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Education, Educational Policy and Growth

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Abstract

?This paper reviews the recent theoretical and empirical literature that relates education to growth, and draws some lessons for the Swedish experience. First, the ?human capital accumulation? approach is discussed: agents decide, at each moment of their lives, to forego time or resources to improve their future productivity. The quality of the educational system is argued to be a crucial determinant of the decision to invest in human capital and of the growth rate of the economy. Hence, qualified teachers and appropriate incentive schemes within the schooling sectors are important for the long-run performance of the economy. Next, the trade-off between basic innovation (promoted by a restricted subset of economic activities) and learning-by-doing (which occurs at a more diffuse level in the economy) is analysed. It is argued that the former can be fostered by investments in ?elite? research institutions, while the latter depends on the average educational attainment of the working population. Finally, the relationship between education, growth and inequality is discussed. The second part of the paper analyses recent trends in educational attainments in Sweden. Data show that enrolment rates in tertiary education in Sweden have lagged behind the major industrialised countries during the 1980s. Quantitatively, however, this is unlikely to be a major explanation of the productivity slowdown experienced by Sweden after 1970. But it is emphasised that (i) low educational premiums may harm incentives for people to invest in human capital; and (ii) low relative wages and low-power incentive schemes for teachers may cause a deterioration in the quality of education with negative effects on long-run growth.

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Summary

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The second part of the paper analyses recent trends in educational attainments in Sweden. Data show that enrolment rates in tertiary education in Sweden have lagged behind the major industrialised countries during the 1980s. Quantitatively, however, this is unlikely to be a major explanation of the productivity slowdown experienced by Sweden after 1970. But it is emphasised that (i) low educational premiums may harm incentives for people to invest in human capital; and (ii) low relative wages and low-power incentive schemes for teachers may cause a deterioration in the quality of education with negative effects on long-run growth. ■

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"The good Education of Youth has been esteemed by wise Men in all Ages, as the surest Foundation of the Happiness both of private Families and of Common-wealths. Almost all Governments have therefore made it a principal Object of their Attention, to establish and endow with proper Revenues, such Seminaries of Learning, as might supply the succeeding Age with Men qualified to serve the Public with Honour to themselves, and to their Country."

Benjamin Franklin, 1749, Proposals Relating to the Education of Youth in Pennsylvania.

Economic theory provides a number of reasons that help to explain the importance of education for economic growth. In Section 1, we will review the way in which education has been dealt with in economic theory. However, the assessment of the quantitative importance of human capital and education in the growth process is an empirical issue. A large body of empirical literature, part of which is reviewed in Section 2, has developed to address this important question. The literature documents robust empirical evidence to show that countries with a better educated labour force perform better in terms of growth. The quality of education also seems to matter.

To better understand the implications of the theoretical and empirical findings for the Swedish experience, we then discuss the basic facts about Swedish economic growth and human capital accumulation in Section 3. It is a striking fact that Sweden exhibited a remarkably strong growth performance between 1870 and 1970, while growth slowed down significantly thereafter (Lindbeck, 2000). In this context, we provide an assessment of the role played by human capital accu-

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mulation in this slow-down. We summarise the main conclusions and the policy advice which we believe can be inferred from this analysis in Section 4.

1. The theoretical growth literature

The recent economic literature has examined, from a variety of perspectives, the role of education and learning in understanding technological innovation and long-run economic growth. Earlier "neoclassical" theories, as developed in the late 1950s and early 1960s, identified the accumulation of *physical* capital as the engine of economic growth. A major prediction of this approach is that the growth of income per capita would fade away in the long run. The reason is that, on the one hand, the only source of growth is the process of savings and investments, which increases the stock of capital per employee in the economy over time. On the other hand, (net) investment per employee is predicted to decline over time, and fall to zero in the long run. This decline in investment is attributable to the fall in the marginal productivity of capital over time as the economy grows and its capital intensity (capital per employee) increases.[1]

The prediction that economies would fall into stagnation in the long run is contradicted by the observation that the process of growth has continued steadily in the industrialised world for about two centuries. This criticism has been the motivation for the new theory of economic growth which was started in the late 1980s, following the contributions of Romer (1986) and Lucas (1988). The problem had in fact already been noticed long before. Solow (1956) formalised the idea that growth would not die off in the long run if labour productivity grew over time, due to technical progress. This progress, however, was postulated rather than explained within the framework of traditional growth theory. Long-run growth remained outside the realm of the phenomena which economic theory attempted to explain. Overcoming this limitation, and providing a theory of the determinants of long-run growth, was one of the main objectives of the "new growth theory" research program.

[1] More in general, economic theory predicts growth to vanish in the long run as long as there are decreasing returns to the set of "reproducible" factors of production in the economy. Non-reproducible factors of production (or factors in "exogenous supply") are those inputs whose accumulation and growth rate are not determined by people's willingness to save and accumulate wealth.

In this new paradigm, long-run growth depends on a set of economic decisions and incentives. Among them, education has acquired a central role. When decisions of skill acquisition (via education, training, etc.) are explicitly embedded into the theory, the economy can continue to grow even when the stock of labour is limited. Labour productivity increases over time not only because a larger amount of physical capital per employee becomes available, but also because the stock of knowledge and skills embodied in each employee grows over time. Expressed in the language of recent economic theory, the accumulation of *human* rather than physical capital is the fundamental source of growth in modern economies.[2]

What is it, then, that gives rise to long-run economic growth? Or, more precisely, why does labour productivity grow at a sustained rate? The large body of recent research on the sources of economic growth can be classified into three fundamental explanations.

1. Human capital accumulation;
2. Generation of new ideas;
3. Learning-by-doing.

In the *human capital accumulation approach*, economic agents purposefully devote effort, time and resources to increase their productivity (Lucas, 1988). Usually, this occurs through education. Human capital investments are similar in nature to physical capital investments. Both investments require that current consumption be foregone in order to increase future productivity and consumption. Investments in physical capital require that certain resources which are available to the society for consumption be set aside and used for the production of capital goods. The mechanism for human capital accumulation is similar: a share of the population of working age is withdrawn from the labour force and, rather than producing consumption goods, is put into schools – or other training institutions – in order to increase future labour productivity. This theory generally emphasises the importance of education to promote growth, and the potential causes for a market economy to generate an undereducated labour force.

The generation of new ideas approach shares certain similarities with the former, but also exhibits important differences. It stresses that in order for a society to generate high growth, many workers must be

[2] By human capital, economists refer to the skills and knowledge which individuals acquire through education, training and experience, and which enhance the productivity of the worker who embodies them.

devoted to the creation of new ideas and designs for more efficient productive processes and more attractive consumption goods (Aghion and Howitt, 1992; Grossman and Helpman, 1992). The crucial determinant of growth is, then, the share of the workforce that is employed in innovation-oriented industries and activities. These include both research and development (R&D) carried out by firms and basic research carried out by specialised institutions.

This approach emphasises the need that (i) private firms find it profitable to invest in research and innovation; (ii) a large share of the workforce has the necessary skills to undertake these activities (engineers, scientists, etc.); and (iii) universities and other institutions find it rewarding to be actively involved in research, because of either market incentives or publicly provided (targeted) support. While the general notion of human capital accumulation would not discriminate between different types of education, the "generation-of-ideas" approach would emphasise the importance of supporting *higher* education and advanced research institutions to promote R&D-driven growth.

Finally, according to the *learning-by-doing* approach, workers' productivity increases over time as workers are repeatedly confronted with a particular task or problem, and learn how to cope with it efficiently. Empirical research supports the view that the speed of the learning process of a particular technique first increases over time, and then decreases, as all its "secrets" unravel (Mansfield, 1968). As new techniques are introduced, renewed opportunities for workers to learn and improve new tasks become available. Capital accumulation plus learning-by-doing can in fact lead to self-sustained growth, under certain assumptions (Romer, 1986; Zilibotti, 1995), although empirical research has found these assumptions to be rather unrealistic (Caballero and Jaffe, 1993).

The "learning-by-doing" approach emphasises work experience rather than education as the main source of growth. Since education implies less work experience, this approach suggests, in contrast to the previous ones, that over-education might harm growth. This argument is controversial, however, since it seems reasonable that educated or well-trained workers learn more rapidly than non-educated or untrained workers.

1.1. Human capital accumulation

The modern version of growth theory with human capital accumulation has been provided by Lucas (1988). In this model, people decide at each moment in their life how to allocate their time between labour activity and raising their productivity through education. In addition, they decide how much of their income should be consumed and saved respectively. Physical and human capital are similar in many respects. The main difference is the technology that is used to produce them. While both capital and labour are necessary to produce physical goods and capital, human capital production only requires labour. This is intended to capture the notion that although educational activities require buildings, infrastructure, etc., the contribution of human inputs—teachers, administrators, etc.—is generally more significant than in the production of machinery and plants.

According to this theory, the growth rate in the long run only depends on the productivity of the education sector and on the time people devote to schooling. The latter, in turn, increases with the efficiency of schooling. An increase in the efficiency of the provision of education has, therefore, unambiguously positive effects on long-run growth.

This theory has some interesting policy implications. Firstly, the government should put a large emphasis on both the quality and efficiency of educational services. Consider, for instance, a system like the Swedish one, which is mainly based on public schools and in which pay differentiation has been very limited. The reduction over time of teachers' relative wages—as has been observed in Sweden—might imply a deterioration of educational standards, because intellectually gifted persons have an incentive to work in the private sector rather than to become teachers. The theory suggests that this trend is destined to harm long-run growth by lowering the quality of schools and the incentives for young people to invest in human capital.

Secondly, the *effort* of teachers also matters for the quality of schools. Concerning this issue, we can learn from the recent *moral hazard* literature dealing with incentives and work effort (Kreps, 1990). The starting point, here, is that employees (teachers) dislike effort and that managers (i.e. university/school administrations) only get an imperfect signal of the effort exerted by their employees through observing the output (*knowledge* of graduating students). The crux is to construct reward schemes such that the teachers have the right *incentives* to do a good job and provide a high quality service. In the Swedish schooling system, however, this type of monetary reward has been virtually absent. In particular, teachers' wages have been independent of any measure of the productivity of their teaching. This holds true for all levels of schools, from kindergarten to university.

But how should one measure teachers' and schools' performance? One approach, which is highly emphasised in other countries (e.g. the UK and Canada), is to submit all students within the national system to a common exam, and publicise the results school by school. In order to avoid unfair conclusions, it is important that the information about the scores of students leaving, say, high schools, is complemented with the information about test scores taken when students first entered the high school. One would then avoid that scores reflect family background and other social factors, rather than the skills learnt during the school period. Well-performing schools should be assessed on the basis of the average improvement in the students' ability during the school period, rather than on the absolute success of graduating students. Schools which are most successful in improving their students' initial skills should be rewarded, while poorly performing schools should be closely monitored, and their management put under some kind of pressure (to be passed on to the local teachers).

This test-oriented approach is not uncontroversial. The standard argument against it is that it would bias the teaching and the students' learning efforts towards skills that are quantifiable, i.e. facts and definitions (see Bishop, 1999). This could lead to a neglect of important skills that cannot be quantified, like the scientific process, cooperation, etc. The importance of this bias is a quantitative issue. Bishop (1999) argues, based on Canadian data, that the biases in teaching introduced by leaving examinations are quantitatively small or non-existent. At the university level, it seems to us that such biases should be even less relevant.

Thirdly, improvements in the education sector may have a positive effect on growth even when they are costly, and their financing causes other distortions. For instance, it can be shown explicitly from the Lucas model that financing school improvements have, in most cases, positive growth effects, even if they are financed by higher corporate taxes.[3] This prediction contrasts with the popular notion – derived from standard models using only physical capital – that only policies affecting the profitability of business activities have effects on growth.

Lastly, we would like to point out an interesting feature of human capital theories concerning the economic growth that arises as a result of sudden changes in human or physical capital. In the long run, according to this theory, the value of both physical and human capital are constant proportions of GDP. If a country is suddenly hit by a sudden event creating a physical capital shortage (i.e. a war or an earthquake), physical capital accumulation will tend to be very high in the aftermath of the shock, and the country will promptly return to the old proportion of physical capital to GDP. A similar, though opposite, process would occur after a sudden event causing a shortage of human capital (e.g. the exodus of engineers from East Germany at the beginning of the cold war or the black plague).

The theory predicts, however, an important asymmetry between the two cases. In particular, a country would recover more rapidly from a destruction of physical capital than from a destruction of human capital. The reason is the following. After a war, physical capital is scarce, and the return to savings and investments in physical capital is therefore high. People then want to save and accumulate at a high rate, and the original ratio of physical capital to GDP is restored in a relatively short time. This might explain the good growth performance of Western European economies after the physical destruction during World War II. After a brain drain, however, the adjustment of the economy would be slower. The reason is that the scarcity of human capital leads to high wages which, in turn, makes people reluctant to spend time in school instead of working for a wage. This retards the reconstruction of the human capital lost by the brain drain and causes slower growth.[4]

[3] According to the Lucas model, long-run growth only depends on the productivity of the education sector (together with other parameters describing people's preferences). Although increasing corporate taxes would have effects on short-run investments and growth, these effects would vanish in the long run, while the improvement in education would raise growth permanently, both directly and through its impact on the choices of how much education to undertake.

[4] In the Lucas model, a reduction in human capital will increase wages, even for the low-skilled, since high-and low-skilled labor simply represent different efficiency units of the same factor of production. In models where different levels of education represent different factor inputs, the implications for the speed of recovery

1.1.1. Future generations and inequality

In this section, we consider more closely the generational aspects of education. The quality of educational achievements of one generation impacts on the opportunities of the next generation. This happens via some kind of cultural transmission mechanism both at school and in the family. One problem that has been studied in the economic literature is that each generation might take its education decisions without fully taking into account the positive impact of their educational attainments on the opportunities available to future generations. Some work (Azariadis and Drazen, 1990) has emphasised that the consequences of these intergenerational links may be quite dramatic.

Assume, to give a simple example, that each person decides whether or not to pursue education. The learning capabilities and, thus, the amount of skills an individual can acquire through education critically depend on the family (and social) background. In particular, children learn faster if their parents are better educated. Skill acquisition is, therefore, a "cumulative process" through successive generations. Additionally, the availability of well-trained teachers and school infrastructure is a precondition for young people to find it beneficial to go to school rather than to work when young. Consider now two consecutive generations. If the average family background of the older generation is poor and/or good teachers are not available, the younger generation will not become educated, and the stock of human capital in the society will not grow. This in turn will cause the subsequent generation not to choose education, and so on. The economy would therefore become locked into a low-education, low-income trap, where the absence of human capital accumulation implies low growth. This poverty trap could have been avoided if the first generation had been induced to invest in education.

The poverty trap issue has been mainly discussed in the context of developing economies. It may, however, illustrate problems which even advanced societies may face when the incentives for a generation to accumulate knowledge and human capital are weak. For instance, if redistributive policies induce a wage compression that reduces the incentives for the current generation to engage in education (particularly higher education), the resulting shortage of human capital

after a brain-flight might be quite different from those of the Lucas model. See Barro and Sala-i-Martin (1995) for more details.

may have rather persistent effects on growth, due to the mechanism of intergenerational knowledge transmission described above.

We have so far analysed whether the population undertakes *on average* the right amount of education. Another important issue is whether it is the most intellectually talented agents in the society who undertake education. There are a number of reasons to believe that this may not be the case in a market economy in the absence of public intervention. People differ in both intellectual capabilities and wealth (say, the wealth which their parents put at their disposal for education purposes).[5] If there were no borrowing contracts, wealth would not matter for educational decisions. Talented people who happen to be poor could borrow when young to finance their study, paying back their debt out of their future income. However, in reality, the access of poor people to private lending for financing their education is severely limited. Thus, the access to education tends to be distorted in favour of the rich. Apart from concerns for justice, this problem would cause an inefficient resource allocation, and potentially reduce economic growth.

Another reason for inefficient allocation of talent and bias due to wealth inequality would be one in which education (especially higher education) has both a consumption and an investment value. In other words, not only does education increase an individual's future productivity and wages, but it also carries with it a status value. If this status value is a "luxury good" (i.e. people care more about it the wealthier they are), then for given economic incentives to take education, children from wealthier families would find education more attractive than kids from poorer families. This argument accords with recent empirical evidence (Sjögren, 1999) that, in Sweden, children from lower class families tend to be more responsive in their educational and career choices to economic incentives than children from upper class families. To the extent that this argument is relevant, misallocation of talents would tend to be particularly severe in countries where policies of wage compression (i.e. reductions of educational premium) make economic incentives less important relative to status effects.

Another important consideration is that "peer effects" matter, i.e. individuals' achievements in school tend to be better, the higher the intellectual potential of their schoolmates. These observations are re-

[5] Bergman (1999) studies economic growth and the choice of education under such assumptions.

lated to an important policy issue concerning which system is best to finance education (Glomm and Ravikumar, 1992; Benabou, 1996; Aghion and Howitt, 1998). Assume that children from rich families start up with more human capital than those from poor families, due to a family background effect. Is it better—from an efficiency standpoint—to bring together more and less advantaged kids, or, rather to segregate them?

Consider, to address the point, two polar models of school financing which would achieve rather opposite results. At one extreme, education is financed by local communities where each community is populated by families that have identical wealth per household. In this scenario, there will be rich neighbourhoods where parents are willing to pay high school fees and kids have high quality schools, and poor neighbourhoods where parents can only pay low school fees and where schools are of low quality. Peer effects will reinforce this segregation. The opposite extreme is a system where schools are financed by centralised nation-wide funding, and all schools in the country provide services of identical quality. Since location is less important for quality of schooling, neighbourhoods will tend to be less segregated, i.e. people with different wealth levels will be found in each neighbourhood. These two systems can be regarded as stylised representations of the US and the Swedish (as well as other Continental European) school systems, respectively.

Clearly, the former system will tend to perpetuate (or even exacerbate) initial inequality in the human capital distribution, while the latter would induce equalisation. But which system will promote faster growth? This question is addressed by Benabou (1996). According to his work, the extent of inequality in human capital is detrimental for human capital accumulation and growth, irrespective of the way the school system is financed. It turns out that if one takes inequality as given, it is ambiguous which financing system maximises *short-term* growth. On the one hand, in the integrated system, the poorly educated benefit from interacting with students with more human capital, but, on the other hand, those with more human capital are harmed by the presence of the less fortunate students. This ambiguity is, however, removed when considering *long-run* growth, i.e. when taking into account the long-run effects over time of the schooling system on inequality and prosperity. Nation-wide financed school systems tend to decrease inequality over time and, thus, induce a better growth performance in the long-run. In summary, while it is unclear which system maximises short-run growth, the nation-wide funded system is unambiguously better for long-term growth.

1.2. Generation of new ideas and learning-by-doing

Overall, the theory discussed in the previous section supports the view that educational systems stressing equalisation of opportunities and integration are desirable not only on grounds of justice, but also on grounds of efficiency and long-run growth. Some recent theories point, however, to forces which may alter this conclusion. According to an important branch of modern growth theory, the engine of growth lies not in education in general, but in a restricted subset of economic activities producing technological innovation (Aghion and Howitt, 1992, 1998; Romer, 1990). These activities demand intensively very specific and "advanced" skills, and the rate of growth of an economy will depend on the availability of these skills in the society.

One conclusion is that a country should invest in the creation of an intellectual and scientific elite. In other words, for the purpose of promoting growth, it is not really important to have well-educated blue-collar workers, but, rather, to have some excellent higher education institutions which prepare competent managers, engineers, etc. who can engage in innovative activities. In particular, given a certain school budget, this theory would stress the importance of using resources to extract the maximum potential from the most gifted pupils rather than targeting the average, or the most disadvantaged students.

The rationale for such elitist educational policies would be to promote the formation of skills that can be used for innovative activities and growth. This would benefit the entire society, including the low-skilled population. For example, the social benefits generated by the activity of a skilled engineer or medical researcher might go well beyond the return which they can privately appropriate. Thus, unless the government intervenes, a market economy provides too weak private incentives for capable students to engage in these professions.

One reason why the market fails is the following. Innovations can be patented and patents sold to firms, creating a profit for innovators. This provides an incentive to carry out innovative activity. The flow of new ideas associated with innovations, however, will also inspire additional research which were not taken into account when the innovation was first conceived. Since only a limited part, if any, of these additional benefits is received by the original innovators, the society provides too little private incentive for production of new knowledge.

This argument suggests that subsidies targeted directly to increase the profitability of research activities would be desirable. Public investments in support of higher education programs, increasing the supply of skills which are used intensively in research activities, would be another policy option to enhance efficiency and growth.

Once again, there are important linkages between the labour market structure and educational policies. To strengthen the incentives for young agents to acquire the skills needed to carry on innovation-oriented activities, it is necessary that a significant wage premium be attached to them. In a society with a highly compressed wage structure, these incentives tend to be particularly weak. This exacerbates the under-provision of research-oriented skills. To compensate for this distortion, government intervention can make human capital accumulation attractive via a generous policy of subsidies and student loans. The problem with this approach is that—unless these policies are carefully targeted to a few specific areas of knowledge—they can make higher education in general attractive, while failing to induce the desired emphasis on those areas of specialisation that are crucial to promote economic growth. Thus, a society may tend to over-invest in certain areas of knowledge (some of which one might wish to keep alive, but for consumption rather than investment purposes) and, yet, suffer from a scarcity of skills in other crucial sectors.

This discussion tends to go against the earlier conclusions in favour of an egalitarian rather than elitist approach. Although the arguments presented in this section should be kept in mind, we believe, however, that the stress on an elitist approach should not be overemphasised. Some recent literature even argues that the role of research as the fundamental engine of growth should be de-emphasised (Young, 1993). The theory of research-driven growth argues that research provides more and more productive techniques over time, and that these are implemented quickly. This may, however, be a rather unrealistic description of the process of growth and technological development. Many historians think, for instance, that most of the innovations and technologies associated with the British Industrial Revolution were available long before they were used in factories (Hobsbawn, 1968; Rosenberg and Birdzell, 1986). The process of industrialisation in the Western world did not coincide with a boom of research activity, but, rather, with the formation of a workforce capable to adapt to the needs of the factory system, development of entrepreneurial skills and development of capital markets (Acemoglu and Zilibotti, 1997).

A more realistic description of the process of growth is one where basic research activity provides a stock of public knowledge which can potentially improve the productive capacity of a society. But between the original innovation and the full exploitation of its potential, there is a process of what can be called "secondary innovation" taking place in a more scattered fashion in the productive sectors of the economy. The main force in this process is *learning-by-doing*.

While basic research requires highly skilled workers, the efficiency of the process of learning-by-doing might, arguably, depend on the *average* human capital of the labour force in the society. Translating this theory into a concrete example, the secret of the success of the US as the technological leader in the world is not the mere availability of highly qualified engineers trained at Stanford University and operating in Silicon Valley, but, rather, a combination of the highly skilled engineers and the high average quality of the American labour force (which has the highest percentage of secondary school attainment and completion in the world). This has enabled the rapid and efficient implementation of new ideas and techniques in ordinary productive activities.

Once the complementarity between basic and secondary innovation is acknowledged, economic theory stresses the importance of having both a high average level of human capital in the population and centres of excellence in higher education that train a limited number of highly qualified individuals for innovation-oriented activities.

1.2.1. Education and skill-biased technical change

A major argument for promoting human capital accumulation is provided by the extensive recent literature on growth and skill-biased technical change. Many authors have argued that technological development in the last thirty years has reduced the relative demand for unskilled versus skilled workers, making aggregate labour productivity more dependent today than in the past on the availability of a well-trained and well-educated labour force (Katz and Murphy, 1995; Berman et al, 1998).[6]

[6] See also Calmfors and Holmlund (2000) for a discussion of this issue.

There are two fundamental arguments that explain why technological change may have become skill-biased. Firstly there has been a progressive reduction (documented by the empirical literature) in the price of capital relative to that of labour in the industrialised world (Krusell et al, 2000). Capital—it is argued—acts as a substitute for unskilled labour and as a complement to skilled labour, thereby increasing its productivity and demand. Capital-intensive techniques require more maintenance services, and the activity of workers who can operate specific equipment, e.g. computers. For instance, the introduction of computerised assembly lines reduces the need for unskilled workers, while demanding qualified workers to control the process. Thus, as a result of the falling price of capital equipment, firms have switched their demand away from technologies using low-skilled workers into technologies that use more capital and high-skilled workers. This change in the relative demand of skills has caused a fall in the price of unskilled labour and an increase in the returns to education in flexible labour markets like that of the US. In Europe, where institutional factors tend to compress the wage structure, the adjustment has instead tended to take the form of an increase in the unemployment rate for low-skilled workers.

The alternative theory notes that during the late 1960s and early 1970s, there has been an exceptional increase in educational attainment and in the number of college graduates in the US (Acemoglu, 1998; Acemoglu and Zilibotti, 1999). These changes, caused by particular events such as conscription in the Vietnam war, would have first caused a decrease in the wage premium to education (which was in fact observed during the 1970s), but later generated an increase in research activity directed at creating new technologies which demand skilled labour. Since the US accounts for a very large share of the technological innovation in the world (35 per cent of the world expenditure in R&D originates in the US), this would have had an impact on the nature of technology development in the world as a whole. This change in the direction of technology development may have caused, over time, an increase in earning inequality between educated and non-educated workers. This means that the rest of the world, which depends to a large extent on innovations in the US, must raise the average educational attainments of the working population, in order to benefit from the new technologies generated.

This mechanism—i.e. the acceleration of skill-biased research and innovation—may have been reinforced by other factors, such as, especially, the increase in the volume of international trade between developed and developing countries (Wood, 1994). The labour force in developing countries is, on average, less educated than in developed countries. A reduction in the barriers to trade would induce, according to standard economic theory, an increase in the inequality between educated and non-educated workers in developed countries, even if there were no changes in the pattern of technology development. Thus, the effect of trade liberalisation would per se increase the demand for educated workers in industrialised countries.

Although different theories differ in their explanation of why recent technical change has been skill-biased, there is little dispute on its occurrence. This means that the future prosperity in industrialised economies will depend, even more than in the recent past, on the human capital of their workforce. While the market mechanism—via increases in the education premium—does contribute to incentives to undertake the socially desirable additional human capital investment, these incentives may be weaker in economies where the market adjustment is largely distorted by institutional constraints (such as e.g. wage compression). Although there is evidence of increasing wage inequality in some European countries, like Sweden, educational policy will have to take continual account of the impact of technological change on the growing need for a highly qualified and educated labour force.

2. Empirical results

There is a substantial body of empirical literature which has tried to assess the importance of human capital and education for economic growth. The standard approach (Barro and Sala-i-Martin, 1995; Barro, 1999) is to explain the growth rates of different countries by a set of explanatory variables including human capital indicators, institutional variables (political instability, rule of law, democracy, etc.), policy variables (government consumption as a percentage of GDP, tax distortions, etc.), investment rates and initial GDP per capita. The standard finding is that an increase in the average years of schooling of the working population has positive and significant effects on growth.

Different indicators for human capital have been used. Barro (1999) finds that a one-year increase in the average secondary and higher education of the working population causes an increase in GDP per capita growth by .72 per cent per year (everything else being held constant). This means that a significant part of the differences in growth rates across countries can be attributed to differences in the human capital of the labour force. For example, according to the data set used by Barro, the average years of secondary and post-secondary schooling in the US, Sweden and France in 1990 were, respectively, 6.2, 4.2 and 2.7. According to these estimates, the component of growth attributable to human capital differences would cause the annual growth rate of the US to be 1.4 per cent higher than that of Sweden, and the growth rate of Sweden to be 1.1 per cent higher than that of France. Human capital would account for even larger differences when comparisons are made between developed and developing countries. For instance, the difference in growth rates between Sweden and an average African country attributable to human capital differences would be 2.6 per cent per annum.

These results suggest that the stock of human capital is an important determinant of growth. One would expect, however, that differences in *growth rates*, and not just in the initial stock, of human capital, would matter. Economic theory suggests that a country which invests a lot in education and, as a result, substantially increases the average human capital of its labour force, should grow faster.[7] The evidence on the effects of human capital growth are, however, less clear. Benhabib and Spiegel (1994) analyse how differences in growth rates of GDP per capita can be explained by differences in the *growth rates* (as opposed to the stocks) of human capital across countries, and find no significant effects. This finding is consistent with panel studies looking simultaneously at differences over time and across countries (Caselli et al, 1996; Islam, 1995).

There is, thus, robust empirical evidence that countries with a better educated labour force, *ceteris paribus*, perform better in terms of growth. However, there is less robust evidence that countries that have improved their educational achievements have grown faster. This puzzling finding – which stands in contrast to the results of a large body of micro-empirical literature suggesting that education substantially improves individual productivity (Angrist and Krueger, 1991; Björklund, 2000) – may well reflect problems with the measurement of human capital, rather than a failure of the predictions of

[7] Bils and Klenow (2000) stress the reverse causality; if education is a normal good, then growth in productivity and output should increase the demand for higher education.

economic theory. Krueger and Lindahl (1998) argue, for instance, that changes in human capital over time are measured less precisely than differences between the stocks of human capital across countries. They show that this lack of precise measurement would tend to bias the econometric results towards finding no effects of changes in human capital on growth. Once Krueger and Lindahl adjust for this type of statistical problem, they find evidence that countries that have a higher growth rate of human capital indeed tend to grow faster.

Finally, there is some evidence that the *quality* of education matters. Barro (1999) supports this claim, using information on test scores for science, reading, and mathematics, which are available for 51 countries. In particular, countries with better science scores seem to be doing significantly better in terms of growth. The same is true, although less clearly, for test scores in mathematics. When these indicators of quality of schooling are taken into account, the average years of secondary and higher schooling still constitute an important explanation of growth, although the quantitative effect falls by about one-half. This suggests, as one would expect, that both the quality and quantity of schooling have an important effect on growth.

3. Implications for Sweden

What message does the growth literature convey for Sweden and Swedish educational policy? From a macro perspective, it is remarkable to observe that Sweden, while being the fastest growing country in the world between 1870 and 1970, has subsequently been bypassed by fourteen OECD countries in terms of GNP per capita (Lindbeck, 2000). From now on, these countries are labelled the *C14*. One possible explanation could be, according to Leamer and Lundborg (1997), that Sweden has had less human capital accumulation than the C14 group. In this section, we assess the validity of this claim by reviewing human capital accumulation, educational participation, and the flow of graduates in selected fields in Sweden relative to other OECD countries.

3.1. Human capital in Sweden

In order to understand the role of human capital accumulation (education) in accounting for Swedish growth performance, we present a number of measures of educational performance for Sweden and contrast them with corresponding measures for other OECD countries (see also Edin, Fredriksson and Holmlund, 1993).

3.1.1. Human capital stocks

To measure the growth in human capital across countries, we use data from Barro and Lee (1993), who base their estimates on various UNESCO reports.[8] Figure 1 shows a standard measure of the stock of human capital—the average years of schooling for the adult population over 25.[9] The graph shows that during the whole period 1960-90, the stock of human capital in Sweden was substantially larger than in the C14 countries, but substantially lower than in the US.[10] The C14 figures are based on population weighted averages. In fact, between 1970 and 1990 Sweden increased its educational advantage over the C14 from .7 years to 1.2 years! Sohlman (1999) confirms this picture. Using OECD data, she shows that Sweden's position in terms of average human capital, relative to main competitor (OECD) countries, *improved* during the 1970s and remained constant during the 1980s and 1990s. However, if we look at the average years of higher education (Figure 2), the expansion of Swedish educational attainment is practically identical to that of the C14. Sweden has had a .1 year lead over C14 throughout the period.

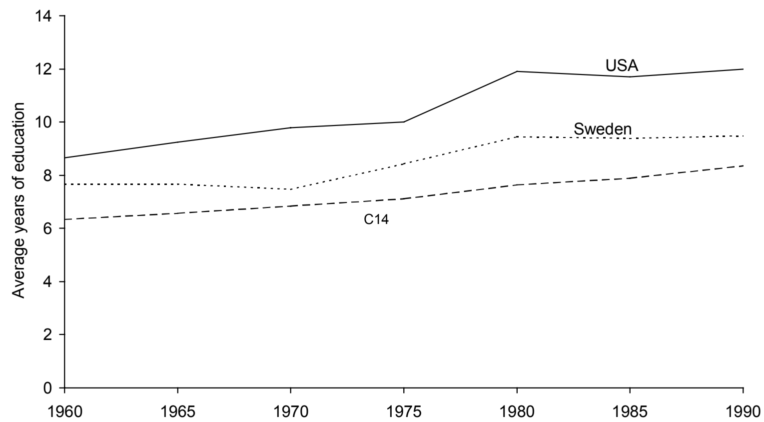
These data show that the stock of human capital, as measured by the average years of education of the population aged 25 and over, has not declined in Sweden, relative to the C14 countries. Therefore, it is unlikely that changes in the average human capital stock can explain the slowdown in Swedish economic growth.

[8] Barro and Lee's database has been widely used as the main source of information for empirical growth studies across countries. It contains information at five-years intervals for 126 countries for the period 1960-90.

[9] There are, of course, some problems associated with this measure: education does not necessarily measure skills, and education is heterogeneous, so degrees in e.g. engineering and humanities are counted alike.

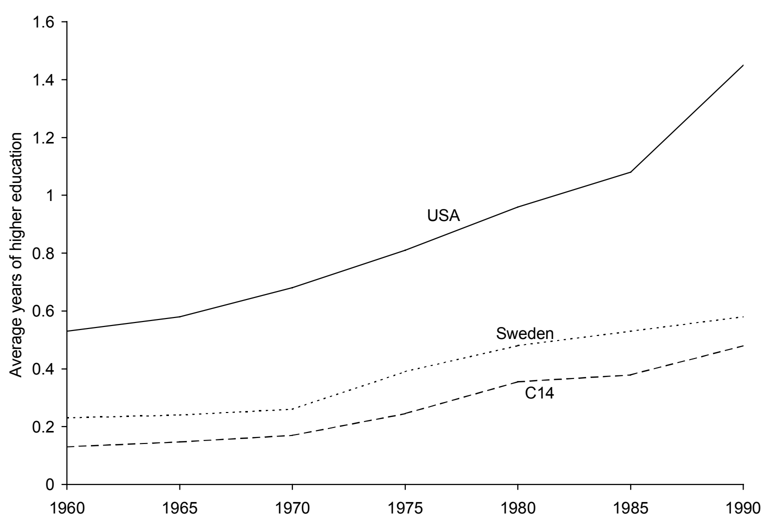
[10] The sharp increase from 1975 to 1980, followed by a decrease from 1980 to 1985 suggests that the observation for average years of schooling in the US in 1980 (Figure 1) is likely to be subject to some measurement error. However, even if we ignore this observation, the fact that the average years of schooling in the US (i) is higher; and (ii) has been growing faster since 1960 than in Sweden and the C14 countries, remains clear.

Figure 1. Average years of education for population over 25



Source: Barro & Lee (1993).

Figure 2. Average years of higher education for population over 25

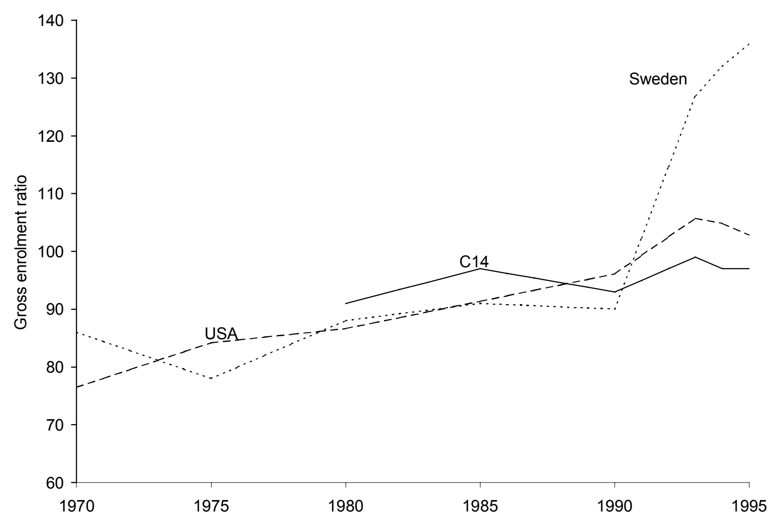


Source: Barro & Lee (1993).

3.1.2. Human capital accumulation—flows

We now turn our focus to the *flows* of human capital. Figure 3 shows the participation rates in secondary education 1970-1995 for Sweden, the C14 and the US, according to UNESCO Statistical Database and UNESCO (1998). The graph suggests that participation in secondary education was roughly equal across Sweden, C14 and the US between 1970 and 1990. Due to the so called *Kunskapslyftet* (an expansion of secondary education for grown-ups as part of a policy offensive against unemployment—see Sohlman, 1999) the participation rate in Sweden increased in the mid 1990s.[11]

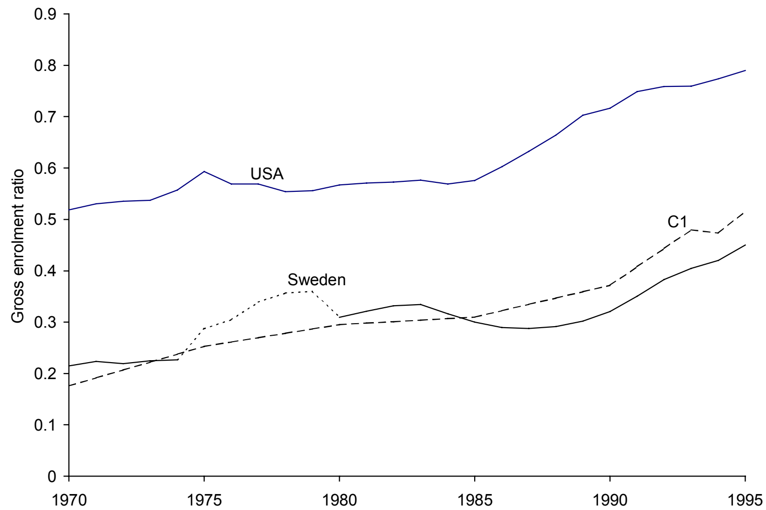
Figure 3. Gross enrolment ratio for secondary education



Source: Barro & Lee (1993).

[11] This statistic is computed by taking the number of people in secondary education divided by the size of the population in the relevant age groups, e.g. 13-18 for Sweden. As "Kunskapslyftet" puts a number of middle-aged individuals into secondary education, the gross enrolment ratios can exceed 100 per cent, as it appears in Figure 3 for Sweden after 1992. The database is accessible on http://unescostat.unesco.org/database/DBframe.htm.

Figure 4. Gross enrolment ratio for tertiary education.



Source: Barro & Lee (1993) and UNESCO.

Figure 4 shows the enrolment ratios in higher education for the period 1970-1995.[12] For Sweden, enrolment rose by less than 8 percentage points between 1970 and 1988, well below the increase for the C14 (over 17 percentage points) and the US (over 14 percentage points). Thereafter, there has been a substantial expansion of enrolment in higher education (16 percentage point increase between 1988 and 1995), in line with the expansion in the C14 countries (+17 percentage points) and the US (+12.5 percentage points). The differences in the Swedish pattern of development across the two subperiods may be explained in two ways: changes in wage premia and changes in unemployment. Fredriksson (1997), for instance, argues that the changes in wage premia in 1968-1991 can account for most of the changes in enrolment during that time period, although changes in unemployment also matter significantly. During the 1970s,

[12] The jump in enrolment in 1975 for Sweden (Figure 4) is due to a change to a broader definition of higher education without a revision of previous figures. Note also that the observations for the years 1975-1979 are dashed as the change of definition in 1975 was accompanied by a significant measurement error which was not corrected before 1980.

wages became increasingly compressed—the after-tax premium on higher education declined from 11.5 per cent in 1968 to .5 per cent in 1981 (Edin, Fredriksson and Holmlund, 1993)—while unemployment remained very low. During the 1980s, however, the after-tax wage premium started to increase (from .5 per cent in 1981 to 4.5 per cent in 1991). Concerning unemployment, it is well known that this rose sharply in the early 1990s. This may have increased the incentives for people to undertake higher education (low unemployment increases the opportunity cost of going to school, as also argued by Leamer and Lundborg, 1997). Thus, both increased wage premia and higher unemployment may have contributed to bringing Sweden back to the trend of the other industrialised countries in terms of enrolment in tertiary education (note, however, that this trend started already in the late 1980s, before the rise of unemployment).

Cross-country comparisons of enrolment rates are somewhat problematic, due to differences in school systems. Bearing this proviso in mind, it is interesting to notice that enrolment rates in the C14 countries surpassed those in Sweden during the mid 1980s, while the US rates remained at a 20-30 per cent higher level throughout the whole period. Although the differences between Sweden and the C14 do not look very large—about 6 percentage points—and have not increased since 1988, we find it alarming that Sweden, which had traditionally substantially higher educational achievements, has lagged behind the major industrialised countries since 1985.[13]

Next, we turn to the *composition* of education. Using data from the OECD Educational Database, we explore whether the composition of education in Sweden has evolved in a different way than in the C14 and the US. In particular, one could conjecture that, although higher education was expanding, the expansion might have been driven by enrolment in fields that are less important for growth, while the same has not occurred in other OECD countries. The data, however, do not support this conjecture. The number of university level science graduates in 1994 (engineering, math, and natural sciences) as a percentage of the total number of university graduates is higher for

[13] These findings are consistent with Sohlman (1999). She documents, for instance, that, in terms of higher educational attainment, Sweden's position relative to the main competitors is weaker for the younger cohorts in the labor force: Sweden ranks fifth, third and second among its main competitors for the age groups 25-34, 35-44 and 45-64, respectively.

Sweden (25.5 per cent) than for both the C14 (22.9 per cent) and the US (15.4 per cent).[14]

We also consider the time series evidence concerning the number of graduating engineers. The supply of newly educated engineers could be of special importance, if they acquire cutting-edge knowledge in school and the adoption of new technologies, in driving growth (Section 1.2). Indeed, Murphy et al. (1991) find that engineers matter significantly for growth. Table 1 shows the number of engineering graduates per 100,000 inhabitants in Sweden and the US in the period between 1971 and 1994 (corresponding data for all C14 countries are, unfortunately, not available).[15] As is evident from the table, the number of Swedish engineering graduates was substantially below the corresponding US figure in 1970, irrespective of whether we consider only Bachelor degrees or include Masters and Ph.D. degrees. By 1994, however, Sweden had basically caught up with and surpassed the US in terms of undergraduate engineering degrees.

Cross-country comparisons of educational attainment, especially disaggregated by field of study are always problematic. Hence, all conclusions should be taken with caution. Our overall feeling is, however, that, even though the expansion of higher education was slower in Sweden than in the C14 in 1978-1993, it seems unlikely that this has been an important factor behind the economic slowdown. Moreover, when considering a specific technology-oriented field of study—engineering—the Swedish performance during this period seems quite strong, even compared with the US.

[14] When expressed as a proportion of the working population, however, the C14 and the US had, respectively, about 25 per cent and 50 per cent more science graduates than Sweden in 1994. Note that these figures concern *university* degrees only, while Figure 4 include all forms of higher education. The data from the OECD Educational Database can be freely accessed at http://www.oecd.org/cde/EDU_UOE/datasets/RGRADSTY.html. For methodological details, see Barro and Lee (1993).

[15] We would like to thank Johan Sittenfeld at Civilingenjörsförbundet for providing data on the number of graduating civil engineers.

Table 1. The number of engineering graduates per 100,000 inhabitants in the US and Sweden

	1971	1980	1985	1990	1994
Sweden: Civil Engineers	26.8	35.3	38.4	44.7	59.0
USA: Bachelors	38.7	45.7	60.3	49.4	46.0
USA: Masters + PhD + Bachelors	54.2	58.1	75.9	67.5	67.1

Note: "Masters + Ph.D. + Bachelors" refer to the total number of engineering degrees awarded at all university levels.
Source: Civilingenjörsförbundet and Statistical Abstract of the United States 1997.

3.1.3. Quality of education

Lastly, we turn to the quality of the educational system. As discussed above, cross-country evidence suggests that the test scores in science and mathematics matter significantly for growth. Table 2 reports the available test scores for 13-year old students (once again the data set is from Barro and Lee, 1993). The scores in mathematics reveal that the performance of Sweden was poor, relative to other countries, in 1964 and 1982 (the lowest scores among all sampled countries). However, it improved somewhat during the 1990s—nudging past the US, for instance. In science, which, according to Barro (1999), has the strongest predictive power for growth, the performance of Swedish students is about average (although slightly worse in 1993-98 than in 1984).

Any conclusion based on these limited observations has to be taken with caution. Overall, the evidence collected suggests that the quality of education provided by Swedish (primary) schools is of an average standard relative to that of other OECD countries. As discussed in Section 2, there is evidence that the quality of schooling (especially as measured by test scores in mathematics and science) exerts a positive influence on growth. Accordingly, there would appear to be scope for policies that aim to improve the quality of the Swedish educational system, especially in the areas of mathematics and science. We see, however, no clear evidence of a deterioration over time in the levels of knowledge of Swedish students relative to other OECD countries. Thus, if knowledge in mathematics and science was equally important for growth in the 1960s as in the 1990s, changes in the quality of the Swedish school system do not seem to account for the disappointing growth performance of Sweden after 1970.

***Table 2*. International test scores in mathematics and science**

	Math	Math	Math	Math	Science	Science	Science	Science	Science
	1964	**1982-1983**	**1988**	**1993-1998**	**1970-1972**	**1984**	**1988**	**1990-1991**	**1993-1998**
	13	13	13	13	14	13	13	13	13
Country									
Canada		50.9	52.3	49.4		62	50.6	68.8	49.9
USA	25.4	46	47.4	47.6	27	55	47.9	67	50.8
Japan	46	63.5		57.1	39	67.3			53.1
Austria				50.9					51.9
Belgium	43.4	52.8		53.3	22.9				48.5
Denmark				46.5					43.9
Finland	37.7	48.2			25.6	61.7			
France	30	53.5		49.2				68.6	45.1
Germany	36.3			48.4	29.6				49.9
Iceland				45.9					46.2
Ireland			50.4	50			46.9	63.3	49.5
Italy					23.1	55.7		69.9	
Luxembourg		37.9							
Holland	30.6	58.1		51.6	22.3	66			51.7
Norway				46.1		59.7			48.3
Sweden	21.9	43.5		47.7	27.1	61.3			48.8
Australia	27			49.8	30.8	59.3			50.4

Note: Test scores in mathematics and science for 13- and 14-years-old students: international comparisons since 1964.
Source: Barro & Lee (1993).

4. Conclusions

This chapter has explored the relationship between education and growth, and discussed the implications for Sweden.

Modern theories of economic growth emphasise the idea that education is a key factor for sustained economic growth. Indeed, the empirical literature documents robust evidence that countries with a better educated labour force perform better in terms of growth.

Moreover, some evidence suggest that countries which have increased their educational achievements over time have improved their growth performance.

We have reviewed the theories based on human capital accumulation as the engine of growth. A major implication of these theories is that a country's growth rate could be permanently raised by increasing the efficiency of the education sector and by inducing people to undertake more education. We have stressed that an important part of the policy of providing good educational services involves hiring highly qualified, motivated and talented teachers, and providing them with incentives to do a good job. In order for high-ability individuals to be attracted to the teaching profession, teachers' salaries should reflect the importance that society places on this job and on its role in promoting future growth.

We have also discussed the issue of whether an egalitarian or elitist school system is better for promoting growth, excluding considerations about social justice. While the implications of different theories are fairly diverse, our view can be summarised as follows. We believe that it is important to maintain the general egalitarian character of the Swedish educational system, especially at the primary and secondary level. At the same time, the theories of research-driven growth suggest the importance of introducing a greater emphasis on rewarding excellence, in particular in higher education. In our view, the entire society would benefit from the establishment of top-notch research centres which both promote basic research directly and can train highly qualified students, especially in the areas where spillovers are most important (engineering, computer science, medicine, economics etc.).

We also believe that it is important that young people have monetary incentives to undertake the "right" economic activities. The educational premium in Sweden is exceptionally low compared to other countries (Asplund and Telhado Pereira, 1999, Table 4). Part of this is due to an institutional compression of the wage structure relative to the differences in labour productivity between employees with and without a university degree.[16] This implies that, in many cases, the private return from choosing the "right" education is too low, and fails to induce a socially desirable career choice.

[16] An alternative view is presented in Edin and Holmlund (1995), who argue that the fall in the wage premium for university graduates between 1970 and the mid 1980's can be accounted for by the increase in the supply of university graduates.

We have argued that in recent years the cost of this distortion may have increased due to the (skill-biased) nature of technical progress, which, in Sweden, has been translated only to a very limited extent into increasing wage inequality.[17] Some of the effects of this distortion on the educational choices of individuals may have already manifested themselves in lower enrolment ratios in higher education compared to the other major industrialised countries. While this has not yet given rise to a large reduction in the Swedish human capital stock relative to that of other countries, the continuation of this tendency might be highly detrimental for future economic growth. We advocate, therefore, labour market reforms which introduce greater flexibility into the wage structure. At the same time, public policy should strengthen the commitment to education and research and promote continued growth in investment in schooling.

[17] Flam (1987) and Lindqvist (1999) also study the costs of wage compression, but their analyses lie outside of the endogenous growth framework.

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