Essays on Economic Growth and Imperfect Markets

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2 GROWTH, DEFICITS AND R&D: AN INTERNATIONAL PERSPECTIVE

2.1 Introduction

In the orthodox neoclassical theory, set out by Solow (1956) and others, the possibility of sustained economic growth is ascribed to an exogenous factor of production, i.e. technology that develops with the passage of time. This result is intimately linked to one of the properties of the neoclassical production function that is employed in this theory. This function relates the output to factor inputs, the stock of accumulated physical capital goods (machinery, computers and the like) and labour. It displays decreasing returns to scale with respect to the use of each (reproducible) factor of production. It follows that an increase in the stock of capital goods, given the employed amount of labour, yields a less than proportionate increase in the output. Expansion of the capital stock implies a decline in the return on a further expansion and for this reason may ultimately cease. Opportunities for profitable investments are limited and will eventually be exhausted. Technical changes, however, that improve the productivity of labour and thus of 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, capital, output and consumption will eventually also grow at this exogenous rate on an equilibrium (also called balanced) growth path. Accumulation of capital is in this sense complementary to ongoing technical developments. Neoclassical theory does not provide an economic explanation for these developments, but rather imposes a time trend on the model for the long-run rate of economic growth. Neoclassical theory does attempt to explain the speed of adjustment towards a balanced growth trajectory.

The possibility of exogenous technical progress reconciles the neoclassical theory with Kaldor's 'stylised facts' (1961): a steady growth rate of output (per worker); a more or less constant ratio between output and the capital stock; a constant return on investment; a fairly stable functional distribution of income. However, as technical progress is assumed to be exogenous in the older vintages of growth theory, not much explanatory power is gained from its introduction. Furthermore, when the standard Solow model is calibrated to real data in order to explain the adjustment towards balanced growth paths, the predictions for the speed of convergence or for the national income share of capital income are too high.

Many empirical studies try to attribute the growth of output mainly to quantitative and qualitative changes in the stocks of productive factors. The residual growth in output that cannot be explained by growth in the factors of production is referred to as the Solow residual. The calculation of Solow residuals usually supposes perfect competition in factor and output markets so that the contribution of the growth in capital and in labour to growth in output are weighted by the national income shares of capital and labour, respectively. Empirical studies typically find that part of the growth in output cannot be accounted for by growth in the factors of production alone. The resulting Solow residuals are normally ascribed to technical progress and may be of considerable size as Table 2.1 shows.

Table 2.1 *Gross domestic product and augmented joint factor productivity* annual average compound growth rate

	1870-1913	1913-1950		1950-1973		1973-1984	
	GDP	GDP	AJFP	GDP	AJFP	GDP	AJFP
France	1.7	1.1	0.6	5.1	3.1	2.2	0.9
Germany	2.8	1.3	0.2	5.9	3.6	1.7	1.1
Japan	2.5	2.2	0.0	9.4	4.7	3.8	0.4
Netherlands	2.1	2.4	0.5	4.7	2.4	1.6	0.1
U.K.	1.9	1.3	0.4	3.0	1.5	1.1	0.6
U.S.	4.2	2.8	1.2	3.7	1.1	2.3	-0.3

Source: Maddison (1987), Table 1 and 11b. The augmented joint factor productivity (AJFP) equals production growth (GDP) minus the contributions of the changes in quantity and quality of labour and of capital.

This chapter attempts to survey the contributions that have been made in the literature to explain the presence of sizeable Solow residuals and at the same to provide an understanding of what factors determine the long-run rate of growth of an economy in the global economy and of how this helps to understand issues of development.

Section 2 discusses how a large variety of the new theories of endogenous growth build on the classic work of Uzawa (1965) and Conlisk (1969). The assumption of decreasing returns to a narrow concept of capital is rejected in favour of constant returns to a very broad measure of capital. The long-run rate of growth then depends on a host of supply-side determinants such as learning by doing, intentional investment in human capital, research and development in the capital goods and consumption goods industries, and public infrastructure and other public goods. Section 3 applies the new theories of economic growth to obtain a grasp of issues of catching-up and development. It analyses under what conditions rates of economic growth and levels of per-capita income will converge or diverge. This section also explains why the orthodox theory of economic growth may be somewhat more optimistic about development and catch up of poor with rich countries than the new theories of endogenous growth.

Section 4 gives a two-country analysis of endogenous growth, based on the notion of learning by doing respectively on government spending affecting the productivity of capital. This section explicitly takes into account international knowledge spillovers. Section 4 also allows for departures from Ricardian equivalence between debt issue and taxation; absence of an intergenerational bequest motive and overlapping generations are introduced to show the possible consequences of conventional macroeconomic and budgetary policies for private investment. It analyses the international spillover effects of demand-side policies: once allowance is made for departures from Ricardian debt neutrality, the new theories of economic growth can explain for the first time that high national income share of government consumption and high ratio's of government debt to national income depress growth prospects.

Section 5 directs attention at a view on endogenous growth which stresses the role of variety in consumer products as well as research and development, along the lines of Grossman and Helpman (1991). This view is based on the idea that more labour assigned to the R&D sector or to human capital accumulation rather than to the production of goods boosts growth, where Grossman and Helpman (1991) focus on knowledge as a non-rival public good and Lucas (1988) focuses on knowledge as a rival good. It applies the theory to address the question of growth and trade. Section 6 gives a brief summary of empirical studies that are relevant for the discussion in the preceding sections. Finally, section 7 concludes the chapter.

2.2 New theories of endogenous growth

In the traditional theory the long-run rate of growth of variables such as aggregate private consumption, capital and output corresponds to the natural rate of growth, being the growth in efficiency units. The natural rate of growth corresponds to the sum of population growth and labour-augmenting technical progress (m) and is *exogenous*. The new theories of growth attempt to explain the long-run growth rate. In this section and section 3 we give a verbal survey of these new theories of growth and examine their implications for issues in international macroeconomics. In sections 5 and 6 we then present analytical models based on endogenous growth and explore some issues to do with the global economy and development.

The pioneering work of Uzawa (1965) and Conlisk (1969) attempts to endogenise the rate of technical progress in the neoclassical model. Conlisk, in particular, conveys radically different conclusions from the orthodox neoclassical theory of economic growth and provides one of the first theories of endogenous growth:

"*In the Solow-Swan model a change in the rate of savings, in the depreciation rate or in the constant rate of unemployment will not change the equilibrium growth rate g^* (...); whereas g^* will indeed be affected in the model of this paper*" (p. 69).

The new theories take up the same route set out by Uzawa and Conlisk and amend orthodox neoclassical theory by offering a formulation of endogenous technical change.[2] The new theories of growth abandon the assumption that production displays decreasing returns to scale with respect to the use of capital. Instead, the definition of capital is enlarged to also allow for investment in many reproducible factors of production (such as reclamation of land through building dykes, accumulation of human capital through training, build-up of know-how through R&D, spending on infrastructure and other public goods, etc.). It then seems reasonable to assume constant (increasing) returns to scale with respect to this very broad measure of capital.[3]

2.2.1 Relationship to old theories of growth

Harrod (1935) and Domar (1937) discuss the (in)stability of the growth process. On a balanced growth path the warranted growth rate must be equal to the natural growth rate. The warranted growth rate of an economy is given by the ratio of the aggregate savings rate divided by the capital-output ratio, and the natural growth rate by the sum of the rate of population growth and the rate of labour-augmenting technical progress. In general, one can think of four main channels by which balanced growth can be ensured and each of these channels is associated with a particular brand of theory of economic growth (see van der Ploeg (1984) for a survey).

The first channel is through adjustments in the aggregate savings rate arising from changes in the functional distribution of income. These are the Post-Keynesian stories of the symbiotic contradictions of capitalism and the class struggle associated with the names of Michael Kalecki, Joan Robinson, Nicholas Kaldor, Richard Goodwin and Luigi Pasinetti ("UK Cambridge"). The idea is that workers save a smaller proportion of their income than capitalists so that the savings ratio and the warranted rate of economic growth decline when the national income share of labour increases. The

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[2] Scott (1989) is one of the few recent contributions to the literature on growth that acknowledges the classic work of Conlisk (1969).

[3] Both Scott (1989) and King and Robson (1989) postulate a technical progress function, somewhat in the spirit of Kaldor (1957), rather than a neoclassical production function. Other contributors to this issue take this tack, so we focus on the use of neoclassical production functions to explain endogenous growth.

second channel relaxes the Post-Keynesian assumption of complementarity between the factors of production and thus arrives at balanced growth through adjustments in the capital-output ratio. This is, of course, achieved by neoclassical substitution between the factors of production and is associated with the names of Robert Solow and others ("US Cambridge); this was the route emphasized in the traditional theories of economic growth whose international features were highlighted in section 2.[4]

The third and fourth channels arrive at balanced growth through adjustments in the natural rate of growth. The third channel does this through adjustments in the population growth rate and is associated with the name of Robert Malthus. The fourth channel, in contrast, does this by adjustments in the rate of technical progress and is highlighted by the new theories of endogenous growth.

The new theories of endogenous growth adopt the assumption of a constant ratio of a very broad measure of capital to national income. At least four different views on the relevant concept of capital, i.e. on the engine of endogenous growth, have been put forward in the recent literature on economic growth.

2.2.2 Learning by doing

First, Romer (1986) has revived the work of Arrow (1962) on learning by doing and should get the credit for making theoretical and empirical research into questions of economic growth fashionable again. In many ways one could argue that the new theories of economic growth tackle old and important questions with new tools.

Both Romer and Arrow assume that investment in knowledge by one firm has a positive effect on the production possibilities of other firms, as knowledge cannot be perfectly patented or hidden from other rival firms in the industry or the economy. Consequently, production of consumption and capital goods may display constant or increasing returns to scale with respect to reproducible productive factors, i.e. physical capital and knowledge, at an aggregate level but decreasing returns to scale at a firm level. Due to the absence of an effective patent market, the stock of knowledge is like a public good. As firms do or cannot fully internalise the effect of its investment on the publicly available stock of knowledge and technology, the rate of economic growth is beneath the socially optimal level. This provides a strong reason for government intervention in order to correct for the absence of patent markets. This provides a justification of why many politicians argue for public subsidies for private expenditures on R&D.

[4] The standard Ramsey model achieves balanced growth through adjustments in both the capital-output ratio and the aggregate savings rate. Growth in private consumption occurs when the market rate of interest exceeds the subjective rate of time preference, particularly if the elasticity of intertemporal substitution is high. The aggregate savings rate, however, only increases with the interest rate if the substitution effect dominates the income effects (i.e. if the elasticity of intertemporal substitution exceeds unity).

When an effective patent market does exist, however, there may be a danger of overinvestment in the sense that the growth rate of a decentralised market economy may then be higher than the socially optimal growth rate. The problem may be that firms are engaged in a R&D race in which each of them tries to win a contest in which the price at the end of the race is an infinitely-lived patent (see Beath, Katsoulacos and Ulph (1992) for a survey of these issues). Of course, the required policy response of the government in such a situation is very different from the case in which patent markets are missing.

2.2.3 Intentional accumulation of human capital

The second tack that the literature on endogenous growth has taken is based on Lucas (1988), who has focussed on the intentional accumulation of human capital. Embodied knowledge can be increased by devoting time to learning, but naturally this goes at the expense of time devoted to work or leisure. Human capital can be considered as an asset, so that the financial return on investment in human capital (i.e. training, education, etcetera) must be compared to the return on non-human financial assets. Building on the classic work of Uzawa (1965), Lucas (1988) assumes that the accumulation of human capital is subject to constant (or increasing) returns to scale.

Lucas formulates his model for infinitely-lived households. He also defends the validity of his model if households have finite lives by arguing that the stock of human capital may be transferred from older generations to younger generations. Like Romer and Arrow, Lucas presupposes that the stock of knowledge, i.e. the stock of human capital, has a positive external effect on the production of goods, though this is not a necessary assumption for a sustainable and endogenous rate of economic growth. Hence, knowledge is according to this view very much a public good. A striking example of an external effect is language. It is not much use being able to speak a particular language if the people that you have social and economic relations with do not speak the same language as well. Similar arguments hold for the use of computer software and many other skills.

Again it is easy to argue that in a competitive market economy the public good character of intentional accumulation of knowledge yields a growth rate that is lower than the socially optimal growth rate. This provides a strong rationale for government intervention in the form of publicly provided schooling (particularly at the elementary level) and training. One could also think of government subsidies to private training programmes in order to achieve an efficient growth rate.

2.2.4 Research and development

Third, some authors have put research and development central in their analysis of the engine of economic growth (for example, Romer, 1990, Grossman and Helpman, 1990, 1991, Aghion and Howitt, 1992). The output of R&D may be seen as blueprints for new products or for a better quality of products. The initial investment in R&D is counterbalanced by a subsequent stream of profits, because the producer of a differentiated good has at least temporarily a monopoly arising from, for example, a patent on the blueprint for this newly developed good.

The Schumpeterian idea that innovative activities depend on the expected profitability is clearly reflected in these models. An increase in monopoly power, in other words an increase in the discounted value of future profits arising from (say) a lower price elasticity for the demand for the product that is being sold, typically implies an increase in R&D. This implication is not at odds with the common belief that competition fosters economic growth. It only emphasises that urge for and existence of profits are essential for firms to conduct innovative activity.

Consumers benefit from the production and sale of the invented goods both directly and indirectly. The reason is that, on the one hand, consumers value variety or quality while, on the other hand, productivity depends positively on the variety or on the quality of factors of production (e.g. those bought from the capital goods industry). The growth rate of the economy corresponds to the growth in the number of varieties or in the quality of consumer and capital goods.

Technological spillovers play an important role. In the case of expanding product variety, the productivity of R&D is thought to be positively linked to the pool of public knowledge. An increase in the number of varieties decreases profits per brand, as expenditure is spread (evenly) over all varieties, but the higher number of varieties increases productivity of R&D. As both forces tend to cancel each other, investment in R&D remains profitable. In the case of rising product quality introduction of a product on the market contributes to the stock of knowledge, because the attributes of the products can be studied and effort can be directed to improve upon the state of the art.

2.2.5 Public infrastructure

The fourth direction in which the new theories of endogenous growth have progressed is based on the work of Barro (1990) and Barro and Sala-i-Martin (1992). They have exploited the idea that government investments in both the material infrastructure (think of public highways and railways) and the immaterial infrastructure (think of education, protection of property rights and the like) are essential to economic growth. Effectively, the production function is extended to include government services that raise the productivity of private capital. The idea is that there is constant (or increasing) returns to scale with respect to capital of all the firms in the industry or economy together as well as the spending on public goods. Clearly, an increase in the national income share of public investment goods boosts the rate of economic growth.

However, in as far as the increase in public goods must be financed by distortionary taxes, the after-tax marginal productivity of capital, the rate of interest and the rate of economic growth are diminished. This part of the literature adds some public finance arguments by examining the optimal tax rate and provision of public goods.

2.2.6 Evaluation of various theories of endogenous growth

The recent elaborations of the orthodox neoclassical theory are not mutually exclusive and have many common features. They share the notion that technical progress is not manna from heaven, but is related to economic activity. With the exception of the fourth view the intentional accumulation of knowledge is brought to the fore as the driving force behind economic growth. The deliberate search for new and better products or production techniques, the conscious exploration and exploitation of the economic environment, whether this environment is to an individual scientist nature or to a particular firm a market, rather than the duplication of already existing means, methods and ideas, constitutes the basis of technical progress.

The level of technology cannot increase suddenly and drastically. Technical advancement proceeds gradually, and productivity and augmentation of productivity in the present are conditional on investment (in a broad measure of capital) in the past. The pace of economic growth depends on intertemporal preferences of households, i.e. on the choice between consumption and saving, as is emphasised by the Ramsey (1928) model of economic growth. In the Ramsey model households are thought to choose a consumption path over time. The steepness of this path, i.e. the growth rate of private consumption, depends negatively on the degree of impatience for current consumption and positively on the willingness to substitute current for future consumption and the real rate of return on savings, particularly so if the elasticity of intertemporal substitution is high.

An increase in the real rate of return induces households to save a greater fraction of their income if the substitution effect dominates the income effect. It also induces households to postpone consumption, so that the rate of growth of private consumption is increased. Many authors however think that the decision to save is distorted by the impossibility to collect the yield of investment fully, as ideas cannot be kept secret and the use of ideas cannot be adequately protected by law. The development of the computer program 'Windows' by Microsoft has at least been inspired by the success of Macintosh. However, the external effect of investment may not be confined to investment in R&D or in education.

Obviously, France or the United Kingdom never considered to build the Chunnel on its own. Other examples of an external effect of investment in public infrastructure are the passes in Switzerland that are crucial to the efficient flow of traffic within the European Union. The downward bias in the return on investment causes the rate of private savings to be too low.

The recent neoclassical theories may differ in their characterisation of knowledge. Knowledge can be considered a rival or a non-rival productive factor. A factor can be called non-rival if usage for one purpose does not limit usage for other purposes. Clear examples are dykes, television programs and the principle of the internal combustion engine. Romer (1986, 1990) and Grossman and Helpman (1990, 1991) represent knowledge, especially the contributions of R&D, as a non-rival productive factor. From Lucas (1988), however, derives the notion that knowledge and labour may be intangible. A surgeon can devote his attention to only one patient at the same time.[5] The same distinction applies to publicly provided goods. Barro (1990) argues that few of these goods are not subject to congestion. This argument can be illustrated by many examples, like roads or recreation areas (think of traffic jams or of a coastal resort on a sunny day). It also applies to protection of property rights, as employment in the legal system, for example the number of criminals, is a function of the size of the population.

Non-rival technology implies that production is subject to economies of scale at an aggregate level. Remember that production is at least linearly related to a broad measure of capital, so that a doubling of both the labour force and the stock of capital amount to more than a doubling of production. This outcome often incites the criticism that ongoing accumulation of capital and growth of the population therefore imply that the rate of economic growth accelerates rather than approaches a constant value.

The impeccable logic of this argument can be questioned. First, Romer (1986) implicitly refers to the traditional idea (see for example Hicks, 1949) that an upper boundary on the rate of economic growth may exist. Second, the argument is partial and has to be extended to include an explanation for the population growth; one may wonder whether the decrease in the population growth in the western world is a mere coincidence or can be partially attributed in a Malthusian fashion to the increase in the standard of living (see for the subject of endogenous population growth Barro and Becker, 1989). Besides, Romer (1990) provides rudimentary evidence that the rate of economic growth has risen over the last two centuries.

[5] As usual the distinction may be ambiguous in practice: a book can be read by one person at the same time, but by many persons in time.

2.3 Growth and development: Convergence or divergence?

Differences in growth rates between countries should perhaps have been on Kaldor's list of stylised facts. The orthodox neoclassical theory clearly predicts that the growth rates of different countries should converge in the long run. The crucial assumption for this convergence in growth rates is diminishing marginal productivity of capital. Poor countries with a dilapidated and low level of the capital stock have lots of investment opportunities and face high real interest rates, so that consumers have a strong incentive to postpone consumption and save. This is why neoclassical theory predicts that poor countries have higher growth rates than rich countries on the adjustment path towards the equilibrium growth path. In fact, neoclassical theory also strongly suggests that there is a natural tendency for production per head of different countries to converge, mainly because technology is universally available and applicable.

Neoclassical theory thus has a fairly optimistic view on growth and development. However, the empirical speed of convergence is much slower than the traditional neoclassical theory predicts. This is why Mankiw, Romer and Weil (1992) include human capital as a separate factor of production into a Solow-style growth model. This way they explain the observed too low pace of convergence and rehabilitate the main qualities of the Solow (1956) model. However, their extension of the traditional theory does not consider the possibility of capital mobility.

2.3.1 Saving, investment and the current account

As the marginal productivity of capital in poor countries is thought to exceed that in rich countries, it is efficient for the poor countries to borrow from the rich countries at a large scale. A flow of funds from North to South could increase the speed of convergence of growth rates considerably and would be an excellent policy to raise productivity in the South. The theory suggests that, in the absence of any restrictions on the mobility of capital (for example irreversibility of investment), the speed of convergence should be infinite. Perfect mobility also implies that domestic saving and domestic investment should be uncorrelated. The "golden rule" says that the optimal level of the current account deficit being the net increase in the wealth of a nation should be equal to the level of investment *with a market rate of return.*[6]

However, empirical estimates by Feldstein and Harioka (1980) sharply contradict this prediction. Barro, Mankiw and Sala-i-Martin (1995) claim that in practice the flow of capital is restrained by

[6] Changes in net wealth should also reflect any shortfalls of the current level of production from the permanent level of production minus any discrepancies between the current level of public spending and the permanent level of public spending. See e.g. Sen (1993).

imperfections on the market. In particular, they assume that the collateral value of human capital is negligible in practice and the amount of debt is restricted by the collateral value of physical capital. In the case of capital mobility and an operative restriction on borrowing, the speed of convergence is faster than in the case of capital immobility but nevertheless finite. The process of convergence in a partially open economy resembles that of a closed economy. Still, capital is thought to flow during the process of adjustment from rich countries to poor countries. The particular imperfection of the capital market, unfortunately, restores the link between domestic saving and domestic investment. It yields a partial explanation of the Feldstein-Horioka puzzle, as only some countries encounter restrictions on borrowing.

2.3.2 International spillovers of investment

Theories of economic growth are usually formulated and developed for a closed economy. The predictions from the new theories of growth about convergence and development depend on the translation of these theories to the context of open and interdependent economies. Recent literature suggests that international spillovers of investment may provide besides (perfect) capital mobility a strong reason for convergence of growth rates, although differences in levels of output and of consumption between countries may remain (see for example Grossman and Helpman, 1991, and Alogoskoufis and van der Ploeg, 1994b). Spillovers of technology cause the marginal productivity of a broad measure of capital in a backward area to exceed that in an advanced area, so that the incentive to invest in the former area is higher than in the latter area. What are the territorial boundaries of the spillovers? Are external effects of investment confined to an area like Silicon Valley or are spillovers international? Although the external effects of investment in R&D are more likely to cross borders than those of investment in human capital, this question has to be answered empirically rather than theoretically. Note however that both the older and the newer theories (may) predict convergence between countries, in levels of productivity respectively in rates of growth, so that they are not easy to distinguish empirically.

Grossman and Helpman (1991), Buiter and Kletzer (1991) and Alogoskoufis and van der Ploeg (1990, 1994b) have constructed examples in which growth rates of output differ between countries permanently. Even though international mobility of (physical) capital is perfect, differences can arise in these examples when the production of a tradable commodity requires non-tradeable and reproducible inputs. The results of Buiter and Kletzer and Grossman and Helpman rely on the assumption that international spillovers of knowledge are absent. Buiter and Kletzer focus on the accumulation of human capital. Due to differences in intertemporal preferences of households or, more importantly, in public expenditure on schooling countries grow at disparate rates. Grossman and Helpman show that, under the assumption that invention and production of a variety are intrinsically related, a large country can gain an (absolute) advantage in the research for and the development of new varieties due to economies of scale. It follows that a large country can specialise in the conduct of R&D at the expense of innovative activity in a small country. Alogoskoufis and van der Ploeg model international spillovers of knowledge and find convergence of growth rates, unless the costs of adjustment for investment projects differ between countries. These adjustment cost can, in fact, be considered as a non-tradable input.

The point of international spillovers in the production process is that there are decreasing returns to capital at a national level but constant (or increasing) returns to capital at a global level. This means that there is some scope for convergence, particularly if there is capital mobility and the importance of non-traded factors of production is not too large, while at the same time the growth rate of the global economy is endogenous. More analytical details on these arguments may be found in section 4.

2.3.3 Subsistence, poverty and growth

Examples of lasting differences in growth rates do not necessarily imply that the welfare of households in distinct countries develops differently, for the households may face due to perfect mobility of capital the same possibilities for investing their savings. However, this has the odd implication that developing countries are best helped by an unrestricted access to the global capital market. Note that differences in levels of consumption may be persistent. Rebelo (1992) therefore focuses attention on subsistence levels of private consumption. Consumption in poor countries may then grow at a slower rate than in rich countries, for in poor countries resources are devoted to subsistence consumption needs rather than to savings. In the case of a closed or partially open economy this may temporarily reverse the theoretical predictions. In the traditional story a developing country may have abundant opportunities to invest, so that the incentive to save is high and the growth rate can exceed that in a developed country. However, funds for investment may not abound as in developing countries a large part of income is used to satisfy the basic needs. For this reason the convergence in levels of productivity or in the rates of growth, as is predicted by the traditional respectively recent theory of growth, may be very slow (cf. Kuznets, 1966). In fact, poor countries whose citizens need to devote a large part of their income to subsistence needs may grow at a slower rate than rich countries. This is, of course, in strong contradiction with the orthodox neoclassical theory of economic growth.

2.4 Growth and fiscal policy

The familiar framework of optimizing infinitely-lived agents often yields Ricardian equivalence between public debt issue and taxation (Barro, 1974). However, this equivalence is violated by the birth of new households (see Weil, 1985). The current stock of public debt is in the hands of the existing households, but will in the future be serviced in part by yet non-existing households. If the former households do not value the consumption of the latter, a fraction of the public debt is net wealth to the existing households. This section will show that as a consequence public debt and government spending may crowd out private investment and depress economic growth. It builds on work by Alogoskoufis and van der Ploeg (1991, 1994a, 1994b).

The analysis distinguishes two countries that produce a homogenous, perfectly substitutable goods and impose no restrictions on trade. Also, domestic and foreign assets are perfect substitutes and the flow of capital between the countries is unrestricted. The countries are identical with respect to the technology of production, intertemporal preferences of the households and demographic structure, but may differ in the stock of public debt and in government spending. Firms produce under perfect competition and face constant returns to scale, but benefit from both domestic and international spillovers of knowledge and from public investment. Governments spend on two types of public goods, *viz.* (pure Samuelson-style) public consumption goods and growth-promoting public infrastructure (training, R&D, etc.), levy lump-sum taxes and issue debt. Households do not have an intergenerational bequest motive. Entry (i.e. birth) of new households occurs at the rate β and households face a constant instantaneous probability of death λ, so that the growth rate of population amounts to $n \equiv \beta - \lambda$. Hence, attention is focussed on a world with two main types of externality: (i) production externalities arising from spillovers in production; and (ii) consumption externalities because the currently alive cannot trade with generations that will be born in the future. This section investigates the analytical implications of endogenous growth and overlapping generations for the international economy.

2.4.1 *An overlapping generations model for two countries.*

Expected utility of a household born at time v and living at time t can be written as

$$U(v,t) = \int_t^\infty u(c(v,s))\, e^{-(\rho+\lambda)(s-t)}\, ds, \tag{2.1}$$

where the effective discount rate equals the sum of the subjective rate of time preference (ρ) and the probability of death (λ), u represents instantaneous utility and c denotes private consumption. Instantaneous utility is an iso-elastic function of consumption

$$u(c(v,t)) = \frac{c(v,t)^{1-\frac{1}{\sigma}}}{1-\frac{1}{\sigma}}, \quad \sigma > 0, \sigma \neq 1, \tag{2.2}$$
$$= \ln c(v,t), \quad \sigma = 1,$$

where σ represents the intertemporal elasticity of substitution. The household maximizes expected utility subject to the budget constraint

$$\frac{da(v,t)}{dt} = [r(t)+\lambda]a(v,t) + w(v,t) - \tau(v,t) - c(v,t), \tag{2.3}$$

where a, w and τ denote non-human assets, gross wage income and lump-sum taxes. Households leave their estate contingent on their death to insurance companies, but receive premiums (λa) during their lifetime from these companies. Under the assumption of free entry and perfect competition the payments by and the receipts of the insurance companies exactly match, so that the insurance premium is actuarially fair and no profits are made. Private consumption amounts to a fraction of the sum of non-human and human wealth:

$$c(v,t) = \varphi(t)\ (a(v,t) + h(v,t)), \tag{2.4}$$

where φ is the marginal propensity to consume out of wealth,

$$\varphi(t) \equiv \left\{ \int_t^\infty e^{-\int_t^s [(1-\sigma)r(u)+\sigma\rho+\lambda]du} ds \right\}^{-1}, \tag{2.5}$$

and human wealth (h) is the present discounted value of future wage income minus taxes,

$$h(v,t) \equiv \int_t^\infty e^{-\int_t^s [r(u)+\lambda]du} [w(v,s) - \tau(v,s)]\ ds. \tag{2.6}$$

The marginal propensity to consume is also determined by the future path of the real interest rate. The effect of the real interest on spending depends on the magnitude of the intertemporal elasticity of substitution. If $\sigma > 1$ the substitution effect dominates and spending is negatively related to the interest rate, because the main effect of a higher interest rate is a reduction in the price of future goods which induces substitution away from current to future goods. However, if $\sigma < 1$ the income effect dominates and spending is positively related to the interest rate, so that the main effect of a higher interest rate is a higher level of real income which induces more consumption of both current and future goods. If the intertemporal elasticity of substitution equals unity, the substitution and income effect exactly cancel and the marginal propensity is constant and equals the effective discount rate, i.e. the sum of the subjective rate of time preference and the instantaneous probability of death ($\rho+\lambda$). Both wage income and taxes are assumed to independent of age, so that differences in human wealth between households vanish.

The cohort of households born at time v is at time t only a fraction of the initial size, $\beta L(v)\exp[-\lambda(t-v)]$, where $L(v) = \exp(nv)$ denotes the size of the population at time v. This can be used to aggregate variables. Given that newly born households do not inherit non-human wealth (i.e. there is an absence of an intergenerational bequest motive), differential equations for total private consumption, total private non-human wealth and the marginal propensity to consume can be obtained (cf. Blanchard and Fischer, 1989, Chapter 3):

$$\dot{C}(t) = [\sigma(r(t)-\rho)+n]\,C(t) - \beta\varphi(t)A(t), \tag{2.7}$$

$$\dot{A}(t) = r(t)A(t) + W(t) - \mathrm{T}(t) - C(t), \tag{2.8}$$

$$\dot{\varphi}(t) = [(1-\sigma)r(t)+\sigma\rho+\lambda]^{-1}\varphi(t) - 1. \tag{2.9}$$

The government finances its consumption (G) and the interest payments on debt (D) by lump-sum taxation (T) and/or the issue of debt:

$$\dot{D}(t) = r(t)D(t) + G(t) - T(t). \tag{2.10}$$

Solvency of the government requires that sum of the current stock of debt and the present value of future consumption does not exceed the present value of future taxes,

$$D(t) + \int_t^{\infty} e^{-\int_t^s r(u)du}\, G(s)\, ds \le \int_t^{\infty} e^{-\int_t^s r(u)du}\, T(s)\, ds. \tag{2.11}$$

The world consists of two countries. As domestic and foreign goods and assets are perfect substitutes and the flow of goods and of assets are unrestricted, the agents in both countries face the same price on the product market and the same real interest rate. The accumulation of external assets (F) can be deduced from the current account. The accounting identity for an open economy says that the current account matches national income (Y), which is in this case the sum of production and interest payments on external debt or receipts from external assets, minus domestic absorption:

$$\dot{F}(t) = r(t)F(t) + Y(t) - C(t) - I(t) - G(t), \text{ where } I(t) = \dot{K}(t) + \delta K(t). \tag{2.12}$$

The trade balance is the excess of domestic production over domestic absorption (Y-C-I-G). Equilibrium on the world goods markets requires that, given that we assume that the law of one price holds throughout the world, total demand for goods by households, firms and governments in the two countries must equal total supply of goods by the two countries.

2.4.2 Domestic and international spillovers in production

The model combines the orthodox theories of economic growth with the new theories of endogenous growth by assuming decreasing returns to capital at the national level but constant returns to a broad measure of capital at the global level.

Firms are identical and operate in perfectly competitive goods and factor markets. They produce according to the production function $P(K,ML)$, which displays constant returns to scale with respect to the use of capital (K) and labour (ML), where the latter is measured in units of efficiency. The efficiency of labour, M, depends on the capital stock in the two countries as well as on domestic public infrastructure. The labour market is assumed to clear at any instant and the labour supply is exogenous (and assumed to equal unity for an individual household).

Technology of firm j at time t is given by:

$$y(j,t) = P(k(j,t), m(t)l(j,t)) \quad \text{with} \quad m(t) = \frac{M(K(t),K^*(t),S(t))}{L(t))} \tag{2.13}$$

where y, l, S, K^* and m denote output, employment, public infrastructure, foreign capital and the efficiency of labour, respectively. The economy-wide efficiency of labour (m) increases when the capital (think of R&D, ideas, etc.) of other firms in the domestic economy or abroad increases and when expenditures on public infrastructure increases. The former two effects capture external effects of the type stressed by Arrow (1962) and Romer (1986), whereas the latter effect has been stressed by Barro (1990). Note that the productivity of labour depends on a rival good. The novel feature is that this production function integrates the old and the new theories of growth by allowing for decreasing returns to private capital at the national and *a fortiori* at the firm level ($\eta_1<\eta_1+\eta_2<1$) but constant returns to capital and public infrastructure at the global level. The production function $P(.)$ is assumed to display constant returns to scale and to have a Cobb-Douglas specification:

$$y(j,t) = \theta k(j,t)^{\eta_1} l(j,t)^{1-\eta_1}\left[\frac{K(t)^{\eta_2} K^*(t)^{\eta_3} S(t)^{1-\eta_1-\eta_2-\eta_3}}{L(t)^{1-\eta_1}}\right], \quad \theta,\eta_1,\eta_2,\eta_3 \geq 0, \quad \eta_1+\eta_2+\eta_3<1, \tag{2.14}$$

where θ denotes the efficiency of production.

Under the assumption of perfect capital mobility the dynamic optimization problem of the firm collapses into a static one. Maximization of the present discounted value of the firm demands that the marginal productivity of capital equals the user cost of capital, i.e the sum of the interest rate and the depreciation rate δ, and that the marginal productivity of labour equals the wage. In symmetric equilibrium, we obtain:

$$r(t)+\delta = \eta_1\left[\frac{y(j,t)}{k(j,t)}\right] = \eta_1\theta\left[\frac{K^*(t)}{K(t)}\right]^{\eta_3}\left[\frac{S(t)}{K(t)}\right]^{1-\eta-\eta_3}, \quad \eta \equiv \eta_1+\eta_2 . \tag{2.15}$$

There is a global capital market. Arbitrage ensures that interest rates are equalized throughout the world ($r=r^*$). Foreign variables are denoted with an asterisk. It follows that the equilibrium world interest rate and relative capital stock can be rewritten as:

$$r = r^* = \eta_1\sqrt{\theta\theta^*[(S/K)(S^*/K^*)]^{1-\eta-\eta_3}}-\delta, \quad K/K^* = \left[\left(\frac{\theta}{\theta^*}\right)\left(\frac{S/K}{S^*/K^*}\right)^{1-\eta-\eta_3}\right]^{\frac{1}{2\eta_3}} . \tag{2.16}$$

The global interest rate increases with the geometric average of the domestic and foreign efficiency of production, and both the home and foreign intensity of public infrastructure. Countries with a higher efficiency of production and a higher intensity of public infrastructure end up with more private capital than other countries. Note that aggregate non-asset income corresponds to the return on domestic and foreign spillovers in production and the return on public infrastructure, all of which individual firms do not have to pay a price for, i.e. $W=(1-\eta 1)Y$ which corresponds to the wage bill when firms set the marginal productivity of labour equal to the wage. Aggregate home and foreign production can be written as:

$$Y = \theta K^{\eta} K^{*\eta_3} S^{1-\eta-\eta_3} = \Theta K, \quad Y^* = \Theta K^*, \quad \Theta \equiv \sqrt{\theta\theta^*[(S/K)(S^*/K^*)]^{1-\eta-\eta_3}} . \tag{2.17}$$

Note that the existence of a global capital market ensures that all countries have the same output-capital ratio and that this ratio increases when efficiency of production or public infrastructure at home or abroad increases. Hence, there is international convergence of growth rates of both output and capital:

$$\gamma \equiv \frac{\dot{K}}{K} = \frac{\dot{Y}}{Y} = \gamma^*, \quad \pi \equiv \gamma - n, \; \pi^* \equiv \gamma - n^* \; . \tag{2.18}$$

Of course, there is no international convergence in levels of income per capita. Poor countries (low θ, low S/K) have a lower output and capital stock than rich countries. Clearly, countries with a fast-growing population must tolerate a lower growth in income per head (π) than other countries.

2.4.3 Loose budgetary policy stances destroy global growth prospects

The evolution of private consumption, public debt and foreign assets are still described by equations (2.7), (2.10) and (2.12). A glance at equations (2.9) and (2.16) reveals that the marginal propensity to consume out of wealth is constant as the ratio of public investment to the capital stock in the two countries is assumed to be constant at any point of time. In the following the variables will be scaled by private capital.

Since the external assets of one country are matched by the external liabilities of the other country and we assume that the structures of the home and foreign country are symmetric, the global and relative effects of budgetary policy can be analysed separately. If one denotes global averages of variables with the subscript A (e.g. $CA \equiv \frac{1}{2}[(C/K) + (C^*/K^*)]$), the world economy can be described by:

$$\dot{C}_A = [\sigma(r-\rho) + n - \gamma]C_A - \beta[\sigma\rho + (1-\sigma)r + \lambda](1 + D_A) \tag{2.19}$$

$$\dot{D}_A = (r-\gamma)D_A + G_A + S_A - T_A \tag{2.20}$$

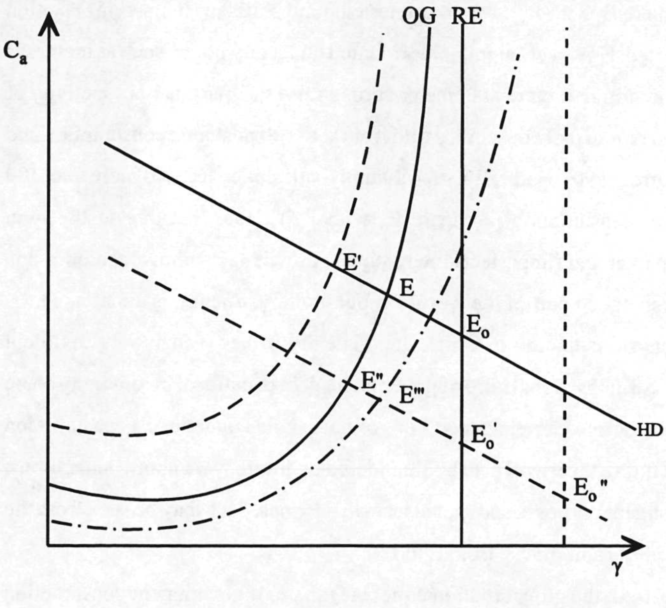
where the global interest rate and the growth rate are given by

$$r = \eta_1\Theta - \delta, \quad \gamma = (\Theta - C_A - G_A - S_A) - \delta \; . \tag{2.21}$$

The expression for the global growth rate is no less than the Harrod-Domar condition for balanced growth in the world economy, that is the net growth rate (γ-δ) equals the propensity to save (i.e. one minus the sum of private and public propensities to consume) divided by the capital-output ratio. It thus defines a negative relationship between the global private consumption (C_A) and the global growth rate, namely the HD-locus in Figure 2.1. The HD-locus shifts down when government consumption is increased. Public infrastructure also crowds out private savings and investment and reduces growth prospects, but at the same time it raises the productivity of private capital and boosts growth prospects.

The equation for the evolution of private consumption will be called the Overlapping Generations locus. When there is no entry of new generations (β=0), the OG-locus reduces to the Ricardian Equivalence locus. The RE-locus is vertical, since it defines the global growth rate as the modified golden rule ($\gamma = \sigma(r - \rho) + n$). This RE growth rate is the growth rate stressed by Romer (1986) and others. It increases when the efficiency of production at home or abroad increases, when public infrastructure at home or abroad increases, when the extent of domestic and international spillovers in production is large, and when households become more patient. These effects are large when the elasticity of intertemporal substitution is big. The RE growth rate does not depend on non-productive budgetary policy stances or intertemporal shifts in taxation, which is a logical consequence of debt neutrality.

Figure 2.1 *Overlapping generations and endogenous growth*



The RE growth rate provides an upper bound on the growth rate of a world with consumption externalities (β>0), that is the RE-locus is an asymptote of the OG-locus. This is not surprising, because the fact that households are finitely lived and know that they can shift the burden of future taxes to yet unborn generations makes them consume more and save less so that less funds are available for investment purposes and growth prospects decline. The OG-locus slopes upwards, because a higher growth rate of private consumption means that households save a lot of assets so that in equilibrium households can afford to consume more.

Global equilibrium is at the intersection of the HD- and OG-locus. As long as the ratio's of government debt to national income are constant, there is no transitional dynamics. Both private consumption and the growth rate immediately jump to their new equilibrium values. The OG-HD equilibrium induces a lower growth rate and higher national income share of private consumption than the RE-HD equilibrium (compare E with E_0). Since new generations of households share the burden of servicing the government debt, current generations consume more and save less than in a world with infinite horizons and intergenerational bequest motives. As a result, less funds are available for investment and growth is less. Hence, global growth is less than in a first-best outcome on account of both consumption externalities (β>0) and of domestic and foreign spillovers in production (η_1<1).

In a world characterized by Ricardian debt neutrality (β=0) pure demand-side oriented budgetary policy cannot affect global growth. Increases in government consumption lead to 100 per cent crowding out of private consumption (compare E_0 with E_0'), whereas intertemporal shifts in (lump-sum) taxation leave private consumption unaffected. However, supply-side oriented budgetary policy such as increases in national income shares of public infrastructure at home or abroad raise the marginal productivity of private capital and thus the interest rate so that households find it attractive to postpone consumption and growth prospects improve (cf., Barro, 1990). Naturally, such a supply-side policy leads to more than 100 per cent crowding out of private consumption (compare E_0 with E_0''). Note that due to the twin assumptions of a global capital market and (imperfect) international knowledge spillovers, it does not matter for the global growth rate in which part of the world the public infrastructure is undertaken.

Now consider a more realistic situation in which there is entry of new generations and debt neutrality does not hold (β>0). A rise in the global ratio of government debt to national income may come about through a postponement of taxation. Current generations of households undertake a consumption bonanza, because they know that future taxes will also be shouldered by future, yet unborn generations. Less funds are available for investment purposes and global growth declines. This may be seen from the upward shift of the OG-locus (equilibrium moves from E to E').

A balanced-budget increase in the global (national income) share of government consumption (G_A) crowds out private consumption on account of the higher taxes that are required to finance government spending. Since part of the burden of higher taxes in the future is born by future generations, crowding out is less than 100 per cent. On balance global savings and investment decline so that the global growth rate falls. The above is confirmed by the inward shift of the HD-locus (equilibrium moves from E to E'').

Clearly, a looser (demand-side oriented) budgetary policy, irrespective of whether it occurs at home or abroad, destroys growth prospects throughout the world. An expansion of supply-side budgetary policies such as public infrastructure has two effects. On the one hand, it suffers from the usual crowding out of private consumption and fall in growth that is associated with any increase in government expenditures. On the other hand, it raises the marginal productivity of private capital and boosts global growth. In addition to the inward shift of the HD-locus, there is an outward shift of the OG-locus so that the equilibrium moves from E to E'''. Although it is clear that the national income shares of private consumption must fall, it is not possible to say *a priori* whether the global growth rate will decrease or increase.

2.4.4 External debt and government debt

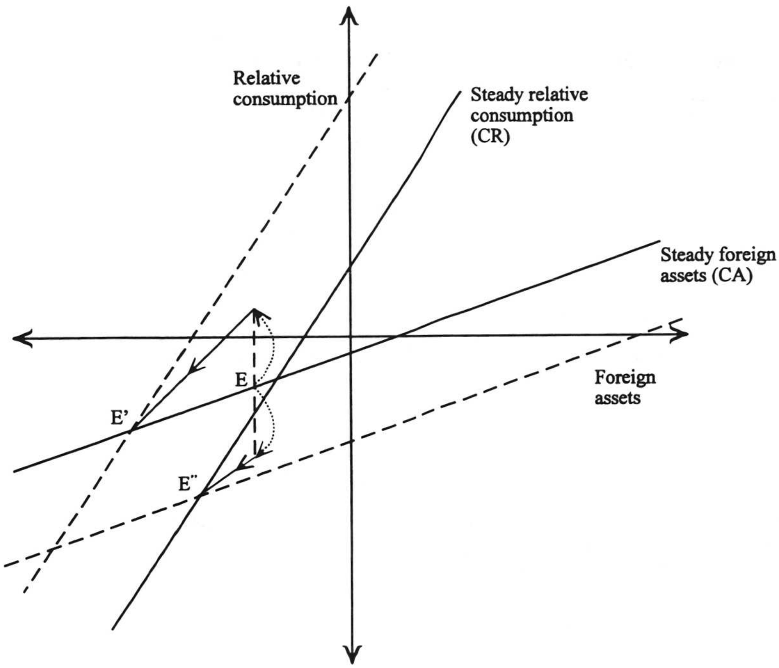
To complete the solution of the world model, it is necessary to analyse the global differences which will be denoted by the subscript R (e.g. $CR \equiv (C/K) - (C^*/K^*)$):

$$\dot{C}_R = [\sigma(r-\rho) + n - \gamma]C_R - \beta[\sigma\rho + (1-\sigma)r + \lambda](D_R + F_R) \tag{2.22}$$

$$\dot{F}_R = (r-\gamma)F_R - C_R - G_R - S_R \tag{2.23}$$

where r and γ have already been determined by the global averages. Assume that the world interest rate exceeds the world growth rate ($r > \gamma$) and that the home country has a higher national income share government spending than the foreign country ($G_R + S_R > 0$). It follows that the locus describing equilibrium on the current account (the CA-locus) slopes upwards and has a negative intercept with the vertical axis in Figure 2.2. The locus describing common growth rates in the national income shares of private consumption (the CR-locus) slopes upwards, as $\gamma - n < \sigma(r-\rho)$. Assume the saddle-path condition is satisfied.

Figure 2.2 *Budget deficits and foreign debt*



An instantaneous increase in the ratio of government debt to national income at home relative to that ratio abroad (higher D_R) shifts the CR-locus to the left. The new equilibrium E' is associated with an decrease in private consumption at home relative to abroad and an accumulation of foreign debt by the home country. On impact relative private consumption misadjusts, i.e. rises on account of the postponement of taxation at home. Along the adjustment path the home country experiences deficits on the current account and builds up foreign debt. In the long run the home country must generate a trade surplus in order to generate sufficient income to service the accumulated foreign debt. The long-run result of an increase in relative government debt must thus be a fall in relative private consumption. The short-run pattern corresponds somewhat to the experience of the US in the early eighties, whereas part of the long-run pattern may be occurring in the early nineties.

An increase in the national income share of government consumption of the home country shifts the CA-locus to the right and changes the long-run equilibrium from E to E''. The initial fall in relative consumption undershoots, so the home country builds up a foreign debt along the adjustment path. Over time the burden of servicing the foreign debt increases, so relative private consumption falls over time.

Hence, if one country goes for a postponement of taxation, it boosts private consumption in the short run but worsens growth prospects for all other countries in the world, leads to an accumulation of foreign debt and reduces private consumption in the long run. If one country goes for an increase in government consumption, it must tolerate a build-up of foreign debt and ongoing falls in private consumption and at the same it reduces global interest and growth rates.

2.4.5 Budgetary policies, interest rates and adjustment costs for investment

An unsatisfactory feature of the analysis so far is that the global interest rate depends on technological parameters and supply-side oriented policies such as expenditures on public infrastructure, R&D, etc. but not on demand-side oriented government policies. One would expect the global interest rate to rise when budgetary policies throughout the world become looser. Such an extension may also help to explain an empirical puzzle. The analysis so far predicts a positive correlation between interest rates and growth rates. The source of this correlation is a variety of technology shocks, because it is reasonable to suppose that these shocks dominate preference shocks (in particular shocks in the subjective rate of time preference). Empirically it is hard to detect such a positive correlation, hence the puzzle. These are two good reasons why the analysis must be extended to also allow for an effect of demand-side policies on interest rates. A straightforward way to do this is to allow for adjustments costs for private investment.

Firm j maximizes the present value of future profits:

$$\int_t^{\infty} \left(y(j,v) - w(v)\, l(j,v) - \left[1 + \psi\left(\frac{i(j,v)}{k(j,v)} \right) \right] i(j,v) \right) \exp\left[- \int_t^{v} r(u)du \right] dv \tag{2.24}$$

where i denotes gross investment and ψ stands for the adjustment cost parameter. It follows that the marginal productivity of capital plus the marginal reduction in adjustment costs arising from an additional unit of capital must equal the user cost of capital and that the investment rate increases when the value of the firm (q) rises. Ignoring the effects of public infrastructure ($\eta_1 + \eta_2 + \eta_3 = 1$, $S = S^* = 0$), aggregation across firms of these optimality conditions yields:

$$q = 1 + 2\psi \frac{I}{K}, \quad \eta_1 \theta \left(\frac{K}{K^*} \right)^{\eta - 1} - \psi \left(\frac{I}{K} \right)^2 = \left(r + \delta - \frac{\dot{q}}{q} \right) q \,. \tag{2.25}$$

Perfect capital mobility throughout the world then yields in steady state the global interest rate:

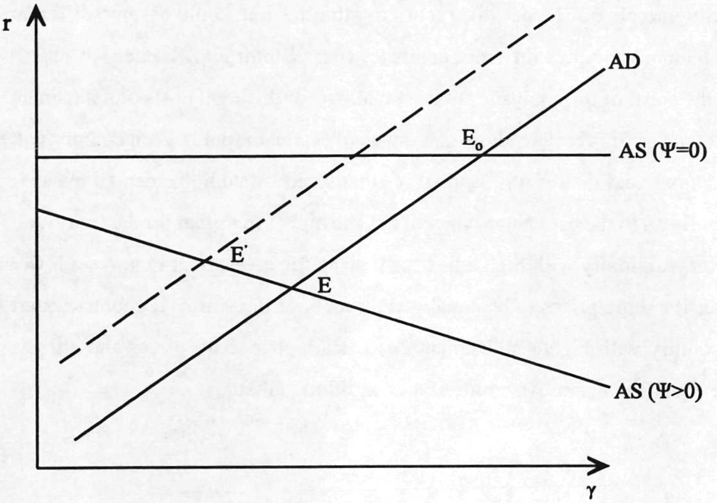
$$r = \frac{\dot{q}}{q} - \delta + \left(\frac{\eta_1 \Theta - [q-1]^2/4\psi}{q} \right), \quad q - 1 = 2\psi(\gamma + \delta) \ . \tag{2.26}$$

Since the value of the firm is the discounted value of future profits, there is a negative relation between the interest rate (r) and the value of the stock market (q). Since a high value of Tobin's "Q" induces a high investment rate and $I/K = \gamma + \delta$, it is clear that the production side of the economy defines a negative relationship between the interest rate and the growth or (net) investment rate. This asset market equilibrium and aggregate supply relationship is represented by the AS-locus in Figure 2.3. The AS-locus slopes downwards and lies entirely below the real interest rate that would prevail if there are no adjustment costs for investment, *viz.* $r = \eta_1 \Theta - \delta$. The steady-state global consumption function and the Harrod-Domar condition yield the following aggregate demand relationship between growth and interest rates:

$$\gamma = \sigma(r - \rho) + n - \left(\frac{\beta[\sigma\rho + (1-\sigma)r + \lambda](1 + D_A)}{\Theta - G_A - \delta - \gamma} \right) \tag{2.27}$$

which is represented by the AD-locus in Figure 2.3. The AD-locus slopes upwards, as long as $(\rho + \lambda)/(\gamma - n) > 1 - 1/\sigma$ holds which will definitely be the case if the intertemporal substitution effect is at least as big as the income effect (σ>1). In that case, an increase in the global interest rate induces a smaller propensity to consume out of wealth so that households save more and the world economy can grow at a higher rate.

Figure 2.3 *Real interest rates and growth rates*



Global equilibrium occurs at the intersection of the AD- and AS-curves. Clearly, adjustment costs for investment lead, independent of whether debt neutrality holds or not, to a lower global interest rate and lower global growth (compare E with E_o). In general, looser budgetary policies, *viz.* a postponement of taxes that induces a rise in the global ratio of debt to national income or an increase in government consumption, cause a rise in global interest rates, a fall in share prices throughout the world and a reduction in global growth. Those countries that are responsible for the laxer budgetary policies build up foreign debt and eventually have to pay for their effervescent fiscal policies with lower *levels* as well as lower *growth* of private consumption. The other countries build up foreign assets and enjoy higher *levels* of consumption, but have to suffer a lower growth rate.

The extension explains the empirical puzzle mentioned above as long as one allows for departures from Ricardian debt neutrality. If debt neutrality holds, only technical shocks induce shifts in interest rates and growth rates. This results in a positive correlation between interest rates and growth rates. To obtain a negative correlation between interest rates and growth rates, it is necessary to depart from debt neutrality. In that case, changes in budgetary policies induce shifts in the AD-curve and a negative correlation between interest and growth rates. If shocks to budgetary policies are of the same order of magnitude as technical shocks, one observes no correlation between interest and growth rates.

2.4.6 Divergence in growth rates

So far, the assumption of a global capital market ensures that the growth rates of various countries must be the same. This is obviously unrealistic. To get divergent growth rates one could assume different intensities of investment in human capital in different countries (e.g., Buiter and Kletzer,1991). An alternative that stays within the spirit of the analysis so far is to allow for different costs of adjustment of investment for different countries. It is easy to show that, in steady state, output in each country will be proportional to its capital stock and that, if $\theta>\theta^*$ and $\psi>\psi^*$, that steady-state home capital exceeds foreign capital, $K>K^*$. Capital flows to the country in which it has the higher marginal productivity, and costs of adjustment are higher. A country with high adjustment costs for investment requires a lower gross investment rate in order for share prices to be equalized throughout the world. If countries start with the same capital, the country with higher adjustment costs has higher share prices and attracts capital until share prices are equalized again. An equilibrium condition is that

$$\psi(\gamma+\delta) = \psi^*(\gamma^*+\delta^*) \tag{2.28}$$

holds. The country, with other things equal, that faces higher adjustment costs for investment or a higher depreciation rate of its capital, will end up with a lower growth rate than other countries.

2.5 Research and development: An engine of growth

An important engine of economic growth is the intentional accumulation of knowledge by the research for and development of new or better products (for example, Romer, 1990, Grossman and Helpman, 1991, Aghion and Howitt, 1992). The following presents a theory, along the lines of Grossman and Helpman (1991), in which R&D involves a continuous expansion of product variety. It is based on the ideas surveyed in previous sections.

2.5.1 A model of expanding product variety

The economy consists of two sectors: (i) a monopolistic competitive sector which produces differentiated final goods; (ii) a competitive sector which conducts R&D. Labour is the only primary factor of production. Both labour and financial capital are perfectly mobile across sectors. All households are identical. Consumption and savings decisions follow from the life-cycle hypothesis. The preferences of the infinitely-lived representative household may be written as:

$$U(t) = \int_t^{\infty} \left(\frac{C(v)^{1-\frac{1}{\sigma}}}{1-\frac{1}{\sigma}} \right) \exp[-\rho(v-t)]\,dv \tag{2.29}$$

where ρ is the subjective rate of time preference, σ denotes the elasticity of intertemporal substitution, and C represents an index of private consumption. The representative household has a love for diversity, so the index not only depends on the consumed amount of each variety (x_j) but also on the number of varieties (N):

$$C \equiv \left[\int_0^N x_j^{\eta}\,dj \right]^{\frac{1}{\eta}}, \quad 0<\eta<1 \ . \tag{2.30}$$

For convenience, the range of available varieties is assumed to be continuous and the integer constraint is not considered.[7] Maximization of utility subject to the household budget constraint yields the Keynes-Ramsey rule:

$$\frac{\dot{C}}{C} = \sigma \left(R - \frac{\dot{P}_C}{P_C} - \rho \right) = \sigma\ (r-\rho), \quad r \equiv R - \frac{\dot{P}_C}{P_C} \tag{2.31}$$

where R is the producer (nominal) interest rate and P_C is the ideal index for the price of consumption, such that the product of the indices for this price and for private consumption equals household expenditure (E). The ideal price index is given by:

$$P_C = \left[\int_0^N p_j^{\frac{\eta}{\eta-1}}\ dj \right]^{\frac{\eta-1}{\eta}} \ . \tag{2.32}$$

The representative household postpones consumption and thus saves when the consumer (real) interest rate (r) exceeds the rate of time preference (ρ), and particularly if the elasticity of intertemporal substitution is high (σ). The household spends a fraction of its expenditure on each available variety:

[7] This formulation has also been used in other models of growth as (part of) a production function. The interpretation is naturally different, because then a variety represents an intermediate input (Grossman and Helpman, 1991) or a capital good (Romer, 1990). An increased number of varieties entails an increased factor productivity due to a higher degree of specialization in production.

$$x_i = \left(\frac{p_i^{-\varepsilon}}{\int_0^N p_j^{1-\varepsilon}\, dj} \right) E, \quad \varepsilon \equiv \frac{1}{1-\eta}, \tag{2.33}$$

where ε is the elasticity of substitution between any pair of varieties.

Each variety is produced by a single firm. The monopolistic power of firms is derived from infinitely-lived patents.[8] A firm buys a patent from the R&D sector on a free market. This set-up cost is financed by the issue of equity shares. Production of each firm displays constant returns to scale with respect to the use of labour. Each firm maximizes profits subject to the perceived demand function for its products, given total household expenditure, the prices set by other firms and the wage. As all firms are identical and face the same conditions, firms charge the same price (p) and supply the same amount (x). The price charged to consumers will be a constant mark-up over the wage, and profits (π) are a fraction of total revenue:

$$p = \left(\frac{1}{1-\frac{1}{\varepsilon}} \right) w = \frac{1}{\eta} w, \quad \pi = (1-\eta)\frac{E}{N} = \frac{1}{\varepsilon}\frac{E}{N}. \tag{2.34}$$

Dividends fully exhaust profits of firms. The return on equity consists of these dividends and the expected change in its stock market value. Arbitrage ensures that the rate of return on equity coincides with the producer interest rate:

$$\frac{\pi}{P_N} + \frac{\dot{P}_N}{P_N} = R. \tag{2.35}$$

In a perfect-foresight equilibrium that excludes speculative bubbles in asset prices, the stock market value of a typical firm in the final goods sector (P_N) matches the present discounted value of future profits. As the output of the R&D-sector is blueprints for new products and patents are infinitely-lived, the share price of such a firm also equals the price of a patented blueprint.

A representative firm in the R&D-sector can "add incrementally to the set of available products by devoting a given finite amount of labour to R&D for a brief interval of time", so the number of

[8] Grossman and Helpman also try to underpin the assumption of single firm by Bertrand competition between an innovator and an imitator when imitation is costly and both products are perfect substitutes. However, if imitation is not too costly, Bertrand price setting may not be credible.

varieties cannot be increased instantaneously (Grossman and Helpman (1991, page 51). The productivity in the R&D sector depends on the freely accessible economy-wide accumulated stock of knowledge as represented by the number of available varieties. Ideas and information that are contained in new products are instantaneously and freely available to current R&D. As a consequence, output of R&D is only partly appropriable. Knowledge in this form is a non-rival input and its accumulation is given by:

$$\dot{N} = ANL_N \tag{2.36}$$

where L_N denotes labour employed by the R&D sector. Profit maximization implies, if demand for labour is positive but bounded, that productivity of labour employed in the R&D sector must equal the relevant producer wage for that sector:

$$P_N AN = w \; . \tag{2.37}$$

The supply of labour by the households (L) is given. Labour can be used either for R&D (L_N) or for the production of differentiated goods. As the firms in the monopolistic competitive sector are alike, the equilibrium condition for the labour market can be written as:

$$L = \frac{1}{A}\frac{\dot{N}}{N} + \frac{E}{p} \tag{2.38}$$

where, for simplicity, the labour coefficient for the final goods industry is normalized to unity. To pinpoint nominal magnitudes of variables private expenditure - rather than a price - is normalized to unity, that is E=1 and thus C=1/P_C. For a detailed derivation of the solution, the reader is referred to Grossman and Helpman (1991).

There are no transitional dynamics, so the economy immediately jumps to a balanced growth path. Along this path the division of labour over both sectors remains constant, so that the number of product varieties expands at the rate γ_N. The balanced growth path is furthermore characterized - due to the chosen normalization - by a constant value for the price of a typical variety, the wage and the price of a share on the stock market. However, the effective price of private consumption decreases, and thus the index of private consumption increases at a constant rate.

From the equilibrium conditions for the capital market and for the labour market and from the first-order conditions for profit maximization, a negative relationship between the growth rate and the consumer (real) interest rate (r) can derived. A change in the latter directly affects the present discounted value of future profits, and therefore the allocation of labour over the R&D and final goods sector. For the same reason, the rate of innovation depends on the elasticity of substitution between consumer varieties. More monopoly power entails higher profits, and boosts R&D at the expense of the production in the final goods sector. Given the interest rate, the size of the labour force influences positively the level of activity in both sectors. The growth in the number of varieties can thus be written as:

$$\gamma_N = \left(\frac{1-\eta}{\eta}\right) AL - r = \left(\frac{1}{\varepsilon - 1}\right) AL - r \,. \tag{2.39}$$

The intertemporal preferences of the household can be summarized by the Keynes-Ramsey rule, which dictates a positive relationship between the rate of innovation and the real interest rate. If the household is more willing to substitute current consumption for future consumption (an increase in σ) or becomes more patient (a decrease in ρ), the desired growth rate in private consumption rises given the interest rate:

$$\gamma_N = \sigma(r-\rho)\left(\frac{\eta}{1-\eta}\right) \,. \tag{2.40}$$

It follows that the equilibrium growth rate in the number of varieties is:

$$\gamma_N = \frac{\sigma}{1+\sigma\frac{\eta}{1-\eta}}\left(AL - \frac{\eta}{1-\eta}\rho\right) \,. \tag{2.41}$$

The growth rate of consumption (γ_C) is a constant fraction of the innovation rate:

$$\gamma_C = \left(\frac{1-\eta}{\eta}\right)\gamma_N = \left(\frac{1}{\varepsilon - 1}\right)\gamma_N \,. \tag{2.42}$$

Hence, the equilibrium rate of innovation rises with the efficiency of labour in the R&D sector (A), the size of the labour force (L) and the degree of monopoly power ($1/\eta$), and the innovation rate declines with the degree of impatience (ρ). These effects on growth are amplified when the elasticity of intertemporal substitution rises. Note that a growing population leads in this simple model to an ever-increasing growth rate of the economy.

2.5.2 R&D subsidies

A remarkable feature of the recent literature on economic growth is the overwhelming support for the idea that investment has positive external effects on production possibilities. The return on investment cannot be fully reaped and the intertemporal choices by households are biased in favour of consumption and at the expense of savings. The assumption of an external effect implies an active role of the government. It may take measures to improve upon the intertemporal allocation of resources, because the outcome of decentralised decisions by the various private agents are not optimal. At a general level of thought an external effect stems from an inadequate definition and protection of property rights. Examples abound in which uncertainty about property rights has inhibited investment. One can think of the unsettled claims on land and buildings in former Eastern Germany or of the political instability in South America.[9] Clearly, a system of patents may be essential to protect the research for and development of new or better products and production methods against 'cheap' imitation. After all, firms are only willing to conduct R&D if at least temporarily profits can be earned.

In practice, the cost of defining and protecting property rights are sometimes prohibitive, and the government must resort to other instrument to bring about an efficient allocation of resources. In the current model the government could rely on R&D subsidies to raise the innovation rate and attain the optimal rate, γ_N^g:

$$\gamma_N^g = \sigma\left(AL - \frac{\eta}{1-\eta}\rho\right). \tag{2.43}$$

The optimal rate is clearly higher than the innovation rate in (2.41) that is achieved by decentralised decision-making.

2.5.3 International trade and R&D

Trade and economic integration can clearly affect the dynamic performance of economies. Though the nature of the advantages or disadvantages may be static, changes in efficiency affect the decision to save and invest. As Baldwin (1989) points out, the commotion about Europe 1992 cannot be caused by the prediction of an one-time increase in productivity, but the excitement is based on the presumption of a (temporary) increase in growth. What are the possible effects of trade? The familiar argument emphasises the possibility of specialisation in production among countries. The pattern of inter-industry trade

[9]. In fact Barro (1990) finds a negative (conditional) correlation between the number of assassinations and the number of revolutions on the one hand and the growth rate on the other hand for South American countries. Though this result nicely illustrates the text, it should not be taken too seriously.

reflects, according to the Heckscher-Ohlin Theorem, the relative endowment of, for example, skilled and unskilled labour in countries. International specialisation has an ambiguous effect on economic growth, for it may imply that resources are devoted less to innovative activity and more to production of goods (see Grossman and Helpman, 1991)

Another gain from trade is the expanded range of available products. Compare as an experiment of thought a closed economy with an open economy. In the closed economy the price of foreign relative to domestic products is infinite, whereas in the open economy this price is a finite and the presence of intra-industry trade enriches the choice of consumers. Consumers love variety and therefore value the expansion in the range of available products. This gain is static and does not necessarily affect the dynamic performance of an economy.

International trade can also alter the intertemporal choice to save and invest directly. Removing impediments to international trade can increase the rate of innovation. The point is that isolated countries do not carry out R&D as efficiently as two or more integrated countries. One the one hand, the exchange of goods and services fosters the exchange of ideas and information, improving the productivity in the R&D sector. On the other hand, international trade discourages redundant, duplicative efforts to create a new product. To show these two effects the model must be adapted to apply to a world of two countries. For expository purposes a strict distinction between trade and communication is made, and only balanced growth paths are considered.[10]

Assume that the exchange of ideas and information between countries A and B is perfect, but that the trade of differentiated products between them is not allowed. The set of available varieties in the two countries may overlap. The degree to which varieties are produced both in country A and in country B is arbitrary. Although the magnitude of the overlap can change over time it will taken to be constant. The common stock of knowledge (M) is - as before - related to past investments in R&D. The possibility of learning from duplicative R&D is discarded. The common stock of knowledge can thus be expressed as a time-invariant fraction of the available varieties, say $M = \zeta(N^A + N^B)$.

The model developed for a country in autarky can easily be adjusted to incorporate the spillover effect. The main difference is that the productivity of the R&D-sector also depends on the number of available varieties in the other country, so that the economic development of countries throughout the world becomes intertwined. The condition for a balanced growth path is that rates of innovation in both countries are the same. If the countries do not differ in preferences or technology, the steady-state set of

[10] The distinction between a flow of ideas and a flow of goods and services was first introduced by Rivera-Batiz and Romer (1990).

available varieties in a country is proportional to the size of its labour force. The rate of innovation (γ_N^k) along a balanced growth path of an economy with international R&D spillovers in autarky is given by:

$$\gamma_N^k = \frac{\sigma}{1+\sigma\frac{\eta}{1-\eta}}\left(\zeta A(L^A+L^B)-\frac{\eta}{1-\eta}\rho\right). \tag{2.44}$$

Comparison with the growth formula for a closed economy (2.41) shows that international transmission of knowledge boosts the rate of innovation in both countries. The gains are however curbed by redundant investments, as only new blueprints contribute to reduction in the cost of R&D.

However, international trade of goods will remove the redundancy in R&D, because it gives an economic incentive to direct efforts towards the invention of new products rather than towards the imitation of existing products. Both invention and imitation entail costs, but the rewards in case of a monopoly exceed those in case of a duopoly.[11] Exchange of the differentiated products induces international competition in R&D, even though the blueprints itself are not traded.

Compared with the above expression for γ_N^k, the expression for the pace of innovation in the steady state (γ_N^t) is only changed for the value of the parameter ζ. Ultimately the overlap in the produced varieties will virtually vanish because of the introduction of trade:

$$\gamma_N^t = \frac{\sigma}{1+\sigma\frac{\eta}{1-\eta}}\left(A(L^A+L^B)-\frac{\eta}{1-\eta}\rho\right). \tag{2.45}$$

Trade promotes competition, avoiding duplicative R&D and thereby raising the innovation rate.

International trade also implies more competition on the goods markets: the number of firms increases. However, the size of the goods market also increases. The first effect puts a downward pressure on profits, whereas the second effect raises the return on investment in R&D. The result of both forces is therefore ambiguous, and in the model the two effects exactly cancel.

In summary, trade may foster growth by a better exploitation of scale economies and by creating an incentive to innovate rather than to imitate. These positive effects will deluge any negative effect of inter-industry specialisation, as long as countries have identical relative endowments of basic inputs. A reallocation of resources at the expense of R&D may occur if dissimilar countries engage in trade.

[11] This argument is strengthened if Bertrand competition is a viable and credible policy for the incumbent producer.

2.5.4 Diverging growth rates

In the absence of international spillovers countries can grow at different rates. Grossman and Helpman (1991) show that trade of goods and capital may then increase growth differences, so that a large country, that is better able to exploit the economies of scale, can eventually dominate the market for differentiated goods. The possibility of lasting differences in growth rates relates to the structure of the model: similar to the model of Buiter and Kletzer (1991) a non-traded or non-transferable good is used as an input in the production of a traded good.

The possibility of different and diverging growth rates disappears in the presence of knowledge spillovers, even if countries differ in R&D technology as represented by the parameter A in equation (42). Differences in R&D technology, while allowing for knowledge spillovers and international trade, imply differences in wealth of the households. The number of varieties in relation to the size of the labour force is higher in the more productive country than in the less productive country. In the former country the wages exceed those in the latter country, so that the supplied amount per variety differs between the countries. The country with a comparative advantage in research "specializes" in the number of varieties rather than in the production of each variety.

2.6 The empirics of growth

This section covers some empirical studies on economic growth, that touch upon the discussion in previous sections. It does not provide a complete overview of the empirical literature on economic growth. (See, however, for a recent and comprehensive survey of empirical growth literature Temple, 1999.) The renewed interest in the process of economic growth has not only produced a vast amount of theoretical articles and books, but has also initiated a great deal of empirical work. This section starts with empirical testing of endogenous versus exogenous growth theories. It then briefly characterizes empirical evidence on three engines of growth: human capital, public infrastructure and R&D.

Up to now this chapter has been almost entirely devoted to endogenous growth theories. This should not be taken to imply that these theories have rendered the traditional Solow growth model obsolete. Mankiw, Romer and Weil (1992) have jumped to the defence of this model. They claim that once the model is augmented to incorporate human capital, it explains the data reasonably well. Countries (and regions) converge, but rather slowly. The Solow model can explain convergence whereas often simple endogenous growth models cannot. However, the Solow model cannot explain the observed rate of convergence. To explain the observed rate, the elasticity of production with respect to the reproducible factors in production (costs) must be higher than the usual one-third, being the share of physical capital in production costs. Broadening the concept of capital to include both physical and human capital increases the elasticity and allows the (augmented) model to explain not only convergence but also the observed rate of convergence.

Jones (1997) takes a different research approach but also ends up criticizing endogenous growth theories. He argues that according to these theories a temporary increase in the investment rate should raise production indefinitely, whereas the Solow model predicts that it raises production only temporary. A time-series analysis gives support for the latter idea and not for the former.

A similar problem is that in cross-country regressions the variance of the dependent variable, the rate of economic growth, is much higher than that of the explanatory variables. Swings in the growth rates are therefore not easily explained by variables suggested in endogenous growth theories. Whereas, for example, systems of public education or government investments in infrastructure do not change radically, the growth rates can. Easterly et al. (1993) show that the correlation between growth rates in two subsequent decades is low, and often even negative. These findings fit well into the Solow model, in which convergence is central, but are at odds with simple models of endogenous growth.

Solow's model of growth is thus still relevant today. However, the various forms of critique should not bear so much weight as to deny the relevance of endogenous growth theories, for several reasons. First, the naive Solow model suggests a too low elasticity of production with respect to reproducible factors. Typically, the elasticity is given a value of one-third, corresponding to the share of capital in national income. The work initiated by Romer and Lucas suggest a value of one, or even higher. A value of one-third is definitely too low and a value of one is perhaps too high. Important is that an elasticity significantly higher than one-third, implies a much higher return of government policies than economists used to assume. Second, simple model of endogenous growth may not predict convergence, but more elaborate models may very well exhibit this property. More elaborate models often incorporate the plausible assumption that poor countries may (partly) catch up with rich countries through a slow process of copying and learning state-of-the-art technologies. This makes the models of endogenous and exogenous growth observationally equivalent, since both types of growth models then predict (conditional) convergence. Third, the theoretical contributions have given economists more and better tools to analyse and to understand the process of economic growth. For example, many endogenous growth theories reject the traditional assumption that technology is universally available and applicable. Instead, they adopt the idea that technological spillovers between two countries are imperfect or sometimes even absent. The spillovers are often thought to depend on trade between the countries or on the education level of their respective labour force. Indeed, based on this idea Coe and Helpman (1995) look for international spillovers. Their results point to strong effects of R&D by one country on total factor productivity in other countries in the club of rich countries.

More important than the distinction between endogenous and exogenous growth theories is the distinction between successful and unsuccessful policies. Here, attention is confined to three possible driving forces behind high growth or productivity: human capital, public infrastructure and R&D.

In the cross-country regressions of Barro (1990, 1991), and also in later work by others, human capital shows up as an important determinant of productivity (growth).[12] Investment in human capital may improve the long-run economic performance by directly raising productivity, but also by facilitating the adoption of new, foreign technologies. This is suggested by the results of Benhabib and Spiegel (1994). They include in Barro-like regressions a term capturing the interaction between human capital and (foreign) technology, and find that this term significantly explains productivity growth. The evidence for human capital is however not undisputed. Islam (1995) uses panel data to estimate growth equations and cannot find a positive effect of human capital variables. When allowing for unobserved heterogeneity the human capital variables become statically insignificant. In more simple terms, country-specific constants give statistically a better explanation than human capital variables.

Other factors than human capital also contribute to economic growth. Many studies, often pre-dating and different from the cross-country growth regressions, find large effects of public investment as well as R&D expenditure on productivity, though different studies about public investment yield less consistent results than those about R&D. Empirical work, initiated by Aschauer (1989), finds sometimes no effect and sometimes large effects of government investment on productivity and production. 'Too good to be true?' wonders the World Bank (1994). Indeed, the estimated effects are sometimes implausibly high. (See for an overview of the empirical literature Sturm, 1997)

Ambivalence does not arise from studies into the effect of R&D on productivity (growth) at sectoral or firm level. Typically the impact is found to be large and the private return on R&D investment is often estimated to be 30% or more (see for references Nadiri, 1993). Jones and Williams (1998) argue that the estimated rate of return on R&D provides a lower bound for the true social rate. Assuming a social return of 30% they suggest that the United States does not invest enough in R&D and should quadruple (!) expenditure on R&D. Jones and Williams consider a closed economy. For the United States this assumption is not too bad, but for small economies it is not appropriate when accounting for the possibility of international spillovers. A small open economy is less likely to appropriate the returns of R&D fully. However, Jacobs, Nahuis and Tang (1999) find strong evidence for significant spillovers

[12] Barro was not the first to come up with cross-country regressions. Nevertheless, they are often called Barro regressions.

within the Dutch economy, implying that the suggestion of Jones and Williams is also relevant for small open economies.

A general conclusion is that relation between human capital and public infrastructure on the hand and growth on the other hand is not robust. Some studies find a positive relation, whereas others do not. R&D, however, has a robust, positive effect on growth. There is also ample evidence that the social return is higher than the private return.

Naturally, there are more determinants of growth than the three that have been discussed in this section so far. Different researchers try different variables in cross-country growth regressions. For example, growth is impeded by government consumption in Barro (1991), by public debt in Beetsma and Van der Ploeg (1996) and by inflation Fischer (1993). However, the problem with this type of research is that many results are not robust. A variable is statistically significant in one regression, but is insignificant in another regression. This is true for human capital, public infrastructure but also for many other variables. Levine and Renelt show that often one can find two different sets of explanatory variables, producing such an ambiguous result. The consequence is that successful policies are not easy to identify.

2.7 Concluding remarks

This survey has dealt with several engines of growth: research for and development of new products, learning by doing as a side effect of private investment and public investment in, for example, infrastructure. Another, deliberately neglected but important, approach focuses on investment in human capital. Although these views on growth may at first sight appear to rather different from each other, they are not mutually exclusive and share common features. First, in contrast to the orthodox neoclassical theory savings do matter for the determination of the rate of economic growth. Consequently the design of the fiscal system, the definition and the protection of property rights and the functioning of financial markets are crucial to economic growth. Taxes on capital income, the fiscal method of depreciation, patents on inventions, uncertainty about property rights (think of the situation in Eastern Europe or of the political stability in South America), the channelling of funds from lenders to borrowers, all these factors affect the rate of return on investment and therefore the willingness to postpone consumption. However not only structural policies but also ordinary budgetary policies interfere with growth if the Ricardian equivalence does not hold. We have shown that an increase in public consumption or in government debt will diminish the available funds for investment; consumption of the current generation will not be totally crowded out as yet unborn generations will partly pay the higher taxes in the future. Second, almost all the views on economic growth relate the accumulation of knowledge to externalities, so that private decisions to save and to invest are not optimal and growth is from a social point of view too low. Naturally, this implies an active role for the government; depending on the engine of growth the government should try to support research and development, improve the channels of international communication, promote investment, maintain and expand the infrastructure and/or invest in education.

The predictions of the recent theories in an international setting depend clearly on the translation from these theories from the context of a closed economy to one of an open economy and are therefore not clear-cut. For example, the theoretical relationship between trade and growth has been thoroughly investigated but is ambiguous; empirical results reveal that it may be positive (Roubini and Sala-i-Martin, 1991).

The orthodox theory of growth has a rather optimistic view on the issue of growth and development. In contrast, the recent theories indicate that differences in levels of and even in growth rates of production and consumption may persist. An interesting avenue for further research is therefore to extend these theories to allow for international migration of labour (see for example Burda and Wyplosz, 1992). This line of research may provide a real-world perspective on the issue of growth and development.