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Explaining Cross-Country Income Differences[†]

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ABSTRACT

This chapter reviews the literature that tries to explain the disparity and variation of GDP per worker and GDP per capita across countries and across time. There are many potential explanations for the different patterns of development across countries, including differences in luck, raw materials, geography, preferences, and economic policies. We focus on differences in economic policies and ask to what extent can differences in policies across countries account for the observed variability in income levels and their growth rates. We review estimates for a wide range of policy variables. In many cases, the magnitude of the estimates is under debate. Estimates found by running cross-sectional growth regressions are sensitive to which variables are included as explanatory variables. Estimates found using quantitative theory depend in critical ways on values of parameters and measures of factor inputs for which there is little consensus. In this chapter, we review the ongoing debates of the literature and the progress that has been made thus far.

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1. Introduction

Gross domestic product (GDP) per worker of rich countries like the United States is about 30 times that of poor countries like Ethiopia. The fastest growing countries now grow at 9 percent per year, whereas 100 years ago the highest rates of growth were around 2 percent. Over the postwar period, there is virtually no correlation between income levels and subsequent growth rates, and growth rates show very little persistence. This chapter reviews the literature that tries to explain these and other facts about the cross-country income distribution.

There are many potential explanations for the different patterns of development across countries, including differences in luck, raw materials, geography, preferences, and economic policies. As in most of the literature, we focus on economic policy and ask to what extent can differences in policies across countries account for the variability in levels of income and their growth rates. Are policies responsible for only a few percent of the income differences or for most of the variation? If they are responsible for most of the variation, which policies are particularly helpful or harmful?

We show that while some progress has been made in answering these questions, it has been fairly limited. There are estimates of the effects of policy on income and growth for a wide range of policy variables. However, in most cases, their magnitudes are under debate. Moreover, there is little consensus concerning methodology.

We review two approaches used to obtain estimates of the effects of policy on income and growth. The most widely used approach is to run cross-sectional regressions of growth rates on initial levels of income, investment rates, and economic policy or political variables. [See, for example, Kormendi and Meguire (1985), Barro (1991), and Barro and

Sala-i-Martin (1995).] Policy variables found to have a significant effect on growth in these regressions include measures of market distortions such as the average government share in GDP or the black market premium, measures of political rights or stability, and measures of financial development. For example, Barro and Lee (1994) show that as a result of differences in the ratio of government consumption to GDP and in the black market premium between a group of East Asian countries and a group of sub-Saharan African countries, the East Asian countries were predicted to grow 3.5 percent per year faster. The actual difference in growth rates was 8.1 percent per year. Thus, these differences in the two variables account for a large fraction of the difference in growth rates.

In this literature, the estimated coefficients on variables designated as policy variables have been shown to be sensitive to which variables are included in the regression. Levine and Renelt (1992) find that a large number of policy variables are not robustly correlated with growth. Hence, estimates of the impact of economic policy on growth are under debate.

Another approach to calculating the effects of economic policy, which we call quantitative theory, is to specify explicit models of economic development, parameterize them, and derive their quantitative implications. In our review of quantitative theory, we start with studies that explore the extent to which differences in economic policies account for differences in levels of income. We consider the effects of fiscal policies, trade policies, policies affecting labor markets, and policies impeding efficient production. [Examples of such studies include Chari et al. (1997) on investment distortions, Romer (1994) on tariffs, Hopenhayn and Rogerson (1993) on labor market restrictions, Parente and Prescott (1994, 1997) on barriers to technology adoption, and Schmitz (1997) on inefficient government production.] To illustrate the quantitative effects of some of these policies, we derive explicit formulas for cross-country income differences due to inefficient government production, taxes on investment, and tariffs. These formulas show that measured differences in policies can potentially explain a significant fraction of observed income disparity.

However, there is also debate in this literature about the magnitude of the impact of policy on income. Much of the debate centers around the choice of model parameters. For example, measured differences in investment distortions can account for a significant fraction of observed income disparity if shares on accumulable factors are on the order of 2/3 or larger. Shares on the order of 1/3 imply very little disparity in incomes. Measured differences in tariff rates imply significant differences in incomes if the number of imports are assumed to vary significantly with the tariff rate. Otherwise, the effects of tariffs are very small.

We also review studies in quantitative theory that explore the extent to which differences in economic policies account for differences in growth rates of income. We review two standard endogenous growth models: a two-sector "AK" model and a model of research and development (R&D). For the AK model, we consider the effects of changes in tax rates on long-run growth rates as in King and Rebelo (1990), Lucas (1990), Kim (1992), Jones et al. (1993), and Stokey and Rebelo (1995). To illustrate the quantitative effects of these tax policies, we derive explicit formulas for the steady-state growth rate in terms of tax rates and parameters of the model. Here, too, the estimated impact of tax changes on growth varies dramatically in the literature. For example, the predicted decline in the growth rate after an increase in the income tax rate from 0 percent to 20 percent ranges from 7/10ths of a percent to 4 percentage points. Using the explicit formulas, we show how the estimates of tax effects on growth are sensitive to certain model parameters.

Unlike the AK model, there has been little work to date assessing the effects of policy changes on growth rates in the R&D models. [See, for example, Romer (1990), Grossman and Helpman (1991a, b) and Aghion and Howitt (1992).] This is likely due to the fact that the main quantitative concern for these models has been their predicted scale effects. That is, most of these models predict that the growth rate increases with the number of people working in R&D. We describe a discrete-time version of the model in Romer (1990) and Jones' (1995a) version of the model which eliminates scale effects. [See also Young (1998).] We also discuss the possible growth effects of policies such as the subsidization of R&D and show that these effects depend critically on certain model assumptions.

Both approaches to estimating the effects of policy, then, the growth regression approach and the quantitative theory approach, have provided estimates of the impact of policy on income and growth. But, as the examples above indicate, within each approach, the magnitude of the impact of policy is under some debate. But in comparing the two approaches, we need to compare more than the precision of their estimates of policy's effect on incomes and growth. For example, the growth regression literature has come under considerable criticism because of econometric problems. [See, for example, Mankiw (1995), Kocherlakota (1996), Sims (1996), and Klenow and Rodríguez-Clare (1997a).] One serious problem is the endogeneity of right-hand-side variables in these regressions. The quantitative theory approach is not subject to such econometric criticisms. Hence, while the growth regression approach is the most widely used approach, we think the quantitative theory approach will ultimately be the predominant one. Thus, we place more emphasis on it in our review.

The rest of our review proceeds as follows. Section 2 presents some basic facts about the cross-country income distribution using data on GDP per worker for 1960–1990 compiled by Summers and Heston (1991) and on GDP per capita for 1820–1989 compiled by Maddison (1991, 1994). In Section 3, we review the accounting literature which has been a source of data on factor inputs and total factor productivity. Studies in the accounting literature attempt to apportion differences in country income levels or growth rates to technological progress and factor accumulation. [See, for example, Krueger (1968), Christensen et al. (1980), Elías (1992), Mankiw et al. (1992), Young (1995), Hsieh (1997), Klenow and Rodríguez-Clare (1997a), and Hall and Jones (1998).] These studies do not directly address why factor inputs differ across countries, but they do provide measures of labor and capital inputs, estimates of the shares of these inputs, and thus an estimate of either the level or the growth rate of total factor productivity (TFP). We show that, as yet, there is still no consensus on the level or growth of human capital and TFP or on the size of factor shares.

The remainder of the chapter is concerned with estimating the effects of policy on income and growth. In Section 4, we review the empirical growth literature. In Section 5 we review studies applying the quantitative theory approach–considering first those concerned with differences in income levels and then those concerned with growth.

The two literatures within quantitative theory, that examining disparity and that examining growth, have developed in large part separately from each other. There have been few attempts to account for more than one key regularity in the data and few attempts to compare the implications of competing theories for data. We conclude the chapter by considering the implications of two standard growth models, the neoclassical exogenous growth model and the AK model, for some of the basic features of the data from Maddison (1991, 1994) and Summers and Heston (1991). To make a direct comparison, we use the same tax processes as inputs in both models. We show that these models do fairly well in accounting for the large range in relative incomes, the lack of correlation in incomes and subsequent growth rates, and the lack of persistence in growth rates. However, both models have trouble replicating the large increase in maximal growth rates observed over the past 120 years.

2. Some Basic Facts

In this section, we review some basic facts about the distribution of country incomes and their growth rates. We have historical data for various years over the period 1820–1989 from Maddison (1994) for 21 countries. For the period 1870–1989, data are available from Maddison (1991) in all years for 16 countries. More recent data are from the Penn World Table (version 5.6) of Summers and Heston (1991) and cover as many as 152 countries over the period 1950–1992.[1] These data show that disparity in incomes is large and has grown over time, that there is no correlation between income levels and subsequent growth rates, that growth rate differences are large across countries and across time, and that the highest growth rates are now much higher than those 100 years ago. These basic features of the data are summarized in Figures 1–4. [See Parente and Prescott (1993) for a related discussion.]

In Figure 1, we provide two perspectives on the disparity of per capita GDP across countries. First, we plot per capita GDP in 1985 U.S. dollars for 21 countries for various years between 1820 and 1989. These data are taken from Maddison (1994). Each country-year observation is represented by a square. Second, for 1989, we display the distribution of relative GDP per capita using the 137 countries with available data in the Summers and Heston data set (variable RGDPCH). To construct the relative GDP, we divide a country's

[1] All of the data used in this chapter are available at our web site.

per capita GDP by the geometric average for all 137 countries. A value of 8 implies that the country's per capita GDP is 8 times the world average, and a value of $\frac{1}{8}$ implies that the country's per capita GDP is $\frac{1}{8}$ of the world average.

One noteworthy feature of Figure 1 is the increase in disparity in GDP per capita over the last 170 years in Maddison's (1994) 21-country sample.[2] The ratio of the highest per capita GDP to the lowest in 1820 is 3.0, whereas the ratio in 1989 is 16.7. Hence, the range of GDPs per capita in this sample increased by a factor of 5.6 ($16.7 \div 3$).

If we consider the Summers and Heston sample of 137 countries in 1989 (shown in the insert of Figure 1), we find that the average GDP per capita for the top 5 percent of countries is nearly 34 times that of the bottom 5 percent. Another notable aspect of the 1989 distribution is its near uniformity in the range $\frac{1}{8}$ to 8. Thus, it is not true that being very rich (having a per capita GDP from 4 to 8 times the world average) or being very poor (having a per capita GDP from $\frac{1}{8}$ to $\frac{1}{4}$ of the world average) is uncommon. Furthermore, over the period 1960–1990, the ratio of the relative incomes of rich to poor has been roughly constant; 1989 is not an unusual year.[3]

The data that we plot in Figure 1 are GDP per capita since we do not have data on the number of workers prior to 1950. However, much of our analysis in later sections will deal with GDP per worker. If we instead use GDP per worker to obtain an estimate of disparity in 1989, we get a similar estimate to that found with GDP per capita. In 1989 the average GDP per worker for the most productive 5 percent of the countries is about 32 times that of the least productive 5 percent.

[2] Prescott (forthcoming) calculates the disparity between western and eastern countries and finds a significant increase in disparity over the past 200 years.

[3] The same is true of the Maddison 21-country sample. The ratio of the highest to lowest per capita GDP was 19.0, 19.6, and 16.7 in 1950, 1973, and 1989, respectively.

Next consider Figure 2, which has in part motivated the cross-sectional growth literature. Figure 2 presents average annual growth rates in GDP per worker over the 1960–1985 period versus the relative GDP per worker in 1960. For this period, data are available from Summers and Heston (1991) for 125 countries. There are two key features to note. First, there is no correlation between 1960 productivity levels and subsequent growth rates. The correlation is 0.01. Second, the range in average annual growth rates is large. Even over a 25-year period, some countries had average growth rates of over 5 percent per year while some countries had average annual growth rates that were negative. These features of the data are also found for GDP per capita and for the subset of the Summers and Heston countries that have data available through 1990. [For example, see Barro and Sala-i-Martin (1995), who use GDP per capita.]

Figure 3 presents average annual growth rates of GDP per worker for a country over 1973–1985 versus average annual growth rates over 1961–1972 for the same sample of countries used in Figure 2. As Easterly et al. (1993) note, the correlation between growth rates in the two subperiods is low. The correlation in this case is 0.16. A striking feature of the growth rates is the magnitudes across subperiods. For example, Saudi Arabia grew at a rate of 8.2 percent in the first half of the sample and then at a rate of -1.8 percent in the second half. Guinea's growth rate in the first half of the sample was about 0 and jumped to 4.2 in the second half.

Figure 4 plots growth rates of the fastest growing countries over time. Starting in 1870, for each country for which data are available, we calculate the average annual growth rate within each decade between 1870 and 1990. For each decade, we select the country that achieved the maximum growth rate and plot this growth rate along with the country names in Figure 4. For example, the United States achieved the maximum average annual growth over the 1870–1880 decade, about 2.5 percent. The sample of countries in Figure 4 are from two sources. From 1870 to 1950, the data are GDP per capita from Maddison (1991). Over this period, there are only 16 countries.[4] From 1950 to 1990, the data are GDP per capita from Summers and Heston (1991). We included all countries with available data.

The pattern in Figure 4 is striking. The maximum average annual growth rates over a decade have increased dramatically through time, from the 2–3 percent range in the late 1800s to the 8–9 percent range that we currently observe. An obvious concern is that the pattern in Figure 4 is driven by the fact that the sample of countries increased dramatically after 1950. The countries in Maddison (1991) are the ones that are the most productive today; they are the most productive today because they had the greatest growth in productivity from 1870 to 1950. There may have been episodes during this period in which some of the poorer countries had miraculous growth rates. But, to our knowledge, no such episodes have been identified. Thus, we suspect that if data for all countries were available back to 1870 and we again drew Figure 4, the picture would not change very much.[5]

Before reviewing the progress that has been made in estimating the effects of policy on income and growth, we review the levels and growth accounting literatures. The objective of these literatures is to estimate the contributions of physical capital, labor, educational attainment, and technological progress to differences in levels or growth rates of output. While they do not directly address why factor inputs differ across countries, the accounting exercises are nontheless important steps to explaining cross-country income differences. For example, to estimate the effects of policy in quantitative theories, reliable estimates for

[4] Unlike the 21-country sample used for Figure 1, the data from Maddison (1991) are primarily rich countries.

[5] In fact, if we use the Maddison (1991) data, which are available until 1980, to construct growth rates between 1950 and 1980, the pattern is the same for all years except 1970–1980.

certain parameters, like the capital shares, are needed. The accounting exercises provide careful measures of labor and capital inputs, estimates of the shares of these inputs, and an estimate of TFP or its growth rate.

3. Accounting

We start this section with some results of levels accounting. We show that the estimates of TFP are sensitive to the measurement of human capital and the shares of income to physical and human capital. As yet, there is little consensus on the size of the stock of human capital or on the magnitude of the factor shares. Thus, when we calculate the fraction of income differences explained by differences in observed factor inputs, we find a wide range of estimates.

We then discuss some recent work in growth accounting estimating the growth in TFP for the East Asian newly industrialized countries. Here, there is less disagreement about whether good economic performances were due in large part to factor accumulation or to total factor productivity.

3.1. Levels Accounting

The objective in levels accounting studies is to apportion differences in income levels to differences in levels of total factor productivity and factor inputs. Typically, the starting point is an aggregate production function F–assumed to be the same across countries–of the form

$$Y = F(K, H, L, A), \tag{3–1}$$

where Y is output, K is the stock of physical capital, H is the stock of human capital, L is the labor input, A is an index of the technology level, and income is defined to be output per worker (Y/L). These studies construct measures of K, H, and L and treat A as a residual in equation (3–1).

Many levels accounting studies assume that the production function has a Cobb-Douglas form given by

$$Y = K^{\alpha_k} H^{\alpha_h} (AL)^{1-\alpha_k-\alpha_h}, \tag{3–2}$$

where α_k and α_h are capital shares for physical and human capital, respectively, and $\alpha_k + \alpha_h < 1$. Equation (3–2) is then rearranged to get

$$y = A \left(\frac{K}{Y}\right)^{\frac{\alpha_k}{1-\alpha_k-\alpha_h}} \left(\frac{H}{Y}\right)^{\frac{\alpha_h}{1-\alpha_k-\alpha_h}}, \tag{3–3}$$

where $y = Y/L$. With measures of K/Y and H/Y, these studies ask, To what extent do cross-country variations in these capital intensities account for the large variation in y?[6]

There is substantial disagreement on the answer to this question. For example, Mankiw et al. (1992) argue that differences in K/Y and H/Y can account for a large fraction of the disparity in y whereas Klenow and Rodríguez-Clare (1997b) and Hall and Jones (1998) argue that it accounts for much less.

In this section, we ask the following question: To what extent can differences in capital intensities account for the income disparity between the richest and poorest countries? To be precise, we calculate the ratio

$$\frac{y_{\text{rich}}}{y_{\text{poor}}} = \frac{\frac{1}{N_r}\sum_{i\in\text{rich}} \left(\frac{K_i}{Y_i}\right)^{\frac{\alpha_k}{1-\alpha_k-\alpha_h}} \left(\frac{H_i}{Y_i}\right)^{\frac{\alpha_h}{1-\alpha_k-\alpha_h}}}{\frac{1}{N_p}\sum_{i\in\text{poor}} \left(\frac{K_i}{Y_i}\right)^{\frac{\alpha_k}{1-\alpha_k-\alpha_h}} \left(\frac{H_i}{Y_i}\right)^{\frac{\alpha_h}{1-\alpha_k-\alpha_h}}}, \tag{3–4}$$

[6] A notable exception is Krueger (1968), who does not have measures of physical capital. She estimates income levels that could be attained in 28 countries if each country had the same physical capital per worker and natural resources as the United States, but each country had its own human resources. Krueger finds that there would still be large per capita GDP differences between the United States and many of these countries even if they had the physical capital and natural resources of the United States. Using logged differences in incomes, her findings imply that the fraction of the income disparity explained by differences in human capital is in the range of 20 to 40 percent.

where the "rich" are the N_r most productive countries and the "poor" are the N_p least productive countries. Note that (3–4) assumes no differences in technology A across countries. Thus, if we use observations of K/Y and H/Y in (3–4), the ratio is a prediction of the disparity in income levels due only to variations in capital intensities. In our calculations, we use the measures of capital intensities in Mankiw et al. (1992), Klenow and Rodríguez-Clare (1997b), and Hall and Jones (1998).

The measure of K/Y is very similar across the studies of Mankiw et al. (1992), Klenow and Rodríguez-Clare (1997b), and Hall and Jones (1998). Therefore, we use the same K/Y for all of the calculations that we do. We construct estimates of the capital stock for each country using the perpetual inventory method. With data on investment, an initial capital stock, and a depreciation rate, we construct a sequence of capital stocks using the following law of motion for K_t:[7]

$$K_{t+1} = (1-\delta)K_t + X_{kt}, \qquad (3\text{–}5)$$

where δ is the rate of depreciation. We choose a depreciation rate of 6 percent. For the initial capital stock, we assume that the capital-output ratio in 1960 is equal to the capital-output ratio in 1985 in order to get our estimate.[8]

In Figure 5, we plot the physical capital-output ratio, K/Y, for 1985 versus the relative GDP per worker in 1985 for all countries that have complete data on GDP per worker and investment [variables RGDPW and I in Summers and Heston (1991)] over the sample period 1960–1985. There are 125 countries in the sample. The figure shows that capital-output ratios for the most productive countries are on the order of 3, whereas capital-output

[7] We use I×RGDPCH×POP from the Penn World Table of Summers and Heston (1991) for investment.

[8] This way of estimating the final capital-output ratio leads to a good approximation if the economy is roughly on a balanced growth path. As a check, we tried other initial capital stocks and found that the final capital-output ratio was not sensitive to our choices.

ratios for the least productive countries are around 1 or below. The correlation between the capital-output ratio and the logarithm of relative GDP per worker is 0.67.

We next consider measures of H/Y which vary a lot across the three studies. We start with the measure used by Mankiw et al. (1992). Motivated by the work of Solow (1956), Mankiw et al. (1992) assume that

$$\frac{H}{Y} = \frac{s_h}{n+g+\delta}, \tag{3–6}$$

where s_h is the fraction of income invested in human capital, g is the growth rate of world-wide technology, n is the growth rate of the country's labor force, and δ is the rate at which both physical and human capital depreciate. The expression in (3–6) is a steady-state condition of Solow's (1956) model augmented to include human capital as well as physical capital. Mankiw et al. (1992) use the following measure for s_h

$$s_h = \text{ secondary school enrollment rate } \times \left[\frac{15-19 \text{ population}}{15-64 \text{ population}}\right], \tag{3–7}$$

which approximates the percentage of the working-age population that is in secondary school. To construct this measure, we use (3–7) with secondary school enrollment rates from Barro and Lee (1993) [variables Sxx, xx=$60, 65, \ldots, 85$] and population data from the United Nations (1994). We construct s_h for each of the six years (1960,1965, ..., 1985) in which data are available and take an average.[9] This investment rate is divided by $n+g+\delta$ with $g = 0.02$ and $\delta = 0.03$ as in Mankiw et al. (1992) and n given by the growth rate of the country's labor force constructed from the Summers and Heston data set.[10]

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[9] Data are unavailable in all years for Namibia, Reunion, Seychelles, Puerto Rico, Czechoslovakia, Romania, and the U.S.S.R.

[10] Mankiw et al. (1992) use working-age population, while we construct growth rates of the labor force using Summers and Heston's (1991) RGDPCH×POP/RGDPW. The results are quantitatively similar.

In Figure 6, we plot average secondary school enrollment rates [the average of variables Sxx, xx=$60, 65, \ldots$, 85 from Barro and Lee (1993)] versus the relative GDP per worker in 1985. Figure 6 has two noteworthy features. First, there is a very strong correlation between the secondary enrollment rate and the logarithm of output per worker across countries. The correlation is 0.83. Second, there is a large range in secondary enrollment rates. There are many countries with secondary enrollment rates under 10 percent, and as many with rates over 60 percent. Weighting the enrollment rates by the population (as in (3–7)) and deflating them by $n + g + \delta$ (as in (3–6)) does little to change the pattern displayed in Figure 6. Hence, there are large differences between the human capital-output ratios for the most productive and least productive countries, with the correlation between H/Y and the logarithm of GDP per worker equal to 0.79.

With this measure of H/Y for Mankiw et al. (1992), the K/Y series described above, and values for the capital shares α_k and α_h, we can calculate the ratio of incomes in (3–4). In this calculation, N_r and N_p in (3–4) are the richest 5 percent of countries and the poorest 5 percent of countries, respectively. In Table 1, we report our results. In the first row of the table, we assume that $\alpha_k = 0.31$ and $\alpha_h = 0.28$ as estimated by Mankiw et al. (1992). In this case, the predicted income disparity–assuming only differences in capital stocks–between the richest and poorest countries in 1985 is 12.8. The actual ratio is 31.4.

The numbers in the last column of Table 1 are the ratios of predicted to actual income disparity–both in logarithms. This is a measure of the gap in productivities attributable to variation in human and physical capital. For Mankiw et al.'s (1992) human capital measure and parameter values, we find that 74 percent (that is, $\log(12.8)/\log(31.4)$) of the gap in actual incomes can be explained by differences in capital intensities.[11] We also

[11] Mankiw et al. (1992) run a regression of the logarithm of output per worker on their measures of

find that the correlation between the predicted and actual logarithms of GDP per worker is 0.84.

We should note, however, that the results are very sensitive to the choice of capital shares. For example, suppose that we use slightly higher values for capital shares; say, $\alpha_k = \alpha_h = \frac{1}{3}$. The results of this case are reported in the second row of Table 1. In this case, the prediction for the ratio of productivities of the top 5 percent to the bottom 5 percent is 33.7–more than twice what it was in the case with $\alpha_k = 0.31$ and $\alpha_h = 0.28$ and almost exactly in line with the data.

Klenow and Rodríguez-Clare (1997b) argue that Mankiw et al.'s (1992) measure of human capital overstates the true variation in educational attainment across the world because it excludes primary school enrollment, which varies much less than does secondary. Figure 7 plots the primary enrollment rates [the average of variables Pxx, xx=60, 65, . . . , 85 from Barro and Lee (1993)] versus GDP per worker. Again, there is a strong positive correlation. But note that there is much less variation in primary enrollment rates than in secondary enrollment rates, which are displayed in Figure 6. Only ten countries have a rate below 0.40.

Suppose that we redo our calculation of the ratio $y_{\text{rich}}/y_{\text{poor}}$ using a measure of s_h in (3–6) that includes primary, secondary, and post-secondary enrollment rates. In particular, suppose that we use the fraction of 5- through 64-year-olds who are enrolled in school averaged over the period 1960–1985; this is a weighted average of the three enrollment rates in Barro and Lee (1993). In Table 1, in the row marked "Variation on Mankiw et al.," we report the predicted disparity, which is only 5.4. This ratio implies that roughly

K/Y and H/Y. They find an R^2 statistic of 0.78 and parameter estimates $\hat{\alpha}_k = 0.31$ and $\hat{\alpha}_h = 0.28$. They view the high R^2 statistic and the reasonable estimate for physical capital's share as strong evidence that variation in factor inputs can account for most of the variation in output per worker.

half (49 percent) of the observed disparity in incomes is explained by differences in capital-output ratios. Thus, adding primary and tertiary enrollment rates to the measure of s_h significantly reduces the contribution of human capital to income differences. (Compare the first and third rows of Table 1.) Although the predicted disparity is smaller, we still find a strong positive correlation between y_i and $(K_i/Y_i)^{\alpha_k/(1-\alpha_k-\alpha_h)}(H_i/Y_i)^{\alpha_k/(1-\alpha_k-\alpha_h)}$. The correlation in this case is 0.79.

As before, the magnitude of this disparity depends critically on the capital shares. Making a slight change from $\alpha_k = 0.31$ and $\alpha_h = 0.28$ to $\alpha_k = \frac{1}{3}$ and $\alpha_h = \frac{1}{3}$ leads to an increase in the percentage explained from 49 percent to 66 percent. If we choose $\alpha_k = \frac{1}{3}$ and $\alpha_h = 0.43$, then almost all of the income disparity can be explained by differences in capital stocks across countries. As Mankiw (1997) notes, we have little information about the true factor shares–especially for human capital.

Klenow and Rodríguez-Clare (1997b) and Hall and Jones (1998) argue that a more standard way of measuring human capital is to use estimates of the return to schooling from wage regressions of log wages on years of schooling and experience. [See Mincer (1974).] For example, Klenow and Rodríguez-Clare (1997b) report estimates of the human capital-output ratio constructed as follows:

$$\frac{H}{Y} = \left(e^{\gamma_1 s} \sum_i \omega_i e^{\gamma_2 \mathrm{exp}_i + \gamma_3 \mathrm{exp}_i^2} \right)^{\frac{1-\alpha_k}{\alpha_h}} \frac{AL}{Y}, \tag{3–8}$$

where s is the average years of schooling in the total population over age 25 taken from Barro and Lee (1993) [variable HUMAN85], exp_i is a measure of experience for a worker in age group i and is equal to $(\mathrm{age}_i - s - 6)$, and ω_i is the fraction of the population in the ith age group. The age groups are {25-29,30-34,...,60-64} and $\mathrm{age}_i \in \{27, 32, \ldots, 62\}$. The coefficients on schooling and experience in (3–8) are given by $\gamma_1 = 0.095$, $\gamma_2 = 0.0495$, and

$\gamma_3 = -0.0007$, which are averaged estimates from regressions of log wages on schooling and experience.

The measure of the human capital-output ratio used by Hall and Jones (1998) does not depend on experience and is given by

$$\frac{H}{Y} = \left(e^{\phi(s)}\right)^{\frac{1-\alpha_k}{\alpha_h}} \frac{AL}{Y}, \tag{3–9}$$

where s is the average years of schooling in the total population over age 25 taken from Barro and Lee (1993) [variable HUMAN85] and $\phi(\cdot)$ is a continuous, piecewise linear function constructed to match rates of return on education reported in Psacharopoulos (1994).[12] For schooling years between 0 and 4, the return to schooling $\phi'(s)$ is assumed to be 13.4 percent which is an average for sub-Saharan Africa. For schooling years between 4 and 8, the return to schooling is assumed to be 10.1 percent, which is the world average. With 8 or more years, the return is assumed to be 6.8 percent, which is the average for the OECD countries.

It turns out that the measures of H/Y constructed by Klenow and Rodríguez-Clare (1997b) and Hall and Jones (1998) are very similar. If we set γ_2 and γ_3 equal to 0 in (3–8) and ignore experience, then we get roughly the same capital intensities as those constructed by Klenow and Rodríguez-Clare (1997b). Similarly, if we set $\phi(s) = 0.095s$ in (3–9) and assume the same rate of return on education across countries, then we get roughly the same capital intensities as those constructed by Hall and Jones. As a result, the residuals, A, constructed in these two studies are very similar. The correlation between the two residual series is 0.88 if we use the countries that appear in both data sets.

[12] Substituting H/Y in (3–9) into (3–3) and simplifying gives $y = A(K/Y)^{\frac{\alpha_k}{1-\alpha_k}} e^{\phi(s)}$, which is the form of the GDP per worker used in Hall and Jones (1998). We have written their implied H/Y so as to compare it to that of Mankiw et al. (1992).

We now see how the measures of human capital defined by Klenow and Rodríguez-Clare (1997b) and Hall and Jones (1998) affect the ratio $y_{\text{rich}}/y_{\text{poor}}$ in (3–4). For our calculations, we assume, as they do, that α_k is the same across all countries. In Table 1, we report our predictions of income disparity and the gap in productivities attributable to differences in capital intensities. For Klenow and Rodríguez-Clare (1997b), we find that only 36 percent of the gap in productivities is attributable to differences in capital stocks. For Hall and Jones, 40 percent of the difference in productivities is explained by differences in capital stocks.[13]

To see why the results reported in Table 1 are so different across studies, consider the data in Figure 8. We plot the human capital-output ratios of Mankiw et al. (1992) and Klenow and Rodríguez-Clare (1997b). Due to data availability, only 117 of the original 125 countries in our sample are included. Both measures of human capital to output are plotted against the relative GDP per worker in 1985. For both series, we fit an exponential curve. As is clear from the figure, there is much larger variation in the human capital-output ratio of Mankiw et al. (1992) than in that of Klenow and Rodríguez-Clare (1997b). For Klenow and Rodríguez-Clare (1997b), the correlation between H/Y and GDP per worker is close to zero. In fact, if we had used $\alpha_k = \frac{1}{3}$ and $\alpha_h = \frac{1}{3}$ when constructing H/Y for Klenow and Rodríguez-Clare (1997b), we would have found a *negative* correlation between the human capital-output ratio and GDP per worker.

3.2. Growth Accounting

The objective in growth accounting is to estimate the contributions of technological progress and factor accumulation to differences in growth rates of output. As we saw

[13] Klenow and Rodríguez-Clare (1997b) and Hall and Jones (1998) find that the average contribution of A to differences in y is about 1/2 (that is, the mean of the A_i's relative to A for the United States is approximately 1/2).

in Figure 4, the growth rates of the fastest growing countries were on the order of 8 or 9 percent in the post-World War II period. These growth rates far exceed those of the fastest growing countries a century before. During three of the four decades between 1950 and 1990, East Asian countries led the pack. During the 1950s and 1960s, Japan had the highest growth rate. During the 1980s, South Korea had the highest growth rate. Among countries growing at 6 percent or better over the 1950–1990 period are three other East Asian countries, namely, Hong Kong, Singapore, and Taiwan. A question which has interested many people, then, is, Is factor accumulation or TFP growth responsible for growth rates of 8 or 9 percent?

The studies of Young (1995) and Hsieh (1997) focus on the newly industrialized countries in East Asia, namely, Hong Kong, Singapore, South Korea, and Taiwan. Young (1995) finds that the extraordinary growth performances of the Asian countries are due in large part to factor accumulation. The output growth rates over the period 1966–1990 for Hong Kong, Singapore, South Korea, and Taiwan are 7.3, 8.7, 10.3, and 9.4, respectively.[14] The estimates of average TFP growth over the same period for Hong Kong, Singapore, South Korea, and Taiwan are 2.3, 0.2, 1.7, and 2.6, respectively.

Hsieh (1997) estimates TFP growth for the East Asian countries using both the primal approach as in Young (1995) and the dual approach. The *primal approach* is to use the growth rates of quantities of capital and labor to back out measures of TFP growth whereas the *dual approach* is to use the growth rates of prices of these factors. Hsieh finds TFP growth rates for Hong Kong, Singapore, South Korea, and Taiwan of 2.7, 2.6, 1.5, and 3.7, respectively.[15]

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[14] The data on output for South Korea and Taiwan do not include agriculture and the period for the Hong Kong data is 1966–1991.

[15] The period for Singapore used in Hsieh (1997) is 1971–1990. Using the primal approach yields an

As these estimates suggest, there is much more agreement in these two studies than in the levels accounting studies reviewed above. Both agree that factor accumulation was much more important than TFP growth. There is some disagreement on the estimate for Singapore. Young (1995) finds that factor accumulation, especially of capital, is the whole story behind Singapore's high growth rates, whereas Hsieh (1997) finds that a significant fraction is due to TFP growth. Hsieh argues that while capital increased significantly, the real return to capital did not fall. The higher is the growth rate in the real return of capital, the higher would be Hsieh's estimate of TFP growth.

While growth rates of TFP on the order of 2 percent are high, they are not extraordinarily high. In the United States, for example, Christensen et al. (1980) find growth rates of TFP of 1.4 percent over the period 1947–1973 when growth rates in output were around 4 percent. The growth rates in output for the East Asian countries over the period 1966–1990 were significantly higher since the growth in capital and labor was extraordinarily high.

In the remainder of the chapter, we turn to the literatures which directly estimate the impact of policy on income and growth.

4. Growth Regressions

In this section, we review a literature–the cross-sectional growth literature–that quantifies the effects of observed policies on country growth rates. We begin with a brief overview of the literature. We discuss the motivation for the studies in this literature and the typical growth regression that is run. We then describe the results of Barro and Lee

estimate of -0.7 for this shorter sample.

(1994) and their estimates of the effects of policies on growth. Finally, we discuss some critiques of the methodology used in the literature.

As we noted in Section 2, average growth rates vary widely across countries and are uncorrelated with initial income levels. (See Figure 2.) The fact that income levels and subsequent growth rates are uncorrelated was at one time thought to be a puzzle for standard growth theory which predicted that poor countries should grow faster than rich countries in per capita terms. Such a prediction would imply a negative correlation between income levels and subsequent growth rates. This result depends, of course, on countries having the same steady-state income levels. If countries do not converge to the same steady-state income levels, the pattern predicted by theory is potentially consistent with Figure 2.[16] Analyses in the growth regression literature attempt to uncover the relationship between initial incomes and subsequent growth rates, holding constant variables that determine countries' long-run steady-state income levels.

The typical exercise involves regressing the growth rate of per capita GDP on the initial level of GDP, initial factor endowments such as educational levels, and control variables which are assumed to be determinants of the steady-state level of per capita output. Without the initial factor endowments and control variables, the coefficient on initial GDP is positive (as suggested by Figure 2). With these variables included, the coefficient on initial GDP is negative.

The set of control variables typically includes the ratio of investment to GDP, measures of market distortions such as the ratio of government consumption to GDP and the black market premium on foreign exchange, measures of political instability, and measures of financial development. Again, the purpose of these variables is to sort countries into

[16] In Section 5, we provide a different explanation for this fact.

more homogeneous groups, that is, groups that have similar steady states. Thus, one would expect that those control variables that are highly correlated with income would be significant in the regression.

In Section 3, we saw that the average ratio of investment to GDP as constructed by Summers and Heston (1991) is highly positively correlated with income. Variables proxying market distortions are negatively correlated with income. In Figures 9–10, we plot the ratio of government consumption to GDP and the logarithm of 1 plus the black market premium, respectively, versus per capita GDP.[17] We see that averages of both of these measures over the period 1965–1984 are negatively correlated with per capita GDP in 1985.

In Figure 11, we plot Gastil's (1987) index of political rights averaged over the period 1972–1984 versus per capita GDP in 1985. A value of 7 for the index indicates that citizens of the country have relatively few democratic rights, such as freedom of the press, freedom of speech, and so on, whereas a value of 1 indicates the most freedom. The correlation between this index and relative income is strongly negative. Finally, in Figure 12, we plot King and Levine's (1993) measure of the ratio of liquid liabilities to GDP, averaged over the period 1965–1984 versus the relative GDP per capita in 1985. Liquid liabilities are the sum of currency held outside the banking system and demand and interest-bearing liabilities of banks and nonbank financial intermediaries. We see that this measure of financial development is positively correlated with per capita GDP.

We now turn to a specific example of a growth regression given in Barro and Lee

[17] In Figures 9–12, we use an average of GVXDXE5x, x=$65-69, \ldots, 80-84$ for government share of GDP, an average of BMPxL, x=$65-69, \ldots, 80-84$ for the logarithm of one plus the black market premium, an average of PRIGHTSx, x=$72-74, 75-79, 80-84$ the index of political rights, and an average of LLYx, x=$65-69, \ldots, 80-84$ for the measure of liquid liabilities. These data are all taken from the data set of Barro and Lee (1993).

(1994). Their preferred regression equation is given by

$$
\begin{aligned}
g = & \underset{(.0035)}{-.0255}\ \log(\mathrm{GDP}) && \underset{(.0042)}{+.0138}\ \mathrm{MALE\_SEC} && \underset{(.0047)}{-.0092}\ \mathrm{FEM\_SEC} \\
& \underset{(.0139)}{+.0801}\ \log(\mathrm{LIFE}) && \underset{(.0270)}{+.0770}\ I/Y && \underset{(.0340)}{-.1550}\ G/Y \\
& \underset{(.0094)}{-.0304}\ \log(1+\mathrm{BMP}) && \underset{(.0089)}{-.0178}\ \mathrm{REV},
\end{aligned}
\tag{4-1}
$$

where g is the growth rate of per capita GDP, MALE_SEC and FEM_SEC are male and female secondary school attainment, respectively, LIFE is life expectancy, I/Y is the ratio of gross domestic investment to GDP, G/Y is the ratio of government consumption to GDP less the ratio of spending on defense and noncapital expenditures on education to GDP, BMP is the black market premium on foreign exchange, REV is the number of successful and unsuccessful revolutions per year, and means have been subtracted for all variables. Eighty-five countries were included over the period 1965–1975 and 95 countries over the period 1975–1985.[18] These results show that countries with a higher I/Y, a lower G/Y, a lower black market premium, and greater political stability had on average better growth performances.

In Table 2, we reprint results from Barro and Lee (1994) which show the fitted growth rates for the regression equation in (4-1) and the main determinants of these growth rates. The fitted growth rates are reported in the second to last column, and the actual growth rates are reported in the last column. The first five columns of the table are the sources of growth. To obtain their contributions to the fitted growth rate, one multiplies the values

[18] The school attainment variables and log(GDP) are the observations for 1965 in the 1965–1975 regression equation and for 1975 in the 1975–1985 regression equation. The life expectancy variable is an average for the five years prior to each of the two decades, namely, 1960–1964 in the first regression equation and 1970-1974 in the second regression equation. Variables I/Y and G/Y are sample averages for 1965–1975 and 1975–1985 in the regression equations for the two decades, respectively. The revolution variable is the average number over 1960–1985. For the regression, lagged explanatory variables are used as instruments.

of explanatory variables for a specific group of countries (expressed relative to the sample mean) by the coefficients in (4-1). The net convergence effect adds up the contributions of initial per capita GDP, secondary schooling, and life expectancy. The contributions of all other variables are shown separately.

Variables used as proxies for market distortions, namely the government share in output and the black market premium, account for a large fraction of the differences in observed growth rates. For example, over the period 1975–1985, differences in G/Y accounted for a 2 percent per year difference in growth rates between the fast-growing East Asian countries and the slow-growing sub-Saharan African countries. Over the same period, differences in the black market premium accounted for a 1.5 percent per year difference in growth rates between the East Asian countries and the slow-growing sub-Saharan African countries. Together these variables account for a difference of 3.5 percent. The actual difference in growth rates was 8.1 percent.

Table 2 provides results for only one regression. The literature, however, is voluminous and there have been many other policy variables identified as potentially important sources of growth. Examples include measures of fiscal policy, trade policy, monetary policy, and so on. In many cases, variables to include are suggested by theory. For example, King and Levine (1993) include the measure of the state of financial development in Figure 12 in the growth regressions that they run. They motivate inclusion of such a variable with a model of R&D in which financial institutions play a central role because they facilitate innovative activity. [See also Greenwood and Jovanovic (1990).] Another example is income inequality which Alesina and Rodrik (1994) and Persson and Tabellini (1994) argue is harmful for growth. They include measures of within-country income inequality in the regressions they run on the basis of simple political economy models of taxation. In their models, growth depends on tax policies which are voted upon. The lower is the capital stock of the median voter, the higher is the tax rate and the lower is the growth rate given that tax proceeds are redistributed. In both cases, the theory and data analysis are only loosely connected. Many of the explanatory variables in the regressions are not variables in the models, and relations such as (4–1) are not equations derived directly from the theory.

The exercise of Barro and Lee (1994) and others in this literature suggest that differences in policies play an important role for the variation in country growth rates. However, as we noted earlier, the magnitudes are in debate. For example, Levine and Renelt (1992) show that the results of such regressions are sensitive to the list of variables included. They identify more than 50 variables that have been found to be significantly correlated with growth in at least one cross-sectional growth regression. From their extreme-bound robustness tests, Levine and Renelt (1992) conclude that a large number of fiscal and trade policy variables and political indicators are not robustly correlated with growth. The list of variables that are not robustly related to the growth rate in per capita GDP includes the ratio of government consumption expenditures to GDP, the black market premium, and the number of revolutions and coups–the main variables used in the Barro and Lee (1994) regression. Sala-i-Martin (1997) uses a weaker notion of robustness but still finds that the main variables in Barro and Lee (1994) are not robustly correlated with growth.

There are also deeper methodological debates with the growth regression approach. First, there are many econometric problems such as endogeneity of right-hand-side variables, too-few observations, omitted variables, and multicollinearity which call into question the estimates found in this literature. The problem most emphasized is the endogeneity of regressors. [See, for example, Mankiw (1995), Kocherlakota (1996), Sims (1996), Klenow and Rodríguez-Clare (1997a), and Bils and Klenow (1998).] Consider, for example, the black market premium which is sometimes included in the regressions. Most theories say that this ratio is jointly determined with the growth rate–with changes in both induced by changes in some policy. To deal with this problem, researchers use instrumental variable methods. However, their choices of instruments (e.g., political variables or lagged endogenous variables) have been criticized because they are not likely to be uncorrelated with the error terms in the regressions. As Sims (1996) emphasizes, to say more about the characteristics of the instruments, one must be specific about the equations determining all of the other variables–those equations that are not estimated. Sims (1996) concludes that the coefficient on the policy variable of interest "represents, at best, a small piece of the story of how policy-induced changes ... influence output growth and at worst an uninterpretable hodgepodge."

We turn next to an approach that is not subject to these same criticisms. The approach puts forward fully articulated economic models relating fundamentals, such as preferences, technologies, and policies, to quantifiable predictions for output per worker. Using quantitative theory, we try to tighten the link between theory and data–making the mapping between policies and GDP very explicit.

5. Quantitative Theory

In this section, we consider explicit models that map assumptions about preferences, technologies, and policies to predictions for GDP. We make no attempt here to review all models of growth and development. Instead, we focus on several standard models and their quantitative implications. Policies that we consider include taxes on investment, government production, tariffs, labor market restrictions, granting of monopolies, monetary policies, and subsidies to research and development. We first consider implications for disparity of incomes and then implications for growth in incomes. We derive specific answers to the question: How much of the cross-country differences in income levels and growth rates can be explained by differences in particular economic policies? We also discuss assumptions that are critical for the results.

5.1. Effects of Policy on Disparity

In this section, we consider theories of income disparity and their quantitative predictions. By *disparity*, we mean the ratio of GDP per worker of the most productive countries to the least productive. As we saw in Section 2, the productivity levels of the most productive 5 percent of countries are on the order of 30 times that of the least productive. We ask, How much of this difference is due to policies such as taxes on investment, inefficient government production, trade restrictions, labor market restrictions, and granting of monopolies? To illustrate the quantitative effects of some of these policies, we derive explicit formulas for cross-country income differences. We show, under certain assumptions, that measured differences in policies imply significant income disparity.

5.1.1. Policies Distorting Investment

In this section, we work with the neoclassical growth model and derive formulas for income differences due to policies distorting investment. Many have pointed to disincentives for investment such as government taxation of capital, corruption, and inefficient bureaucracies as possible explanations for differences in observed income levels. [See, for example, de Soto 1989 who describes inefficiency and corruption in Peru.] Such distortions on investment seem a natural candidate to generate variations in income given the large differences in capital-output ratios across countries (see Figure 5) and the strong association between growth rates and investment rates–especially for investment in machinery–as found in DeLong and Summers (1991, 1993).

Schmitz (1997) studies one type of distortion on investment which occurs when governments produce a large share of investment goods and bar private production of these goods. In Egypt, for example, the government share of investment production has been close to 90 percent. This is in contrast to the United States and many European countries where the government share of investment production is close to zero. Schmitz (1996) presents evidence on the government's share of manufacturing output where a subset of investment goods is produced. He shows that there is a negative correlation between the government's share of manufacturing output and productivity in a country. Figure 13 documents this pattern. In Figure 13, we display the public enterprise share of manufacturing output versus relative incomes for various years. The correlation between the government share of output in manufacturing and relative incomes is -0.47. Figure 13 then suggests that some governments produce a large share of investment goods. One expects there to be a large impact on productivity due to this policy because if the government produces investment goods inefficiently, this will have an impact on capital per worker.

Unfortunately, it is hard to find specific measures for the many other distortions to investment. However, in many models, differences in distortions on investment across countries imply differences in the relative price of investment to consumption. Jones (1994) uses the PPP-adjusted price of investment divided by the PPP-adjusted price of consumption as a comprehensive measure of the many distortions in capital formation. He does so for various components of domestic capital formation like transportation equipment, electrical machinery, nonelectrical machinery, and nonresidential construction. When he includes these relative price variables in a growth regression of the type studied in Barro (1991), he finds a strong negative relationship between growth and the price of machinery.

Chari et al. (1997) use a similar measure of relative prices for the tax on investment in a standard neoclassical growth model. In particular, they use the relative price of investment goods to consumption goods from the Summers and Heston data set (PI/PC). Figure 14 presents this relative price in 1985 versus the relative GDP per worker (for the sample of 125 countries with complete data on GDP per worker over the period 1960–1985). There are two aspects of this figure worth noting. First, there is a very strong negative correlation between relative investment prices and the relative GDP per worker. The correlation is -0.65. Second, there is a large range in relative prices. Assuming the relative price of investment to consumption is a good measure of investment distortions, one expects that the large variation in prices implies a large variation in cross country incomes.

Using the following simple two-sector model, we can show how investment distortions such as those studied in Schmitz (1997) and Chari et al. (1997) affect income. The representative household chooses sequences of consumption and investment to maximize

$$\sum_{t=0} \beta^t U(C_t), \tag{5–1}$$

where C_t is consumption at date t. The household's budget constraints are given by

$$C_t + p_t X_t = r_t K_t + w_t L, \quad t \geq 0, \tag{5–2}$$

where the subscript t indexes time, p is the relative price of investment to consumption, X is investment, r is the rental rate of capital, K is the capital stock, w is the wage rate, and L is the constant labor input. The capital stock is assumed to depreciate at a rate δ and have the following law of motion:

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

The economy is assumed to have two sectors: one for producing consumption goods and one for producing investment goods. The capital good can be allocated to either sector. The aggregate capital stock satisfies $K_c + K_x = K$, where K_c and K_x are capital stocks used to produce consumption and investment goods, respectively. Similarly, the aggregate labor input satisfies $L_c + L_x = L$, where L_c and L_x are inputs used to produce consumption and investment goods, respectively. Production functions in both sectors are assumed to be Cobb-Douglas. Firms in the consumption-good sector choose K_c and L_c to maximize profits; that is

$$\max_{K_c, L_c} \; C - rK_c - wL_c, \quad \text{subject to } C = A_c K_c^{\alpha} L_c^{1-\alpha}, \tag{5–3}$$

where A_c is an index of the technology level in the consumption-good sector. Similarly, firms in the investment-good sector choose K_x and L_x to maximize profits:

$$\max_{K_x, L_x} \; pX - rK_x - wL_x, \quad \text{subject to } X = A_x K_x^{\gamma} L_x^{1-\gamma}, \tag{5–4}$$

where A_x is an index of the technology level in the investment-good sector.

Note that the above economy with different productivity factors in the consumption- and investment-good sectors is equivalent to one in which the productivity factors are the same but there are distortions on investment. Suppose that the productivity factors in the two sectors are the same (that is $A_x = A_c$). But suppose that of the K_x units of capital used in the investment sector, $K_x/(1+\tau_x)$ units are used in production and the remaining $\tau_x K_x/(1+\tau_x)$ units are needed to overcome regulatory barriers, with the same true of the labor input. Then, the investment technology is given by

$$X = A_c \left(\frac{K_x}{1+\tau_x}\right)^{\gamma} \left(\frac{L_x}{1+\tau_x}\right)^{1-\gamma} = \frac{A_c}{1+\tau_x} K_x^{\gamma} L_x^{1-\gamma}.$$

[This is a version of the economy in Chari et al. (1997).] By setting $A_c/(1+\tau_x) = A_x$, we see that the two specifications are the same.[19]

[19] If we allow for trade, however, the interpretation may matter. If $1/(1+\tau_x)$ is a measure of resources used to overcome regulatory restrictions rather than a country-specific productivity factor, it is easy to imagine that such distortions also apply to imported goods.

We now derive an explicit formula for differences in GDP per worker due to differences in productivity factors A_x in the investment sector across countries as in Schmitz (1997). We compare the aggregate productivity of a country like the United States in which the government produces no investment goods to that of a country like Egypt in which the government produces a vast majority of the investment goods. For simplicity, we assume that it produces all of the investment goods. We also assume that $\alpha = \gamma$, that $A_x = A_g$ for Egypt, and that $A_x = A_p$ for the United States, where A_g denotes government productivity and A_p denotes private productivity. The only difference between countries is the productivity factor in the investment sector.

We compare steady-state GDP across the two countries. With capital shares equal in the two sectors, the capital-labor ratios are equated and are equal to the economy-wide capital-labor ratio $k = K/L$, which is proportional to $A_x^{\frac{1}{1-\alpha}}$. Outputs in the consumption and investment sectors are therefore given by $C = A_c k^\alpha L_c$ and $X = A_x k^\alpha L_x$, respectively. In comparing GDPs across countries, it is common practice to use a set of world prices. For the model we assume that the world price of investment equals the U.S. price (that is, A_c/A_p). Let y denote the GDP per worker in international prices. In this case, $y = C/L + A_c X/(A_p L)$, and therefore, the relative productivities are given by

$$\frac{y(A_x = A_p)}{y(A_x = A_g)} = \left(\frac{A_p}{A_g}\right)^{\frac{1}{1-\alpha}} \left(\frac{L_x}{L} + \left(1 - \frac{L_x}{L}\right)\frac{A_p}{A_g}\right)^{-1}, \tag{5–5}$$

where $y(A_x = A_p)$ is the GDP per worker for the country with investment goods produced privately and $y(A_x = A_g)$ is the GDP per worker for a country with investment goods produced by the government. Note that L_x/L in this model is the same in both countries. If the government produces goods less efficiently than the private sector, then $A_g < A_p$. In this case, one can show that, for all values of α in (0,1) and all values of L_x/L in (0,1), the ratio in (5–5) exceeds one.

Estimates of the relative productivity factors A_p/A_g can be found in Krueger and Tuncer (1982) and Funkhouser and MacAvoy (1979). Their estimates lie between 2 and 3. The fraction of labor in the investment sector is equal to the share of investment in output. Suppose this share is $\frac{1}{5}$. Suppose also that the capital share α is $\frac{1}{3}$. If private producers have a productivity factor that is 2 times as large as government producers, then the model predicts that a country with no government production of investment has a labor productivity 1.57 times that of a country whose investment is entirely produced by the government. If private producers are 3 times as productive as government producers, then a country with no government production of investment has a labor productivity that is 2 times that of a country where the government produces all investment goods.

During the 1960's when Egypt was aggressively pursuing government production of investment, productivity in the United States was about 8 times that of Egypt. The calculations above indicate that this policy makes the United States about 2 times as productive as Egypt. What fraction of the productivity gap should be attributed to this policy? One way to measure the fraction of the gap in productivity attributable to this policy is to take the logarithm of the ratio of output per worker in the model and divide this by the logarithm of the ratio of output per worker in the data. Under the assumption that the productivity factor for private firms is twice as large as that for the government, this results in $\ln(1.57)/\ln(8) \cong 0.22$. Under the assumption that the multiple is 3, we have $\ln(2)/\ln(8) \cong 0.33$. Hence, under this measure, the policy accounts for between 22 and 33 percent of the productivity gap.

As we noted above, the formula in (5–5) also applies to the case with variations in distortions as described in Chari et al. (1997). The ratio A_i/A_j is simply replaced by the ratio $(1+\tau_{xj})/(1+\tau_{xi})$. In another version of their model, Chari et al. (1997) allow for distortions such as bribes that have to be paid to undertake investments. Under this interpretation, bribes are simply transfers from one agent to another. In this case, the budget constraints of the household are given by

$$C_t + p_t X_t = r_t K_t + w_t L + T_t, \quad t \geq 0, \tag{5–6}$$

where T_t is the value of these transfers at date t. In this case, the profit-maximization problem solved by the investment-goods firm is given by

$$\max_{K_x, L_x} \frac{p}{1+\tau_x} X - rK_x - wL_x, \quad \text{subject to } X = A_c K_x^{\gamma} L_x^{1-\gamma}, \tag{5–7}$$

and the problem of the consumption-goods firm is the same as before. The specification in (5–7) implies that bribes are proportional to the scale of the investment.

We now derive an explicit formula for differences in income due to differences in investment distortions that, like bribes, are simply transfers from one agent to another. For now we assume that $\alpha = \gamma$. In this case, the relative price of investment to consumption p is proportional to the distortion $1 + \tau_x$ in equilibrium. For the model we assume that the world prices of consumption and investment goods are one (so that the world price of investment equals the price of a country with a distortion of zero.) If we assume that all investment is measured in national income accounts, then GDP per worker in the model is given by $C/L + X/L$. Assuming that the only difference across countries is the level of τ_x that they face, we find that the ratio of productivities of countries i and j is given by

$$\frac{y_i}{y_j} = \left(\frac{1+\tau_{xi}}{1+\tau_{xj}} \right)^{\frac{\alpha}{\alpha-1}} \tag{5–8}$$

in the steady state.

If we assume, as Chari et al. (1997) do, that half of the capital stock is organizational capital and is therefore not measured in national income accounts, then GDP per worker in the model is given by $C/L + \frac{1}{2}X/L$. [See Prescott and Visscher (1980) for a discussion of the concept of organization capital.] In this case, the ratio of productivities of countries i and j is

$$\frac{y_i}{y_j} = \frac{a(1+\tau_{xi})^{\frac{\alpha}{\alpha-1}} - b(1+\tau_{xi})^{\frac{1}{\alpha-1}}}{a(1+\tau_{xj})^{\frac{\alpha}{\alpha-1}} - b(1+\tau_{xj})^{\frac{1}{\alpha-1}}},$$

where a and b are positive constants that depend on β, δ, and α (and growth rates of population and world-wide technology which we have abstracted from here). For the parameters used in Chari et al. (1997), a is about 5 times larger than b. Therefore the ratio of measured incomes is approximately equal to the expression in (5–8).

Consider again the data in Figure 14. Is the range in relative prices large enough to account for the 30-fold difference in relative incomes? It is, if one views K as a broad measure of capital that includes not only physical capital but also stocks of human capital and organizational capital. For example, if we assume a capital share on the order of 2/3, then differences in relative prices (and hence, differences in the ratio $(1+\tau_{xi})/(1+\tau_{xj})$) on the order of 5 or 6 imply a factor of 30 difference in incomes since we square relative prices. In Figure 14, we see that four of the poor countries have relative prices exceeding 4. If we compare these countries with the richest countries who have relative prices that fall below 1, we can get relative productivities on the order of 30.

There is a potential bias in the measure of distortions that we plot in Figure 14. If consumption goods are largely nontraded labor-intensive services, we would expect that they are systematically cheaper in capital-poor countries. In this case, the relative price overstates the real distortion. To demonstrate this, we can use the steady state conditions of the model to derive an expression for the relative price of investment to consumption in terms of the distortions τ_x. The expression is given by

$$p = B\,(1+\tau_x)^{\frac{1-\alpha}{1-\gamma}},$$

where B depends on parameters assumed to be the same across countries. Above we assumed $\alpha = \gamma$ and therefore had $p = B(1 + \tau_x)$. However, if production of investment goods is more capital intensive than production of consumption goods ($\gamma > \alpha$), then the ratio of prices of two countries is larger than the ratio of their true distortions; that is, $p_i/p_j > (1 + \tau_{xi})/(1 + \tau_{xj})$ where $\tau_{xi} > \tau_{xj}$. Chari et al. (1997) find for Mexico and the United States that, if anything, the relative prices understate the true distortion since estimates of capital shares imply $\alpha > \gamma$ for both countries.

The estimates derived in this section illustrate that the effects of certain policies distorting investment are potentially large. Inefficient government production can explain 22 to 33 percent of the productivity gap between countries like Egypt and the United States. For more comprehensive measures of distortions like the relative price of investment to consumption, the implied differences in incomes across countries are large if we assume that the distortions affect not only physical capital but also human and organizational capital.

However, the estimates of the impact of policy on income found above are sensitive to choices of the capital share and to magnitudes of measured versus unmeasured capital. For example if we assume a capital share of 1/3, then differences in relative prices on the order of 5 imply differences in incomes on the order of the square root of 5, which is significantly smaller than differences on the order of the square of 5.

Before closing this section, we have three general comments concerning this literature. First, a number of quantitative studies have extended the basic neoclassical model explored above. One aim of these studies is to ask whether observed policy differences have a larger impact on measured incomes in the extended models as compared to the standard model.

Jovanovic and Rob (1998) extend the basic model to include vintage capital. The extended vintage capital model yields predictions for income disparity that are similar to those of the standard model. Parente et al. (1997) introduce home production into the standard model. Policies that influence capital accumulation now also have an impact on the mix of market and non-market activity. Their model can imply (for a given difference in policies) a much larger difference in income disparity across countries than does the standard model.

Second, the analysis above illustrates that theories of the kind described here cannot rely on variations in TFP (that is, variations in A_c) alone to explain income differences. For example, the following is true in the steady state with $\alpha = \gamma$:

$$\frac{\alpha}{1+\tau_x}\frac{Y}{K} = \frac{1}{\beta} - 1 + \delta, \tag{5–9}$$

where $Y = A_c K^{\alpha} L^{1-\alpha}$. This condition shows why variation across countries in the residual A_c is not enough. There are large differences in K/Y across countries. With τ_x constant, this model predicts that K/Y is constant. Thus, we need variation in some intertemporal distortion (for example, τ_x) in order to generate differences in the capital-output ratio.[20]

Third, to simplify matters, we assumed no cross-country variation in TFP in deriving our predictions of income differences. However, when there is unmeasured capital, it is hard to distinguish between an economy with a small capital share and variations in both A_c and τ_x (where A_c and τ_x are correlated) and an economy with a larger capital share and only variations in τ_x. For example, if Klenow and Rodríguez-Clare (1997b) or Hall and Jones (1998) were to construct measures of TFP simulated from a stochastic version of the model above with half of the capital stock unmeasured, they would conclude that

[20] Even if we do not abstract from growth, the theory with only variations in A_c will do poorly. The capital-output ratio is highly correlated with income, but growth rates of the poor and rich are not very different.

TFP accounts for much of the variation in output per worker–even if it accounted for none of the variation in output per worker. Thus, one must be cautious when interpreting the results of Klenow and Rodríguez-Clare (1997b) and Hall and Jones (1998). And, as Prescott (1997) points out, a theory of TFP differences is still needed.

We turn next to the trade literature and again derive formulas relating policies to differences in income levels.

5.1.2. Policies Affecting Trade

The earliest research using models to measure the impact of policies on country income and welfare focused on trade policies.[21] The trade literature is large. In this section, we provide a broad historical outline of this literature. We first discuss several measures of trade restrictions and their relationship to country productivity. We then discuss work relating trade restrictions to differences in income levels.

Figure 15 presents measures of tariff rates on capital goods and intermediate goods constructed by Lee (1993) versus the relative GDP per worker for 91 countries in 1980. When plotting the data, we dropped the observation for India, where income in 1980 was approximately $\frac{1}{3}$ of the world average and the tariff rate was 132 percent. This point was dropped so we could more easily view the other data points. Not surprisingly, there is a negative relationship between tariff rates and incomes. The correlation between tariff rates and incomes is -0.38. As Easterly and Rebelo (1993) point out, taxes on international trade fall as a share of government revenue as income rises, while the share of income taxes rises. For many of the low- and middle-income countries, the tariff rates are in the range of 25 to 50 percent. But rates among the rich are, in general, quite low.

[21] In fact, Johnson (1960) discusses the work of Barone (1913) who attempts to measure the impact of tariffs on income and welfare.

In Figure 16, we present additional evidence on trade restrictions. We plot Sachs and Warner's (1995) measure of a country's "openness" for the period 1950–1994 against relative GDP per worker in 1985. A country is open if (i) nontariff barriers cover less than 40 percent of its trade; (ii) its average tariff rates are less than 40 percent; (iii) any black market premium in it was less than 20 percent during the 1970s and 1980s; (iv) the country is not socialist under Kornai's (1992) classification; and (v) the country's government does not monopolize major exports. Sachs and Warner construct an index that measures the fraction of years in the period that a country has been "open." As we see from Figure 16, the correlation between the Sachs and Warner index and GDP per worker is strongly positive; economies with policies that promote trade are those with high productivities.

In an early paper, Johnson (1960) reviews and extends prior studies that measure the cost of protection. His measure of the cost of protection is defined to be "the goods that could be extracted from the economy in the free-trade situation without making the country worse off than it was under protection–some variation of the Hicksian compensating variation" (p. 329). In the two-good version of his general equilibrium model, the cost of protection in percentage of national income is

$$\text{Cost} = \frac{1}{2}\left(\frac{\tau}{1+\tau}\right)^2 \eta V,$$

where τ is the tariff on imports, η is the compensated elasticity of demand for imports, and V is the ratio of imports at market prices to domestic expenditure. Johnson argues that the cost is small given it is an elasticity multiplied by three fractions, each of which is small. The example he gives is a tariff of $33\frac{1}{3}$ percent and an import share of 25 percent. To obtain a cost of 4 percent of national income, the compensated demand elasticity has to be slightly above 5–a value he dismisses as implausibly high. When Johnson extends the analysis to many goods, he cannot conclude as easily that the cost of protection is small.

However, when he analyzes data from two studies on Australia's and Canada's commercial policies, he concludes that the cost is small in both countries.

During the 1960s, a number of studies continued the work reviewed by Johnson. A good reference is Balassa (1971). The findings of Balassa (1971) are similar to those of Johnson (1960). The cost of protection is on the order of a few percent of GDP, with the highest cost being 9.5 percent of income in Brazil.

A further development in the quantitative study of tariffs was the computational general equilibrium (CGE) literature. There are a number of good surveys of this literature, such as Shoven and Whalley (1984). Some notable contributions to this literature are Cox and Harris (1985), Whalley (1985), and the papers in Srinivasan and Whalley (1986). Most of the CGE literature found–as did the earlier literature–that reductions in observed tariffs would lead to small increases in welfare and income, typically on the order of 1 percent of GDP.

Since the mid-1980s, there have been attempts to extend the models in this literature under the presumption that larger gains in income follow tariff reductions. One avenue has been to develop dynamic models in which the capital stock adjusts to the reductions in tariffs. The CGE literature typically studied static models, so, for example, the models did not consider the response of capital stocks to changes in tariffs. A recent paper that looks at such responses of capital stocks is Crucini and Kahn (1996). This study examines the increase in tariffs that followed passage of the Smoot-Hartley tariff during the Great Depression. They find that if "tariffs had remained permanently at levels prevailing in the early 1930s [due to the Smoot-Hartley tariff], steady-state output [in the United States] would have declined by as much as 5 percent" as a result of the higher tariffs (p. 428). At least for this episode then, considering changes in the capital stock does not significantly change the conclusion that the effects of tariffs on income are small. Another recent paper is that by Stokey (1996) who examines dynamic gains from trade as capital stocks adjust. Stokey finds larger gains from capital adjustment than do Crucini and Kahn.

Another avenue that has been pursued is to allow for changes in the set of goods available in the economy as tariffs change. One example is Romer (1994) who argues that tariffs may have a large impact on productivity. He constructs an example of a small open economy which imports specialized capital inputs to use in a love-for-variety production function. Foreign entrepreneurs that sell the capital inputs face fixed costs of exporting to the small open economy. In the model, increases in tariffs result in a narrowing of goods imported and a fall in productivity. Romer's back-of-the-envelope calculations show that the effects on productivity may be large. Here, we review his calculations and discuss Klenow and Rodríguez-Clare's (1997c) study of this mechanism for Costa Rica.

Romer (1994) considers a small open economy that produces a single good according to the production function

$$y = L^{1-\alpha} \int_0^N x_i^\alpha \, di,$$

where L is the labor input and x_i is the input of the ith specialized capital good, $i \in [0, N]$. The capital goods are imported from abroad. The number of types of goods imported N is not a priori fixed; in equilibrium, it will depend on the tariff rate.

Each specialized capital good is supplied by a foreign monopolist. The foreign monopolist faces a constant marginal cost of producing each unit equal to c and a fixed cost to export equal to $c_0(i) = \mu i$, where μ is a positive constant. The small open economy charges a tariff of τ percent on all purchases of the specialized capital goods.

Let the timing of events be as follows. The small open economy announces a tariff τ. Given this τ, foreign entrepreneurs decide whether or not to export to the country. Because of the symmetry of the capital goods in final production, all foreign entrepreneurs that export face the same demand curve and earn the same revenue. Profits differ, of course, since fixed costs differ. Marginal entrepreneurs are those whose profit just covers their fixed cost. The product of the marginal entrepreneur is N.

The problem facing the foreign entrepreneur i if he enters is

$$\max_{x_i}\ (1-\tau)p(x_i)x_i - cx_i,$$

where the inverse demand function $p(x_i) = \alpha(L/x_i)^{\alpha-1}$ is derived from the marginal productivity condition for capital. It is easy to show that the profit-maximizing price is a simple markup over marginal cost and that the profit-maximizing quantity is

$$x(\tau) = \left[\frac{\alpha^2(1-\tau)}{c}\right]^{\frac{1}{1-\alpha}} L,$$

which depends on the level of the tariff τ. Since the tariff is the same for all producers, we have dropped the index i on x. Setting gross profit equal to fixed costs, we can solve for the marginal product N as a function of $x(\tau)$; that is,

$$N(\tau) = \frac{(1-\alpha)c}{\alpha\mu} x(\tau).$$

With these expressions for $x(\tau)$ and $N(\tau)$, we can write GDP in equilibrium as $y = L^{1-\alpha}N(\tau)[x(\tau)]^{\alpha}$.

What is the impact of tariffs on GDP? One way to measure the impact is to compare the GDP of a country with no tariffs to one with tariff rate τ; that is,

$$\frac{y(\tau=0)}{y(\tau>0)} = \frac{N(0)}{N(\tau)}\left(\frac{x(0)}{x(\tau)}\right)^{\alpha} = (1-\tau)^{\frac{\alpha+1}{\alpha-1}}. \tag{5–10}$$

This expression assumes that the labor input is the same in the two countries.

Before making some back-of-the-envelope calculations with this ratio, let us present another formula. Romer (1994) argues that the effects of tariffs on GDP can be large and, in particular, much larger than traditional analyses have suggested. In the traditional calculations, the implicit assumption is that the set of products does not change with tariffs. In the context of the above model, the traditional analysis assumes a different timing of events. The timing in the traditional analysis assumes that entrepreneurs decide to export or not, assuming there is a zero tariff. After this decision is made, the small open economy posts an unanticipated tariff of τ. Because the fixed costs are sunk, entrepreneurs continue to export (as long as net profits are positive). What is the impact of tariffs in this case? In this case, the relevant ratio is

$$\left.\frac{y(\tau=0)}{y(\tau>0)}\right|_{N=N(0)} = \left(\frac{x(0)}{x(\tau)}\right)^{\alpha} = (1-\tau)^{\frac{\alpha}{\alpha-1}}. \tag{5--11}$$

Note that the key difference between (5–10) and (5–11) is that $N(0)$ replaces $N(\tau)$. In essence, the key difference between these formulas is the exponent on $(1-\tau)$. In the latter case, where the number of imports varies with the tariff rate, the exponent is larger.

To do some rough calculations, Romer (1994) assumes that $\alpha = \frac{1}{2}$. Suppose that τ is 25 percent. Using the formula in (5–10), we find that GDP is 2.4 times higher without tariffs than with tariffs. Using the formula in (5–11), we find that GDP is only 1.3 times higher without tariffs than with tariffs. Thus, we significantly underestimate the effect on GDP if we do not allow the number of goods to vary with the tariff rate. Furthermore, the result is nonlinear. If we assume that τ is 50 percent, then the first formula yields a ratio of 8, while the second yields a ratio of 2.

Two conclusions can be drawn from these simple calculations. First, the effects of tariffs on productivity may be much larger when we consider that the set of products changes with tariffs. Second, the effects of tariffs on GDP are potentially large. The rough calculations that we did above use rates in the range observed for the low- and middle-income countries. (See Figure 15.)

Romer's (1994) estimates led Klenow and Rodríguez-Clare (1997c) to consider the effects of tariffs in Costa Rica. Klenow and Rodríguez-Clare (1997c) find that considering changes in the set of goods imported can significantly change the traditional cost-of-tariff calculation. For example, they find that their cost-of-tariff calculation leads to a loss from trade protection that is up to 4 times greater than the traditional calculation. In the particular case they study, the Costa Rican tariff reform in the late 1980s, the traditional calculation leads to rather small gains from tariff reduction. Hence, Klenow and Rodríguez-Clare's (1997c) estimates of the gain are also rather small–just a few percent of GDP. Still, it may be that in other countries or time periods, their formula may imply gains from tariff reductions that are a large fraction of GDP.

5.1.3. Other Policies

There are many other studies that have examined the quantitative impact of particular policies on income. In labor economics, there are studies of the effects of labor market restrictions such as impediments to hiring and firing workers on productivity and income. In industrial organization, there are studies assessing the quantitative effects of policies toward monopoly. In public finance, there are studies concerned with the quantitative effects of tax policies on income. In this section, we discuss some examples.

In many countries (developed and less developed), there are legal restrictions on the actions of employers. These laws range from requiring paying termination costs when firing employees to prohibiting firms from closing plants. Putting such legal restrictions on the actions of employers obviously influences their decision to hire employees. The laws, then, have implications for the equilibrium level of employment. A number of studies have tried to quantify the effects of such laws on aggregate employment and income. For example, Hopenhayn and Rogerson (1993) study the costs of imposing firing costs on firms. They construct a general equilibrium and use it to study the consequences of a law that imposes a tax equal to one year's wages if a firm fires an employee. They find that such a policy reduces employment by about 2.5 percent and reduces average productivity by 2 percent.[22]

An old issue is the relationship between monopoly and economic progress. In much of the R&D literature discussed later, there is an emphasis on the idea, attributed to Schumpeter, that entrepreneurs need to capture rents in order to innovate and introduce new products. Hence, this idea suggests that monopoly leads to economic progress. There is, of course, some truth to this idea. But for developing countries in which the issue is primarily one of technology adoption and not creation, the idea may be of little quantitative importance. Developing countries need to worry less about the incentives to invent new products than do developed countries. Hence, if monopolies have costs as well, monopolies may be more costly in developing countries.

But the cost of monopoly is low in most models. The cost of monopoly is usually due to a restriction on output. The costs of such output restrictions are usually estimated to be a small share of GDP. Bigger costs would emerge if monopoly were tied to restrictions on technology adoption. Parente and Prescott (1997) present a new model that argues that monopoly does restrict technology adoption. Parente and Prescott study the consequences

[22] Other work in this area includes Bertola (1994) and Loayza (1996) who study the effects of certain labor market restrictions on growth.

of giving a group the right to use a particular technology. If the group is given such a right, then it may try to block the adoption of new technologies that would reduce the gain from the monopoly right. Moreover, the group may use existing technologies inefficiently.

There is also a branch of the CGE literature that studies public finance issues. Among the policies that have been quantitatively explored in this literature are the abolition of government taxes, indexation of tax systems to inflation, and replacement of income taxes with consumption taxes. A good survey of some of this literature is contained in Shoven and Whalley (1984).

5.2. Effects of Policy on Growth

Up to now, we have focused on disparity in the levels of income across countries. However, much of the recent literature has focused instead on income growth. Of particular interest is the significant increase in the standard of living of the richest countries over the past 200 years and the recent growth miracles in East Asia. (See Figures 1 and 4.) An objective in this literature–typically referred to as the endogenous growth literature–is to develop models in which growth rates are endogenously determined. One of the main questions of this literature has been, What are the determinants of the long-run growth rate? To illustrate the kinds of quantitative predictions that have been found, we analyze two prototype endogenous growth models. The first is a two-sector model with growth driven by factor accumulation. The second model assumes that growth is driven by research and development. For both models, we derive steady-state growth rates and show how they depend on economic policies. Under certain assumptions, measured differences in policies imply significant differences in growth rates.

5.2.1. Policies in a Two-Sector AK Model

In this section, we analyze the balanced growth predictions of a prototype two-sector endogenous growth model.[23] There are three main differences between this model and the exogenous growth model discussed in Section 5.1.1. First, here we assume that there are constant returns to scale in accumulable factors. Second, we introduce elastic labor supply. Adding elastic labor supply does not change the results of Chari et al. (1997) significantly, but does have a large effect on the predictions of the endogenous growth models. Third, we add taxes on factor incomes as in Stokey and Rebelo (1995).

We assume that there is a representative household which maximizes

$$\sum_{t=0} \beta^t U(c_t, \ell_t) N_t, \tag{5-12}$$

where c is consumption per household member, ℓ is the fraction of time devoted to work, and N_t is the total number of household members. Since we are using a representative household in our analysis, we refer to the units of c as per capita and to N_t as the total population at date t. As before, we assume here that the growth rate of the population is constant and equal to n. For our calculations below, we assume that $U(c,\ell) = \{c(1-\ell)^\psi\}^{1-\sigma}/(1-\sigma)$ with $\psi > 0$.

There are two sectors of production in the economy. Firms in sector 1 produce goods which can be used for consumption or as new physical capital. The production technology in this sector is given by

$$c + x_k = y = A(kv)^{\alpha_k}(h\ell u)^{\alpha_h}, \tag{5-13}$$

where x_k is per capita investment in physical capital; A is the index of the technology level; v and u are the fractions of physical capital and labor, respectively, allocated to sector 1;

[23] For more discussion of this model, see Rebelo (1991) and Jones and Manuelli (1997). In Section 5, we analyze simulations of the model using as inputs the process for investment tax rates estimated in Chari et al. (1997).

and k and h are the per capita stocks of physical and human capital, respectively. In this case, we assume constant returns to the accumulable factors; that is, $\alpha_k + \alpha_h = 1$.

The human capital investment good is produced in sector 2 with a different production technology, namely,

$$x_h = B\left(k(1-v)\right)^{\theta_k}\left(h\ell(1-u)\right)^{\theta_h}, \tag{5–14}$$

where x_h is per capita investment in human capital and B is the index of the technology level. Again, we assume constant returns in accumulable factors so that $\theta_k + \theta_h = 1$. As do Uzawa (1965) and Lucas (1988), we allow for the possibility that the production of human capital is relatively intensive in human capital (that is, $\theta_h > \alpha_h$). Note that if $\alpha_k = \theta_k$ and $A = B$, then this model is equivalent to a one-sector endogenous growth model.

The laws of motion for the per capita capital stocks k and h are given by

$$(1+n)k_{t+1} = (1-\delta_k)k_t + x_{kt} \tag{5–15}$$

$$(1+n)h_{t+1} = (1-\delta_h)h_t + x_{ht}, \tag{5–16}$$

where the term $(1+n)$ appears because we have written everything in per capita terms.

Households supply labor and capital to the firms in the two sectors. Their income and investment spending are taxed. A typical household's budget constraint is given by

$$\begin{aligned} c_t + (1+\tau_{xkt})x_{kt} + &(1+\tau_{xht})q_t x_{ht} \\ &\le (1-\tau_{k1t})r_{1t}k_t v_t + (1-\tau_{k2t})r_{2t}k_t(1-v_t) \\ &+ (1-\tau_{h1t})w_{1t}\ell_t h_t u_t + (1-\tau_{h2t})w_{2t}\ell_t h_t(1-u_t) + T_t, \end{aligned} \tag{5–17}$$

where q is the relative price of goods produced in the two sectors, τ_{xk} is a tax on physical capital investment, τ_{xh} is a tax on human capital investment, r_j is the rental rate on physical capital in sector j, w_j is the wage rate in sector j, τ_{kj} is a tax on income from physical capital used in sector j, τ_{hj} is a tax on income from human capital used in sector j, and T is per capita transfers.

We assume that households maximize (5–12) subject to (5–15), (5–16), and (5–17), the processes for the tax rates τ_{xk}, τ_{xh}, τ_{kj}, τ_{hj}, $j = 1, 2$, and given factor prices. Assuming competitive markets, one finds that factor prices in equilibrium are marginal products derived using the technologies in (5–13) and (5–14).

We turn now to some calculations. Following Stokey and Rebelo (1995), we parameterize the model to mimic different studies in the literature. In Table 3A, we display four such parameterizations corresponding to the studies of King and Rebelo (1990), Lucas (1990), Kim (1992), and Jones et al. (1993). For all four models and all of the numerical experiments we run, we normalize the scale of technology in sector 1 with $A = 1$ and adjust B so as to achieve a particular growth rate in our baseline cases. Although there are slight differences between the model described above and those we are comparing it to, when we run the same numerical experiments as these studies, we find comparable results.

Here we run the same numerical experiment for all four models. The experiment is motivated by the data on income tax revenues and growth rates for the United States reported in Stokey and Rebelo (1995). Stokey and Rebelo note that in the United States, there was a large increase in the income tax rate during World War II. Despite this, there was little or no change in the long-run U.S. growth rate. Stokey and Rebelo argue that this evidence suggests that the models in the literature predict implausibly large growth effects of fiscal policies.[24]

[24] The small change in growth could also be due to the fact that there were other policy changes such as lower tariffs or increased public spending on education as in Glomm and Ravikumar (1998) that had offsetting effects on the growth rate.

Suppose that we parameterize our model using the values given in Table 3A. The parameter B is set so as to achieve a steady-state growth rate of 2 percent when all tax rates are 0. Now consider an increase in the tax rates τ_{k1}, τ_{k2}, τ_{h1}, and τ_{h2} from 0 percent to 20 percent. In Table 3B, we display the after-tax steady-state growth rates for all four parameterizations. The new growth rates range from a value of -1.99 for Jones et al.'s (1993) parameters to 1.31 for Kim's (1992) parameters.

To get some sense of the magnitudes, imagine two countries that start out with the same output per worker but one follows a 0 percent tax policy and the other a 20 percent tax policy. After 30 years, one would predict that their incomes differ by a factor of 1.23 using Kim's parameters and 3.31 using Jones et al.'s (1993) parameters. After 200 years, the factors would be 3.89 versus 2,924. Thus, there is a large difference between the predictions of Lucas (1990) or Kim (1992) and King and Rebelo (1990) or Jones et al. (1993) if growth rates are compounded over many years.

Table 3B shows clearly that the estimated impact of policy on growth varies dramatically in the literature. Here, too, there is still much debate about the magnitude of the estimates of policy effects.

To get some sense of why the results are so different, we consider two special cases of the model and derive explicit formulas for the growth rate of productivity in the steady state. Suppose first that incomes from capital and labor used in sector j are taxed at the same rates. That is, let $\tau_j = \tau_{kj} = \tau_{hj}$. Suppose that tax rates on physical and human capital investment are equal; that is, $\tau_x = \tau_{xk} = \tau_{xh}$. Suppose also that the capital shares are equal in the two sectors, with $\alpha = \alpha_k = \theta_k$. Finally, assume that the depreciation rates are equal for physical and human capital, and let $\delta = \delta_k = \delta_h$. In this case, the steady-state growth rate for output per worker is given by

$$g = \left[\beta \left(1 - \delta + [A\alpha(1-\tau_1)]^\alpha [B(1-\alpha)(1-\tau_2)]^{1-\alpha} \frac{\ell(\tau)^{1-\alpha}}{1+\tau_x} \right) \right]^{\frac{1}{\sigma}} - 1, \qquad (5\text{–}18)$$

where $\tau = (\tau_x, \tau_1, \tau_2)$ is the vector of tax rates and $\ell(\tau)$ denotes the fraction of time spent working in the steady state, which is a function of the tax rates. From the expression in (5–18), we see that predicted effects of a tax increase depend on the discount factor, the depreciation rate, the capital share, and the elasticity of labor.

The parameters of King and Rebelo (1990) fit the special case in (5–18). But they further assume that labor is supplied inelastically, and therefore, $\ell(\tau) = 1$. Consider two variations on King and Rebelo's (1990) parameter values given in Table 3A. First, suppose they had assumed $\delta = 0$ rather than $\delta = 0.1$. Using the formula in (5–18) with $\alpha = 0.33$, $\delta = 0$, $\beta = 0.988$, $\sigma = 1$, $A = 1$, and $B = 0.0154$, we find that the pre-tax growth rate is 2 percent and the after-tax growth rate is 1.36 percent, which is significantly higher than -0.62. (See Table 3B.) Now consider increasing σ. If we set $\delta = 0$, $\sigma = 2$, and $B = 0.032$ so as to get a pre-tax growth rate of 2 percent, then the after-tax growth rate is 1.48 percent, which is even higher than the estimate found with Kim's (1992) parameter values.

We now consider a second special case. Suppose that the sector for producing human capital uses no physical capital. In this case, the steady-state growth rate for output per worker is given by

$$g = \left[\beta \left(1 - \delta_h + B\ell(\tau) \frac{1-\tau_{h2}}{1+\tau_{xh}} \right) \right]^{\frac{1}{\sigma}} - 1, \qquad (5\text{–}19)$$

where $\tau = (\tau_x, \tau_{k1}, \tau_{k2}, \tau_{h1}, \tau_{h2})$ is the vector of tax rates and $\ell(\tau)$ is the time spent working in the steady-state equilibrium. The parameters of Lucas (1990) fit this special case. In this case, no physical capital is allocated to sector 2, and therefore, changes in τ_{k2} have no effect at all. Furthermore, changes in tax rates in sector 1 only affect growth if they affect the supply of labor. If labor is inelastically supplied, the taxes levied on factors in sector 1 have no growth effects at all.

Lucas (1990) chooses a near-inelastic labor supply elasticity ($\psi = 0.5$). Suppose, for his case, we use $\psi = 5$, implying an elastic labor supply as in Jones et al. (1993), and set B=0.219 to hit the baseline growth rate. With these changes, the steady-state labor supply ℓ is 0.209 when the tax rates are 20 percent and 0.283 when the tax rates are 0 percent. Using the formula in (5–19), we find that the pre-tax growth rate is 2 percent and that the after-tax growth rate is 0.79 percent. Thus, the growth effects are sensitive to the choice of labor elasticity.

The formulas in (5–18) and (5–19) illustrate how sensitive the quantitative predictions are to certain parameter assumptions. In particular, the predictions are sensitive to choices of the labor elasticity, depreciation rates, and the intertemporal elasticity of substitution. Stokey and Rebelo (1995) attribute the wide range of estimates of the potential growth effects of tax increases cited in the literature to different assumptions for these parameters. The conclusion that Stokey and Rebelo (1995) draw from the U.S. time series evidence is that tax reform would have little or no effect on growth rates in the United States. They do not dispute that the two-sector endogenous growth model yields a good description of the data if it is parameterized as in Lucas (1990) or Kim (1992).

Jones (1995b), however, uses the U.S. time series as evidence that the model is not a good description of the data. He notes that after World War II, we saw large increases in the investment-output ratio in France, Germany, Great Britain, Japan, and the United States. But growth rates in these countries changed little. If the data were well described by a one-sector AK growth model, then Jones (1995b) argues that we should have seen larger increases in the growth rate accompanying the increases in the investment-output ratio.

The model Jones (1995b) works with is a one-sector version of the model above in which labor is supplied inelastically and the total population is constant. Suppose that $A = B$, $\alpha = \alpha_k = \theta_k$, $\delta = \delta_k = \delta_h$, $\psi = 0$, and $n = 0$. In this case, the ratio of human to physical capital is given by the ratio of their relative shares $(1-\alpha)/\alpha$. Here, as in the AK model, total output can be written as a linear function of k, namely, as $Ak^\alpha h^{1-\alpha} = A[(1-\alpha)/\alpha]^{1-\alpha}k$. Thus, the growth rate in output is equal to the growth rate in capital. From (5–15), we can derive the steady-state growth rate in capital, which we denote by g, by dividing both sides of the equation by k_t and subtracting 1. The growth rate in this case is

$$g = -\delta + \frac{x_k}{k} = -\delta + A\left(\frac{1-\alpha}{\alpha}\right)^{1-\alpha} \frac{x_k}{c + x_k + x_h}, \tag{5–20}$$

where we have used the steady-state relation between capital and total output $c + x_k + x_h$. Jones (1995b) points out that while investment-output ratios have risen over the postwar period, growth rates have stayed roughly constant or have fallen. The formula in (5–20) implies the opposite: increases in investment-output ratios should be accompanied by increases in growth rates.

There are several caveats to be noted with Jones' (1995b) argument. First, in countries such as the United States, the changes in the investment-output ratio are not that large, and by (5–20) we would not expect a large change in the growth rate. Suppose $\alpha = \frac{1}{3}$ and A is set equal to $\frac{1}{4}$ to get a capital-output ratio of roughly $2\frac{1}{2}$. Suppose also that the depreciation rate is 5 percent. These values would imply that an increase in the investment-output ratio from 16.5 percent to 18.1 percent, as reported by Jones (1995b) for the United States over the period 1950–1988, should lead to a change in the growth rate from 1.55

percent to 2.18 percent. Given the size of growth rate variations in the data, it is hard to detect such a small change in the long-run growth rate over such a short period of time. Second, the relationship between growth rates and the investment-output ratio is not given by (5–20) as we relax many of the assumptions imposed by Jones (1995b). For example, if labor is elastically supplied or the two sectors of the model have different capital shares, then (5–20) does not hold. In such cases, we have to be explicit about what is changing investment-output ratios in order to make quantitative predictions about the growth rates. If, for example, we use Lucas' (1990) model to investigate the effects of income tax changes, we find a small effect on growth rates but a big effect on investment-output ratios.

In this section, we discussed the effects of changes in tax rates on growth. The AK model has also been used to study the effects of monetary policy on growth. For example, Chari et al. (1995) consider an AK model with several specifications of the role for money. In all cases, they find that changes in the growth rate of the money supply has a quantitatively trivial effect on the growth rate of output. As we saw above, large growth effects require large effects on the real rate of return. Changes in tax rates can have a potentially large effect on the real rate of return, but changes in inflation rates do not. On the other hand, Chari et al. (1995) find that monetary policies that affect financial regulations such as reserve requirements on banks can have nontrivial effects (on the order of a 0.2 percentage point fall in the growth rate with a rise in inflation from 10 to 20 percent) if the fraction of money held as reserves by banks is high (on the order of 0.8). These effects are small, however, relative to the effects of fiscal policy that have been found.

5.2.2. Policies in a R&D Model

A large literature has developed theoretical models of endogenous growth based on devoting resources to R&D. This literature includes new product development models [such as in Romer (1990)] and quality-ladder models [such as in Grossman and Helpman (1991a, b) and Aghion and Howitt (1992)]. As compared to the theoretical literature that explores the quantitative link between policies and disparity (as in Section 5.1) and the two-sector endogenous growth literature that explores the quantitative link between policies and growth (as in Section 5.2.1), this R&D literature has far fewer studies exploring the quantitative link between policies and growth. This is likely due to the fact that the main quantitative concern for these models has been their predicted scale effects. Though there has been little explicit analysis of the effect of policy in these models, we think that it is important to review this important literature.

We begin by describing a discrete-time version of the model in Romer (1990). Recall that in Section 5.1.2 we considered the problem of a small open economy importing intermediate goods that had already been developed in the rest of the world. Here we focus on the R&D activity. Technological innovation–new blueprints for intermediate inputs–is the driving force behind growth in this model. We show that the model implies a scale effect: the growth rate increases with the number of people working in R&D. This implied scale effect has been criticized by Jones (1995a) who offers a possible solution without significantly changing the model. [See also Young's (1998) model of quality ladders.] We review Jones' (1995a) model in which there is no scale effect. We lastly turn to the evidence on this point.

The discrete-time version of the economy in Romer (1990) that we consider has three production sectors. In the research sector, firms use existing blueprints and human capital to produce new blueprints. In the intermediate goods sector, firms use existing blueprints and capital to produce intermediate capital goods. In the final goods sector, firms use intermediate capital goods, labor, and human capital to produce a final good that can be consumed or used to produce new capital. In addition, there is a household sector. Households buy consumption and investment goods with wages, rental earnings, and profits.

Consider first the problem of the final goods producers. Their production function is given by

$$Y = H_Y^{\alpha} L^{\gamma} \int_0^N x_i^{1-\alpha-\gamma} \, di,$$

where H_Y is human capital devoted to final goods production, L is labor, N is the total number of intermediate goods currently in existence, and x_i is the quantity of the ith intermediate good. Final goods producers choose inputs to maximize their profits and, therefore, solve

$$\max_{H_Y, L, \{x_i\}} \; Y - w_H H_Y - w_L L - \int_0^N p_i x_i \, di, \tag{5--21}$$

where w_H is the price of a unit of human capital, w_L is the wage rate for labor, p_i is the price of intermediate good i, and the final good is the numeraire. Profit maximization implies that

$$p_i = (1-\alpha-\gamma) H_Y^{\alpha} L^{\gamma} x_i^{-\alpha-\gamma} \tag{5--22}$$

and that

$$w_H = \alpha H_Y^{\alpha-1} L^{\gamma} \int_0^N x_i^{1-\alpha-\gamma} \, di.$$

Consider next the problem of intermediate goods producers. We start by assuming that the blueprint for intermediate good i has been purchased. The technology available to the producer of intermediate good i is linear and is given by

$$x_i = \frac{1}{\eta} k_i, \tag{5--23}$$

where k_i is the capital input. Conditional on having purchased blueprint i, the producer of intermediate good i maximizes profits π_i:

$$\pi_i = \max_{x_i} \; p(x_i)\, x_i - rk_i \tag{5–24}$$

subject to (5–23), where $p(\cdot)$ is the demand function given by (5–22) and r is the rental rate for capital.

The decision to purchase a blueprint is based on a comparison of the cost of the blueprint versus the benefit of a discounted stream of profits from using the blueprint. Free entry into intermediate good production implies that

$$P_{Nt} = \sum_{j=t}^{\infty} \prod_{s=t}^{j} \left(\frac{1}{1+r_s} \right) \pi_j$$

where P_{Nt} is the price of blueprint N at date t and π_j are profits at date j.

Next we consider the problem of research firms who produce new blueprints and sell them to intermediate goods producers. Given an input of human capital, $\tilde{H}$, a firm can produce $\delta \tilde{H} N$ new blueprints, where δ is a productivity parameter and N is the total stock of blueprints in the economy. Let H_{Nt} denote the aggregate human capital input in R&D; then the stock of blueprints evolves according to

$$N_{t+1} = N_t + \delta H_{Nt} N_t. \tag{5–25}$$

In equilibrium, it must be true that

$$w_H = P_N \delta N.$$

Lastly, consumers maximize expected utility subject to their budget constraint. Preferences for the representative household over consumption streams are given by

$$\sum_{t=0}^{\infty} \beta^t \frac{C_t^{1-\sigma} - 1}{1-\sigma},$$

where C_t are units of consumption at date t. Denoting the interest rate by r_t, one finds that the maximization of utility subject to the household's budget constraint implies that

$$U'(C_t) = \beta U'(C_{t+1})(1 + r_{t+1}). \tag{5–26}$$

We now compute a steady-state equilibrium growth rate for output. Assume that the total stock of human capital $H = H_N + H_Y$ and the supply of labor L are both fixed. Romer (1990) shows that a symmetric equilibrium exists in which output Y, consumption C, and the number of blueprints N all grow at the same rate. Denote this growth rate by g, and denote the quantities, prices, and profits in the intermediate good sector by $\bar{x}$, $\bar{p}$, and $\bar{\pi}$. From (5–25), we know that $g = \delta H_N$. Thus, to compute the growth rate of output, we need to derive the stock of human capital devoted to R&D in equilibrium.

The returns to human capital in the research sector and in the final goods sector must be equal in equilibrium; therefore,

$$P_N \delta N = \alpha H_Y^{\alpha-1} L^{\gamma} N \bar{x}^{1-\alpha-\gamma}. \tag{5–27}$$

Using (5–22), (5–23), and the first order condition from (5–24), we have that

$$\bar{\pi} = (\alpha + \gamma)(1 - \alpha - \gamma) H_Y^{\alpha} L^{\gamma} \bar{x}^{1-\alpha-\gamma}.$$

Equating the price of blueprints to the discounted value of the profits from use of the blueprints implies that

$$P_N = \frac{1}{r}\bar{\pi} = \frac{1}{r}\{(\alpha + \gamma)(1 - \alpha - \gamma) H_Y^{\alpha} L^{\gamma} \bar{x}^{1-\alpha-\gamma}\}. \tag{5–28}$$

Substituting (5–28) in (5–27) and simplifying yields the following expression for human capital in production:

$$H_Y = \frac{\alpha r}{\delta(1 - \alpha - \gamma)(\alpha + \gamma)}.$$

Therefore, the growth rate is

$$g = \delta\left(H - \frac{\alpha r}{\delta(1-\alpha-\gamma)(\alpha+\gamma)}\right) = \delta H - \Lambda r, \tag{5–29}$$

where $\Lambda = \alpha/[(1-\alpha)(1-\alpha-\gamma)]$. From the household's first-order condition in (5–26) we have that

$$g = [\beta(1+r)]^{\frac{1}{\sigma}} - 1. \tag{5–30}$$

Thus, in (5–29) and (5–30), we have two equations from which we can determine the growth rate g and the interest rate r on a balanced growth path.

Notice that g depends positively on the stock of human capital H. Thus, there is a scale effect, as we noted above. As Jones (1995a) points out, one need not even proceed past the specification of growth in the number of blueprints and the description of technologies to know that there is a scale effect. The main assumption of the model is that a doubling of the number of people working on R&D implies a doubling of the growth rate by (5–25). However, in many countries, particularly the OECD countries, there has been a dramatic increase in the number of scientists and engineers and a dramatic increase in the resources devoted to R&D with little or no increase in growth rates over a sustained period.

Within the context of Romer's (1990) model that we just described, Jones (1995a) offers a possible solution to the problem of the existence of a scale effect. In particular, he assumes that the evolution of blueprints is given by

$$N_{t+1} = N_t + \delta H_{Nt}^{\lambda} N_t^{\phi}, \tag{5–31}$$

with $0 < \lambda \leq 1$ and $\phi < 1$, rather than by (5–25). Jones (1995a) also assumes that $\gamma = 0$ and that the growth rate of H is given by n, where H is now interpreted to be the total labor force. On a balanced growth path, H_{Nt}^{λ} must grow at the same rate as $N_t^{1-\phi}$. (See equation (5–31).) Thus, it follows that

$$g = \frac{\lambda n}{1 - \phi}, \tag{5–32}$$

where g is the growth rate of blueprints and output per worker. Note that g now depends on the growth rate of the labor force rather than the total number of researchers. Thus the scale effect is removed.

Is the relationship in (5–32) consistent with the data? The answer to this question depends a lot on how the model is interpreted. For example, if we interpret this model as one of a typical country, then the answer is no. The correlation between growth rates of GDP per worker and growth rates of the labor force over the period 1960–1985 is -0.12 (based on all countries with GDP per worker available). The relationship in (5–32) implies a positive correlation. If we interpret this model as one relevant only for countries in which there is a lot of activity in R&D, we still find that the correlation between the growth rates of GDP per worker and the labor force are around zero or slightly negative.

Suppose, finally, that we view the model as one relevant for the world economy. Using the data of Bairoch (1981), we see that the growth rate in real GDP per capita for the world and the growth rate of the world population followed the same trend over the period 1750–1990. Hence, under this interpretation, the model is roughly consistent with the data assuming that the growth rate of the world population is a good proxy for the growth rate of the number of researchers world-wide.

With growth in output per worker determined by a variable assumed to be exogenous, namely the growth rate in the labor force, policies intended to encourage innovation such as subsidies to R&D or capital accumulation have no growth effects in Jones' (1995a) model. However, we do know that there are many countries that have a large fraction of

R&D spending financed by their government. Examples include France, Germany, Japan, and the United States. In fact, Eaton and Kortum (1996) attribute more than 50 percent of the growth in each of the OECD countries to innovation in Germany, Japan, and the United States. But the effects of policies encouraging innovation are still being debated. [See, for example, Aghion and Howitt (1998).]

6. Two Growth Models and all of the Basic Facts

In Section 5.1, we reviewed the literature that studies the implied disparity in incomes in various parameterized models, while in Section 5.2, we reviewed the literature that studies the implied growth rates in various parameterized models. These studies typically focus on one or the other dimension of the income distribution–that is, disparity or growth. As Lucas (1988) argues, "the study of development will need to involve working out the implications of competing theories for data other than those they were constructed to fit, and testing these implications against observation" (p. 5). We turn to that task in this section.

We look at implications of two of the above parameterized models for numerous dimensions of the income distribution over the last 100 or so years (in particular, the features in Figures 1–4). As we just mentioned, few studies actually perform this exercise. A big difficulty in performing such an exercise is coming up with reasonable measures of factor inputs such as human capital and economic policies for such a long period of time. We do not solve that problem here. What we do is take the measure of distortions on capital investment that Chari et al. (1997) use for the post-World War II period and suppose the process applies to the last 200 years or so.[25] Our purpose in this section is not to argue that investment distortions were the only factor determining variations in incomes but only to show what can be learned by conducting the exercise that Lucas (1988) suggests. For example, we learn that the parameterized models, with the distortions from Chari et al. (1997), do a reasonable job in explaining some figures, but not all.

The models that we analyze here are a standard exogenous growth model and a standard AK endogenous growth model. For both models, we generate panel data sets and compare them to the data compiled by Maddison (1991, 1994) and Summers and Heston (1991). This is done by producing analogues of Figures 1–4 for the two models.

The exogenous growth model can be written succinctly as the following maximization problem:

$$\max_{\{c_t,\ell_t,x_{kt},x_{ht}\}} \sum_{t=0}^{\infty} \tilde{\beta}^t (c_t(1-\ell_t)^{\psi})^{1-\sigma}/(1-\sigma) \tag{6–1}$$

$$\begin{aligned}
\text{subject to}\quad & c_t + (1+\tau_{xt})(x_{kt}+x_{ht}) \le w_t\ell_t + r_{kt}k_t + r_{ht}h_t + T_t \\
& (1+g)(1+n)k_{t+1} = (1-\delta)k_t + x_{kt} \\
& (1+g)(1+n)h_{t+1} = (1-\delta)h_t + x_{ht} \\
& r_{kt} = F_1(\bar{k}_t, \bar{h}_t, \bar{\ell}_t) \\
& r_{ht} = F_2(\bar{k}_t, \bar{h}_t, \bar{\ell}_t) \\
& w_t = F_3(\bar{k}_t, \bar{h}_t, \bar{\ell}_t) \\
& T_t = \tau_{xt}(\bar{x}_{kt} + \bar{x}_{ht}) \\
& F(k,h,\ell) = Ak^{\alpha_k}h^{\alpha_h}\ell^{1-\alpha_k-\alpha_h},
\end{aligned}$$

with $x_{kt}, x_{ht} \ge 0$, $\tilde{\beta} = \beta(1+g)^{1-\sigma}(1+n)$, and $\alpha_k + \alpha_h < 1$. Original variables have been

[25] In recent work, Jones et al. (1998) have included stochastic tax and productivity processes in an endogenous growth model in order to study the effects of uncertainty on the growth rate.

converted to per capita terms and, if necessary, divided by the level of technology in order to make them stationary (for example, $\ell_t = L_t/N_t$, $c_t = C_t/(A_t N_t)$, $k_t = K_t/(A_t N_t)$, and so on, where $N_t = (1+n)^t$ is the total population and $A_t = A(1+g)^t$ is the level of technology). A bar over the variable denotes the economy-wide level.[26]

The endogenous growth model can be written succinctly as the following maximization problem

$$
\begin{aligned}
\max_{\{c_t,\ell_t,x_{kt},x_{ht},v_t,u_t\}} \quad & \sum_{t=0}^{\infty} \tilde{\beta}^t (c_t(1-\ell_t)^{\psi})^{1-\sigma}/(1-\sigma) \qquad (6\text{–}2)\\
\text{subject to} \quad & c_t + (1+\tau_{xt})(x_{kt} + q_t x_{ht}) \le r_{1t} k_t v_t + r_{2t} k_t (1-v_t) \\
& \qquad + w_{1t}\ell_t h_t u_t + w_{2t}\ell_t h_t (1-u_t) + T_t \\
& (1+n)k_{t+1} = (1-\delta)k_t + x_{kt} \\
& (1+n)h_{t+1} = (1-\delta)h_t + x_{ht} \\
& r_{1t} = F_1(\bar{k}_t \bar{v}_t, \bar{h}_t \bar{\ell}_t \bar{u}_t) \\
& w_{1t} = F_2(\bar{k}_t \bar{v}_t, \bar{h}_t \bar{\ell}_t \bar{u}_t) \\
& r_{2t} = q_t G_1(\bar{k}_t(1-\bar{v}_t), \bar{h}_t \bar{\ell}_t (1-\bar{u}_t)) \\
& w_{2t} = q_t G_2(\bar{k}_t(1-\bar{v}_t), \bar{h}_t \bar{\ell}_t (1-\bar{u}_t)) \\
& q_t = F_1(\bar{k}_t \bar{v}_t, \bar{h}_t \bar{\ell}_t \bar{u}_t)/G_1(\bar{k}_t(1-\bar{v}_t), \bar{h}_t \bar{\ell}_t (1-\bar{u}_t)) \\
& T_t = \tau_{xt}(\bar{x}_{kt} + q_t \bar{x}_{ht}) \\
& F(K,H) = AK^{\alpha_k} H^{\alpha_h} \\
& G(K,H) = BK^{\theta_k} H^{\theta_h},
\end{aligned}
$$

with $x_{kt}, x_{ht} \ge 0$, $\tilde{\beta} = \beta(1+n)$, $\alpha_k + \alpha_h = 1$, and $\theta_k + \theta_h = 1$. Variables are in per capita units, and a bar over the variable denotes the economy-wide level.

[26] The model in Section 5.1.1 with $\alpha = \gamma$ is a simplified version of the model specified here. Under certain specifications of the parameters, they are isomorphic to each other.

In order to simulate the models, we need to choose parameter values and a process for the policy variable τ_x. In Table 4A, we report the parameter values that we use. Many of the parameter values are chosen to be the same in the two models. In particular, we choose physical capital shares equal to $\frac{1}{3}$, depreciation rates of 6 percent on both types of capital stocks, a discount factor equal to 97 percent, and the weight on leisure in utility equal to 3. These parameter values fall in the ranges typically used in the literature. We set the growth rate of the population equal to 1.5 percent, which is consistent with the data reported in Maddison (1994). The growth rate in technology in the exogenous growth model is set equal to 1.4 percent to achieve the same long-run growth patterns seen in Maddison's (1994) sample. In the endogenous growth model, we set $A = B$ and $\alpha_k = \theta_k$ so as to mimic a one-sector model. We then experiment with a different value of θ_k–one that implies that the human capital sector is human capital-intensive–to see if the results are affected.

For the risk aversion parameter, we experiment with $\sigma = 2$ and $\sigma = 5$. As we showed earlier, growth rates in the endogenous growth model are very sensitive to this parameter. If we choose a value that is too small (for example, near 1), then the disparity after 200 years is much greater than that actually observed. A value of 5 gives reasonable predictions for the distribution of incomes over time in the endogenous growth model. Results in the exogenous growth model are much less sensitive to this choice. However, the variation in growth rates is still affected significantly.

For both models, we conduct the same experiment. We assume that all countries face the same process for investment distortions. All other tax rates are assumed to be equal to 0. Recall that relative prices of investment to consumption can be used as a measure of the distortion on investment. With the data on relative prices of investment to consumption over the sample period 1960–1985, Chari et al. (1997) estimate a regime-switching process for the stochastic process on the relative price of investment to consumption. In particular, they assume that conditional on being in regime R, the relative price $1 + \tau_x$ follows an autoregressive process given by

$$(1 + \tau_{x,t+1}) = \rho_R(1 + \tau_{x,t}) + \mu_R(1 - \rho_R) + \sigma_R\,\varepsilon_{t+1},$$

where ε_t is i.i.d. and is drawn from a standard normal distribution. The probability of switching regimes depends on the number of periods since the last regime switch. Let m denote the number of periods since the last switch. The probability of switching from regime R to R', conditional on having been in R for m periods, is

$$\pi_{RR'}(m) = a_R - b_R(m - 1).$$

Chari et al. (1997) find that the data are well characterized by a process with two regimes. In one regime, the distortions are highly persistent over time, and in the other, they are more volatile. Chari et al. (1997) refer to the regimes as the *persistent* and the *turbulent* regimes.

In Table 4B, we display the maximum likelihood parameter estimates of Chari et al. (1997) for the process governing the distortion on investment. The subscript P indicates values for the persistent regime, and the subscript T indicates values for the turbulent regime. Conditional on being in the persistent regime, the coefficient on the lagged relative price is 0.993, and the standard deviation of the innovation is 0.074. Conditional on being in the turbulent regime, the coefficient on the lagged relative price is 0.865, and the standard deviation of the innovation is 0.789. The unconditional variance of the relative price is 2.47 in the turbulent regime and 0.39 in the persistent regime. Thus, the relative price fluctuates a lot more in the turbulent regime than it does in the persistent regime. Notice that in the turbulent regime, relative prices show more mean reversion than they do in the persistent regime. Note also that the unconditional mean of the relative price is 2 in the persistent regime and 2.5 in the turbulent regime.

The parameters of the switching probability functions are given in Table 4B. The probability of switching from the persistent to the turbulent regime, conditional on having switched to the persistent regime in the previous period, is 0.244, while this probability is 0.016, conditional on having been in the persistent regime for 20 periods or more. The probability of switching from the turbulent to the persistent regime, conditional on having switched to the turbulent regime in the previous period, is 0.350, while this probability is 0.046, conditional on having been in the turbulent regime for 20 periods or more. Thus, the probability of leaving the persistent regime is lower than the probability of leaving the turbulent regime. Notice that the turbulent regime is aptly named because of two characteristics: conditional on being in the regime, relative prices fluctuate more, and the probability of leaving the regime is higher.

Using estimates for the process for $1+\tau_x$ as inputs, we simulate an artificial panel data set for both the exogenous growth model and the endogenous growth model. We assume that all countries have the same factor endowments and investment distortions (that is, values for k, h, τ_x, R, and m) in the year 1750, and as we noted above, we assume the same process for investment distortions. This choice of initial year is motivated by Bairoch's (1981) GNP per capita data. His numbers show that the average standard of living of the developed countries and the Third World were very similar in 1750. The initial conditions for the relative price are set as follows. We set the relative price equal to 1 (and, hence, the tax on investment equal to 0) for all countries in 1750 and assume that they are in the persistent regime and have been for 20 or more periods. For k and h, we use the corresponding steady-state values (with h normalized to be 1 in 1750 in the endogenous growth model). With these initial conditions, we produce two panel data sets–one for each model–for the period 1750–1990 for 1,000 countries.

6.1. An Exogenous Growth Model

In this section, we describe simulation results for the exogenous growth model. We start with the case in which $\sigma = 2$. Results in this case are summarized in Figures 17–20. We then describe how the results change when we increase σ to 5. Results in this case are given in Figures 21–24. Both sets of results are compared to their analogues in the data, namely, Figures 1–4, which are discussed in Section 2.

In Figure 17, we display the time series of income distributions for the model. We display the 25th and 75th percentiles of the distribution as well as the 10th and 90th percentiles. We plot the percentiles since we are comparing the model to a very incomplete set of data back to 1820. Recall that we have per capita GDP data for only 21 countries. Since we do have a number of the very poor countries and many of the rich countries in this set of 21, it is likely that a good comparison can be made with the 10th and 90th percentiles for our model. We include the 25th and 75th percentiles, however, in order to give some feeling for the size of the tails of the distribution.

The model shows a gradual fanning out of the distribution as is observed in the data. In 1820 the country at the 90th percentile has a per capita GDP equal to 4.3 times that of the country at the 10th percentile. By 1989, this factor is 16.5, which is very close to the ratio of 16.7 in the data. The insert in Figure 17 is a snapshot of the distribution of per capita output in 1989. We keep the axes the same in Figure 17 as in Figure 1 to make it easier to compare the figures. As a result, only 94.3 percent of the countries are shown for the model since there were some outliers with per capita output greater than 8 times the world average and less than $\frac{1}{8}$ of the world average. In the data, the distribution of per capita GDP is close to uniform. The distribution of per capita output in the model in 1989 is closer to normal.

Next consider the predicted correlation between incomes in 1960 and subsequent growth rates. In Figure 18, we plot the model's growth rates in incomes for the period 1960 to 1985 versus the relative incomes in 1960. Again, we keep the axes the same as in Figure 2, which shows the relationship between growth and initial income for the data. In this case all but 1 percent of the countries are shown. The pattern for the model looks like a cloud–similar to that in Figure 2. The correlation between initial incomes and growth rates is negative for the model, but only slightly.

As noted before, the transition dynamics occurring when capital is off its steady state lead to a negative correlation between initial capital and subsequent income growth. Here, however, there are two forces at work: transition dynamics of capital and stochastic disturbances in investment distortions. Because the data on the relative price of investment to consumption display large fluctuations, output displays large fluctuations. Therefore, we find a lot of mobility of countries and little correlation between initial incomes and subsequent growth rates. Note also that, in the data, countries with the most persistent relative prices of investment to consumption over time are the richest and the poorest. Countries with relative prices that vary significantly over time are middle income countries. These features of the data are well mimicked by the model because countries with policies that switch regimes frequently are middle-income countries. As a result, growth rates for the middle-income countries show the greatest variation.

In Figure 19, we plot the growth rates of GDP for two subperiods, 1961–1972 and 1973–1985. Here, as in the data, we find a weakly positive correlation between the growth rates in these subperiods. The correlation for the growth rates in the model is 0.21, whereas the correlation for the data is 0.16. This lack of persistence is evident in both Figure 19 for the model and Figure 3 for the data. For the model, countries with very different growth rates in the two subsamples are typically in a turbulent regime with tax rates falling (rising) over the first half of the sample and rising (falling) over the second half. Note, however, that although the growth rates are not correlated across the subsamples, the average investment-output ratios are correlated–both in the data and in the model. In the model, there is uncertainty about future tax rates which keeps agents from rapidly changing their saving behavior in the face of rising or falling rates.

Another feature of the model's simulation that is similar to the data is the range of growth rates. In Figure 19, we see that most of the growth rates calculated for the model fall in the range of those observed in the data: -5 percent to 10 percent. There are only 1.6 percent of the model countries with growth rates that fall outside of this range. We will see shortly how important the choice of σ is for this result.

Next we construct maximum growth rates of GDP per capita for the model. To avoid relying too heavily on growth rates for outlier countries, we take an average of the top $2\frac{1}{2}$ percent of growth rates over each decade and call these the maximum growth rates. In Figure 20, we plot these growth rates. Notice that the growth rates for the model are higher throughout the sample period than those observed in the data presented in Figure 4. Furthermore, the model growth rates show no significant upward trend. Although there is a lot of mobility of countries in the model, maximal decade growth rates are higher than 6 percent over the whole simulated sample period, 1750–1990. In the model, these high growth rates are tied to falling tax rates, which is the only impediment to faster growth. Obviously, the model has to be modified to incorporate the idea that higher growth rates are achievable only when outside opportunities (for example, world technology) are better.

In Figures 21–24, we show results for the same experiment described above. In this case, we set the risk aversion parameter σ equal to 5. There are several differences between the cases with $\sigma = 2$ and $\sigma = 5$ worth noting. First, the range of the distribution over time displayed in Figure 21 is significantly smaller than in the case with $\sigma = 2$. This can be seen by comparing Figures 17 and 21. In 1989, output per capita for a country in the 90th percentile is only 7.1 times that of a country in the 10th percentile. Second, variation in growth rates is also reduced as is clear when we compare Figures 22 and 23 with Figures 18 and 19. It is not surprising, then, that we find that the maximum growth rate is smaller the larger is σ. This is evident when we compare Figures 20 and 24.

In summary, in both simulations (with $\sigma = 2$ and $\sigma = 5$), we find a large range in the distribution of 1989 incomes, little correlation between incomes and subsequent growth rates, and little persistence in growth rates. Yet, in both simulations, we find little agreement between maximal growth rates in the model and those in the data.

6.2. An Endogenous Growth Model

Results for the endogenous growth model with $\alpha_k = \theta_k$ are reported in Figures 25–28. These figures can be compared to Figures 1–4 for the data and Figures 21–24 for the exogenous growth model with $\sigma = 5$.

In Figure 25, we display four of the percentiles of the distribution of incomes for the model over the period 1820–1989. Here, as in the data, there is a gradual fanning out of the distribution. However, by 1989, the ratio of GDP per capita for the country at the 90th percentile to that of the 10th percentile is 43.9, which exceeds the ratio in the data. With constant returns to scale in accumulable factors, the model predicts that the disparity of incomes increases with time. How quickly this occurs depends on choices of risk aversion, depreciation, and labor supply elasticity, as the formulas derived in Section 5.2.1 make clear. Part of the distribution for 1989 is displayed in the insert of Figure 25. Only 82.4 percent of the countries have a relative GDP per worker in the range of $\frac{1}{8}$ to 8. However, the distribution of incomes is roughly uniform, as it is in the data.

In Figure 26, we plot the relative GDPs per worker in 1960 and the annualized growth rates for 1985 over 1960. As with the data displayed in Figure 2, growth rates for countries with low initial GDPs per worker are not systematically higher than those for countries with high initial GDPs. Another feature that is similar to the data in Figure 2 is the range of growth rates. For most countries, growth rates fall in the range of -1 to 3.

In Figure 27, we plot the growth rates of GDP over the subperiods 1961–1972 and 1973–1985. The correlation across subperiods is 0.78–which is significantly higher than the correlation of 0.16 in the data. As $\alpha_k + \alpha_h$ approach 1, the transition dynamics in the growth model become much slower, and the growth rates vary much less. For this reason, we find a much smaller correlation in the exogenous growth model than in the endogenous growth model.

In Figure 28, we plot the maximum growth rates in each decade for the simulation. Comparable figures for the data and the exogenous growth model are Figures 4 and 24, respectively. Notice that by 1880, there is no trend in maximum growth rates. It does not persist because the optimal investment strategy is to get the ratio of physical to human capital, k_t/h_t, back to a constant level. Once this occurs, there is little variation in the growth rates across alternative distortion levels. Therefore, we do not come close to mimicking the pattern of increasing growth rates seen in Figure 4.

When we simulate an artificial panel data set for the two-sector endogenous growth model, with $\theta_k = 0.03$ and $\theta_h = 0.97$, we find results very similar to those displayed in Figures 25–28. As in the case with $\alpha_k = \theta_k$, we find a large range in the distribution of 1989 incomes and little correlation between incomes and subsequent growth rates. Yet in both simulations, we find more persistence in growth rates than is found in the data and little agreement between maximal growth rates in the model and those in the data.

In this section, we have worked out the implications of two standard growth models for the basic facts on income described in Section 2. We went beyond what is typically done and considered both the time-series and cross-sectional aspects of the data generated by the model. For the basic facts that we consider, the exogenous growth model does a better job simultaneously accounting for the dispersion of incomes over time, the lack of persistence in growth rates, and the range in cross-country growth rates than the AK model does. However, more exploration of these models is needed before we can definitively say how well the models do in explaining cross-country income differences. What we found is that the models–despite their simplicity–do fairly well mimicking some of the basic features of the data.

7. Concluding Remarks

In this chapter, we have reviewed some of the basic facts about cross-country incomes and some studies in the recent literature on growth and development meant to explain these facts. As we have noted throughout, there are still many open issues and unanswered questions. Quantifying the role of economic policies for growth and development depends on policy variables that are difficult to measure and on models that have predictions which rely on controversial parameterizations.

What we have done in this chapter is to review the progress made thus far. Further progress can be made with better measures of factor inputs, especially human capital, better measures of policy variables, and greater synthesis of theory and data.

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TABLE 1

Income Disparity Due to Different Factor Intensities, 1985

Human Capital Measure Based On:	Physical Capital Share	Human Capital Share	Predicted Income Disparity[a]	Percentage Difference Explained[b]
Mankiw et al. (1992)	0.31	0.28	12.8	74
	1/3	1/3	33.7	102
Variation on Mankiw et al.	0.31	0.28	5.4	49
	1/3	1/3	9.9	66
	1/3	0.43	30.1	99
Klenow-Rodríguez (1997b)[c]	0.30	NA	3.4	36
Hall-Jones (1998)[c]	1/3	NA	4.0	40

[a] Income disparity is defined to be the ratio of the average income of the richest 5 percent of countries to the average income of the poorest 5 percent (where income is output per worker).

[b] The percentage difference explained is defined to be the logarithm of the predicted income disparity divided by log(31.4), which is the logarithm of the actual income disparity.

[c] NA means not applicable. No value of α_h is reported because the production function used in this study can be written as follows: $Y = K^{\alpha_k}(ALg(s))^{1-\alpha_k}$ where the function g does not depend on either capital share. Thus, the income disparity does not depend on α_h.

TABLE 2

Sources of Growth for Groups of Countries

Group	Period	Net Convergence Effect	Investment Share in Output	Government Share in Output	Black Market Premium	Revolutions Per Year	Fitted Growth	Actual Growth
14 Sub-Saharan	1965-75	-0.2	-0.6	-1.1	-0.2	-0.3	-2.3	-2.8
Africans	1975-85	0.6	-0.6	-1.0	-0.9	-0.3	-2.2	-3.9
slow growers	1985-95	1.7	-0.7	-1.1	-0.7	-0.3	-1.0	
5 Latin-	1965-75	-0.9	0.0	0.2	-0.3	-0.1	-1.1	-1.9
American	1975-85	-0.4	-0.3	-0.8	-1.0	-0.1	-2.5	-4.1
slow growers	1985-95	0.2	-0.3	-1.1	-1.6	-0.1	-2.9	
4 Sub-Saharan	1965-75	2.2	-0.4	-0.6	0.0	0.2	1.4	3.2
Africans	1975-85	1.0	0.0	-0.8	0.1	0.2	0.4	1.6
fast growers	1985-95	0.4	0.1	-0.8	0.3	0.2	0.1	
3 Latin-	1965-75	0.4	0.2	0.2	0.0	0.0	1.0	2.6
American	1975-85	-0.5	0.2	0.2	0.1	0.0	0.0	1.2
fast growers	1985-95	-0.7	0.2	0.3	0.0	0.0	-0.2	
8 East-Asian	1965-75	1.6	0.2	0.6	0.3	0.1	2.8	3.1
fast growers	1975-85	0.8	0.6	1.0	0.6	0.1	3.0	4.2
	1985-95	-0.1	0.6	1.0	0.7	0.1	2.3	
6 OECD	1965-75	0.5	0.8	0.1	0.4	0.1	2.0	1.6
fast growers	1975-85	0.5	0.5	0.1	0.5	0.1	1.7	2.5
	1985-95	-0.5	0.5	0.1	0.7	0.1	0.8	

NOTE: Each entry shows the average contribution of the indicated variable to the fitted growth rate of real per capita GDP (expressed relative to the sample mean). The contributions are averages for the designed group of countries and time period. The net convergence effect is the combined impact from the initial values of log(GDP), male and female secondary school attainment, and log(life expectancy). The fitted growth rate is the sum of the contributions shown separately. the actaul growth rate refers to the average deviation from the sample mean for the indicated grup of countries and time period.

Source: Barro and Lee (1994), Table 6.

TABLE 3A

Parameter Values for Tax Experiments in the Two-Sector Endogenous Growth Model

Parameters	King-Rebelo (1990)	Lucas (1990)	Kim (1992)	Jones et al. (1993)
	Model			
Capital shares:				
Sector 1 (α_k)	0.33	0.24	0.34	0.36
Sector 2 (θ_k)	0.33	0.0	0.34	0.17
Depreciation rates:				
Physical capital (δ_k)	0.1	0.0	0.05	0.1
Human capital (δ_h)	0.1	0.0	0.01	0.1
Preferences:				
Discount factor (β)	0.988	0.98	0.99	0.98
Share on leisure (ψ)	0.0	0.5	0.0	5.0
Risk aversion (σ)	1.0	2.0	1.94	1.5
Growth in population (n)	0.0	0.014	0.0	0.0
Technology level (B)	0.126	0.078	0.048	0.407

TABLE 3B

Steady-State Growth for a 0 Percent and 20 Percent Income Tax in the Two-Sector Endogenous Growth Model

	Model			
	King-Rebelo (1990)	Lucas (1990)	Kim (1992)	Jones et al. (1993)
Steady-state growth rate				
Tax rate = 0	2.00	2.00	2.00	2.00
Tax rate = 0.2	−0.62	1.17	1.31	−1.99
Ratio of incomes				
After 30 years	2.18	1.28	1.23	3.31
After 200 years	182	5.12	3.89	2,924

TABLE 4A

Parameter Values Used in Simulations of the Exogenous and Endogenous Growth Models

Model Components	Parameter Values
A. Exogenous Growth Model	
Production:	
$y = Ak^{\alpha_k} h^{\alpha_h}$	$A = 1,\ \alpha_k = \frac{1}{3},\ \alpha_h = \frac{1}{3}$
Evolution of capital:	
$(1+n)(1+g)k_{t+1} = (1-\delta_k)k_t + x_{kt}$	$n = 0.015,\ g = 0.014,\ \delta_k = 0.06$
$(1+n)(1+g)h_{t+1} = (1-\delta_h)h_t + x_{ht}$	$\delta_h = 0.06$
Preferences:	
$\sum_t \tilde{\beta}^t \{c_t(1-\ell_t)^\psi\}^{1-\sigma}/(1-\sigma)$	$\beta = 0.97,\ \psi = 3,\ \sigma = 2$ or 5
$\tilde{\beta} = \beta(1+g)^{1-\sigma}(1+n)$	
B. Endogenous Growth Model	
Production:	
$y = A(kv)^{\alpha_k}(h\ell u)^{\alpha_h}$	$A = 1,\ \alpha_k = \frac{1}{3},\ \alpha_h = \frac{2}{3}$
$x_h = B(k(1-v))^{\theta_k}(h\ell(1-u))^{\theta_h}$	$B = 1,\ \theta_k = \frac{1}{3},\ \theta_h = \frac{2}{3}$, or
	$\theta_k = 0.03,\ \theta_h = 0.97$
Evolution of capital:	
$(1+n)k_{t+1} = (1-\delta_k)k_t + x_{kt}$	$n = 0.015,\ \delta_k = 0.06$
$(1+n)h_{t+1} = (1-\delta_h)h_t + x_{ht}$	$\delta_h = 0.06$
Preferences:	
$\sum_t \tilde{\beta}^t \{c_t(1-\ell_t)^\psi\}^{1-\sigma}/(1-\sigma)$	$\beta = 0.97,\ \psi = 3,\ \sigma = 5$
$\tilde{\beta} = \beta(1+n)$	

TABLE 4B

Stochastic Process for Distortions Used in Simulations of the Exogenous and Endogenous Growth Models

Model Components	Parameter Values
Autoregressive Parameters:	
$(1+\tau_{x,t}) = \rho_R(1+\tau_{x,t-1})$	$\rho_P = 0.993,\ \mu_P = 1.976,\ \sigma_P = 0.074$
$+\mu_R(1-\rho_R) + \sigma_R\,\varepsilon_t,$	$\rho_T = 0.865,\ \mu_T = 2.459,\ \sigma_T = 0.789$
Switching Probability Parameters:	
$\pi_{RR'}(m) = a_R - b_R(m-1),$	$a_P = 0.244,\ b_P = -0.012$
	$a_T = 0.350,\ b_T = -0.016$

Fig. 1. GDP Per Capita, 1820-1989

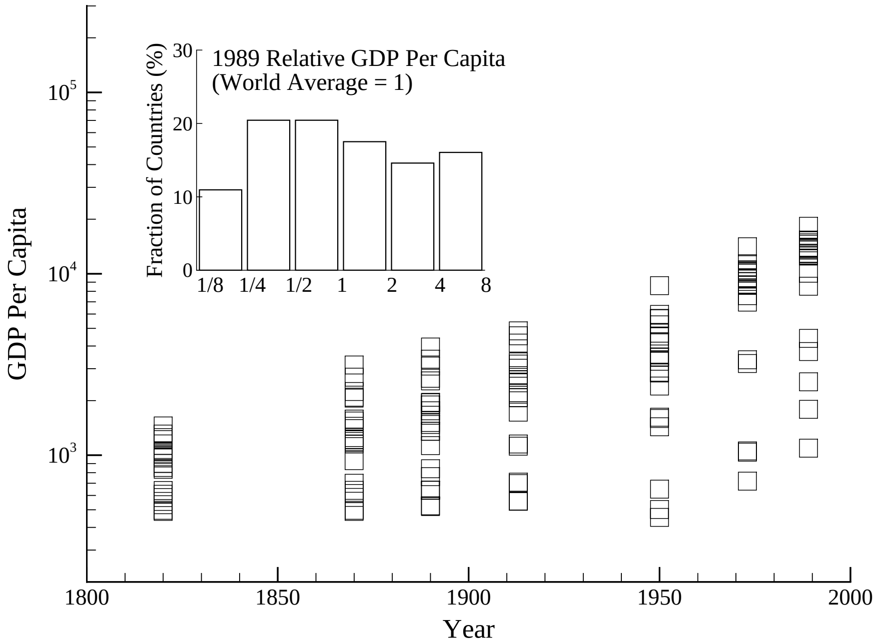


Fig. 2. Growth versus Initial GDP Per Worker, 1960-1985

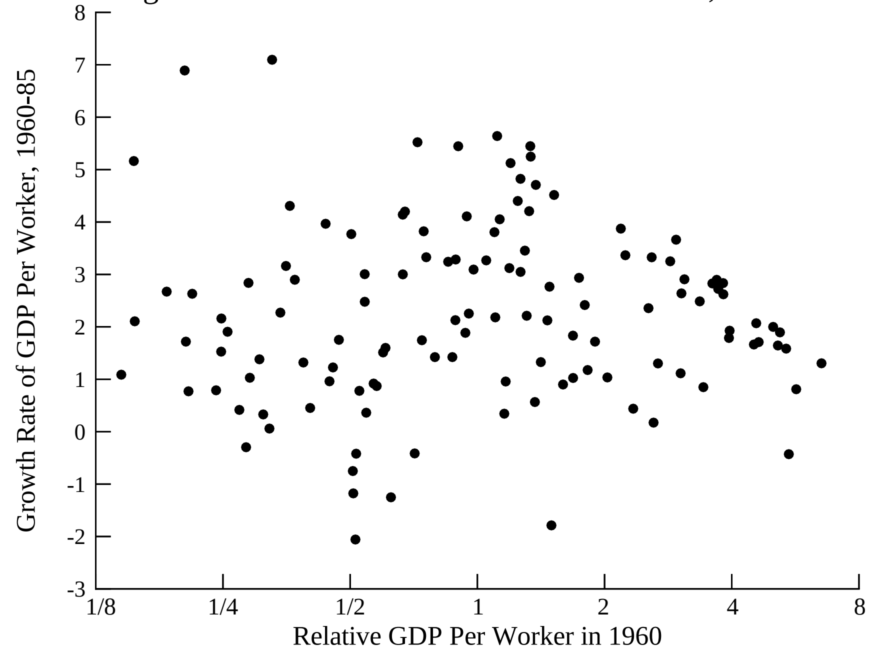


Fig. 3. Persistence of Growth Rates, 1960-1985

Fig. 4. Maximum GDP Per Capita Growth, 1870-1990

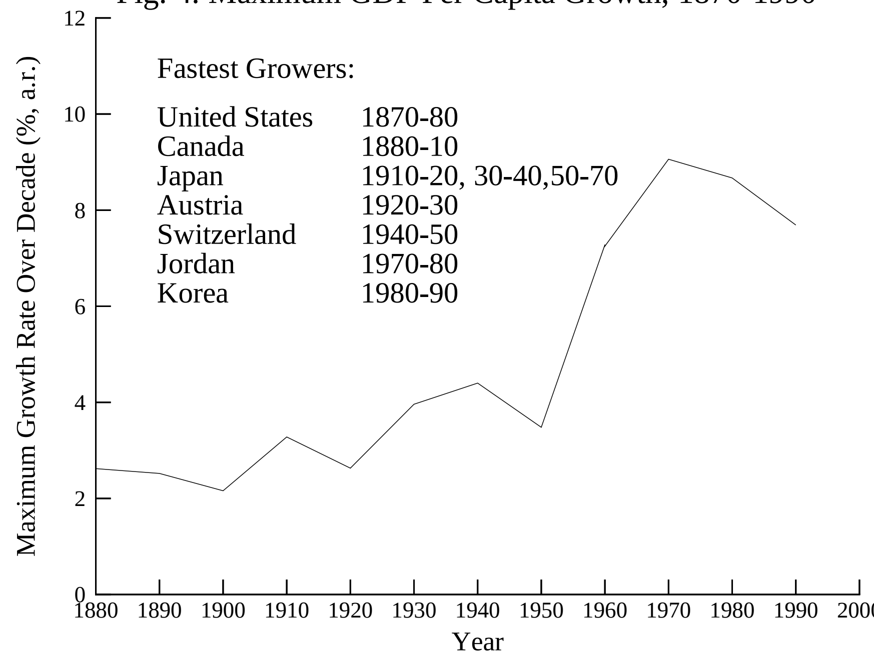


Fig. 5. Physical Capital-Output Ratio vs. Income, 1985

Fig. 6. Secondary Enrollment vs. Income, 1960-1985

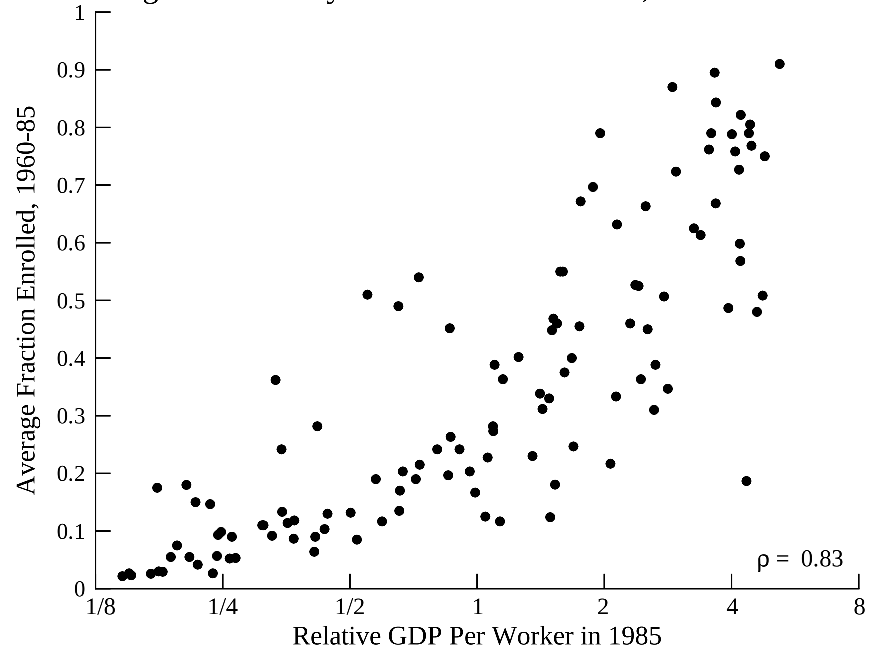


Fig. 7. Primary Enrollment vs. Income, 1960-1985

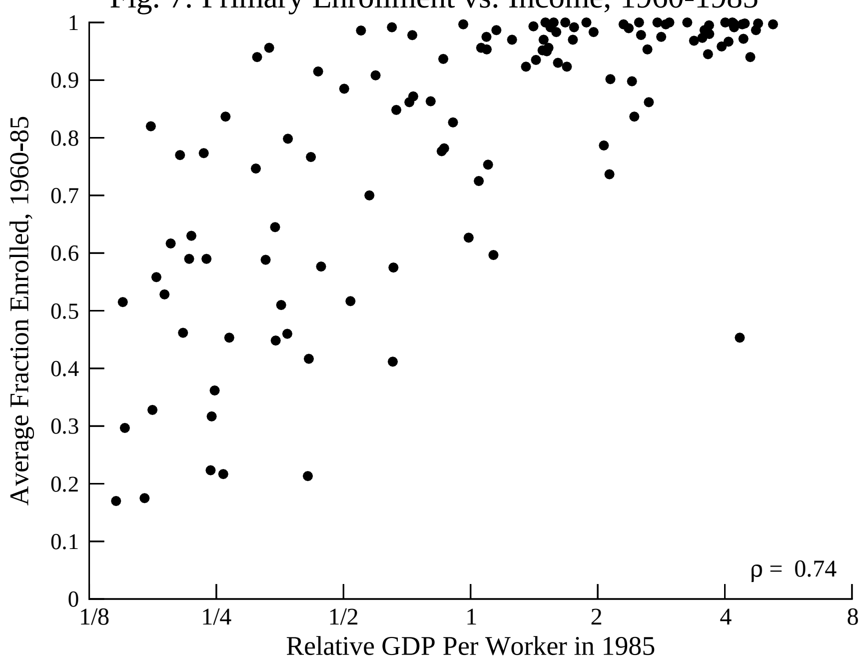


Fig. 8. Human Capital-Output Ratio vs. Income, 1985

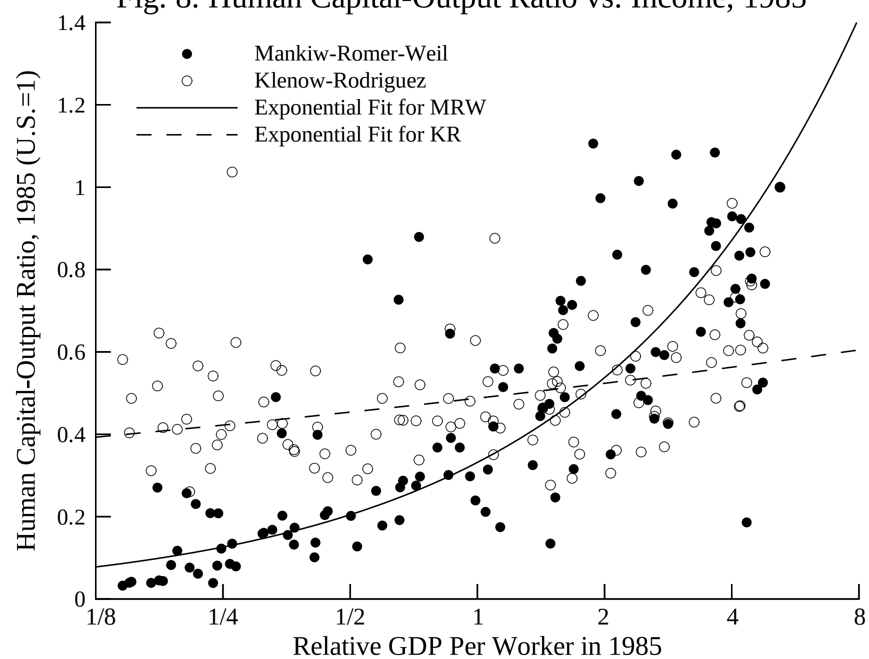


Fig. 9. Government Share vs. Income, 1965-1985

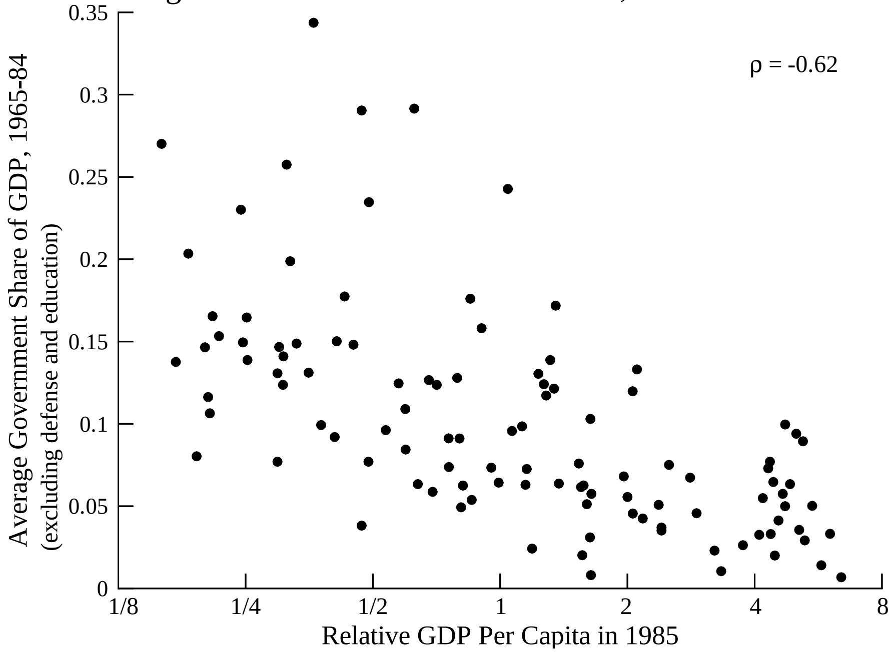


Fig. 10. Black Market Premium vs. Income, 1965-1985

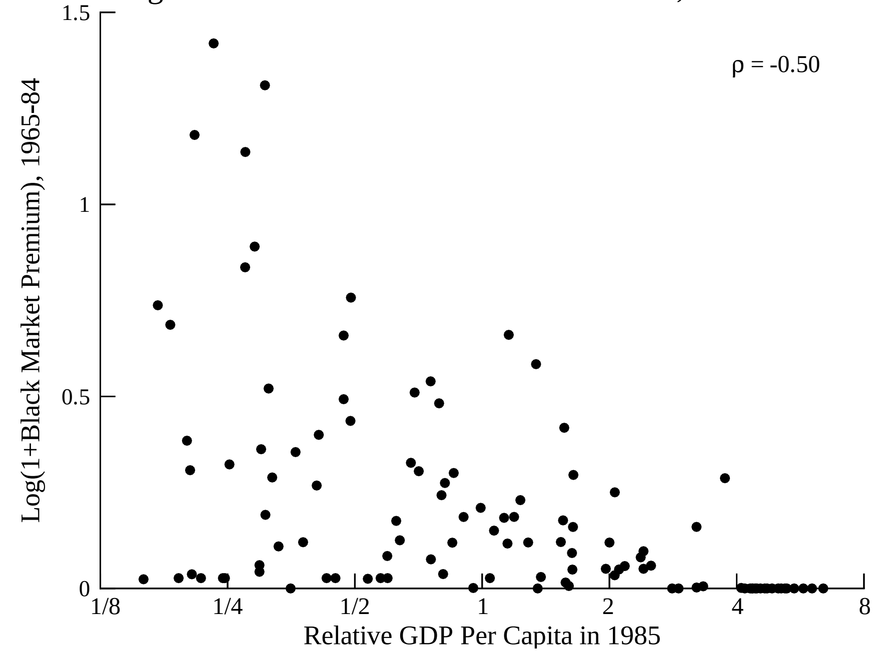


Fig. 11. Political Rights vs. Income, 1972-1985

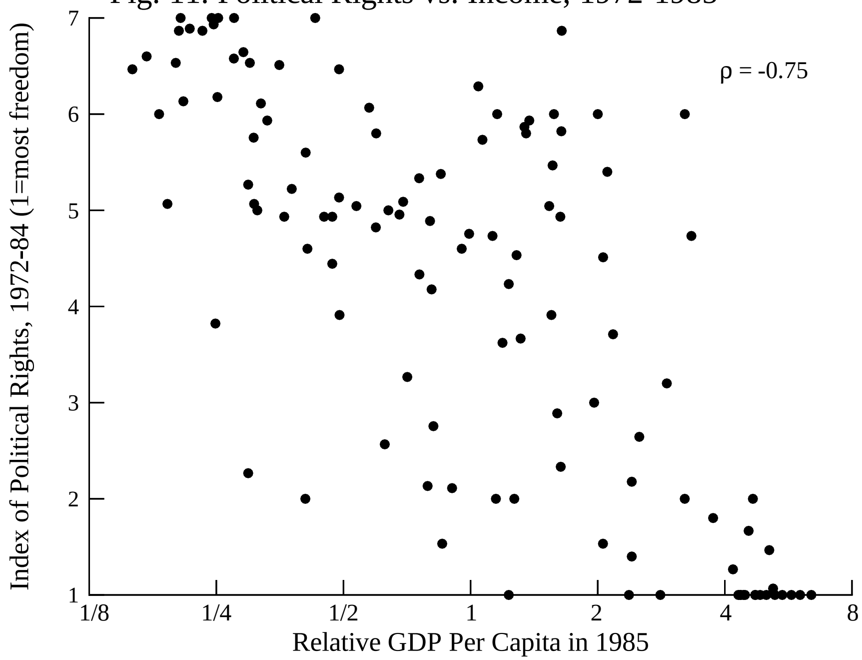


Fig. 12. Financial Development vs. Income, 1965-85

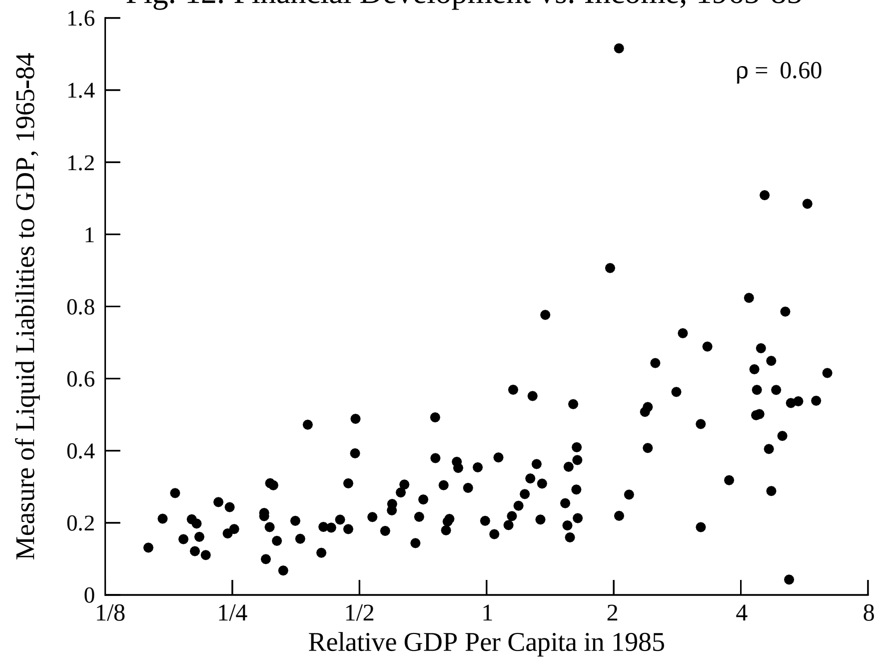


Fig. 13. Public Enterprise Share vs. Income, Various Years

Fig. 14. Relative Price of Investment vs. Income, 1985

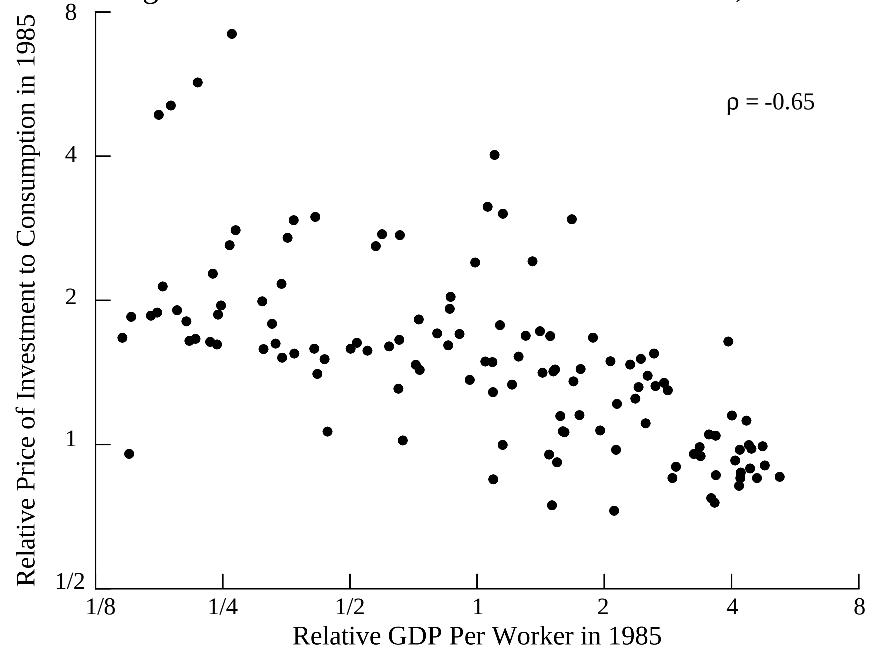


Fig. 15. Tariff Rates vs. Income, 1980

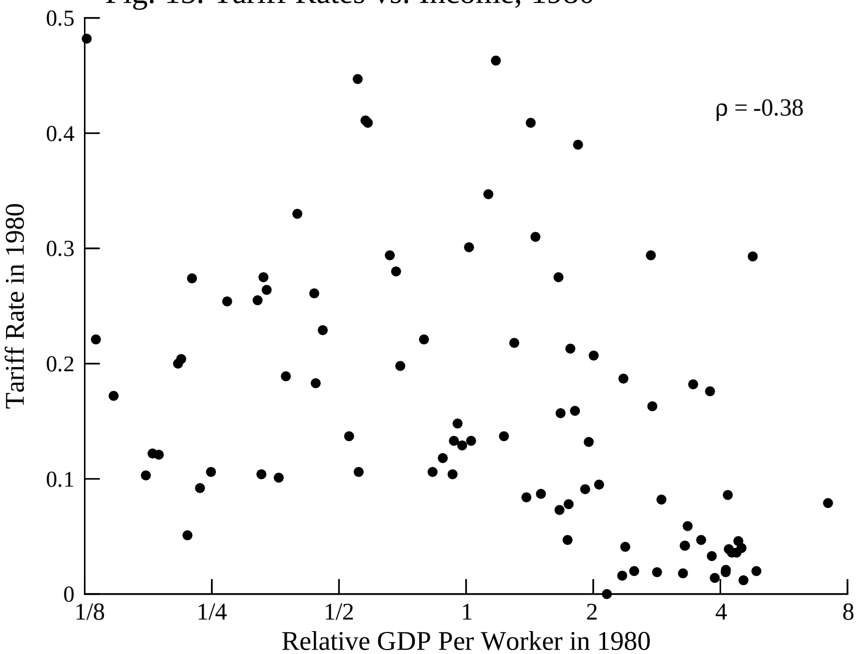
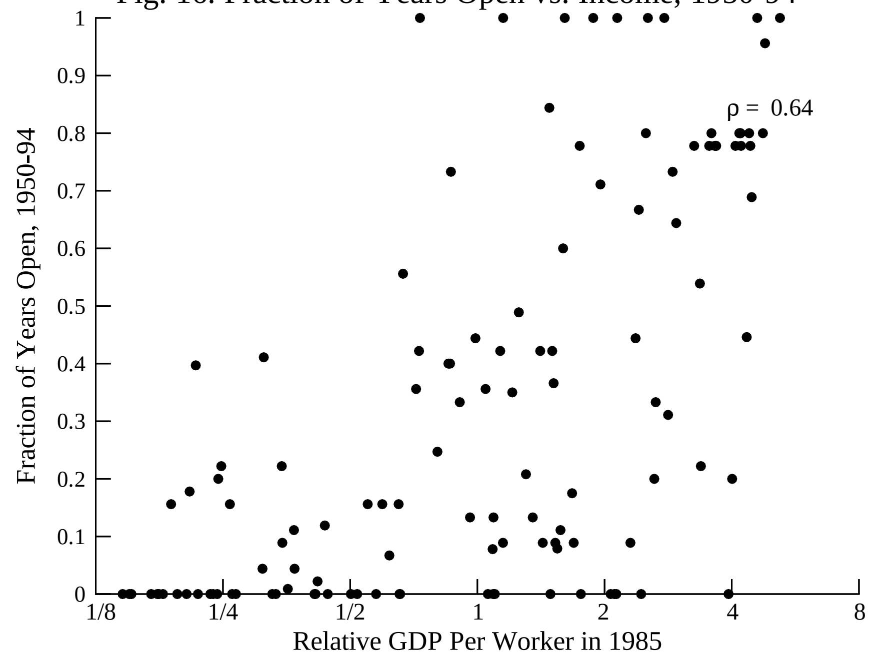


Fig. 16. Fraction of Years Open vs. Income, 1950-94



Results for Exogenous Growth Model, σ=2

Fig. 17. GDP Per Capita, 1820-1989

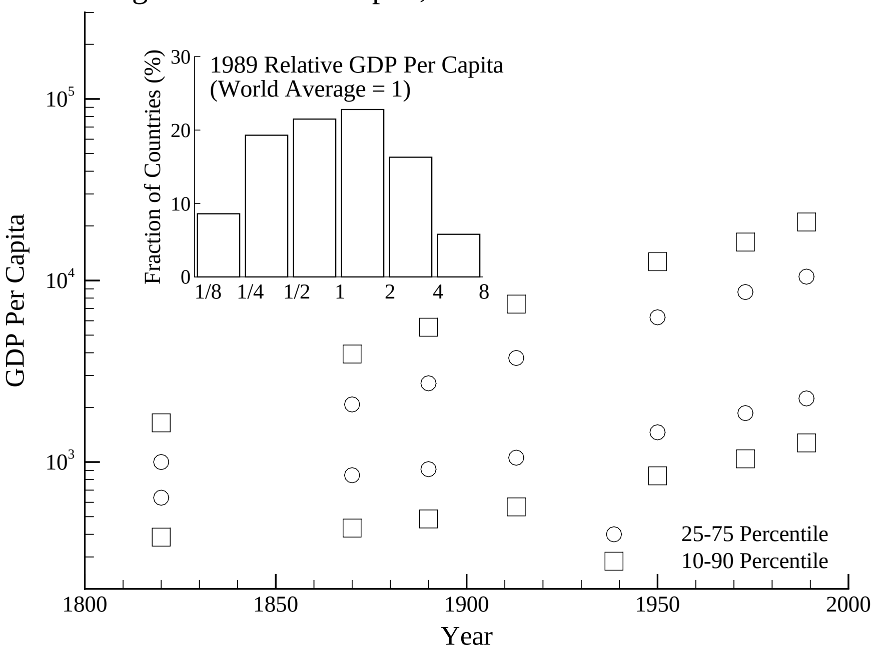


Fig. 18. Growth versus Initial GDP Per Worker, 1960-1985

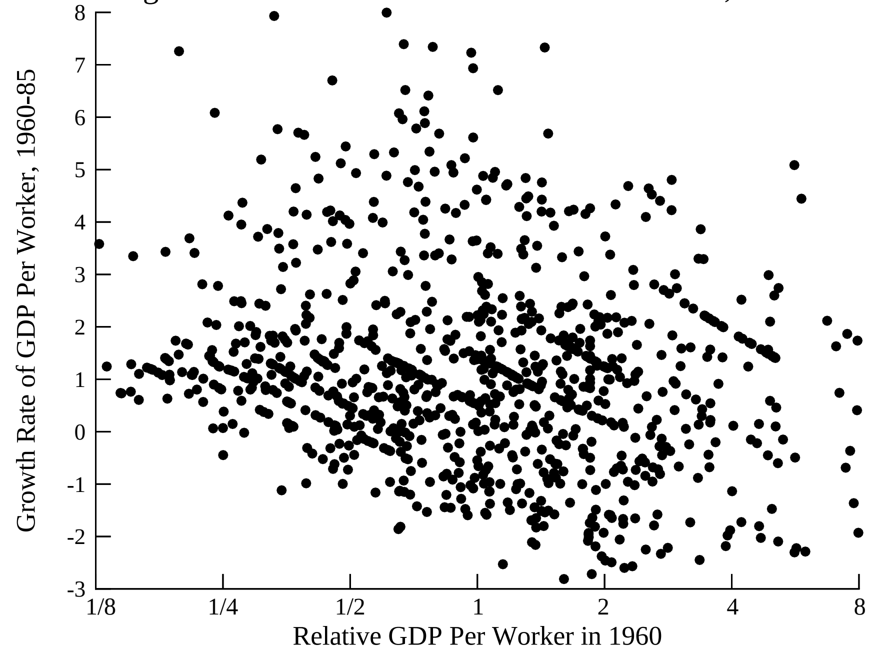


Fig. 19. Persistence of Growth Rates, 1960-1985

Fig. 20. Maximum GDP Per Capita Growth, 1870-1990

Results for Exogenous Growth Model, σ=5

Fig. 21. GDP Per Capita, 1820-1989

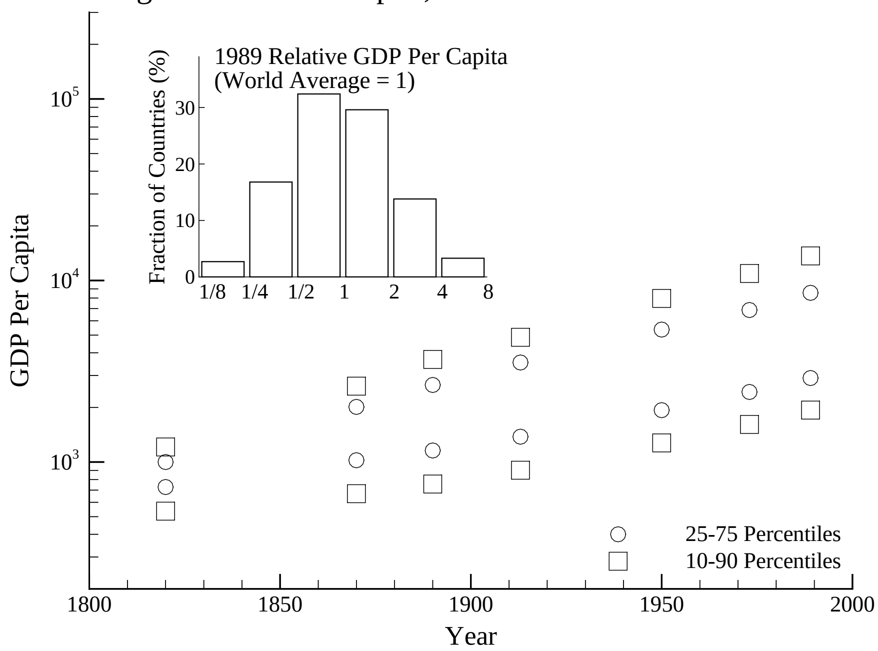


Fig. 22. Growth versus Initial GDP Per Worker, 1960-1985

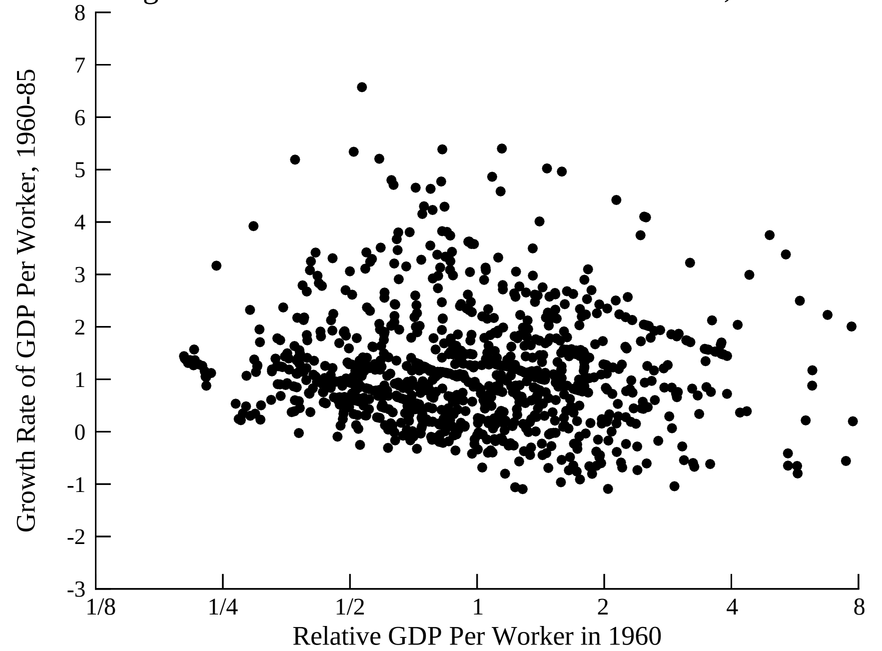


Fig. 23. Persistence of Growth Rates, 1960-1985

Fig. 24. Maximum GDP Per Capita Growth, 1870-1990

Results for Endogenous Growth Model, $\alpha_k=\theta_k$

Fig. 25. GDP Per Capita, 1820-1989

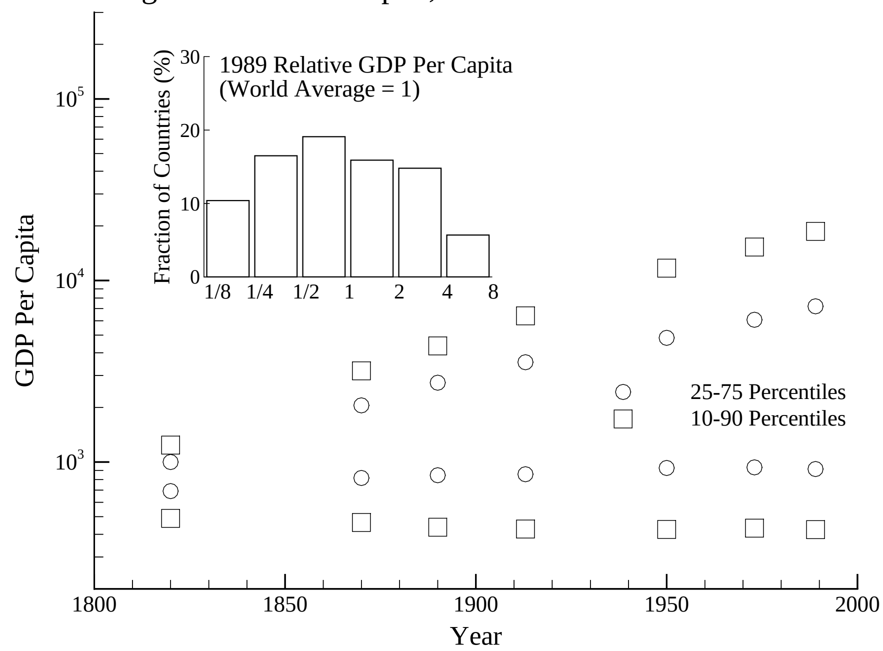


Fig. 26. Growth versus Initial GDP Per Worker, 1960-1985

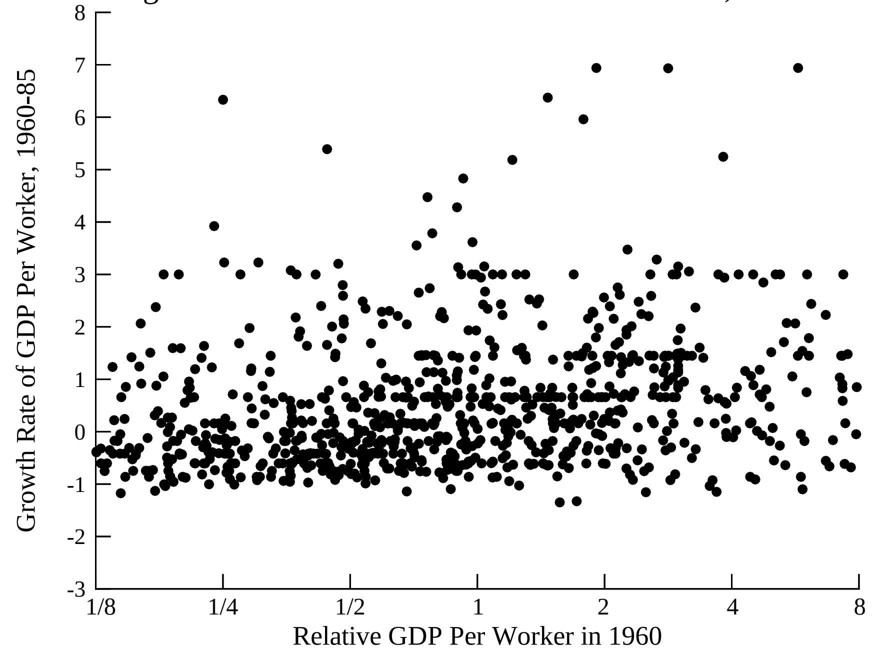


Fig. 27. Persistence of Growth Rates, 1960-1985

Fig. 28. Maximum GDP Per Capita Growth, 1870-1990