efficiency parameter equal to one. The assumption that efficiency in the leader is one in the unified theory is not important to any of the results as it is just a normalization. Again, only relative efficiencies matter and can be determined. This is the case for countries at a given time and across time in a given country.

We do not introduce cross-country differences in the efficiency parameter associated with traditional production. As mentioned in the introduction, incomes did differ slightly prior to 1700, with the richest countries being no more than two or three times richer than the poorest. One possible explanation for these pre-1700 differences in income levels is that countries differed in policies that increased the inputs required for producing goods with the traditional production function. Because this technology corresponds to traditional farming and even manufactures produced within a home setting, we think the effect of policy differences for relative efficiencies associated with traditional production is small. For this reason, we favor the alternative explanation that some countries were better able to defend themselves from outside expropriations because of geography and thus were able to maintain a higher constant living standard during the pre-1700 era. Countries that enjoyed such an advantage were England and Japan.

We interpret delays in the start of the transition to modern economic growth to late starters having a lower relative efficiency in the modern sector, at least up until the date their transitions began. We attribute the persistent percentage between a country that started modern economic growth later than did the industrial leader to the continuation of its low relative efficiency. Finally, we attribute catch-up, including growth miracles, to large increases in relative efficiency in countries.

We begin by computing the relative efficiency of a late starter required to delay the start of its transition by a given length of time. The size of the required efficiency difference between the leader and the laggard that gives rise to any given delay is a function of the capital share parameter in the modern production function. *Main finding:* The differences in relative efficiency required to generate delays in starting dates of the lengths observed in the historical data are reasonable for all capital shares above 0.40.

We then compute the entire equilibrium path of these late starters assuming that their efficiency levels relative to the leader never change. The main finding is that the gap in incomes between late and early starters never narrows. Large differences in incomes exist even after the late starters are in the modern economic growth phase. In fact, the gap between the leader and late starters increases for some time after the laggards have started the transition to modern economic growth. This is the case even though the transition period of late starters is shorter compared to early starters. The difference in relative efficiencies between late and early starters needed to generate a given factor difference in per capita outputs when both sets of countries are experiencing modern economic growth again depends upon the capital share parameter.

The final set of experiments allows for a one-time increase in a country's relative efficiency parameter. We assume that the change is unexpected from the standpoint of the late starter and viewed as permanent in nature. We then compute the equilibrium path relative to the leader's level and determine the country's output relative to the leader subsequent to the change. *We find that the late starter's path of output relative to the leader subsequent to the change in its efficiency parameter is consistent with the experience of growth miracle countries such as Japan, but only if the capital share is between one-half and two-thirds.*

The finding that capital's share must be large for the unified theory to be a successful theory of the evolution of international income levels has important implications for the size of investment in intangible capital. Namely, it implies that the size of this investment is a large fraction of GDP. Investment in intangible capital goes unmeasured in the national income and product accounts. Thus, it is not possible to determine whether a large capital share is plausible by examining national account data. One must examine micro evidence to determine the plausibility of a large capital share. Thus, we conclude this section by examining the micro evidence on the size of unmeasured investment in the economy. We conclude from this evidence that the size of unmeasured investment in the economy is as large as the size predicted by the unified theory.

Delays in Starting Dates

We first examine whether the unified theory predicts large delays in the start of the transition to modern economic growth that some countries have experienced. In particular, we determine the size of the difference in efficiency required to delay the start of the transition to modern economic growth by a certain number of years.

For the purpose at hand, it is important to provide a more thorough picture of the different starting dates for the transition corresponding to the experiences of individual countries. An issue is how to date the start of modern economic growth. Our definition of the *start* of modern economic growth is the earliest point in a country's history with the property that the trend growth rate is 1 percent or more for all subsequent time.[20] Figure 7 shows the path of output in a number of countries relative to the industrial leader going back to 1800. As can be seen, starting dates vary substantially across countries. Mexico started the transition to modern economic growth sometime between 1800 and 1850; Japan started sometime between 1850 and 1900. Brazil started in the early twentieth century, and India started its transition sometime between 1950 and 1980. As a result of these different starting dates, the disparity in income has increased.

The key expression for determining the delay in the starting date associated with differences is equation (2.12), which rewritten in relative efficiencies is

$$E_S^i A_{St} < \left(\frac{r_{Mt}}{\theta}\right)^{\theta} \left(\frac{w_{Mt}}{1-\theta}\right)^{1-\theta} . \qquad (4.1)$$

A country will not use the modern production function as long as the relation given by (4.1) is satisfied. Once a country's efficiency, $E_S A_{St}$, exceeds the critical level given by the right-hand side of (4.1), which it must, the country begins its transition to modern economic growth. Assuming as we do that relative efficiencies associated with the traditional production function do not differ across countries, the rental prices of land

[20] The concept of trend employed here is a highly smoothed path of per capita income.

and labor will not differ much across countries over the periods when each country specializes in the traditional production function.[21] Consequently, this critical level of efficiency will not differ much across countries. It follows that the difference in starting dates between two countries *i* and *j*, with different relative efficiencies, is approximately given by the dates t_i and t_j for which

$$E_S^i A_{St_i} = \left(\frac{r_M}{\theta}\right)^{\theta}\left(\frac{w_M}{1-\theta}\right)^{1-\theta} = E_S^j A_{St_j}. \tag{4.2}$$

It is not obvious looking at equation (4.2), but the required relative efficiency E_S^i / E_S^j that gives rise to a particular delay in the start of the transition depends on the size of the capital share in the modern production function. The reason for this is that the required factor difference in relative efficiencies equals the factor difference in the stock of pure knowledge, A_s, between starting dates. It follows that the required relative efficiency difference is smaller for larger increases in the stock of pure knowledge between starting dates. The size of the increase in the stock of pure knowledge depends importantly on its asymptotic growth rate, γ_S. The value of this parameter is calibrated so that the growth rate of per capita output associated with the steady-state rate of the modern-growth-only model, given by $(1 + \gamma_S)^{1/(1-\theta)}$, equals 2 percent per year. Thus, the calibrated value of γ_S and hence the size of the increase in pure knowledge between starting dates t_j and t_i, depends on capital's share in the modern growth production function.

We now compute the efficiency of the early starter relative to a late starter required to generate a given delay in the transition to modern economic growth. We do this for a range of the capital share parameters, since the value of capital's share is not well restricted. For each capital share value, we recalibrate the asymptotic growth rate of pure knowledge, γ_S, and the value of A_{s0} so that the country with $E_s = 1$ always starts its transition in 1700. These are the only parameters whose values are changed in the experiments.

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[21] They are roughly equal because the rental prices will not be constant in all periods that the economy specializes in the traditional production function. This is because agents will start to accumulate more capital per household member in anticipation of the modern production function being used.

We assume that late starters are endowed with an initial capital stock equal to the steady-state level associated with the classical model of subsection 2A. For the purpose of determining the date at which an economy starts to use the modern growth function, it is not necessary that we fully specify the population growth function of the late starters. In particular, it is not necessary to specify the population growth function for consumption levels sufficiently greater than the constant consumption level, c_m, associated with the pre-1700 period. For consumption levels below this, we use a population growth function with a sufficiently large and positive slope at c_M and for which $g(c_M) = (1+\gamma_M)^{1/(1-\phi-\mu)}$. These assumptions ensure that the living standard in a late starter is roughly constant prior to the period it begins its transition.

Table 2 reports the efficiency of the early starter relative to the late starter required to generate a 100-year, a 200-year, and a 250-year delay in the transition to modern economic growth. These delays roughly represent the difference in the start of the transition to modern economic growth between England and Mexico, England and Japan, and England and India. As Table 2 shows, the factor difference in efficiency needed for a given delay decreases as the modern production capital share increases. The size of the required difference needed to delay the start of development for 250 years is plausible for all values of θ in Table 2, with θ = 0.40 probably at the lower bound of plausible values.

Table 2. Required Factor Difference in Relative Efficiencies for Delays

θ	1800 Start	1900 Start	1950 Start
.40	1.60	3.2	5.7
.50	1.25	2.5	4.0
.60	1.20	2.2	3.3
.70	1.18	1.9	2.5

No Catch-Up After the Transition

A number of countries, many of which are located in Latin America, started their transitions to modern economic growth in the nineteenth century. Despite this, these countries have failed to eliminate the gap with the leader over the last century. We now examine whether the model can account for this feature of the data. In particular, we seek to determine if the model predicts a narrowing of income levels once a country begins modern economic growth absent any changes in relative efficiency.

We address this question by examining whether the model absent any assumed subsequent changes in relative efficiencies predicts a narrowing or widening of income levels between early and late starters. In particular, we now compute the equilibrium paths of per capita output for the model economies associated with the required differences in relative efficiencies reported in Table 2. We also report their relative incomes.

Before undertaking these experiments, it is necessary to address two issues. First, it is necessary to specify the population growth rate function for the late starters in these experiments because increases in population affect the size of the increases in per capita output over the transition. For this specification, we simply use the post-1800 population growth rates of Mexico for the model economy that starts its transition in 1800, the post-1900 population growth rates of Japan for the model economy that starts its transition in 1900, and the post-1950 population growth rates of India for the model economy that starts its transition in 1950. These population growth data are taken from Lucas (2002, Table 5.1). Second, for capital share values that reflect a broad concept of capital, it is necessary to adjust output by the amount of investment in intangible capital. This adjustment must be made in order to compare the predictions of the model with the national income and product account data, because the latter fails to measure investments in intangible capital.

A country's unmeasured investment as a fraction of its measured output can be determined given the decomposition of the capital share between its physical capital and intangible capital components. For a given total capital share, the physical capital component can be calibrated to the ratio of investment to physical capital to measured GDP in the leader countries of roughly 20 percent. In particular, the share parameters can be calibrated to the steady state of the modern growth-only-economy using this observation from the leader countries. With value of the individual share parameters in the modern growth production function, it is possible to compute the amount of unmeasured investment at any date of the equilibrium path.

Table 3 reports the size of the intangible capital share parameter and the asymptotic ratio of intangible capital investment to GDP for each of the total capital share values considered in Table 2. As the total capital share increases, both the intangible capital share and the intangible capital investment share of GDP increase. The sizes of the unmeasured investment shares range from 0.0 for θ = 0.40 to 0.50 for θ = 0.70.

Table 3. Implied Intangible Capital Share and Investments

θ	θ_I	$X_I/(Y-X_I)$
.40	.00	.00
.50	.28	.26
.60	.41	.41
.70	.53	.62

Figure 8 plots the path of per capita GDP for late starters relative to the leader over the 1700 to 2050 period. The paths correspond to the case where θ = 0.40. The paths are essentially the same for the other capital share values. For this reason, we do not report their paths in the paper. Asymptotically, the model is just the steady state of the modern growth model of subsection 2B, and so income differences are just $(E_s^i / E_s^j)^{1/(1-\theta)}$. For the 1800 starter, the asymptotic relative income level is 50 percent of the leader, for the 1900 starter it is 16 percent, and for the 1950 starter it is 6 percent.

Most of the difference in relative incomes in 2000 is the consequence of the poor country starting the development process later. However, even after starting to develop, a late starter's disparity with the leader increases, although at a much slower rate than before. There are two reasons for this. First, the disparity continues to increase because the traditional production function is still widely used at the start of the transition and the growth rate of TFP associated with the traditional production function is lower than the growth rate of TFP associated with the modern production function. Second, the population growth in these countries tends to be higher compared to the leader over the comparable period. The disparity with the leader stops increasing only after the modern production function starts being used on a large scale. For the 1800 starter, the disparity stops increasing around 1900. For the 1900 starter, the disparity stops increasing around

2000. And for the 1950 starter, the disparity stops increasing around 2050.[22] The increase in disparity over the 1950–2000 period for the 1950 starter is consistent with the fact that many sub-Sahara African countries have fallen further behind the leader in the 1950–2000 period despite experiencing absolute increases in living standards over this period.

Laggards do experience larger increases in their income over their transition periods compared to earlier starters. For example, the country that starts its transition in 1700 realizes a factor increase of 1.2 in its per capita income by 1750. In comparison, the country that starts its transition in 1900 realizes a factor increase of 2 in its per capita income over the next 50 years.[23] The reason for this difference is that the growth rate of knowledge associated with the modern production function is initially low, but rises over time. Thus, TFP growth in the modern production function over a late starter's transition period is higher compared to an earlier starter's transition period. This gives late starters an inherent advantage.

The data needed to verify whether this pattern exists are not readily available. In particular, per capita output numbers going back to the eighteenth century exist for only a limited number of countries. Although it is not possible to say whether transition periods have become shorter over time, there is strong evidence that late starters have been able to double their incomes in far shorter time periods compared to earlier starters.

Figure 9 documents this general pattern. It plots the number of years a country took to go from 10 percent to 20 percent of the 1985 U.S. per capita income level versus the first year that country achieved the 10 percent level. The 1985 U.S. level was 20,000 in 1990 dollars. The set of countries considered had at least 1 million people in 1970 and had achieved and sustained per capita income of at least 10 percent of the 1985 U.S. level by 1965. There are 56 countries that fit these criteria and for which data are available. Of these 56 countries, all but four managed to double their per capita income

[22] This is a key difference between our formulation and that of Ngai (2000). Ngai examines the effect of policy on the starting date within Hansen and Prescott's overlapping generations model. In contrast, she finds that some part of the income gap will be eliminated once poor countries start their transitions.

[23] This assumes the same population growth functions for both economies.

by 1992. The four exceptions all had protracted armed insurgencies that disrupted their development.

The difference in the length of the doubling period between the sets of late and early starters is dramatic. For early starters, which are those achieving 10 percent of the 1985 U.S. level before 1950, the median length of the doubling period is 45 years. For late starters, defined as those achieving 10 percent of the 1985 U.S. level after 1950, the median length of the doubling period is 15 years. The choice of starting level is not important. A similar pattern emerges when the starting level is fixed at 5 percent and at 20 percent of the 1985 U.S. level.

Although the model absent changes in relative efficiency infers an advantage to late starters, quantitatively it is inconsistent with the number of years in which many late starters have been able to double their income. Many late starters that doubled their income in less than a 35-year period after 1950 did in fact narrow the gap with the leader over that period. The unified theory absent changes in relative efficiencies does not predict any catch-up for late starters. For the theory to account for this catch-up, it must consider changes in relative efficiency in a given country over time.

Catch-Up and Growth Miracles

We now examine whether the theory can account for the record of catch-up. A key feature of the evolution of international income levels is that many countries have been able to narrow the gap with the leaders, with some realizing large increases in output relative to the leader in a relatively short period of time. Countries such as Botswana, China, Japan, South Korea, and Taiwan were all able to double their living standards in less than a decade at some point in time over the post-1950 period. These growth miracles are a relatively recent phenomenon and are limited to countries that were relatively poor prior to undergoing their miracle. No country at the top of the income distribution has increased its per capita income by a factor of 4 in 25 years, and the leader has always taken at least 80 years to quadruple its income.

To account for the catch-up, including growth miracles, the theory, therefore, requires an increase in the efficiency of a country relative to the leader.[24] In light of the Parente and Prescott (2000) theory, these changes in relative efficiency are easy to understand. Namely, they reflect policy changes. Following an improvement in policy that leads to a significant and persistent increase in efficiency, the theory predicts that the income of a late starter will go from its currently low level relative to the leader to a much higher level. As it does, its growth rate will exceed the rate of modern growth experienced by the leader countries, and the gap in incomes will be narrowed.

We now consider an increase in a late starter's relative efficiency. In particular, we examine whether the unified theory can account for the growth miracle of Japan.[25] Figure 10 depicts the path of per capita output for the Japanese and U.S. economies over the 1900 to 1995 period. There is really nothing special about Japan versus other economies that similarly experienced growth miracles. The precise time period of the Japanese growth miracle we consider in the analysis is the 1957–69 period. We choose this period because by 1957 Japan had fully recovered from the wartime disruptions. Moreover, this period is one of the most dramatic in terms of Japan's catch-up. In this 12-year period, per capita GDP doubled from 25 percent of the leader to 50 percent of the leader (Summers and Heston, 1991). This catching up was not the result of the leaders' growth rate slowing down. Indeed, U.S. per capita GDP grew by 40 percent in this period. The Japanese economy in this period is a dramatic example of catching up.

In the experiment, we assume that there is an unexpected increase in 1957 in the relative efficiency of the model economy, which started its transition in 1900, to the leader's level. This assumption is made because the data suggest that Japan in the 1957–69 period was converging to the U.S. balanced growth path. In calculating the equilibrium path of the model economy following this increase, we take the initial population to be the population corresponding to the equilibrium path of the model economy that starts the transition in 1900. The initial capital stock is assumed to be such that per capita

[24] Additionally, an increase in efficiency can hasten the start of the transition to modern growth for countries that have not already begun this phase of development.

[25] Ngai (2000) studies this same issue within the Hansen and Prescott model.

GDP relative to the leader equals 25 percent.[26] The population growth rate function for the model economy is the same as before and is based on Japanese population dynamics.

The important finding is that the total capital share must be large for an economy to take 12 years to move from 25 percent to 50 percent of the leader. Figure 11 plots the path of per capita GDP predicted by the model economy over this period for various values of θ. For a value of θ equal to 0.40, the predicted path shows too large an increase over the period. At the other end of the range, namely, $\theta = 0.70$, the predicted path shows too small an increase over this time period. This leads us to conclude that capital share values in the range of 0.55 and 0.65 are consistent with the growth miracles. [27]

It is possible to introduce this increase in efficiency in the poor country at a much earlier date, say in 1800. The theory does not, however, predict that the poor country will experience a growth miracle. The theory, therefore, is consistent with the fact that growth miracles are a relatively recent phenomenon. Growth miracles are a relatively recent phenomenon because, as Figure 8 shows, differences in relative incomes between the low-efficiency and high-efficiency countries widen over time before leveling off. This widening is due to growth in the stock of pure knowledge associated with the modern production function, which the high-efficiency country uses from a very early date. Thus, as one goes back in time, the gap that a low-efficiency country could close by becoming a high-efficiency country becomes smaller and smaller. Obviously, if the gap is less than 50 percent, the low-efficiency country can never double its income in less than a decade. For the same reason, the unified theory is consistent with the fact that late starters have been able to double their incomes in far shorter times compared to early starters.

The theory is also consistent with the fact that growth miracles are limited to countries that were initially poor at the time their miracles began. Growth miracles are limited to this set of countries because a growth miracle in the theory requires a large increase in a

[26] In the case where capital is broadly defined, we assume the initial mix of physical and intangible capital is optimal in the sense that returns would be equal.

[27] There are a number of reasons to believe that capital's share may be somewhat less than 0.60. For one, we abstracted from leisure. For another, we abstracted from household durables. For an in-depth discussion of this issue, see Parente and Prescott (2000).

country's relative efficiency. A large increase in efficiency can only occur in a poor country with a currently low efficiency parameter. This rules out a rich country, which by definition uses its resources efficiently.

Unmeasured Investment

For capital shares that are consistent with the evolution of international income levels, the implied size of unmeasured investment is between 35 and 55 percent of GDP. Are these intangible capital investment share numbers plausible? This is not an easy question to answer. The difficulty in coming up with measures of the size of intangible capital investment is that the national income and product accounts (NIPA) treat investments in intangible capital as ordinary business expenses. Parente and Prescott (2000) attempt to estimate the size of intangible capital investment in the U.S. economy. They conclude that the size of this investment may be as large as 50 percent of GDP. In constructing their estimates, Parente and Prescott (2000) use the principle implied by theory that *investment* is any allocation of resources that is designed to increase future production possibilities. Using this principle, they identify such activities as starting up a new business, learning-on-the-job, training, education, research and development, and some forms of advertising as investments in intangible capital.[28] Such estimates are consistent with capital share values between one-half and two-thirds.

5. Catching Up

The implication of the theory is that countries will be rich if they do not constrain production units as to which technologies can be operated and the manner in which a given technology can be operated. Currently poor countries will catch up to the industrial leaders in terms of production efficiency if existing barriers to efficient production are eliminated and an arrangement is set up to ensure that barriers will not be re-erected in the future. The removal of such constraints is a necessary condition for catching up. As discussed in Section 3, there is strong evidence that suggests that these constraints exist to protect the interests of industry groups vested in the current production process. As such, their removal is likely to be contentious. For this reason, it is instructive to examine the record on catch-up in greater depth for the purpose of

[28] Additionally, McGrattan and Prescott (2002) estimate the size of unmeasured investment in the corporate sector only and conclude that it is roughly 10 percent of GDP.

determining the reasons for circumstances under which barriers to efficient use of technology were reduced and catching up with the efficiency leader occurred.

Catching up is not uniform across regions in this period, as can be seen in Figure 12. Latin America began modern economic growth in the late nineteenth century and has not subsequently closed the living standards gap with the industrial leader. Its per capita income remained at roughly 25 percent of the industrial leader throughout the twentieth century. In comparison, Asian countries with the exception of Japan began modern economic growth later. This set of countries experienced significant catching up in the 1970–2000 period.

The large Western European countries, namely, Germany, Italy, and France, caught up to the industrial leader in the post–World War II period after trailing the leader for 100 years. Modern economic growth in these countries began about 1840. At that time, their living standard was about 60 percent of the industrial leader, which at that time was the United Kingdom. For nearly 100 years, these countries maintained an income level that was about 60 percent that of the industrial leader. In the post–World War II period, output per hour worked in these countries, which is a good measure of living standards because it recognizes the value of nonmarket time, increased from 38 percent of the U.S. level in 1950 to 73 percent in 1973 and to 94 percent in 1992. Today, most of the difference in per capita output between the Western European countries and the United States is accounted for in differences in the fraction of time that people work in the market, and not in the efficiency with which resources are used.

Another important example of catching up is the U.S. development experience in the 1865–1929 period. In 1870, U.K. per capita GDP was nearly a third higher than that of the United States. By 1929, the United Kingdom's per capita GDP was a third lower than that of the United States. The dramatic growth performance of the United States in this period is an important fact that needs to be explained.

Reasons for Catching Up

We begin with the Asian catching-up observation. Countries such as South Korea, Taiwan, and Japan were forced to adopt policies that did not block efficient production as a condition for support from the United States. Further, the need to finance national defense made protecting those with vested interests in inefficient production too expensive to South Korea and Taiwan. These development miracles along with the Hong Kong and Singapore growth miracles made it clear to the people of the democratic states in the region that the policy that their elected representatives followed mattered for their living standard. Their elected representatives had no choice but to cut back on protecting industry insiders with vested interests in inefficient production or be voted out of office.

The rapid development of China began in 1978 when the Chinese government became more decentralized, with much of the centralized planning system dismantled. Although the central government gave more power to regional governments, it did not give the regional governments the right to restrict the flow of goods across regions. In fact, when individual regions attempted to erect trade barriers in the late 1980s and early 1990s, the central government immediately took steps to restore the free flow of goods and services.[29] The resulting competition between businesses in different provinces led to rapid growth in living standards.

The comparison of Russia's performance under capitalism with China's is interesting and informative. Russia's experiment with capitalism to date can only be considered a failure, as its output has actually contracted since 1992. In contrast to China, there is no free trade club in Russia. Migration of individuals between regions is restricted, and local and regional governments have the power to discriminate against producers from other member states operating within their borders. Parente and Riós-Rull (2001) argue that establishing a decentralized system with competition between regions in Russia was undoubtedly a much more difficult endeavor compared to China for a number of reasons. First, by being more industrialized at the time of its transition, Russia had more vested interest groups. Second, Soviet central planners concentrated industry in particular regions, without an economic justification for such locations.

Turning now to the questions of why the United States caught up with and surged past the United Kingdom in the 1865–1929 period and why Western Europe caught up with the United states in terms of labor productivity in the 1957–93 period, our answers are

[29] See Young (forthcoming).

as follows. The answer to the first question is that the United Sates was and continues to be a free trade club, while the United Kingdom was not a member of a free trade club in this earlier period. Our definition of a *free trade club* is as follows. A set of states constitutes a free trade club if it meets two conditions. Member states cannot impose tariffs and other restrictions on the import of goods and services from other member states. In addition, member states must have a considerable degree of economic sovereignty from the collective entity. Just as no single state is able to block the movement of goods between states, the collective entity cannot block the adoption of a superior technology in one of its member states. Thus, a free trade club in our definition is far more than a set of countries with a free trade agreement.

In democratic states with legislatures representing districts, vested interests in other districts have a limited ability to block the adoption of technology in a given district if the citizens of the given district want that technology adopted. In the United States, for example, Toyota was able to locate an automobile plant with its just-in-time production in Tennessee in 1985. Those with vested interests in the less efficient technology in Michigan and other states with a large automotive industry were not able to prevent this from happening. The people in Tennessee wanted the large construction project in their state and the high paying jobs in the automobile factory. Thus, the United States is a free trade club. With the formation of NAFTA and the recent approval of the free trade agreements with Chile and Singapore, the set of states constituting the free trade club to which the U.S. states belong may be getting larger.

The European Union has become an equally important free trade club. Its states enjoy even greater sovereignty than do U.S. member states. However, the German state cannot block the Toyota introduction of just-in-time production in Wales even though German politicians would if they could in response to domestic political pressure. If Toyota starts gaining market share, it will not be long before the auto industry throughout Europe adopts the superior technology, and productivity in the production of automobiles increases. This is just competition at work.

The historical statistics lend strong empirical support to the theory that a trading club arrangement results in greater efficiency of production. Table 4 reports labor productivity for the original members of what became the European Union and the labor productivity of members that joined in the 1970s and 1980s. Productivities are reported for an extended period before the EU was formed as well as for the period subsequent to its creation.

The Treaty of Rome was signed in 1957 by Belgium, France, Italy, Netherlands, Luxembourg, and West Germany to form the union. In 1973 Denmark, Ireland, and the United Kingdom joined. In 1981 Greece joined, followed by Portugal and Spain in 1986. The most recent additions are Austria, Finland, and Sweden in 1995.

One striking fact is that prior to forming the European Union, the original members had labor productivity that was only half that of the United States. This state of affairs persisted for over 60 years with no catching up. However, in the 36 years after forming what became the EU, the Treaty of Rome signers caught up with the United States in terms of labor productivity. The factor leading to this catch-up is an increase in the efficiency with which resources are used in production. Changes in capital/output ratios are of little significance in accounting for the change in labor productivity.

Also reported in Table 5 is the productivity of the EU countries that joined the union in 1973. These countries experienced significant productivity catch-up subsequent to joining the union. It will be interesting to see if Greece and Portugal, the two EU countries that have far lower productivity than the other EU members, continue to improve their relative productivity performance.

Another interesting comparison is between the productivity performance of Switzerland and the Western European countries that did not join the EU until 1995. Norway was not included in this set of countries because of the large size of its oil industry. We label this set of four countries *other*. Table 5 reports labor productivities of these other countries relative to the original EU countries.

The important finding is that the original EU countries and the other countries are equally productive in the prewar period. In the 36 years from 1957 to 1993, the other countries fell from 1.06 times as productive as the original EU countries to only 0.81 as productive in 1993. This constitutes strong empirical evidence that membership in the EU fosters higher productivity.

Table 4. Labor Productivities of European Union Members as a Percentage of U.S. Productivity[a]

Year	Original Members	Members Joining in 1973
1870	62	
1913	53	
1929	52	
1938	57	
1957	53	57
1973	78	66
1983	94	76
1993	102	83
2002	101	85

[a] The prewar numbers are population weighted labor productivity numbers from Maddison (1995). The postwar numbers are also population weighted and were obtained from Maddison's Web page, http://www.eco.rug.nl/GGDC/index-series.html#top.

Table 5. Labor Productivity of Other Western European Countries as a Percentage of Original EU Members[a]

Year	Others / Original
1900	103
1913	99
1938	103
1957	106
1973	96
1983	85
1993	81

[a] The prewar figures are from Maddison (1995). For this period, GDP per capita is used as a proxy for productivity. The postwar numbers are also population weighted and were obtain from Maddison's Web page, http://www.eco.rug.nl/GGDC/index-series.html#top.

A free trade club, which prohibits individual states from discriminating against the goods produced in other member states and against producers from other member states operating within their borders, has the advantage that industry insiders in the various member states face elastic demand for what they supply. As a consequence, they are not hurt by the adoption of more efficient production methods as the increase in output leads to an increase in employment in that industry. If demand were inelastic, an increase in efficiency would lead to a fall in employment, something which industry insiders strongly oppose.

Industry studies document the effect of free trade of goods and services on the adoption of better technology and work practices. Galdon and Schmitz (1998), for example, document the effect of increased competition in iron ore mining in the 1980s. Increased competition from Brazilian iron ore mines had major consequences for productivity in U.S. mines. Output per unit of input increased by a factor of 2 as competition made it in the interest of specialized factor suppliers to permit the doubling of productivity. Ferreira and Rossi (forthcoming) document large increases in output per worker in 16 industries in Brazil at the two-digit level following the trade liberalization in the early 1990s. After declining at an annual rate of 1.6 percent per year from 1985 to 1990, it increased at a rate of 6 percent per year thereafter. The increases in productivity were associated with a decline in employment and hours.

We turn now to Latin America and why Latin America failed to catch up. There was no free movement of goods and people between the set of relatively sovereign states. A consequence of this is that often industry insiders in the sovereign states faced inelastic demand for their products or services, and this led them to block the adoption of more efficient production practices. If Brazil were to decentralize and restrict the authority of its central government to be like the United States in the 1865–1930 period, Brazil would quickly become as rich as Western Europe and the United States, or maybe richer.

6. Concluding Remarks

Will the whole world be rich by the end of the twenty-first century? The implication of the theory reviewed in this chapter is that a country will catch up to the leading industrial countries only if it eliminates the constraints relating to the use of technology. Although it is clear what a country must do to become rich, it is not clear whether a country will have either the political will or political power to make the necessary reforms. Removal of the constraints to the efficient use of resources is bound to be contentious, because such constraints typically exist to protect specialized groups of factor suppliers and corporate interests. As recent events in Argentina show, these groups can overthrow a government.

The increase in the number of free trade clubs in the last decade, the central Andean Community and North America, for example, is evidence that some countries have achieved the political will to reduce these constraints. However, the lack of the emergence of free trade clubs in many other regions of the world, particularly Africa, the Indian subcontinent, and South America, is evidence of a lack of political will. A thorough understanding of why one country has this political will and another does not is something we are currently lacking. If we had this understanding it might be possible to determine what should be done to minimize the resistance to reform by groups with interests vested to current production processes.

A first step in addressing this issue is to understand how constraints to the efficient use of resources come to exist in the first place. Surely, many constraints exist to protect the vested interests of individuals in the status quo. What we really seek to understand is the mechanism by which these groups and their interests succeed in getting these constraints put in place. Policy, namely, the imposition of constraints on the efficient use of resources, is undoubtedly the outcome of a game between policymakers and the economy’s actors. Consequently, fruitful research in this area will most likely require a game-theoretical approach. Some progress is being made in this area. Grossman and Helpman (1994), Krusell and Ríos-Rull (1996; 2002), Holmes and Schmitz (1995; 2001), McDermott (1999), Kocherlakota (2000), Ngai (2000), Bridgman, Livshits, and MacGee (2001), Parente and Ríos-Rull (2001), Samaniego (2001), Teixeira (2001), and Parente and Zhao (2002) all deal with this issue. In our view, this area of research will dominate the study of development and growth in the years to come.

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Figure 1: Evolution of International Incomes: 1700–1990 (Fraction of Leader)

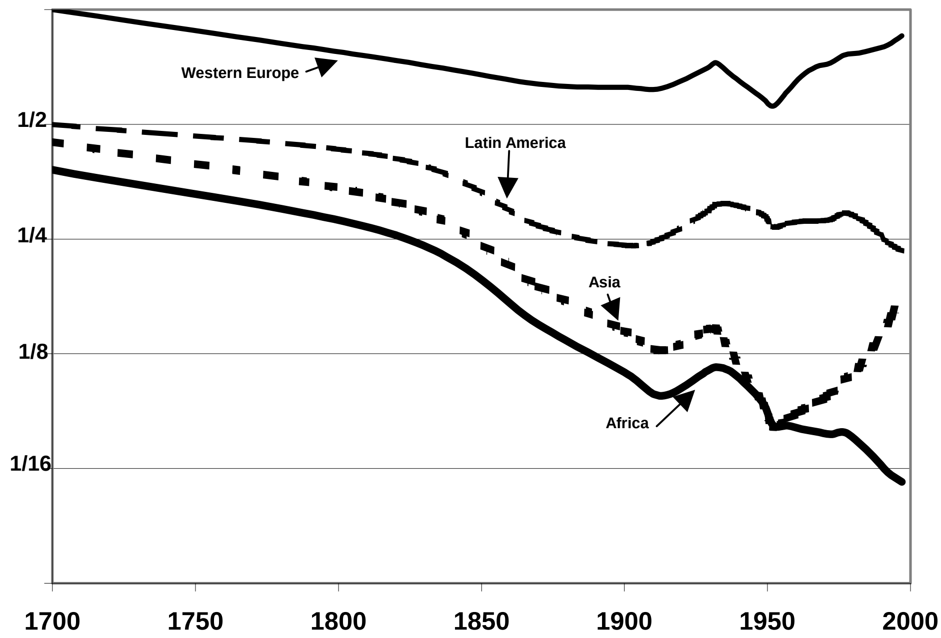

Figure 2: The Leader's Per Capita GDP Relative to Pre-1800 Level

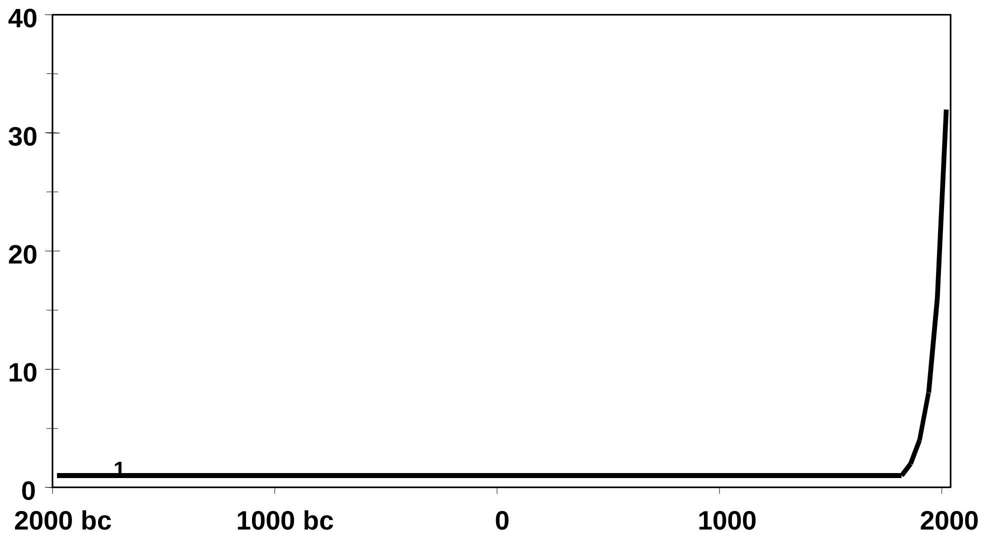

Figure 3: Population Growth Function *g*(*c*)

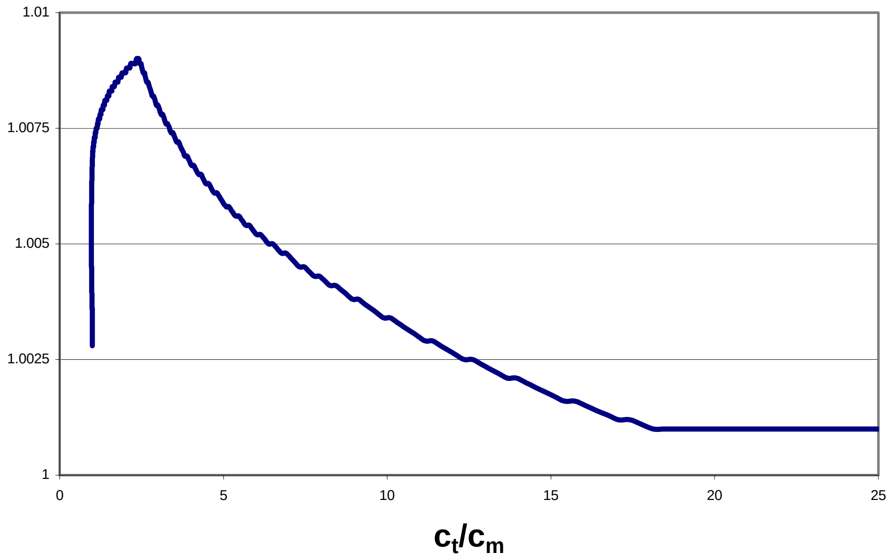

Figure 4: Per Capita Output Relative to 1700

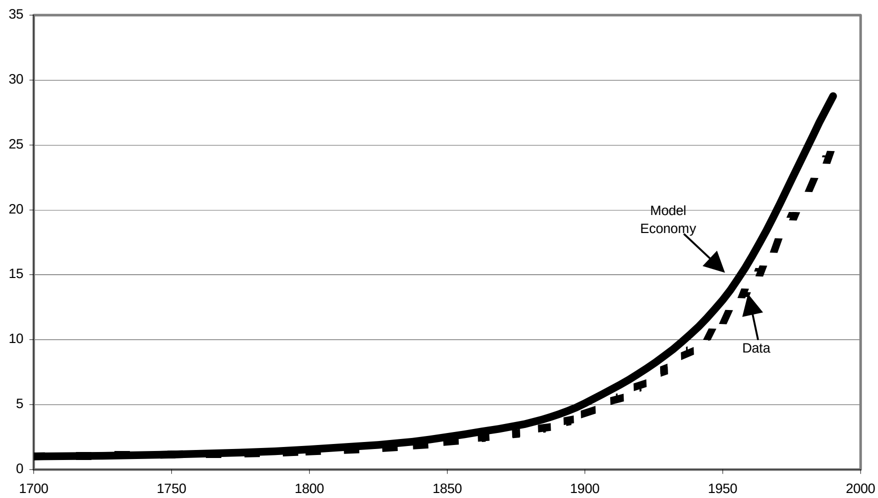

Figure 5: Growth Rate of per Capita Output

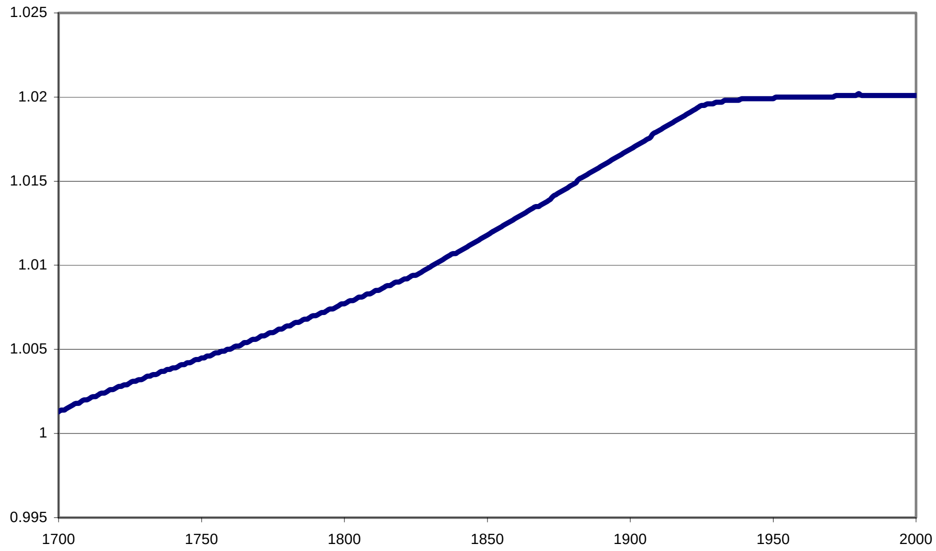

Figure 6: Rental Prices (1700 =1)

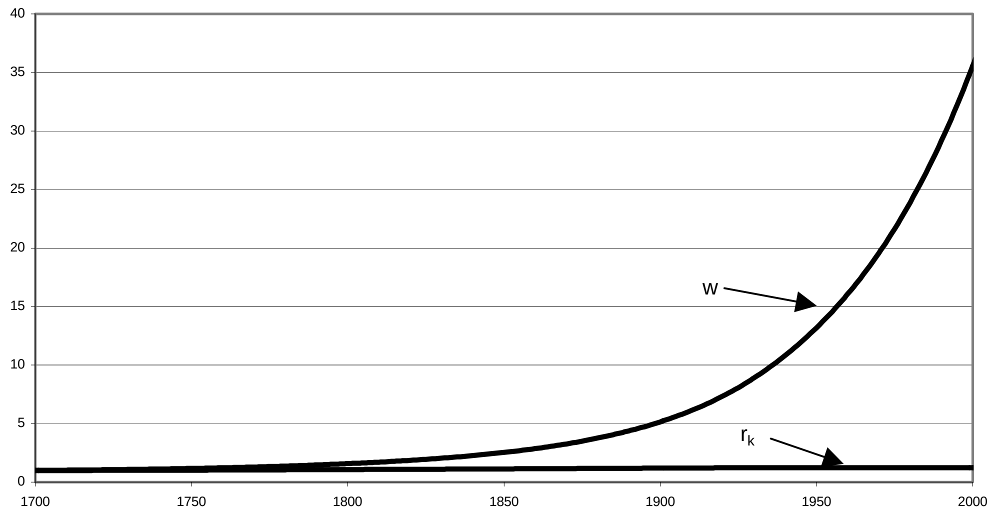

Figure 7: Different Countries Start at Different Times

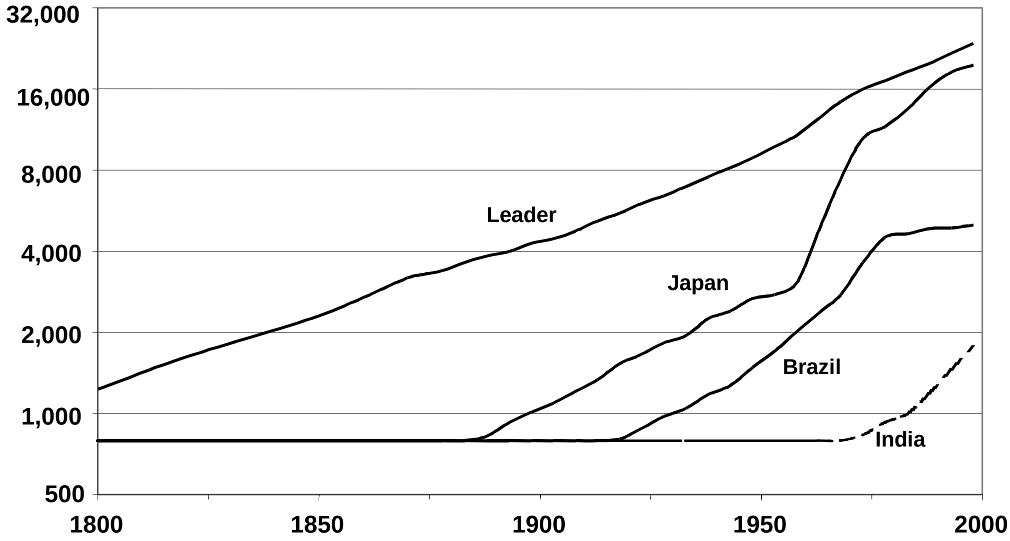

Figure 8: Late Start (Output Relative to the Leader)

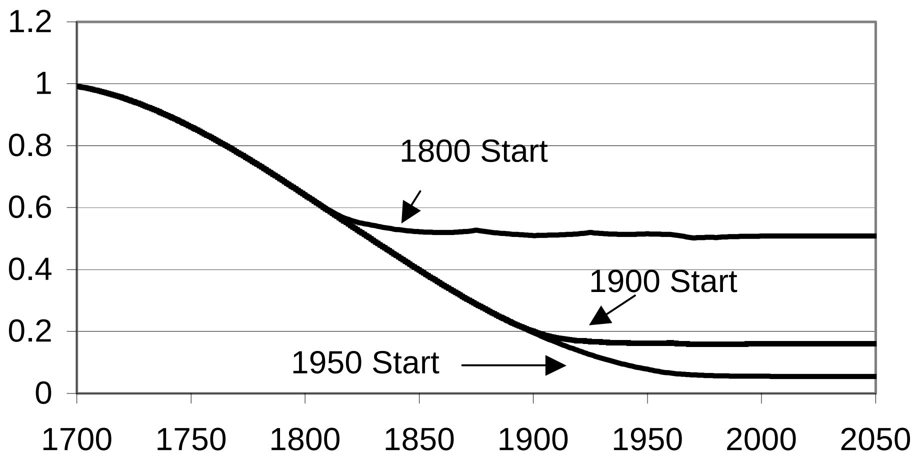

Figure 9: Years for Per Capita Income to Grow from 2,000 to 4,000 (1990 $US)

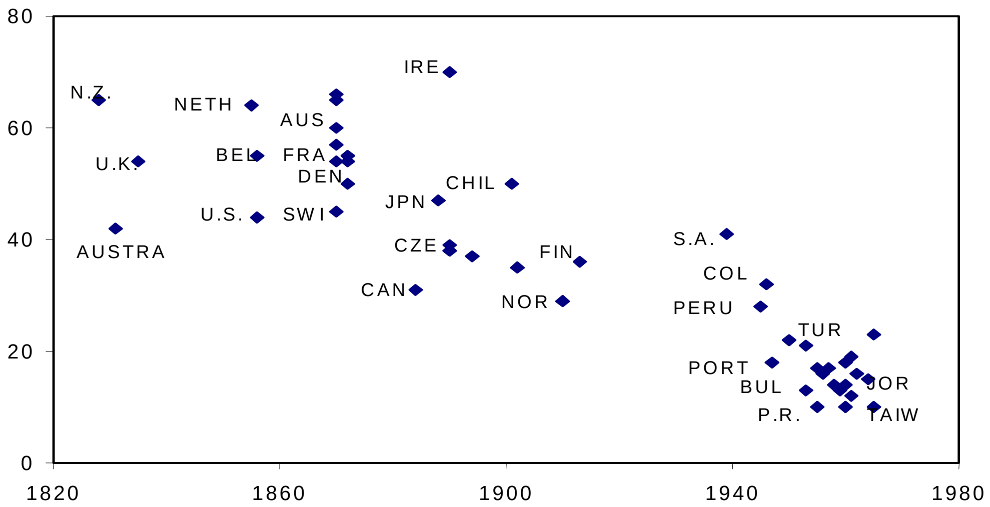

Figure 10: Trends in Output per Capita 1900–95 (1990 $US)

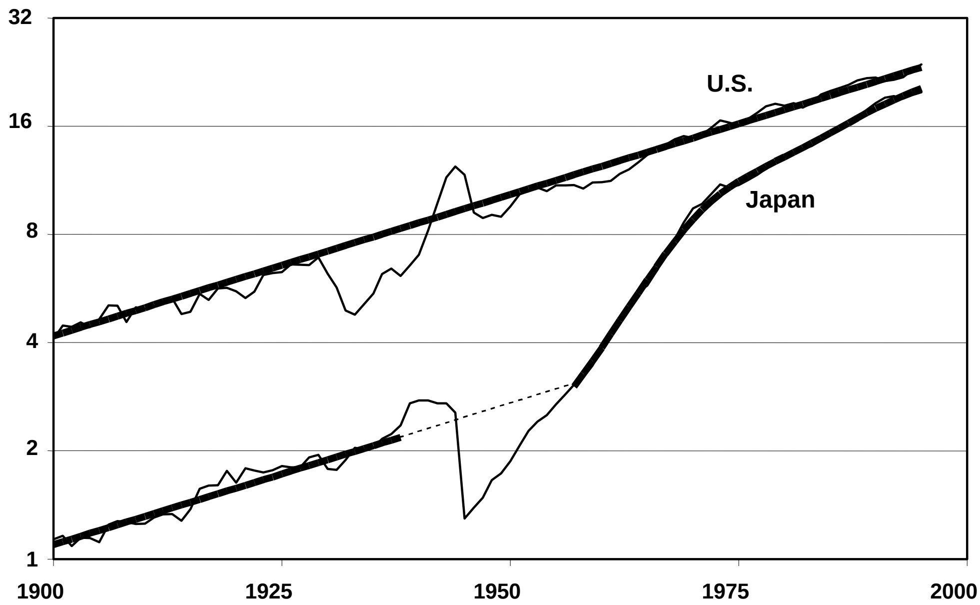

Figure 11: Growth Miracles

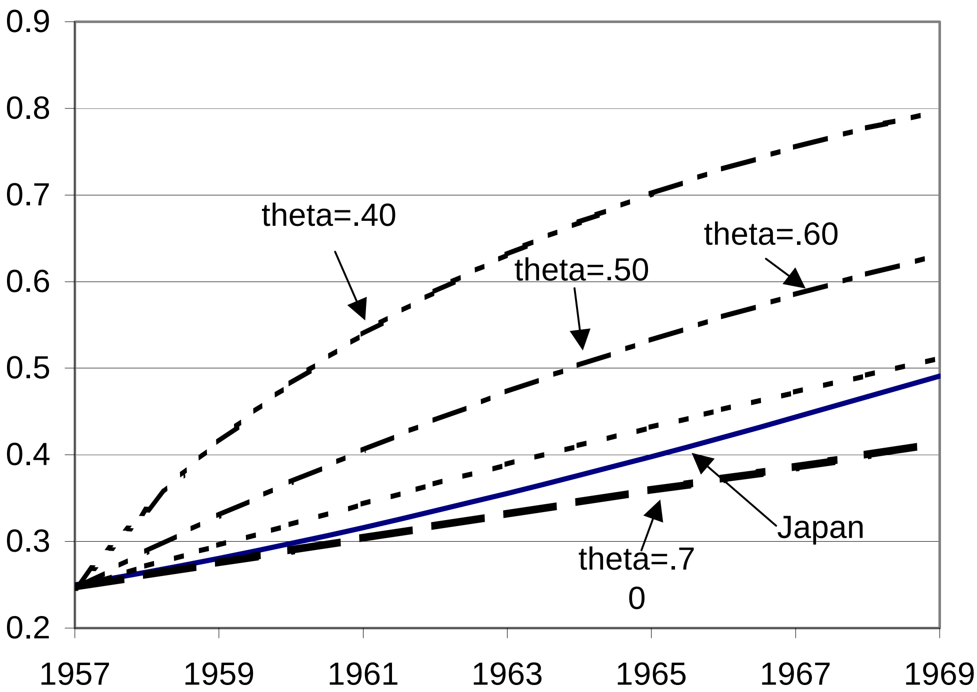

Figure 12

Different Countries Start at Different Times