Economic Growth across the Asian Countries: an Econometric Analysis

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Abstract

The economic growth rates of the Asian countries have experienced large fluctuations both across countries and through time. Many economists (e.g. Lucas, 1988) suggest that we do not need to look to economic theory for an account of either of these fluctuations. On the other hand, the successful growth experience of the newly-industrialised South East Asian economies suggests the possibility of policy influences on long run growth rates and tends to reject the neoclassical hypothesis of convergence.

This study tests for income convergence across countries, considers an ad hoc growth regression model to identify the factors affecting long run growth rates, estimates a single country production function, and tests for endogenous growth indirectly through testing its policy implications. The results of the study show that there is no absolute convergence across structurally different economies, including our sample of Asian economies. However, all the economies, no matter how different in their structures, conditionally converge after holding constant the variables that account for their differences. Although human capital is considered as the most important factor influencing the growth rate in many endogenous growth theories, there is no empirical evidence supporting this idea either in previous studies or in this thesis.

Technological progress is endogenously determined in the Iranian economy. However, the underlying growth model (that of Kaldor) is not endogenous in the sense of having no policy implications. The empirical results from a model that nests both exogenous and endogenous growth indicate that the public capital share of GDP influences the long-run growth rate in Iran. However, the effect is negative which could be interpreted as evidence of government mismanagement of the economy.

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Introduction

Neoclassical growth theory assumes that technology is exogenous to the economic system and does not depend on the other variables in the model. Therefore, economic activities such as investment expenditures can not control technical progress. Long-run growth is independent of investment and is determined by the rate of technological progress and the rate of population growth. Since these rates are exogenous to the model, the theory provides no framework for identifying the factors that affect growth.

Solow's model includes an unexplained residual, assumed to be exponentially growing at a constant rate, which is the long-run steady state growth rate. The idea behind endogenous growth models is to try and explain this residual inside the model and endogenise the productivity. These models introduce different mechanisms of technological improvement. The first group of models are attempts to endogenise Solow's residual and explain growth without relying on time and were introduced just after Solow presented his theory. In these models, technological progress is determined by investment in physical capital. The second group has revived the issue of endogenous growth by considering other variables (e.g. physical investment rates, human capital investment rates, export shares, inward orientation, the strength of property rights, government consumption, population growth, and regulatory pressure) to explain the technological progress.

Although these models look like extensions to the Solow model, they imply a key feature, namely, that there are not diminishing returns to the factors of production that can be accumulated, so that the productivity of investment is not reduced. There have been two ways of ensuring this result. First, a group of models employ an extended measure of capital, which includes different types of capital other than physical, such as human capital or the state of knowledge. Second, another group of models assumes either (a) overall increasing returns via the introduction of increasing returns at the aggregate level but constant returns at the firm level (i.e. using Marshallian externalities) or (b) the introduction of imperfect competition, where temporary monopoly power motivates private innovations.

Another advantage of endogenous growth models is that they all entail significant supply-side policy implications. These theories consider the potential for government action through, for instance, the provision of education and infrastructures, which are directed towards activities that generate positive externalities.

However, there have been very few systematic tests of endogenous growth theory. Also there is still a big gap between the theoretical formulations and their empirical implementations (e.g. it is very difficult to find wholly satisfactory ways of measuring human capital and research and development) and they have not produced strong policy implications yet. The hypothesis of endogenous growth, i.e., constant returns to the reproducible factors, has been tested before, but the results are not strongly supportive.

An early critical appraisal of the neoclassical model of growth from Kaldor (1957) argues that it is pointless to try to distinguish between investment and technical change. He attempts to endogenise the growth rate by formulating a technical progress function that presents the growth rate as a function of changes in capital per worker. A much later study from Eltis (1971) also introduces a technical progress function in which the share of investment in income is the source of technical progress. Some other models of this kind refer to the inflow of foreign technology as a major source of technical progress. Additionally, endogenous growth models based on learning by doing argue that increases in per capita income could only be due to learning from experience (which reduces the number of workers per machine). These models exhibit increasing returns to scale (at an aggregate level), which is a result of increasing marginal productivity of the stock of knowledge. Yet other endogenous growth models are based on an explicit role for human capital. These models are attempts to endogenise the technical change through a mechanism of human capital accumulation. Technical change, in fact, arises as a side effect of investment in human capital (i.e. the process of education). Another class of endogenous growth models introduces government expenditure (on infrastructures) as the source of endogenous growth through its supply-side effects on productivity. The idea behind this class of models is that there is a positive external effect from public capital to private capital.

Testing for convergence is seen as a way of checking the validity of the neoclassical growth model. The neoclassical assumption of diminishing returns to capital implies that, other things being equal, countries with low amounts of capital are predicted to grow faster. While the finding of convergence has been generally thought of as evidence in support of Solow's growth model, the absence of convergence has been regarded as supportive of endogenous growth theories.

The presentation of the thesis is structured around seven chapters. The first briefly reviews some endogenous growth models that might be relevant in explaining the differences in growth performance of the Asian economies. It outlines the main ideas behind endogenous growth theory and reviews the results of the few available empirical tests.

The central focus of chapter 2 is the issue of convergence. The chapter begins with a review on the theoretical aspects of the neoclassical growth model and explains the convergence controversy. It then applies a panel data econometric approach in order to explain the variation in the standard of living across a selection of Asian economies. The neoclassical assumption about the steady state growth rate is then criticised and a dynamic framework is suggested in order to test the conditional convergence across the same economies.

Chapter 3 applies an ad hoc growth model based on a variety of endogenous growth models in order to identify different factors affecting long run growth rates of the above mentioned sample of countries. Chapter 4 begins with a brief look at endogenous models based on human capital and suggests a model based on both the supply-side and the demand-side of the economy, which nests both neoclassical and endogenous growth models. The model is then applied to the sample of Asian countries in order to test the importance of human capital investment in explaining growth rates.

Chapters 5 and 6 study the Iranian economic performance using a time series econometric approach in order to explain the large variations in production behaviour during the last few decades in Iran. While chapter 5 tests the endogenous growth theory directly through estimation of a production function, chapter 6 evaluates the theory through testing for the effect of economic policy variables on the growth rate. Chapter 7 summarises the theoretical and empirical conclusions and considers their implications.

Chapter 1

An Overview of Economic Growth Theories

1.1 Introduction

The neoclassical growth theory of Solow (1956) assumes that technology is exogenous to the economic system and does not depend on the other variables (such as investment) in the model. Technical progress, therefore, can not be deliberately controlled as the result of economic activities (such as investment expenses). Long run growth is also independent of investment and is determined by the rate of technological progress and the rate of population growth. Since these rates are exogenous to the model, the theory provides no framework for identifying the factors that affect growth. Therefore, 'increasing the rate of per capita growth is not only not easy in this model, it is impossible unless the rate of technological progress can be altered deliberately' (Solow 1994, p. 48). However, Romer points out that 'no economist, so far as I know, has ever been willing to make a serious defence of the proposition that technological change is literally a function of elapsed calendar time' (Romer, 1994, p. 12). The Solow model includes an unexplained residual, assumed to be exponentially growing at a constant rate, which is the long run steady state growth rate. The idea behind the endogenous growth models is to try to explain this residual inside the model and endogenise the productivity. For example, in Lucas's (1988) model (an augmented version of which is used in chapter 4 to explain the economic growth across the Asian economies), the residual is explained in terms of the growth of the quality of labour through cumulative knowledge.

This chapter briefly reviews some endogenous growth models that might be relevant in explaining the differences in growth performance of the Asian economies.[1] These models introduce different mechanisms of technological improvement. By 'model' here we mean the production function associated with each theory. The first

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[1] Barro and Sala-i-Martin (1995), among others, is one of the best surveys in this context.

group of models, i.e. the technical progress functions of Kaldor (1957) and Eltis (1971) and the learning by doing models of Arrow (1962) and Sheshinski (1967) are attempts to endogenise the Solow residual and explain growth without relying on time and were introduced just after Solow presented his theory. In these models, technological progress is determined by investment in physical capital.

The second group consists of the learning by doing model of Romer (1986), the model of human capital through schooling of Lucas (1988), and the model with government expenditures of Barro (1990). There is also another class of theories in this category, which specially deals with the recent success of the East Asian economies in reaching high growth rates for a long period of time. These theories are based upon the idea that the technology follower countries imitate technology from leaders because it is cheaper than innovation. Nelson and Pack (1999) provide the most recent version of imitation models. All the above models have revived the issue of endogenous growth using new tools and, therefore, are referred to here as new endogenous growth models.

The chapter is structured as follows: Section 1.2 briefly introduces the main ideas of the new endogenous growth theories. Section 1.3 reviews the results of the very few empirical works relevant to this study. In section 1.4 we describe the theoretical aspects of endogenous growth models and the empirical time-series framework to test them. Section 1.5 concludes the chapter.

1.2 Endogenous growth theories

Neoclassical growth theory suffers from such major deficiencies as the convergence controversy[2], the assumption that steady state depends on the exogenously given growth of population, and the use of perfect competition as a basis for modelling the growth. The new endogenous growth models address these shortages in an attempt to explain the forces behind the technological changes. Although these models look like extensions to the Solow model, they imply a new key feature; namely, that there are not diminishing returns to the factors of production that can be accumulated, so that the productivity of investment is not reduced.[3]

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[2] One of the main results of Solow's model is that countries would converge after controlling for the determinants of the steady state. The convergence issue is considered in detail in chapter 2.

[3] The main two features of the neoclassical growth theory are diminishing returns to both capital and labour and constant returns to all factors.

There have been two ways of exhibiting a non-reducible productivity of investment. First, a group of models employ an extended measure of capital, which includes different types of capital other than physical, such as human capital or the state of knowledge (Lucas 1988). The *AK* model of Rebelo (1991) is the simplest endogenous growth model, which employs a broad concept of physical and human capital. This model exhibits both overall constant returns to scale and constant returns to capital and generates a perpetual growth of per capita GDP because a constant return of investment can result in an ever growing capital stock. Therefore, in order to generate growth, the saving rate should be increased.

Second, another group of models assumes overall increasing returns. However, such an assumption would inevitably result to the problem of not finding a set of prices to support a general competitive equilibrium. In order to solve this problem, two methods have been used. The first one is to introduce increasing returns at the aggregate level but constant returns at the firm level (i.e. using Marshallian externalities) so that perfect competition can be achieved. The models of production externalities and spillovers of Romer (1986) and Lucas (1988, 1993) deal with this method. The idea behind these models is that raising the level of knowledge in the society has external benefits on the total productivity of the economy. Growth is generated via constant returns in all inputs that can be accumulated. The decision made by each individual firm affects the output of all other firms, but none of them takes this into account. Hence, the economy as a whole faces a production function with increasing returns to scale. In other words, there are constant returns to scale at micro level and increasing returns to scale at macro level. These models have, in fact, extended the neoclassical theory to account for production externalities that arise as consequence of human capital accumulation or learning by doing. The second method is to introduce imperfect competition. Romer (1990) assumes that technological progress is an output from a separate technology sector (R&D) that supplies the other sectors with new technologies. In these models, temporary monopoly power motivates private innovations. Under an imperfect competition framework, input shares do not exhaust output and there are rents that can be rewarded to activities that are not directly productive but that contribute to growth such as R&D. This method is a very important contribution to growth theory because the assumption of perfect competition is no longer valid in the real world and the role of competitive markets and the conclusion of ‘laissez faire’ is no longer valid. Some models, such as Aghion and Howitt (1992) introduce both imperfect competition and externalities at the same time.

The most important feature of all these models is that they generate endogenous growth based on constant returns to scale in all inputs that can be accumulated. The most relevant models to an empirical study of the Asian economies (especially the newly industrialised ones) are those with externalities and spillovers. As stern (1991, p. 127) comments, the problem with the last group of models (so-called R&D models) is that 'it is extremely difficult to identify anything approximating to a knowledge-producing sector in real economies. R&D activity, for example, is poorly defined, difficult to interpret and in many cases in practice probably contains little real research in the sense of the 'ideas' in the model'.

One important positive aspect of the models we are looking at is that they entail significant supply-side policy implications. For example, a rise in the ratio of investment to GDP through public expenditure would imply an increase in the growth rate in the short run both in the neoclassical and in the endogenous growth models. However, in the long run, the neoclassical theory would exhibit a return to the long run steady state growth, while the endogenous growth theory would predict a permanent increase in the growth rate. Another advantage of these endogenous growth theories is that they consider the potential for government action through, for instance, the provision of education and infrastructures, which are directed towards activities that generate positive externalities (i.e. investment in health and education) and generate increasing returns (i.e. improvements in physical infrastructures).

However, despite their theoretical advances, these new endogenous growth models have important shortcomings, especially from an empirical point of view.[4] The main shortcoming stems from the differences between these models and Solow's (and some of the early endogenous growth models). While both Solow and the initial endogenous growth models led to the conclusion that the long run rate of growth could not be affected by policy (except the model of Eltis), the new models allow the economy to reach a sustainable growth, and the growth rate could be modified by appropriate policy interventions. In this sense, it is important to clarify what we mean by endogenous growth. The term endogenous growth refers to a mechanism where growth is persistent and the growth rate is determined within the model (i.e. it

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[4] See Pack (1994).

depends on the other parameters of the model). This internal mechanism is usually explained by the public good feature of technological progress. However, even if all this is clear from a theoretical aspect, the empirical implementation of these models for testing purposes is not. The issue is how to test these models. Do we test their premises, or their predictions e.g. divergence? Is a single equation model, the production function, appropriate for empirical purposes? And taking into account our sample of Asian economies, most of which are developing economies, is the neoclassical framework upon which these models are constructed the correct structure? Also it is generally suggested that all types of investment, physical, human and intellectual, are important to growth and countries invest in all types simultaneously. The problem of interrelationships between these variables makes the analysis of their impact a difficult job. On the other hand, further research work is required to make these new models useful for policy guidance for the most underdeveloped countries because these models have received their idea from countries, which have already developed.

1.3 Empirical studies

Writing in 1994, Pack emphasises the scarcity of empirical papers testing directly the endogenous growth models. In his words, 'There have been very few systematic tests of endogenous growth theory. Most of the empirical work motivated by endogenous growth theory has actually tested implications of the Solow-style neoclassical growth model rather than endogenous growth theory itself' (Pack 1994, p. 58). Some authors have argued that these new models of endogenous growth can not fully explain what the original neoclassical model left unexplained, i.e. the 'Solow residual'. Also there is still a big gap between the theoretical formulations and their empirical implementations (i.e. it is very difficult to measure correctly human capital and research and development) and they have not produced strong policy implications yet, since their advice is too general and too macroeconomic. In reference to the Asian new industrialised countries, Pack comments " ... models that posit externalities from physical or human capital can not account for the extraordinary GDP growth rates unless such externalities are very strong, so that α (the elasticity of output with respect to capital) is indeed close to unity [...]. In one set of endogenous growth models, such externalities arise from improved designs in the domestic machinery-producing sector. But for much of the period of rapid growth, these countries imported a very large percentage of their machinery. There is little theoretical basis for arguing that externalities ... are generated by the use of foreign-produced equipment' (Pack 1994, p. 61).

The hypothesis of endogenous growth, i.e., constant returns to the reproducible factors, has been tested before, but mainly for developed countries. Crafts (1992) mentions a study by Englander and Mittelstadt (1988) which applied Romer's (1986) model to the OECD countries with cross-section data and found an exponent on capital of only 0.4 to 0.5, far from 1. Benhabib and Jovanovic (1991), on the other hand, regressed output on capital and labour in levels and obtained a value of 1.06 (statistically equal to 1) for the U.S. post-war period.

However, the above papers used traditional OLS regressions without testing for the existence of a unit root in the series. For instance, Benhabib and Jovanovic (1991) report Durbin-Watson statistics of 0.6 and 0.78 in Tables 7 and 8, respectively. This could result to the problem of spurious regressions and makes inference invalid (since *t*-ratios are not *t*-distributed).

Finally, there is another class of tests concerning the prediction of convergence. One of the main implications of Solow's model is that countries' growth rates would converge after controlling for the determinants of the steady-state (conditional convergence). Therefore, one way to test the endogenous growth model is to test for convergence in a cross-country regression where the growth of per capita GDP depends on the initial GDP per capita, plus other variables such as the share of investment and education. Convergence would be confirmed if the estimated coefficient on the initial per capita GDP has a negative sign. A positive sign, therefore, is taken as evidence supporting divergence and the endogenous growth models. The general result found is that there seems to have been convergence among developed countries (i.e. OECD) but not among a broad sample of countries including both developed and developing ones (Baumol 1986, De Long 1988, Barro and Sala-i-Martin 1992, and Mankiw, Romer and Weil 1992). However, 'even when conditional convergence does not occur as measured in these regressions, it does not prove that the endogenous growth theory (in whatever form) is true, nor does it necessarily invalidate the Solow model' (Pack 1994, p. 65). The convergence context is studied in detail in Chapter 2.

1.4 The growth models

1.4.1 Technical progress function

Capital accumulation technical progress function

Kaldor (1957) introduces the idea that technological progress is determined by the act of investment and that new fixed capital is the carrier of technical change. In his words, 'the use of more capital per worker inevitably entails the introduction of superior techniques which require inventiveness of some kind [...]. It may be assumed that some increases in productivity would take place even if capital per man remained constant over time, since there are always some innovations, which enable production to be increased without additional investment. But beyond these the growth in productivity will depend on the rate of growth in the capital stock' (Kaldor 1957, pp. 595-6). Criticising the neoclassical model of growth, Kaldor argued that it is pointless and artificial to try to distinguish either between investment and technical change or between shifts in the production function and shifts along it.

Thus, he formulates a *technical progress function* that presents the relationship between the growth of labour productivity (i.e. output per worker), g_y, and the growth of capital per worker, g_k, namely

$$(1.1) \quad g_y = F(g_k)$$

with $F'>0$, $F''<0$ and $F(0)>0$ (i.e. the production function is concave and shows decreasing returns to capital per worker), but F does not depend on the investment to output ratio[5]. The previous relationship simply says that the rate of growth of labour productivity is faster the faster the rate of growth of capital per worker. It is important to note that although Kaldor viewed this expression as a production relationship, he did not have a neoclassical production function in mind. Moreover, this expression is not derived from any structural relationship. However, the technical progress function can be obtained easily from a Cobb-Douglas production function. Here we consider a linear relation, an assumption that is true in steady state. However, unlike Kaldor, we do not assume that a part of the technical progress can be exogenous, since this would lead us to include the time trend in the regression equation, which results in serious statistical problems.

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[5] Kaldor's model contains two more relations, a saving function and an investment function. For our purposes, however, the relevant relationship is the technical progress function.

The procedure of including a time trend in the production function regression in levels to account for technological progress (as is done in the original neoclassical production function) may cause problems of spurious de-trending. The reason is that the time trend is included in the production function to account for technical progress; however, from a statistical point of view, what this does is to de-trend the series assuming that the variables in the production function are trend stationary or deterministic trends. If the variables (output and inputs) are difference stationary (i.e. contain a unit root) or stochastic trend, the procedure will be spurious and it is very likely that the time trend, which by definition is I(0), is highly significant even in the absence of technological progress. Therefore, this trend variable is spurious and merely reflects common trends in the data. *If*, on the other hand, the variables included in production function are trend stationary, the correct method is to estimate the equation in levels allowing for a time trend to correctly de-trend the data even if there is no technological progress. All this means that the neoclassical model with technology proxied by a time trend is an incorrect statistical framework to analyse growth.

According to the above technical progress function, the rate of technical progress is

$$(1.2) \quad \delta = \mu . g_k$$

This model displays the paradoxical feature that the steady state rate of productivity growth does not depend on the ratio of investment to output (which is central to the original neoclassical model), but only on the parameters of the technical progress function. The linear form of the production relationship is

$$(1.3) \quad g_y = \alpha + \mu \cdot g_k$$

In steady state, under the assumption of a constant working population (and full employment), the growth rate of output per worker equals the growth rate of the stock of capital per worker, i.e. $g_y = g_k = g$, so that

$$(1.4) \quad g = \frac{\alpha}{1 - \mu}$$

that is, a constant.[6] For this reason, even though growth arises endogenously in Kaldor's technical progress function, the model is not truly an endogenous growth model because the neoclassical theory of growth refers to the same idea.

For empirical purposes, one could use a dynamic and extended version of Kaldor's technical progress function. Here, we include the (varying) working population as an explanatory variable. In this case, α in (1.3) represents the exogenous rate of the growth of population.

Consider the following Cobb-Douglas production function

$$(1.5) \quad Y_t = AK_t^{\theta_1} L_t^{\theta_2}$$

with K and L as physical capital stock and labour force, respectively. Since Y, K and L are not always in equilibrium, it is not possible to observe their long run relationship directly from this production function. All we can see (Considering two lags) is the disequilibrium relationship (all lowercase variables refer to natural logarithms)

$$(1.6) \quad y_t = a_0 + \alpha_1 y_{t-1} + \alpha_2 y_{t-2} + \beta_0 k_t + \beta_1 k_{t-1} + \beta_2 k_{t-2} + \gamma_0 l_t + \gamma_1 l_{t-1} + \gamma_2 l_{t-2} + u_t$$

which reduces to (1.5) whenever equilibrium happens. The corresponding Error Correction Model (ECM) is

$$(1.7) \quad \Delta y_t^w = \alpha_0^* + \alpha_1^* \Delta y_{t-1} + \beta_0^* \Delta k_t^w + \beta_1^* \Delta k_{t-1} + \gamma_0^* \Delta l_t + \gamma_1^* \Delta l_{t-1}$$
$$- \lambda_0 y_{t-1} + \lambda_1 k_{t-1} + \lambda_2 l_{t-1} + \varepsilon_t$$

where y_t^w and k_t^w are output and capital per labour and defined as $y_t^w = \ln(Y/L)$ and $k_t^w = \ln(K/L)$, $\alpha_1^* = -\alpha_2$, $\beta_0^* = \beta_0$, $\beta_1^* = -\beta_2$ $\gamma_0^* = \beta_0 + \gamma_0 - 1$, $\gamma_1^* = -\gamma_2$, $\lambda_0 = 1 - \alpha_1 - \alpha_2$, $\lambda_1 = \beta_0 + \beta_1 + \beta_2$, and $\lambda_2 = \gamma_0 + \gamma_1 + \gamma_2$. The second term of the right hand side represents Kaldor's technical progress function, which is now nested in our dynamic form. The interesting feature of this type of formulation is that it allows us to analyse the production relationships within a different environment from the one used when the production function is estimated in pure levels or first differences. As a result, it is compatible with both of the neoclassical production

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[6] See Kaldor (1957)

function and the Kaldor's technological progress function. Equation (1.7) could be rearranged as

$$(1.8)\quad \Delta y_t^w = c + \beta_0 \Delta k_t^w + (\beta_0 + \gamma_0 - 1)\Delta l_t - \alpha_2 \Delta y_{t-1} - \beta_2 \Delta k_{t-1} - \gamma_2 \Delta l_{t-1}$$

$$- (1 - \alpha_1 - \alpha_2)\left[y_{t-1} - \theta_1 k_{t-1} - \theta_2 l_{t-1}\right] + \varepsilon_t$$

where $\theta_1 = \dfrac{\beta_0 + \beta_1 + \beta_2}{1 - \alpha_1 - \alpha_2} = \dfrac{\lambda_1}{\lambda_0}$ and $\theta_2 = \dfrac{\gamma_0 + \gamma_1 + \gamma_2}{1 - \alpha_1 - \alpha_2} = \dfrac{\lambda_2}{\lambda_0}$ are the long run elasticities of output with respect to capital and labour.

This expression is an Error Correction Model (ECM). The dynamic stability condition requires $\alpha_1+\alpha_2<1$. The terms in differences reflect short run dynamics and the terms in levels constitute the long run production function. When there is no stochastic shock and values of all variables are constant (i.e. a static equilibrium), the long run production function is

$$(1.9)\quad y = c + \theta_1 k + \theta_2 l$$

or taking anti logs

$$(1.10)\quad Y = AK^{\theta_1} L^{\theta_2}.$$

A test for constant returns to scale to capital and labour could be carried by testing

$$H_0 : \theta_1 + \theta_2 = 1 \qquad \text{or} \qquad H_0 : -\lambda_0 + \lambda_1 + \lambda_2 = 0$$

If H_0 is not rejected, it is imposed on (1.7) by replacing the three terms

$$(\alpha_1 + \alpha_2 - 1)y_{t-1} + (\beta_0 + \beta_1 + \beta_2)k_{t-1} + (\gamma_0 + \gamma_1 + \gamma_2)l_{t-1}$$

with $\lambda_0 (y_{t-1} - l_{t-1}) + \lambda_1 (k_{t-1} - l_{t-1})$.

If the null hypothesis

$$H_0 : \gamma_0^* = \alpha_1^* = \beta_1^* = \gamma_1^* = \lambda_0 = \lambda_1 = \lambda_2 = 0$$

is not rejected, then (1.7) implies Kaldor's static technical progress function. Note that this implies $\alpha_1+\alpha_2=1$ so that the stability condition does not hold and the long run solution in (1.9) does not exist.

The investment technical progress function

Unlike Kaldor's model, Eltis (1971) sees the *share* of investment in income as the main factor determining the rate of technological progress

(1.11) $\delta = \mu(I/Y) \qquad \mu > 0$

where δ is the rate of technical progress and (I/Y) is the share of investment in income. The idea behind Eltis's technical progress function concerns research and development (R&D) and learning by doing (LBD). With respect to R&D, Eltis assumed that a faster rate of investment involves a higher amount of R&D, which is expected to accelerate productivity growth. He assumed an upward sloping and convex relationship between the annual expenditure on research and development (R) and the annual rate of cost reduction ω (i.e. $dR/d\omega > 0$ and $d^2R/d\omega^2 > 0$). The reason for a positive slope is that 'the cost of a new development will increase if the time span within which it must be completed is contracted beyond a certain point' (Eltis 1971, p. 505). Also $R(0)>0$, reflecting the fact that there is a setup cost associated to R. For these reasons, the average rate of technical progress will depend on the share of investment.

The other side of Eltis's technical progress coin is learning by doing. He assumes that a higher rate of investment results in a faster technical progress through LBD. Each new higher level of productivity, which is reached after learning more about new methods of production and new products, will make the next advance possible.

Eltis indicated that the element of μ which is stemming from R&D is much smaller for less advanced economies than for technological leading economies. On the other hand, given their highly effective R&D, there is no reason for leaders to have a stronger learning by doing function (the LBD component of μ) than the less advanced economies. However, overall, 'the advanced economies should have a higher μ than developing economies' (Eltis 1971, p. 521).

The main difference between this model and those of Kaldor and Arrow (mentioned later in this chapter) is that in this model, the equilibrium growth rate can be affected by investment activities. Eltis clearly distinguishes between his technical progress function and that of Kaldor and points out that, whether the growth rate of productivity depends on I/Y or k (Kaldor's case) makes an important difference. The economy's equilibrium growth rate (g) is

$$(1.12)\quad g_y = \alpha + \mu(\frac{I}{Y})$$

implying that economies with different investment shares will have different equilibrium growth rates.

The effects of foreign technology

An interesting aspect is the inclusion of the foreign technology effect in Eltis's formulation. The inflow of foreign technology has been a major source of technological progress in the set of developing countries of Asia. Therefore, trying to quantify its effect on productivity growth is essential. The previous theoretical research on technological diffusion includes Nelson and Phelps (1966), Krugman (1979), Grossman and Helpman (1991, chs. 11 and 12), and Segerstrom (1991). These studies are concerned with both *innovative* activities of leaders and *imitative* activities of followers. Most of the Asian economies of our interest, however, are involved with imitative rather than innovative technological activities. These countries import technology from the leading countries during the early stages of development until they are ready to get involved in their own innovative activities. The key role of this technology will be to help the country to produce more efficiently, to establish better production facilities and to produce what can be imported from abroad while developing local capabilities.

The Eltis's extended technical progress function based on the above idea is

$$(1.13)\quad \delta = \mu(I/Y) + \phi TT$$

where TT accounts for the effects of foreign technology. One way of incorporating the effects of foreign technology in the production function is to assume that its source is the amount of imports of machinery, which can be converted into a net stock of technology through a perpetual inventory process, assuming a given depreciation rate.[7]

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[7] Note, however, that the capital stock variable that appears in the production function would be the one adjusted by the proportion of recently imported machinery, related to the capital stock.

Now the disequilibrium relationship, incorporating both Kaldor's and Eltis's progress functions (including the effect of foreign technology) becomes

$$(1.14)\quad y_t = a_0 + \alpha_1 y_{t-1} + \alpha_2 y_{t-2} + \beta_0 k_t + \beta_1 k_{t-1} + \beta_2 k_{t-2} + \gamma_0 l_t + \gamma_1 l_{t-1} + \gamma_2 l_{t-2}$$

$$+ \sigma_0 i_t + \sigma_1 i_{t-1} + \sigma_2 i_{t-2} + \tau_0 tt_t + \tau_1 tt_{t-1} + \tau_2 tt_{t-2} + u_t$$

where $i_t = \ln(I/Y)_t$ and $tt_t = \ln(TT)_t$, with the following ECM

$$(1.15)\quad \Delta y_t^w = \alpha_0^* + \alpha_1^* \Delta y_{t-1} + \beta_0^* \Delta k_t^w + \beta_1^* \Delta k_{t-1} + \gamma_0^* \Delta l_t + \gamma_1^* \Delta l_{t-1}$$

$$+ \sigma_0^* \Delta i_t + \sigma_1^* \Delta i_{t-1} + \tau_0^* \Delta tt_t + \tau_1^* \Delta tt_{t-1}$$

$$- \lambda_0 y_{t-1} + \lambda_1 k_{t-1} + \lambda_2 l_{t-1} + \lambda_3 i_{t-1} + \lambda_4 tt_{t-1} + \varepsilon_t$$

where $\sigma_0^* = \sigma_0$, $\sigma_1^* = -\sigma_2$, $\tau_0^* = \tau_0$, $\tau_1^* = -\tau_2$, $\lambda_3 = \sigma_0 + \sigma_1 + \sigma_2$, $\lambda_4 = \tau_0 + \tau_1 + \tau_2$, and the rest are defined as in (1.7). The augmented long run production function is now

$$(1.16)\quad Y = AK^{\theta_1} L^{\theta_2} \left(\frac{I}{Y}\right)^{\theta_3} (TT)^{\theta_4}$$

where $\theta_3 = \dfrac{\sigma_0 + \sigma_1 + \sigma_2}{1 - \alpha_1 - \alpha_2} = \dfrac{\lambda_3}{\lambda_0}$, $\theta_4 = \dfrac{\tau_0 + \tau_1 + \tau_2}{1 - \alpha_1 - \alpha_2} = \dfrac{\lambda_4}{\lambda_0}$ and θ_1 and θ_2 are as defined in (1.8). Note that the Kaldorian term (the growth of the capital-output ratio) does not appear in this formulation although it would appear in the associated ECM; hence, this term only has a short run effect, while the investment share and foreign technology appear as long run determinants.

1.4.2 Learning by doing

Learning by doing in the manufacturing sector

Arrow introduced a model in which learning is the product of increased experience. He argues that increases in per capita income could not simply result from increases in the capital-output ratio. In order to support his idea, he refers to 'Horndal iron' works in Sweden where, without new investment for 15 years and, therefore, no significant changes in the production methods, labour productivity increased at an average rate of 2 percent a year (Arrow 1962, p. 156). He believes that this increase could only be due to learning from experience. He formulated a model in which the number of labour required per-machine declines. This decline, he argues, does not depend on time as in the Solow model, but on cumulative gross investment, G, which occurs from the beginning of time

$$(1.17)\quad G(t) = \int_{-\infty}^{t} I(v) \cdot d(v)$$

where I denotes investment. He argues that total output probably is not a good proxy for Learning by Doing (LBD) because this measure grows even in an economy with no learning. Therefore, he incorporates the idea of LBD by the assumption that the labour efficiency index of workers is a strictly increasing function of cumulative gross investment; that is, technological progress is viewed as a side effect of investment in capital. Algebraically

$$(1.18)\quad A_t = A_0 \cdot G_t^{\mu} \qquad 0 \leq \mu \leq 1$$

where A_t is the level of technology at time t, A_0 is the initial level of technology, G is the index of learning ($dG/dt \geq 0$ since G is a cumulative variable) and μ is the learning coefficient. It means that learning is a result of the dynamic externalities of cumulated gross investment. The above formulation is suggested by Arrow as an alternative to Kaldor's technical progress function. However, one unrealistic feature of this model (as well as its new version by Romer) is the assumption of a continued learning at a given rate in a fixed set of goods; In fact, learning declines over time when product does not change (unless workers and managers undertake new tasks)

Assuming the Hicks-neutral technical progress

$$(1.19)\quad Y_t = A(G_t) \cdot F(K_t, L_t)$$

and substituting the productivity function A_t gives

$$(1.20)\quad Y_t = A_0 \cdot G_t^{\mu} \cdot F(K_t, L_t)$$

Finally, assuming that F is a Cobb-Douglas production function, we have

$$(1.21)\quad Y_t = A_0 K_t^{\beta} L_t^{\gamma} G_t^{\mu}$$

The steady-state rate of growth of output, g, with full employment and labour force growing at g_l is (refer to footnote 6 for proof)

$$(1.22)\quad g = \frac{g_l}{1-\mu}$$

which means that an economy with a static labour force could not grow in the long run. Therefore, although this model treats growth endogenously, the steady-state growth rate is determined by the exogenous growth of the labour force. As in Kaldor's model, this conclusion is not what the endogenous growth theory is seeking because the growth rate is not affected by economic policy. Although doubling investment would double technical progress, the only possible steady-state growth rate depends on the growth rate of the labour force and on the learning coefficient μ, which is not affected by investment.

Empirically, in order to measure G_t one could use the cumulated output in the economy (from the beginning of the time series available) as a proxy variable.

Learning by doing as the source of endogenous growth

Arrow's model has been revived by Romer (1986) applying new tools and solving some of the problems with the original model. Romer also stresses the effects of accumulation through LBD as a determinant of productivity and growth. The production function for the representative firm is

$$(1.23)\quad Y_i = G(K_i, L_i, \kappa)$$

where K_i and L_i are the stock of capital and employment, respectively, used by firm i, and $\kappa = \sum_{i=1}^{n}(KN)_i$ is the aggregate level of knowledge in the economy where (KN) accounts for the level of knowledge capital. Although the choice of κ is external to the firm, it is assumed to have a spillover effect on output. Therefore, there is an externality in regard with the aggregate level of knowledge. In this model, LBD represents experience, which is knowledge available to all firms. There is a research technology that produces knowledge from foregone consumption in last period. The learning by doing function now becomes

$$(1.24)\quad LBD(t) = \int_{-\infty}^{t} \pi.R(v)\cdot d(v) = \kappa(t)$$

where R is the research expenditures and π is the rate at which research activities are transformed to new knowledge. For empirical purposes, the production function could take the Cobb-Douglas form

$$(1.25)\quad Y_t = A_0 K_t^{\beta} L_t^{\gamma} \kappa_t^{\Psi} \qquad \beta, \gamma, \Psi < 1 \qquad \gamma + \beta = 1 \qquad \beta + \gamma + \Psi > 1$$

At an aggregate level, this model postulates constant returns to reproducible factors, physical capital and labour force, in a world with increasing returns to scale, where increasing returns are external to individual firms in order to guarantee the existence of competitive equilibrium. That is, production may display constant returns to reproducible factors at an aggregate level, but decreasing returns to such variables at the firm level. However, note that increasing returns to scale by themselves are not enough to generate endogenous growth. The key aspect in this model, which questions the entire conclusions of traditional growth models, is the assumption of increasing marginal productivity of the stock of knowledge. In fact, the decreasing returns to reproducible factors at the firm level turn to constant returns in aggregate level as a result of the externality effect of the stock of knowledge.

1.4.3 The role of human capital

In this section we analyse the role of human capital in explaining growth. Table 1 shows some basic indicators of the level of human capital in 18 Asian countries. We can see the important increase in the level of formal education achieved by the population aged over 25. This seems to be especially relevant in the case of Newly Industrialised Countries (NIC's) such as Korea and Taiwan where the formal schooling grew by an average of 0.178 and 0.145 years, respectively, during each year between 1960 and 1985.

Consider the contribution of education in a neoclassical framework, where human capital is a third input and only plays an accumulating role. The neoclassical model with human capital can be written in Cobb-Douglas form as

$$(1.26)\quad Y_t = A_0 K_t^{\beta} L_t^{\gamma} H_t^{\delta}$$

where H denotes human capital and δ is the elasticity of output with respect to education.

Table 1.1
Average years of schooling in the total population over age 25

Country	**Primary**		**Secondary**		**Higher**		**Total**		
	1960	**1085**	**1960**	**1985**	**1960**	**1985**	**1960**	**1985**	**Mean annual growth**
Bangladesh	0.536	1.349	0.238	0.568	0.020	0.057	0.794	1.974	0.045
Hong Kong	3.507	4.396	1.547	2.876	0.135	0.239	5.189	7.511	0.089
India	1.328	2.110	0.099	0.812	0.000	0.125	1.427	3.046	0.062
Indonesia	1.026	3.127	0.078	0.582	0.003	0.041	1.107	3.750	0.102
Iran	0.316	2.181	0.119	1.013	0.016	0.087	0.452	3.281	0.109
Iraq	0.120	2.112	0.071	0.764	0.023	0.163	0.214	3.039	0.109
Israel	5.325	6.644	1.226	2.059	0.291	0.707	6.842	9.410	0.099
Japan	4.898	5.288	1.607	2.650	0.205	0.521	6.710	8.458	0.067
Jordan	1.044	2.618	0.326	1.336	0.026	0.353	1.396	4.308	0.112
Korea	2.484	4.679	0.657	2.764	0.090	0.407	3.231	7.850	0.178
Malaysia	1.840	3.902	0.441	1.386	0.055	0.074	2.336	5.361	0.116
Pakistan	0.457	1.073	0.159	0.771	0.011	0.076	0.628	1.920	0.050
Philippines	3.022	4.596	0.550	1.296	0.205	0.589	3.776	6.481	0.104
Singapore	1.924	3.149	1.063	1.258	0.000	0.146	2.987	4.553	0.060
Sri Lanka	2.390	3.483	1.024	1.844	0.012	0.044	3.426	5.371	0.075
Syria	0.867	2.622	0.110	1.107	0.017	0.258	0.994	3.987	0.115
Taiwan	2.434	4.469	0.678	2.199	0.128	0.331	3.239	6.999	0.145
Thailand	3.196	4.238	0.232	0.642	0.024	0.201	3.451	5.081	0.063

Source: Barro and Lee (1993)

Human capital as the source of endogenous growth

Lucas (1988) endogenised Harrod neutral (i.e. labour augmenting) technological change through a mechanism of human capital accumulation. He argues that not only do workers increase their productivity by learning new skills, but also the average level of skills in the economy has a spillover effect on the productivity of all workers in the economy and vice versa (i.e. an individual worker is more productive, regardless of his skill level, if other workers are more qualified, that is, if they have more human capital). These externalities (public learning) are not internalised by individual agents whose production exhibits constant returns to scale. For the economy as a whole, however, the externalities generate increasing returns to scale. Therefore, human capital not only adds to labour supply, by operating as a third factor (as in the neoclassical model), but also has an externality effect that contributes to total factor productivity growth. In the model proposed by Lucas (1988), technological progress arises as a side effect of education. The model endogenises growth by assuming that accumulation of human capital (which is a production process itself) is proportional to the time spent at school, that is

$$(1.27)\quad \frac{\overset{\circ}{h}}{h} = \delta(1-u)$$

where u is the fraction of time individuals are at work and h is a measure of the average quality of labour, which in empirical applications is usually measured by the mean years of schooling of the working force. Unlike Romer's model, here there is no presumption of increasing marginal product of knowledge. Now, however, the assumption of non-diminishing returns in the production of knowledge is necessary, since that is the sector that leads the economy towards a sustained positive growth rate.

Lucas proposes the following production function

$$(1.28)\quad Y_t = A \cdot K_t^{\beta}(uh_t L_t)^{\mu}(h_a^{\gamma})_t \qquad 0<\beta,\mu,\gamma<1$$

where (uhL) is the effective labour force or human capital, h_a is the economy's average human capital of the labour force and h_a^{γ} is intended to capture the positive external effects of human capital on the production of goods (although this is not a necessary assumption for sustainable endogenous growth), and $\mu=1-\beta$. Knowledge is, therefore, considered as a public good. Note that this production function exhibits constant returns to physical and human capital, but increasing returns to all factors $(1+\gamma$ where γ is the external effect). Setting $h=h_a$, we have

$$(1.29)\quad Y_t = AK_t^{\beta}H_t^{\theta}N_t^{-\gamma}$$

where $H=uhL$, $N=uL$, and $\theta=\mu+\gamma$. The null hypothesis of endogenous growth is $H_0: \beta+\theta=1$.

As in Romer's model, the growth accounting equation corresponding to this model shows that there is no residual

$$(1.30)\quad g_y = \beta g_k + \mu g_{l*}$$

where l^* indicates labour in efficiency units (i.e. human capital). Note that this model differs from the augmented Solow model with human capital analysed in the previous section. Rather, here the whole residual is disappeared and labour is upgraded and represented in effective units.

Note that, for empirical purposes, what would be supposed to be estimated here is the growth rate of output per unit of human capital, $y_t^H = \ln(Y_t/H_t)$, and not output per worker, $y_t^w = \ln(Y/L)$, as in (1.7). Also, here we have the variable Δk^h, where k^h is (the log of) the stock of physical capital per unit of human capital, $k_t^H = \ln(K_t/H_t)$, and not capital per worker, $k_t^w = \ln(K/L)$, as before.

1.4.4 The role of government

The analysis of the effects of government activities on economic growth is not clear out. In most cases, the existence of state intervention with inward-looking policies leads to distortions and low growth rates. Liberalisation and market orientation, on the other hand, is usually followed by high rates of growth. This is a subject of debate especially in the case of East and Southeast Asian countries due to the particular role played by governments. The neoclassical growth theory supports free markets and non-intervention because a large government size is believed to be harmful to economic growth. On the other hand, structuralists argue that government intervention plays a critical role in the process of development. The fact is that most countries, in particular the developing Asian ones, seem to have chosen some degree of state regulations. In this section we review two models in the context of the effects of government activities on economic growth.

Externality effects and relative factor productivity

First, we study the externality effect of government size on the rest of the economy, and the relative factor productivity of government and non-government sectors to see which sector is more efficient. Feder (1982) proposes a two-sector model with two production functions[8]

$$(1.31)\quad NG = NG(K_{NG}, L_{NG}, G)$$

$$(1.32)\quad G = G(K_G, L_G)$$

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[8] Originally, Feder introduces his model to study the relation between export performance and economic growth and deals with two export and non-export sectors of the economy.

where *NG* is non-government sector output, *G* is government sector output, and *K* and *L* are the stock of capital and employment with the corresponding subscripts. The relationship between the marginal productivity of the two sectors is assumed to be

$$(1.33)\quad \frac{G_K}{NG_K}=\frac{G_L}{NG_L}=1+\eta$$

where the subscripts denote partial derivatives. The model assumes that there are positive external effects (i.e. η>0) from the government sector to the rest of the economy but not in the opposite direction. It could happen through such factors as the development of more efficient management, production, etc. Therefore, the inclusion of government output in the production function has a structural interpretation. This (in the absence of externalities) leads to the following specification

$$(1.34)\quad \frac{\overset{\circ}{Y}}{Y}=\alpha(\frac{I}{Y})+\beta(\frac{\overset{\circ}{L}}{L})+\gamma(\frac{\overset{\circ}{G}}{G})(\frac{G}{Y})$$

where *G* is the proxy for government size, the dots denote changes in the respective variable over time, α measures the marginal product of capital of the non-government sector, and γ measures the relative efficiency of the government sector (i.e. overall effect of government size) or the gain from shifting resources from the non-government to the government sector.

If we extend the above formulation to include the intersectoral externality effect, the last term of the previous equation can be split into two components to give the second specification as following

$$(1.35)\quad \frac{\overset{\circ}{Y}}{Y}=\alpha(\frac{I}{Y})+\beta(\frac{\overset{\circ}{L}}{L})+[\frac{\delta}{1+\delta}-\theta](\frac{\overset{\circ}{G}}{G})(\frac{G}{Y})+\theta(\frac{\overset{\circ}{G}}{G})$$

where δ is the difference between the government and non-government factor marginal productivity, and θ denotes the marginal externality effect of the government sector (in terms of size) on the rest of the economy.

Government infrastructure spending as the source of endogenous growth

The second model introduces the government expenditures on infrastructures as the source of endogenous growth. Barro (1990) developed a model where government investment in material infrastructures (such as highways, railways, power stations, roads, airports, ports, etc.) is essential to economic growth. This suggests a supply-side role for government affecting productivity. The production function is extended to include public capital that has a positive external effect on private capital. The idea is that there are constant (or increasing) returns to capital of all firms in the economy together, as well as the spending on public goods. The production function is as follows

$$(1.36)\quad Y_t = AK_t^{\beta} L_t^{\gamma} G_t^{\mu} \qquad 0<\beta,\gamma,\mu<1 \qquad \beta+\gamma=1 \qquad \beta+\mu \geq 1$$

where G_t is government investment in material infrastructures (i.e. public inputs) and $\beta+\gamma=1$ is the usual assumption of constant rate of returns for private sector inputs in a Cobb-Douglas production function. It is clear that this setting is similar to the production function of Arrow (1962) discussed above, except that here the aggregate capital stock has been replaced by the amount of public goods (G). Nevertheless, as Barro and Sala-i-Martin (1995) point out, even though this formulation assumes that G refers to the flow of government purchases, an alternative approach would include the stock of accumulated capital.

Note that the form of the production function implies that private inputs, K and L, are complementary to public services (G), in the sense that an increase in the latter raises the marginal product of K and L. In this respect, Barro points out: 'Then the government just buys a flow of output (including services of highways, sewers, battleships, etc.) from the private sector. These purchased services, which government makes available to households, corresponds to the input that matters for private production' (Barro 1990, p. s107). The key assumption is that the production function exhibits constant (or increasing) returns to private capital and government spending together, but decreasing returns to each of them separately. Again, in order to generate endogenous growth, we need $\beta+\mu \geq 1$. Growth in this model is achieved by the provision of public inputs by government. This avoids diminishing returns to capital, so that individuals keep investing forever at constant rates (this is the ultimate source of growth). This is a big-push type model in that the government provides investment goods that could generate spillovers and are essential for industrialisation. In words of Murphy et al. 'an important component of industrialisation … is investment in jointly used intermediate goods, for example infrastructures such as railroads and training facilities. To the extent that the cost of an infrastructure is largely fixed, each industrialising firm that uses it helps defray this fixed cost and so brings the building of the infrastructure closer to profitability. In this way, each user indirectly helps other users and, therefore, makes their industrialisation more likely. As a result, infrastructures develop only when many sectors industrialise and become its users' (Murphy et al. 1989, p. 1006).

1.4.5 The role of imitation

Nelson and Pack (1999) offer yet another view of the economic growth performance of Newly Industrialised East Asian countries or NICs (i.e. Hong Kong, Korea, Taiwan and Singapore), popularly referred to as the "Asian Miracle". During the past forty years, these economies recorded higher growth rates than most leading developed economies over the last century. They try to answer the question as to *how* this was achieved by comparing two thought schools in this regard, namely the accumulationist and the assimilationist. Economists of the accumulation school argue that learning, entrepreneurship and innovation are more or less automatic by-products of investment in physical and human capital. In contrast, those of assimilation school believe that these are central to the ability to absorb new technologies and believe that investment in human and physical capital is only a necessary, but not a sufficient, part of the assimilation process. The learning that underlay technology absorption has been instrumental in preventing a decline in the marginal product of capital despite very high investment ratios in these countries. Learning, in turn, reflected the interaction of a favourable policy environment (which rewards innovations) and the entrepreneurial efforts of firms.

A two-sector model is used in which the development process takes place through the shift of resources from an old (or craft, in their words) to a modern technology. During this process, learning how to use new technologies and producing efficiently in new sectors requires expansion of new skills, new ways of organising economic activities, and becoming familiar with new markets. All these involve risk taking entrepreneurship and good management. Although a successful adoption of advanced technologies from abroad requires high rates of investment in physical and human capital, they are not all that is required. The role of "learning by doing" becomes clearer here in Nelson and Winter (1982) who refer to the fact that only a small portion of what one needs to know to employ a technology is explained in machine manuals, textbooks and blueprints; much of it is tacit and learning by doing and using is at least as important as reading and studying. In Nelson and Pack's model, such learning, and consequently access to the high levels of productivity offered by newly imported equipment, allows the modern sector to gradually increase its share of output, capital and labour. This, in turn, results in the comparative advantage of the modern sector. This model emphasises how education is critical to realising changes in the sectoral structure of NICs.

The most interesting feature of these models is not only the idea that physical investment can not by itself explain growth, but also an increased level of education is not, by itself, decisive. Thus the growing supply of well-trained technical people is seen as the most important factor in facilitating the technology absorption in NICs. In contrast, in many other countries initially as poor as NICs in 1950s, the market for educated people is almost exclusively restricted to government bureaucratic jobs, where skills make little contribution to economic development.

1.5 Conclusion

In this chapter we reviewed several endogenous growth models that offer different explanations of how technological progress and long run growth occur. The models were chosen in a way that the effect of different factors in the income growth rate (including capital investment, foreign technology, learning by doing, human capital, government activities and imitation) could be analysed. All these models propose different mechanisms to explain economic growth without the need to appeal to any exogenous and unexplained factor. We also proposed a time-series version of these models and developed a dynamic reparameterisation of an autoregressive distributed lag model that is able to nest several models and that allows us to follow a general-to-specific testing strategy. Our proposed time-series framework has highlighted the importance of including dynamics in the production function, as well as the advantages of separating short run from long run dynamics in order to avoid spurious regressions. However, since annual time series data are not available for most of the Asian economies, the models have not been tested for all of these countries. In chapters 5 and 6, however, we use time series techniques in order to study the behaviour of growth rates in Iran.

Chapter 2
Testing for Convergence across a Selection of Asian Economies

2.1 Introduction

The economics of growth addresses such important questions as why do different countries grow differently? Do they become more similar in terms of income growth? Can growth rates be improved by designing economic policies? To answer such questions, the specification of an economic growth model is essential.

The neoclassical assumption of diminishing returns to capital implies the convergence hypothesis: other things being equal, countries with low amounts of capital are predicted to grow faster. Testing for convergence is, therefore, seen as a way of testing for the applicability of the neoclassical growth model.

The central focus of this chapter is the issue of convergence. In particular, it examines whether Solow's growth model is consistent with observed variation in the standard of living across the Asian economies. In recent years there has been considerable empirical work on cross-country growth. While the finding of convergence has been generally thought of as evidence in support of Solow's growth model, the absence of convergence has been regarded as supportive of endogenous growth theories [1].

Beginning with a traditional cross-country framework, I find that Solow's growth model fails to provide a satisfactory explanation of the cross-country variation and exhibits no convergence. However, the convergence patterns are likely to be far more complex than implied by traditional cross-country regression techniques. This chapter argues that the critical assumption of a fixed steady state, made by the traditional studies, is inappropriate. Instead, a dynamic panel data framework is used to allow for differences in the aggregate production function across a sample of Asian countries. This enables us to classify the economies into different groups in terms of differences in technology. The results of panel estimation show that there are

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[1] Barro and Sala-i-Martin (1992) and Romer (1986), among others, provide evidence in support of neoclassical and endogenous growth models, respectively.

significant differences between the country effects, implying that the neoclassical assumption of a common production function should be replaced by an endogenous growth model, such as those pioneered by Romer (1986) and Lucas (1988).

The chapter is organised as follows: Section 2.2 reviews the theoretical aspects of the neoclassical growth model and explains different concepts of convergence. Section 2.3 briefly describes the data used here as well as those analysed in recent studies on convergence. Section 2.4 uses alternative static specifications of the neoclassical model in order to explain the variation in the standard of living across the Asian economies. Section 2.5 highlights the misspecified assumption of the static models about the steady state and suggests a dynamic framework that is formulated and tested in section 2.6. Section 2.7 considers a broad concept of physical and human capital and tests for the contribution of the latter to the model. Section 2.8 focuses on individual country effects and classifies the Asian countries according to differences on production efficiency. Section 2.9 contains the conclusions and some extensions.

2.2 Convergence in the basic neoclassical growth model

The neoclassical growth model of Solow (1956) starts with the assumption that economies produce a single output Y that can be either consumed or saved and invested. The labour force (L_t) is assumed to grow at a constant rate (n)

$$(2.1) \qquad L_t = L_0 \cdot e^{nt}.$$

Investment and saving are a constant fraction of output, so that

$$(2.2) \qquad \frac{dK_t}{dt} \equiv I_t = S_t = s \cdot Y_t.$$

Y is a function of two inputs, namely the stock of capital (K) and labour force (L),

$$(2.3) \qquad Y_t = F(K_t, L_t).$$

For all $K > 0$ and $L > 0$, $F(\bullet)$ exhibits positive and diminishing marginal products with respect to each input and also constant returns to scale, i.e. it is homogenous of degree one in all inputs.

The main question we are trying to address is whether there is any equilibrium value for per capita output ($y \equiv Y/L$) and per capita capital ($k \equiv K/L$). Using the homogeneity assumption, output can be written in an intensive form as

(2.4) $$y = f(k)$$

In order to see the dynamic behaviour of capital stock, we may take the logarithm of both sides of $k_t \equiv \frac{K_t}{L_t}$ to linearise it as

(2.5) $$\ln(k_t) = \ln(K_t) - \ln(L_t).$$

The growth rate of per capita capital, *k*, is given by the differential of (2.5) as

(2.6) $$\overset{\circ}{k}_t \equiv \frac{dk/dt}{k} = \frac{dK/dt}{K} - \frac{dL/dt}{L} \equiv \overset{\circ}{K} - \overset{\circ}{L}.$$

Substituting for *dK/dt* from (2.2) and for $\overset{\circ}{L}_t$ from (2.1), (2.6) gives

(2.7) $$\overset{\circ}{k} = \frac{s \cdot f(k)}{k} - n.$$

Equation (2.7) implies that if the saving rate, *s*, were 0, then *k* would decline due to growth of *L* at the rate *n*.

In steady state the various quantities grow at constant rates. For the neoclassical model, the steady state corresponds to $\overset{\circ}{k} = 0$ [2], so that

(2.8) $$\frac{s \cdot f(k^*)}{k^*} = n.$$

The Dynamics of per capita capital (*k*) is shown in Figure 2.1.[3] Since *k* is constant in steady state, *y* is also constant at the value $y^* = f(k^*)$. Hence, the per capita quantities *k* and *y* do not grow in the steady state. It means that the levels of variables – *K* and *Y*– grow in the steady state at the rate of population (labour force) growth, *n*.

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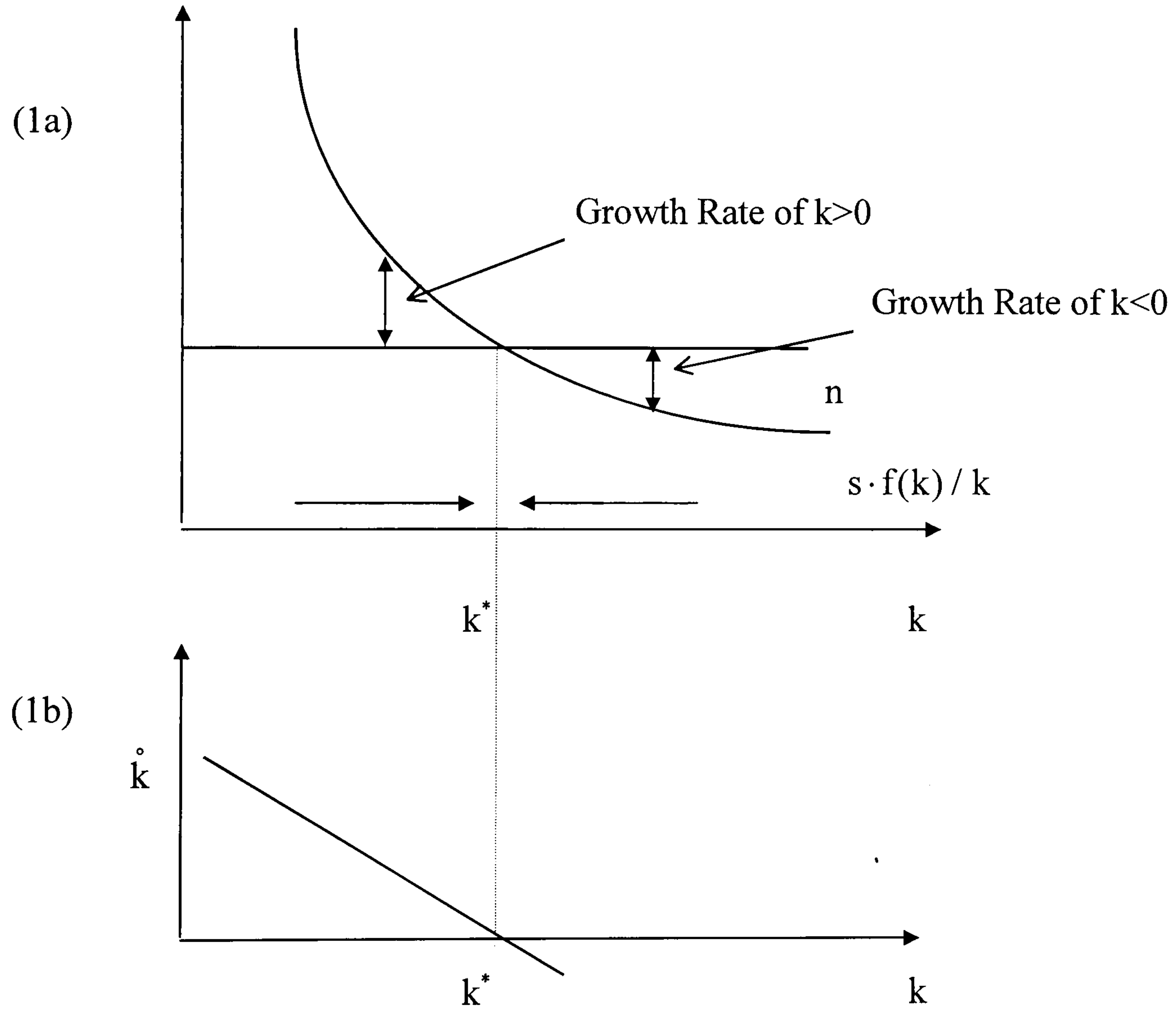
[2] To verify it, we know that in (2.7), s and n are constant. Thus, f(k)/k must be constant in steady state. The time derivative of f(k)/k equals $-\{[f(k) - k \cdot f'(k)] / k\} \cdot \overset{\circ}{k}$. The expression $f(k) - k \cdot f'(k)$ equals marginal product of labour (because from Y=L·f(k)=f(K/L), we have $\frac{\partial Y}{\partial L} = f(k) - k \cdot f'(k) \equiv MPL$) and is positive. Therefore, $\overset{\circ}{k}$ must equal 0 in steady state.

[3] The curve s·f(k)/k has a negative slope because $\frac{\partial[f(k)/k]}{\partial k} = -[f(k) - k \cdot f'(k)]/k^2$. Since the expression in bracket is MPL and positive, the derivative is negative.

Figure 2.1a shows that to the left of the steady state, the *s·f(k)/k* curve lies above horizontal line, *n*. Hence the growth rate of *k* is positive, and *k* rises over time. As *k* increases, $\overset{\circ}{k}$ declines. The s·f(k)/k curve gets closer to the *n* line as *k* gets closer to k^*; hence $\overset{\circ}{k}$ falls. The economy tends asymptotically toward the steady state in which *k* – and hence *y* – does not change.

Figure 2.1. Absolute Convergence



The source of this steady state equilibrium is the diminishing returns to capital: when *k* is relatively low (in a poor economy), the average product of capital, *f(k)/k*, is relatively high. By (2.2), households save and invest a constant fraction, *s*, of this product. Hence when *k* is relatively low, the investment per unit of capital, *s·f(k)/k*, is relatively high. Consequently, the growth rate, $\overset{\circ}{k}$, is also relatively high.

An analogous analysis holds for any $k(0)>k^*$ (a rich country). Thus the system is globally stable. To show the negative relation between $\overset{\circ}{k}$ and k in Figure 2.1b, we can derive the derivative of $\overset{\circ}{k}$ with respect to k as

$$(2.9) \qquad \frac{\partial \overset{\circ}{k}}{\partial k} = s \cdot [f'(k) - f(k)/k]/k < 0 .$$

We can also study the behaviour of output along the transition. Since a poor economy with low level of output has a lower amount of per capita capital, *k*, than a rich economy, the same dynamics exists for per capita output, i.e.

$$(2.10) \qquad \frac{\partial \overset{\circ}{y}}{\partial y} < 0 .$$

This dynamics is called *convergence* of per capita income.

Absolute vs. conditional convergence

In absolute convergence it is assumed that both the poor and rich countries have the same values of parameters *s* and *n* and also have the same production function f(•). These assumptions result in the same steady state values of k^* and y^* for both countries. Therefore the only difference among the economies is the initial quantity of per capita capital, *k(0)*. The model then implies that the poor economies – with lower values of *k(0)* and *y(0)* – have higher growth rates of *k* and *y*.

Consider two economies, one with the low initial value, $k_{0,poor}$, and the other with the high initial value, $k_{0,rich}$. If the two economies have the same underlying parameters, the dynamics of *k* will be determined by the same *s.f(k)/k* and *n* curves. Hence the poorer the economy, the larger the growth rates $\overset{\circ}{k}$ and $\overset{\circ}{y}$. This is the concept of *absolute convergence: among the economies with similar structures, those with lower starting values of* k *(and* y*) have higher per capita growth* $\overset{\circ}{k}$ *(and* $\overset{\circ}{y}$*) and tend to catch up or converge to those with higher* k *(and* y*).*

In the real world, the assumption that all economies have the same parameters, and therefore, the same steady state positions, is not plausible. If the steady states differ, then we have to modify the analysis to consider the concept of *conditional* *convergence: an economy grows faster the further it is from its own steady state position.*

We illustrate the concept of conditional convergence in figure 2.2 by considering two economies that differ in only two aspects: first, they have different initial stocks of per capita capital, $k_{0,poor}<k_{0,rich}$, and second they have different saving rates, $s_{poor}<s_{rich}$. (Empirically, rich countries tend to have higher saving rates.) Here we see that $\overset{\circ}{k}_{poor} < \overset{\circ}{k}_{rich}$ and absolute convergence does not exist. But it is shown in the neoclassical model that each country converges to its own steady state. Algebraically, we can illustrate the concept of conditional convergence by rewriting (2.8) as

$$s = n \cdot \frac{k^*}{f(k^*)}$$

and substituting this in (2.7) to obtain

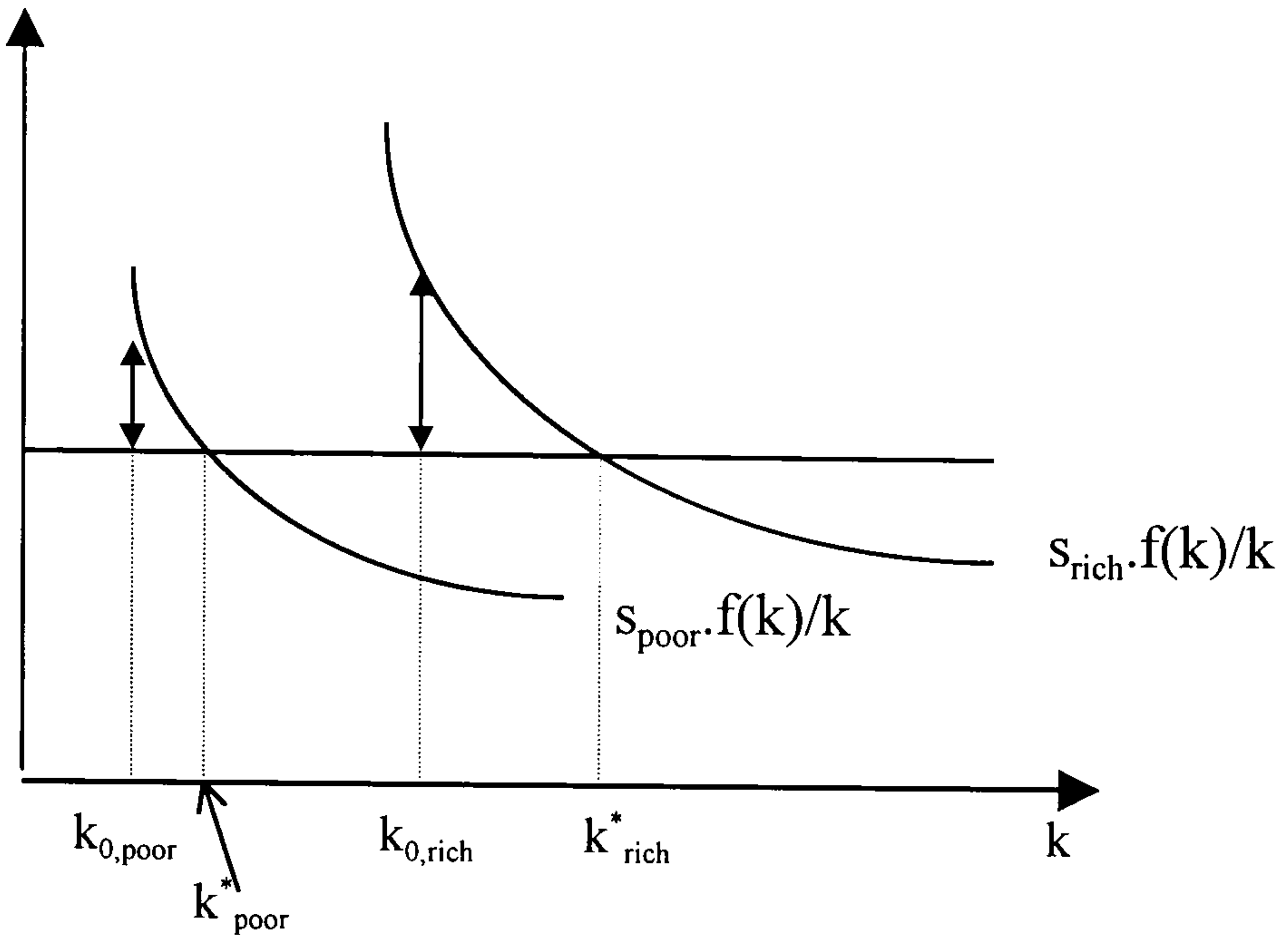
$$\overset{\circ}{k} = n \cdot \left[\frac{f(k)/k}{f(k^*)/k^*} - 1 \right]. \tag{2.11}$$

For given k^*, (2.11) implies that a reduction in k, which raises the average product of capital, f(k)/k, increases $\overset{\circ}{k}$. But we can not always tell that a higher f(k)/k (lower k) tends to cause a higher $\overset{\circ}{k}$; for this to be so, f(k)/k must be high relative to the steady state value, $f(k^*)/k^*$.

Therefore, in order to test the convergence hypothesis we should control for any variables that account for differences in the steady state position, y^*. These differences may be minor for a relatively homogenous group of economies. But for structurally different economies, we should use conditional concept of convergence.

The concept of convergence studied here is that economies with lower levels of per capita income (expressed relative to their steady state levels of per capita income) tend to grow faster in per capita terms. Therefore, poor economies tend to catch up with the rich ones in terms of the level of per capita income or product. This property corresponds to the concept of *β convergence.* This behaviour is often confused with a different concept of convergence, that the dispersion (measured, for example, by the standard deviation of the logarithm of per capita income or product across a group of economies) declines over time. This is called *σ convergence.*[4]

Figure 2.2. Conditional Convergence



2.3 Data and stylised facts

In this study, use is made of the internationally adjusted data collected by Summers and Heston (1988) in order to test for β convergence. Instead of translating the different currencies into one another using inadequate exchange rate comparisons, they use carefully constructed indices of relative purchasing power.

The data for a number of homogenous (structurally similar) economies like the U.S. states, the European regions, and the Japanese prefectures show that there is absolute *β* convergence among each of these groups of economies. The data is reported in Barro and Sala-i-Martin (1995).

Figure 2.3 shows that there is clear evidence of convergence among 48 states of USA. The correlation between the growth rate and the log of initial income is R=-0.93. Since the U.S. states are structurally similar, there is no need to test for conditional convergence.

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[4] Barro and Sala-i Martin (1992) argue that convergence in the sense that poor economies tend to grow faster than rich ones, does not necessarily imply that the cross economy dispersion declines over time. Therefore, even if absolute β convergence holds, the dispersion of per capita income does not necessarily tend to decline over time.

Figure 2.3. Convergence across U.S. states

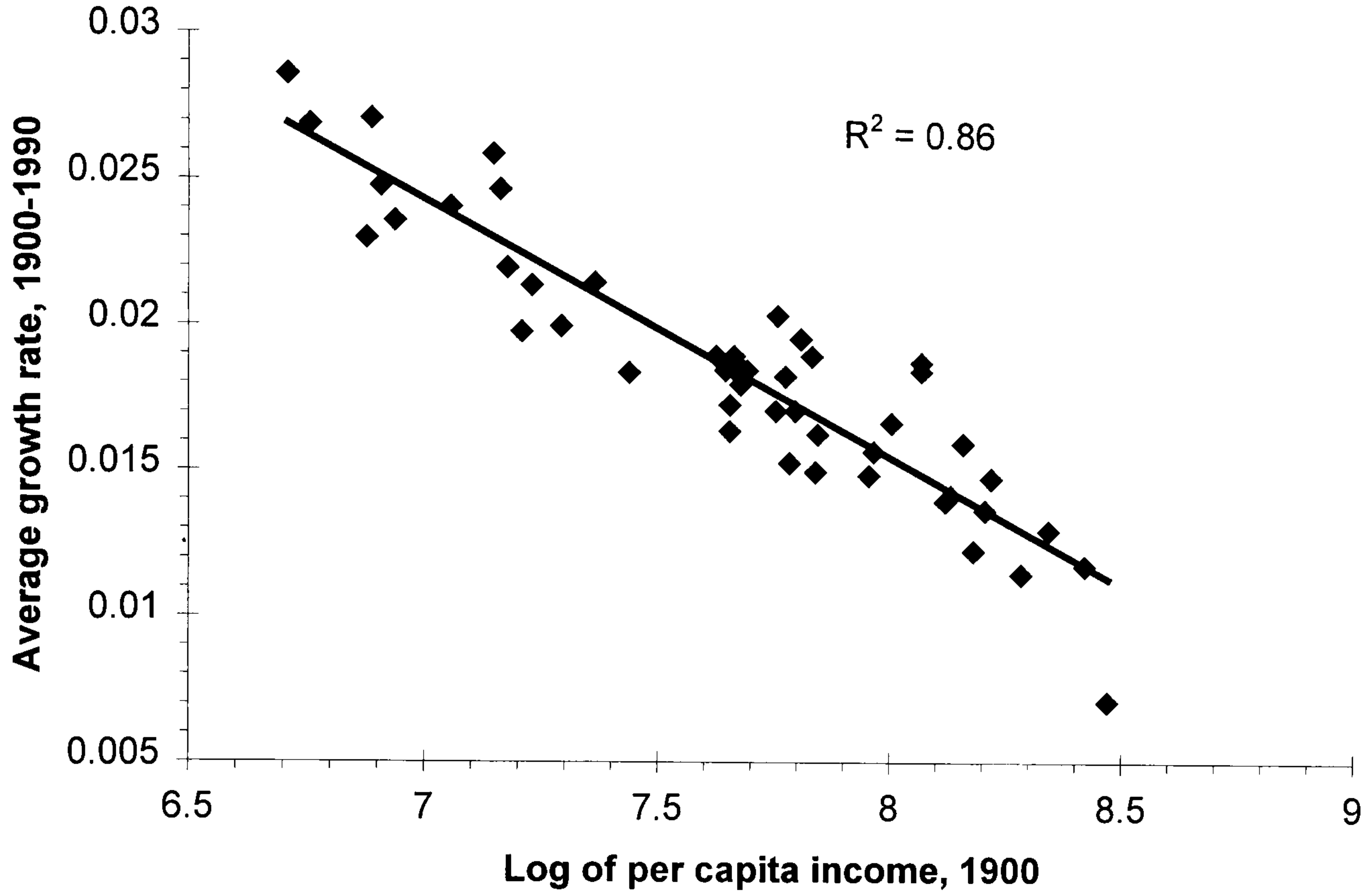


Figure 2.4. Convergence across European regions

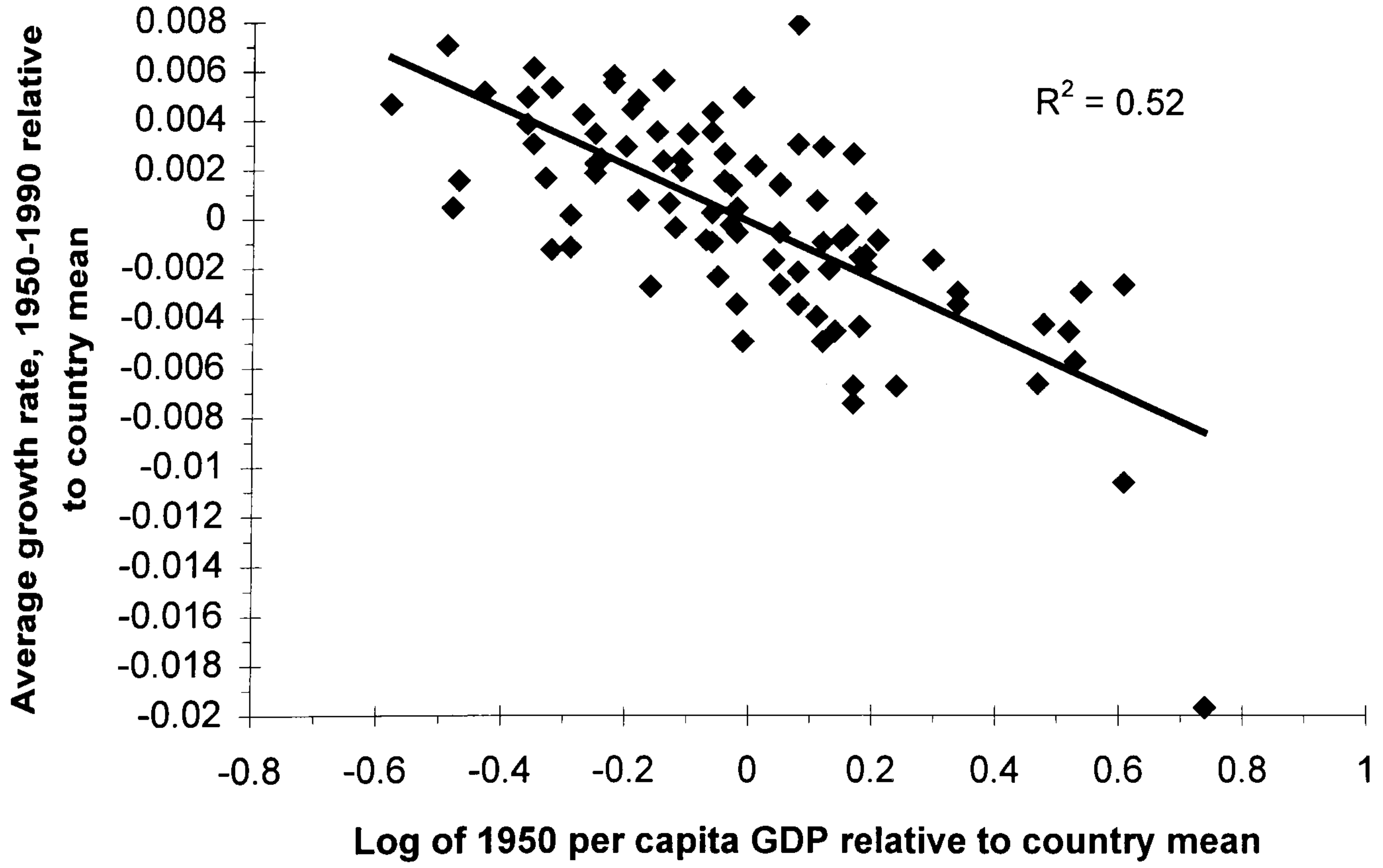
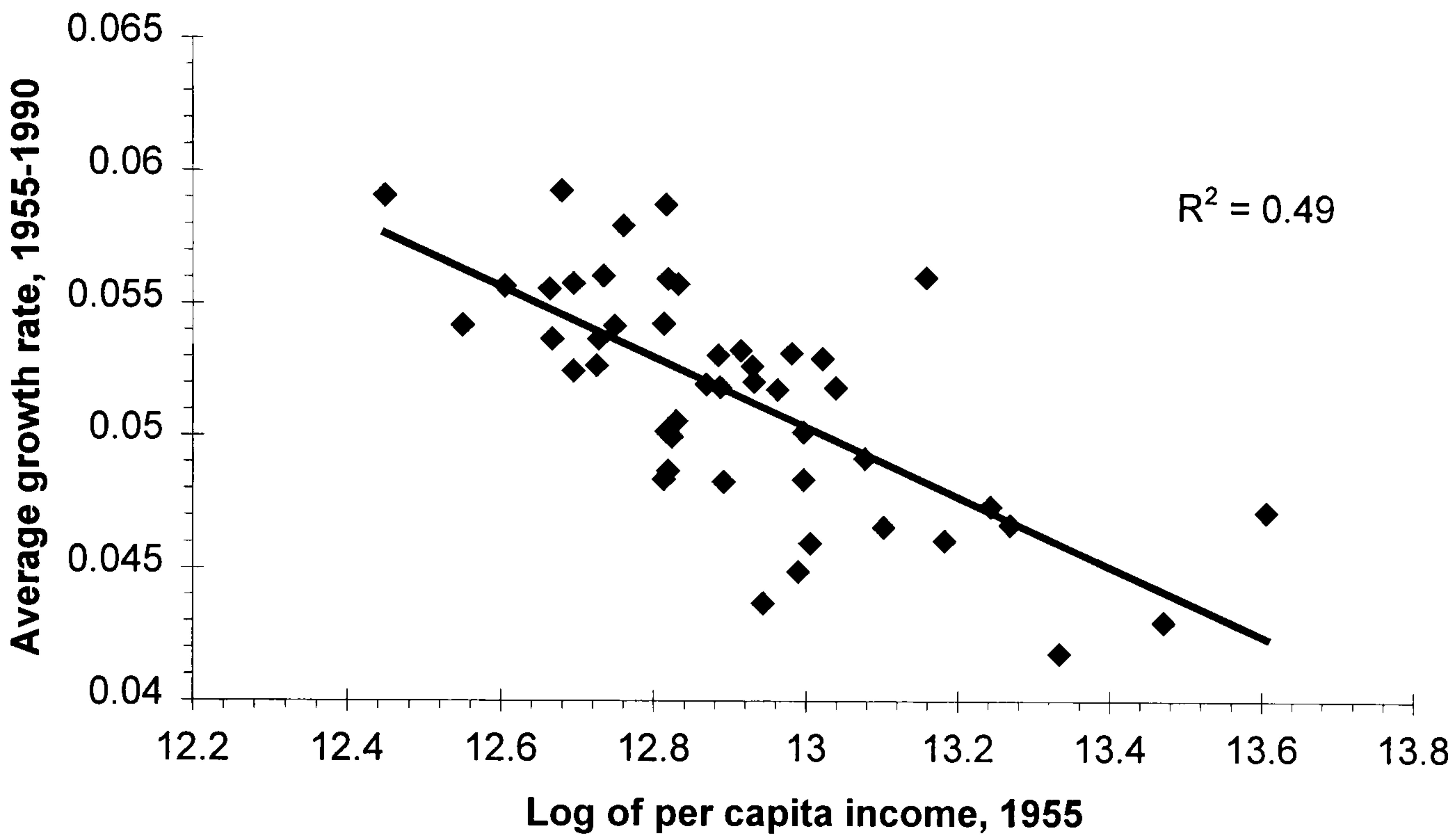


Figure 2.5. Convergence across Japanese prefectures



Another homogenous group of economies is the European regions. Figure 2.4 shows the absolute β convergence among 90 regions in eight European countries (Germany, UK, Italy, France, Netherlands, Belgium, Denmark and Spain). The variables are measured relative to the means of the respective countries. Figure 2.4 shows the negative relation, with R=-0.72. Since the underlying numbers are expressed relative to own-country means, the relation in this figure pertains to β convergence within countries, rather than between countries. If, therefore, we included country dummies in our regression, we would also see that there was convergence across countries.

Figure 2.5 also shows that there is absolute β convergence for per capita income across 47 Japanese prefectures, with a correlation of R = -0.70.

Figures 2.6 and 2.7, however, imply that there is no evidence of absolute convergence across 117 countries worldwide as well as 20 Asian countries. The correlation between initial per capita GDP and growth rate in these two cases is R=0.23 and R=0.13, respectively. This is probably due to the different structures of these economies; the production function, the saving rate, and the population growth rate all vary significantly across these countries.

Figure 2.6. Convergence across 117 countries

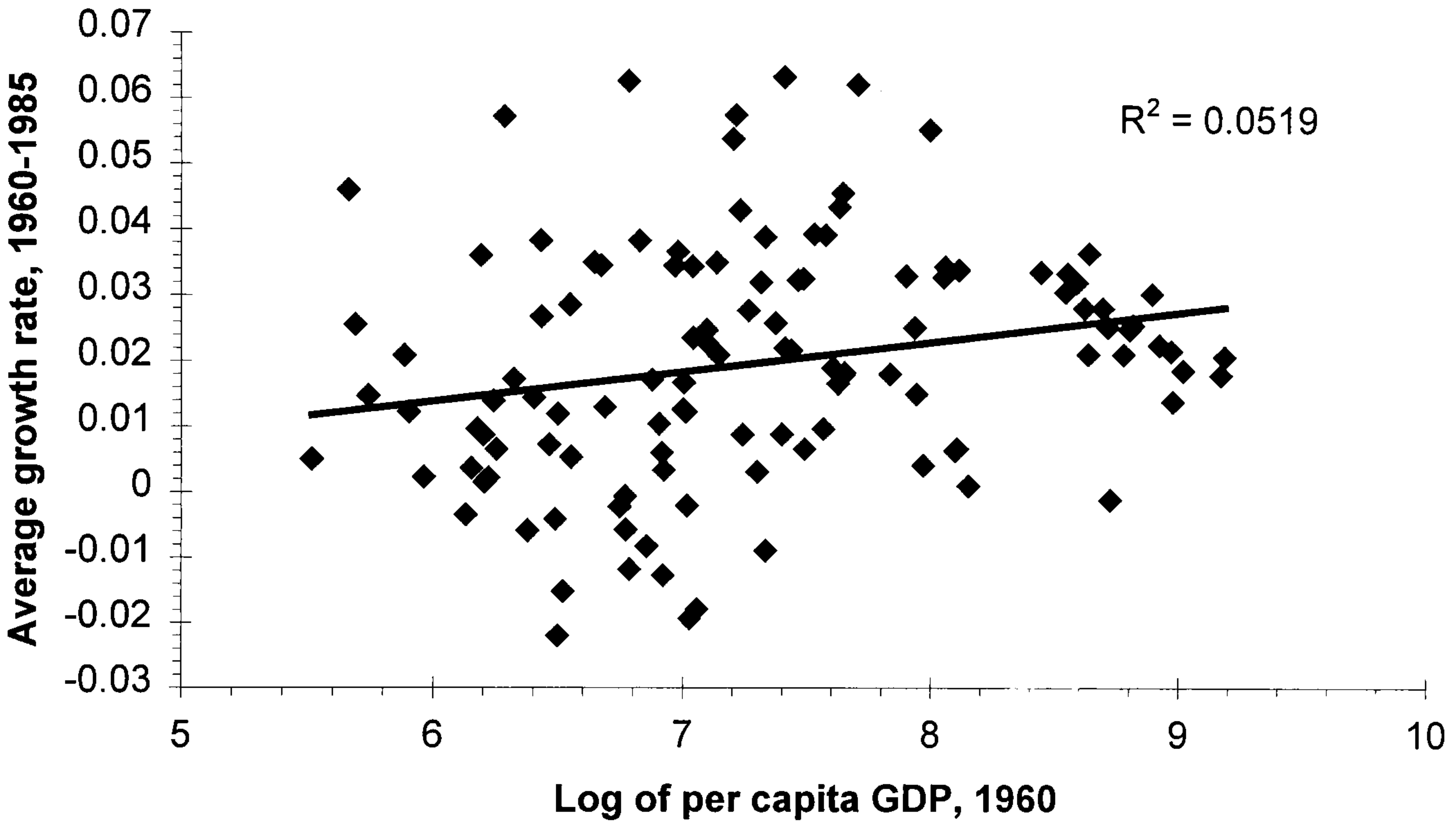
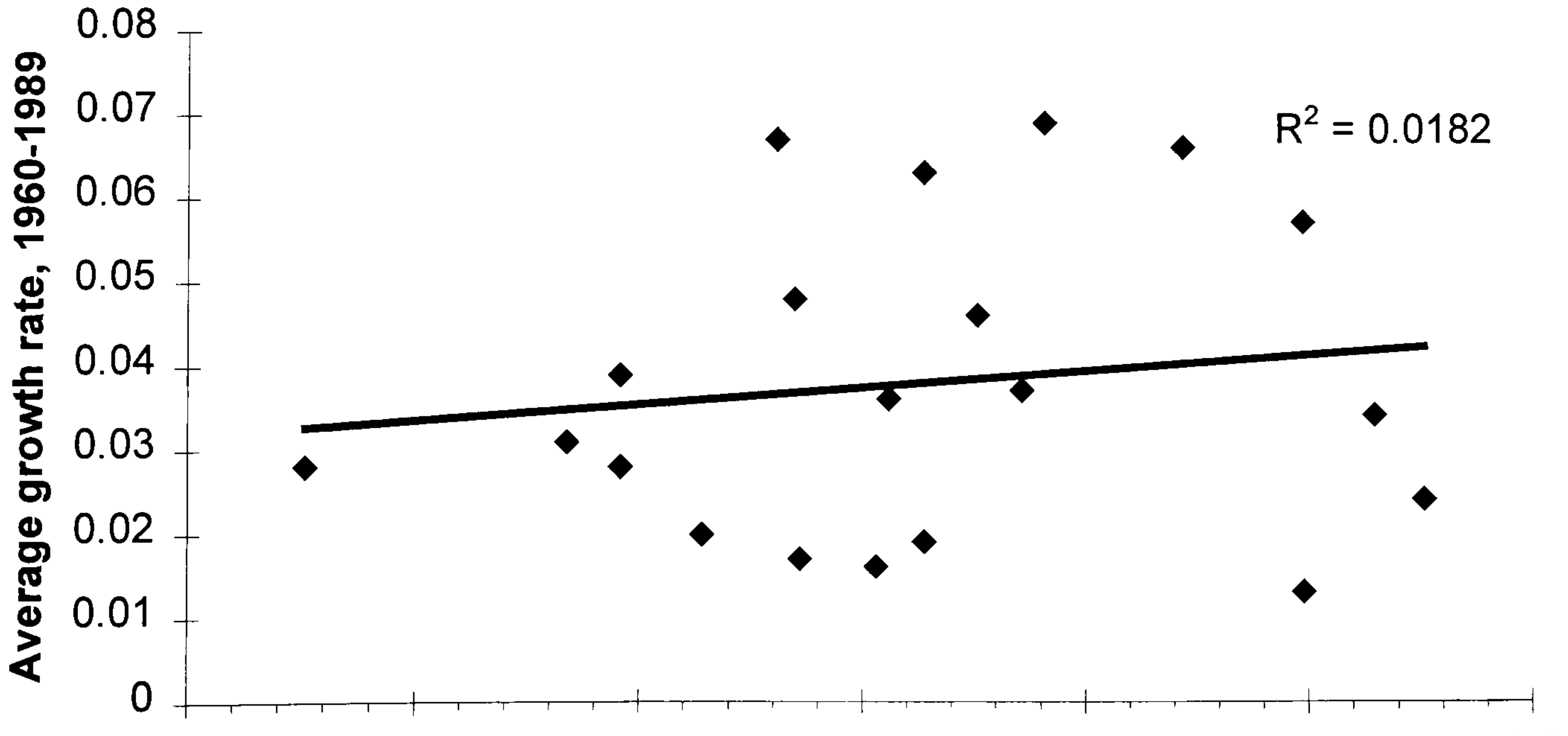


Figure 2.7. Convergence across 20 Asian countries



2.4 Traditional empirical studies on convergence

Now we refer to some of the recent studies that test for convergence. We start with Baumol (1986) as an *ad hoc* model that seems to have no theoretical justification and just forms a basis for comparison with subsequent empirical studies. Although there have been many studies carried out since Baumol, we only refer to two of them because of their important contribution to the literature. Barro and Sala-i-Martin (1992) suggest a measure for the speed of absolute convergence, while Mankiw, Romer and Weil (1992, hereafter MRW) augment Solow's growth model in order to explain the concept of conditional convergence. In each case we use the same analysis in order to test the convergence hypothesis among the Asian countries using the Summers-Heston data.

2.4.1 Baumol: absolute convergence

Baumol (1986) analyses the experience of a group of 16 industrialised countries during the last century using Maddison's (1982) data. The result of his analysis is as listed below

$$\begin{aligned}&\text{Growth Rate (1870-1979)} =\\ &5.25 - 0.75\ \ln(\text{GDP per WorkHr, 1870}) \qquad ; \qquad R^2=0.88.\end{aligned}$$

The fit of the regression is extremely good and supports the convergence hypothesis.

Although the pattern of convergence seems very clear at first sight, De Long (1988) argues that this is largely the result of a sample selection bias and the lack of correction for measurement error. Since Baumol's sample is made up of ex-post successful countries, the convergence result is almost unavoidable but possibly spurious.

For a valid test, says De Long, we need a sample selected according to an ex-ante criterion. He, therefore, tries to include the group of countries which were rich at the beginning of the sample period, and not at its end. After preparing such a sample, De Long showed that there is a weaker tendency to convergence among the ex-ante rich countries.

Using the same analysis that Baumol used, we test for absolute β convergence among 22 Asian countries (where data was available) during 1960-1985.[5] The estimation result, listed below, implies that there is no evidence of absolute β convergence, as would be expected from the evidence in figure 2.7.

Growth Rate (1960-1985) =

0.008 + 0.004 ln (per capita GDP, 1960) ; $R^2 = 0.02$

(0.045) (0.006)

(Standard errors in brackets)

2.4.2 Barro and Sala-i-Martin: deriving the speed of convergence

To test the convergence hypothesis, Barro and Sala-i-Martin (1992) use a Ramsey model in which each representative household maximises its overall utility in the life time, *U*, subject to a budget constraint,

$$\text{(2.12)} \qquad \max. \quad U = \int_0^{\infty} u[c(t)] \cdot e^{nt} \cdot e^{-\rho t} \cdot dt$$

$$\text{(2.13)} \qquad \text{s.t.} \quad \overset{\circ}{a} = w + r \cdot a - c - n \cdot a ,$$

where *u[c(t)]* is the time flow of utility, *n* is the rate of family growth, ρ (>0) is the rate of time preference, *a* is the households' net asset per person (measured in units of consumables), *w* is the wage rate, *r* is the interest rate, and $\overset{\circ}{a}$ is the change in assets over time. The felicity function, *u(c)*, is assumed to be increasing in *c* and concave, and satisfy Inada conditions (i.e. $u'(c) \to \infty$ as $c \to 0$ and $u'(c) \to 0$ as $c \to \infty$).

If we assume the following functional form for *u(c)*

$$\text{(2.14)} \qquad u(c) = \frac{c^{(1-\theta)} - 1}{1-\theta} \quad ; \quad \theta > 0,$$

then, the first order condition in this optimisation problem leads to the optimality condition

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[5] The countries included in the sample are Bangladesh, China, Hong Kong, India, Indonesia, Iran, Iraq, Israel, Japan, Jordan, Rep. of Korea, Malaysia, Myanmar, Nepal, Pakistan, Philippines, Saudi Arabia, Singapore, Sri Lanka, Syria, Taiwan and Thailand.

(2.15) $$\frac{\overset{\circ}{c}}{c} = (\frac{1}{\theta}).(r - \rho).$$

The firms, on the other hand, produce goods, pay wages for labour input, and make rental payment for capital input and have access to the production technology

(2.16) $$\hat{y} = f(\hat{k}),$$

where $\hat{y} \equiv Y / \hat{L}$ and $\hat{k} = K / \hat{L}$ are output and stock of capital per unit of effective labour, respectively, and $\hat{L} = L \cdot A_t$ is the effective amount of labour input and the level of the technology grows at the constant rate $g \geq 0$, so that $A_t = e^{gt}$ with $A_0=1$. The representative firm's profit at any point in time is given by

(2.17) $$\pi = \hat{L} \cdot [f(\hat{k}) - (r + \delta)\hat{k} - we^{-gt}],$$

where δ is the physical capital depreciation rate. A competitive firm, which takes r and w as given, maximises profit for given $\hat{L}$ by setting

(2.18) $$f'(\hat{k}) = r + \delta;$$

in order for profit to be 0, the wage rate is set to

(2.19) $$w = [f(\hat{k}) - \hat{k} \cdot f'(\hat{k})] \cdot e^{xt}.$$

In equilibrium, using $a=k$, $\hat{k} = ke^{-xt}$ and substituting for r and **w** from (2.18) and (2.19) in (2.13) we get

(2.20) $$\overset{\circ}{\hat{k}} = f(\hat{k}) - \hat{c} - (x + n + \delta) \cdot \hat{k},$$

where $\hat{c} \equiv C / \hat{L} = c \cdot e^{-xt}$.

This differential equation determines the evolution of $\hat{k}$ and $\hat{y} = f(\hat{k})$ over time. But $\hat{c}$ in (2.20) is not determined yet. To find its path, we use the conditions $r = f'(\hat{k}) - \delta$ and $\hat{c} = c \cdot e^{-xt}$ in (2.15) to get

(2.21) $$\frac{\dot{\hat{c}}}{\hat{c}} = \frac{\dot{c}}{c} - x = (\frac{1}{\theta})\cdot[f'(\hat{k}) - \delta - \rho - \theta x].$$

Equations 20 and 21 form a system of two differential equations in $\hat{c}$ and $\hat{k}$. Given the initial condition, $\hat{k}(0)$, we can determine the time paths of $\hat{c}$ and $\hat{k}$.

Barro and Sala-i-Martin (1992) apply a log-linearization method to (2.20) and (2.21) through expanding them around the steady state position, to get

(2.22) $$\log[\hat{y}(t)] = e^{-\lambda t}\cdot\log[\hat{y}(0)] + (1 - e^{-\lambda t})\cdot\log(\hat{y}^{*}),$$

where $\hat{y}^{*}$ is the steady state value of $\hat{y}$. Here λ is the speed of convergence. The average growth rate of output over an interval from an initial time 0 to any future time $T \geq 0$ is given by

(2.23) $$(\frac{1}{T})\cdot\log[\frac{y(T)}{y(0)}] = x + \frac{(1 - e^{-\lambda T})}{T}\cdot\log[\frac{\hat{y}^{*}}{\hat{y}(0)}].$$

(2.23) implies a conditional concept of convergence, where the growth rate depends negatively on the ratio of $\hat{y}(0)$ to $\hat{y}^{*}$.

We can apply (2.23) to discrete periods of unit length and add a disturbance u_{it} to get

(2.24) $$\log(\frac{y_{it}}{y_{i,t-1}}) = a - (1 - e^{-\lambda})\cdot\log(y_{i,t-1}) + u_{it},$$

where $a \equiv x + [(1 - e^{-\lambda})\cdot[\log(\hat{y}^{*}) + x(t-1)]$, and the subscript *i* denotes the country or region (economy).

Now reconsidering the average growth rate for a period of time 0 to *T* we have

(2.25) $$(\frac{1}{T})\cdot\log(\frac{y_{iT}}{y_{i0}}) = a - \frac{(1 - e^{-\lambda T})}{T}\cdot\log(y_{i0}) + u_{i0,T},$$

where $a \equiv x + \frac{(1 - e^{-\lambda T})}{T}\cdot\log(\hat{y}^{*})$.

The regression equation to be estimated here, namely (2.25), is identical to that used by Baumol (1986). However, the theory behind the former allows us to derive the speed of absolute convergence, λ, directly from the estimated coefficient on logy_0.

Barro and Sala-i-Martin (1995) apply regression (2.25) to estimate the speed of convergence across the US states, Japanese prefectures and European regions. Using regional dummies and structural variables, they estimate a speed of about two percent per year for the convergence across the US states. Also using district dummies and structural variables, they find a speed of two to three percent for convergence across the Japanese prefectures. For European regions, using country dummies as well as variables that measure each region's share of agriculture and industry in total employment or GDP of the respective country, they obtain a value of about two percent as the annual speed of convergence across these regions.

Applying OLS procedure and using the 22 Asian country sample in order to derive λ from (2.25), where y_0 and y_T are per capita GDP in 1960 and 1985, respectively, and T=25 is the length of the period, the implied λ is -0.0036. This anomalous result is due to significant structural differences between the economies included in the sample.

2.4.3 Mankiw, Romer and Weil: conditional convergence

To this point, the estimation results show that there is no evidence of absolute β convergence among the Asian countries.

Mankiw, Romer and Weil (1992, hereafter MRW) start with a textbook Solow model featuring the Cobb-Douglas production function with labour augmenting technological progress,

$$(2.26) \qquad Y_t = K_t^{\alpha} \cdot (A_t \cdot L_t)^{1-\alpha} \quad ; \qquad 0<\alpha<1.$$

L and A are assumed to grow exogenously at rates n and g

$$(2.27) \qquad \begin{aligned} L(t) &= L(0) \cdot e^{nt} \\ A(t) &= A(0) \cdot e^{gt}. \end{aligned}$$

Assuming that s is the constant fraction of output that is saved and invested, the dynamic equation for $\hat{k}$ is given by

$$(2.28) \qquad \dot{\hat{k}}_t = s \cdot \hat{y}_t - (n+g+\delta) \cdot \hat{k}_t$$
$$= s \cdot \hat{k}_t^{\alpha} - (n+g+\delta) \cdot \hat{k}_t$$

where δ is the constant rate of depreciation. $\hat{k}$ converges to its steady state value

$$\hat{k}^* = \left(\frac{s}{n+g+\delta} \right)^{1/(1-\alpha)} .$$

Substituting this into the production function and taking logs, we find that steady state income per capita is

$$(2.29) \qquad \ln\left[\frac{Y_t}{L_t}\right] = \ln A_0 + gt + \frac{\alpha}{1-\alpha} \cdot \ln(s) - \frac{\alpha}{1-\alpha} \cdot \ln(n+g+\delta) .$$

MRW assume that countries are currently in their steady state, and use this equation to see how differing saving and labour force growth rates can explain the differences in the current per capita income across countries.

MRW relied on a crucial assumption. Apart from the saving and population growth variables (while g and δ are assumed to be constant across countries), this equation contains the term $[\ln A_0 + gt]$. Since the exogenous rate of technological progress, g, is thought to be the same for all countries, and for cross-section regression, t is just a fixed number, the term gt in the equation is just a constant. However, this can not be said of A_0. They rightly noted '…the A_0 term reflects not just technology but resource endowments, climate, institutions, and so on; it may therefore differ across countries' (MRW p. 411). They, therefore, assume that

$$(2.30) \qquad \ln A_0 = a + \varepsilon ,$$

where a is a constant and ε is a country-specific shift or shock term. Substituting this into (2.29) and subsuming gt into the constant term a, they derive the specification

$$(2.31) \qquad \ln\left(\frac{Y_t}{L_t}\right) = a + \frac{\alpha}{1-\alpha}\cdot\ln(s) - \frac{\alpha}{1-\alpha}\cdot\ln(n+g+\delta) + \varepsilon\,.$$

Here they make a crucial assumption about ε, that is, it is independent of the explanatory variables s and n. This assumption is required in order to apply OLS to estimate (2.31). In order for s and n to be independent of ε, we should also assume that preferences are isoelastic. This in turn represents an additional restriction. In general, the country-specific technology shift term ε is likely to be correlated with the saving and population growth rates experienced by that country. Since A_0 is defined not only in the narrow sense of production technology, but also to include resource endowments, institutions, etc., it is not entirely convincing to argue that saving and fertility behaviour will not be affected by all that is included in A_0.

MRW try to estimate the speed of convergence as well as the elasticity of output with respect to capital, α. Approximating around the steady state, the speed of convergence is given by

$$(2.32) \qquad \frac{d\ln\hat{y}_t}{dt} = \lambda\cdot\left[\ln\hat{y}^* - \ln\hat{y}_t\right]$$

where λ represents the convergence rate, $\hat{y}^*$ is the steady state level of income per effective worker, and $\hat{y}_t$ is the actual value of income per effective worker at time t. Since $\hat{y}^*$ is a fixed value and $\ln\hat{y}(t) = e^{-\lambda t}\cdot\ln\hat{y}(0)$, where $\hat{y}(0)$ is the initial value of income per effective worker, we can write

$$\ln(\hat{y}^*) - \ln(\hat{y}) = e^{-\lambda t}\cdot\left[\ln(\hat{y}^*) - \ln\hat{y}(0)\right].$$

Then (2.32) implies that

$$(2.33) \qquad \ln\hat{y}(t_2) = (1-e^{-\lambda\tau})\cdot\ln(\hat{y}^*) + e^{-\lambda\tau}\cdot\ln\hat{y}(t_1),$$

where $\hat{y}(t_1)$ is income per effective worker at some initial point of time and $\tau = t_2 - t_1$. Subtracting $\ln\hat{y}(t_1)$ from both sides of (2.33) yields the partial adjustment process

$$\text{(2.34)} \qquad \ln\hat{y}(t_2) - \ln\hat{y}(t_1) = (1 - e^{-\lambda\tau}) \cdot \ln(\hat{y}^{*}) - (1 - e^{-\lambda\tau}) \cdot \ln\hat{y}(t_1).$$

Finally, substituting for

$$\hat{y}^{*} = \left(\frac{s}{n + g + \delta}\right)^{\alpha/1-\alpha}$$

results to

$$\text{(2.35)} \qquad \ln\hat{y}_{t2} = (1 - e^{-\lambda\tau}) \cdot \frac{\alpha}{1-\alpha} \cdot \ln(s)$$
$$- (1 - e^{-\lambda\tau}) \cdot \frac{\alpha}{1-\alpha} \cdot \ln(n + g + \delta) + e^{-\lambda\tau} \cdot \ln\hat{y}_{t1},$$

Using the Summers and Heston (1988) data set, MRW consider three samples of different sizes. The most comprehensive consists of all countries for which data are available other than those for which oil production is the dominant industry. This sample consists of 98 countries. They justify the exclusion of these countries by noting that 'one should not expect standard growth models to account for measured GDP in these countries' (MRW p. 413). Their second sample excludes countries whose population in 1960 was less than one million. This sample consists of 75 countries. Their third sample consists of 22 OECD countries with populations greater than one million. Their estimation results, listed in table IV of MRW (1992) provide strong evidence of convergence in all these samples. But the implied values of λ (0.006, 0.01 and 0.017 for non-oil, intermediate and OECD samples, respectively) are much smaller than the textbook Solow model prediction of 2 percent

To estimate (2.35) we use the data for 22 Asian countries. y_{t2} and y_{t1} is per capita income in 1985 and 1960, respectively. We follow MRW in assuming that g=0.02 and δ=0.03 for all countries, figures that are approximately true for the United States. The saving and population growth rates, s and n, are taken to be equal to the respective averages over 1960-85. The results of the OLS estimation for both the unrestricted and restricted forms are listed in table 2.1. The restriction is that the coefficients of the investment and population growth variables are equal in magnitude but opposite in sign. According to the results of both unrestricted and restricted forms, there is no convergence, as the implied λ is nearly zero. Also, the implied value of 0.97 for α, derived from the restricted form, is much higher than the conventional value of about one third. The main reason for such unreasonable estimates of λ and α might be that this formulation does not control for the technology shift term ε, or that regression (2.35) does not take into account a broad concept of capital including both physical and human components. These two possibilities are tested for later in this chapter.

Table 2.1

Single cross-section regression results, 1960-1985

Dependent Variable: $\ln y_{85}$; *No. of observations: 22*

	Unrestricted	Restricted
Constant	-2.688 (-0.93)	-2.053 (-2.22)
$\ln y_{60}$	0.999 (7.41)	0.982 (8.89)
ln(s)	0.55 (3.17)	
$\ln(n+g+\delta)$	-0.801 (-0.82)	
$\ln(s) - \ln(n+g+\delta)$		0.576 (4.47)
$\bar{R}^2$	0.843	0.851
Implied λ	0.00004 (7.41)	0.0007 (8.89)
Implied α		0.97 (5.41)
Wald test of restriction (χ_1^2 value):	0.054 [0.817]	

Figures in bracket are t statistic.

2.5 A critique to the traditional approach

In the traditional approach used by all of the above studies, the conditional variables (investment and population growth) explain the permanent growth component or trend, while the initial condition (initial income level) controls for transitory dynamics. These studies use average values of s, n, and growth rate and, therefore, imply that every economy has a steady state growth path, well approximated by a time trend. This view is necessary for the covariation of the time-averaged growth rate with proposed explanatory variables to indicate something stable. Of course, the average could be a good proxy for the steady state value only if the long run movements in income were well described by smooth time trends that are not affected by ongoing economic disturbances or if there was no significant economic shock during the long run trend under study.

To show that neither of the above scenarios appears to well describe the cross-country income data, we use a simple approach employed by Quah (1993), which can be viewed as an informal way of examining non-stationarities like broken trends and unit roots in time-series data. First, the whole period of 1960-90 is split into two sub-periods, 1960-75 and 1976-90. Then two linear time trends are fitted to the log of per capita GDP for each of the 22 countries separately with a dummy to allow for changes in constant in 1975-76. The regressions are estimated by OLS, with standard errors corrected (where required) for heteroscedasticity and autocorrelation. Figure 2.8 graphs the slope of each country's time trend after 1975-76 against that before. The scatter points are far away from the 45 degree line suggesting a change in the slope of time trend in 1975. According to Wald test results, the time trends exhibit a significant change in 1975 in 12 countries (55 percent of the sample).

Figure 2.9 similarly graphs the standard deviation of log of income fluctuations about the fitted trend line after 1976 against that measure before. As the majority of economies are not near the 45-degree line, there is evidence of a change in the size of the income fluctuations.

Together, Figures 2.8 and 2.9 suggest that the convergence hypothesis can not be examined under the assumption of a fixed steady state as there is no stable growth path and there are large disturbances in most of the countries.

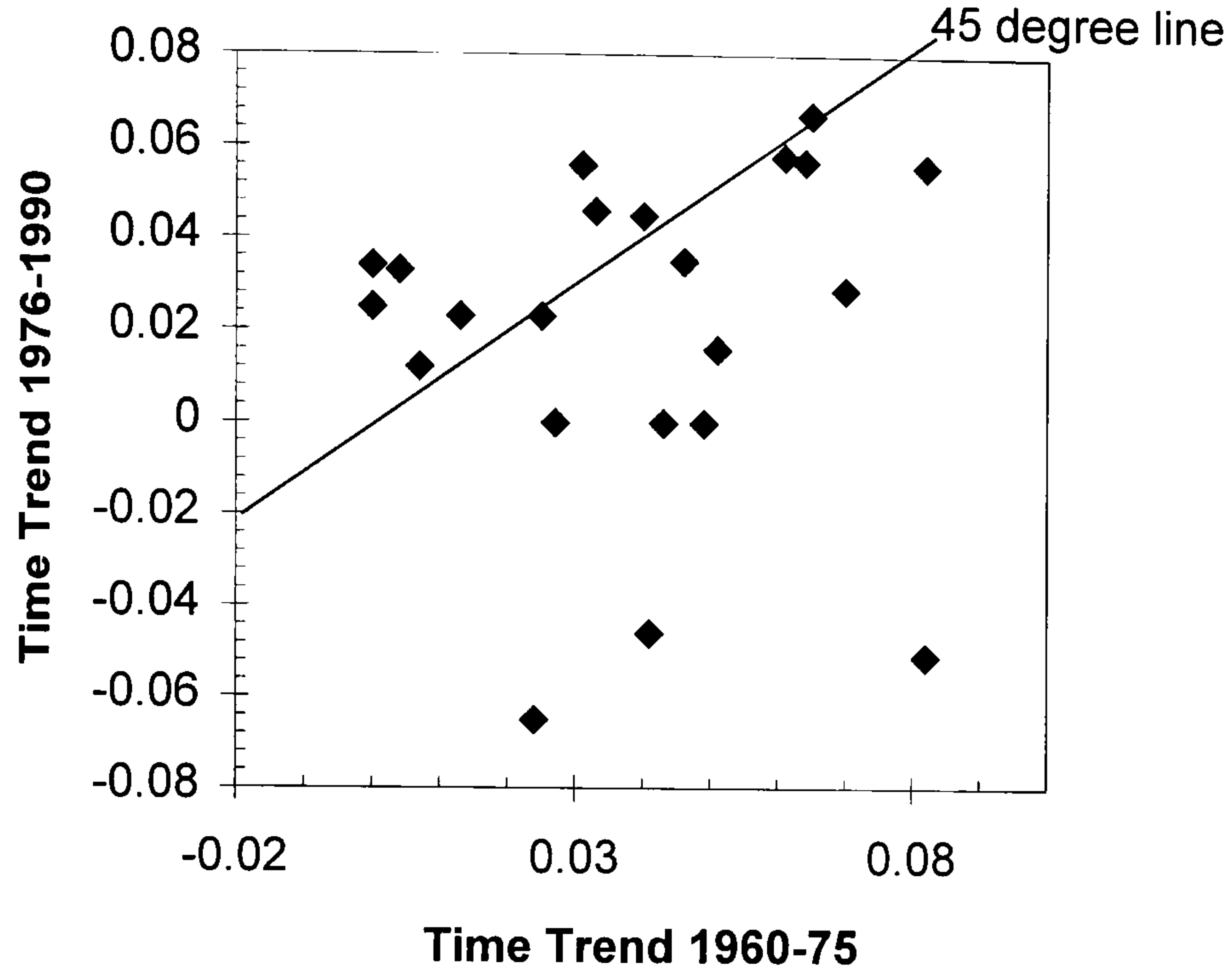
Figure 2.8. Time Trends

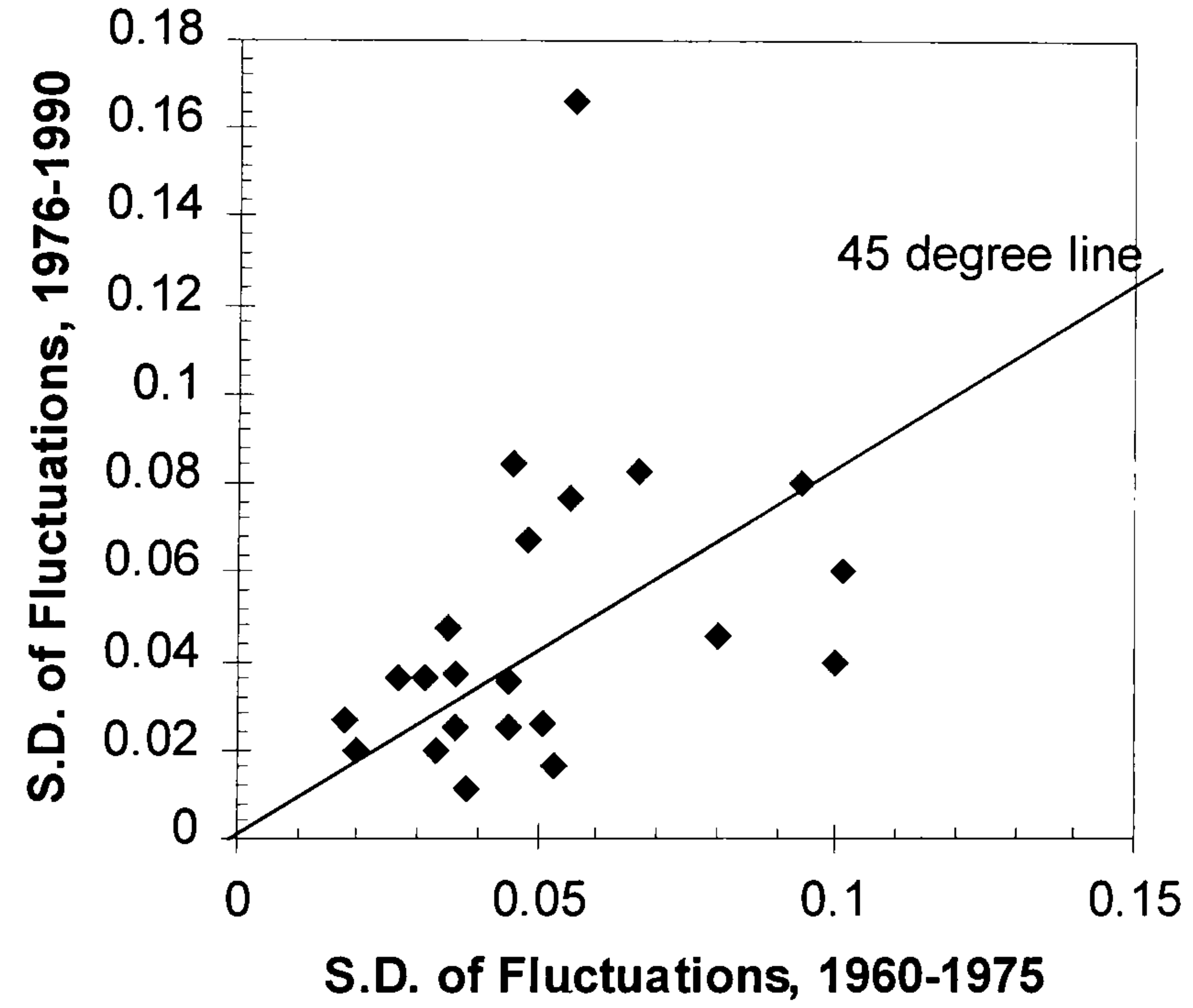
Figure 2.9. Standard Deviation of Fluctuations

Quah (1996a) and Durlauf and Johnson (1995) introduce a new outlook of Baumol's idea about convergence clubs (polarisation, persistent poverty and clustering): per capita income of countries that are identical in their structural characteristics converge to one another in the long run provided that their initial conditions are similar as well. This idea of club convergence is similar but not identical with conditional convergence. The conditional convergence hypothesis suggests that countries that are identical in their fundamentals (and therefore in their dynamic systems) converge to one another regardless of their initial conditions (transitory shocks in this scenario affect the income ranking of an economy in the short run but do not have a lasting effect). But according to the club convergence hypothesis, countries that are similar in their structural characteristics converge to the same steady state equilibrium only if the initial per capita output levels are similar as well (transitory shocks in this scenario may affect the economic performance of a country permanently).

2.6 A dynamic specification

There are two reasons for using a dynamic panel data approach[6]: first, it helps to study the intermediate - rather than just the one-period or alternatively steady state - dynamics of the evolving income distributions across countries. It seems reasonable to assume that in a medium term, there is a steady state growth path that is well approximated by a time trend. Second, the issue of correlation between unobservable A_0 and the observed included variables is not apparent in (2.35) because it has been formulated in terms of income per effective worker. In actual implementation, however, MRW worked with income per capita [as we did in estimation of (2.35)]. A panel data framework provides a better and more natural setting to control for the technology shift term ε. Islam (1995), therefore, reformulates this equation in terms of income per capita. Income per effective labour is

$$(2.36) \qquad \hat{y}_t = \frac{Y_t}{A_t \cdot L_t} = \frac{Y_t}{L_t \cdot A_0 e^{gt}},$$

so that

$$(2.37) \qquad \ln \hat{y}_t = \ln\left(\frac{Y_t}{L_t}\right) - \ln A_0 - gt$$

$$= \ln y_t - \ln A_0 - gt,$$

where y_t is the per capita income, $[Y_t/L_t]$. Substituting for $\hat{y}_t$ into (2.35), we get the usual "growth-initial level" equation

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[6] The econometrics of panel data is discussed in detail in chapter 3.

$$(2.38)\qquad \ln y_{t2} = (1-e^{-\lambda\tau})\cdot\frac{\alpha}{1-\alpha}\cdot\ln(s) - (1-e^{-\lambda\tau})\frac{\alpha}{1-\alpha}\cdot\ln(n+g+\delta)$$
$$+e^{-\lambda\tau}\cdot\ln y_{t1} + (1-e^{-\lambda\tau})\cdot\ln A_0 + g(t2 - e^{-\lambda\tau}\cdot t1)\,.$$

Equation (2.38) is a dynamic panel data model with $(1-e^{-\lambda\tau})\cdot\ln A_0$ as the time-invariant individual country-effect term. The error term of the regression in this formulation varies across countries and time period and has mean equal to zero. By panel data estimation of this equation we can control for the individual country effects. Instead of spanning the entire period in a single cross-section, as MRW did, we can move to cross-sections for the several shorter periods that constitute it.

This equation is based on an approximation around the steady state and is supposed to capture the dynamics towards the steady state. Also, in the single cross-section regression, s and n are assumed to be constant for the entire period. Such an approximation is more realistic over shorter periods of time. If the character of the process of getting near to the steady state remains essentially unchanged over the period as a whole, then considering that process in consecutive shorter time spans should reflect the same dynamics.

An important issue in such a panel data estimation is whether the country and time effects are to be thought of as fixed or random. In the case of random individual effects, it is assumed that the effects are uncorrelated with the exogenous variables included in the model. But since the basis of our argument for the panel approach is the existence of such a correlation between the effects and exogenous variables, the assumption of random effect is not suitable in our case (Islam (1995), p. 1138). The random effect model is an appropriate specification only if we are drawing N individuals from a large population. This is usually the case for household panel studies. In this case, N is usually large and a fixed effects model would lead to an enormous loss of degree of freedom (since we use N-1 dummy variables to consider N individual country effects in the regression).

For our study where we are focusing on a specific set of Asian countries and our inference is restricted to the behaviour of this set of countries, the fixed effects model is the appropriate specification.

If (2.38) is the true model, Baltagi (1995) argues that Least Squares Dummy Variable (LSDV) estimation provides the Best Linear Unbiased Estimator (BLUE) as long as the error term of regression is the standard classical disturbance with mean 0 and variance-covariance matrix $\sigma^2 I_{NT}$, where N is the number of countries and T is the number of time periods.[7]

In order to switch from a single cross-section to a panel framework, we divide the total period into several shorter time spans. The question is how short the spans should be. If time spans are too short, say yearly, disturbances may seem to be large. Since we are interested in long run growth behaviour, it seems better to choose five year spans in order to reduce the influence of short run business cycle fluctuations on the regression disturbance term. Error terms are, therefore, less likely to be serially correlated. Thus, considering the period 1960-1990 for 18 Asian countries, we have six data points for each country: 1965, 1970, 1975, 1980, 1985, and 1990. When t=1965, for example, time t-1 refers to 1960, and saving and population growth variables are averages over 1960-65.[8]

Before we move to LSDV estimation, it is better to see whether dividing the growth period into short run spans has any significant effect. To do that, we implement a pooled regression on the basis of the five-year span data. Table 2.2 presents the results of the estimation. The fit of the pooled regression is much better than that of single cross-section regression in terms of R-squared and t-statistics. The Wald statistic also shows that the restriction holds. However, note that the estimated values of λ and α are nearly the same: The implied values of λ and α are 0.0007 and 0.97 for cross-section regression and 0.0095 and 0.77 for pooled regression, respectively. Therefore, the main effect of panel data is to increase the efficiency of regression results.

We now move to panel estimation and start with testing for the significance of country as well as time effects. The test results are presented in table 2.3. Model I includes all the explanatory variables, country effects and time effects. In models II and III the time effects and country effects are excluded, respectively. Model IV

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[7] Note that as $T \to \infty$, the fixed effect estimator is consistent. However if T is a fixed number and $N \to \infty$ as typical in short labour panels, then only the fixed effects estimator of the coefficients of exogenous variables, and not the fixed effects estimator of the individual effects, is consistent.

[8] There is no data for the whole period 1985-1990 for Iraq and Nepal. Also, since we are going to include the human capital variable in our model later, China and Saudi Arabia are excluded from our sample because there is no data on human capital for these countries. Thus, with six five-year spans for each of the remaining 18 countries, there are 108 observations used in our regressions.

includes only the explanatory variables which is, in fact, the pooled regression reported before. The first row of table 2.3 presents the results of testing model II against model I. According to the F test results (at 5 percent significance level) we conclude that time effects are not significant as a group and, therefore, our regression equation reduces to a one-way panel regression. The second row implies that we reject the null hypothesis that the country effects are all zero. Finally we test for the significance of country effects, with the time effects excluded, by comparing models II and IV. The result confirms the significance of country effects. In the rest of this chapter, we work with model II that includes explanatory variables as well as country dummies.

Table 2.2
Pooled regression results

Dependent Variable: $\ln y_{t2}$; *No. of observations: 108*

	Unrestricted	Restricted
Constant	-0.154 (-0.85)	-0.292 (-2.00)
$\ln y_{t1}$	0.942 (39.85)	0.954 (43.51)
ln(s)	0.181 (5.21)	
$\ln(n+g+\delta)$	-0.105 (-2.25)	
$\ln(s) - \ln(n+g+\delta)$		0.153 (5.68)
$\bar{R}^2$	0.968	0.968
Implied λ	0.012 (39.85)	0.0095 (43.51)
Implied α		0.768 (10.73)
Wald test of restriction (χ_1^2 value):	1.601 [0.206]	

Figures in bracket are t statistic.

Table 2.3
Significance test of country and time effects

Test	F-statistic	Table entry at 5% significance level	Result
II v. I	1.115	F(5,82) = 2.33	Time effects are insignificant
III v. I	2.12	F(17,82) = 1.79	Country effects are significant (in the presence of time effects)
IV v. II	2.18	F(17,87) = 1.78	Country effects are significant (in the absence of time effects)

Model I includes the explanatory variables, country effects, and time effects.
Model II includes the explanatory variables and country effects.
Model III includes the explanatory variables and time effects.
Model IV includes the explanatory variables and the constant term.

Table 2.4 shows the unrestricted and restricted estimation results of LSDV for our 18-country panel. In order to concentrate on the main results, the estimated country effects are not reported here. The results imply that controlling for country-effects leads to more reasonable estimates of the speed of convergence and the elasticity of output with respect to capital, as the implied values of λ and α are now 0.033 and 0.49, respectively. Here, the implied λ is derived from the restricted model because the Wald Statistic shows that the restriction holds.

Since our estimators are asymptotically consistent in the direction of T[9], it seems better to employ as much data as available for each country. It leads us to use an "incomplete" or "unbalanced" panel data set because some countries in our 22 country sample can be traced back longer than the others. Now the sample size equals $\sum_i T_i$ where T_i is the number of observations for ith country. Thus, the sample size increases from 108 for balanced panel to 149 for unbalanced panel. As Baltagi (1995) argues, since we are using a fixed effects model, the LSDV estimation procedure is not affected.

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[9] For more econometric details in this context see Baltagi (1995)

Table 2.4
LSDV balanced panel regression results

Dependent Variable: $\ln y_{t2}$; *No. of observations: 108*

	Unrestricted	Restricted
$\ln y_{t1}$	0.821 (20.4)	0.848 (22.24)
$\ln(s)$	0.236 (3.94)	
$\ln(n+g+\delta)$	-0.094 (-2.04)	
$\ln(s) - \ln(n+g+\delta)$		0.147 (4.09)
$\bar{R}^2$	0.974	0.973
Implied λ	0.039 (20.4)	0.033 (22.24)
Implied α		0.49 (6.71)

Wald test of restriction (χ_1^2 value): 3.417 [0.065]

Figures in bracket are t statistic.

The estimation results, employing White's heteroscedasticity-consistent standard errors, are listed in table 2.5. The Wald statistic ($\chi_1^2=0.43$) implies that the restriction holds. The implied values of λ and α, derived from the restricted regression, are 0.033 and 0.35, respectively. The value of λ means that 3.3 percent of the gap between poor and rich economies in our 22 Asian countries sample vanishes every year. This is not very different from the value of $\lambda=0.02$ predicted by the Neoclassical growth model and derived by Barro and Sala-i-Martin (1995) for different groups of economies.

It should be noted that the model supports convergence only after controlling for country specific effects. That is why there seems to be no evidence of convergence among the Asian economies in figure 2.4. The value of α=0.35, resulting from our estimation, is also very close to the conventional value of one third.

Table 2.5
LSDV unbalanced panel regression results

Dependent Variable: $\ln y_{t2}$*; No. of observations: 149*

	Unrestricted	Restricted
$\ln y_{t1}$	0.857	0.847
	(23.09)	(25.39)
ln(s)	0.062	
	(0.73)	
ln(n+g+δ)	-0.109	
	(-1.78)	
ln(s) - ln(n+g+δ)		0.084
		(1.74)
$\bar{R}^2$	0.966	0.966
Implied λ	0.031	0.033
	(20.83)	(25.1)
Implied α		0.352
		(4.03)
Wald test of restriction (χ_1^2 value):	0.432 [0.511]	

Figures in bracket are t statistic.

2.7 Human capital

We now examine the effect of adding the human capital accumulation into the Solow model. At the theoretical level, properly accounting for human capital may change one's view of the nature of the growth process. Lucas (1988), for instance, assumes that the returns to all reproducible capital (human plus physical) are constant. Romer (1986) goes further by assuming that there are increasing returns to a broad concept of capital. At the empirical level, in regression (2.38) human capital is an omitted variable.

Let the augmented neoclassical production function be

$$Y_t = K_t^{\alpha} \cdot H_t^{\gamma} \cdot (A_t \cdot L_t)^{1-\alpha-\gamma} \tag{2.39}$$

where H is the stock of human capital. Let each country augment its physical and human capital stocks at the constant saving rates s_k and s_h while both stocks depreciate at the same rate δ. The final equation analogous to (2.38) in this case is

$$\begin{aligned} \ln y_{t2} &= (1-e^{-\lambda\tau})\frac{\alpha}{1-\alpha-\gamma}\cdot\ln(s_k) \\ &+ (1-e^{-\lambda\tau})\frac{\gamma}{1-\alpha-\gamma}\cdot\ln(s_h) \\ &- (1-e^{-\lambda\tau})\frac{\alpha+\gamma}{1-\alpha-\gamma}\cdot\ln(n+g+\delta) + e^{-\lambda\tau}\cdot\ln y_{t1} \\ &+ (1-e^{-\lambda\tau})\cdot\ln A_0 + g(t2-e^{-\lambda\tau}t1). \end{aligned} \tag{2.40}$$

First, even if ln(s_h) is independent of the right hand side variables, the coefficient on ln(s_k) is greater than $\alpha/(1-\alpha)$. Hence, the presence of human capital accumulation increases the impact of physical capital accumulation on income.

Second, the coefficient on ln$(n+g+\delta)$ is now larger in absolute value than the coefficient on ln(s_k). In this model, therefore, high population growth lowers income per capita because the amounts of both physical and human capital must be spread more thinly over the population.

The broad concept of investment in human capital, besides education, includes health, among other things. However, since there is no data on such other measures of human capital investment for the whole of our sample, our data on human capital investment only reflect the level of education.

MRW use a proxy for the human capital accumulation (s_h) that measures approximately the percentage of the working age population that is in secondary school. But using such a proxy leads to some problems: they first begin with data on the fraction of the eligible population (aged 12 to 17) enrolled in secondary school obtained from the UNESCO yearbook. Then they multiply this enrolment rate by the fraction of the working age population that is of school age (aged 15 to 19). As they rightly mention 'this variable, which we call SCHOOL, is clearly imperfect: the age ranges in the two data series are not exactly the same, the variable does not include the input of teachers, and it completely ignores primary and higher education' (MRW, p. 419).

There is no data set for the variable SCHOOL for all of the Asian countries in our sample. Barro and Lee (1993) have made important progress in putting together a human capital data set for a wide cross-section of countries. They have constructed a human capital variable, called HUMAN, which gives the average schooling years in the total population over age 25. While the SCHOOL is based on secondary school information only, HUMAN includes schooling at all levels, primary, secondary and higher, complete and incomplete. HUMAN gives a direct measure of the stock of human capital, and hence makes it possible to estimate the equation in which human capital appears as a stock.

Table 2.6 shows the results of the estimation of (2.40). The sample is the same as that used in table 2.4. In general, the results are broadly similar to the balanced panel results that we obtained earlier without human capital. Inclusion of the human capital variable does not change the speed of convergence significantly, as the implied value of λ has decreased only slightly (from 0.033 to 0.027). Note also that the physical capital coefficient (in restricted form) is very similar, 0.147 and 0.197, respectively, in the models excluding and including the human capital.

The similarity of the results mentioned above is not surprising in the light of the fact that the human capital variable does not prove to be significant and appears with the wrong sign, -0.077. Using this figure, the implied values of α and γ are 0.806 and -0.315, respectively (the latter is, however, insignificant).

This anomalous result regarding the role of human capital in the growth process could be explained by two facts. *First*, there may be a difference between the theoretical variable H in the production function and the actual variable used in regression. The enrolment rates or the rate of literacy were always very partial measures of the rate of investment in human capital and can not account for the differences in the quality of schooling. Empirically this results in a negative temporal relationship between the human capital variable used and economic growth within countries. Our results show that even Barro and Lee's HUMAN variable is not free from the issue of discrepancy between the quantity and quality of education.

Second, there may be some specification errors in the production function with respect to human capital. Romer (1989) and Benhabib and Spiegel (1994), among others, have tried to introduce different production functions in order to prove that the human capital plays a very important role in the process of economic growth.

Table 2.6

LSDV balanced panel regression results with human capital

Dependent Variable: $\ln y_{t2}$; *No. of observations: 108*

	Unrestricted	Restricted
$\ln y_{t1}$	0.841 (16.87)	0.875 (20.73)
$\ln(s_k)$	0.244 (3.99)	
$\ln(s_h)$	-0.041 (-0.69)	
$\ln(n+g+\delta)$	-0.090 (-1.96)	
$\ln(s_k) - \ln(n+g+\delta)$		0.197 (4.02)
$\ln(s_h) - \ln(n+g+\delta)$		-0.077 (-1.49)
$\bar{R}^2$	0.973	0.973
Implied λ	0.035 (16.87)	0.027 (20.73)
Implied α		0.806 (2.83)
Implied γ		-0.315 (-1.17)

Wald test of restriction (χ_1^2 value): 1.635 [0.201]

Figures in bracket are t statistic.

2.8 Country effects

In the case of LSDV estimation of (2.38), the time-invariant country effect terms $(1-e^{-\lambda\tau}).\ln A_{0,i}$ are simply the estimated coefficient of country dummies. We compute the $\ln A_{0,i}$ by dividing the estimated country effects by $(1-e^{-\lambda\tau})$, where $e^{-\lambda\tau}$ is the estimated coefficient of $\ln y_{t1}$.

These figures are presented in table 2.7. Given $A_{0,min}$ as the lowest value of A_0 (in the present case, that of Myanmar), the relative position of countries can be highlighted by an A_0 index which is computed by dividing the A_0 of each country by that of Myanmar. The value of A_0 index, presented in the fourth column of table 2.7, ranges from one to 19.9 demonstrating that the Asian countries do vary considerably in this regard. Most countries have A_0 less than 5 while Israel, Japan, Korea, Singapore, Taiwan and Hong Kong have A_0 greater than 6.

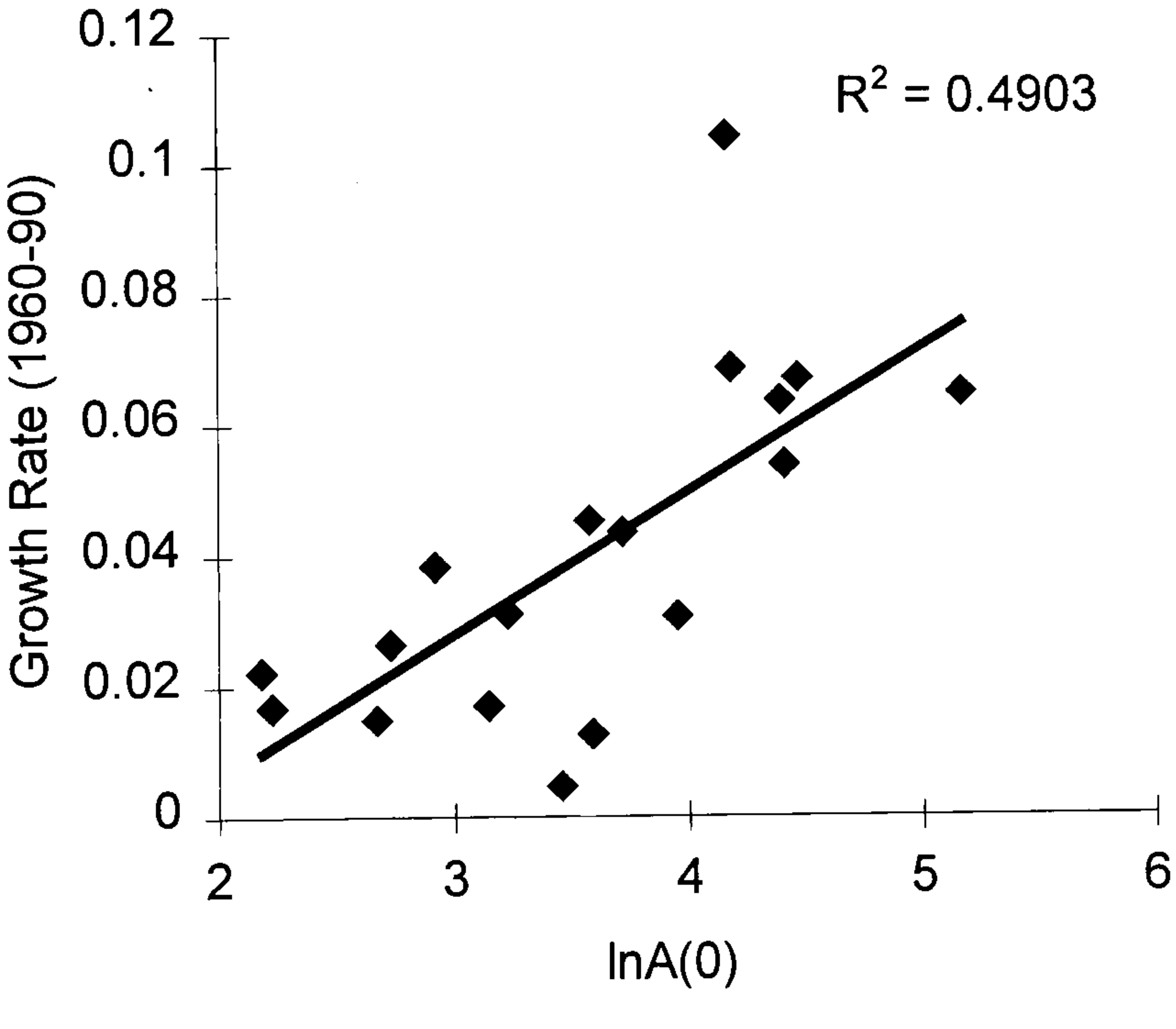
Table 2.7
Estimated Country Effects and Average Growth Rates

Country	Country Effect	$\ln A_0$	$A_0/A_{0,min}$	Rank	Growth Rate (60-85)
Bangladesh	0.547	3.589	4.08	9	0.013
Hong Kong	0.789	5.173	19.91	1	0.065
India	0.339	2.224	1.04	17	0.017
Indonesia	0.446	2.922	2.10	14	0.038
Iran	0.527	3.456	3.58	11	0.005
Israel	0.636	4.169	7.30	6	0.105
Japan	0.673	4.415	9.33	3	0.054
Jordan	0.493	3.229	2.85	12	0.031
Korea	0.638	4.185	7.41	5	0.069
Malaysia	0.567	3.717	4.64	8	0.044
Myanmar	0.333	2.182	1	18	0.022
Pakistan	0.461	2.730	1.73	15	0.026
Philippines	0.408	2.671	1.63	16	0.015
Singapore	0.682	4.472	9.90	2	0.067
Sri Lanka	0.480	3.147	2.63	13	0.017
Syria	0.603	3.954	5.88	7	0.031
Taiwan	0.670	4.396	9.16	4	0.064
Thailand	0.546	3.577	4.04	10	0.046

Islam (1995) interprets the A_0 index as a measure of efficiency with which the economies are transforming their capital and labour resources into output. We may, therefore, think of the A_0 index as a good proxy for the conventional concept of total factor productivity (TFP).[10]

Finally, we examine the importance of A_0 term in explaining growth. According to the Solow model, steady state growth is given by the exogenous rate of technical progress. The focus here is, therefore, on growth in transition: can A_0 affect transitional growth? Figure 2.10 represents a scatter plot of the average growth rate of per capita GDP for the period 1960-90 and lnA_0. We find a strong positive relationship between the two (the simple correlation coefficient is 0.7).

Figure 2.10. Scatter Plot of Growth Rate versus lnA(0)



Since higher values of A_0 are associated with higher growth rates, the next question is to specify the determinants of A_0.[11]

2.9 Conclusion and extensions

Taking Solow's growth model as a starting point, this chapter has re-examined the Summers-Heston data set to test for convergence across Asian economies. A linear

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[10] While the TFPs are computed using the individual country time series data, the A_0 index is derived on the basis of cross country comparisons.

[11] This is the subject of chapters 3 and 4.

cross-section regression exhibits neither evidence of convergence nor a reasonable estimate of the elasticity of output with respect to physical capital. This problem is overcome through a panel-data approach, which yields more reasonable estimates for the speed of convergence and the capital share. The results highlight the significant differences in the aggregate production functions.

These results shed light on the issue of policy activism. The faster rate of convergence may appear to reinforce the policy-irrelevance ideas ascribed to the Solow model. Traditionally, only the saving and population growth rates were thought to be the variables for policies to be directed to. However, the panel data model here highlighted the role of the technology term A_0 as a determinant of the steady state level of income.

The insignificance of the estimated parameter on human capital should not be taken as conclusive evidence. Many economists emphasise the importance of human capital in the process of economic growth. The insignificance of this variable might be a result of measurement error. The specification of model, on the other hand, may be wrong; an endogenous growth model could highlight the role of human capital in economic growth.

Finally, the chapter derived an index of total factor productivity for the Asian economies. The index significantly correlates with growth rates. The identification of factors affecting the technology term A_0 is, therefore, very important in the study of economic growth and policy making issues.

The economic growth debate is still going on and there have been many contributions during the last few years. For instance, it is shown that a negative correlation between growth rates and the initial level of income in a cross-section regression says nothing about the poor catching up with the rich. Quah (1996b), among others, points out that ‘what is important for convergence is how economies perform relative to each other, not how a single economy performs relative to its own history’ (p. 1064). We saw that the assumption of every economy having a steady state growth path, well-approximated by a time trend, is not verified for a group of Asian countries. Since panel data approach also concerns with steady state (although for shorter spans of time), its estimation results should not be taken as much reliable.

Chapter 3

Empirical Investigation of the Determinants of Economic Growth

3.1 Introduction

Growth rates vary enormously across countries over long periods of time. While Singapore experienced high average per capita growth rate of 7.3 percent over the period 1960-85, the per capita GDP in Iraq increased only by an average rate of 1.1 percent during the same period. The empirical econometric analysis of this chapter can be viewed as a study of the characteristics that make it likely for a country to end up in either of these two extreme situations.

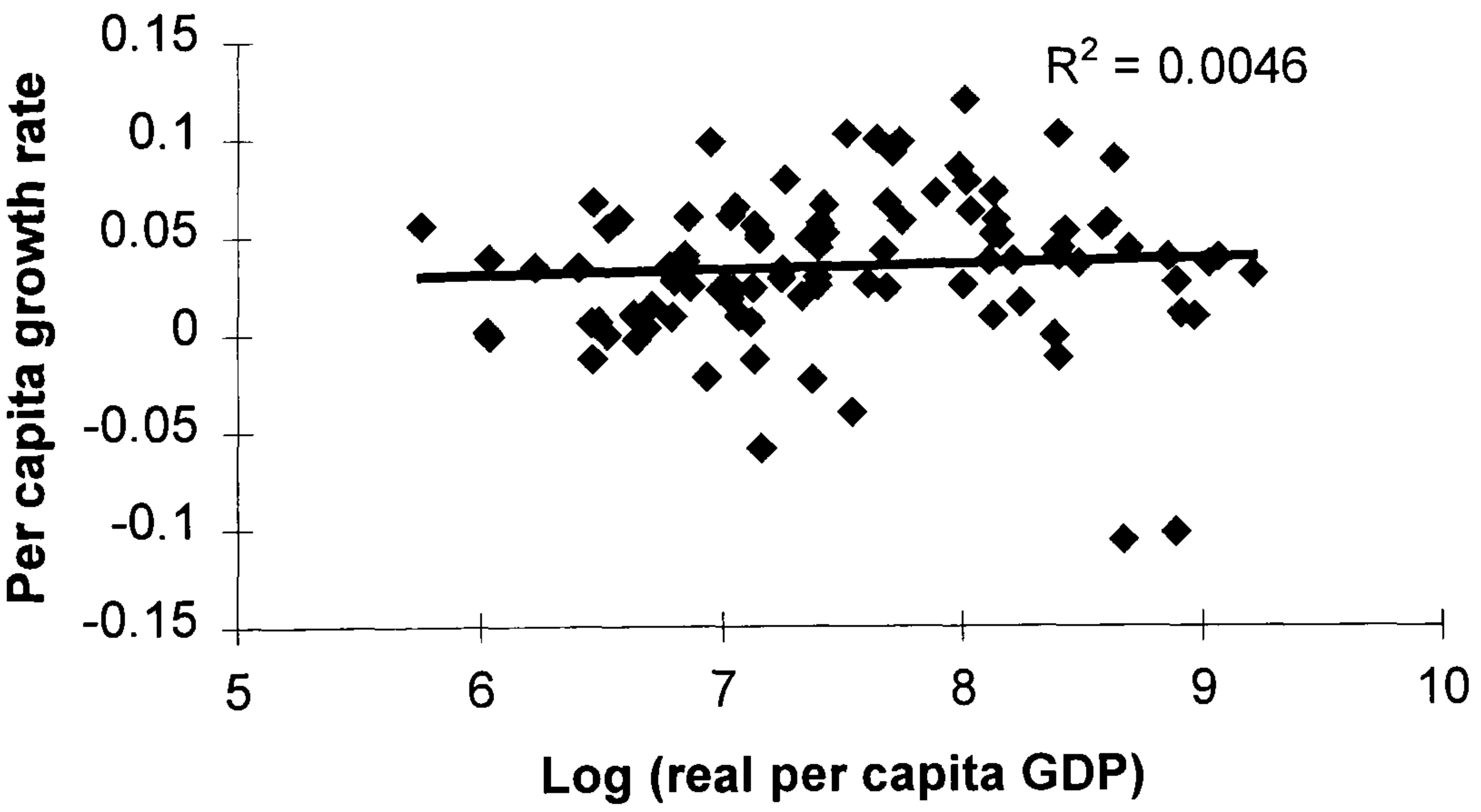
One hypothesis from the Solow-Swan-Ramsey model of Chapter 2 is that of absolute convergence: poorer countries typically grow faster per capita and tend to catch with the richer countries. This hypothesis implies that the growth rate of real per capita GDP, averaged over five year spans, would tend to be inversely related to the level of real per capita GDP in the starting year of each span. Figure 3.1 shows that this proposition fares badly in terms of the panel data: for 90 panel observations, the five-year average growth rate is basically unrelated to the log of per capita GDP in the starting year ($R^2 = 0.0046$). This, in fact, accords with models that assume constant returns to a broad concept of reproducible capital, which includes human capital. In these models, the growth rate is independent of the starting level of income.

Thus any hope of reconciling the convergence hypothesis with the data has to rely on the concept of conditional convergence. We have to examine the relation between the growth rate and the starting position after holding constant some variables that distinguish the countries. In this chapter, therefore, we study the effects of different factors on economic growth in an *ad hoc* model.

This chapter, in fact, provides a bridge between the concept of conditional convergence, explained in chapter 2, and the endogenous growth models of subsequent chapters. Absolute convergence is undoubtedly a consequence of the neoclassical (exogenous) growth model, in which the differences between countries are determined by exogenously given technical progress. Now consider an endogenous growth model.

Human capital plays a special role in a number of models of endogenous growth. Barro (1991) proves that a country's subsequent growth rate is positively related to its initial human capital. Moreover, given the human capital variable, he shows that subsequent growth is substantially negatively related to the initial level of per capita GDP. A poor country tends to grow faster than a rich country, but only for a given quantity of human capital, that is, only if the poor country's human capital exceeds the amount that typically accompanies the low level of per capita income. This is the concept of conditional convergence.

Figure 3.1. Per capita growth rate versus initial per capita GDP (five-year average growth rates for 18 Asian countries during 1960- 85)



That is why there is not much to learn from the concept of convergence because it does not increase our knowledge about the differences between the neoclassical exogenous growth model and a variety of endogenous growth models. This chapter, instead, applies an *ad hoc* growth model, which studies the effects of state and control variables on the growth rate of per capita GDP using a sample of 18 Asian countries. Section 3.2 introduces the determinants of growth and classifies them into two groups:

state and control variables. Section 3.3 provides a brief description of the panel data econometric techniques used in the chapter. Data and estimation results are discussed in section 3.4, followed by a general conclusion in section 3.5.

3.2 Determinants of economic growth

We use an empirical framework, similar to that of Barro (1991) that relates the real per capita growth rate to two kinds of variables[1]. First, we use the initial levels of the state variables, such as the stock of physical capital and the stock of human capital in the form of educational attainment and health. The second kind of variables is the control and environmental variables, which in part could be controlled by government or private agents.

3.2.1 State variables

We use two proxies for the human capital stock, the first one of which is the school attainment at various levels, as constructed by Barro and Lee (1993), and the second one is the standard United Nations number of life expectancy at birth (to represent the initial level of health).

The data on physical capital is not available and even if it were, it would be unreliable because it depends on arbitrary assumptions about depreciation and also relies on inaccurate measures of benchmark stocks and investment flows. As an alternative to using the limited data that are available on physical capital, we assume that for any given values of schooling and health, a higher level of initial per capita GDP reflects a greater stock of physical capital per person (or a larger quantity of natural resources, as in the oil-based economies).

Therefore, we consider the following functional form

$$Dy_{it} = F(y_{i,t-1}, h_{i,t-1}; \ldots), \tag{3.1}$$

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[1] There are, however, some differences between the procedures used in the two studies; the number and definition of variables are different and also the estimation method employed here (panel data estimation) differs from the cross-sectional analysis used by Barro (1991).

where Dy_{it} is per capita growth rate of country i in period t and $y_{i,t-1}$ and $h_{i,t-1}$ are initial per capita GDP and initial human capital per person (based on measures of educational attainment and health), respectively.

The Solow-Swan-Ramsey model and some of its extensions (such as Mankiw, Romer and Weil [1992]) predict that, for given values of the control variables denoted by '...' in (3.1), an equiproportionate increase in $y_{i,t-1}$ and $h_{i,t-1}$ would reduce Dy_{it}. That is, because of diminishing returns to reproducible factors, a richer country (with higher levels of y and h) tends to grow at a slower rate. However, when there is an inbalance between $y_{i,t-1}$ and $h_{i,t-1}$ (in an endogenous growth model), for any given y_{t-1} , a higher h_{t-1} tends to raise the growth rate.

Empirically, we enter the initial level of per capita GDP into the growth equation in the form of $log(y_{i,t-1})$ so that the coefficient on this variable represents the rate of convergence. The variable $h_{i,t-1}$ is represented by average years of educational attainment at various levels and by the logarithm of life expectancy at birth.

In their technological diffusion theory, Nelson and Phelps (1966) assume that more human capital raises the ability to absorb new technologies. This process happens when, for instance, an increase in human capital lowers the cost of imitating the ideas that were discovered elsewhere. This effect means that a higher level of human capital raises the responsiveness of the growth rate to reductions in the initial level of per capita GDP. It means that the reaction of Dy_{it} to $log(y_{i,t-1})$ - the speed of convergence - is greater the higher $h_{i,t-1}$. We follow Benhabib and Spiegel (1993) in capturing this effect empirically by including in the regressions not only the level variables, $log(y_{i,t-1})$ and $h_{i,t-1}$, but also the interaction term, $log(y_{i,t-1}).h_{i,t-1}$. A negative coefficient on the interaction term means that a higher $h_{i,t-1}$ speeds up convergence.

3.2.2 Control and environmental variables

In the Solow-Swan-Ramsey model, the control and environmental variables determine the steady-state level of output per effective worker. A change in any of these variables affects the steady state level of output but not the long run growth rate. The long run or steady state growth rate is given by the rate of exogenous technological progress. In contrast, in the endogenous growth models, these variables affect the growth rate of output permanently. For instance, in R&D based endogenous growth models, control and environmental variables that affect R&D intensity, also influence long run growth rates. These variables would include preferences for saving and fertility, government policies with respect to spending and market distortions and so on. Some of these variables can be controlled by government as policy variables while others can not be controlled (at least instantly) by any economic agent and are subject to environmental changes (such as fertility rate).

The control and environmental variables we consider in different regressions below are the ratio of real gross domestic investment (private plus public) to real GDP; the ratio of government consumption net of spending on defence and education to GDP; the black market premium on foreign exchange; a measure of political instability; the growth rate of terms of trade; total fertility rates; the growth rate of population; the share of population under 15 in total population; and the ratio of government war and defence expenditures to GDP. In order to take account of the likely endogeneity of these variables, we could use their lagged values as instruments. The small size of our sample, however, does not allow us to do so.

3.3 Panel data econometrics

In this section we describe some common econometric models for panel data[2]. We start with one way or one factor design which allows for individual country effects to be taken into account. Then we generalise to a two way or two factor case, which considers time effects as well.

3.3.1 One way fixed and random effects models

The models estimated with this design are of the form

$$y_{it} = \mu_i + \beta'\mathbf{x}_{it} + \varepsilon_{it} \quad i=1,...,N; \quad t=1,...,T \tag{3.2}$$

with *i* denoting households, firms, or as in our case, countries, and *t* denoting time. Subscript *i*, therefore, denotes the cross-section dimension whereas *t* denotes the time series dimension. β is $K\times1$ and x_{it} is the ith observation on K explanatory variables. μ_i denotes the unobservable country specific effect and ε_{it} denotes the remainder classical stochastic disturbance with

$$(3.3) \qquad E[\varepsilon_{it}] = 0 \qquad \text{and} \qquad Var[\varepsilon_{it}] = \sigma_\varepsilon^2$$

Fixed effects model

A common formulation of the model assumes that differences across countries can be captured by differences in the constant term. μ_i is a separate constant term for each country. Thus the model may be written

$$(3.4) \qquad \begin{aligned} y_{it} &= \alpha_1 d_{1it} + \alpha_2 d_{2it} + \cdots + \beta'\mathbf{x}_{it} + \varepsilon_{it} \\ &= \alpha_i + \beta'\mathbf{x}_{it} + \varepsilon_{it} \end{aligned}$$

where the α_i's are country specific constants, and the d_j's are group specific dummy variables which equal 1 only when $j=i$. This is usually referred to as the *Least Squares Dummy Variable (LSDV)* model.

The fixed effects model is a classical regression model. The only complication for the usual least squares procedure is that N may be very large so that the usual procedures for computing least squares coefficients are cumbersome to apply[3].

Random effects model

The fixed effects model is a reasonable specification when we can be confident that the differences between units can be viewed as parametric shifts of the regression function. This model might be viewed as applying only to the cross-sectional units in the study, not to additional ones outside the sample. For example, our intercountry comparison may well include the full set of countries for which it is reasonable to assume that the model is constant. In other settings, it might be more appropriate to view individual specific constant terms as randomly distributed across cross-sectional units.

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[2] Baltagi (1995) is a valuable reference in the econometrics of panel data.

[3] The model may be estimated in a simpler form by exploiting the algebra of least squares. The reader is referred to any of the standard texts for details, such as W. H. Greene (1991). B. Baltagi (1995) is also recommended as a more advanced textbook.

This would be appropriate if we believed that the sample cross-sectional units were drawn from a large population.

In this case, μ_i is an individual specific disturbance. The model is

(3.5) $$y_{it} = \alpha + \beta'\mathbf{x}_{it} + \varepsilon_{it} + u_i$$

where

$$E[u_i] = 0, \qquad Var[u_i] = \sigma_u^2, \qquad Cov[\varepsilon_{it}, u_i] = 0.$$

The *Random Effects Model (REM)* is a generalised regression model. The overall disturbances has variance

(3.6) $$Var[\varepsilon_{it} + u_i] = \sigma^2 = \sigma_\varepsilon^2 + \sigma_u^2.$$

But, for a given *i*, the disturbances in different periods are correlated by virtue of their common component,

(3.7) $$Cor[(\varepsilon_{it} + u_i),(\varepsilon_{is} + u_i)] = \rho = \sigma_u^2 / \sigma^2.$$

The efficient estimator is generalised least squares. For estimation purposes, we use a two step procedure. The variance components are first estimated by using the residuals from ordinary least squares regression. Then, Feasible Generalised Least Squares (*FGLS*) estimates are computed using the estimated variances.

3.3.2 Two way fixed and random effects

The panel data estimator also allows two way or two factor fixed and random effects models. The fixed effects model for a two way design is

(3.8) $$y_{it} = \alpha_0 + \alpha_i + \gamma_t + \beta'\mathbf{x}_{it} + \varepsilon_{it}.$$

Notice that this model has an overall constant as well as a group effect for each group and a time effect for each period. The problem of multicollinearity - the time and group dummy variables both sum to one - is avoided by imposing the restrictions

(3.9) $$\sum_i \alpha_i = \sum_t \gamma_t = 0.$$

The random effects model for a two way design is

(3.10) $$y_{it} = \alpha + \beta'\mathbf{x}_{it} + \varepsilon_{it} + u_i + w_t.$$

Since our estimation results given later reject the two way models, they are not described further here[4].

3.3.3 Testing for fixed effects

The distinction between the fixed and random effects models depends on the validity of the assumption in the error component regression model (3.2) that $E[(\mu_i + \varepsilon_{it})|x_{it}] = 0$. This is important given that the disturbances contain individual invariant effects (the μ_i) which are unobserved and may be correlated with the x_{it}. There is no justification for treating the individual effects as uncorrelated with the other regressors, as is assumed in the *REM*. If there is such a correlation, the GLS estimator $\hat{\beta}_{GLS}$ becomes biased and inconsistent for β. However, the *LSDV* approach wipes out these μ_i's and leaves the *LSDV* estimator $\hat{\beta}_{LSDV}$ unbiased and consistent for β. The *REM* treatment, therefore, may suffer from the inconsistency due to omitted variables[5].

In order to test for orthogonality of the random effects and the regressors, the specification test devised by Hausman (1978) can be used. The test is based on the idea that under the null hypothesis of no correlation, H_0: $E[(\mu_i + \varepsilon_{it})|x_{it}] = 0$, both *OLS* in *LSDV* and *GLS* in *REM* are consistent, but *OLS* is inefficient. Under the alternative, however, they have different probability limits and *OLS* is consistent but *GLS* is not. In fact, $\hat{\beta}_{LSDV}$ is consistent whether H_0 is true or not, while $\hat{\beta}_{GLS}$ is BLUE, consistent and asymptotically efficient under H_0, but is inconsistent when H_0 is false. Therefore, under the null hypothesis, the two estimates should not differ systematically, and a test can be based on the difference $(\hat{\beta}_{LSDV} - \hat{\beta}_{GLS})$. The other ingredient for the test is the variance of the difference vector

$$(3.11)\quad \mathrm{Var}[\hat{\beta}_{LSDV} - \hat{\beta}_{GLS}] = \mathrm{Var}[\hat{\beta}_{LSDV}] + \mathrm{Var}[\hat{\beta}_{GLS}]$$
$$-\mathrm{Cov}[\hat{\beta}_{LSDV}, \hat{\beta}_{GLS}] - \mathrm{Cov}[\hat{\beta}_{LSDV}, \hat{\beta}_{GLS}]'.$$

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[4] See Baltagi (1995) for details.

[5] See Hausman and Taylor (1981).

The essential result is that the covariance of an efficient estimator, $\hat{\beta}_{GLS}$, with its difference from an inefficient estimator, $(\hat{\beta}_{LSDV} - \hat{\beta}_{GLS})$, is zero. This implies that

$$(3.12) \qquad \mathrm{Cov}[(\hat{\beta}_{LSDV} - \hat{\beta}_{GLS}), \hat{\beta}_{GLS}] = \mathrm{Cov}[\hat{\beta}_{LSDV}, \hat{\beta}_{GLS}] - \mathrm{Var}[\hat{\beta}_{GLS}] = 0,$$

or that

$$(3.13) \qquad \mathrm{Cov}[\hat{\beta}_{LSDV}, \hat{\beta}_{GLS}] = \mathrm{Var}[\hat{\beta}_{GLS}].$$

Inserting this in (3.11) produces the required variance matrix for the test,

$$(3.14) \qquad \mathrm{Var}[\hat{\beta}_{LSDV} - \hat{\beta}_{GLS}] = \mathrm{Var}[\hat{\beta}_{LSDV}] - \mathrm{Var}[\hat{\beta}_{GLS}] = \Sigma.$$

The chi-squared test is based on

$$(3.15) \qquad H = [\hat{\beta}_{LSDV} - \hat{\beta}_{GLS}]' \ \hat{\Sigma}^{-1} \ [\hat{\beta}_{LSDV} - \hat{\beta}_{GLS}].$$

For $\hat{\Sigma}$, we use the estimated variance matrices of the slope estimator in the *LSDV* model and the estimated variance matrix in the *REM* model, excluding the constant term. Large values of the H statistic, compared to the critical value, argue in favour of the *LSDV* model over the *REM* model.

3.4 Data and regression results for growth rates

The sample of 18 Asian countries, listed in Table A2 in the Appendix, covers a broad range of experience from high- to low-growth-rate countries. The internationally adjusted data used are collected by Summers and Heston (1988) and those on schooling are from Barro and Lee (1993). The countries were selected according to availability of data. The main analysis deals with growth rate over up to five time spans (i.e. 1960-65, 1965-70, 1970-75, 1975-80 and 1980-85) and thereby contains a limited amount of time series variation for (relatively) high amount of cross-country observations. This results in consistent estimations as, in the fixed effects panel estimation methods employed here, the consistency results hang on increasing number of cross sections, not time series. Table A1 in the Appendix defines the variable symbols used for the estimation purposes.

Table 3.1 reports the basic regression estimation results using four different measures of educational attainment in order to choose one of them as the best proxy for educational attainment. These four measures are total gross enrolment ratio, average years of schooling, percentage of school attainment and percentage of school completion. They are also categorised according to sex (male and female) and school level (primary, secondary and higher education). According to the hypothesis test results, both the explanatory variables and the country effects (each as a whole group) are significant[6]. Also the results of the Hausman tests reject the random effects hypothesis in favour of the fixed effects (H=33.8 with d.f.=14 and p=0.00). However, the estimated country effects are not reported in Tables 3.1 to 3.3. Since the two-way fixed and random effect models are rejected, there are no time effects in the reported results. Total gross enrolment ratio is believed to best explain the growth rate as regression (1) has the highest R-squared value. From now on, therefore, our interpretation of the estimated coefficients is based on the estimation results of regression (1).

-Initial per capita GDP. The variable L(Y0) is the log of real per capita GDP for the starting year of each five-year span. The estimated coefficient confirms the conditional convergence reported in the last chapter, but the magnitude of the coefficient, 12 percent (which is the speed of convergence), is much higher than that reported in various studies[7].

-Educational attainment. In general, the best result (in terms of R^2) was derived from the regression, which employs the gross enrolment ratio for primary, secondary and higher

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[6] Consider regression model (I) including constant term only, model (II) including country effects only, model (III) including explanatory variables only, and model (IV) including explanatory variables and country effects. We performed the following Likelihood Ratio hypothesis tests

Test	Chi-squared	d.f.	Prob. Value
Model (II) vs (I)	26.2	17	0.071
Model (III) vs (I)	45.3	14	0.000
Model (IV) vs (I)	99.4	31	0.000
Model (IV) vs (II)	73.1	14	0.000
Model (IV) vs (III)	54.1	17	0.000

Which support the significance of explanatory variables as well as country effects.

[7] Barro and Sala-i-Martin (1992) and Mankiw, Romer and Weil (1992) report an estimation of 2 percent for the speed of convergence across other sample of countries.

education in male and female population as proxy variables for educational attainment. These variables, based on information from the United Nations, measure the number of students enrolled in the designated grade levels relative to the total population of the corresponding age group.

In an attempt to measure possible differences in the quality of education across countries, after choosing the gross enrolment ratio as the best candidate for educational attainment, the other three measures of educational attainment were also added as extra explanatory variables. Regressions (5) to (7) in Table 3.2 present the results. The joint F-test results support the insignificance of the other three educational measures.

In regression (1), the hypothesis that all six schooling variables do not enter into the growth equation is rejected at 5 percent level of significance with an F-value of 3.2 (p-value = 0.01). Also joint tests have been carried out for the significance of different schooling subgroups: male schooling variables are insignificant (p-value = 0.47); female schooling variables are significant (p-value = 0.003); primary schooling variables are significant (p-value = 0.004); secondary schooling variables are insignificant (p-value = 0.15); and higher schooling variables are insignificant (p-value = 0.57).

A puzzling finding in the estimation results of regression (1) is that the only highly significant educational variable, PENRF (female gross enrolment ratio for primary education), enters negatively in the growth rate equation; the estimated coefficient is -0.19 for female primary education. The results here are similar to those of Barro and Sala-i-Martin (1995) in that the most significant subgroup of schooling is the female schooling; their explanation for the negative coefficients is that a large spread between male and female schooling is a good measure of backwardness; less female schooling, therefore, signifies more backwardness and accordingly higher growth potential through the convergence mechanism. One problem with these results is that the school enrolment ratios might proxy for the flow of investment in human capital, rather than the initial stock of human capital. In this case, the causation need not be simply in the direction from an initial stock of human capital to a subsequent rate of growth.

-Life expectancy. The variable appears in the form of log of life expectancy at birth. The significant estimated coefficient is 0.305. The reason of such an effect may be that life expectancy proxies for features other than good health that reflects desirable performance of a society. Higher life expectancy might, for example, be a good proxy for better work habits and a higher level of skills.

-Investment ratio. In such endogenous growth models as Rebelo (1990) and Barro (1990), per capita growth and the investment ratio tend to move together. For example, an exogenous improvement in productivity tends to raise the growth rate and the investment ratio. Also in models that include human capital, such as Romer (1990) and Becker, Murphy and Tamura (1990), an increase in the initial stock of human capital tends to raise the ratio of physical investment to GDP.

The estimated coefficient on the five-year average ratio of real gross domestic investment (private plus public) to real GDP is 0.0011 and is insignificant. This result provides the most striking contrast with the results from typical growth regressions (see Barro [1991], Levine and Renelt [1992], Mankiw, Romer and Weil [1992], and De Long and Summers [1991]). Barro (1991), for instance, reports an estimated coefficient of 0.06 on investment ratio.

Figure 3.2
Investment ratio vs. growth rate

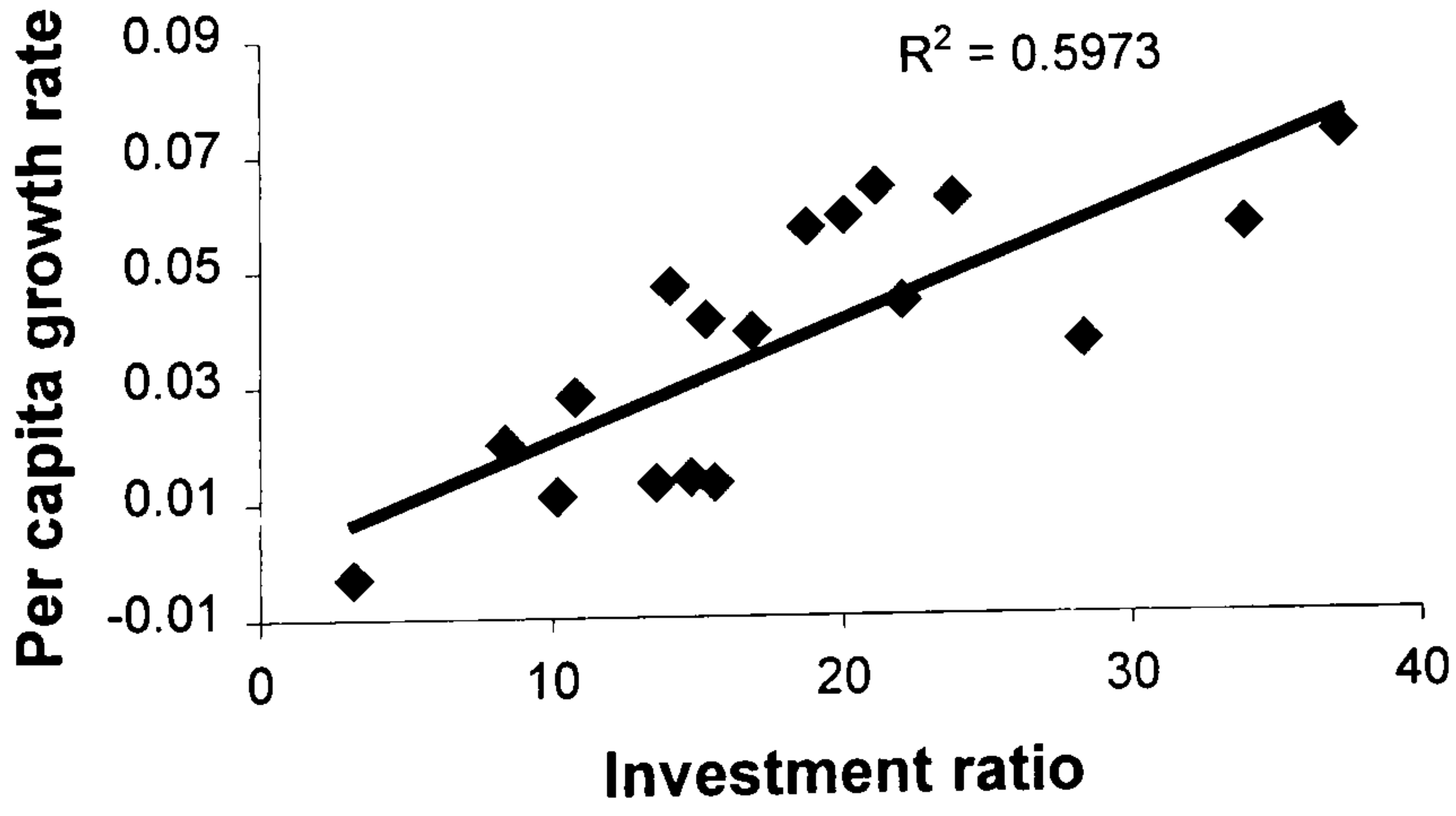

Figure 3.2 indicates a positive simple correlation between growth rate and investment ratio across the Asian economies. However, the relation between these two variables is weak and insignificant once the other explanatory variables are held constant. Therefore, the positive correlation shown by Figure 3.2 might reflect primarily the influence of growth on the propensity to invest. The reason could be that investment has to be treated as endogenous and there may be a reverse causation from growth to investment, rather than from investment to growth. Therefore, once the other explanatory variables have been held constant, exogenous shifts in the investment ratio are not significantly related to growth.

The other possible reason for the low explanatory power of investment ratio for growth is that the measure of investment used (including both public and private) is inappropriate. Unfortunately, there is no separate data on investment for public and private sectors for the sample we use. However, most studies employ the same kind of investment data as we do.

Another reason for the difference between our results about investment and some previous findings is that we hold constant some additional explanatory variables, such as life expectancy, that turn out to diminish the role of the investment ratio. Life expectancy, as mentioned before, may represent better work habits and high level of skills and, therefore, leads to an underestimation of the investment ratio coefficient. That is why we eliminated the life expectancy variable from the basic regression (1).The results are listed as regression (1') in Table 3.3. Excluding this variable improves the results as the estimated coefficient for the investment ratio, 0.0024, is now more significant. From now on we concentrate on the results of the regressions which exclude life expectancy.[8]

-The interaction between GDP and human capital (LY0HUM). This variable appears as the initial value of log(GDP) multiplied by the average schooling years in the total

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[8] This does not seriously affect either the result that the enrolment ratio variables are the best proxies for the educational attainment or the estimated coefficients of the other variables and their significance.

population over age 25. Although Nelson and Phelps (1966) rightly suppose that a higher level of human capital raises the responsiveness of the growth rate to reductions in the initial level of income and, therefore, expect to obtain a negative estimate for the coefficient of the interaction term, the story is different for the countries of our interest. In many Asian countries, specially the more underdeveloped ones, education is a luxury. Governments, therefore, spend a large fraction of their expenditures on education with actually no effort to link it to the productive sectors of the economy. Therefore, we do not expect to observe a negative coefficient on the interaction term, and indeed the inefficient spending on education could perhaps justify a positive sign. The estimated coefficient is, however, very low (0.002) and does not suggest a change in our conclusions about convergence.

-*Government consumption.* This variable is measured by the five-year average ratio of real government consumption expenditure net of spending on defence and on education to real GDP. Easterly and Rebelo (1993a) and Barro (1990) suggest a negative association between the ratio of real government consumption expenditure to real GDP and growth rate (government consumption is believed to proxy for political corruption or other aspects of bad government as well as for direct effects of non-productive public expenditures and taxation[9]). However, our estimated coefficient, 0.5, is significantly positive. The reason is that in most of the Asian countries included in our sample, government is the dominant sector in the economic activities and has a significant contribution to economic growth through its expenditures. On the other hand, we have already taken the negative effects of non-productive public expenditures and taxation into account by the addition of direct measures of the quality of political institutions into the regression.

-*Black market premium on foreign exchange.* We use five-year average of log(1 + black market premium), where black market premium is the ratio of black market exchange rate to official exchange rate minus 1 and the exchange rate is the local currency per dollar. We think of this variable as a proxy for government distortions of markets and, therefore, expect to find a negative relation with the growth rate. The estimated coefficient of the black market premium is -0.059 and statistically significant.

-Political instability. Following Barro (1991) we define political instability as five year average of revolutions per year and political assassinations per million inhabitants per year. Since political instability is expected to threaten the property rights through political turmoil, it has a negative influence on investment and lowers the growth rate for given values of the state variables. The estimated coefficient on political instability is –0.021, but not significant.

-The terms of trade. This variable, defined as growth rate of export prices minus growth rate of import prices, is treated as exogenous because it is determined in world markets and, therefore, exogenous to the behaviour of an individual country. Iran, for example, experienced high growth rates whenever there was an increase in oil prices. The positive estimated coefficient (0.086) supports this idea.

3.4.1 Additional explanatory variables

Regressions (8) to (13) in Table 3.3 show the effects of some additional variables which have been used by previous studies.

-Average schooling years. Regression (8) adds average schooling years in the total population over age 25 (HUMAN). As the best measure of schooling was found to be the average years of primary, secondary and higher schooling, the estimated coefficient is insignificant.

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[9] The argument is that government consumption has no direct effect on private productivity (or private property rights), but lowers saving and growth through the distorting effects from taxation or government expenditure programs.

-Fertility rate and population growth. Regression (9) adds the log of fertility rate, the typical woman's prospective number of live births over her life time. This variable has a negative effect on the steady-state level of output per effective worker in neoclassical growth models with exogenous population growth.

In growth models with endogenous fertility, such as Barro and Becker (1989) and Becker, Murphy and Tamura (1990), per capita growth and net fertility tend to move inversely. However, the relationship between fertility rate and growth rate is more complicated in the models of endogenous fertility. If fertility were higher because people like children more, then the relation would tend to be negative. But if higher fertility reflects lower costs of raising children, then the relation could be positive. The estimated coefficient, -0.076, implies a negative relationship between the two variables across the countries of our interest.

Regression (10) uses the growth rate of population instead of fertility rate. The estimated coefficient is insignificant. Regression (11) also examines, as an alternative demographic variable, the population proportion under 15 years of age. This variable is expected to have a negative sign partly because of the increasing number of non-working population and partly because the work effort of adults would be directed more toward child rearing. This variable, however, turns out to be statistically insignificant in the regression.

Regression (12) includes both the fertility rate and the growth rate of population. The estimated coefficient on fertility is significantly negative, while that on the population growth rate is positive, but this time less insignificantly. For given fertility, a higher population growth rate signals higher net immigration or lower mortality, elements that would be positively related to growth. These variables are, however, jointly insignificant as the probability value is 0.248.

-Government defence expenditures. In addition to political instability, pressures from actual and threatened military conflicts affect economies, usually adversely. Regression (13) employs the average ratio of nominal government expenditures on defence to

nominal GDP to reflect the effects of such pressures on the growth rate. The estimated coefficient is, as expected, negative but not very significant.

3.4.2 Country effects and diagnostic tests

In the LSDV estimation procedure, the individual effects are directly recovered because in a one-way fixed-effects model they are the estimated coefficients, $\hat{\alpha}_i$ *'s*, of the country dummies. We first used 18 dummies with no constant term to run regression (1') in order to find the economy with the lowest country effect. After recognising Bangladesh as having the lowest country effect, we run the regression (1') again, but this time with 17 dummies. The estimated coefficient of each dummy variable, therefore, represents the difference between the individual effect of the respective country and that of Bangladesh.

The results are presented in Table 3.4. The countries are listed in descending order according to the magnitude of their estimated effects. The value of the country effects ranges from 0 to 0.24, demonstrating that the countries do vary considerably in this regard. Countries are classified into three groups according to their estimated country effect. The figures represent a large difference between the growth performance of countries. Clearly, it is not a good idea to use the word ''country effects'' in order to explain the differences; being Iraq or India is not a good reason to have the very high or very low country effects, respectively: there must be some variable(s) which could explain such a special effect.

The above classification does not necessarily mean that countries of the same group are converging and/or have the same explanatory variables excluded from the growth regression; it could be concluded, however, that the higher the group the more the number of missing variables. However, some common features could be highlighted for countries of the same group. Most of the countries in group one, for example, are situated in the geo-politically unstable area of Middle East and their growth rates are expected to be influenced by many factors, both inside and outside the area. Iran and Iraq have always been influenced by changes in world oil markets while Israel, Jordan and Syria have long been affected by political conflicts and war between Israel and Arabs. However, Hong Kong and Singapore are two exceptions in this group. These two countries are extreme examples of economies that absorbed new technologies from abroad and have been supported by foreign investments. On the other hand, group two includes newly industrialised East Asian economies, which experienced a long period of economic stability and high growth rates (except for Philippines).

The diagnostic test results, listed in Table 3.4, are not very supportive for regression 1´. The main problem appears to be the non-normality of the estimated coefficients as the Chi-squared statistic for Jarque-Bera normality test is 38.2 [p=0.00]. (the diagnostic test results for all of the other regressions are similar, if not better than, those reported for regression 1´)

These are good reasons to turn to the single-country growth regressions in order to identify the explanatory variables for each individual country. The lack of data for many of the potential explanatory variables in a multi-country panel regression as well as the high value of country effect for the country of our interest, Iran, necessitate the time series analysis of growth for the Iranian economy, which will be performed in chapters 5 and 6.

3.5 Conclusion

Differences in per capita growth rates across Asian economies are large and relate systematically to a set of quantifiable explanatory variables. One element of this set is a net convergence term, the positive effect on growth when the initial level of per capita GDP is low relative to the starting amount of the human capital in the forms of educational attainment and life expectancy. Therefore, the empirical findings on conditional convergence are consistent with the neoclassical model of chapter 2. It was established earlier, however, that conditional convergence is not in contrast with endogenous growth models. The concept of conditional convergence does not reject the endogenous growth assumption that policy variables, introduced by control and environmental variables, could influence the long run growth rate of per capita GDP.

The empirical findings on the effect of educational variables in growth rate are puzzling because the effects turn out to be negative. Barro and Sala-i-Martin interpret such a negative effect as a measure of backwardness: less (female) education signifies more backwardness and, therefore, higher growth potential through the (conditional) convergence mechanism. However, life expectancy (which represents a higher level of human skills) could be considered as a good proxy for human capital, which influences growth rate positively.

For given values of per capita GDP and human capital (state variables), growth depends negatively on variables that reflect distortions. These variables are the black market premium on foreign exchange, political instability and the government expenditures on defence. Although government expenditures on defence is known to be supportive for property rights, in most of the countries in our sample it usually affects the growth rate adversely through wars and threats of military conflicts both within and between the countries. These effects from government actions are consistent with the neoclassical growth model (because of their short term effects on growth rates), but would also arise in theories of endogenous growth.[10]

Growth rate, on the other hand, increases with favourable movements in some other control and environmental variables such as the terms of trade and the government consumption expenditures. Government consumption is normally known as a distortive factor in empirical growth studies of advanced economies because it disturbs the ideal performance of competitive markets. However, in most of the developing countries of our sample, there is no perfect competition. On the other hand, during the last few decades, government expenditures have been the engine of growth (especially through long term economic plans), particularly in the newly industrialised East Asian economies.

When the above mentioned variables are held constant, the regression results indicate a weak relationship between growth rate and the investment ratio. Therefore, the observed positive correlation, across Asian countries, between these two variables (as shown by Figure 3.2) might reflect primarily the influence of growth on the propensity to invest.

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[10] This subject is discussed in detail in chapter 6.

Table 3.1
Regressions for growth rate of per capita GDP, part 1

Variable	**(1)**	**(2)**	**(3)**	**(4)**
LY0	-0.12 (-4.96)	-0.15 (-3.89)	-0.12 (-3.96)	-0.11 (-3.95)
LLIFEE	0.305 (2.37)	0.15 (1.71)	0.10 (0.74)	0.11 (0.85)
LY0HUM	0.0008 (0.58)	0.01 (1.48)	0.003 (0.9)	0.002 (0.56)
I	0.0011 (0.74)	0.0006 (0.36)	0.000 (0.05)	0.0008 (0.49)
GCON	0.32 (1.6)	0.3 (1.46)	0.33 (1.6)	0.38 (1.64)
BMPL	-0.049 (-2.33)	-0.07 (-2.96)	-0.057 (-2.5)	-0.072 (-3.17)
PINST	-0.028 (-1.04)	-0.04 (-1.2)	-0.03 (-1.03)	-0.0001 (-0.1)
TOT	0.038 (0.68)	0.08 (1.34)	0.067 (1.15)	0.073 (1.21)
	Total gross enrolment ratio	**Average years of schooling**	**Percentage of school attainment**	**Percentage of school complete**
Primary-male	0.032 (0.55)	-0.082 (-2.22)	-0.002 (-2.19)	-0.0003 (-0.18)
Primary-female	-0.19 (-3.17)	0.024 (0.88)	0.002 (2.01)	-0.0003 (-0.19)
Secondary-male	-0.059 (-1.09)	0.027 (0.62)	-0.002 (-0.72)	-0.002 (-0.48)
Secondary-female	0.13 (1.94)	-0.077 (-0.88)	0.002 (0.98)	0.011 (1.52)
Higher-male	0.25 (0.98)	-0.027 (-0.21)	-0.001 (-0.12)	-0.002 (-0.42)
Higher-female	-0.36 (-1.06)	-0.25 (-1.26)	-0.004 (-0.75)	-0.01 (-1.2)
Hausman test	33.8 (p=0.002)	30.76 (p=0.006)	34.72 (0.002)	19 (0.165)
Joint F test for:				
a) explanatory variables	3.54 (p=0.00)	3.18 (0.00)	3.37 (0.00)	3.7 (0.00)
b) fixed effects	2.72 (p=0.004)	2.5 (0.001)	2.29 (0.013)	1.83 (0.05)
R^2	0.716	0.690	0.685	0.667

Table 3.2
Regressions for growth rate of per capita GDP, part 2

Variable	**(1)**	**(5)**	**(6)**	**(7)**
LY0	-0.12 (-4.96)	-0.15 (-3.61)	-0.13 (-4.42)	-0.12 (-4.24)
LLIFEE	0.305 (2.37)	0.31 (2.03)	0.26 (1.64)	0.33 (2.17)
LY0HUM	0.0008 (0.58)	0.007 (1.00)	0.003 (1.02)	0.002 (0.6)
I	0.0011 (0.74)	0.0004 (0.21)	0.0004 (0.27)	0.0009 (0.513)
GCON	0.32 (1.6)	0.27 (1.26)	0.27 (1.26)	0.35 (1.41)
BMPL	-0.049 (-2.33)	-0.05 (-1.93)	-0.039 (-1.7)	-0.05 (-2.14)
PINST	-0.028 (-1.04)	-0.034 (-0.99)	-0.043 (-1.3)	-0.01 (-0.28)
TOT	0.038 (0.68)	0.04 (0.67)	0.038 (0.66)	0.03 (0.5)
PENRM	0.032 (0.55)	0.034 (0.56)	0.049 (0.79)	0.026 (0.42)
PENRF	-0.19 (-3.17)	-0.17 (-2.5)	-0.19 (-2.85)	-0.17 (-2.42)
SENRM	-0.059 (-1.09)	-0.033 (-0.58)	-0.025 (-0.42)	-0.06 (-1.00)
SENRF	0.13 (1.94)	0.077 (0.9)	0.047 (0.59)	0.09 (1.02)
HENRM	0.25 (0.98)	0.13 (0.42)	0.12 (0.43)	0.15 (0.49)
HENRF	-0.36 (-1.06)	-0.78 (-0.19)	-0.027 (-0.07)	-0.14 (-0.304)
PYRM	-	-0.046 (-1.09)	-	-
PYRF	-	0.02 (0.65)	-	-
SYRM	-	0.008 (0.17)	-	-
SYRF	-	-0.07 (-0.75)	-	-
HYRM	-	0.03 (0.18)	-	-
HYRF	-	-0.25	-	-

		(-1.31)		
PRIM	-	-	-0.002 (-1.56)	-
PRIF	-	-	0.002 (1.8)	-
SECM	-	-	-0.0007 (-0.315)	-
SECF	-	-	-0.0004 (-0.13)	-
HIGHM	-	-	0.0009 (0.19)	-
HIGHF	-	-	-0.006 (-1.04)	-
PRICM	-	-	-	0.0003 (0.17)
PRICF	-	-	-	-0.0007 (-0.32)
SECCM	-	-	-	-0.002 (-0.63)
SECCF	-	-	-	0.006 (0.69)
HIGHCM	-	-	-	-0.001 (-0.21)
HIGHCF	-	-	-	-0.01 (-1.13)
F **(p-value)**	-	**0.66** **(p=0.68)**	**0.93** **(p=0.49)**	**0.46** **(p=0.83)**

Table 3.3
Regressions for growth rate of per capita GDP, part 3

Variable	1’	8	9	10	11	12	13
LY0	-0.106 (-4.33)	-0.094 (-2.91)	-0.116 (-4.65)	-0.106 (-4.26)	-0.107 (-4.09)	-0.116 (-4.62)	-0.097 (-3.8)
LY0HUM	0.002 (1.28)	-0.0012 (-0.23)	0.0014 (1.05)	0.0018 (1.26)	0.0017 (1.26)	0.0017 (1.18)	0.0019 (1.39)
I	0.0024 (1.58)	0.0023 (1.53)	0.0025 (1.66)	0.0023 (1.54)	0.0024 (1.56)	0.0023 (1.57)	0.0025 (1.65)
GCON	0.5 (2.52)	0.47 (2.31)	0.528 (2.69)	0.505 (2.49)	0.504 (2.44)	0.56 (2.77)	0.408 (1.95)
BMPL	-0.059 (-2.72)	-0.051 (-2.06)	-0.056 (-2.62)	-0.059 (-2.68)	-0.059 (-2.67)	-0.058 (-2.69)	-0.055 (-2.56)
PINST	-0.021 (-0.74)	-0.021 (-0.77)	-0.039 (-1.31)	-0.019 (-0.65)	-0.021 (-0.74)	-0.035 (-1.16)	-0.022 (-0.81)
TOT	0.086 (1.60)	0.086 (1.59)	0.105 (1.94)	0.085 (1.56)	0.087 (1.56)	0.104 (1.91)	0.104 (1.89)
PENRM	0.048 (0.78)	0.047 (0.77)	0.029 (0.48)	0.049 (0.79)	0.047 (0.74)	0.032 (0.51)	0.027 (0.42)
PENRF	-0.13 (-2.34)	-0.15 (-2.36)	-0.11 (-1.91)	-0.133 (-2.28)	-0.13 (-2.12)	-0.119 (-2.0)	-0.093 (-1.43)
SENRM	-0.043 (-0.77)	-0.044 (-0.79)	-0.037 (-0.66)	-0.044 (-0.77)	-0.042 (-0.74)	-0.042 (-0.74)	-0.035 (-0.62)
SENRF	0.12 (1.71)	0.11 (1.57)	0.063 (0.79)	0.125 (1.67)	0.119 (1.61)	0.070 (0.87)	0.095 (1.3)
HENRM	0.38 (1.45)	0.39 (1.49)	0.33 (1.28)	0.385 (1.45)	0.38 (1.43)	0.349 (1.33)	0.328 (1.24)
HENRF	-0.52 (-1.5)	-0.51 (-1.46)	-0.42 (-1.2)	-0.53 (-1.48)	-0.52 (-1.46)	-0.468 (-1.31)	-0.514 (-1.5)
HUMAN	-	0.025 (0.57)	-	-	-	-	-
LFERT	-	-	-0.076 (-1.55)	-	-	-0.088 (-1.69)	-
GPOP	-	-	-	0.26 (0.17)	-	1.12 (0.71)	-
POP15	-	-	-	-	-0.021 (-0.09)	-	-
GDEF	-	-	-	-	-	-	-0.234 (-1.27)
R²	0.682	0.684	0.697	0.682	0.682	0.70	0.692
p-value	-	-	-	-	-	0.284	-

Table 3.4
Estimated Country Effects
(measured as deviation from Bangladesh's country effect)

	Country	**Estimated country effect***
Group 1	Iraq	0.237
	Iran	0.232
	Hong Kong	0.231
	Singapore	0.227
	Syria	0.192
	Israel	0.182
	Jordan	0.170
Group 2	Malaysia	0.148
	Korea	0.131
	Thailand	0.121
	Japan	0.112
	Philippines	0.108
	Indonesia	0.088
	Taiwan	0.085
Group 3	Sri Lanka	0.085
	Pakistan	0.061
	India	0.021
	Bangladesh	-

Diagnostic statistics for regression 1'
[p-values in brackets]

LM test for serial correlation	χ_1^2=7.55 [0.006]
RESET test for functional form	χ_1^2=9.22 [0.002]
Jarque-Bera test for normality	χ_2^2=38.21 [0.000]
LM test for heteroscedasticity	χ_1^2=1.21 [0.271]

Chapter 4

An Endogenous Growth Model with Human Capital

4.1 Introduction

Human capital is central to the growth process in the new endogenous growth and augmented Solow models. Its role in the diffusion of knowledge and technology offsets the diminishing returns to physical capital that otherwise occurs. Per capita output, therefore, grows without bounds.

This chapter extends the neoclassical growth theory and focuses on the effects of physical, human and knowledge capital accumulation on per capita income growth. It differs from chapter 3 in two aspects. First, unlike chapter 3, which used an ad hoc model to identify the main factors affecting the growth rate of the Asian countries, this chapter is based on growth models that specifically focus on the effects of human capital on economic growth. This resort to endogenous growth models with human capital has the benefit of increasing the number of observations from 79 in chapter 3 to 90 as many variables, for which data are not available for some countries, do not appear in this chapter. Second, this chapter classifies countries by differences in their investment ratios as well as educational attainments.

In a neoclassical framework, moving along the production function displays diminishing returns when only physical capital is considered. With human capital and knowledge capital included in the model, however, these diminishing returns are offset and there is long run growth of per capita output. Total capital accumulation is further extended by endogenous total investment and total saving, with the result that diminishing returns to physical capital are offset altogether and there can even be increasing returns.

The chapter is organised as follows: Section 4.2 briefly reviews the development of exogenous and endogenous growth models with human capital and explains two of the most popular endogenous growth models in this regard. Section 4.3 outlines the supply side and the demand side of the economy for both the neoclassical and the endogenous growth models and the differences between them with regard to the equilibrium growth rate. Section 4.4 describes how income growth is influenced by the growth of labour and population, which are usually confused in empirical studies. Sections 4.5 and 4.6 briefly explain the econometric procedure employed to test the model and the data used, and also present the results. Section 4.7 contains some conclusions and suggestions.

4.2 The theory and origins of growth models with human capital

4.2.1 Exogenous growth theories

Classical economists thought that the main source of technological progress and economic growth were capital accumulation and increasing division of labour and specialisation (Adam Smith, 1977). There are two basic assumptions in the classical theory of growth. First, capital accumulation and specialisation in special fields generating economies of scale, provide the tools for improving not only the performance of workers' job, but also productivity. Second, a free market system would be the best policy for economic agents. With respect to the role of human capital in classical theory of growth, Smith states that a man, educated at the expense of much labour and time for any employment requiring extraordinary dexterity and skill, may be compared to one of quality expensive machines.

During the 19th century, neoclassical economists believed more and more in the role of capital accumulation as the source of economic growth. Yet they considered the importance of the division of labour and specialisation and came to think that such a division is determined by the available technology, which was dealt as an exogenous force because it was dependent on inventions. Therefore, they concluded that the study of capital accumulation alone plus exogenously driven technical change would produce the understanding of variations in economic growth.

Since the neoclassical economists considered savings to be the source of funds for investment and capital accumulation, they started to study savings behaviour and the relationship between savings and growth. Neoclassical growth theories, such as the

Harrod-Domar model, attribute the changes in output growth to changes in domestic savings behaviour. Thus, while they might show how growth occurs, they don't explain the reason *why* the savings behaviour changes or *why* growth occurs. The more recent neoclassical growth model of Solow-Swan has focussed on endogenising the capital-labour and output-labour ratios. It uses the basic assumption that factors can be used in various proportions and that constant returns to scale exist in the production process. However, the Solow-Swan model is similar to the Harrod-Domar model in assuming the growth rate to be determined by changes in savings behaviour.[1]

4.2.2 Endogenous growth theories:

Since the development of the Solow growth model in the 1950s, economists have been uneasy about several of its aspects and implications. The two big problems with the Solow model raised by the new endogenous growth theory can be labelled the exogeneity and convergence controversies.

Standard neoclassical growth has important implications that are not supported by the observed pattern of growth. This is mainly due to the assumption of diminishing returns to physical capital. Until recently, the possibility of increasing returns to capital was not considered for two reasons. First because the model focused on physical capital which seems to have diminishing returns, and second because a solution of the model with increasing returns was not obvious, and "technical change" introduced into the neoclassical model produces increasing returns but is exogenous (dropping from the sky totally unexplained). Economic theory suggests that increasing returns has to be modelled as an externality, otherwise a firm enjoying increasing returns to scale will monopolise the market. This latter would make the model seem to be irrelevant to the real world.

Since the early 1980s, human capital has come to be seen as perhaps at least as important as physical capital in determining economic growth. Because economists have recognised that human capital accumulation may explain increasing returns to scale, they have tried to develop models with human capital explaining the increasing returns.

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[1] For a more detailed discussion on Solow-Swan model of economic growth see chapter 2.

The Romer model

Romer has explained growth as endogenously driven technical change aided by human capital formation through endogenous investment in education. The latter includes learning on the job about technological advances. Romer's initial idea was to reject diminishing returns to capital. This would allow the returns to additional investment to be as high in advanced countries as it is in less developed countries. In his first paper on growth (Romer, 1986), he assumed that all capital is human capital for simplicity. Let the aggregate output of firm i (i=1,...,M) in an economy with M identical firms be

$$(4.1) \quad Y_i = F(L_i, K_i, R_h) = AL_i^{\alpha} K_i^{\beta} R_h^{\gamma-\alpha-\beta}$$

where R_h stands for the average amount of human capital per firm i or the stock of results from expenditures on research and development by firm i in the economy[2], and $\alpha<1$, $\beta<1$, $\gamma>1$ are constant parameters, and Y_i, K_i and L_i are the level of output, the amount of (human) capital stock and the number of workers in firm i, respectively.

An equilibrium with many firms can exist if each firm takes R_h as given and $\alpha+\beta=1$. Since all firms are identical, $R_h=K_i$ and $M=N/L_i$ (and also $N=L$) and (4.1) can then be rewritten as

$$(4.2) \quad \begin{aligned} Y &= \frac{N}{L_i} Y_i = \frac{N}{L_i} AL_i^{\alpha} K_i^{\beta} R_h^{\gamma-\alpha-\beta} \\ &= NAL_i^{\alpha-1} K_i^{\gamma-\alpha} = NAL_i^{\gamma-1} \left(\frac{K_i}{N_i} \right)^{\gamma-\alpha} \end{aligned}$$

or, in per capita terms, as

$$(4.3) \quad y = A \left(\frac{N}{M} \right)^{\gamma-1} k^{\gamma-\alpha}$$

where lower case letters denote per capita (or, alternatively, per worker) variables. Differentiating (4.3) with respect to k results in the marginal product of capital as follows

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[2] $R_h = \frac{K}{M}$ where $K = \sum_{i=1}^{M} K_i$ is total capital in the economy and total population (which equals the number of workers) and total output are defined as $N = \sum_{i=1}^{M} L_i$ and $Y = \sum_{i=1}^{M} Y_i$, respectively.

(4.4) $$\frac{\partial y}{\partial k} = (\gamma - \alpha)\left(\frac{N}{M}\right)^{\gamma - 1} k^{\gamma - \alpha - 1}$$

If (4.4) is increasing in k (i.e. if $\gamma > \alpha + 1$), the per capita production function (4.3) will exhibit increasing returns to k.

Suppose that the employment size of each firm is constant (i.e. the number of firms grows at the rate of growth of population). Considering a constant rate for depreciation, δ, and population growth, n, we can derive

(4.5) $$\frac{\partial k}{k} = \frac{\partial K}{K} - n = \frac{sY}{K} - \delta - n$$

Therefore, the growth rate of per capita output is

(4.6) $$g = (\gamma - \alpha)\frac{\partial k}{k} = (\gamma - \alpha)(\frac{sY}{K} - \delta - n) = (\gamma - \alpha)\{sA(\frac{N}{M})k^{\gamma - \alpha - 1} - \delta - n\}$$

Note that, since the employment size of each firm is constant, the growth rate increases with k if $\gamma > \alpha + 1$. Therefore, if initially $g > 0$, we will have $\frac{\partial k}{\partial t} > 0$ and the economy grows without bound. Moreover, g will be increasing over time if it is initially positive. On the other hand, per capita growth will remain stagnant (will decline sharply) if initially $g = 0$ ($g < 0$).

The Lucas model

Lucas' model is structurally very similar to Romer's. For Lucas, it is investment in human capital rather than physical capital that has spillover effects that increase the level of technology. Lucas (1988) argued that increasing returns may occur at the point of production of human capital. This effect in turn gives rise to endogenous growth.

Lucas' model assumes that a typical firm i takes the form

(4.7) $$Y_i = F(\mu h L_i, K_i) H_a^{\gamma}$$

where L_i is the number of workers, μ is the proportion of the time that each worker devotes to production, h is the human capital of workers employed by firm i, K_i is physical capital stock, H_a is the average human capital in the economy, and γ is a positive parameter. Note that in this formulation, effective labour input, $\mu h L_i$, replaces the simple labour input L specified in the standard neoclassical model. As in Romer's model, the coefficient H_a^γ is the externality effect of human capital. If, as in the standard neoclassical model, F is assumed to be homogenous of degree one, we can write

$$(4.8) \quad Y = \mu hLF(1, \frac{K}{\mu hL})H_a^\gamma = \mu hLF(k)H_a^\gamma$$

where $k = \frac{K}{\mu hL}$. For simplicity, we will assume $f(k) = k^\beta$. Since in equilibrium, $H_a = h$, per worker income at each moment is given by

$$(4.9) \quad y = \mu k^\beta h^{1+\gamma}$$

and the rate of growth of per capita income is given by

$$(4.10) \quad g = \beta\frac{\partial k}{k} + (1+\gamma)\frac{\partial h}{h}$$

The rate of growth of capital stock per unit of effective labour, k, follows a similar rule as in the neoclassical growth model

$$(4.11) \quad \frac{\partial k}{k} = \frac{\partial K}{K} - \frac{\partial h}{h} - \frac{\partial N}{N} = sk^{\beta-1}h^\gamma - \delta - \frac{\partial h}{h} - n.$$

For the growth of human capital, which is the central part of the model, Lucas assumed that ∂h is proportional to the amount of labour that an individual *can* use for education. Since the share, u, of a worker's time is used in production, the available labour for educational purposes is $1\text{-}u$.[3] The proportionality factor is assumed to be a function of the existing amount of human capital as follows

$$(4.12) \quad \partial h = \theta(1-u)h^\sigma \Rightarrow \frac{\partial h}{h} = \theta(1-u)h^{\sigma-1}$$

where σ is a non-negative parameter.

In the Lucas model, the human capital investment of an individual person is said to lead to greater learning on the job later. For example, when one learns something, he also learns how to learn faster and, as a result, learning other things becomes easier. Lucas argues that studies of productivity growth suggest $\sigma = 1$. This implies a constant

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[3] Note that u is different from μ. In fact, $(1\text{-}u)$ percent of workers' time is free and *could* be allocated to education. However, they actually spend μ ($<1\text{-}u$) percent of their time to educational purposes.

long run growth rate for the economy, which conforms to the observation that long run US growth in the last 100 years has been more or less constant at a rate of about 2.5-3 percent a year. If $\sigma=1$, then $\frac{\partial h}{h}=\theta(1-u)$ and per capita human capital grows at a constant rate. In this case, the steady state growth of capital stock per unit of effective labour will also be constant, say at rate g_k, as follows

$$(4.13)\quad \frac{\partial k}{k}=g_k=sk^{\beta-1}h^{\gamma}-\delta-\theta(1-u)-n$$

Note that since g_k is constant, changes in k and h must satisfy $dg_k=0$, so that

$$(4.14)\quad (1-\beta)\frac{\partial k}{k}=\gamma\frac{\partial h}{h}=\gamma\theta(1-u)\quad\Rightarrow\quad g_k=\gamma\theta\frac{1-u}{1-\beta}$$

Substitutions from (4.13) and (4.14) into (4.10) yield the steady state growth rate of per capita income as

$$(4.15)\quad g=\{\frac{\gamma\beta}{(1-\beta)}+1+\gamma\}(\frac{\partial h}{h})=\theta(1-u)\frac{1-\beta+\gamma}{1-\beta}$$

Note that the growth rate is positive even if there is no human capital externality (i.e. $\gamma=0$). The extent of externality simply increases the rate of growth. However, if $\sigma<1$, then the rate of growth will gravitate towards zero as $\frac{\partial h}{h}$ declines with the rise in h.

Therefore, in the long run for the growth rate to be positive, $\sigma=1$ is crucial. Note that when $\sigma>1$, the rate of growth will increase without bound, which is an unrealistic outcome.

4.3 The basic growth model with human capital

In further developing to implications of Romer/Lucas kinds of model, we follow Lucas by adding the human capital into the production function. Our endogenous growth model is similar to the neoclassical model in that the forces behind the supply side and demand side of the economy jointly determine the equilibrium growth rate of real output per capita, in each point of time.

The supply side

Suppose the production function takes the following simple Cobb-Douglas form:

$$Y = \bar{a} N^{\alpha_1} K^{\alpha_2}, \tag{4.16}$$

where Y denotes real GDP, K is the stock of physical capital, N is the stock of labour and $\bar{a}$ is the level of technology. The neoclassical growth model assumes that $\bar{a}$ is a function of time and, therefore, technical change is exogenous to the model and increasing returns are the result of the factors outside the model that affect $\bar{a}$. As Solow comments '...the real value of endogenous growth theory will emerge from its attempt to model the endogenous component of technological progress as an integral part of the theory of economic growth...' (Solow 1994, p. 51).

When human and knowledge capitals are included in the production function, they replace the $\bar{a}$ term with H and A respectively and a new residual "a":

$$Y = a N^{\alpha_1} K^{\alpha_2} H^{\alpha_3} A^{\alpha_4} \tag{4.17}$$

where H denotes the human capital formed by deliberate investment in education required for the diffusion of technology, and A denotes the stock of knowledge formed by endogenous investment in R&D. We define the accumulation equations of these stocks as follows

$$\begin{aligned} K_t &= K_{t-1} + I_K + \delta_K(K_{t-1}) \\ H_t &= H_{t-1} + I_H + \delta_H(H_{t-1}) \\ A_t &= A_{t-1} + I_A + \delta_A(A_{t-1}) \end{aligned} \tag{4.18}$$

where the δ's are the respective depreciation rates. The endogeneity of the model comes from the fact that all of the investment components (i.e. I_K, I_H, and I_A) are functions of, among other things, output and economic policies.

The demand side

Let s be a constant fraction of output saved in the economy each year. Since we have already introduced total investment, we treat "s" as total saving rate that, in a closed economy, is also the ratio of gross investment to output. Adjusting for the production cyclical fluctuations, sY is the rate of growth of total capital stock in the long run. The demand side income/output equality requires

$$(4.19) \qquad C + I_K + I_H + I_A + G = Y = C + sY + T,$$

where C, G and T refer to consumption, government expenditure, and individual and business taxes, respectively. Assuming a balanced government budget, the income/output equality condition on the demand side implies

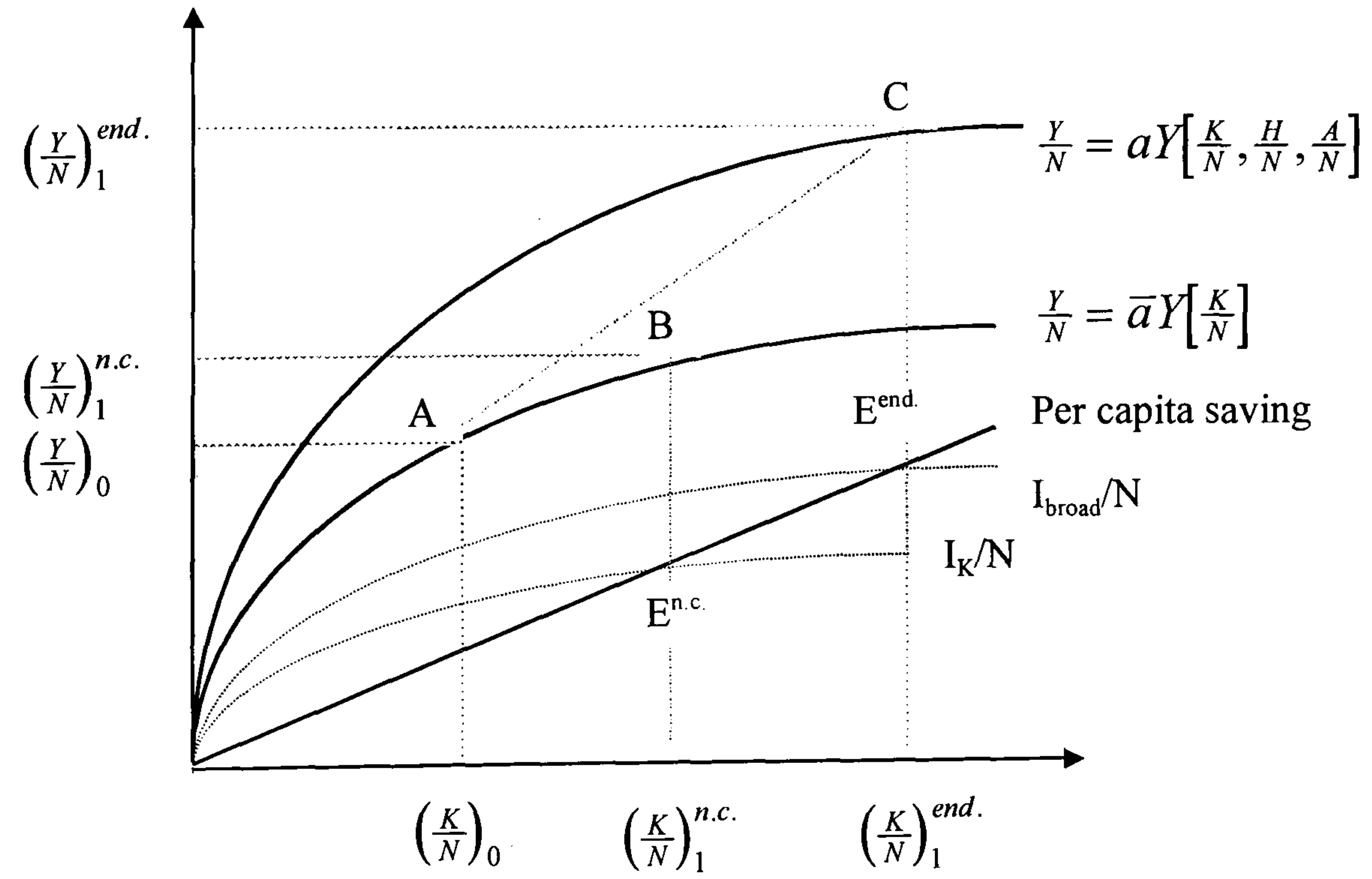
$$(4.20) \qquad \frac{I}{N} = \frac{S}{N}$$

where $S = s.Y$ is total saving and $I = I_K + I_H + I_A$ is total investment.

Solution

Figure 4.1 displays the steady state solution in the endogenous growth model outlined above.

Figure 4.1. The steady state equilibrium solution



Moving from point A to B displays diminishing returns when there is only physical capital available. Each of the steady state equilibrium points $E^{n.c.}$ and $E^{end.}$ depict intersection of a steady state investment function and the saving line. At the neoclassical equilibrium point $E^{n.c.}$, personal per capita saving (S'/N) equals per capita investment in physical capital (I_K/N). However, in our endogenous model with a broad concept of capital, including both physical and human components as well as the stock of knowledge, the equilibrium at point $E^{end.}$ is determined by the equality of total investment (I_{broad}/N) and total saving (S/N). In this case, diminishing returns to physical capital are offset and there may even be increasing returns to broad capital. Starting from the disequilibrium point A, physical capital accumulation in a short period of time moves the economy to point B. However, when total capital accumulation effects work themselves out in the production function, the economy moves to point C in a medium term basis indicating even increasing returns to broad capital.

It is not realistic to find theoretical solutions to this system by imposing the assumption of linearity on production. Such an assumption, especially when longer periods of time are considered, does not allow for diminishing returns to occur. The non-linearity must be considered in the production function if substitutions between physical capital, raw labour and educated labour are to be allowed. The total capital accumulation effects could be accommodated in the following production function

(4.21) $$Y = Y\left(K, L, H, A, (Y/N)_0, \mu\right),$$

where $(Y/N)_0$ denotes the initial GDP per capita and μ denotes disturbances to productivity growth. The effects of total capital accumulation over time as a dynamic process could be shown by totally differentiating the above reduced form for production function and dividing through by real output. As a result, the growth rate of output as a percentage rate of change over time is

(4.22) $$\frac{\partial Y}{\partial t}\frac{1}{Y} = \frac{\partial Y}{\partial K}\frac{\partial K}{\partial t}\frac{1}{Y} + \frac{\partial Y}{\partial L}\frac{\partial L}{\partial t}\frac{1}{Y} + \frac{\partial Y}{\partial H}\frac{\partial H}{\partial t}\frac{1}{Y} + \frac{\partial Y}{\partial A}\frac{\partial A}{\partial t}\frac{1}{Y} + \frac{\partial Y}{\partial \mu}\frac{\partial \mu}{\partial t}\frac{1}{Y}$$

The partial derivative of each type of capital stock with respect to time is assumed to be equal to gross investment (we ignore the replacement investment). Also, the partial derivative of output with respect to each input is marginal physical product of that input. If we use lower case letters to represent percentage rates of change over time as follows

(4.23) $$y = \frac{\partial Y}{\partial t}\frac{1}{Y} \qquad l = \frac{\partial L}{\partial t}\frac{1}{L} \qquad \alpha_1 = \frac{\partial Y}{\partial \mu}\frac{1}{Y}$$

Then (4.22) above becomes

$$(4.24) \qquad y = MP_K \frac{I_K}{Y} + MP_H \frac{I_H}{Y} + MP_A \frac{I_A}{Y} + \frac{MP_L \cdot l \cdot L}{Y} + \alpha_0 \left(\frac{Y}{N}\right)_0 + \alpha_1 \frac{\partial \mu}{\partial t},$$

according to which the growth of real output, after controlling for the initial real output and shocks, can be explained in terms of contributions made by the rate of investment in physical, human, and knowledge capital each weighted by its respective marginal product, and also by the employment growth of unimproved labour weighted by its marginal product.

4.4 The effect of "labour" growth rate

The growth rate of per capita real output can be obtained by subtracting the population growth rate n from both sides of (4.24). Per capita growth rate is determined by, among other things, the following term

$$(4.25) \qquad \frac{MP_L \cdot L}{Y} \cdot l - n$$

l, the growth rate of labour force (or the labour absorptive rate), is not necessarily equal to n, the growth rate of population (or the labour participation rate). If $n \geq l$, then the above term has a negative contribution on per capita growth rate. The contribution is positive only if the product of the share of the labour force in total output and the growth rate of unimproved labour force is greater than the growth rate of population. In empirical studies, n is usually used as a proxy for l because the latter is merely the growth rate of unskilled raw labour, which is a linear function of the growth rate of total population. These two variables, on the other hand, are similar in that they are both endogenous variables in our model since both are a function of, among other things, the investment in human capital.[4]

There are two reasons why we expect a negative effect of the growth of raw labour force on per capita income. First, growth in unimproved raw labour without other forms of capital accumulation can generally be expected to be associated with falling, and

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[4] It is clear by economic theory that $L=L(I_H)$. However, since the investment in human capital could affect the fertility rate through the population control training programs, the population growth function could be formulated as $N=N(I_H$, female size).

not rising, output per capita[5]. Second, only in six countries (out of our 18-country sample) is the labour absorptive rate greater than the labour participation rate. These ideas are confirmed by a significantly negative estimated coefficient for the population growth rate in our growth regression results reported later.

4.5 Empirical model and data

Before we explain the econometric method used to test the above model, some points have to be noted. In order to reveal more specific details about the effects of human capital on per capita growth rates, we partition human capital into the three levels of primary, secondary, and higher education. For empirical purposes, however, the enrolment rates are used as proxy variables for investment in each educational level. In the previous chapter we explained how employing enrolment rates, rather than educational expenditures, could better represent the quality of education.

In our model we assumed that the stock of knowledge, A, is increased directly as a result of rises in R&D expenditures. Since the data on R&D expenditures is not available for the whole panel of our interest, we have to use a proxy variable to represent investment in the stock of knowledge. The contribution of R&D in economic growth could be conceived of as the contribution of physical capital embodying the new technology and of human capital embodying the new technology. Since our sample includes both advanced and developing countries, this seems to be a reasonable assumption. In an advanced technology-initiator economy, those R&D activities that initiate new technologies are accomplished by R&D scientists, who are educated by the higher education sector. In a developing economy, on the other hand, the higher education sector produces scientists and technicians who adopt and disseminate the new imported technology.

Higher education, therefore, could well explain R&D activities which, in turn, lead to initiation of new technologies (in an advanced technology-initiator economy), or adoption of imported technologies (in a developing technology-follower economy). These

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[5] If $L=N$, then (4.25) becomes $(\frac{MP_N \cdot N}{Y} - 1)n$. The term in parentheses is raw labour's share of national

two cases are, however, the most extreme examples and in the real world, a country could be placed anywhere between these two situations where it is able to both initiate new technologies and adopt imported technologies.

Note, however, that from a *developing* country's of view, R&D accomplishments in advanced economies are also embodied in the physical capital which is then transferred to that country disseminating the technology. Physical capital, therefore, is assumed here to have two roles: first as a physical means of production and second as a knowledge means of production. A new piece of industrial equipment, for instance, is used to effect a change in production. This is simply the physical capital role that this machine plays. However, the idea behind such a new machine (either invented or imported from abroad) could be instructive both in terms of skill improvement of workers employing it and the knowledge improvement that it brings to industrial machine designers who are not required to repeat all the basic research needed for designing another new machine. Such a technological idea behind physical capital is thought of here as knowledge capital.

The data for the growth rate of real GDP per capita (1985 international prices) are average increments for the 5-year time periods of 1960-65, 1965-70, 1970-75, 1975-80, and 1980-85. The 5-year growth increments of real GDP and population, the 5-year averages of real investment share of GDP (1985 international prices), and the ratio of total workers to population are from Summers and Heston (1988 and earlier versions available on diskette). Total gross enrolment ratio for different levels of education, ratio of total nominal government expenditure on education to nominal GDP, and average schooling years in the total population over age 25 are from UNESCO Statistical Yearbooks (various issues).

4.6 Methodology and results

The methodology described in Greene (1993, Ch. 16) will be used to correct (and test) for heteroskedasticity and autocorrelation. Let $i=1,\dots,N$ and $t=1,\dots,T$ refer to country and time, respectively. The model allows for groupwise heteroskedasticity, $E[\varepsilon_{it}^2]=\sigma_{ii}$, cross

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output minus one, which is expected to be negative.

group correlation, $Cov[\varepsilon_{it}\varepsilon_{jt}] = \sigma_{ij}$, and within group autocorrelation, $\varepsilon_{it} = \rho_i \varepsilon_{i,t-1} + u_{it}$. We use a general procedure for all computations as follows. Let Σ=N×N period specific covariance matrix, $[\sigma_{ij}]$. Then, there are the following three alternatives from a cross-section aspect of view:

(S0) $\Sigma = \sigma^2 I$ (classical homoskedastic disturbances),

(S1) $\Sigma = diag[\sigma_{11}, \sigma_{22}, ..., \sigma_{NN}]$ (groupwise heteroskedastic disturbances),

(S2) Σ = an N×N positive matrix (groupwise heteroskedastic and cross group correlated disturbances)

Also, let ρ= N×1 vector of group specific autocorrelation coefficients. Then there are the following three alternatives from a time-series aspect of view:

(R0) ρ=0 (nonautocorrelated disturbances),

(R1) ρ=(ρ,ρ,...,ρ) (common autocorrelation coefficient),

(R2) $\rho=(\rho_1, \rho_2, ..., \rho_N)$ (individual autocorrelation coefficients).

Thus, there are nine models when all three contemporaneous covariance specifications are crossed with the three autocorrelation specifications. Our approach here is to test all of them against the most general model, (S2,R2).

We use a GLS method to estimate these models. In each case, we first estimate ρ using OLS residuals of a primary ordinary, pooled least squares regression (set $\rho_i=0$ for case R0). Then, using the Cochran-Orcutt transformation, compute OLS estimates again to remove the autocorrelation and use the OLS residual sum of squares and cross products to compute

(4.26) $S = [s_{ij}] = e_i'e_j / (T - j)$ (j=0 for R0, j=1 otherwise),

and finally use S to estimate $\hat{\beta}_{GLS}$ and its standard error. The different specifications are estimated by restricting Σ and/or ρ.

For testing homoskedasticity (S0) as a restriction on (S1) we use a LM test statistic as

(4.27) $LM = (T/2)\sum_i [(s^2 / s_{ii}) - 1]^2$, and to test groupwise heteroskedasticity (S1) as a restriction on (S2), another LM statistic is used as

(4.28) $LM = T\sum_{i}\sum_{j \prec i}\left[s_{ij}^{2}/(s_{ii}s_{jj})\right]$

Both of the above statistics have chi-squared distributions with *N-1* and *[N(N-1)]/2* degrees of freedom, respectively.

No specific test is given for autocorrelation. We test the significance of the estimated correlations, themselves, by referring

(4.29) $(T-1)r_{i}^{2}/(1-r_{i}^{2})$

to the value 3.84, which is the 95% critical value from the Chi-squared distribution with one degree of freedom.

According to (4.29), if | r |≥0.7, the assumption of no autocorrelation is rejected. The estimated common correlation coefficient for (R1) is -0.21. Also, almost all of the individual country correlation coefficients for (R2), listed in table 4.1, are statistically insignificant. Therefore, we rule out six models associated with (R1) and (R2). Starting with model (S0,R0), we reject a classical homoskedastic regression in favour of a groupwise heteroskedastic one, as the LM statistic of 38.9 lies above the critical value of 33.4 (d.f.=17, 1-α=0.99). However, we do not reject the groupwise heteroskedasticity as a restriction on a groupwise heteroskedastic and cross-group correlated regression as the LM value of 187.6 is less than the critical value of 195.8 (d.f.=153, 1-α=0.95). Model (S1,R0) is, therefore, chosen as the best one.

For empirical purposes, we have to modify (4.24). It was discussed in section 4.5 that how the investment in higher education and physical capital could proxy for investment in knowledge, I_A. Also, in a panel data framework, the disturbances to productivity growth, μ, could be represented by country effects. The following modified version of (4.24) is, therefore, used for empirical purposes

(4.30) $y = \beta_0 + \beta_1 \frac{I_K}{Y} + \beta_2 I_{HP} + \beta_3 I_{HS} + \beta_4 I_{HH} + \beta_5 g_{pop} + \beta_6 Y_0 + u_{it}$

where I_{HP}, I_{HS} and I_{HH} are investment (proxied by enrolment rate) in primary, secondary and highrer education, respectively, g_{pop} is the growth rate of population, Y_0 is the initial level of income and u_{it} is the disturbance term of the regression.

The estimation results for (4.30) using models (S0,R0) and (S1,R0) are listed in table 4.2. It is clear that when we shift from homoskedastic to heteroskedastic regression, the results do not change significantly. Therefore, we stick with the homoskedastic rather than heteroskedastic regression and shift from pool estimation method to LSDV in order to allow for different combinations of country effects.

Table 4.1. Autocorrelation coefficients

Country	**Autocorrelation coefficient**
Bangladesh	-0.2
Hong Kong	0.25
India	0.1
Indonesia	0.55
Iran	-0.47
Iraq	-0.39
Israel	-0.08
Japan	-0.53
Jordan	-0.22
Korea	-0.2
Malaysia	-0.75
Pakistan	-0.28
Philippines	0.01
Singapore	-0.23
Sri Lanka	-0.17
Syria	0.07
Taiwan	-0.6
Thailand	-0.61
Common	-0.21

Before applying the LSDV estimation approach, some points should be considered. There are some differences between countries with regard to educational systems that make it difficult to interpret the estimated coefficients. Duration in years of primary and secondary education, for instance, is different across countries.[6] Different countries also have different educational qualities. Investment, on the other hand, must also be dealt with differently in different economies. A country like Bangladesh with an investment ratio of as low as 3.2 percent is expected to have a higher effect of investment on per capita growth than Singapore with such a high investment ratio as 37.3.

Table 4.2
Two-step GLS pooled regression estimation
Dependant Variable: growth rate of per capita GDP

Variable	Homoskedastic Regression (S0,R0)		Heteroskedastic Regression (S1,R0)	
	Coefficient	**t-ratio**	**Coefficient**	**t-ratio**
Investment Ratio	0.0019	2.43	0.0027	5.63
Primary Enrolment Rate	-0.108	-2.73	-0.099	-3.08
Secondary Enrolment Rate	-0.0057	-0.1	-0.03	-0.85
Higher Enrolment Rate	0.065	0.6	0.056	0.76
Growth Rate of Population	-2.36	-3.0	-2.52	-4.6
Initial Per capita GDP	-0.17E-04	-5.02	-0.17E-04	-7.28

The estimated coefficients for constant and country effects are not reported

To take these differences into account, the regression model includes not only the individual country constants, but also the interaction terms between country dummies and different educational variables as well as between country dummies and investment ratio. However, including four groups of interaction terms at the same time would result to an enormous loss of degrees of freedom (besides other explanatory variables, there would be 90 dummy variables in the model). To avoid such a problem, use is made of a group-stepwise regression method as explained below.

Step 1. Four regression models are estimated which, besides other explanatory variables as explained before in (4.30), include interaction terms for investment and for primary,

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[6] Duration years of primary education ranges from 5 (Bangladesh, Pakistan, Sri Lanka) to 8 (India and Israel) and that of secondary education ranges from 4 (Israel and Philippines) to 7 (Hong Kong, Malaysia, Pakistan and Sri Lanka)

secondary and higher education, respectively. Then the hypothesis that the interaction terms are all equal to zero is tested for each case. The p-values for F tests are 0.61, 0.82, 0.21 and 0.42, respectively. Choosing the third model as a starting point, countries are classified into two groups according to their respective estimated coefficients on secondary education interaction term. The first group refers to countries with positive secondary education interaction term and the second to those with no significant interaction term. A single interaction term for secondary education, calculated as the sum of the individual interaction terms for countries included in the first group, is then defined and used in subsequent steps.

Step 2. Substituting the above mentioned secondary education interaction term for the secondary education variable, three new regressions are estimated including, besides the normal explanatory variables, interaction terms for investment and for primary and higher education, respectively. This time, according to the same F test, the model with investment interaction terms was chosen as the p-values are 0.19, 0.55 and 0.53 for interaction terms of investment, primary education and higher education, respectively. Then, three groups of countries were recognised with high positive, low positive, and no interaction terms for investment. Two interaction terms for investment, calculated as the sum of the individual interaction terms of those countries included in each of non-zero groups, were then defined and used in the next step.

Step 3. The same procedure as in step 2 above was repeated. This time, the decision could not be made according to F test results as the p-values are 0.33 and 0.34 for models with primary and higher education interaction terms, respectively. Therefore, the adjusted R-squared was used as an alternative measure which supported the model with higher education interaction terms. Here, four groups of countries were distinguished with negative, zero, low positive and high positive interaction terms for higher education. Three interaction terms for higher education were, therefore, calculated as the sums of the individual interaction terms of countries included in each of non-zero groups.

Step 4. Given the general interaction terms with regard to investment, secondary education and higher education, the same procedure was used for the last remaining variable, primary education. Three groups of countries were identified with negative, zero and positive values for primary education interaction terms and, therefore, two interaction terms were calculated as the sum of individual negative and positive interaction terms, respectively.

The final regression includes such variables as investment for two groups of countries, primary education for two groups of countries, secondary education for one group of countries, higher education for three groups of countries, growth rate of population and initial per capita income as well as a constant and seventeen country dummies (Thailand is considered as the base country). Table 4.3 represents the estimation results while table 4.4 lists the countries included in each of interaction terms.

The results suggest that the initial per capita GDP and the growth rate of population are both significant. The negative sign of the estimated coefficient on initial per capita GDP once again confirms the results of the last two chapters with regard to conditional convergence of per capita growth rate (controlling for levels of education and investment) across the countries of our interest. Also, as noted before, the growth rate of population is expected to have a negative effect on per capita growth rate. Since in most of the countries included in our sample, the growth rate of population is greater than that of labour force, its effect on per capita growth rate becomes negative according to (4.25).

Countries are classified in three groups with regard to the effect of investment on per capita growth rate. The first group includes such countries as Indonesia, Japan, Korea, Malaysia, Singapore, Taiwan and Thailand, most of which had an average investment ratio of more than 20 percent. A 10-percentage point increase in investment ratio would raise per capita growth rate by 4 percent. However, in such countries as Bangladesh, Jordan, Pakistan and Sri-Lanka with an investment ratio of less than 15 percent, a ten percent increase in investment ratio would raise their per capita growth rate by 11 percent. The estimation results here, therefore, support diminishing returns to physical capital in general with a few exceptions. The final group includes those with no investment effect on growth rate. Since the investment ratio (as a percentage of GDP) in these countries (India, Iran, Iraq, Philippines and Syria) is 15 percent or less, one would expect a high effect for such economies. Apart from India, other countries of this group were all facing unstable political shocks, which would not allow them to develop the infrastructures required in order to absorb new investments. Iran, Iraq and Syria are situated in an important geopolitical area with many wars and political changes. Philippine, on the other hand, is well known as the least successful East-Asian economy.

An increase of 10 percentage points in the primary school enrolment rate would raise per capita income growth by 3 percentage points in Japan, Korea, Pakistan, Philippines and Taiwan. However, Primary Schooling has no effect on the growth rate in Bangladesh, Hong Kong, India, Indonesia, Iran, Iraq, Malaysia, Singapore, Sri-Lanka, Syria and Thailand. A 10-percentage points increase in the primary school enrolment rate would even lower the per capita income growth of Israel and Jordan by 4 percentage points. Such unexpected results for primary schooling, especially the negative contribution on growth in a number of countries, should not be taken seriously. Since the primary school enrolment rate is close to 100 percent in most of the countries of our sample, this variable does not have high enough variance for reliable estimates to be obtained.

An increase of 10 percentage points in the secondary school enrolment rate would raise the growth rate by 4 percentage points in Hong Kong, India, Israel, Japan, Pakistan, Singapore and Syria. Secondary education, however, has no contribution on the growth rate for the rest of the countries in our sample.

Higher education enrolment rates also have different effects on the growth rate of different groups of countries. In such countries as Indonesia, Iran, Philippines, Singapore, Sri-Lanka and Syria, an increase of 10 percentage points in higher education enrolment rate would lower the growth rate by 4 percentage points. The growth rate of India, Jordan, Korea, Pakistan, Taiwan and Thailand is not affected by higher education enrolment rate. However, a 10 percentage points increase of higher education enrolment rate would raise the growth rate by 6 percentage points in Hong Kong, Israel and Japan, and by a large 10 percentage points in Bangladesh, Iraq and Malaysia.

Table 4.3. LSDV regression results

Variable		**Estimated coefficient**	**t-ratio (p-value)**
Initial Per capita GDP		-0.43E-04	-10.05 (0.00)
Growth rate of population		-2.267	-3.28 (0.00)
Investment Ratio (group 1)		0.004	4.75 (0.00)
Investment Ratio (group 2)		0.011	7.36 (0.00)
Primary enrolment rate (group 1)		-0.368	-2.76 (0.01)
Primary enrolment rate (group 2)		0.314	2.02 (0.05)
Secondary enrolment rate (group 1)		0.422	6.46 (0.00)
Higher enrolment rate (group 1)		-0.397	-2.74 (0.01)
Higher enrolment rate (group 2)		0.641	4.33 (0.00)
Higher enrolment rate (group 3)		0.987	2.82 (0.01)
Overall constant		0.1	3.5 (0.00)
Country effects	**Bangladesh**	-0.051	-2.42(0.02)
	Hong Kong	-0.213	-4.84 (0.00)
	India	-0.112	-4.31 (0.00)
	Indonesia	-0.011	-0.77 (0.45)
	Iran	0.175	7.25 (0.00)
	Iraq	0.142	5.1 (0.00)
	Israel	-0.084	-0.64 (0.53)
	Japan	-0.657	-3.88 (0.00)
	Jordan	0.27	2.34 (0.02)
	Korea	-0.303	-1.97 (0.05)
	Malaysia	-0.005	-0.33 (0.74)
	Pakistan	-0.265	-3.59 (0.00)
	Philippines	-0.195	-1.23 (0.21)
	Singapore	-0.108	-3.62 (0.00)
	Sri Lanka	-0.068	-2.8 (0.01)
	Syria	0.031	1.2 (0.24)
	Taiwan	-0.27	-1.77 (0.08)
Adjusted R-squared		0.716	
LM test for serrial correlation		χ_1^2 =7.55 [p=0.006]	
RESET test for functional form		χ_1^2 =9.22 [p=0.002]	
Jarque-Bera test for normality		χ_2^2 =38.21 [p=0.000]	
LM test for heteroscedasticity		χ_1^2 =1.21 [p=0.271]	

Table 4.4
Countries included in different interaction terms

Variable	**Countries Included**
Investment ratio (group 1)	Indonesia, Japan, Korea, Malaysia, Singapore, Taiwan and Thailand
Investment ratio (group 2)	Bangladesh, Hong Kong, Israel, Jordan, Pakistan and Sri Lanka
Primary Education (group 1)	Israel and Jordan
Primary Education (group 2)	Japan, Korea, Pakistan, Philippines and Taiwan
Secondary Education (group 1)	Hong Kong, India, Israel, Japan, Pakistan, Singapore and Syria
Higher Education (group 1)	Indonesia, Iran, Philippines, Singapore, Sri Lanka and Syria
Higher Education (group 2)	Hong Kong, Israel and Japan
Higher Education (group 3)	Bangladesh, Iraq and Malaysia

Now a question arises as to why the investment in knowledge capital (proxied here by higher education enrolment rate) is negatively, or not, related to per capita GDP growth. Below we will explore further why this regression result appears. It should be noted that initial income may proxy for initial technological advantage (Nelson and Phelps, 1966). This framework allows for the catch-up of technology not to an exogeneously growing theoretical level of knowledge, but to the technology adapted from the leading country. Therefore, the negative coefficient may be regarded as a technological catch-up result.[7] This is known in the growth literature as the Rosenberg (1976) effect according to which, the lower the initial technological advantage (proxied here by higher education level), the faster the speed of catch up (in terms of adapted technology) to the leading high-technology country.

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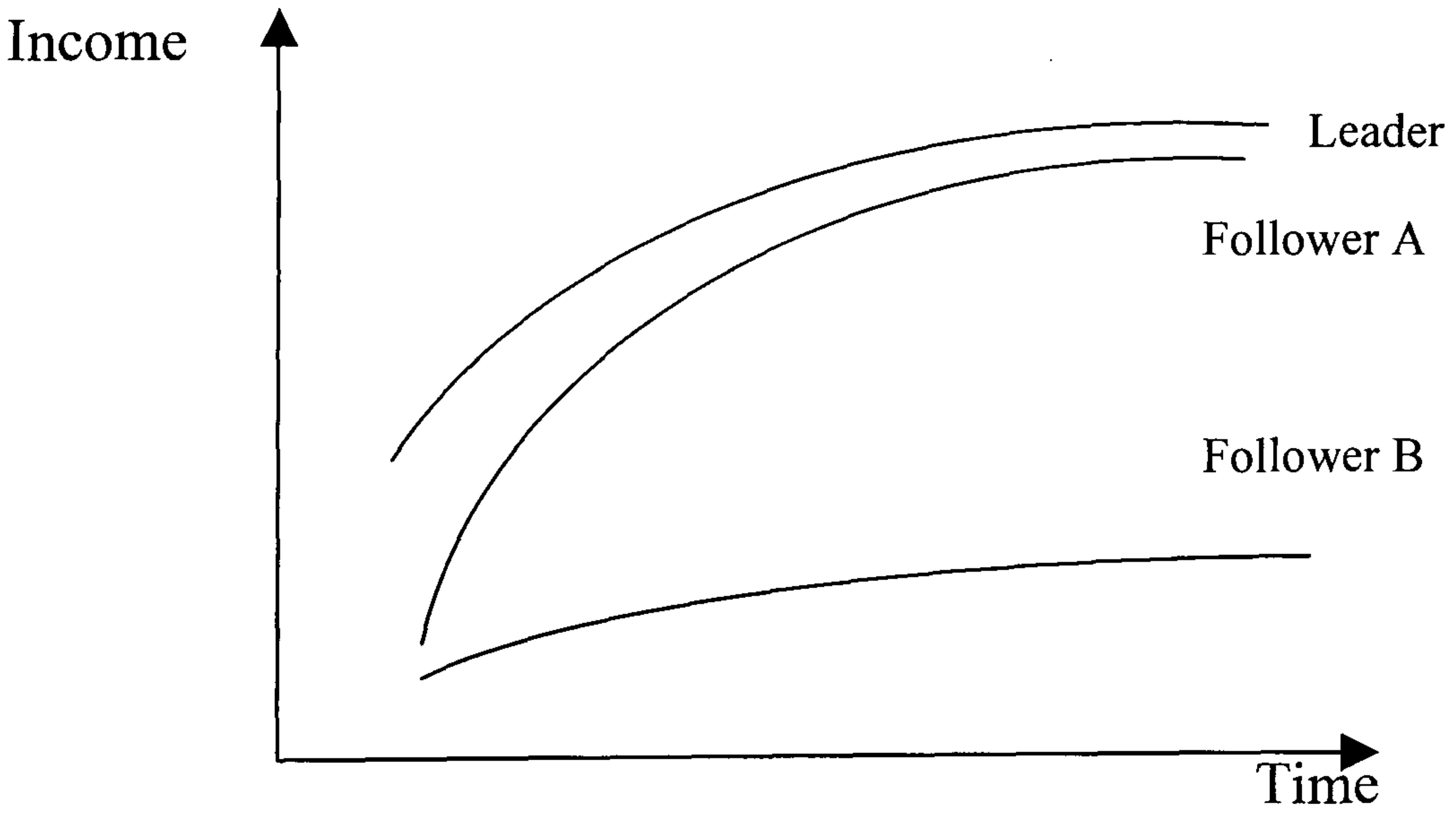
[7] See Benhabib and Spigel (1993)

However, according to our regression results, not all of the economies appear to have the same pattern for technological catch-up. Consider two countries, say A and B, with a similar low level of initial technology. Country A can have a much higher growth rate than the leading country, because of its high rate of adoption of existing technology due in large part to its high educational attainment (see figure 4.2). Country B, on the other hand, may, in fact, have even lower growth rate than the leading country because the catch-up effect may be insignificant due to a large educational gap.

This explanation could, to an extent, apply to secondary education as well. Therefore, those countries that have a higher quality secondary and higher education have a higher catch-up effect. High quality education, in fact, leads to a far easier technology adoption by followers.

Figure 4.2.
Technological catch-up in leader and follower countries



There could be some other explanations for a negative coefficient on higher education. First, our empirical results show a high correlation between secondary and higher education (r=0.75). It may therefore be difficult to observe the direct positive effects of higher education on growth, if this effect is already picked up by secondary education. Second, the contribution of higher education to growth (through R&D efforts) is limited because scientific discoveries are communicated to the follower countries, an effect picked up in part by the initial productivity level term. Finally, the Rosenberg effect causes many of the costs of failed research and innovation, and hence of diminishing returns to R&D, to be born by the leading countries (McMahon, 1984).

4.7 Conclusion and suggestions for possible extensions

The model outlined in this chapter attempted to include the endogenous component of technological progress as an integral part of the economic growth. Technological progress is, in fact, represented here by human and knowledge capital accumulation. However, the growth rate of the stock of knowledge capital is proxied by the investment in higher education mainly as a result of lack of data.

The estimation results once again confirm the validity of our results in the last two chapters with regard to the convergence controversy. The population growth contributes negatively to economic growth of the countries of our interest. This result was expected because, in most of these countries, the population growth leads to an increase in unskilled labour force. The estimation results for physical capital investment ratio support the "diminishing returns to physical capital" theorem with some reasonable exceptions.

The estimation results for the primary (and to an extent, secondary) education variable are not very reliable because (among other reasons) of the nature of the educational data: the data does not contain enough variability. The negative sign for the estimated coefficient on higher education (and to an extent, the zero coefficient on secondary education), however, could be interpreted as a result of the technological catch-up or "Rosenberg" effect. An economy with an initial technological disadvantage would catch-up (in terms of the adopted technology) with the leading economy. Therefore, the leading economy would have a lower growth rate than the follower. However, there could be an exception to the Rosenberg theorem: if the follower is facing a large educational gap (in terms of its educational qualities), it might have a lower growth rate than the leading economy (and in some extreme cases, a negative rate of growth).

As an extension to this study, one could look for a better proxy variable for human capital investment, which could represent the real quality of educational activities. Also, the regression model of this chapter estimates only the direct effects of human capital formation on growth. In chapter 3 we discussed that there is a possibility of physical investment being affected by growth rate of income. This possibility could also exist when there is a broad concept of investment including both physical and human components. The demand for investment in education could itself be financed by the human capital formation contribution to income growth. In order to account for such a two-way causation between income growth and (broad) investment, one could treat investment as endogenous by considering a simultaneous equations framework, in which the effect of income growth in different types of capital investment is depicted. However, we did not attempt specifying such a system here because the economics of education does not provide us with enough variables explaining the investment in different levels of human capital. Therefore, designing a system, the equations of which are exactly identified, is not an easy job.

Chapter 5

The Estimation of a Production Function for Iran

5.1 Introduction

Within the advanced countries, growth rates tend to be very stable over long periods of time, provided one averages over periods long enough to eliminate business-cycle effects (or corrects for short term fluctuations in some other way). As Lucas (1988) notes, however, for poorer countries there are many examples of sudden, large changes in growth rates, both up and down. 'Some of these changes are no doubt due to political or military disruption: Angola's total GDP growth fell from 4.8 percent in the 60's to –9.2 percent in the 70's; Iran's fell from 11.3 percent to 2.5 percent, comparing the same two periods. I do not think we need to look to economic theory for an account of either of these declines' (Lucas, 1988, p.4).

Lucas is right in that including *these* countries in a cross-section (or a panel-data where there are only a few observations over time for each country) might distort the econometric estimation results of production function. Therefore, this chapter studies the Iranian economic performance using an individual time-series econometric model that accounts for sudden, large structural changes.

In the last few decades, the oil industry has become a dominant sector of the Iranian economy. It mainly produces crude oil for the world market and provides the modern sectors of the rest of the economy with part of its capital and most of its foreign exchange. The oil industry's linkages to other economic sectors are limited, due to its capital-intensive nature and the underdeveloped state of the modern sector in the capital goods industries.

The Iranian national income data is available since 1959, when agriculture and oil sectors' contribution in total GDP was 27 and 11 percent, respectively. However, the oil sector gradually became a dominant sector. After a short period of economic stagnation in the early 1960's, a period of sustained economic expansion began during 1964 that lasted through to 1973. The rate of growth accelerated steadily from an average of 9.6 percent in the 1962-68 economic plan period to 11.8 percent in the 1968-73 plan period as oil became the leading sector.

The negative effects of the boom years appeared in reduced growth between 1973 and 1978, with an annual average rate of 6.9 percent. During the period 1975-78 the non-oil tax revenue was only 18.5 percent of total government revenue, while the share of oil revenue was 75.5 percent (Amuzegar 1983, pp. 44-45). The growth rate continued dropping afterwards as a result of the Islamic revolution in 1978-79, followed by the war with Iraq and economic sanctions by the United States. During the eight-year war with Iraq, the Iranian economy experienced a protracted period of economic stagnation. The economy was particularly adversely affected over the last three years of war, 1985-87.

Since the end of the war, the rate of real GDP growth rose to an estimated 10.1 percent in 1990-91, mainly as a result of foreign investment as well as a 120 percent increase in oil revenues of government in 1989. However, the sustained fall in oil revenues from 1992 has again left the economy with another period of stagnation since.

This chapter is an effort to apply economic theory, together with econometric methods, in order to explain such large variations in the Iranian production behaviour. The chapter begins with a short review of time series econometric approaches in section 5.2, where the concepts of stationarity, cointegration and error correction models are discussed. Section 5.3 introduces some test methods for stationarity and cointegration, which are used in section 5.4 in order to study the behaviour of the relevant production factors in Iranian economy. Finally, a conclusion ends the chapter.

5.2 Time series econometrics

When the researcher is not aware of the nature of the underlying data generating process, time series methods are of special use in modelling the economic theory under study.

There are two main approaches in order to select an appropriate econometric model, namely the traditional specific-to-general and the more recent general-to-specific methods. In the first approach, also known as the Box-Jenkins approach, the statistical model underlying the data is assumed to be known at first. The economic theory and the results of previous experiences are used in order to specify a proper set of variables for the model. Then, using suitable estimation methods (such as Ordinary Least Squares or its alternatives), the parameters of the specified model are estimated. Finally, the performance of the model is assessed by a diagnostic checking through such measures as t-ratios, R-squared, and Durbin-Watson statistics, among others, in order to test for heteroscedasticity, autocorrelation, multicollinearity and problems of these kinds. If there is an unsatisfactory test result, the model could be modified. This procedure is repeated until the final (conclusive) result appears. The problem with this procedure is that it normally results in a final model that is more complicated than expected at first and, most probably, biases the researcher's judgement. For instance, observing a low DW statistic, the researcher may wrongly use the Cochran-Orcutt iterative procedure given such a low value of DW statistics could be due to the omission of a relevant variable from the model.

Although Leamer (1987 and 1983) and Sims (1980) had already introduced alternative general-to-specific approaches for model selection, Hendry's approach has been the most popular econometric studies during the last two decades or so. Hendry and Richard (1983) suggest the following four steps in specifying an econometric model:

i. Commence from the most general model that is reasonable to maintain and is consistent with what economic theory usually offers as an equilibrium relationship.
ii. Reparameterise the model so that the explanatory variables become closer to orthogonal and are interpretable in terms of the final equilibrium.
iii. Simplify the model to the smallest version that is compatible with the data.
iv. Evaluate the resulting model by extensive analysis of residuals and predictive performance.

In this approach, theory suggests which variables should enter a relationship and the data are used to determine whether this relationship is static or dynamic. The second step above is of much importance and looks more like an art than a science. In general, the variables in a general time series model are likely to be correlated. Therefore, the estimation of a general model in levels of variables would result in the usual problem of large standard errors due to multicollinearity. The variables in the equivalent error correction (ECM) formulation, however, will be less correlated. This facilitates the testing procedure because with low standard errors, the normal t-statistics in an estimated ECM will provide a good guide to which difference variables should be eliminated.

Since the differenced variables simply reflect short run dynamics, about which theory has nothing to say, their elimination from the general model in step iii above does not violate the relevant theory. However, problems arise in this step because there are alternative criteria functions and decision rules for deciding which variables should be removed from the general model. After reaching a final simple model, Hendry's approach tends to compare the finally chosen simplified model with the original one.

Now the question arises as what is the advantage of Hendry's general-to-specific approach to Box-Jenkin's simple-to-general approach? One of the reasons of the misspecification in a model is the inclusion of too many or too few explanatory variables. In the general-to-specific approach, specification errors are hopefully limited to those occurring because of the inclusion of the irrelevant variables rather than the omission of relevant ones. The omitted variable error is the more serious problem because it leads to bias and inconsistency. Moreover, the problem of a lack of efficiency in estimator, arising from the inclusion of irrelevant explanatory variables, becomes less and less serious as the testing down process proceeds and such variables are gradually dropped from the equation.

Testing for stationarity of variables is an important step in order to avoid *spurious* regression results. The following equations give different explanations for the determination of a stochastic process:

$$(5.1) \quad y_t = \varphi_1 y_{t-1} + \varphi_2 y_{t-2} + \cdots + \varphi_p y_{t-p} + \varepsilon_t$$

$$(5.2) \quad y_t = \varepsilon_t + \theta_1 \varepsilon_{t-1} + \theta_2 \varepsilon_{t-2} + \cdots + \theta_q \varepsilon_{t-q}$$

$$(5.3) \quad y_t = \varphi_1 y_{t-1} + \varphi_2 y_{t-2} + \cdots + \varphi_p y_{t-p} + \varepsilon_t + \theta_1 \varepsilon_{t-1} + \theta_2 \varepsilon_{t-2} + \cdots + \theta_q \varepsilon_{t-q}$$

where ε_t is a sequence of independent random variables drawn from a distribution with mean zero and constant variance. These models define the mechanisms by which the observations of y are generated. Model (5.1) is an autoregressive process of order p, AR(p). Model (5.2) is a moving average process of order q, MA(q). Finally, model (5.3) is a mixture of AR and MA processes and is called an autoregressive moving average process of order p and q, ARMA(p,q).

Three conditions must be satisfied for all values of t in order for a stochastic process to be stationary. First and second, the mean and variance of y_t must remain constant over time, and third, the autocovariance between y_t and y_{t-k} must depend only on the lag k.

The importance of stationarity in econometrics stems from the fact that the conventional asymptotic theory for least-squares estimation (such as the standard proofs of consistency and asymptotic normality of OLS estimators) assumes stationarity of the explanatory variables, possibly around a deterministic trend. The variance of stationary x_t is finite whereas in the case of nonstationary it goes to infinity when t goes to infinity. An innovation will affect the values of x_t only temporarily in the case of stationarity but permanently when it is non-stationary. Also the autocorrelations decrease steadily in magnitude for large orders in stationary cases, but tends to 1 as t goes to infinity for non-stationary variables.

Since many important economic time series are non-stationary, OLS estimation may produce *spurious* results, implying that there is significant correlation between underlying variables when, in fact, there is not.

A popular past method to solve the problem of spurious results discussed above has been to respecify the model in differences of variables rather than in levels. However, this removes any information about the long run from the model and is not an ideal approach for forecasting purposes. An alternative to this approach is the ECM method. A major advantage of ECM is that it results in equations with first differences and hence stationary variables while still having the long run information in model.

The ECM was first applied in Economics by Sargan (1964) but in more recent years has been associated with Hendry's approach to econometrics discussed earlier. Correlation can be spurious when the variables involved exhibit consistent trends over time. So, we can not necessarily treat a correlation between dependent and explanatory variables as a causal relationship. One should not, therefore, be impressed with high values of R-squared in time series regressions[1]. As already discussed, the classical statistical inference in general was specially designed for variables that are stationary, whereas many variables in Economics are stochastic and nonstationary and we can not rely on the standard regression procedures.

Consider the following simple dynamic model of the short run adjustment

$$(5.4) \qquad y_t = \alpha_0 + \gamma_0 x_t + \gamma_1 x_{t-1} + \alpha_1 y_{t-1} + u_t$$

where u_t is a white noise error. Rearranging (5.4) results in the following ECM

(5.5) $\Delta y_t = \gamma_0 \Delta x_t - (1-\alpha_1)[y_{t-1} - \hat{\beta}_0 - \hat{\beta}_1 x_{t-1}] + u_t$

where $\hat{\beta}_0 = \hat{\alpha}_0 /(1-\hat{\alpha}_1)$ and $\hat{\beta}_0$ and $\hat{\beta}_1$ are the coefficients of the following long run equilibrium relationship

(5.6) $y_t = \beta_0 + \beta_1 x_t + v_t$.

Estimations of (5.4) and (5.5) are equivalent, but the ECM has several advantages. Assuming x and y are cointegrated (explained later), the ECM incorporates both short- and long run effects; the long run equilibrium (5.6) is incorporated into ECM (5.5) by the term in the squared brackets. If, therefore, the equilibrium holds, the disequilibrium (or error correction) term tends to be zero. However, during the periods of disequilibrium, this term is non-zero and measures the deviation from equilibrium during time t. Therefore, an estimate of $(1-\alpha_1)$ provides information on the speed of adjustment, that is, how fast the variably y_t changes in response to the disequilibrium. For instance, large values of $-(1-\alpha_1)$, tending to –1, indicate that economic agents remove a large percentage of the resulting disequilibrium each period (recall that the model is in logs). Small values (tending to zero), on the other hand, suggest that adjustment to the long run steady state is slow.

Another advantage of the ECM is that all the terms in the model are stationary so standard regression techniques are valid (assuming cointegration).

5.3 Testing for stationarity and cointegration

Stationarity of the variables under investigation is a key factor in determining the econometric modelling strategy. It can be shown that all MA processes such as (5.2) are stationary (see Harvey 1993, p. 12). However, it is not necessarily the case with AR processes. The AR model (5.1) can be demonstrated by $A(L)y_t=\varepsilon_t$, where $A(L)$ is the polynomial lag operator $-\varphi_1 L-\varphi_2 L^2-\ldots-\varphi_p L^p$. Forming the characteristic $(-\varphi_1 L-\varphi_2 L^2-\ldots-\varphi_p L^p=0)$, for given (or estimated) values of the φs, this is an equation in lag operator L. If the roots of this equation are all greater than unity in absolute values, then y_t will be stationary. Having $L=1/\varphi_1$, this means that the absolute value of φ_1 should be less than unity. Dickey-Fuller (DF), Augmented Dickey-Fuller (ADF) and

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[1] In a regression equation using cross sectional data, the trending problem does not arise and the R-squared values are not very high. The spurious results problem, therefore, does not apply in the panel data regressions of previous chapters.

some of their extensions are the various tools by which one could formally test for unit roots in a variable.

The simplest form of the DF test considers an AR(1) model

$$(5.7)\quad (1-L)y_t = \Delta y_t = (\varphi_1 - 1)y_{t-1} + \varepsilon_t$$

where $\varepsilon_t \sim IID(0,\sigma^2)$. The non-stationarity null hypothesis **H₀**: $\varphi_1=1$ is to be tested against the alternative stationarity **H₁**: $\varphi_1<1$. The advantage of (5.7) is that this is equivalent to testing $(\varphi_1-1)=\varphi^*=0$ against $\varphi^*<0$. Under non-stationarity, the statistic computed does not follow a standard t-distribution but, rather, a Dickey-Fuller distribution. Adding a constant and a trend to the model increases the critical values (in absolute terms) and, therefore, makes it more difficult to reject the null hypothesis.

If we face an AR(p) process, then the error term (ε_t) in (5.7) will be autocorrelated to compensate for the miss-specification of the dynamic structure of the process y_t. In this case, the DF statistics will mislead us. ADF test is the DF test adjusted for some appropriate (significant) differenced dependent variable to capture autocorrelation in the error term

$$(5.8)\quad \Delta y_t = \varphi^* y_{t-1} + \sum_{i=1}^{p-1} \varphi_i \Delta y_{t-i} + \varepsilon_t\ .$$

Selecting too few lags may result in over-rejecting the null when it is true, while too many lags may reduce the power of the test because of the loss of degrees of freedom.

Some series in our case study exhibit structural breaks. These are notably associated with the revolution (1978-79), the economic sanctions that followed as well as the eight-year war with Iraq. In such circumstances, the standard tests of the unit root hypothesis against the trend stationary alternatives may not reject the unit root hypothesis. As Perron (1989) argues, a unit root test which does not take account of the structural breaks in the series can result in (wrongly) non-rejecting the differenced stationary hypothesis when, in fact, the trend stationary alternative is true. If the breaks in the series are known a-priori, then it is relatively simple to adjust the ADF test by including appropriate dummy variables to the model. The relevant critical values for unit root tests involving shifts in trend and/or intercept are reported in Perron (1989 and 1990).

Cointegration deals with the connection between relationships between integrated processes (from a statistical point of view) and the concept of steady state equilibrium (from an economic point of view). It could be said that testing for stationarity of a single variable is similar to testing whether a linear combination of variables cointegrate to form a stationary, equilibrium relationship. In fact, static regressions among integrated series are meaningful if and only if they involve cointegrated variables.

The concept of cointegration was introduced by Granger (1981) and extended by Engle and Granger (1987). If a series must be differenced d times before it becomes stationary, then it contains d unit roots and is said to be integrated of order d, denoted by $I(d)$. Consider two time series, y_t and x_t, which are both $I(d)$. If there exists a vector β, such that the disturbance term from the regression is of a lower order of integration, $I(d-b)$, where $b>0$, then Engle and Granger (1987) define y_t and x_t as cointegrated of order (d,b). For instance, if y_t and x_t are both $I(1)$, and the disturbance term is $I(0)$, then the two series are cointegrated of order $CI(1,1)$.

Since the models to be estimated in this study are single equation static production functions, we apply the two-stage Engle-Granger (1987) approach, which uses the residual-based ADF test to test for cointegration between the variables. In order to estimate the long run relationship between the cointegrating variables y_t and x_t, it is only necessary to estimate the static model

$$(5.9) \quad y_t = \beta x_t + \varepsilon_t,$$

which could include an intercept and other explanatory variables and dummies, if necessary. The estimated error term, $\hat{\varepsilon}_t$, should then be tested for stationarity.

The second stage comprises the estimation of the short run ECM itself using the estimates of disequilibrium ($\hat{\varepsilon}_t$) to obtain information on the speed of adjustment to equilibrium

$$(5.10) \quad A(L)\Delta y_t = B(L)\Delta x_t - (1-\mu)\hat{\varepsilon}_{t-1} + \mu_t$$

where $A(L)=1-\alpha_1 L-\alpha_2 L^2-\ldots-\alpha_p L^p$, and $B(L)=\gamma_0+\gamma_1 L+\gamma_2 L^2+\ldots+\gamma_q L^q$. This equation allows for a general dynamic structure to be determined by the data. If y_t and x_t are $I(1)$ and cointegrated, thus all terms in this equation are $I(0)$ and statistical inferences using standard t- and F-tests are applicable.

There are difficulties if one tries to estimate a long run relationship with only a small sample because the estimators produced by this method could be biased. Also the so-called common factor problem is another difficulty with this method (see Cuthbertson and Barlow, 1991).

5.4 Empirical results

5.4.1 Economic growth models

Chapter 1 discusses different growth models in details, four of which are of interest in this chapter, namely those of Kaldor, Eltis, Arrow and Barro. It is not possible to estimate the other models because of lack of data for Iranian economy. The models are as follows (all variables in logarithm)

(5.11) $y_t = a + \theta_1 k_t + \theta_2 l_t$ (Kaldor)

(5.12) $y_t = a + \theta_1 k_t + \theta_2 l_t + \theta_3 i_t$ (Eltis)

(5.13) $y_t = a + \theta_1 k_t + \theta_2 l_t + \theta_4 ic_t$ (Arrow)

(5.14) $y_t = a + \theta_1 k_t + \theta_2 l_t + \theta_5 ig_t$ (Barro)

where y_t is GDP, k_t is capital stock, l_t is labour force (also proxied by population, pop_t), i_t is investment share of GDP, ic_t is total investment accumulation over time and ig_t is government spending.

5.4.2 Data

The data, listed in Table A3 in the Appendix, are annual and cover the period 1959-1996. Figures are all in 1982 prices (where applicable). The data on real GDP, total gross investment, government gross investment, total depreciation of capital stocks, and population are from Iran's Plan and Budget Organisation (PBO) and Central Bank (CB).

There are no published data on capital stocks, so the figures of investment for each year (net of depreciation and war damages to capital stocks during 1980-88) are added into the value of capital stock at the start of the period in order to give an approximation for the value of capital stock at the start of the year after. For this purpose, an estimation of capital stock for year 1959 is taken from Amini et al. (1998). Also, the data on labour force is not officially published and the one used here is that estimated by Amini et al. (1998)[2].

5.4.3 Unit root tests

Table 5.1 lists the results of unit root test for level as well as first difference of variables. Figures 5.1 to 5.18 graph the variables in level as well as first (and, where

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[2] Their estimation does not cover the period 1959-1965. Employing the rest of the sample (i.e. 1966-1996), the relationship between labour force and population is estimated as {Labour = 2108.7+ 0.195(Population) ; R-squared = 0.91},using which the missing figures are approximated.

required, second) difference. For both the level and the difference cases, two regressions are estimated, one with an intercept and the other with an intercept and a linear trend. The LR statistic determines which of Dickey-Fuller or augmented Dickey-Fuller tests should be looked at.

The log of labour force, l_t, seems to be a trend stationary or I(0) variable. However, the ADF statistic value, -3.97, is only significant at 5%, and not 1%, level and, therefore, we think of this variable as both I(0) and I(1). Note that, as explained later, whether this variable is I(0) or I(1) does not change the results of cointegration tests. It is worth mentioning that this result did not change when the first 7 years of this series (that are estimated using the method explained in footnote 2) were excluded as the series was found to be trend stastionary with ADF(1) = –3.74 (with a critical value of –3.56).

The log of real (gross) investment as a share of GDP, i_t, and the log of government investment, ig_t, are found to be first difference stationary or I(1) variables as the relevant DF statistic from Dickey-Fuller regressions with no trend is –4.87 and –4.45, respectively. In the case of ig_t, this result is more strongly confirmed when we take into account the 1978-79 break in first difference of this variable (see figure 5.18).

The log of real GDP, y_t, is critically first difference stationary. However, considering the break at 1976 in first difference (figure 5.2), y_t looks more like an I(1) variable. One reason for the DF test statistic to be so close to the critical value could be the existence of three outliers, 1978-80. That is why, for cointegration purposes below, we deal with this variable as both I(1) and I(2). However, the DF test statistic value of –7.37 from the unit root test of second difference with no trend (not reported in Table 5.1) confirms that the variable is I(2).

It is not also clear whether capital stock series, k_t, is integrated of order one or two. The preliminary results of DF and ADF tests imply that the variable is second difference stationary or I(2). However, looking at figure 5.5, one could easily detect a one-time change in the structure occurring at 1978 (the year of revolution). Following Perron (1989), we consider a model that permits an exogenous change in the level of the (first difference) series (a 'crash'). In addition to the standard variables of the ADF test procedure, two dummies are introduced to explain the crash in 1978; the first dummy takes value one for 1978-1996 and zero otherwise, while the second dummy takes value one for 1977 and zero otherwise. Besides, in order to take the outlier observation at 1986 into account, another dummy is used which takes value one at 1986 and zero otherwise. The result of the Perron test is as follows[3]

$$(5.15)\quad \underset{}{\Delta^2k_t} = \underset{(1.16)}{0.01} - \underset{(-8.26)}{0.44\Delta k_{t-1}} - \underset{(-5.02)}{0.29\Delta^2k_{t-1}} + \underset{(5.54)}{0.002tr} - \underset{(-7.74)}{0.07D} - \underset{(-2.27)}{0.03D_{77}} - \underset{(-14.27)}{0.16D_{86}}$$

where Δ and Δ^2 are first and second difference operator, respectively, *tr* is a trend, D is a dummy variable with value one for 1978-96 and zero otherwise, D_{77} is a dummy variable taking value one for 1977 and zero otherwise, and D_{86} is a dummy with value one for 1986 and zero otherwise. The figures in the bracket are *t-student* statistics. The coefficient on Δk_t is significantly smaller than zero (the corresponding *t* statistics value of -8.26 is significantly less than the critical value of –3.45 at %5 level of significance, taken from Perron, 1990). Therefore, capital stock may be considered as first difference stationary or I(1). However, for cointegration purposes, we still reserve the possibility of capital stock to be an I(2) variable. Note that the DF test statistic from the unit root test of second difference with no trend (not reported in Table 5.1) is –8.06.

The log of real (gross) investment accumulation, *ic*, tends to be I(2). Note that decision must not be made upon the ADF statistic value of -5.94, because it comes from a Dickey-Fuller regression with no trend while, as clearly shown in figure 5.14, the variable does have a trend. It is clear, from figure 5.16, that *ic* is second difference stationary. The strange behaviour of the second difference of this variable before 1963 is inevitable because cumulative variables like this grow very fast during the first few years. The DF test statistic of –7.02 for second difference of *ic* with no trend (not reported in Table 5.1) confirms the above results.

Finally, the log of population, *pop*, is an I(2) variable as the DF statistic for second difference with no trend (not reported in Table 5.1) is –6.55.

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[3] This result refers to a model in which only the intercept of the series is allowed to change. The other two alternatives of Perron test were also fulfilled, one with a change in the slope and another with a change in both intercept and slope. The result reported here is the most significant one.

Figure 5.1
Real GDP (1982 prices)

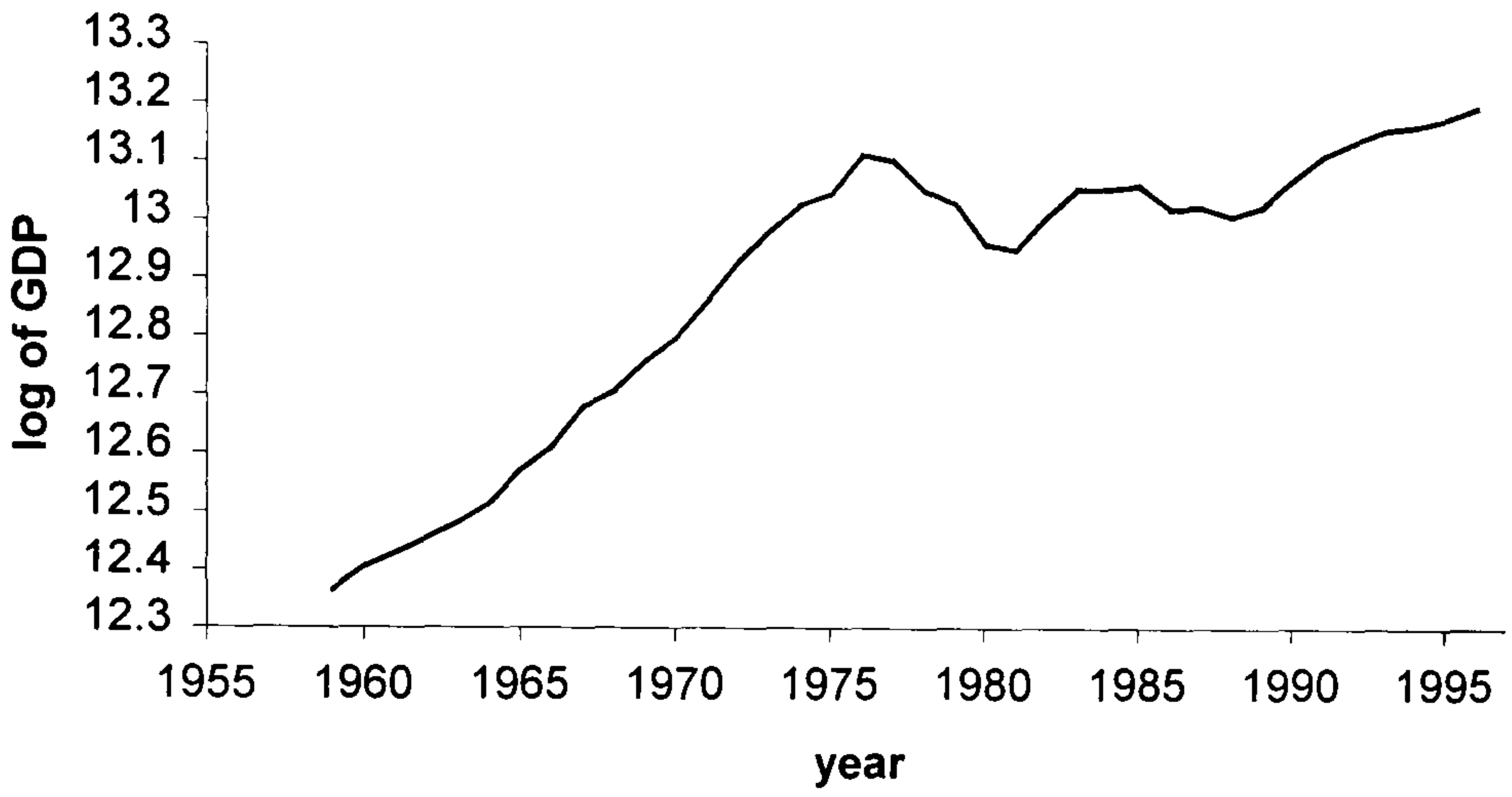


Figure 5.2
Real GDP (1982 prices)-1st difference

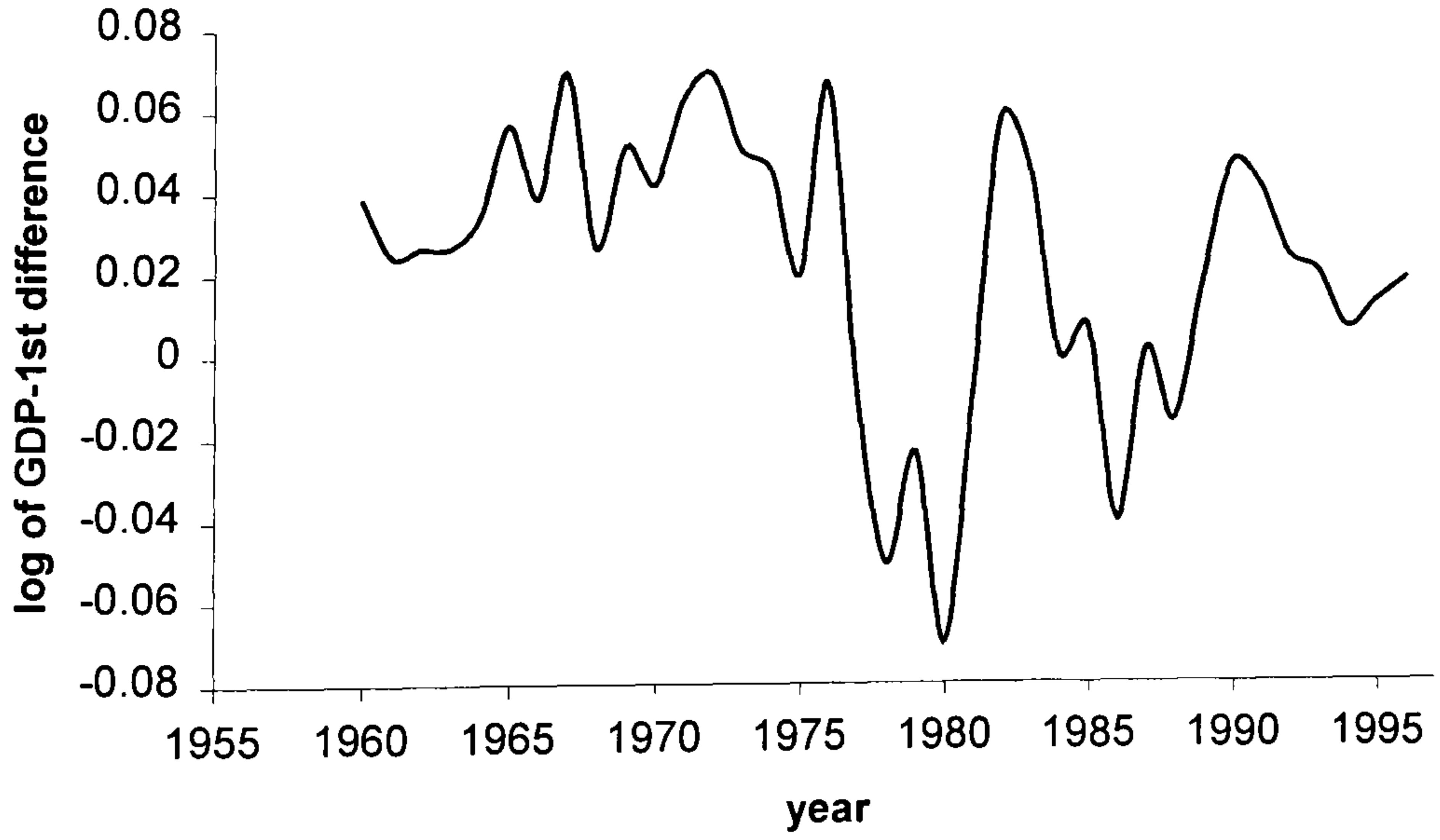


Figure 5.3
Real GDP (1982 prices)-2nd difference

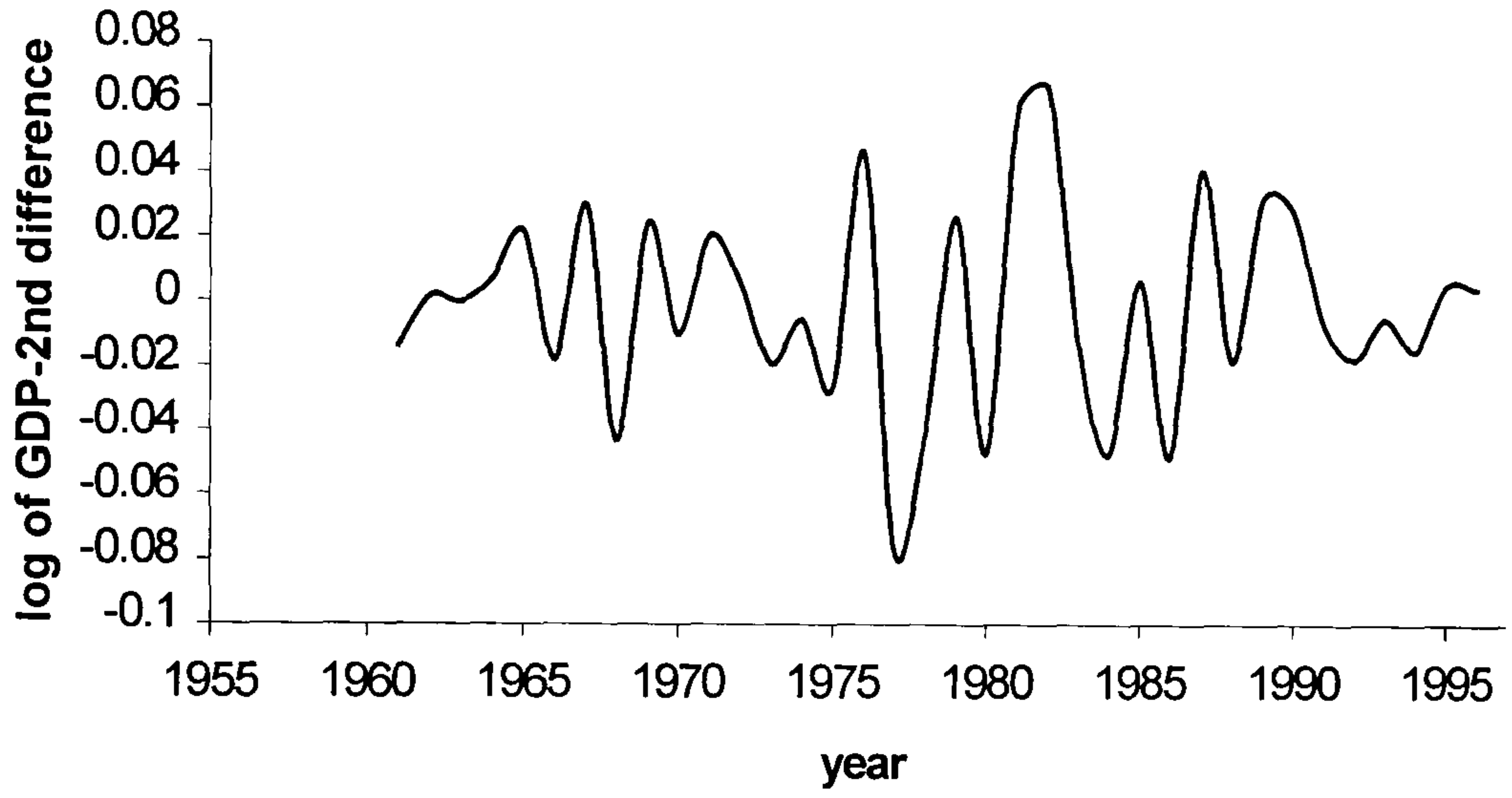


Figure 5.4
Real capital stock (1982 prices)

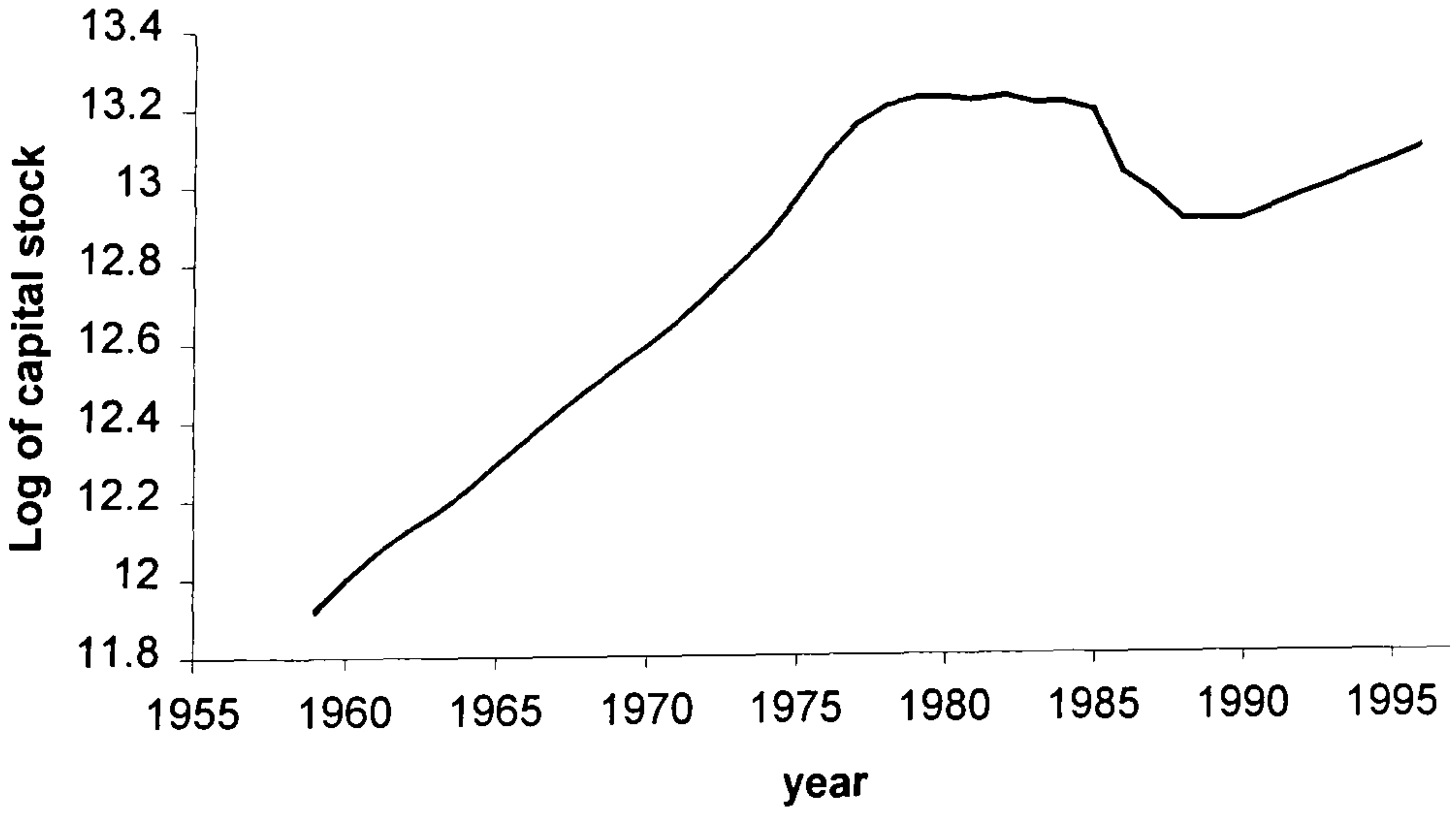


Figure 5.5
Real capital stock (1982 prices)-1st difference

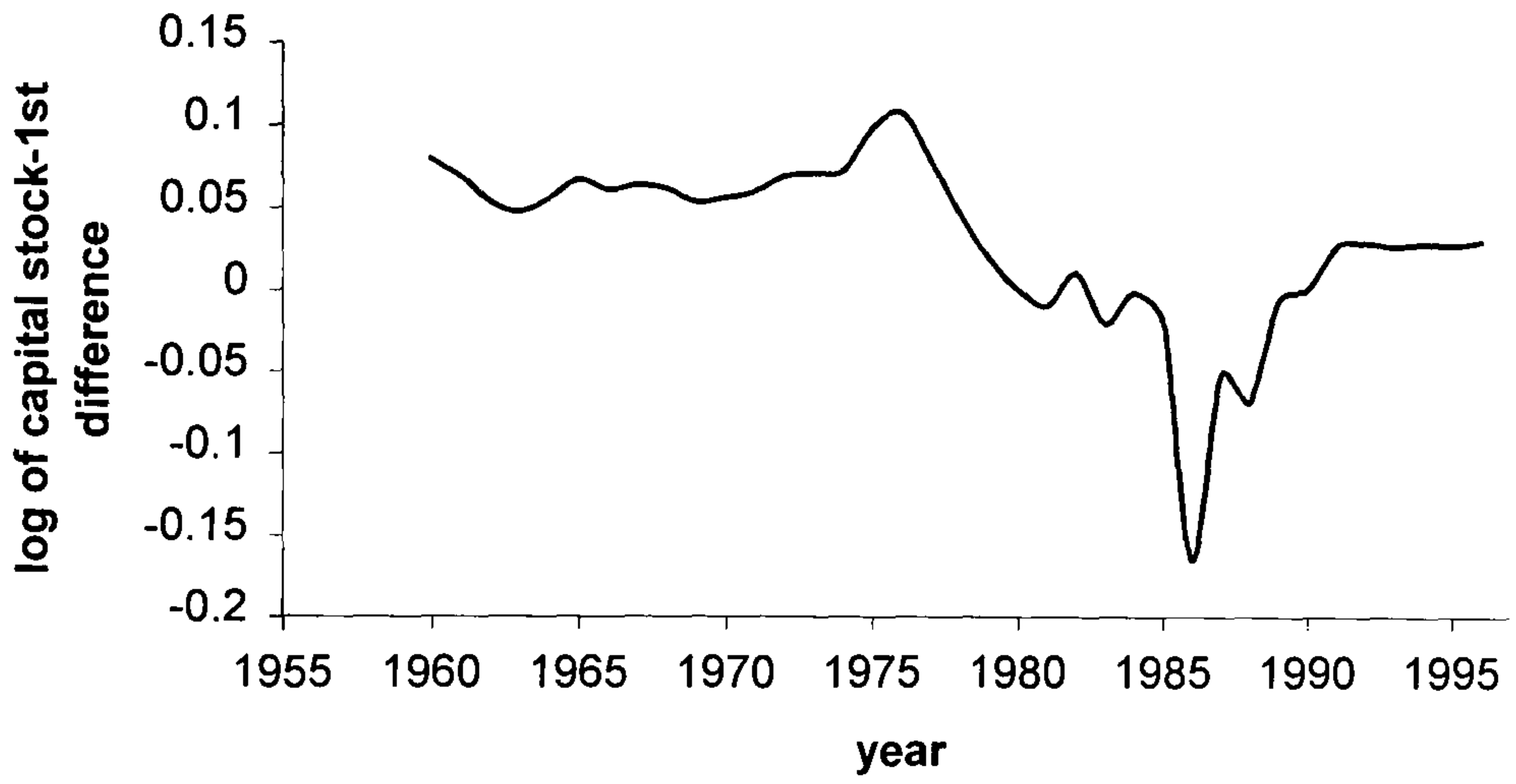


Figure 5.6
Real Capital Stock (1982 prices)-2nd difference

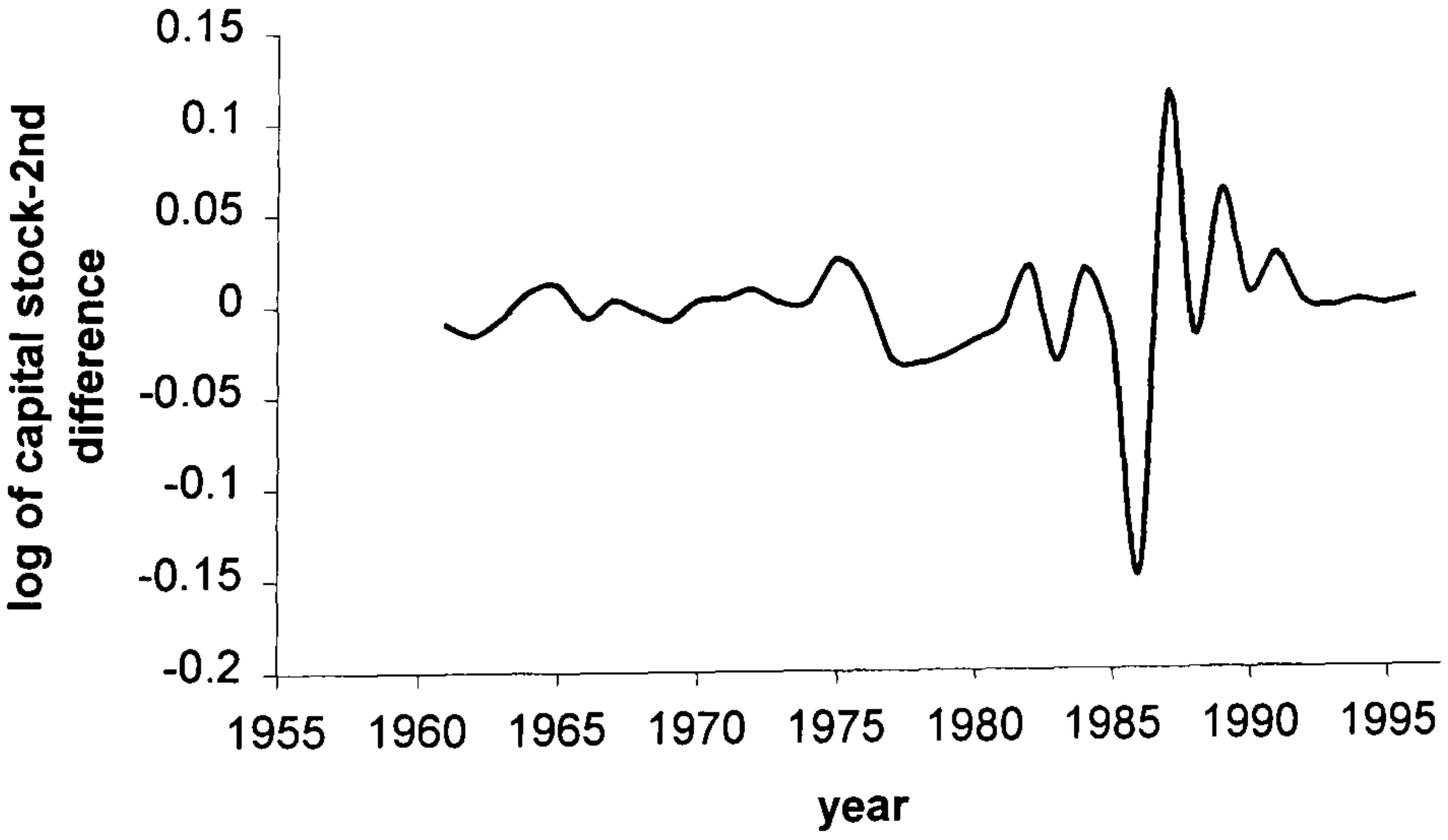


Figure 5.7
Labour force

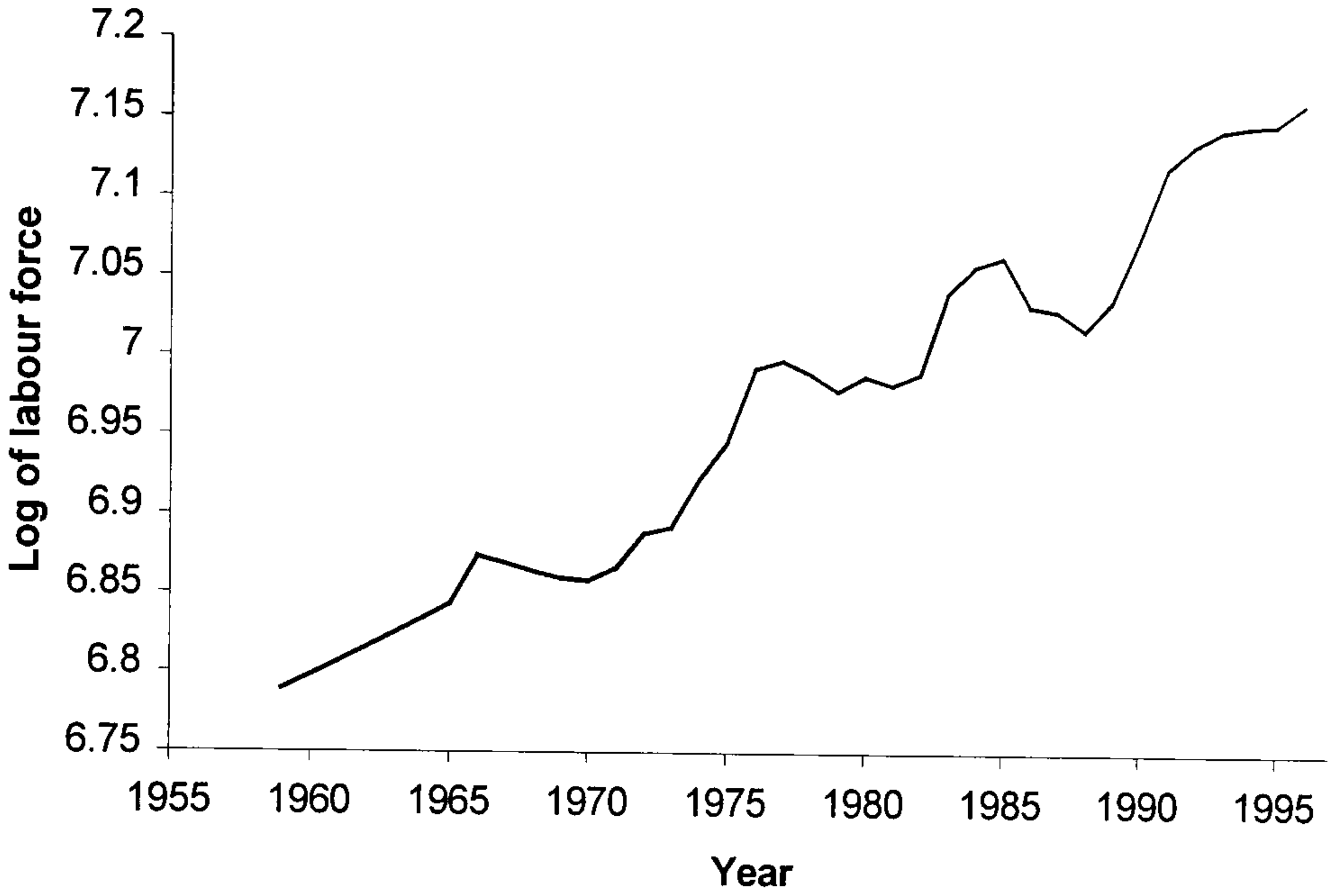


Figure 5.8
Labour force-1st difference

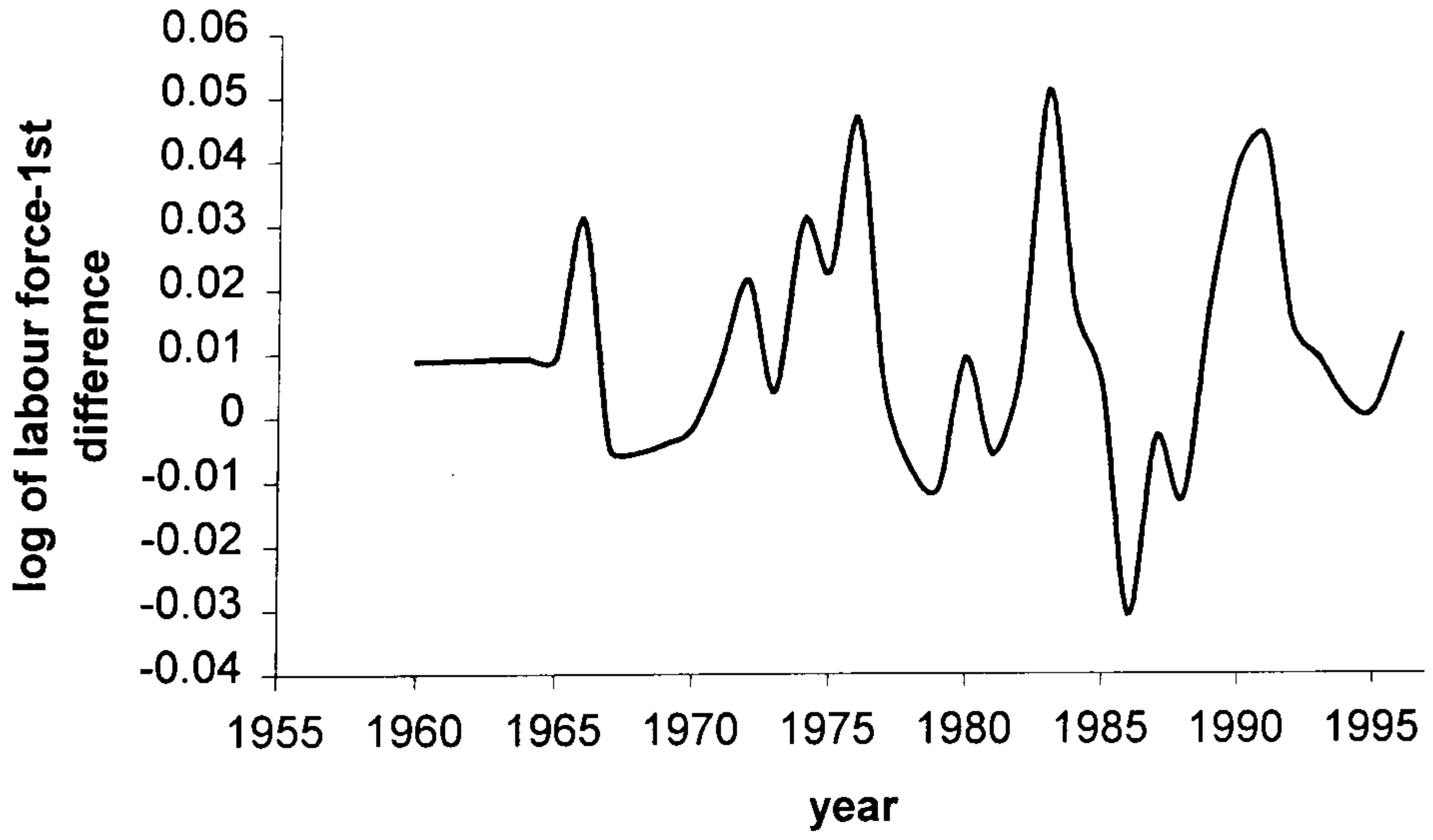


Figure 5.9
Population

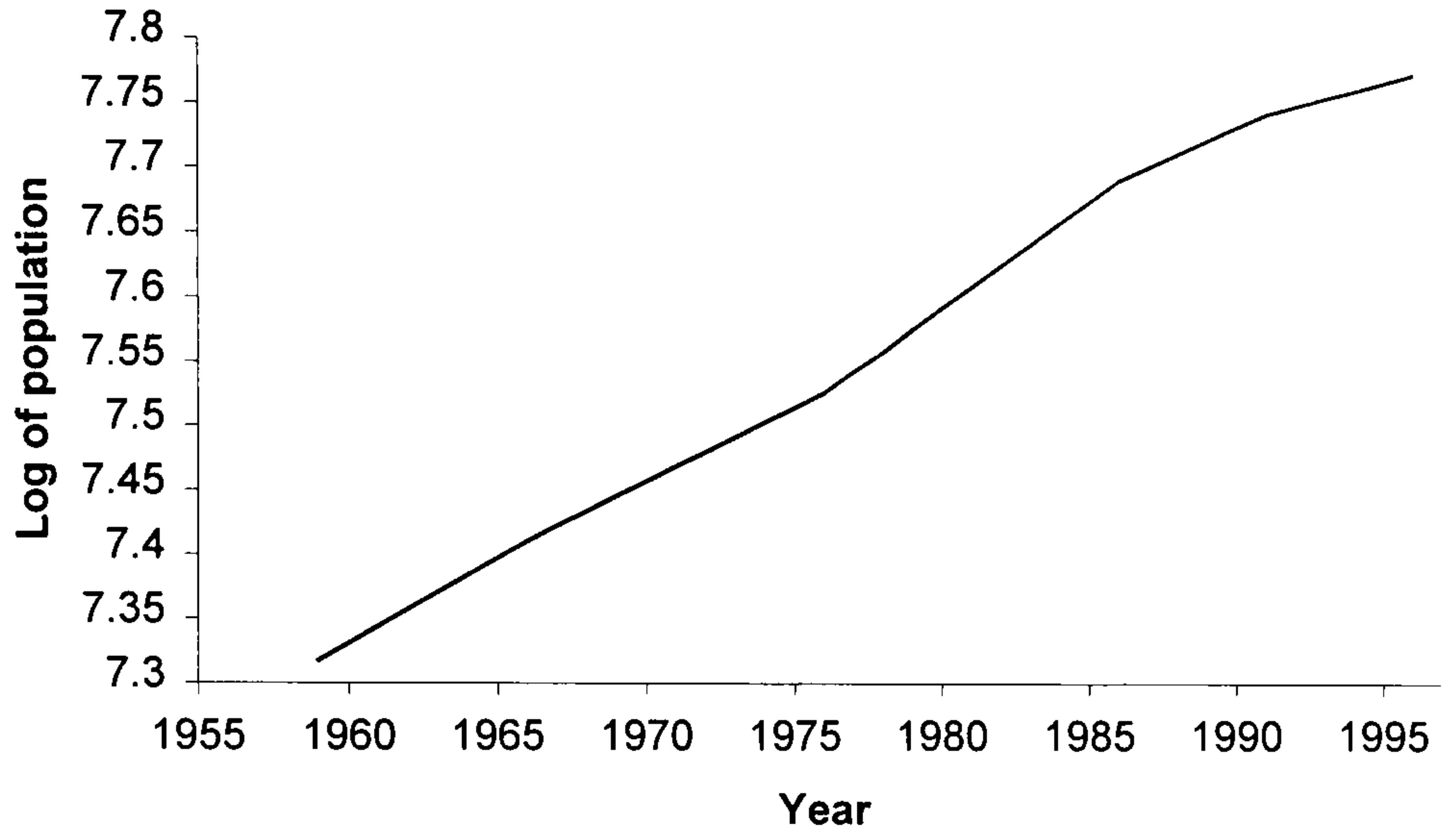


Figure 5.10
Population-1st difference

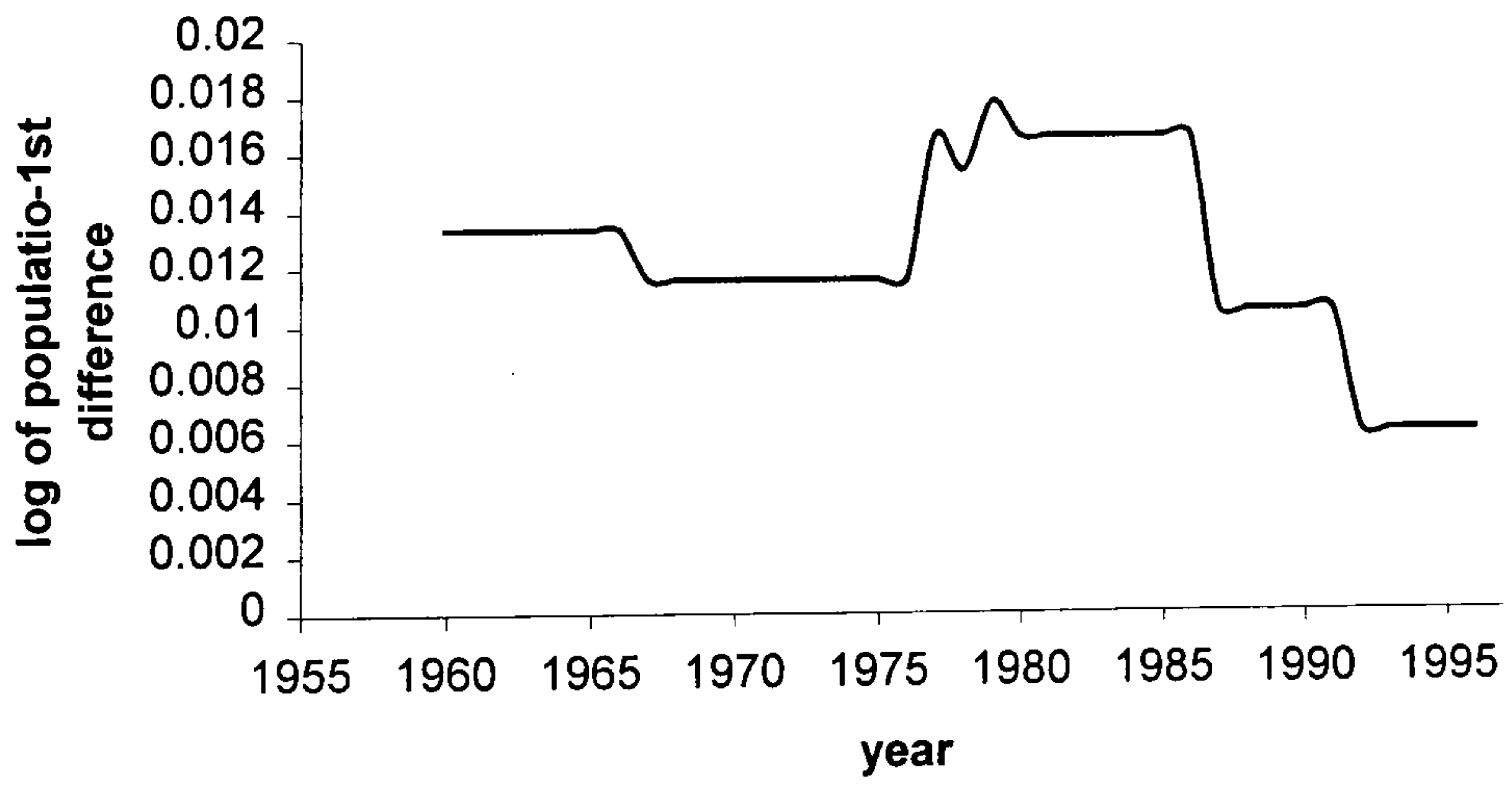


Figure 5.11
Population-2nd difference

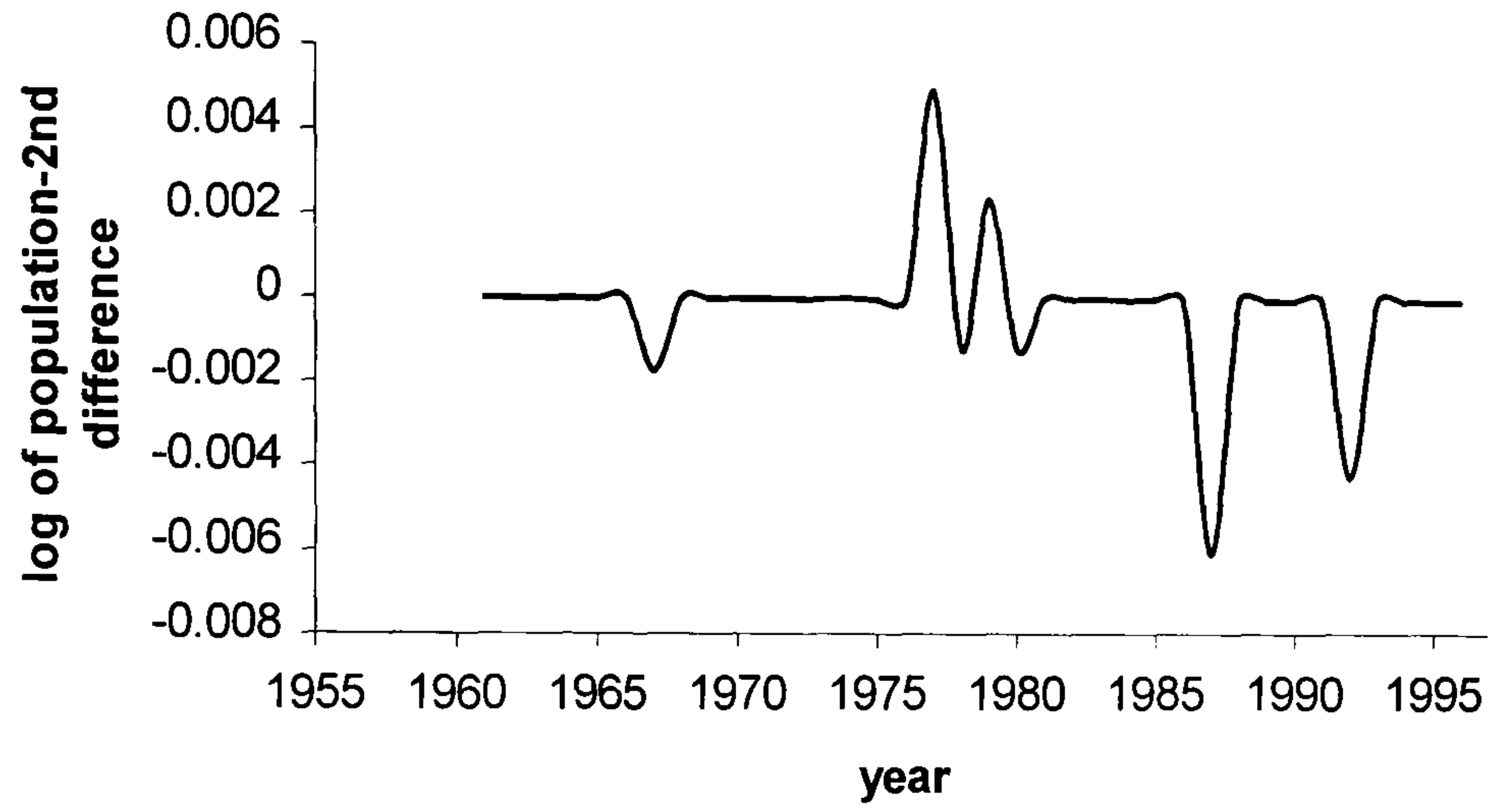


Figure 5.12
Real investment share of GDP (1982 prices)

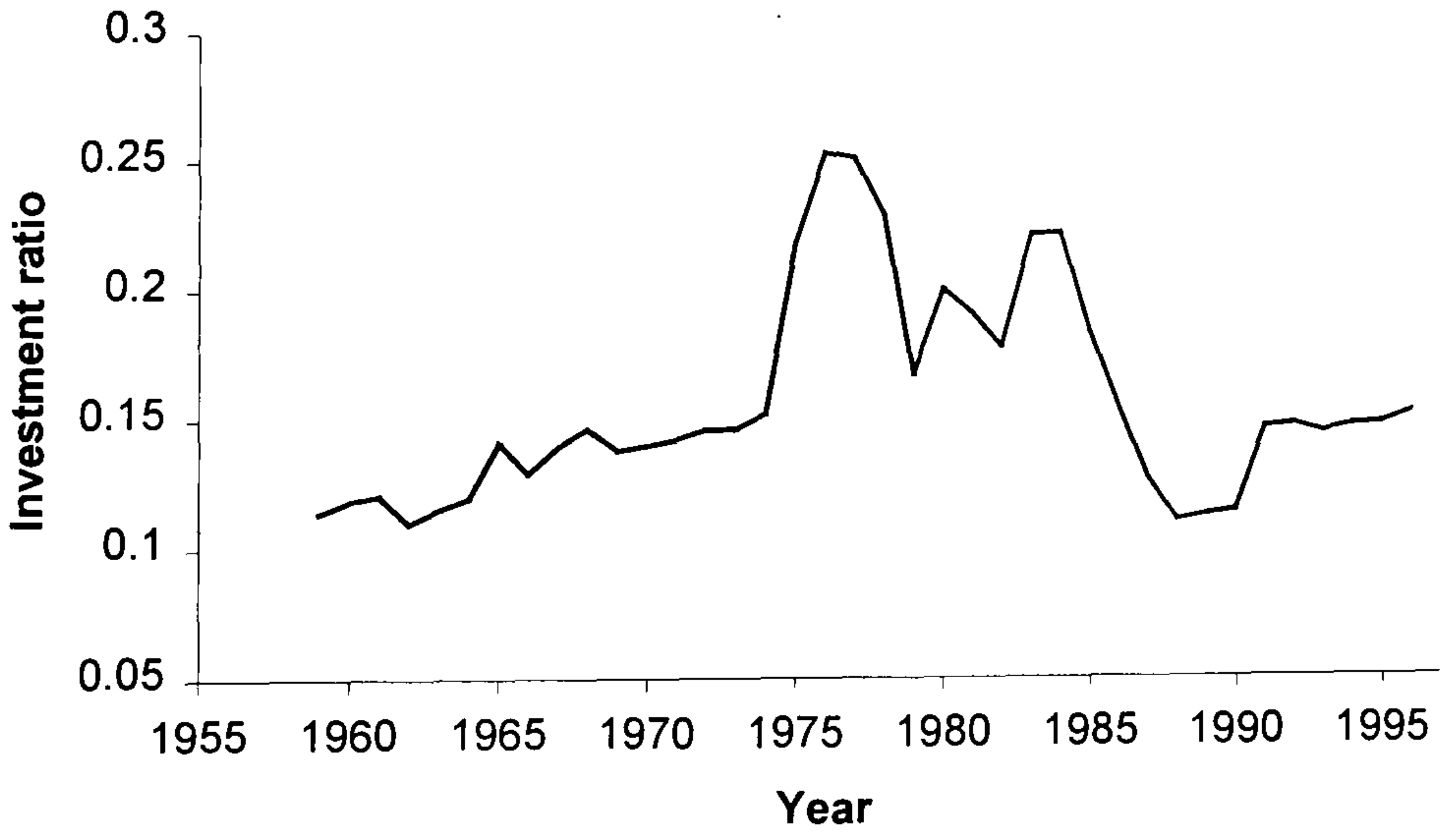


Figure 5.13
Real investment share of GDP (1982 prices)-1st difference

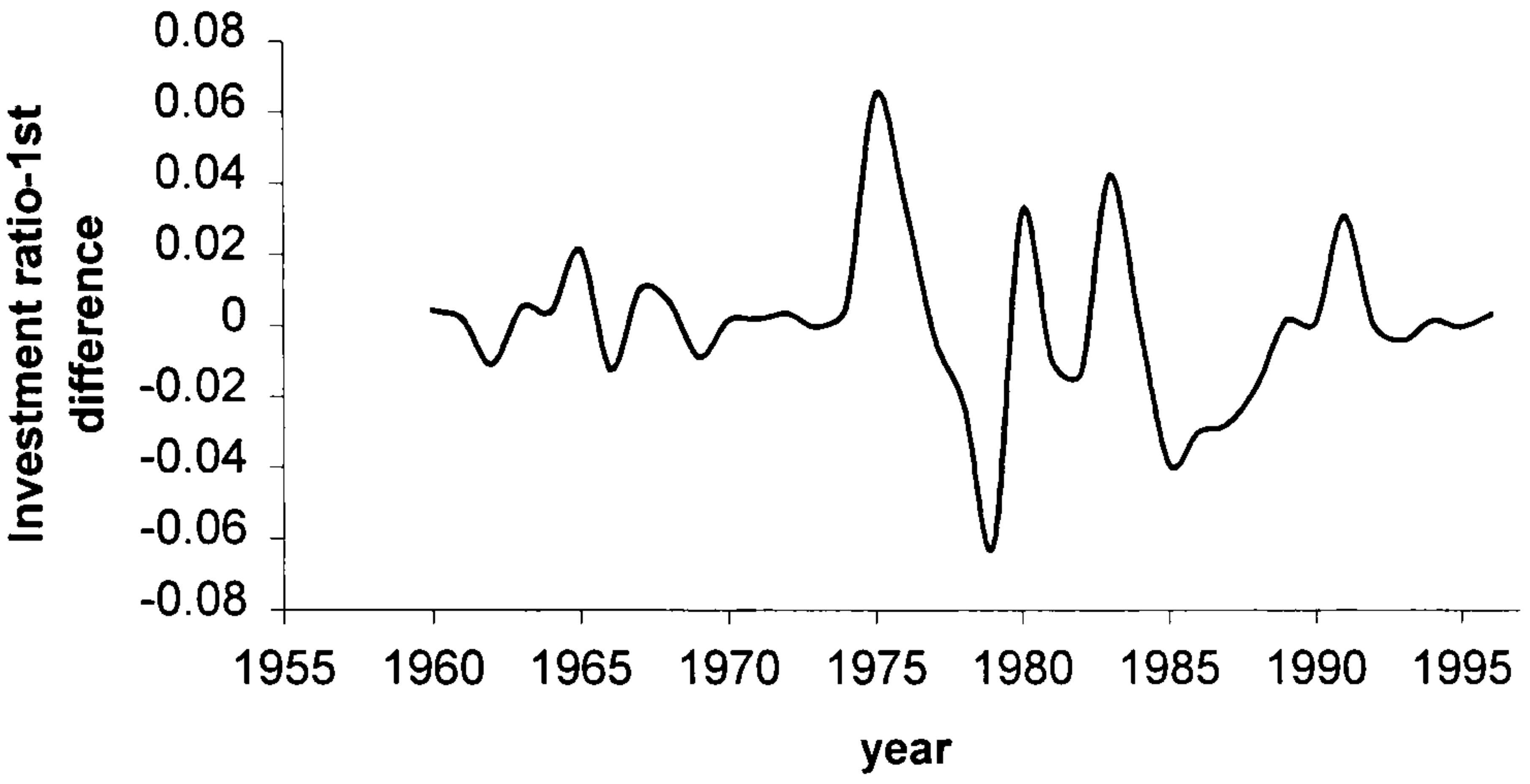


Figure 5.14
Real investent accumulation (1982 prices)

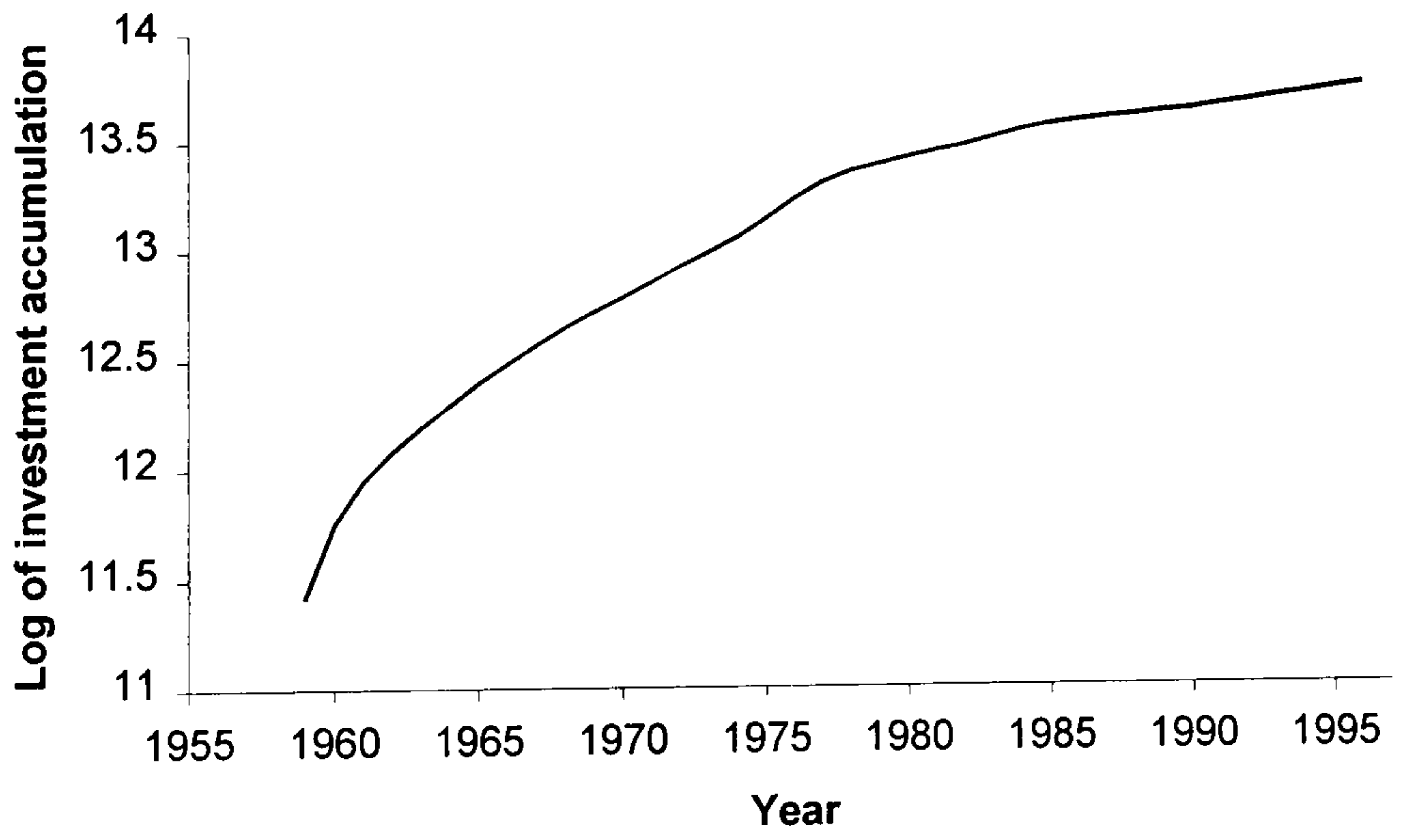


Figure 5.15
Real investment accumulation
(1982 prices)-1st difference

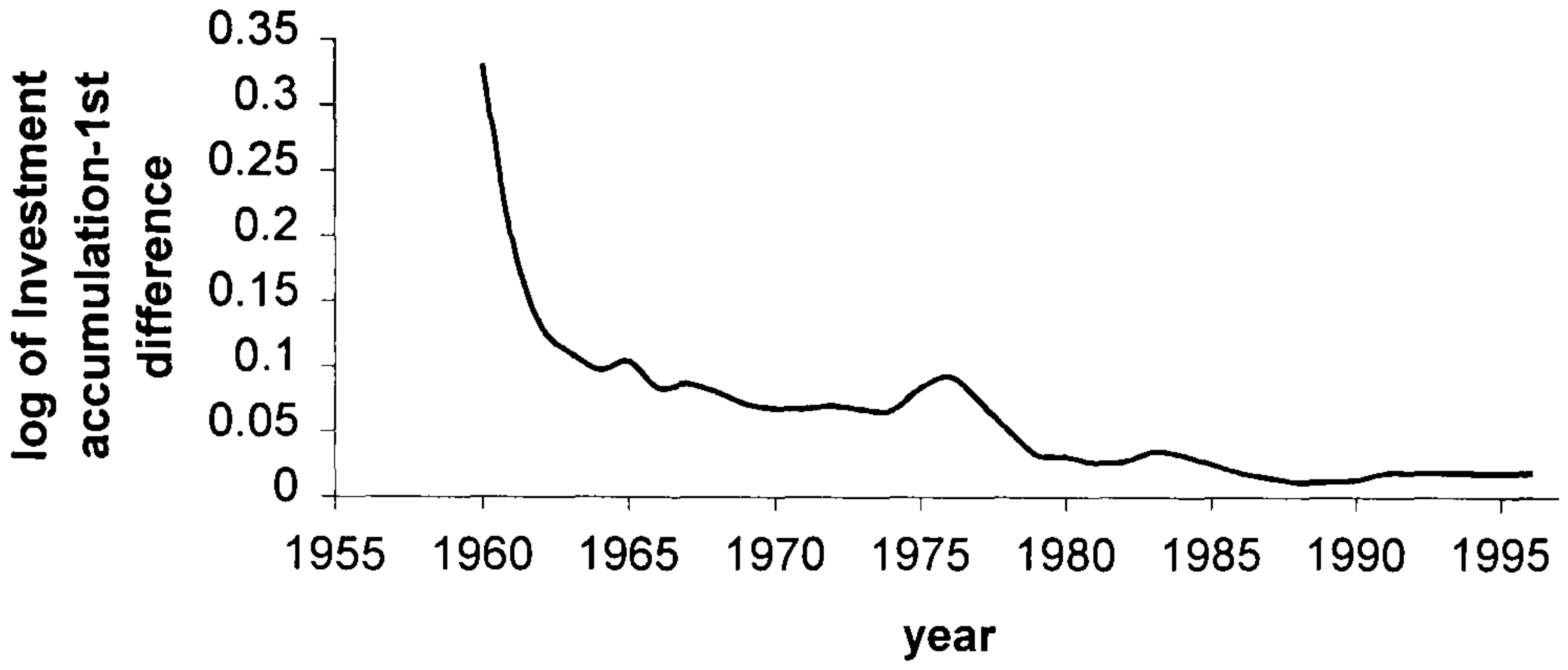


Figure 5.16
Real investment accumulation
(1982 prices)-2nd difference

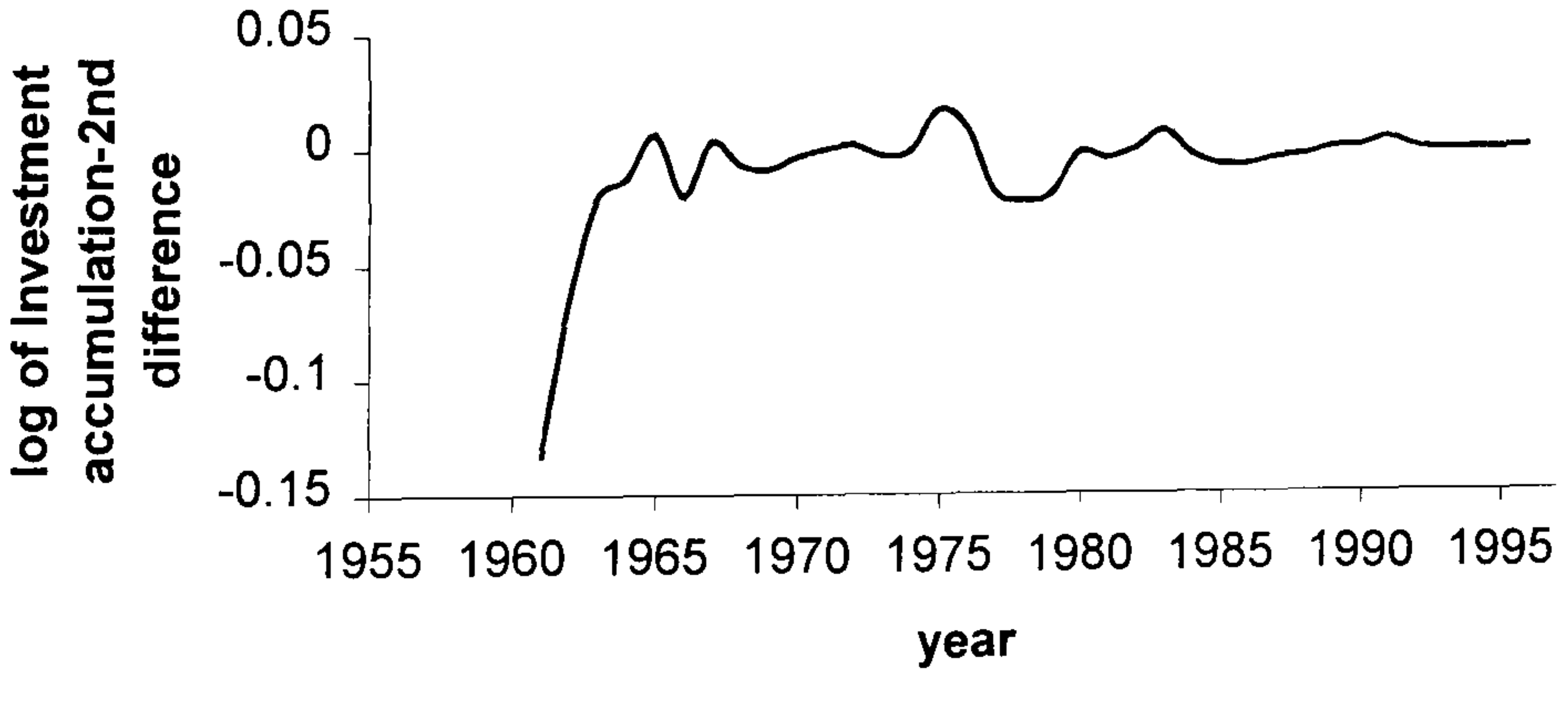


Figure 5.17
Real government investment
(1982 prices)

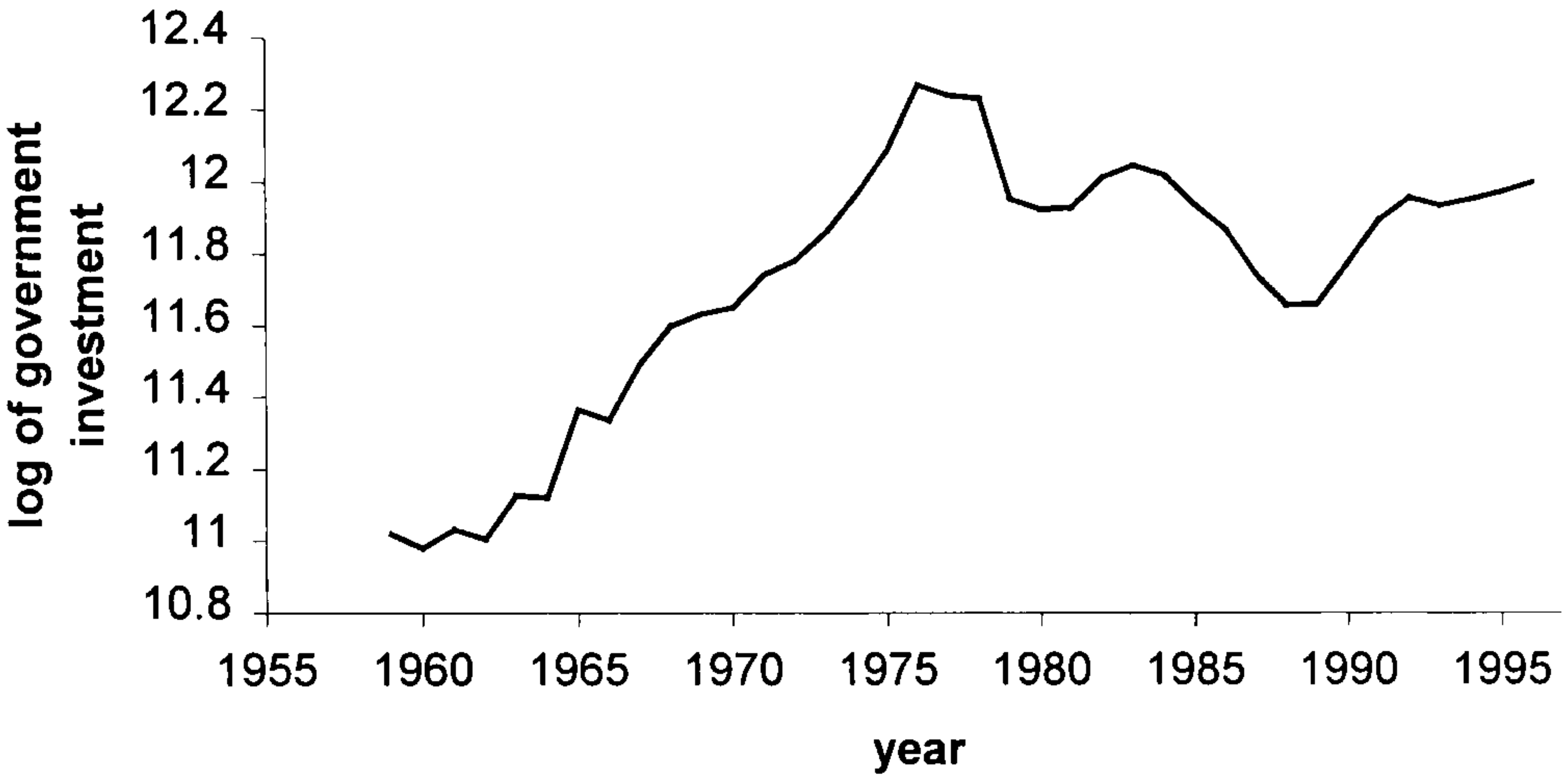
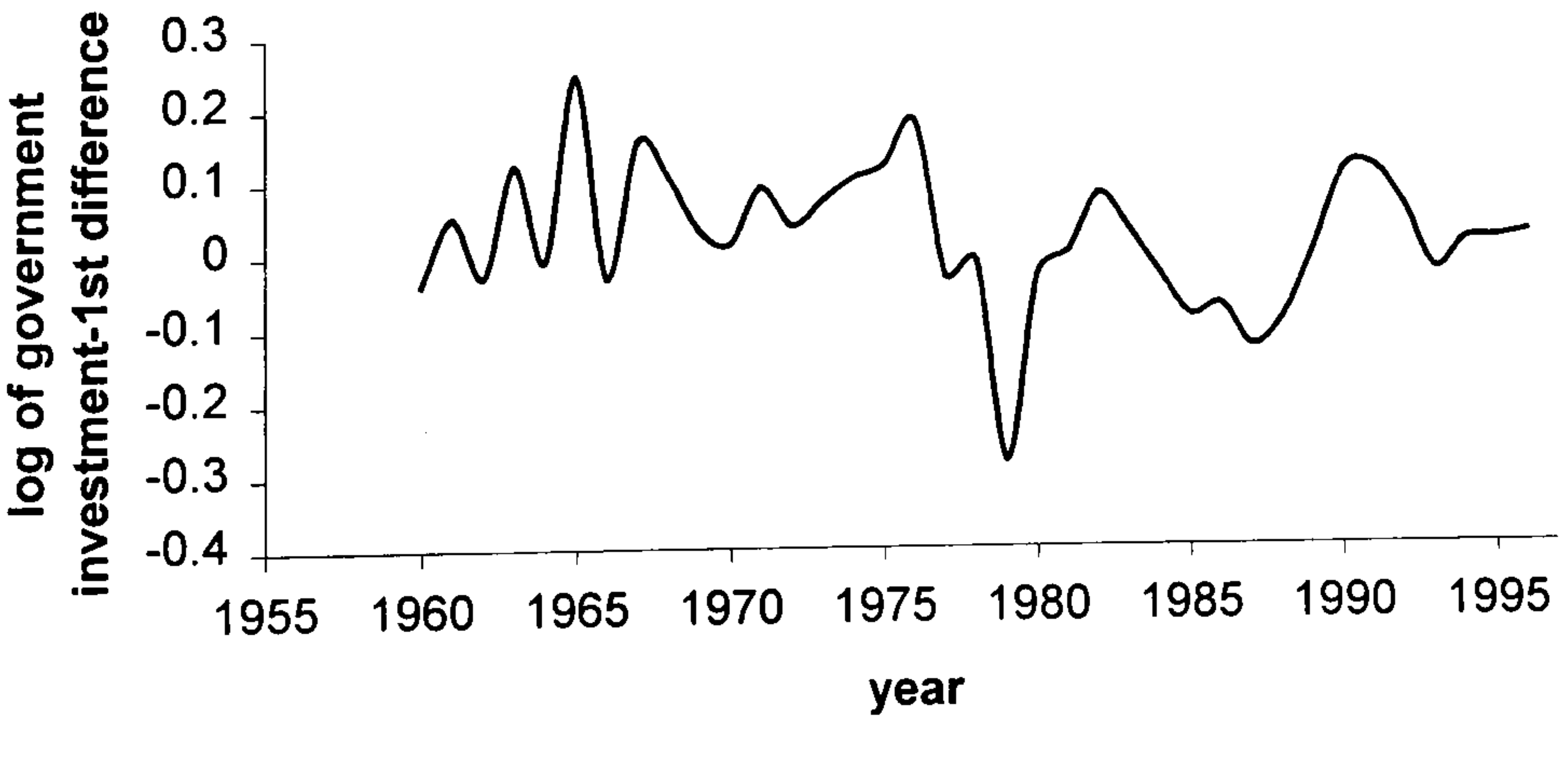


Figure 5.18
Real government investment
(1982 prices)-1st difference



5.4.4 Cointegration tests

It is clear, from figures 5.1 to 5.18, that there have been structural changes in economy during 1978-1988. In this period, the Iranian economy suffered from such shocks as the Islamic revolution in February 1979 (the effects of which began in early 1978), the economic sanction by western countries, and the eight-year war with Iraq. For this reason, a dummy variable is used in all estimations, which takes value one for 1978-88 and zero otherwise.

Table 5.2 lists the preliminary estimation results of models (5.11) to (5.15). Four estimation results are reported for each model. The first two models use labour force, l_t, and the last two use population, pop_t (each with and without a dummy variable taking value one for 1978-1988 and zero otherwise). A very simple way of testing for cointegration is looking at the DW statistics. The value of the DW statistics is, in many cases, very close to zero suggesting no cointegration. Another preliminary cointegration test could be based on the unit root test of the regression residuals. The unit root test statistic reported is either DF or ADF (depending on the corresponding LR test result). The null hypothesis of non-stationary residuals could not be rejected for any model and, therefore, the variables are not cointegrated. For this reason, the t statistics corresponding to the estimated coefficients are not reported as they could be misleading.

However, some preliminary remarks could be pointed out using these results. Kaldor's model exhibits the best result in terms of more reasonable estimated coefficients, which support the constant returns hypothesis. Among other models, that of Barro is better in terms of both adjusted R-squared and DW statistics and, to some extent, the magnitude of estimated coefficients. Also note that in all cases, dummy variable improves the results. However these results are not reliable because they stem from models in which the variables are not proved, for the moment, to be cointegrated.

Because of the low power of unit root test, the cointegration tests based on the unit root test of the residuals must not be taken seriously. A more reliable cointegration test is through the ECM. However, because of the limited number of observations, ECM is not a powerful approach as it is based on the co-integration tests. Johansen and Juselius (1990) propose a maximum likelihood approach for testing and estimating cointegrating vectors in the context of a VAR. However, this method seems to be even a more inappropriate alternative approach given the severe data limitations for the Iranian economy.

In order to develop the error correction models, there is a choice of two different scenarios.

Scenario 1

In this alternative, the log of GDP, y_t, the log of capital stock, k_t, and the log of labour force, *lt*, are assumed to be I(1) variables. This assumption lets us to estimate an ECM regression equation for the models of Kaldor, Eltis and Barro. In Kaldor's model, there is a possibility of the above I(1) variables to cointegrate to a stationary residual. The same applies for Eltis's and Barro's models, which include an extra I(1) explanatory variable (i.e. i_t and ig_t, respectively). Note that whether l_t is treated as I(0) or I(1) does not change the results because in Kaldor's model, for instance, there could be a cointegration between y_t and k_t.

Table 5.3 lists the estimation results of the ECM models when the error term (i.e. the term in squared bracket in (5.5)) is replaced by the residual from regression 2 of Table 5.2 (the static Kaldor model with labour force). The results reported are the final ones, after omitting the insignificant short-term effects. Regression 17 is the Kaldor model with a dummy variable. Regressions 18 and 19 include the long-term and short term effects of the two extra explanatory variables, namely i_t and ig_t, respectively. Regression 20 includes the short- and long run effects of the log of investment ratio, while regression 21 includes those of the log of government investment. Regression 22, finally, includes the short- and long-term effects of both of these explanatory variables. If the absolute value of the estimated coefficient on lagged residual is significantly different from zero, then there is a long-term relationship between the variables of the corresponding model and they are cointegrated. It is obvious from the results that there is no cointegration (or long run relationship) between these I(1) variables. However, there is a small chance of cointegration for the Kaldor model only at %14 level of significance (the p-value of the estimated coefficient).

Table 5.4 alternatively lists the results when the error correction term (or the lagged value of residual) is replaced by the lagged level of variables. Recall that the long run coefficient of an explanatory variable is the estimated coefficient on the lagged level of the corresponding variable divided by the negative value of the estimated coefficient on y_{t-1}. Except for Kaldor regression 23, the estimated coefficient on y_{t-1} is not significantly different from zero and, therefore, there is no long run relationship between the variables. Even the results of regression 23 are not satisfactory as the implied long run coefficient for labour force is unexpectedly negative.

Scenario 2

As another alternative, we assume y_t and k_t to be I(2) variables. This assumption allows us to estimate an ECM regression equation for models of Kaldor and Arrow. In Kaldor's model, there is a possibility of these I(2) variables as well as the log of population, pop_t which is also I(2), to cointegrate to a stationary residual. Arrow's model also includes another I(2) variable (namely the log of investment accumulation, ic_t) which allows us to do the cointegration test under this scenario.

As in Table 5.3 of the first scenario, Table 5.5 lists the estimation results, under this scenario, using an error correction term, which is this time replaced by the estimated residual from regression 4 of Table 5.2 (the static Kaldor model with population). Regression 29 is the ECM for Kaldor model with a dummy variable. Since this scenario assumes that the variables are I(2), the short-term effects are indicated by second difference of variables and, therefore, Δ is replaced by Δ^2. Regressions 30 and 31 include the short-term and long-term effects of the Arrow's extra explanatory variable, ic_t, respectively. Finally, regression 32 includes both the short- and long run effects of ic_t. Note that all four regression models end up with the same estimated coefficients after omitting their respective insignificant short-term effects. The estimated coefficient on the error correction term is significantly negative which supports the cointegration hypothesis for both Kaldor's and Arrow's models.

In Table 5.6 error correction term is replaced by the lagged level of variables. The estimated coefficients of regression 33 are all significant and have the expected signs. The result of regression 34 implies that investment accumulation does not have a short run effect on growth rate of income while the results of regressions 35 and 36 show that this variable is an important factor in the static production function. However, inclusion of this variable alters the estimation result for both capital stock and population. Recall that Arrow introduces this variable in the production function in order to explain the technological progress due to learning by doing. Since learning by doing is a process undertaken by workers who are part of population, this variable (investment accumulation) is reflecting part of the effect of population in production and results in an insignificant estimation for population. On the other hand, it is reasonable that the inclusion of investment accumulation lowers the effect of capital stock because these two variables have similar features.

Using the estimation results of regression 33, the implied long run elasticities of output with respect to capital stock and population are 0.55 and 0.47, respectively. The constant returns hypothesis could be tested by testing the linear restriction that the estimated coefficients on k_{t-1} and pop_{t-1} add up to the absolute value of the estimated coefficient on y_{t-1}. The Chi-squared statistics for a Wald test of this restriction is 0.046. Therefore, the elasticities of production with respect to capital stock and population add up to unity.

5.5 Conclusion

The Iranian economy has experienced large changes in growth rates during the last few decades. It is necessary, therefore, to study the production behaviour of Iran in a single-country time-series framework. This chapter used recent time series econometric methods.

Since two variables in production function, namely output and capital stock, are not clearly either I(1) or I(2), two scenarios were considered in order to obtain a cointegrating long run production function. The alternative when these two variables are I(1) does not result in a cointegrating production function and, besides, does not produce (economically) significant estimate for the coefficient on labour force. The second alternative that takes these two variables as I(2), however, results in a cointegrating long run production function with (statistically and theoretically) significant estimated coefficients. Besides, the second scenario is supported by the diagnostic test results for serial correlation, functional form, normality and heteroscedasticity.

Remember from chapter 1 that the cointegrating production function, namely that of Kaldor, is an endogenous growth model in terms of its attempt to endogenise the technological progress. Kaldor argues that it is pointless to try to distinguish between investment and technical change and that new fixed capital is the carrier of technical progress. Therefore, technical progress has already been implied in a Solow kind of production function through capital stock and there is no need for a time trend to explain it. Therefore, although the technical progress function of Kaldor and the neoclassical production function of Solow look alike, the ideas behind them are different.

In the context of policy implications, however, the growth model of Kaldor could not be classified as an endogenous growth model. While the (new) endogenous growth models allow the growth rate to be modified by appropriate policy interventions, the growth model of Kaldor does not. Even though growth arises endogenously in Kaldor's technical progress function, the model is not truly an endogenous growth model because the neoclassical theory of growth refers to the same idea (that growth rate is fixed and not affected by any policy interventions). The model introduced in next chapter tests for the effect of policy variables on productivity.

Table 5.1
Unit roots test results

Variable	Level						First difference					
	No trend(1)			*Trend*(2)			*No trend*(1)			*Trend*(2)		
	DF	ADF(1)	LR(3)	DF	ADF(1)	LR(3)	DF	ADF(1)	LR(3)	DF	ADF(1)	LR(3)
Y	-2.50	-1.82	10.4	-1.37	-1.83✓	11.5	-3.09✓	-2.60	0.06	-3.31	-2.80	0.0
K	-3.37	-1.87	23.7	-0.98	-1.58✓	21.9	-2.24✓	-1.67	0.13	-2.44	-1.70	1.43
Pop	-2.29	-1.45	51.1	1.4	-2.06✓	52.6	-0.85✓	-0.58	0.34	-1.24	-0.94	0.48
L	-0.13	-0.42	4.4	-2.32	-3.97✓	13.4	-4.03✓	-3.72	0.64	-3.98	-3.67	0.66
I	-1.84	-2.18	2.24	-1.73✓	-2.09	2.22	-4.87✓	-3.88	0.12	-4.83	-3.86	0.14
Ic	-15.01	-5.94	38.0	-4.65	-1.20✓	40.1	-4.98	-1.67✓	18.0	-5.98	-2.97	11.4
ig	-2.28	-2.24	2.2	-1.51✓	-1.74	2.2	-4.45✓	-2.59	3.0	-4.65	-2.76	2.4

(1) *95% critical value for the augmented Dickey-Fuller statistic = -2.95*

(2) *95% critical value for the augmented Dickey-Fuller statistic = -3.54*

(3) *LR=2($LL_{ADF} - LL_{DF}$), where LL_{ADF} and LL_{DF} are maximum log-likelihood derived from augmented Dickey-Fuller and Dickey-Fuller regressions, respectively. It has a Chi-squared distribution with a critical value of 3.84 at 95 percent*

(4) *'✓' highlights the statistic based on which the decision is made*

Table 5.2

Preliminary estimation results of the static production functions

Variable	**Kaldor**				**Eltis**				**Arrow**				**Barro**			
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Intercept	1.88	1.89	2.92	2.21	2.80	4.43	1.23	3.15	4.92	4.40	7.06	3.59	1.16	1.52	1.61	1.72
k_t	0.39	0.55	0.40	0.55	0.42	0.66	0.32	0.59	0.23	0.42	0.18	0.47	0.02	0.30	-0.12	0.12
l_t	0.87	0.57			0.80	0.37			0.38	0.18			0.97	0.73		
pop_t			0.65	0.49			0.78	0.42			-0.02	0.29			0.89	0.74
i_t					-0.11	-0.31	0.20	-0.11								
ic_t									0.19	0.15	0.28	0.09				
ig_t													0.40	0.21	0.52	0.35
Dummy		-0.14		-0.16		-0.16		-0.17		-0.14		-0.15		-0.09		-0.07
Adjusted R-squared	0.923	0.966	0.918	0.973	0.922	0.971	0.917	0.973	0.932	0.973	0.928	0.974	0.963	0.970	0.980	0.985
DW	0.159	0.688	0.164	0.907	0.154	0.913	0.174	0.952	0.189	0.804	0.229	0.890	0.565	0.518	1.216	0.949
Residual unit root test(1)	-2.10	-2.68	-2.34	-3.19	-2.22	-3.22	-1.87	-3.31	-2.31	-3.09	-2.50	-3.32	-2.41	-2.88	-3.92	-3.27
(Critical value)	(-3.99)	(-4.42)	(-3.99)	(-4.42)	(-4.42)	(-4.81)	(-4.42)	(-4.81)	(-4.42)	(-4.81)	(-4.42)	(-4.81)	(-4.42)	(-4.81)	(-4.42)	(-4.81)

(1) The statistics reported is either DF or ADF, depending on the corresponding LR test result.

Table 5.3
ECM estimations with error correction term (scenario 1)

Variable	17	18	19	20	21	22
Intercept	0.033 (3.70)	-0.254 (-0.35)	0.034 (3.40)	1.231 (3.28)	0.247 (1.37)	0.812 (0.96)
Δy_{t-1}	0.448 (2.32)	0.441 (2.16)	0.499 (2.69)	0.301 (2.05)	0.211 (1.08)	0.480 (2.54)
Δk_{t-1}	-0.170 (-1.47)	-0.210 (-1.34)	-0.208 (-1.87)	x	-0.159 (-1.37)	-0.049 (-0.44)
Δl_{t-1}	-0.274 (-0.92)	-0.260 (-0.77)	-0.628 (-1.87)	x	x	-0.629 (-1.81)
Δi_{t-1}			0.206 (2.02)	0.226 (2.57)		0.319 (3.15)
Δig_{t-1}			x		0.110 (1.67)	x
i_{t-1}		0.056 (0.49)		-0.149 (-3.25)		-0.157 (-1.89)
ig_{t-1}		-0.015 (-0.56)			-0.019 (-1.19)	0.010 (0.40)
Dummy	-0.041 (-3.11)	-0.045 (-2.19)	-0.035 (-2.67)	x	-0.027 (-1.71)	x
Lagged residual (from regression 2, Table 5.2)	-0.167 (-1.51)	-0.139 (-1.10)	-0.134 (-1.27)	-0.029 (-0.30)	-0.059 (-0.50)	-0.085 (-0.74)
Adjusted R-squared	0.405	0.370	0.460	0.448	0.430	0.455
LM test for serial correlation	$\chi_1^2=0.12$ [0.73]	$\chi_1^2=0.01$ [0.92]	$\chi_1^2=0.90$ [0.34]	$\chi_1^2=0.62$ [0.43]	$\chi_1^2=0.04$ [0.85]	$\chi_1^2=5.20$ [0.02]
RESET test for functional form	$\chi_1^2=0.44$ [0.51]	$\chi_1^2=1.06$ [0.30]	$\chi_1^2=4.64$ [0.03]	$\chi_1^2=2.86$ [0.09]	$\chi_1^2=8.56$ [0.00]	$\chi_1^2=5.41$ [0.02]
Jarque-Bera test for normality	$\chi_2^2=0.05$ [0.98]	$\chi_2^2=0.13$ [0.94]	$\chi_2^2=0.59$ [0.74]	$\chi_2^2=1.63$ [0.44]	$\chi_2^2=1.37$ [0.50]	$\chi_2^2=1.68$ [0.43]
LM test for Heteroscedasticity	$\chi_1^2=4.06$ [0.044]	$\chi_1^2=2.77$ [0.096]	$\chi_1^2=0.00$ [0.98]	$\chi_1^2=1.67$ [0.20]	$\chi_1^2=0.18$ [0.67]	$\chi_1^2=0.00$ [0.98]

'x' indicates that the corresponding variable was initially included in the regression equation and omitted because of insignificant estimated coefficient.

Figures in bracket are t statistics and those in squared bracket are p-values.

Table 5.4
ECM estimations with levels (scenario 1)

	23	24	25	26	27	28
Intercept	1.242 (3.36)	2.387 (1.85)	1.242 (3.36)	1.902 (2.60)	1.076 (2.49)	3.328 (2.50)
Δy_{t-1}	0.352 (2.20)	0.297 (1.76)	0.352 (2.20)	0.408 (2.25)	0.201 (1.08)	0.282 (1.79)
Δk_{t-1}	-0.255 (-2.39)	x	-0.255 (-2.39)	-0.168 (-1.16)	-0.222 (-1.58)	-0.210 (-1.50)
Δl_{t-1}	x	x	x	-0.407 (-1.18)	x	x
Δi_{t-1}			x	0.256 (2.27)		0.221 (2.18)
Δig_{t-1}			x		0.112 (1.54)	x
y_{t-1}	-0.197 (-2.06)	-0.286 (-1.60)	-0.197 (-2.06)	-0.164 (-1.70)	-0.100 (-0.67)	-0.311 (-1.92)
k_{t-1}	0.156 (2.47)	0.155 (2.21)	0.156 (2.47)	0.150 (2.33)	0.143 (2.18)	0.129 (2.01)
l_{t-1}	-0.093 (-1.05)	-0.001 (-0.01)	-0.093 (-1.05)	-0.099 (-1.06)	-0.147 (-1.27)	-0.036 (-0.31)
i_{t-1}		-0.177 (-1.26)		-0.119 (-1.22)		-0.261 (-1.64)
ig_{t-1}		0.069 (0.64)			-0.047 (-0.62)	0.124 (1.24)
Dummy	-0.084 (-3.77)	-0.063 (-2.80)	-0.084 (-3.77)	-0.055 (-2.07)	-0.067 (-2.53)	-0.054 (-2.00)
Adjusted R-squared	0.516	0.451	0.516	0.549	0.525	0.552
LM test for serial correlation	χ_1^2=6.86 [0.009]	χ_1^2=4.47 [0.037]	χ_1^2=6.86 [0.009]	χ_1^2=13.11 [0.00]	χ_1^2=7.77 [0.01]	χ_1^2=9.91 [0.002]
RESET test for functional form	χ_1^2=0.67 [0.41]	χ_1^2=0.21 [0.65]	χ_1^2=0.67 [0.41]	χ_1^2=1.68 [0.20]	χ_1^2=6.75 [0.01]	χ_1^2=2.56 [0.11]
Jarque-Bera test for normality	χ_2^2=5.32 [0.07]	χ_2^2=7.96 [0.019]	χ_2^2=5.32 [0.07]	χ_2^2=0.23 [0.89]	χ_2^2=0.55 [0.76]	χ_2^2=0.07 [0.97]
LM test for Heteroscedasticity	χ_1^2=0.27 [0.60]	χ_1^2=2.40 [0.12]	χ_1^2=0.27 [0.60]	χ_1^2=0.28 [0.60]	χ_1^2=0.39 [0.53]	χ_1^2=0.31 [0.58]

'x' indicates that the corresponding variable was initially included in the regression equation and omitted because of insignificant estimated coefficient.

Figures in bracket are t statistics and those in squared bracket are p-values.

Table 5.5

ECM estimations with error correction term (scenario 2)

Variable	**29**	**30**	**31**	**32**
Intercept	-0.002 (-0.35)	-0.002 (-0.35)	-0.002 (-0.35)	-0.002 (-0.35)
$\Delta^2 y_{t-1}$	-0.399 (-2.42)	-0.399 (-2.42)	-0.399 (-2.42)	-0.399 (-2.42)
$\Delta^2 k_{t-1}$	x	x	x	x
$\Delta^2 pop_{t-1}$	-6.461 (-1.92)	-6.461 (-1.92)	-6.461 (-1.92)	-6.461 (-1.92)
$\Delta^2 ic_{t-1}$		x		x
ic_{t-1}			x	x
Dummy	x	x	x	x
Lagged residual (from regression 4, Table 5.2)	-0.315 (-2.44)	-0.315 (-2.44)	-0.315 (-2.44)	-0.315 (-2.44)
Adjusted R-squared	0.177	0.177	0.177	0.177
LM test for serial correlation	χ_1^2=0.20 [0.65]	χ_1^2=0.20 [0.65]	χ_1^2=0.20 [0.65]	χ_1^2=0.20 [0.65]
RESET test for functional form	χ_1^2=0.11 [0.74]	χ_1^2=0.11 [0.74]	χ_1^2=0.11 [0.74]	χ_1^2=0.11 [0.74]
Jarque-Bera test for normality	χ_2^2=0.17 [0.92]	χ_2^2=0.17 [0.92]	χ_2^2=0.17 [0.92]	χ_2^2=0.17 [0.92]
LM test for Heteroscedasticity	χ_1^2=0.15 [0.70]	χ_1^2=0.15 [0.70]	χ_1^2=0.15 [0.70]	χ_1^2=0.15 [0.70]

'x' indicates that the corresponding variable was initially included in the regression equation and omitted because of insignificant estimated coefficient.

Figures in bracket are t statistics and those in squared bracket are p-values.

Table 5.6

ECM estimations with levels (scenario 2)

Variable	33	34	35	36
Intercept	1.034 (2.70)	1.034 (2.70)	4.387 (2.90)	4.387 (2.90)
$\Delta^2 y_{t-1}$	-0.458 (-3.02)	-0.458 (-3.02)	-0.491 (-3.45)	-0.491 (-3.45)
$\Delta^2 k_{t-1}$	x	x	x	x
$\Delta^2 pop_{t-1}$	x	x	x	x
$\Delta^2 ic_{t-1}$		x		x
y_{t-1}	-0.438 (-3.92)	-0.438 (-3.92)	-0.525 (-4.72)	-0.525 (-4.72)
k_{t-1}	0.241 (3.21)	0.241 (3.21)	0.124 (1.43)	0.124 (1.43)
pop_{t-1}	0.206 (2.99)	0.206 (2.99)	-0.283 (-1.26)	-0.283 (-1.26)
ic_{t-1}			0.226 (2.28)	0.226 (2.28)
Dummy	-0.072 (-2.86)	-0.072 (-2.86)	-0.068 (-2.91)	-0.068 (-2.91)
Adjusted R-squared	0.309	0.451	0.460	0.396
LM test for serial correlation	χ_1^2=0.14 [0.71]	χ_1^2=0.14 [0.71]	χ_1^2=0.54 [0.46]	χ_1^2=0.54 [0.46]
RESET test for functional form	χ_1^2=0.32 [0.57]	χ_1^2=0.32 [0.57]	χ_1^2=1.30 [0.26]	χ_1^2=1.30 [0.26]
Jarque-Bera test for normality	χ_2^2=0.19 [0.91]	χ_2^2=0.19 [0.91]	χ_2^2=0.21 [0.90]	χ_2^2=0.21 [0.90]
LM test for Heteroscedasticity	χ_1^2=0.28 [0.60]	χ_1^2=0.28 [0.60]	χ_1^2=0.41 [0.52]	χ_1^2=0.41 [0.52]

'x' indicates that the corresponding variable was initially included in the regression equation and omitted because of insignificant estimated coefficient.

Figures in bracket are t statistics and those in squared bracket are p-values.

Chapter 6

Policy Implications of Economic Growth in Iran

6.1 Introduction

The main idea behind endogenous growth is that long run growth depends on investment decisions rather than, as in traditional growth theory, resulting from unexplained or exogenous improvements in technology. Since government policy can influence these decisions both directly through taxes and investments and indirectly through reform of institutional arrangements, intervention might be used to raise investment and hence the long run growth rate. In the literature of endogenous growth, investment usually refers to a broader concept than the physical capital accumulation reported in the national accounts and includes human capital and/or research and development expenditures as well. The key to endogenous steady state growth is that there should be constant returns to this broad capital accumulation. While this is a common property, the precise way in which the result is obtained varies considerably across the many models that have been proposed.

In examining endogenous growth theory, it is important in particular to distinguish between alternative models in this tradition, which have substantially different policy implications. It should also be recognised that, at present, the empirical evidence relating to these models is incomplete and not supportive of the hypothesis that growth should be regarded as fully endogenous. New growth economists have undertaken a large number of econometric analyses of comparative economic growth and there is also useful work on economic history and in the economics of technology, which can be consulted.[1]

The empirical work on this chapter, however, is different from the other comparative empirical studies on growth in that it focuses on the growth behaviour of an individual country. It has to be pointed out that we are not testing one model

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[1] For a brief review on the econometric empirical studies on endogenous growth see Crafts (1996). Barro and Sala-i-Martin (1995) provide a good survey on the history of endogenous growth models.

against an alternative specification, but are merely testing the endogenous growth theory against neoclassical theory from two points of view. In particular, we apply a model nesting both the exogenous and endogenous growth theories in which we test the assumption of diminishing against constant returns to reproducible production factors. Also, using the same model, we examine the relationship between long run growth and public policy.

In section 6.2, some policy implications of endogenous growth models and a simple approach to test them are discussed. Section 6.3 analyses the dynamic behaviour of the relevant policy variables. An empirical econometric model for the evaluation of policy effects on growth rates is introduced in section 6.4, followed by the estimation results and discussions in section 6.5. Section 6.6 concludes the chapter.

6.2 Policy implications of endogenous growth models

The belief that economic policy is a major determinant of economic growth has been expressed in the writings of economists since economics was established as a science in 18th century. The idea that government policy is important in shaping the growth process has been a recurrent theme of the development literature since the Second World War. While these beliefs and ideas are not new, the idea that government policy is important in shaping *long run* or *persistent* growth has only recently been formalised via the endogenous growth literature. In the last few decades, the economic performance of newly industrialised countries of East Asia (which suddenly became high growth performers for long periods of time) led many economists to believe that government policy can have sustained effects on growth rates.

While the neoclassical or exogenous growth models do predict that government policy changes can affect growth rates, they predict that there is no long run effect of these policy changes. Endogenous growth models are, in fact, efforts to introduce a framework in which government policy could have sustained effects on long run growth rates.

Jones (1995) introduces a simple approach to test exogenous against endogenous growth models in this context. In order to have endogenous growth, permanent changes in certain policy variables must have permanent effects on the rate of growth. Many of the policy variables that, according to different endogenous growth models, affect the long run growth rates (such as physical investment rates, human capital investment rates, export shares, inward orientation, the strength of property rights, government consumption, population growth, and regulatory pressure) have exhibited large, persistent movements, generally in the growth-increasing direction in OECD countries during the last 40 years. However, Jones argues that growth rates of these economies exhibit no large persistent increases in the same period or, in other words, the growth rate is a stationary series. Jones suggests two possibilities in this regard: 'either by some astonishing coincidence, all of the movements in variables that can have permanent effects on growth rates have been offsetting, or the hallmark of the endogenous growth models, that permanent changes in policy variables have permanent effects on growth rates, are misleading' (Jones, 1995, p. 496).

6.3 Unit root test of policy variables

We consider tax rates and the share of public capital in output as government fiscal policy variables. As in chapter 5, the data are annual and cover the period 1959-1996. We use the annual growth rate of real GDP as our measure of the growth rate of output. As our measure for tax rate, we do not use tax variables such as tariff rates and sales taxes because both of these variables have been primarily consumption taxes. Instead, we use total direct tax rate measured by total government's direct tax income divided by national income.

There is no published data for public (government) capital stock. In order to estimate the government capital stock assume that the depreciation rate is the same for both government and total capital stock. Then the public capital stock could be derived from

$$(6.1)\quad \frac{K_t^g}{K_t} = \frac{\sum_{i=0}^{t} I_i^g}{\sum_{i=0}^{t} I_i} \quad \Rightarrow \quad \hat{K}_t^g = K_t \cdot \frac{\sum_{i=0}^{t} I_i^g}{\sum_{i=0}^{t} I_i}$$

where K_t^g and K_t are public and total capital stock and I_t^g and I_t are government and total gross investment, respectively. As in chapter 5, the data are from Plan and Budget Organisation and Central Bank of Iran.

In chapter 5, the growth rate (Δy_t) was shown to be either a stationary or an I(1) variable. Table 6.1 lists the unit root test results of the two fiscal policy variables, namely the share of public capital in output, G, and income tax rate, τ. Both variables are clearly first difference stationary. Figures 6.1 to 6.4 also support these results.

These results do not provide a clear picture of the effectiveness of policy variables on growth rates. In order to test for this effectiveness, as in chapter 5, there are two possibilities in this regard. If the growth rate is a first difference stationary variable, a regression analysis must be used to investigate the effectiveness of policy variables. The regression result of growth rate on the log of the share of public capital in output, g, and the log of one minus tax rate, $log(1-\tau)$, is as follows

$$\text{Growth rate} = -0.0127 \underset{(-3.25)}{-0.09\, g} \underset{(-0.32)}{-0.381\, log(1-\tau)}$$

$$\text{Adjusted R-squared} = 0.26 \qquad \text{DW} = 1.186$$

The figures in brackets indicate the t statistic of the respective coefficient. The DW statistic indicates that the variables are cointegrated. To double-check this result about cointegration, a unit root test for the residuals of this regression was conducted. The test statistic of DF = -3.96 (with a 95% critical value of –3.99) critically confirms the above result. Note that the only significantly non-zero coefficient (i.e. the coefficient on the share of public capital in output) is negative, a result that will be discussed later in this chapter.

If, on the other hand, we deal with the growth rate as a stationary variable, the first difference stationarity of both policy variables implies that either there is no long run effect of these variables on growth rates or, in Jones's words, "whatever persistent effects have occurred have *miraculously* been offsetting" (Jones 1995, p. 499). The following section is an effort to test for this *miraculous* alternative.

Table 6.1
Unit root test results

Variable	**Level**		**First difference**	
	No trend(1)	Trend(2)	No trend(1)	Trend(2)
G	ADF(1) = -1.99	ADF(1) = -2.07	DF = -3.16	DF = -3.20
τ	DF = -2.88	DF = -3.08	ADF(1) = -6.25	ADF(1) = -6.23

(1) 95% critical value for the augmented Dickey-Fuller statistic = -2.95
(2) 95% critical value for the augmented Dickey-Fuller statistic = -3.54
- The statistics reported are either DF or ADF(1), depending on the result of LR test.

Figure 1
Public capital (share of GDP)

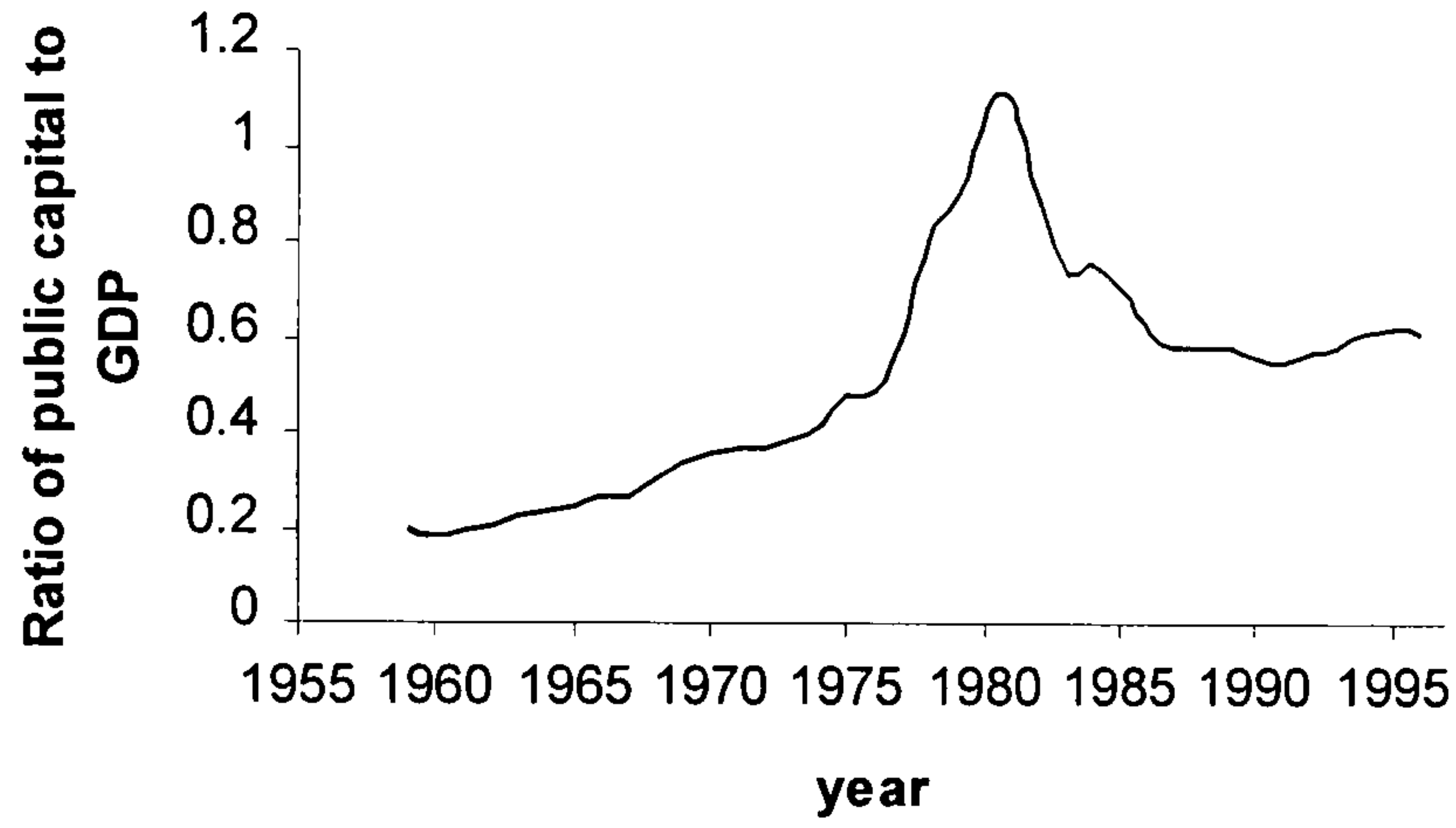


Figure 6.2
Public capital (share of GDP)
1st difference

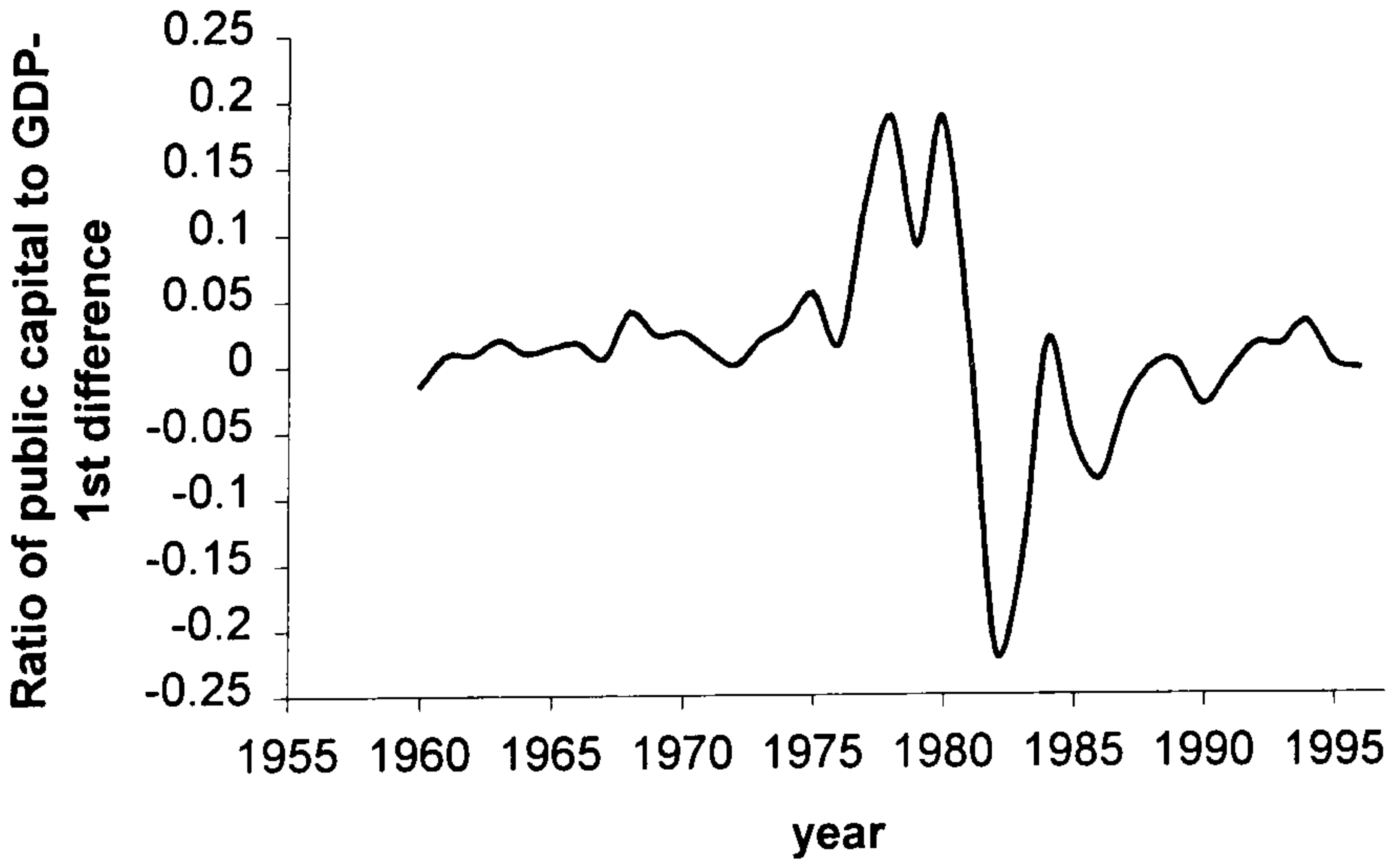


Figure 6.3
Tax rate

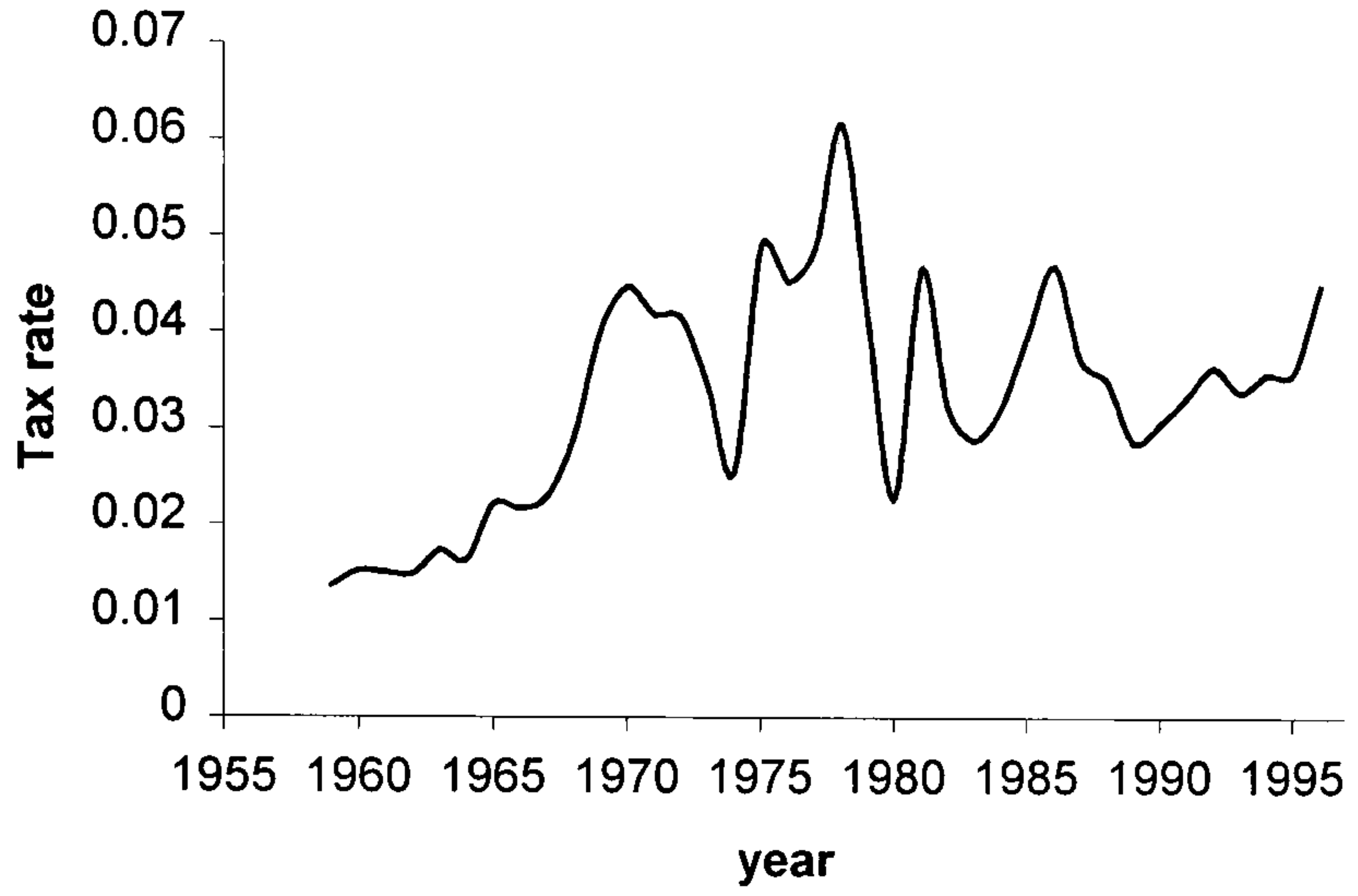
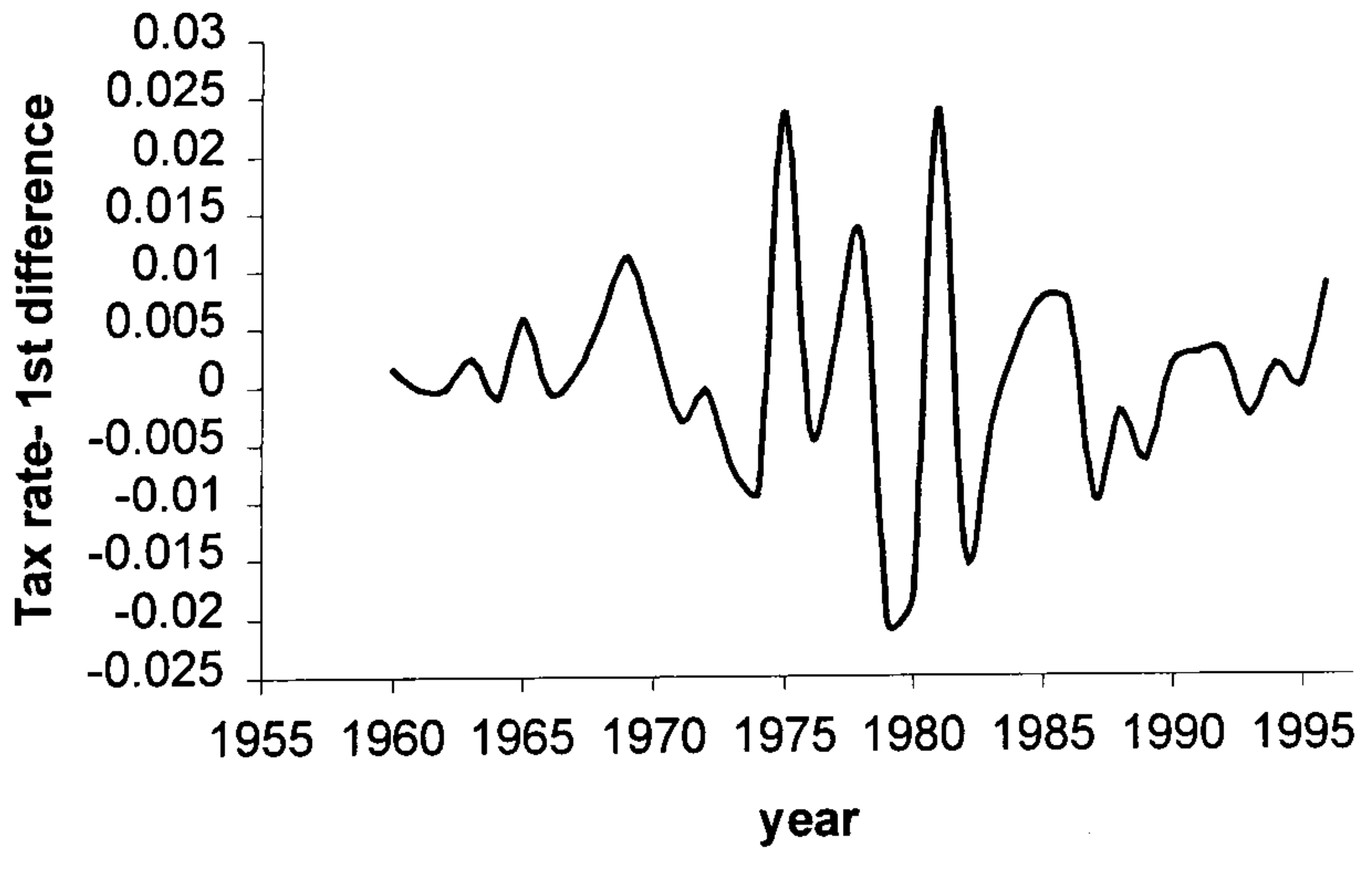


Figure 6.4
Tax rate- 1st difference



6.4 A model for the evaluation of policy effects on growth rates

In chapters 2 to 4, we performed cross-country regressions of average growth rates against various attributes of the countries. While the cross-country literature has made important contributions, it has also been criticised. From a statistical point of view, Levine and Renelt (1992) review most of the early empirical work on endogenous growth and point out that many of the findings in this literature are highly sensitive to the specification of the regression. From an economic point of view, on the other hand, Solow (1994) argues that the experiences of very different national economies are not to be explained as if they represented points on some well defined surface. Pack (1994) also suggests further research work in order to test the insights of endogenous growth against the economic evolution of individual countries using time series data.

Following Kocherlakota and Yi (1997), we use a model that (in reduced form) nests both endogenous and exogenous growth as special cases. In this model, the representative agent generates output according to

(6.2) $Y_t = A_t K_{t-1}^{\alpha} K_{gt-1}^{\beta}$

where A is the technology shock, and K_{t-1} and K_{gt-1} are private and public capital accumulated through the end of period *t-1*, respectively. It may be argued that since the production function does not include labour, the factor payments do not add up to national income. It is shown later that we can easily modify this production function in order to include labour without changing the reduced form relationships that underlie our empirical work. On the other hand, private capital could be thought of as including physical and human capital and even the stock of knowledge.

Private capital accumulates according to

(6.3) $K_t = BK_{t-1} \cdot (I_t / K_{t-1})^{\delta}$ $\qquad 1>\delta>0$

which means that investment has decreasing returns. Considering lowercase letters as log of variables, (6.3) could be rewritten as

(6.4) $k_t = b + (1-\delta)k_{t-1} + \delta i_t$

The after-tax income could be consumed or invested in capital

(6.5) $C_t + I_t = (1-\tau_t)Y_t$

where τ_t is income tax rate. Taking the process generating A_t, τ_t and K^g_{t-1} as given, the agent chooses C and I in order to maximise his utility function.

We already introduced the share of public capital in output, G, as well as the income tax rate, τ, as our policy variables. In equilibrium, total saving, $(1-\tau_t)Y_t - C_t$, equals total investment

(6.6) $I_t = S(1-\tau_t)Y_t$,

where S is the proportion of after-tax income that is saved. The production function (6.2) can be written as

(6.7) $(1-\beta L)y_t = a_t + \alpha k_{t-1} + \beta g_{t-1}$

where L is the lag operator and $g_t = k_{gt} - y_t$. Equations (6.4), (6.6) and (6.7) result in the following relationship for k

(6.8) $(1-\beta L)k_t = (1-\delta)(1-\beta L)k_{t-1} + \delta\alpha k_{t-1} + \varepsilon_t$

where $\varepsilon_t = b(1-\beta) + \delta(1-\beta)s + \delta a_t + \delta\beta g_{t-1} + \delta(1-\beta L)\ln(1-\tau_t)$ and $s = \ln(S)$. Equation (6.8) can be represented as the following polynomial on k

(6.9) $A(L)k_t = \varepsilon_t$

where $A(L) = (1-\beta L)[1-(1-\delta)L] - \delta\alpha L$.

Now consider a case where $\alpha+\beta<1$. We are looking for real roots, which set the polynomial $A(z)$ equal to zero. Since $A(1) = (1-\beta)\delta - \delta\alpha > 0$ and $A(1/(1-\delta)) = -\delta\alpha/(1-\delta) < 0$, the two real roots are $r_1 > 1/(1-\delta)$ and $1 < r_2 < 1/(1-\delta)$. Replacing from (6.9) in (6.7), y_t may be written in terms of current and lagged exogenous variables

(6.10) $y_t = (1-\beta L)^{-1}(a_t + \alpha A(L)^{-1}\varepsilon_{t-1} + \beta g_{t-1})$,

from which the growth rate could be derived as

(6.11) $(1-L)y_t = C_g(L)g_{t-1} + C_\tau(L)\ln(1-\tau_{t-1}) + C_a(L)a_t$

where

$$C_g(L) = \beta(1-L)(1-(1-\delta)L)A(L)^{-1}$$

(6.12) $$C_\tau(L) = (1-L)\alpha\delta A(L)^{-1}$$

$$C_a(L) = \beta(1-L)(1-(1-\delta)L)A(L)^{-1}$$

Since $C_g(1) = C_\tau(1) = C_a(1) = 0$, There is no effect on growth rate from policy variables and the model is an exogenous growth model.

Now consider the case where $\alpha+\beta=1$. Then the roots of the polynomial A(z) become $r_1 = 1$ and $r_2 = 1/(\beta(1-\delta))$. Therefore, the dynamics of capital differs from that represented by (6.9). Now, A(L) has a unit root and can be written as

$$A(L) = (1-L)[1-\beta(1-\delta)L].$$

Hence, (6.9) becomes

$$(6.13)\quad \Delta k_t = (1-\beta(1-\delta)L)^{-1}\varepsilon_t,$$

and, as a result, the growth rate of output becomes

$$(6.14)\quad (1-L)y_t = \alpha(b+\delta s)/(1-\beta(1-\delta)) + D_g(L)g_{t-1} + D_\tau(L)\ln(1-\tau_{t-1}) + D_a(L)a_t$$

where

$$\begin{aligned} &D_g(L) = \beta(1-(1-\delta)L)(1-\beta(1-\delta)L)^{-1} \\ (6.15)\quad &D_\tau(L) = \alpha\delta(1-\beta(1-\delta)L)^{-1} \\ &D_a(L) = \beta(1-(1-\delta)L)(1-\beta(1-\delta)L)^{-1} \end{aligned}$$

Since the coefficients on the policy variables, $D_g(1)$ and $D_\tau(1)$, are both nonzero, the growth rate is affected by policy variables and hence the model features endogenous growth.

6.5 Estimation results

In this model, the growth rate of output is expressed as distributed lags of public capital, tax rates and the technology shock. For empirical purposes, however, we consider the following model with finite number of lags and assume that the moving average of the unobservable productivity shock, a_t, is represented by the error term

$$(6.16)\quad \Delta y_t = constant + \sum_{i=0}^{I}\phi_{gi}g_{t-1-i} + \sum_{i=0}^{I}\phi_{\tau i}\ln(1-\tau_{t-1-i}) + v_t$$

This approach is an alternative to the approach of estimating the production function directly. However, its advantage is that it allows us to get rid of the problems in regard with the definition as well as data availability of capital stock inputs.

We can evaluate the null hypothesis of exogenous growth by testing the following two restrictions

$$(6.17)\quad \sum_{i=0}^{I}\phi_{gi} = \sum_{i=0}^{I}\phi_{\tau i} = 0.$$

When there is a large sample size, the result of the above test is asymptotically valid if we increase the lag length. Considering our small sample size, separate regressions were estimated with from three to eight lags (for both policy variables), the results of which were similar. Therefore, only the results based on five lags of policy variables are reported here.

Table 6.2

The regressions of growth rate on public capital and tax rate

Estimated parameter	Regression 1	Regression 2	Regression 3
$\sum_{i=0}^{4}\phi_{gi}$	-0.044 (-1.30)		-0.0862 (-1.96)
$\sum_{i=0}^{4}\phi_{\tau i}$		1.9165 (1.36)	-1.0227 (-0.62)
Adjusted R-squared	0.499	0.456	0.750
Chi-squared test of the restrictions(1)	1.69 [0.194]	1.84 [0.174]	6.28 [0.043]
LM test for serial correlation	χ_1^2=5.69 [0.017]	χ_1^2=5.56 [0.018]	χ_1^2=4.97 [0.026]
RESET test for functional form	χ_1^2=3.14 [0.077]	χ_1^2=1.43 [0.231]	χ_1^2=2.16 [0.142]
Jarque-Bera test for normality	χ_2^2=0.102 [0.95]	χ_2^2=1.66 [0.44]	χ_2^2=0.242 [0.87]
LM test for heteroscedasticity	χ_1^2=2.07 [0.15]	χ_1^2=6.92 [0.009]	χ_1^2=0.26 [0.61]

(1) The restrictions for regressions 1 to 3 are $\sum_{i=0}^{4}\phi_{gi}=0$, $\sum_{i=0}^{4}\phi_{\tau i}=0$ *and* $\sum_{i=0}^{4}\phi_{gi}=\sum_{i=0}^{4}\phi_{\tau i}=0$, *respectively.*

- Figures in parentheses are t-statistic and those in squared brackets are p-values.

Table 6.2 lists the results[2]. In regressions 1 and 2, only one policy variable is included in the right hand side. Since the null hypothesis of exogenous growth is that the sum of the coefficients is zero (against the alternative that, in an endogenous growth case, the sum is positive), one-tailed tests are conducted. The restriction test result of column 1 apparently provides strong evidence for exogenous growth. Besides, the estimated sum of coefficients has the wrong sign. Only in column 2, the sum of the estimated coefficients on (the legged values of) tax rates has a positive sign. However, the coefficient is not statistically significant and the result again supports the exogenous growth. As explained before in chapter 5, the non-oil tax revenue has always been a small fraction of total government revenue in Iran. Therefore, one would not expect changes in tax rate to be an effective policy variable.

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[2] The estimated short run effects, not reported here, exhibit significant effects of both policy variables on growth in both positive and negative directions in different lags of time.

In column three, however, the hypothesis that the sum of coefficients on both policy variables are zero is rejected at the 5% level of significance. This result should be interpreted carefully because the only statistically significant estimated coefficient, namely the sum of coefficients on the share of GDP of public capital, has a negative sign. This is consistent with the results derived earlier when we regressed a static (cointegrating) relationship between the growth rate and policy variables. In both cases, the coefficients have negative sign and the only significant policy variable is the GDP share of public capital. Also, in both cases, the estimated coefficient on this policy variable is –0.09.

Such a negative effect of government activities on growth rates for underdeveloped economies, such as Iran, might be justified by the fact that government interventions have not usually been in a productive direction. If, for whatever reason, the estimated sum of coefficients on this policy variable is significant (negative or positive), there is endogenous growth. This last result, although still fragile, suggests that models that emphasise constant returns to scale in reproducible inputs have empirical relevance at the aggregate levels.

6.6 Conclusion

This chapter has attempted to provide answers to the questions 'to what extent, and how, can growth rate be influenced by government policies?' and 'are there diminishing returns to reproducible production factors at the aggregate level?' Jones (1995) rules out any possibility of endogenous growth by arguing that, in spite of large movements in policy variables over a long period of time, the growth rates exhibit no significant changes and are stationary series. The unit root test results of this chapter, however, show that both the growth rate and policy variable feature jumps and movements. Also, the cointegration test result shows that there is a long run relationship between these variables. Therefore, Jone's critique does not apply to the Iranian economy.

In this chapter, we estimated a model that nests both endogenous and exogenous growth as special cases. In a regression of growth rate on lagged policy variables, the sum of the coefficients should be nonzero if growth is endogenous and zero if growth is exogenous. We only found weak evidence that when both taxes and public capital are included in the regression, the nonzero sum of coefficients on public capital are consistent with endogenous growth. The results are being referred to as 'weak' because, first, the sum of coefficients on public capital is just significantly different from zero and, second, it has a negative sign which could be interpreted as a result of inefficiency in government expenditures. Regardless of its causes, this (weak) result supports the growth models that emphasise constant returns to reproducible inputs at the aggregate levels. It implies that there might be other government policy variables that could affect the long run growth rate. For instance, one could include publicly financed education that stimulates human capital formation (data for which is, however, not available for Iran).

The endogenous growth theory has been so attractive because it provides the policy makers with the possibility of affecting long run growth rates and welfare of their countries. Until now, however, there has been little evidence supporting the idea that government policy can have persistent, sustained effects on growth rates at the aggregate level. Especially, reviewing the history of economic fluctuations in such countries as Iran, one might recognise that raising the growth rate is difficult and that a return to the growth rates of the golden age of 1960's and early 1970's is highly unlikely.

Chapter 7
Summary and Conclusion

In the neoclassical theory of growth, the possibility of sustained economic growth is ascribed to an exogenous factor of production, modelled simply as the passage of time. The neoclassical production function relates output to factor inputs, the stock of accumulated physical capital and labour force. It displays decreasing returns with respect to the use of each reproducible factor of production. Therefore, an increase in the stock of capital goods results in a less than proportionate increase in output. Expansion of the capital stock implies a decline in the return on a further expansion. However, technical change that improves the productivity of labour and capital, can prevent the rate of return on investment from falling. If the labour force grows at an (exogenous) rate (equal to the sum of population growth and labour-augmenting technical progress), then capital and output will eventually also grow at this exogenous rate on an equilibrium growth path.

Neoclassical theory does not provide an economic explanation for equilibrium growth, but rather includes a time trend in the model to account for the long run rate of economic growth. Increasing the rate of per capita growth in long run is impossible unless the rate of technical progress can be altered deliberately. Since this technical progress is exogenous to the model, and because of the decreasing returns to reproducible input (i.e. capital stock), economies with low amounts of capital grow faster and, as a result, countries converge in terms of per capita growth rates in long run. However, this idea is not consistent with empirical evidence on a group of Asian countries. The convergence hypothesis might, therefore, be examined after holding constant some variables that distinguish the countries (i.e. conditional convergence).

The endogenous growth theory is an attempt to incorporate technological progress as an integral part of the theory of economic growth. Different endogenous growth models use alternative factors in order to endogenise technical progress in the model. Such factors as physical capital investment rates, human capital investment rates, export shares, inward orientation, the strength of property rights, government consumption, population growth and regularity pressures, among others, are used in different endogenous growth models in order to explain technical progress. Since, in these models, long run growth depends on investment decisions rather than resulting from exogenous improvements in technology, economic policies influencing these decisions can raise the long run growth rate. Therefore, examining the relationship between long run growth and economic policy is an alternative approach to testing for endogenous growth.

Applying a traditional cross-country framework in chapter 2, I find that Solow's growth model fails to provide a satisfactory explanation of the cross-country variation and exhibits no convergence across the Asian countries. This chapter argues that the critical assumption of a fixed steady state, made by the traditional studies, is inappropriate. Instead, a dynamic panel data framework is suggested in order to allow for differences in the aggregate production function across the Asian countries. The results of panel estimation show that there are significant differences between the country effects, implying that the neoclassical assumption of a common production function is not valid.

In the real world the assumption that all economies have the same parameters, and therefore, the same steady-state positions, is not plausible. If the steady states differ, then we have to modify the analysis to consider the concept of conditional convergence. Therefore, in order to test the convergence hypothesis we control for any variables that account for differences in the steady state position. There is obviously no evidence of absolute convergence across 117 countries world-wide as well as 20 Asian countries. This is due to the different structures of these economies.

The previous studies use average values of saving rates, the growth rate of population and per capita growth rate and, therefore, imply that every economy has a steady state growth path, well approximated by a time trend. Of course, the average could be a good proxy for the steady state value only if the long-run movements in income were well described by smooth time trends that are not affected by ongoing economic disturbances or if there was no significant economic shock during the long-run period under study, assumptions that are not true for our sample of Asian countries.

In fact, the reason we turn to a dynamic (panel data) approach is that it helps to study the intermediate - rather than just the one-period or alternatively steady state - dynamics of the evolving income distributions across countries. It seems reasonable to assume that in a medium term, there is a steady-state growth path that is well approximated by a time trend.

The results of panel data approach imply that controlling for country-effects leads to more reasonable estimates of the speed of convergence and the elasticity of output with respect to capital. Applying this approach, the model supports convergence only after controlling for country specific effects (the concept of conditional convergence). We examine the importance of A_0 term in explaining growth and find a strong positive effect. These results shed light on the issue of policy activism. Traditionally, only the saving and population growth rates were thought to be the variables for policies to be directed to. However, the panel data model here highlighted the role of the technology term A_0 as a determinant of the steady-state level of income.

The rest of the thesis, therefore, focuses on the determinants of the technology term based on the assumption of conditional convergence. Chapter 3 examines the relation between the growth rate and the starting position after holding constant some variables that distinguish the countries. This chapter applies a model in which a country's subsequent growth rate is positively related to its initial human capital. Moreover, given the human capital variable, subsequent growth is substantially negatively related to the initial level of per capita GDP. A poor country, in this model, tends to grow faster than a rich country, but only for a given quantity of human capital, that is, only if the poor country's human capital exceeds the amount that typically accompanies the low level of per capita income. This, in fact, is the concept of conditional convergence.

In neoclassical growth theory the control and environmental variables determine the steady-state level of output per effective worker. However, they do not affect the long-run growth rate. The long run or steady state growth rate is given by the rate of exogenous technological progress. In contrast, in the endogenous growth theory, these variables affect the growth rate of output permanently. We used the experiences from other empirical works in order to include a variety of control and environmental variables such as the ratio of real gross investment to real GDP, the ratio of government consumption net of spending on defence and education to GDP, the black market premium on foreign exchange, a measure of political instability, the growth rate of terms of trade, total fertility rates, the growth rate of population, the share of population under 15 in total population, and government war and defence expenditure.

The empirical findings on conditional convergence in chapter 3 are consistent with the neoclassical model of chapter 2. It was discussed, however, that conditional convergence is not in contrast with endogenous growth models. The concept of conditional convergence does not reject the endogenous growth assumption that policy variables, introduced by control and environmental variables, could influence the long-run growth rate of per capita GDP.

Chapter 4 focuses on the effect of human capital on growth. The model outlined in this chapter attempts to include the endogenous component of technological progress as an integral part of the economic growth. Technological progress is, in fact, represented here by human and knowledge capital accumulation. The empirical results indicate that the primary (and to some extent, the secondary) schooling is not important in the determination of the growth rate (and for some countries, the effect is negative). This problem, however, is thought to be due to the small variance of these two variables (both across countries and over time). The main question is why investment in knowledge capital (proxied here by higher education enrolment rate) is negatively, or not, related to per-capita GDP growth. It should be noted that initial income may proxy for initial technological advantage. Therefore, the technological advantage has an adverse effect on growth rate across the Asian countries in our sample. This is known in the growth literature as the Rosenberg effect according to which, the lower the initial technological advantage, the faster the speed of catch up (in terms of adopted technology) to the leading high-technology country.

This explanation could, to an extent, apply to secondary education as well. Therefore, those countries that have a higher quality secondary and higher education have a higher catch-up effect. High quality education, in fact, produces a vital means by which its beneficiaries can more easily access new technology and, therefore, results in a far easier technology adoption by followers.

The estimation results of this chapter once again confirm the validity of our results in the previous two chapters with regard to convergence controversy. The population growth contributes negatively to economic growth of the countries of our interest. This result was expected because, in most of these countries, population growth is associated with increases in unskilled labour force. The estimated coefficients for the physical capital investment ratio support the "diminishing returns to physical capital" theorem in general.

The fact that, given control and environmental variables (in chapter 3), country effects still vary significantly across the countries motivates single country growth studies in order to identify the variables that affect each country's growth rate individually. In particular the Iranian economy, during the last few decades, has been facing sudden, large changes in growth rates, both up and down. Chapter 5, therefore, studies the Iranian economic performance using an individual time-series econometric model that accounts for such structural changes.

This chapter is an effort to apply economic theory, together with time series econometric methods, in order to explain such large variations in the Iranian production behaviour. Under the assumption that the growth rate, investment (in physical capital) and the growth rate of population are first difference stationary variables, the results support the cointegration hypothesis for both Kaldor's and Arrow's growth models. The results also indicate that the elasticities of production with respect to capital stock and population add up to unity.

The cointegrating production function, namely that of Kaldor, is an endogenous growth model in terms of its attempt to endogenise the technological progress. Kaldor argues that it is pointless to try to distinguish between investment and technical change and that new fixed capital is the carrier of technical progress. Technical progress is already incorporated in a Solow kind of production function through capital stock and there is no need for a time trend to explain it. Therefore, although the technical progress function of Kaldor and the neoclassical production function of Solow look alike, the ideas behind them and their empirical implications are different.

In the context of policy implications, however, the growth model of Kaldor could not be classified as an endogenous growth model. While the endogenous growth models allow the growth rate to be modified by appropriate policy interventions, the growth model of Kaldor does not. Even though growth arises endogenously in Kaldor's technical progress function, the model is not truly an endogenous growth model because the neoclassical theory of growth refers to the same idea (that growth rate is fixed and not affected by any policy interventions).

That is why, in chapter 6, we studied the endogenous growth hypothesis using a model that tests for the effect of policy variables on productivity. Government policy can influence the investment decisions both directly through taxes and investments and indirectly through reform of institutional arrangements. Many of the policy variables that, according to different endogenous growth models, affect the long-run growth rates (such as physical investment rates, human capital investment rates, export shares, inward orientation, the strength of property rights, government consumption, population growth, and regulatory pressure) have exhibited large and persistent movements, generally in the growth-increasing direction, in OECD countries during the last 40 years. However, growth rates in these economies exhibit no large persistent increases in the same period or, in other words, the growth rate is a stationary series.

In order to test for the effectiveness of policy variables on growth rates, we considered two possibilities. First, we assumed the growth rate to be a first difference stationary series. The cointegration test result shows that there is a long-run relationship between the growth rate and policy variables. Second, we treated the growth rate as a stationary variable. Then the first difference stationarity of the policy variables implies that either there is no long-run effect of these variables on growth rates or the effects have *miraculously* been offsetting.

We estimated a model that nests both endogenous and exogenous growth as special cases. In a regression of growth rate on lagged policy variables, the sum of the coefficients should be nonzero if growth is endogenous and zero if growth is exogenous. We only found weak evidence that when both taxes and public capital are included in the regression, the nonzero sum of coefficients on public capital are consistent with endogenous growth. The results are referred to as 'weak' because, first, the sum of coefficients on public capital is just significantly different from zero and, second, it has a negative sign which could be interpreted as a result of government's mismanagement of the economy. Regardless of its causes, this (weak) result supports the growth models that emphasise constant returns to reproducible inputs at the aggregate levels.

The main results of the thesis can be summarised as follows:

i. There is no absolute convergence across the structurally different economies, including our sample of Asian economies.

ii. All the economies, no matter how different in their structures, conditionally converge after holding constant the variables that account for their differences.

iii. Although human capital is considered as the most important factor influencing the growth rate in many endogenous growth theories, there is no empirical evidence supporting this idea either in previous studies or in this thesis. However, just as physical investment can not by itself explain growth, an increasing level of education is not by itself decisive. For instance, successful absorption and entrepreneurship in the newly industrialised Asian economies certainly was facilitated by the growing supply of well trained technical people.

iv. Technological progress is shown to be endogenously determined in the Iranian economy. However, the underlying growth model (that of Kaldor) is not endogenous in the sense of having no policy implications.

v. The empirical results from a model that nests both exogenous and endogenous growth indicate that the public capital share of GDP influences the long-run growth rate in Iran. However, the effect is negative which could be interpreted as evidence of inefficiency in government expenditures.

Data Appendix

Table A1
Definitions of variables

GR: Growth rate of real GDP per capita (%)

LY0: Log value of real GDP per capita (%) at the beginning of each five-year period

PYR: Average years of primary schooling in the total population over age 25

PYRM: Average years of primary schooling in the male population over age 25

PYRF: Average years of primary schooling in the female population over age 25

SYR: Average years of secondary schooling in the total population over age 25

SYRM: Average years of secondary schooling in the male population over age 25

SYRF: Average years of secondary schooling in the female population over age 25

HYR: Average years of higher schooling in the total population over age 25

HYRM: Average years of higher schooling in the male population over age 25

HYRF: Average years of higher schooling in the female population over age 25

PENR: Total gross enrolment ratio for primary education

PENRM: Male gross enrolment ratio for primary education

PENRF: Female gross enrolment ratio for primary education

SENR: Total gross enrolment ratio for secondary education

SENRM: Male gross enrolment ratio for secondary education

SENRF: Female gross enrolment ratio for secondary education

HENR: Total gross enrolment ratio for higher education

HENRM: Male gross enrolment ratio for higher education

HENRF: Female gross enrolment ratio for higher education

PRI: Percentage of primary school attained in the total population

PRIM: Percentage of primary school attained in the male population

PRIF: Percentage of primary school attained in the female population

SEC: Percentage of secondary school attained in the total population

SECM: Percentage of secondary school attained in the male population

SECF: Percentage of secondary school attained in the female population

HIGH: Percentage of higher school attained in the total population

HIGHM: Percentage of higher school attained in the male population

HIGHF: Percentage of higher school attained in the female population

PRIC: Percentage of primary school complete in the total population

PRICM: Percentage of primary school complete in the male population

PRICF: Percentage of primary school complete in the female population

SECC: Percentage of secondary school complete in the total population

SECCM: Percentage of secondary school complete in the male population

SECCF: Percentage of secondary school complete in the female population

HIGHC: Percentage of higher school complete in the total population

HIGHCM: Percentage of higher school complete in the male population

HIGHCF: Percentage of higher school complete in the female population

HUMAN: Average schooling years in the total population over age 25

LLIFEE: Log value of life expectancy at age 0

LY0HUM: LY0 multiplied by HUMAN

I: Ratio of real gross domestic investment (private plus public) to real GDP

GCON: Ratio of real government consumption expenditure net of spending on defence and on education to real GDP

BMPL: Log value of 1 plus black market premium (black market exchange rate over official exchange rate; exchange rate = local currency per US dollar

PINST: Measure of political instability = 0.5 * (number of assassinations per million population per year) + 0.5 * (number of revolutions per year)

TOT: Terms of trade shock (growth rate of export prices minus growth rate of import prices)

LFERT: Log value of total fertility rate (children per woman)

GPOP: Growth rate of population

POP15: Population proportion under 15

GDEF: Ratio of nominal government expenditure on defence to nominal GDP

GEDU: Ratio of total nominal government expenditure on education to nominal GDP

Table A2 - Asian panel data

Country	**Bangladesh**		
Year	**1975**	**1980**	**1985**
GR	-0.0577	0.0250	0.0231
Y0	1291	959	1085
PYR	0.585	0.708	1.177
PYRM	0.923	1.128	1.733
PYRF	0.196	0.238	0.568
SYR	0.238	0.282	0.46
SYRM	0.411	0.488	0.755
SYRF	0.038	0.051	0.138
HYR	0.022	0.031	0.044
HYRM	0.039	0.055	0.075
HYRF	0.001	0.003	0.01
PENR	0.54	0.73	0.62
PENRM	0.8	0.94	0.78
PENRF	0.34	0.5	0.48
SENR	0.19	0.26	0.18
SENRM	0.3	0.38	0.23
SENRF	0.08	0.11	0.07
HENR	0.021	0.023	0.03
HENRM	0.036	0.051	0.051
HENRF	0.004	0.006	0.009
PRI	9.7	7.93	31.71
PRIM	12.5	6.15	32.35
PRIF	6	10.31	30.48
SEC	6.01	6.9	11.6
SECM	10.25	11.81	18.46
SECF	1.12	1.4	4.1
HIGH	0.63	0.9	1.3
HIGHM	1.16	1.61	2.21
HIGHF	0.03	0.01	0.03
PRIC	2.18	2.74	4.57
PRICM	3.23	4.16	6.53
PRICF	0.96	1.14	2.43
SECC	2.25	2.58	4.2
SECCM	3.89	4.5	7.31
SECCF	0.35	0.44	0.8
HIGHC	0.44	0.63	0.91
HIGHCM	0.81	1.13	1.56
HIGHCF	0.02	0.07	0.2
HUMAN	0.845	1.021	1.681
GEDU	0.0182	0.0133	0.0163
LIFEE	45.2	46.8	48.6
I	3.02	2.8	3.78
GCON	0.273	0.273	0.280
GDEF	0.006	0.012	0.014
BMPL	0.756	0.688	0.593
PINST	0.002	0.301	0.101
TOT	-0.084	0.025	0.009
FERT	6.922	6.35	6.012
GPOP	0.0277	0.0267	0.0279
POP15	0.455	0.457	0.461

Sources: *GR*, *Y0* and *I* come from Summers and Heston (1988); all other variables can be found in Barro and Lee (1993) and various issues of UNESCO Statistical Yearbooks.

Table A2 (Cont.)

Country	**Hong Kong**		
Year	**1975**	**1980**	**1985**
GR	0.0455	0.0910	0.0403
Y0	4504	5627	8697
PYR	3.414	3.651	4.143
PYRM	4.463	4.498	4.834
PYRF	2.394	2.769	3.387
SYR	1.598	1.846	2.368
SYRM	2.206	2.369	2.839
SYRF	1.007	1.301	1.853
HYR	0.154	0.119	0.223
HYRM	0.231	0.178	0.293
HYRF	0.079	0.059	0.147
PENR	1	1	1
PENRM	1	1	1
PENRF	1	1	1
SENR	0.36	0.49	0.64
SENRM	0.44	0.71	0.6
SENRF	0.31	0.47	0.65
HENR	0.073	0.101	0.105
HENRM	0.097	0.147	0.142
HENRF	0.046	0.053	0.064
PRI	41.4	42.3	39.8
PRIM	50.76	49.5	44.37
PRIF	32.3	34.8	34.8
SEC	20.5	25.4	30.5
SECM	27.8	32.02	36.17
SECF	13.4	18.5	24.3
HIGH	4.9	3.8	7.1
HIGHM	7.16	5.53	9.02
HIGHF	2.7	2	5
PRIC	21.6	21.01	23.1
PRICM	28.08	25.35	26.39
PRICF	15.3	16.49	19.5
SECC	11.5	15.5	17.3
SECCM	15.72	19.05	19.95
SECCF	7.4	11.8	14.4
HIGHC	2.8	2.17	4.05
HIGHCM	4.38	3.35	5.62
HIGHCF	1.26	0.94	2.34
HUMAN	5.166	5.617	6.734
GEDU	0.0245	0.0249	0.0276
LIFEE	70.4	72.4	75.2
I	18.34	20.68	21.38
GCON	0.034	0.032	0.027
GDEF	0.005	0.005	0.008
BMPL	0.000	0.000	0.000
PINST	0.000	0.000	0.000
TOT	0.022	-0.047	0.006
FERT	2.934	2.32	1.972
GPOP	0.0202	0.0289	0.0159
POP15	0.370	0.307	0.255

Table A2 (Cont.)

Country	**India**				
Year	**1965**	**1970**	**1975**	**1980**	**1985**
GR	-0.0024	0.0106	0.0040	0.0154	0.0355
Y0	769	760	801	817	882
PYR	1.328	1.468	1.634	1.891	1.915
PYRM	2.067	2.236	2.467	2.842	2.778
PYRF	0.532	0.646	0.752	0.885	1.002
SYR	0.099	0.142	0.227	0.446	0.715
SYRM	0.17	0.223	0.375	0.713	1.082
SYRF	0.024	0.055	0.069	0.163	0.326
HYR	0	0.019	0.037	0.068	0.085
HYRM	0	0.03	0.063	0.113	0.131
HYRF	0.001	0.007	0.01	0.022	0.037
PENR	0.61	0.74	0.73	0.79	0.81
PENRM	0.54	0.69	0.76	0.76	0.98
PENRF	0.26	0.4	0.56	0.6	0.67
SENR	0.2	0.27	0.26	0.26	0.31
SENRM	0.34	0.55	0.41	0.39	0.42
SENRF	0.04	0.07	0.15	0.16	0.22
HENR	0.025	0.053	0.082	0.086	0.088
HENRM	0.027	0.039	0.058	0.13	0.123
HENRF	0.006	0.011	0.019	0.042	0.05
PRI	22.1	22.65	22.7	20.1	11.3
PRIM	33.87	34.22	33.08	28.84	15.17
PRIF	9.4	10.28	11.7	10.86	7.2
SEC	2.4	2.63	3.9	7.88	13.7
SECM	4.09	4.07	6.35	12.34	20.4
SECF	0.58	1.09	1.3	3.16	6.6
HIGH	0	0.56	1.1	2.01	2.5
HIGHM	0	0.89	1.85	3.31	3.82
HIGHF	0.02	0.2	0.3	0.65	1.1
PRIC	6.3	7.67	8.16	7.39	4.19
PRICM	9.64	11.77	12.19	10.9	5.83
PRICF	2.7	3.29	3.89	3.67	2.45
SECC	0.9	0.99	1.46	2.95	5.13
SECCM	1.56	1.58	2.45	4.8	8.01
SECCF	0.18	0.34	0.41	1	2.08
HIGHC	0	0.39	0.77	1.41	1.75
HIGHCM	0	0.63	1.31	2.33	2.71
HIGHCF	0.02	0.13	0.2	0.43	0.73
HUMAN	1.427	1.629	1.899	2.405	2.715
GEDU	0.0243	0.025	0.0244	0.0305	0.0301
LIFEE	43.8	46.2	48.4	51.6	54.8
I	11.48	13.72	13.8	14.8	14.22
GCON	0.156	0.088	0.090	0.090	0.100
GDEF	0.028	0.032	0.032	0.034	0.033
BMPL	0.421	0.427	0.356	0.150	0.139
PINST	0.000	0.201	0.100	0.000	0.001
TOT	-0.022	-0.027	-0.012	-0.063	-0.011
FERT	6.466	6.042	5.596	5.188	4.78
GPOP	0.0228	0.0233	0.0227	0.0227	0.0214
POP15	0.397	0.402	0.405	0.394	0.386

Table A2 (Cont.)

Country	**Indonesia**		
Year	**1975**	**1980**	**1985**
GR	0.0596	0.0607	0.0519
Y0	715	955	1282
PYR	2.019	2.265	2.58
PYRM	2.728	2.971	3.216
PYRF	1.335	1.589	1.974
SYR	0.252	0.345	0.483
SYRM	0.372	0.496	0.672
SYRF	0.136	0.201	0.303
HYR	0.014	0.022	0.023
HYRM	0.023	0.034	0.035
HYRF	0.006	0.01	0.012
PENR	0.8	0.86	1
PENRM	0.8	0.88	1
PENRF	0.71	0.76	1
SENR	0.16	0.2	0.29
SENRM	0.2	0.22	0.33
SENRF	0.1	0.15	0.22
HENR	0.028	0.024	0.039
HENRM	0.047	0.036	0.055
HENRF	0.013	0.013	0.024
PRI	39.1	43.27	48.4
PRIM	51.32	54.79	57.75
PRIF	27.3	32.25	39.5
SEC	5.1	6.73	9.6
SECM	7.38	9.47	13.07
SECF	2.9	4.11	6.3
HIGH	0.5	0.75	0.8
HIGHM	0.81	1.18	1.22
HIGHF	0.2	0.34	0.4
PRIC	17	17.25	16.8
PRICM	23.22	22.92	20.9
PRICF	11	11.83	12.9
SECC	2.3	3.27	4.9
SECCM	3.41	4.7	6.9
SECCF	1.23	1.9	3
HIGHC	0.22	0.33	0.35
HIGHCM	0.35	0.51	0.53
HIGHCF	0.09	0.15	0.18
HUMAN	2.285	2.631	3.086
GEDU	0.0242	0.0199	0.0181
LIFEE	48.6	51.2	53.8
I	13.94	18.34	24.24
GCON	0.051	0.069	0.084
GDEF	0.029	0.036	0.038
BMPL	0.031	0.035	0.043
PINST	0.000	0.100	0.000
TOT	0.193	0.071	-0.005
FERT	5.342	4.78	4.32
GPOP	0.0241	0.0224	0.0209
POP15	0.422	0.417	0.410

Table A2 (Cont.)

Country	**Iran**				
Year	**1965**	**1970**	**1975**	**1980**	**1985**
GR	0.0265	0.0737	0.0371	-0.1053	0.0389
Y0	2987	3405	4858	5829	3341
PYR	0.316	0.603	0.901	1.322	1.557
PYRM	0.393	0.891	1.292	1.816	2.057
PYRF	0.239	0.315	0.509	0.852	1.053
SYR	0.119	0.21	0.281	0.51	0.691
SYRM	0.172	0.318	0.417	0.811	1.017
SYRF	0.066	0.102	0.145	0.223	0.363
HYR	0.016	0.03	0.034	0.049	0.074
HYRM	0.028	0.054	0.059	0.081	0.112
HYRF	0.004	0.006	0.01	0.018	0.036
PENR	0.42	0.47	0.73	0.93	0.87
PENRM	0.56	0.66	1	1	1
PENRF	0.32	0.36	0.52	0.73	0.77
SENR	0.12	0.28	0.27	0.45	0.43
SENRM	0.16	0.39	0.34	0.58	0.52
SENRF	0.07	0.11	0.18	0.33	0.33
HENR	0.012	0.016	0.031	0.049	0.04
HENRM	0.02	0.023	0.045	0.069	0.05
HENRF	0.004	0.008	0.016	0.031	0.025
PRI	3.55	7.2	12.85	16.7	17.43
PRIM	3.89	10.6	18.25	19.87	20.21
PRIF	3.21	3.8	7.43	13.68	14.62
SEC	1.96	3.4	4.72	9.03	11.89
SECM	2.68	4.8	6.65	14.14	17.25
SECF	1.24	2	2.79	4.15	6.49
HIGH	0.49	0.9	1.03	1.47	2.22
HIGHM	0.85	1.6	1.76	2.42	3.32
HIGHF	0.14	0.2	0.3	0.57	1.12
PRIC	2.09	4.3	5.68	6.37	6.24
PRICM	2.18	6.3	8.01	7.53	7.21
PRICF	1.99	2.3	3.22	5.27	5.27
SECC	1.02	1.8	2.57	5.02	6.7
SECCM	1.37	2.6	3.72	8.03	10
SECCF	0.67	1	1.42	2.14	3.37
HIGHC	0.33	0.6	0.69	0.98	1.48
HIGHCM	0.57	1.08	1.19	1.65	2.28
HIGHCF	0.08	0.12	0.18	0.34	0.68
HUMAN	0.452	0.843	1.216	1.881	2.323
GEDU	0.0261	0.0263	0.0307	0.0552	0.0467
LIFEE	46	50	55.9	58.5	60.6
I	10.16	12.56	11.06	17.58	22.42
GCON	0.010	0.010	0.010	0.010	0.051
GDEF	0.04	0.06	0.102	0.124	0.058
BMPL	0.132	0.030	0.031	0.179	1.434
PINST	0.100	0.004	0.010	0.325	0.230
TOT	-0.008	-0.018	0.284	0.132	-0.017
FERT	7	6.85	6.5	6.06	5.66
GPOP	0.0341	0.033	0.0321	0.0303	0.0341
POP15	0.471	0.466	0.462	0.451	0.441

Table A2 (Cont.)

Country	**Iraq**				
Year	**1965**	**1970**	**1975**	**1980**	**1985**
GR	0.0521	0.0005	0.0441	0.0582	-0.1018
Y0	3416	4403	4413	5476	7267
PYR	0.12	0.256	0.817	1.312	1.757
PYRM	0.195	0.41	1.277	1.99	2.601
PYRF	0.044	0.099	0.349	0.625	0.902
SYR	0.071	0.113	0.257	0.449	0.574
SYRM	0.115	0.18	0.415	0.723	0.881
SYRF	0.026	0.044	0.097	0.172	0.263
HYR	0.023	0.03	0.053	0.078	0.124
HYRM	0.04	0.047	0.08	0.12	0.18
HYRF	0.006	0.013	0.025	0.036	0.068
PENR	0.65	0.74	0.69	0.94	1
PENRM	0.94	1	0.96	1	1
PENRF	0.37	0.43	0.41	0.64	1
SENR	0.19	0.28	0.24	0.35	0.57
SENRM	0.29	0.42	0.34	0.48	0.76
SENRF	0.07	0.11	0.14	0.21	0.38
HENR	0.02	0.041	0.052	0.09	0.093
HENRM	0.031	0.058	0.079	0.118	0.122
HENRF	0.009	0.022	0.024	0.06	0.061
PRI	0.6	2.5	11.31	16.73	23.69
PRIM	0.99	3.97	17.03	23.61	33.51
PRIF	0.2	1	5.5	9.77	13.73
SEC	0.9	1.7	4.49	8.35	9.74
SECM	1.39	2.78	7.47	13.69	15.41
SECF	0.4	0.6	1.46	2.95	3.99
HIGH	0.7	0.09	1.58	2.34	3.73
HIGHM	1.19	1.39	2.36	3.55	5.32
HIGHF	0.2	0.4	0.78	1.12	2.13
PRIC	0.2	0.84	3.79	5.6	7.93
PRICM	0.34	1.37	5.9	8.26	11.71
PRICF	0.06	0.3	1.64	2.92	4.1
SECC	0.44	0.83	2.19	4.07	4.57
SECCM	0.69	1.37	3.68	6.75	7.62
SECCF	0.19	0.28	0.68	1.36	1.85
HIGHC	0.47	0.6	1.05	1.56	2.49
HIGHCM	0.81	0.95	1.62	2.44	3.68
HIGHCF	0.12	0.24	0.47	0.68	1.28
HUMAN	0.214	0.399	1.126	1.839	2.456
GEDU	0.0512	0.0473	0.0458	0.0357	0.0268
LIFEE	46	51.6	53	61.4	62.4
I	5.44	4.58	6.5	12.46	22.04
GCON	0.061	0.052	0.028	0.100	0.050
GDEF	0.074	0.093	0.127	0.096	0.255
BMPL	0.119	0.122	0.150	0.168	0.742
PINST	0.700	0.400	0.321	0.308	0.100
TOT	-0.013	-0.019	0.301	0.109	0.013
FERT	7.2	7.2	7.1	7	7
GPOP	0.0305	0.0319	0.0327	0.0362	0.0357
POP15	0.461	0.464	0.466	0.468	0.470

Table A2 (Cont.)

Country	**Israel**		
Year	**1970**	**1975**	**1980**
GR	0.0544	0.0447	0.0112
Y0	4600	5994	7460
PYR	5.45	5.664	5.951
PYRM	5.963	6.127	6.38
PYRF	4.947	5.214	5.541
SYR	1.313	1.523	1.68
SYRM	1.476	1.69	1.837
SYRF	1.154	1.362	1.531
HYR	0.335	0.435	0.519
HYRM	0.427	0.524	0.61
HYRF	0.244	0.349	0.431
PENR	0.95	0.96	0.97
PENRM	0.95	1	0.96
PENRF	0.95	0.95	0.97
SENR	0.48	0.57	0.66
SENRM	0.46	0.31	0.61
SENRF	0.51	0.6	0.71
HENR	0.2	0.199	0.253
HENRM	0.218	0.216	0.248
HENRF	0.181	0.182	0.221
PRI	14.81	37	35.94
PRIM	44.28	38.34	37.2
PRIF	39.39	35.7	34.74
SEC	28.84	31.3	32.76
SECM	30.12	33.05	34.21
SECF	27.58	29.6	31.37
HIGH	11.39	14.8	17.64
HIGHM	14.14	17.28	20.05
HIGHF	8.68	12.4	15.34
PRIC	14	12.39	12.03
PRICM	16.28	14.18	13.78
PRICF	11.75	10.65	10.37
SECC	14.06	15.27	15.98
SECCM	15.39	16.89	17.51
SECCF	12.67	13.69	14.51
HIGHC	5.35	6.96	8.29
HIGHCM	7.21	8.94	10.45
HIGHCF	3.53	5.03	6.23
HUMAN	7.098	7.622	8.15
GEDU	0.0685	0.0683	0.073
LIFEE	71.6	71.6	72.8
I	27.16	31.7	26.42
GCON	0.062	0.010	0.010
GDEF	0.161	0.329	0.28
BMPL	0.099	0.226	0.218
PINST	0.000	0.032	0.000
TOT	0.000	-0.031	0.004
FERT	3.794	3.74	3.48
GPOP	0.0297	0.03	0.0231
POP15	0.346	0.331	0.328

Table A2 (Cont.)

Country	**Japan**				
Year	**1965**	**1970**	**1975**	**1980**	**1985**
GR	0.0869	0.1035	0.0278	0.0375	0.0317
Y0	2943	4464	7304	8376	10068
PYR	4.898	4.952	4.969	5.087	5.23
PYRM	5.035	5.08	5.05	5.155	5.297
PYRF	4.773	4.835	4.895	5.017	5.168
SYR	1.607	1.727	1.652	1.969	2.467
SYRM	1.797	1.91	1.815	2.121	2.605
SYRF	1.434	1.56	1.502	1.828	2.34
HYR	0.205	0.204	0.179	0.238	0.468
HYRM	0.363	0.366	0.336	0.423	0.702
HYRF	0.06	0.055	0.034	0.067	0.252
PENR	1	1	0.99	0.99	1
PENRM	1	1	1	1	1
PENRF	1	1	0.99	0.99	1
SENR	0.74	0.82	0.86	0.91	0.93
SENRM	0.75	0.83	0.87	0.95	0.91
SENRF	0.77	0.83	0.86	0.92	0.92
HENR	0.095	0.129	0.17	0.246	0.305
HENRM	0.151	0.196	0.245	0.331	0.406
HENRF	0.039	0.063	0.096	0.16	0.202
PRI	59.9	57.78	60.6	53.81	45.04
PRIM	57.7	55.47	57.87	51.38	42.97
PRIF	61.9	59.89	63.1	56.07	46.96
SEC	30.9	33.84	33	38.1	39.9
SECM	30.35	32.99	31.58	35.75	37.2
SECF	31.4	34.63	34.3	40.26	42.4
HIGH	6.3	6.26	5.5	7.33	14.4
HIGHM	10.7	10.81	10.07	12.48	19.59
HIGHF	2.3	2.1	1.3	2.57	9.6
PRIC	28.97	27.07	28.04	24.78	20.7
PRICM	28.05	26.26	27.13	23.99	20.04
PRICF	29.81	27.81	28.87	25.5	21.3
SECC	10.06	11.2	11.05	12.86	13.55
SECCM	8.17	9.07	8.77	9.99	10.46
SECCF	11.87	13.16	13.15	15.25	16.41
HIGHC	3.94	3.91	3.44	4.58	9
HIGHCM	7.48	7.47	6.74	8.67	15.5
HIGHCF	0.72	0.65	0.4	0.8	2.99
HUMAN	6.71	6.882	6.8	7.291	8.166
GEDU	0.0413	0.0406	0.0448	0.0559	0.0559
LIFEE	69	71.2	73	75.2	76.6
I	29.58	33.62	39.26	35.16	32.48
GCON	0.071	0.056	0.040	0.036	0.033
GDEF	0.01	0.009	0.008	0.009	0.009
BMPL	0.000	0.000	0.000	0.000	0.000
PINST	0.004	0.000	0.001	0.001	0.000
TOT	-0.055	0.018	-0.057	-0.050	0.014
FERT	2.074	2.064	2.124	1.83	1.784
GPOP	0.0099	0.0107	0.014	0.0085	0.0067
POP15	0.302	0.269	0.240	0.238	0.236

Table A2 (Cont.)

Country	**Jordan**				
Year	**1965**	**1970**	**1975**	**1980**	**1985**
GR	0.0659	-0.0225	0.0803	0.1012	0.0101
Y0	1158	1593	1422	2092	3387
PYR	1.044	1.231	0.999	1.902	1.751
PYRM	1.591	1.834	1.151	2.492	2.405
PYRF	0.471	0.607	0.843	1.286	1.075
SYR	0.326	0.46	0.576	0.817	0.966
SYRM	0.473	0.675	0.821	1.205	1.382
SYRF	0.173	0.238	0.323	0.413	0.537
HYR	0.026	0.054	0.032	0.04	0.216
HYRM	0.043	0.086	0.029	0.06	0.339
HYRF	0.008	0.02	0.035	0.019	0.09
PENR	0.77	0.95	0.89	0.88	1
PENRM	0.94	1	0.8	0.88	1
PENRF	0.58	0.82	0.66	0.77	1
SENR	0.25	0.38	0.37	0.5	0.76
SENRM	0.37	0.52	0.42	0.48	0.79
SENRF	0.12	0.22	0.24	0.35	0.73
HENR	0.006	0.018	0.022	0.09	0.266
HENRM	0.009	0.023	0.029	0.053	0.289
HENRF	0.003	0.012	0.014	0.03	0.242
PRI	13	14.72	5.43	19.89	14.5
PRIM	20.54	22.15	0.54	21.57	18.77
PRIF	5.1	7.03	10.48	18.14	10.1
SEC	6.5	8.37	11.94	16.97	12.7
SECM	9.46	12.34	18.19	25.2	17.45
SECF	3.4	4.25	5.5	8.4	7.8
HIGH	0.8	1.67	0.98	1.24	6.7
HIGHM	1.28	2.55	0.69	1.77	10
HIGHF	0.3	0.75	1.28	0.69	3.3
PRIC	7.2	6.25	2.04	7.08	5.05
PRICM	11.02	9.2	0.06	7.56	6.51
PRICF	3.2	3.21	4.07	6.57	3.55
SECC	2.78	3.63	5.3	7.79	6.1
SECCM	3.75	5.05	7.8	11.42	8.62
SECCF	1.76	2.17	2.72	4	3.5
HIGHC	0.49	1.02	0.6	0.76	4.1
HIGHCM	0.85	1.75	0.74	1.25	6.93
HIGHCF	0.11	0.27	0.46	0.25	1.18
HUMAN	1.396	1.745	1.607	2.759	2.933
GEDU	0.039	0.034	0.0474	0.053	0.0667
LIFEE	48.4	52	56.6	60	63.2
I	8.84	10.36	12.38	18.48	20.52
GCON	0.000	0.022	0.071	0.094	0.069
GDEF	0.166	0.166	0.169	0.17	0.136
BMPL	0.021	0.027	0.052	0.026	0.016
PINST	0.059	0.100	0.572	0.000	0.000
TOT	0.003	-0.079	0.128	-0.121	-0.012
FERT	7.75	7.2	7.87	7.535	6.636
GPOP	0.0293	0.0317	0.0246	0.0234	0.0364
POP15	0.444	0.451	0.459	0.476	0.494

Table A2 (Cont.)

Country	**Korea, Rep**				
Year	**1965**	**1970**	**1975**	**1980**	**1985**
GR	0.0310	0.0990	0.0672	0.0591	0.0640
Y0	898	1046	1677	2321	3093
PYR	2.484	3.327	4.095	3.99	4.338
PYRM	3.304	4.056	4.594	4.534	4.847
PYRF	1.758	2.661	3.627	3.461	3.848
SYR	0.657	0.974	1.293	1.7	2.202
SYRM	1.104	1.526	1.922	2.369	2.918
SYRF	0.261	0.47	0.705	1.06	1.515
HYR	0.09	0.125	0.195	0.24	0.31
HYRM	0.173	0.228	0.336	0.397	0.488
HYRF	0.017	0.031	0.062	0.09	0.139
PENR	0.94	1	1	1	1
PENRM	1	1	1	1	1
PENRF	0.99	0.97	1	1	1
SENR	0.27	0.35	0.42	0.56	0.76
SENRM	0.38	0.44	0.52	0.67	0.85
SENRF	0.14	0.25	0.32	0.48	0.74
HENR	0.047	0.062	0.08	0.103	0.158
HENRM	0.075	0.09	0.118	0.139	0.207
HENRF	0.016	0.032	0.039	0.054	0.075
PRI	29.6	35.2	48.6	39.2	35.4
PRIM	34.57	36.08	44.18	35.12	29.39
PRIF	25.2	34.4	52.75	43.1	39.4
SEC	10.9	17.5	21.8	28.7	39.6
SECM	17.45	25.82	30.13	36.96	44.51
SECF	5.1	9.9	14	20.8	29.6
HIGH	2.6	3.6	5.6	6.9	8.9
HIGHM	4.97	6.56	9.66	11.4	14.01
HIGHF	0.5	0.9	1.8	2.6	4
PRIC	26.2	33.5	33.09	22.59	18.48
PRICM	30.72	34.38	29.39	19.58	15.16
PRICF	22.2	32.7	36.55	25.46	21.68
SECC	5.8	7.76	10.11	14.16	18.7
SECCM	9.41	11.92	14.61	19.2	24.74
SECCF	2.6	3.95	5.89	9.33	12.9
HIGHC	1.92	2.66	4.14	5.11	6.59
HIGHCM	3.86	4.85	7.15	8.44	10.38
HIGHCF	0.37	0.66	1.32	1.91	2.94
HUMAN	3.231	4.426	5.583	5.929	6.849
GEDU	0.0436	0.029	0.0414	0.0264	0.0423
LIFEE	55.2	57.8	61.4	65.4	67.6
I	9.88	18.34	21.88	27.88	27.82
GCON	0.052	0.056	0.042	0.022	0.004
GDEF	0.051	0.04	0.041	0.056	0.057
BMPL	0.471	0.114	0.105	0.068	0.083
PINST	0.104	0.100	0.203	0.303	0.100
TOT	0.018	-0.021	0.007	-0.042	-0.002
FERT	5.346	4.548	4.014	3.186	2.594
GPOP	0.0276	0.0232	0.02	0.0155	0.0148
POP15	0.420	0.418	0.421	0.378	0.340

Table A2 (Cont.)

Country	**Malaysia**				
Year	**1965**	**1970**	**1975**	**1980**	**1985**
GR	0.0340	0.0528	0.0437	0.0736	0.0173
Y0	1409	1665	2154	2668	3805
PYR	1.84	2.196	2.637	3.096	3.3
PYRM	2.861	3.08	3.019	3.852	4.48
PYRF	0.746	1.27	2.244	2.321	2.112
SYR	0.441	0.571	0.711	0.891	1.138
SYRM	0.702	0.843	0.877	1.255	1.763
SYRF	0.161	0.286	0.539	0.517	0.508
HYR	0.055	0.054	0.057	0.055	0.052
HYRM	0.09	0.075	0.087	0.072	0.078
HYRF	0.018	0.032	0.026	0.037	0.025
PENR	0.96	0.9	0.87	0.91	0.95
PENRM	1	0.96	0.95	0.95	0.93
PENRF	0.83	0.8	0.84	0.89	0.91
SENR	0.19	0.28	0.34	0.42	0.49
SENRM	0.25	0.34	0.4	0.48	0.52
SENRF	0.11	0.21	0.28	0.39	0.49
HENR	0.012	0.02	0.017	0.031	0.043
HENRM	0.016	0.026	0.028	0.042	0.054
HENRF	0.008	0.013	0.009	0.016	0.032
PRI	32.7	38.61	44.6	47.61	44.4
PRIM	49.6	51.76	48.68	51.4	50.56
PRIF	14.6	24.85	40.4	43.73	38.2
SEC	7.2	9.39	13.26	15.2	19.9
SECM	11.4	14.06	15.75	21.84	29.64
SECF	2.7	4.49	10.7	8.39	10.1
HIGH	1.5	1.46	1.54	1.48	1.4
HIGHM	2.43	2.01	2.35	1.94	2.1
HIGHF	0.5	0.89	0.7	1.02	0.7
PRIC	11.23	12.88	13.7	22.22	23
PRICM	18.11	18.75	15.74	29.44	35.32
PRICF	3.86	6.74	11.6	14.81	10.6
SECC	2.4	3.99	3.96	7.28	9.8
SECCM	3.8	6	4.6	10.13	16.56
SECCF	0.9	1.89	3.3	4.35	3
HIGHC	1.27	1.24	1.3	1.26	1.18
HIGHCM	2.07	1.73	2.01	1.67	1.8
HIGHCF	0.41	0.72	0.57	0.83	0.57
HUMAN	2.336	2.82	3.404	4.042	4.489
GEDU	0.0332	0.0387	0.043	0.0557	0.0631
LIFEE	55.6	59.4	62.8	65.2	67.8
I	16.22	17.06	22.72	24.04	30.7
GCON	0.076	0.069	0.056	0.048	0.031
GDEF	0.02	0.035	0.04	0.049	0.07
BMPL	0.018	0.015	0.005	0.003	0.003
PINST	0.000	0.000	0.000	0.108	0.000
TOT	-0.035	-0.077	0.030	0.069	-0.040
FERT	6.632	5.938	5.126	4.25	3.886
GPOP	0.03	0.0262	0.0243	0.0232	0.0261
POP15	0.450	0.450	0.451	0.421	0.393

Table A2 (Cont.)

Country	**Pakistan**				
Year	**1965**	**1970**	**1975**	**1980**	**1985**
GR	0.0685	0.0278	-0.0215	0.0378	0.0258
Y0	644	897	1029	923	1111
PYR	0.457	0.716	0.877	0.903	0.93
PYRM	0.457	0.948	1.379	1.393	1.402
PYRF	0.457	0.459	0.333	0.374	0.408
SYR	0.159	0.357	0.675	0.67	0.737
SYRM	0.161	0.512	1.064	1.039	1.146
SYRF	0.156	0.185	0.252	0.271	0.286
HYR	0.011	0.048	0.127	0.12	0.071
HYRM	0.011	0.067	0.188	0.187	0.111
HYRF	0.011	0.026	0.06	0.048	0.026
PENR	0.3	0.4	0.4	0.46	0.43
PENRM	0.46	0.59	0.62	0.69	0.51
PENRF	0.16	0.22	0.22	0.28	0.26
SENR	0.11	0.12	0.13	0.15	0.14
SENRM	0.18	0.18	0.22	0.22	0.2
SENRF	0.05	0.07	0.05	0.07	0.08
HENR	0.01	0.018	0.025	0.019	0.025
HENRM	0.016	0.028	0.038	0.027	0.028
HENRF	0.004	0.007	0.01	0.009	0.011
PRI	11.7	11.05	8	9.47	8.7
PRIM	11.7	13.61	12.41	14.46	12.33
PRIF	11.7	8.21	3.2	4.09	4.7
SEC	2.4	4.65	7.3	7.71	10.5
SECM	2.4	6.65	11.81	11.89	16.22
SECF	2.4	2.42	2.4	3.21	4.2
HIGH	0.3	1.28	3.4	3.23	1.9
HIGHM	0.3	1.81	5.06	5.03	2.99
HIGHF	0.3	0.7	1.6	1.28	0.7
PRIC	1.2	5.75	5.7	4.77	3.68
PRICM	1.2	7.39	9.01	7.34	5.36
PRICF	1.2	3.94	2.1	1.9	1.84
SECC	0.9	1.74	3.6	2.89	3.93
SECCM	1.02	2.62	5.99	4.63	6.3
SECCF	0.76	0.76	1	1.01	1.33
HIGHC	0.26	1.11	2.93	2.79	1.64
HIGHCM	0.26	1.56	4.36	4.34	2.58
HIGHCF	0.26	0.6	1.39	1.11	0.61
HUMAN	0.628	1.121	1.679	1.693	50
GEDU	0.0252	0.025	0.0177	0.0217	1.737
LIFEE	44.2	45.6	46.6	48	0.0209
I	14.76	10.68	9.5	9.36	9.78
GCON	0.121	0.101	0.074	0.069	0.064
GDEF	0.026	0.038	0.056	0.057	0.298622012
BMPL	0.476	0.602	0.619	0.226	0.202
PINST	0.000	0.003	0.305	0.101	-0.016
TOT	0.000	0.008	-0.012	-0.058	6.964
FERT	7.132	7.18	7.024	7	0.0305
GPOP	0.0268	0.0285	0.0317	0.0301	0.4434
POP15	0.437	0.450	0.463	0.453	0.063

Table A2 (Cont.)

Country	**Philippines**				
Year	**1965**	**1970**	**1975**	**1980**	**1985**
GR	0.0187	0.0247	0.0297	0.0298	-0.0391
Y0	1133	1243	1404	1625	1882
PYR	3.022	3.316	3.728	4.077	4.353
PYRM	3.374	3.629	3.971	4.195	4.441
PYRF	2.69	3.017	3.487	3.96	4.266
SYR	0.55	0.651	0.788	0.943	1.146
SYRM	0.657	0.759	0.898	1.049	1.229
SYRF	0.449	0.547	0.679	0.837	1.064
HYR	0.205	0.256	0.317	0.393	0.502
HYRM	0.227	0.273	0.335	0.401	0.49
HYRF	0.183	0.239	0.299	0.384	0.513
PENR	0.95	1	1	1	1
PENRM	0.97	1	1	1	1
PENRF	0.89	1	1	1	1
SENR	0.26	0.41	0.46	0.54	0.62
SENRM	0.28	0.42	0.5	0.55	0.58
SENRF	0.24	0.38	0.5	0.5	0.49
HENR	0.127	0.188	0.199	0.184	0.277
HENRM	0.121	0.169	0.171	0.173	0.268
HENRF	0.132	0.208	0.222	0.217	0.285
PRI	49.7	52.55	56.4	57.6	54.1
PRIM	50.55	52.62	55.59	56.19	53.09
PRIF	48.9	52.49	57.2	59	55.1
SEC	10.6	11.98	14.2	16.4	18.9
SECM	12.93	14.45	16.62	18.92	21.22
SECF	8.4	9.61	11.8	13.9	16.6
HIGH	6.2	7.74	9.6	11.9	15.2
HIGHM	7.05	8.49	10.41	12.5	15.3
HIGHF	5.4	7.03	8.8	11.3	15.1
PRIC	17.42	18.55	20.27	21.7	22.8
PRICM	21.94	22.46	22.71	20.79	21.89
PRICF	13.16	14.8	17.85	22.6	23.7
SECC	4.48	5.06	6	6.93	7.99
SECCM	5.81	6.5	7.48	8.54	9.61
SECCF	3.23	3.69	4.54	5.34	6.38
HIGHC	4.03	5.03	6.24	7.73	9.88
HIGHCM	4.3	5.16	6.33	7.57	9.2
HIGHCF	3.77	4.91	6.15	7.9	10.55
HUMAN	54.4	56.4	58	59.8	61.6
GEDU	3.776	4.222	4.833	5.412	6
LIFEE	0.0262	0.0245	0.0205	0.0182	0.0164
I	11.82	13.72	13.84	19.54	19.1
GCON	0.094	0.089	0.117	0.121	0.109
GDEF	0.292669614	0.088010877	0.076034686	0.068592791	0.105260511
BMPL	0.000	0.000	0.118	0.605	0.417
PINST	0.034	-0.063	0.010	-0.091	-0.031
TOT	6.896	6.694	6.080	5.102	4.720
FERT	0.0297	0.0297	0.0276	0.0267	0.025
GPOP	0.4696	0.4616	0.4548	0.437	0.4206
POP15	0.013	0.012	0.016	0.027	0.022

Table A2 (Cont.)

Country	**Singapore**		
Year	**1975**	**1980**	**1985**
GR	0.1216	0.0566	0.0406
Y0	3022	5363	7063
PYR	2.617	2.84	2.689
PYRM	3.526	3.582	3.255
PYRF	1.668	2.075	2.114
SYR	1.096	1.127	0.888
SYRM	1.479	1.427	1.077
SYRF	0.696	0.817	0.696
HYR	0.067	0.095	0.114
HYRM	0.1	0.136	0.161
HYRF	0.033	0.052	0.066
PENR	1	1	1
PENRM	1	1	1
PENRF	1	1	1
SENR	0.46	0.52	0.58
SENRM	0.47	0.52	0.53
SENRF	0.45	0.53	0.58
HENR	0.068	0.09	0.079
HENRM	0.093	0.109	0.093
HENRF	0.042	0.075	0.063
PRI	29.6	34.33	38.3
PRIM	39.36	42.45	45.29
PRIF	19.4	25.96	31.2
SEC	20.9	20.48	14.6
SECM	27.6	25.05	16.67
SECF	13.9	15.76	12.5
HIGH	2	2.83	3.4
HIGHM	2.96	4.05	4.78
HIGHF	1	1.57	2
PRIC	11.85	13.74	15.33
PRICM	17.07	18.78	20.31
PRICF	6.39	8.55	10.27
SECC	7	6.92	5
SECCM	9.87	9.13	6.18
SECCF	3.99	4.64	3.8
HIGHC	1.36	1.92	2.31
HIGHCM	2.02	2.77	3.28
HIGHCF	0.66	1.03	1.32
HUMAN	68.6	70.6	71.8
GEDU	3.78	4.062	3.691
LIFEE	0.0278	0.0264	0.0345
I	39.12	33.1	39.6
GCON	0.017	0.010	0.001
GDEF	0.004987542	0.002995509	0
BMPL	0.000	0.000	0.000
PINST	0.051	0.012	0.003
TOT	2.868	1.912	1.712
FERT	0.0173	0.013	0.0115
GPOP	0.3881	0.3242	0.2709
POP15	0.053	0.060	0.050

Table A2 (Cont.)

Country	**Sri Lanka**				
Year	**1965**	**1970**	**1975**	**1980**	**1985**
GR	-0.0123	0.0103	0.0070	0.0495	0.0458
Y0	1253	1178	1240	1284	1635
PYR	2.39	2.786	3.146	3.287	3.432
PYRM	2.827	3.295	3.607	3.682	3.73
PYRF	1.862	2.195	2.606	2.839	3.118
SYR	1.024	1.246	1.768	1.748	1.717
SYRM	1.254	1.537	2.089	2.022	1.927
SYRF	0.746	0.91	1.391	1.438	1.497
HYR	0.012	0.02	0.037	0.036	0.034
HYRM	0.018	0.028	0.048	0.047	0.044
HYRF	0.006	0.011	0.023	0.024	0.023
PENR	0.95	0.93	0.99	0.77	0.98
PENRM	1	0.96	1	0.77	1
PENRF	0.9	0.98	0.94	0.74	0.97
SENR	0.27	0.35	0.47	0.48	0.51
SENRM	0.38	0.35	0.51	0.53	0.5
SENRF	0.16	0.34	0.48	0.49	0.52
HENR	0.006	0.015	0.012	0.013	0.028
HENRM	0.009	0.021	0.013	0.017	0.032
HENRF	0.003	0.01	0.01	0.01	0.025
PRI	46.5	46.82	39.9	42.02	48.9
PRIM	54.2	53.88	44.86	48.35	52.32
PRIF	37.2	38.65	34.1	39.11	45.3
SEC	20.7	24.96	35	34.64	34.1
SECM	24.68	29.95	40.13	38.75	36.76
SECF	15.9	19.17	29	29.99	31.3
HIGH	0.4	0.65	1.2	1.17	1.1
HIGHM	0.57	0.89	1.54	1.48	1.39
HIGHF	0.2	0.39	0.8	0.82	0.8
PRIC	6.9	13.39	13.53	15.83	17.97
PRICM	8.39	16.26	16.08	18.46	20.58
PRICF	5.1	10.06	10.54	12.85	15.23
SECC	7.75	9.34	13.1	12.97	12.77
SECCM	10.01	12.19	16.48	16.07	15.52
SECCF	5.02	6.05	9.15	9.46	9.88
HIGHC	0.21	0.35	0.64	0.63	0.59
HIGHCM	0.32	0.5	0.88	0.85	0.8
HIGHCF	0.09	0.18	0.37	0.37	0.37
HUMAN	63.2	64	63.4	66.4	69
GEDU	3.426	4.052	4.95	5.071	5.183
LIFEE	0.0401	0.0365	0.0349	0.0249	0.0295
I	5.26	5.84	6.98	10.04	13.72
GCON	0.162	0.158	0.154	0.119	0.081
GDEF	0.626473047	0.85143216	0.591114455	0.297137231	0.1889661
BMPL	0.000	0.000	0.100	0.000	0.113
PINST	-0.081	-0.041	-0.019	0.004	-0.005
TOT	5.098	4.652	4.206	3.848	3.394
FERT	0.0237	0.0234	0.0151	0.0176	0.0144
GPOP	0.4207	0.4201	0.4189	0.3848	0.3526
POP15	0.010	0.008	0.010	0.010	0.015

Table A2 (Cont.)

Country	**Syria**				
Year	**1965**	**1970**	**1975**	**1980**	**1985**
GR	0.0495	0.0272	0.1000	0.0387	-0.0106
Y0	1577	2008	2296	3698	4471
PYR	0.867	1.148	1.357	1.706	2.172
PYRM	1.415	1.842	2.157	2.623	3.195
PYRF	0.297	0.446	0.548	0.785	1.14
SYR	0.11	0.195	0.27	0.481	0.777
SYRM	0.173	0.303	0.427	0.761	1.182
SYRF	0.045	0.085	0.112	0.2	0.369
HYR	0.017	0.032	0.043	0.091	0.157
HYRM	0.03	0.055	0.074	0.15	0.246
HYRF	0.003	0.009	0.013	0.033	0.067
PENR	0.65	0.78	0.78	0.96	1
PENRM	0.89	1	1	1	1
PENRF	0.39	0.52	0.59	0.78	0.87
SENR	0.16	0.28	0.38	0.43	0.47
SENRM	0.25	0.43	0.55	0.57	0.57
SENRF	0.07	0.12	0.21	0.28	0.35
HENR	0.037	0.08	0.089	0.121	0.176
HENRM	0.06	0.133	0.132	0.175	0.226
HENRF	0.013	0.027	0.037	0.063	0.107
PRI	21.3	23.87	25.9	27.92	30.47
PRIM	35.44	38.89	41.45	42.46	43.88
PRIF	6.6	8.69	10.2	13.32	16.96
SEC	1.8	3.07	4.3	7.1	11.07
SECM	2.67	4.55	6.58	11.01	16.56
SECF	0.9	1.57	2	3.17	5.54
HIGH	0.5	0.96	1.3	2.74	4.27
HIGHM	0.88	1.64	2.19	4.45	7.31
HIGHF	0.1	0.28	0.4	1.01	2.1
PRIC	3	6.33	8.12	9.27	10.33
PRICM	4.64	10.14	12.91	14.05	14.86
PRICF	1.3	2.49	3.28	4.47	5.78
SECC	0.88	1.5	2.1	3.46	5.4
SECCM	1.32	2.26	3.26	5.45	8.22
SECCF	0.42	0.72	0.93	1.47	2.56
HIGHC	0.33	0.64	0.87	1.83	3.15
HIGHCM	0.6	1.11	1.49	3.03	5.01
HIGHCF	0.06	0.17	0.24	0.61	1.27
HUMAN	51.2	54	57	60	62.6
GEDU	0.994	1.374	1.67	2.278	3.106
LIFEE	0.034	0.0309	0.0361	0.052	0.057
I	14.98	14.3	11.92	17.26	17.92
GCON	0.010	0.010	0.003	0.010	0.010
GDEF	0.101653654	0.117783036	0.106160196	0.053540767	0.363253259
BMPL	0.750	0.200	0.300	0.147	0.211
PINST	0.010	-0.148	0.207	0.093	0.000
TOT	7.456	7.738	7.672	7.440	7.168
FERT	0.031	0.0323	0.0345	0.0336	0.0345
GPOP	0.4441	0.4658	0.4888	0.4818	0.4752
POP15	0.075	0.082	0.114	0.157	0.159

Table A2 (Cont.)

Country	**Taiwan**			
Year	**1970**	**1975**	**1980**	**1985**
GR	0.0576	0.0686	0.0793	0.0410
Y0	1651	2185	3044	4458
PYR	2.756	3.121	3.602	4.428
PYRM	3.637	3.889	4.297	4.99
PYRF	1.756	2.197	2.789	3.792
SYR	0.921	1.105	1.218	1.656
SYRM	1.36	1.584	1.629	2.091
SYRF	0.423	0.528	0.738	1.164
HYR	0.13	0.155	0.172	0.281
HYRM	0.214	0.242	0.255	0.389
HYRF	0.035	0.051	0.075	0.159
PENR	0.97	0.98	0.99	1
PENRM	0.96	0.97	0.99	1
PENRF	0.98	0.99	0.99	0.99
SENR	0.57	0.8	0.9	0.97
SENRM	0.93	1	1	1
SENRF	0.21	0.45	0.6	0.78
HENR	0.111	0.169	0.165	0.179
HENRM	0.186	0.275	0.26	0.267
HENRF	0.035	0.064	0.07	0.091
PRI	38.6	40.55	44.7	44.4
PRIM	45.65	43.36	47.69	45.28
PRIF	30.6	37.16	41.2	43.4
SEC	15.1	18.13	20	23.3
SECM	21.27	25.32	26.16	28.34
SECF	8.1	9.47	12.8	17.6
HIGH	4.3	5.14	5.7	9.3
HIGHM	7.03	7.94	8.35	12.66
HIGHF	1.2	1.77	2.6	5.5
PRIC	14.46	16.95	23.96	38
PRICM	18.99	19.75	26.51	39.06
PRICF	9.32	13.58	20.98	36.8
SECC	7	8.41	9.2	13.3
SECCM	10	11.58	11.42	16.04
SECCF	3.6	4.58	6.6	10.2
HIGHC	2.19	2.62	2.9	4.73
HIGHCM	3.65	4.14	4.4	6.77
HIGHCF	0.53	0.78	1.15	2.43
HUMAN	67.2	69.6	71.4	72.4
GEDU	3.807	4.381	4.992	6.365
LIFEE	0.0288	0.0336	0.0359	0.0433
I	18.52	24.8	26.54	25.66
GCON	0.156	0.137	0.124	0.115
GDEF	0.043059489	0.076961041	0.019802627	0.058268908
BMPL	0.000	0.107	0.000	0.000
PINST	0.005	-0.047	-0.035	-0.031
TOT	4.440	3.460	2.800	2.320
FERT	0.0301	0.0191	0.0195	0.0157
GPOP	0.4223	0.3963	0.3566	0.3211
POP15	0.105	0.083	0.070	0.067

Table A2 (Cont.)

Country	**Thailand**				
Year	**1965**	**1970**	**1975**	**1980**	**1985**
GR	0.0382	0.0615	0.0199	0.0527	0.0247
Y0	940	1134	1528	1686	2180
PYR	3.196	2.95	3.254	3.36	3.203
PYRM	3.917	3.595	3.86	3.786	3.548
PYRF	2.485	2.322	2.672	2.954	2.87
SYR	0.232	0.258	0.242	0.332	0.447
SYRM	0.357	0.382	0.346	0.451	0.575
SYRF	0.108	0.137	0.142	0.219	0.324
HYR	0.024	0.034	0.044	0.072	0.116
HYRM	0.036	0.049	0.061	0.092	0.137
HYRF	0.012	0.02	0.028	0.053	0.096
PENR	0.83	0.78	0.83	0.83	0.99
PENRM	1	0.82	0.85	0.82	0.99
PENRF	1	0.76	0.79	0.81	0.96
SENR	0.13	0.14	0.17	0.26	0.29
SENRM	0.09	0.14	0.2	0.28	0.3
SENRF	0.09	0.1	0.15	0.23	0.28
HENR	0.019	0.015	0.033	0.035	0.131
HENRM	0.027	0.02	0.024	0.04	0.147
HENRF	0.012	0.01	0.022	0.027	0.1
PRI	46.4	52.04	60.5	63.86	69.7
PRIM	54.82	59.48	67.69	67.59	72.5
PRIF	38.1	44.8	53.6	60.31	67
SEC	4.9	5.17	4.4	5.59	6.8
SECM	7.54	7.69	6.38	7.85	9.4
SECF	2.3	2.73	2.5	3.43	4.3
HIGH	0.6	0.85	1.1	1.8	2.9
HIGHM	0.9	1.23	1.52	2.31	3.42
HIGHF	0.3	0.49	0.7	1.32	2.4
PRIC	33.9	20.18	21.47	17.37	2.4
PRICM	40.19	25.4	26.82	20.27	3.23
PRICF	27.7	15.1	16.33	14.6	1.6
SECC	1.62	1.71	1.46	1.87	2.3
SECCM	2.56	2.59	2.12	2.55	2.92
SECCF	0.69	0.86	0.83	1.23	1.7
HIGHC	0.6	0.85	1.1	1.8	2.89
HIGHCM	0.9	1.23	1.51	2.3	3.41
HIGHCF	0.3	0.49	0.7	1.31	2.39
HUMAN	53.8	56.8	59.4	61.4	62.8
GEDU	3.451	3.242	3.54	3.764	3.765
LIFEE	0.0209	0.0258	0.0305	0.0347	0.0373
I	13.08	18.5	17.74	17.82	17.4
GCON	0.068	0.071	0.065	0.075	0.083
GDEF	0.026641931	0.0009995	0	0.003992021	0
BMPL	0.000	0.000	0.200	0.302	0.200
PINST	-0.019	-0.041	0.018	-0.033	-0.041
TOT	6.394	6.100	4.948	4.248	3.508
FERT	0.0302	0.0304	0.0292	0.0243	0.0203
GPOP	0.4561	0.4525	0.4486	0.4215	0.3974
POP15	0.025	0.025	0.032	0.039	0.050

Table A3
Iranian time series data

Year	GDP	Total Capital Stock	Population	Labour Force	Investment Ratio	Public Investment	Public Capital Stock	Tax Ratio
1959	2321.6	829.3	20789	6156.3	0.114	104.6	459.6	0.0137
1960	2534.8	995.9	21439	6282.9	0.119	95.9	466.9	0.0152
1961	2682.5	1168	22109	6413.4	0.121	108.1	517.5	0.0151
1962	2851.6	1321.3	22801	6548.0	0.110	101.4	576.4	0.0150
1963	3032.7	1475.9	23513	6686.8	0.115	134.5	673.8	0.0174
1964	3281.9	1681.3	24249	6829.9	0.120	132.5	761.8	0.0164
1965	3738.3	1965.6	25007	6977.5	0.141	233.8	921.0	0.0222
1966	4089.6	2264.9	25789	7492.2	0.129	218.4	1078.2	0.0218
1967	4798.9	2629.3	26489	7412.1	0.139	313.7	1294.4	0.0229
1968	5104.2	3033.7	27208	7320.1	0.147	402.2	1584.6	0.0292
1969	5747.9	3438.4	27946	7252.5	0.138	435.8	1919.2	0.0403
1970	6333.6	3922.6	28705	7228.0	0.140	452.7	2277.1	0.0447
1971	7327.5	4516.5	29484	7368.5	0.142	561.6	2721.9	0.0419
1972	8597.8	5312.3	30284	7743.8	0.146	616.6	3196.7	0.0416
1973	9666.5	6271.4	31106	7818.5	0.146	734.1	3786.8	0.0346
1974	10746.3	7437.5	31951	8393.5	0.152	938.3	4554.4	0.0256
1975	11252.8	9356.1	32818	8852.8	0.218	1249.1	5383.8	0.0492
1976	13131.4	12041.8	33709	9864.1	0.253	1904	6496.6	0.0454
1977	12851.3	14491	35025	9981.6	0.251	1780.9	7943.3	0.0490
1978	11440.9	16190.8	36293	9804.6	0.229	1749.9	9228.3	0.0618
1979	10841.3	16979	37815	9560.9	0.167	917.1	9735.0	0.0412
1980	9228.4	17048.1	39291	9770.5	0.200	861.3	10021.6	0.0229
1981	9031.7	16712.4	40826	9646.8	0.191	873	9996.4	0.0468
1982	10335.4	17177.4	42420	9807.4	0.178	1057.2	9204.3	0.0324
1983	11517.6	16429.9	44077	11044.9	0.221	1144.3	8529.4	0.0290
1984	11522.1	16424.1	45798	11505.8	0.222	1077.8	8748.0	0.0324
1985	11723.6	15787.7	47587	11649.0	0.184	890.7	8258.9	0.0399
1986	10692.5	10817.7	49445	10854.4	0.154	760.7	6614.9	0.0472
1987	10736.2	9630.3	50662	10783.0	0.127	569.7	6308.4	0.0374
1988	10360.6	8257.9	51909	10486.2	0.110	464.3	6078.6	0.0352
1989	10799.7	8171.1	53187	10951.6	0.113	468.8	6367.6	0.0289
1990	12045.2	8218.1	54496	12021.8	0.114	613	6741.1	0.0307
1991	13264.1	8793.2	55837	13313.4	0.146	806.6	7348.4	0.0336
1992	14049.5	9448	56656	13775.9	0.148	934.3	8009.0	0.0366
1993	14742.2	10104.1	57488	14088.1	0.145	889.7	8640.1	0.0341
1994	14984.6	10847.6	58331	14185.6	0.147	927.9	9274.9	0.0359
1995	15454.6	11628.3	59187	14239.7	0.148	972.3	9603.7	0.0362
1996	16141.6	12536.1	60055	14680.3	0.152	1038.2	9987.9	0.0450

Sources: Iran's Plan and Budget Organisation (PBO) and Central Bank (CB).

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