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Contents

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Editorial

This volume is a collection of papers presented and discussed at the workshop "Current Issues of Economic Growth", organized by the Oesterreichische Nationalbank on March 5, 2004 in Vienna. The goal of the workshop was to discuss recent advances in economic growth theory, related empirical studies as well as policy implications. Emphasis was placed on issues that appear to be particular challenges for Austria and other EU countries in the years ahead, such as the role of R&D and human capital formation as well as the possible impact of ageing on productivity and long-run growth.

In his **introductory statement**, *Peter Mooslechner*, OeNB, pointed out that even small growth differentials have rather severe consequences for relative per capita incomes and therefore living standards when accumulated over a long time span. Thus, growth theory and policy can have quite a large impact on economic welfare in the long run.

The contribution by *Bart Verspagen*, Eindhoven University of Technology, focused on the **role of R&D** ratios in Europe. Albeit an ambitious target, the planned increase in R&D spending to three percent of GDP by 2010 as described in the conclusions of the Barcelona Council 2002 will not be enough to reach the productivity level of the U.S.A. according to the simulations presented by Verspagen. Raising R&D expenditure must go hand in hand with other measures, such as human capital development to increase absorptive capacity as well as institutional reforms which encourage interaction between researchers in public and private organizations and ensure an appropriate level of intellectual property rights protection. *Michael Peneder,* WIFO, interpreted the findings as confirmation of the need for micro-level, productivity enhancing structural reforms. In addition to R&D, also incremental production process improvements as well as human capital investments are key to the development of total factor productivity.

The next session of the workshop was devoted to international **technology spillovers** as a source of technological change. International spillovers are often thought of as the main driving force behind productivity growth in small open economies like Austria. In two papers, *Stephen Redding*, London School of Economics, and *Johann Scharler,* Oesterreichische Nationalbank, emphasized that investing in one's own R&D and human capital are important determinants of a country's absorptive capacity, i.e. the ability to absorb and take advantage of technologies initially developed abroad. Thus, R&D and human capital do not only contribute directly to productivity growth but also indirectly via facilitating international technology spillovers. In addition, the second contribution to this session also presented evidence indicating that highly regulated product and labor markets can act as a barrier to the adoption of new technologies. *Robert M. Kunst,* University of Vienna, noted that absorption of foreign technology does not necessarily imply convergence to the leader´s technological level.

In the third session, *Angel de la Fuente*, Institute of Economic Analysis, presented a new, improved data set for measuring **human capital**. Although economic theory leaves little doubt on the importance of human capital formation for long-run growth, it has turned out to be difficult to find unambiguous empirical evidence confirming this relationship. As emphasized by de la Fuente, this might be due to the relatively bad quality of the data sets used as a basis for empirical research. Using de la Fuente´s improved data set, a positive and significant relationship between human capital and productivity is be established. *Jesús Crespo-Cuaresmo*, University of Vienna, showed that different data sets used in the literature provide contradictory conclusions on both the existence and the evolution of a convergence of educational attainment in industrialized countries.

The last session analyzed the **consequences of population ageing for economic growth.** While so far neglected, the issue is important and warrants further research since population ageing is likely to have severe consequences not just for pension and health care systems but also for productivity. *Alexia Fürnkranz-Prskawetz*, Vienna Institute for Demography, finds in her simulations that the – likely imperfect - substitutability between workers of different age groups substantially influences future productivity developments. Raising Austrian labor force participation rates to Northern European levels offers an opportunity to compensate for the expected shrinkage of the labor force due to population ageing. *Landis MacKellar*, Vienna Institute of Demography, quoted evidence that labor productivity indeed declines somewhat with age. The substitutability among younger and older workers likely differs by sector. Whereas in jobs where physical strength is required young workers are at a clear advantage and training cannot make up for age-related loss of performance, in “knowledge jobs” firm-specific knowledge and networks make up for older workers´ outdated skills, and training can to some extent increase the substitutability between age groups. Countries with flexible labor markets are better adapted to respond to ageing than countries with seniority-based wage systems. Ageing may shift labor to low-productivity sectors such as personal services and health care, and it may bias technical progress towards the health sector.

Thomas Lindh, University of Uppsala, argued that population ageing will imply a growth slow down, if no countermeasures are taken. Current growth levels might be preserved by a broad approach comprising intensified and longer utilization of existing human capital combined with labor imports and increased fertility. Important intergenerational issues are raised by ageing. *Helmut Kramer,* WIFO, emphasized the huge macroeconomic and societal implications of ageing, so far not duly recognized by policy-makers. A strategic combination of measures to meet this problem is required and should, in addition to indispensable parametric reforms of pension systems and an increase in labor participation and productivity rates as well as an integration of unemployed into the work process, also include foreign investments by rich, ageing nations in demographically younger nations. Kramer expected that the demographically induced increasing labor scarcity will automatically boost labor productivity and emphasized education as a key ingredient to any comprehensive strategy, so far not sufficiently recognized by decision-makers.

To conclude, the workshop showed that **no single measure** will be able to raise productivity and potential GDP growth in Austria and the EU sufficiently to live up to the aspirations of the Lisbon strategy. Rather, a comprehensive strategy is required which takes due account of various **complementarities** between R&D, human capital, demographic developments and many other policy areas, both within and across countries. The Lisbon Agenda provides a useful framework but considerable further work, both at a conceptual level and in terms of **coherent implementation**, will be required in the years to come.

Ernest Gnan
Jürgen Janger
Johann Scharler

The Challenge of Economic Growth: What Are the Issues?

Peter Mooslechner

".....the rate of growth, a concept which has been little used in economic theory, and in which I put much faith as an extremely useful instrument of economic analysis."

Evsey Domar (1946)

When we first started to think about organizing a workshop on growth issues the world was under the impression of the "New Economy" miracle, in particular in the U.S., and the discussion in Europe was developing around the question if and how Europe could or could not participate in this new phenomenon. This was also the time when the Lisbon agenda was set up to define a strategy and a set of measures how Europe possibly could cope with the U.S. growth and productivity challenge.

Soon afterwards the situation changed completely. The year 2000 stock market correction as well as a number of additional shocks brought the long-lasting period of growth in the U.S. to a sudden end and the whole world went into a severe cyclical downturn. But, once again, this made growth issues – now from a somewhat different perspective – one of the core economic policy questions. Therefore, growth problems continue to stay at the forefront of European issues, in particular, because the cyclical downturn in Europe turned out to be not only much longer than expected but also significantly worse compared to almost all other parts of the world. At the same time, the mid-term review of the Lisbon agenda under way will raise the fundamental growth issues again in a European economic policy context.

In general, and as the recent situation in Europe illustrates, it is not only very complicated to distinguish between short-term cyclical episodes of low growth and deficiencies in long-term (potential) growth performance, the fundamental questions of growth and their discussion are by no means new in economic history. Two quotations from the economic literature may illustrate the historical dimension of the problem:

As early as in 1977, Joan Robinson wrote in her famous paper "What are the Questions", published in the Journal of Economic Literature: "In this situation, the cry is to get growth started again. The European countries in a weak competitive position plead with West Germany to spend money on something or other to improve the market for the rest so that they can permit employment to increase. Any up turn in the indicators in the United States is greeted as a sign that we shall once more be pulled up out of the slough."

And Gregory Mankiw in the 25th anniversary issue of the Brooking Papers on Economic Activity in 1995 wrote on "The Growth of Nations": "After many years of neglect, these questions are again at the centre of macroeconomic research and teaching." "There is an increasing consensus that the role of capital in economic growth should be interpreted more broadly." ……..and……. "Yet some recent work on economic growth suggests that a more activist government could be beneficial."

Why Concentrate on Growth?

Why is growth important? Why have some countries grown rich while others remain poor? It is hard to think of a more fundamental question for economists to answer. (Temple, 1999). It is well known – but neglected most of the time - that even moderate growth differentials can lead to substantial differences in the level of per capita GDP – and hence also in welfare - across countries. This is in sharp contrast to business cycle fluctuations which are often found to have minor welfare implications overall. Thus, growth theory appears to be the branch of macroeconomics that really matters in the long-run, although good cyclical policies may be seen as an important prerequisite to become successful.

To appreciate the consequences of apparently small growth differentials the following example borrowed from Barro and Sala-i-Martin (1995) is quite useful: The U.S.A. has grown on average by 1.75 % over the period 1870 to 1990. If the average growth rate had been lower by just one percentage point, than U.S. real per capita GDP in 1990 would have been quite close to that in Mexico or Hungary and also around USD 1.000 below that in Portugal or Greece. But growth obviously matters not only for income levels. Okun's law, or rather, the negative association between unemployment and GDP growth, can still be observed. At the same time and obviously of crucial importance today, sufficient growth also takes away pressure from public finances and makes long-term oriented policies possible and much more likely.

Europe vs the U.S.A.: The Ongoing Growth Match

Many times, relative growth performance between countries and rankings of countries in growth performance are in the centre of public interest. History tells us that the relative growth performance of countries as well as their rank according to GDP- or wealth levels changes considerably over time, due to a large number of different factors. Even looking at the historical period since industrialization only, countries like Argentina or the Czech Republic once ranked among the most developed countries of the industrialized world, which today clearly have lost position compared to the group of high income countries. In the same vain, history since World War II can be interpreted as a sequence of growth comparison stories – and, much more, of growth gap stories - between Europe and the U.S.A., with the U.S.A. in the lead during some periods and Europe in the lead during others.

Nowadays, it is usually claimed that economic growth in Europe has been lagging behind the U.S.A. since the 1980s. Even more worrying - for the first time in decades the EU is now on a lower trend productivity growth path than the U.S.A.. Or, how the OECD postulates the question in its recently published growth project: "What makes some countries seemingly able to thrive on new technological opportunities while others are held back?" (OECD, 2003a and 2003b).

Looking a little bit behind the available figures, European economic performance is not that bad in a long-term perspective. Over 10 years there is an almost equal performance of the U.S.A. and the EU in growth per capita and productivity growth (Daly, 2004). From 1993 to 2003, GDP per head grew at an equal rate of 2.1% in the U.S.A and in the Euro area without Germany, which still suffers from the consequences of the reunificiation as the latest OECD country survey (2004) concedes. With Germany, the Euro area achieved a growth rate of 1.8% which is only slightly lower than 2.1%. In addition, since 1997 European employment has grown by 8%, whereas employment in the U.S.A. has only grown by 6%. As Lisbon relates to a long-term programme (10 years), this time span should be adopted for the economic analysis as well.

Europe seems now to be somewhat similar than the situation was in the U.S.A. in the 1980s – raising employment prevents productivity gains in the short term. We should also mention that the recent American recovery which has widened the gap relative to Europe has been supported by a unprecedented large fiscal and monetary stimulus and is certainly not only – if at all - the result of America's superior supply-side performance. In a recent article, The Economist (2004) writes that optimistic American policymakers stress success, while playing down macro-economic imbalances (and acting rather pragmatically on economic policy), while European policymakers only complain.

Last but not least, there is another important empirical aspect to be mentioned here, although it is clearly beyond the European topic to be discussed here: Africa. “We have learned a lot about growth in the last few years. However, we still do not seem to understand why Africa turned to have such dismal growth performance…..Understanding the underlying reasons for this gargantuan failure is the most important question the economics profession faces as we enter the new century.” (Sala-i-Martin, 2002).

What Can Growth Theory Tell Us?

The number of insights – both theoretically and empirically – has increased tremendously since the renewed interest in economic growth that started in the mid 1980s because of the lack of convergence to U.S. income levels. Although factor accumulation is important, it seems to be mainly growth in total factor productivity (TFP) which determines long-run growth. This means that those countries which are best able to introduce new work practices – i.e. raising the efficiency of the input factors - will grow fastest. For example: The recent productivity pick-up in the U.S.A has been linked to the role of ICT in the economy – a general-purpose technology that is changing work practices and may be one of the drivers of TFP-growth.

In this particular context, Easterly and Levine (2002) – when documenting what they call five stylized facts of economic growth – stress very much the importance of “something else” besides factor accumulation to play a prominent role in explaining differences in economic performance. The TFP-residual accounts for most of the cross-country and cross-time variation in growth. And they also conclude, that overall growth is highly unstable over time, while factor accumulation is much more stable. In a very stimulating way Jones (2003) addresses the whole issue from the perspective of “ideas”, how they are produced and how they contribute to understand TFP-growth.

Some of the main drivers of or barriers to TFP-growth are the core of the European agenda today – R&D, R&D diffusion, human capital as well as ageing. The important contributions of R&D and human capital to TFP growth has been known for some time, but new theoretical and empirical work sheds new light on those issues. That ageing may not only have consequences for public finances, but also for productivity growth is a very recent and urgent issue developed in the much broader context of the ageing agenda.

There are important effects of each of these elements, but there is no single cause. It seems that each country pursues a rather different growth mix determined by its productivity growth regime. Several studies show that TFP growth has more country-specific components than it has cross-country components. This suggests a large role for national policies and to take a much broader picture of a country's overall structural features to be relevant in this context. In face of the population ageing and the declining productivity trend in Europe, the need for an explicit growth strategy is obvious but very hard to agree upon below the level of (too) general policy messages.

Many empirical findings remind us to be very careful in our (pre-)judgement of economic performance and in our pinpointing the "culprits" come out of a paper by Pritchett (2000) and a recent paper by Hausmann, Pritchett and Rodrik (2004). The first tells us that the more typical pattern of economic growth is that countries experience phases of growth, stagnation or decline of varying length. The second finds that what they define as growth accelerations (an increase of per-capita growth of 2% sustained for eight years) is highly unpredictable and that most instances of economic reform do not produce successful growth accelerations. It finds as well that growth accelerations seem to require more investment, more exports and a more competitive real exchange rate. They do not seem to happen by pure accelerations in total factor productivity alone. Of course, this does not mean that reforms are not necessary and that we can be complacent, but one should keep in mind that we should be careful blaming slow growth only on very narrow reasons.

At the same time, one very important development also seems to be, that the new economic growth literature has quantified the importance of having the right institutions to let growth develop (Sala-i-Martin, 2002). Empirically, it has become increasingly clear that institutions are an important determinant of growth, but we are still in the early stages when it comes to incorporating institutions to our theories. For example: What are better institutions and policies for encouraging the efficient amount of research? The extent to which individual firms might underinvest in research as well as estimates of the "true" social rates of return to research are well documented in the literature. To the extent the marginal benefit of research to the overall economy and to society are underestimated, better institutions might improve allocations and thereby foster welfare and growth (Jones, 2003).

The Lisbon Agenda and Growth Policy

The EU-Lisbon Strategy of March 2000 has the intention to make the European Union the "most competitive and dynamic knowledge-based economy in the world" by 2010. The member states are to meet a number of defined and mostly quantified targets in this respect. Beyond the overall strategy defined at EU level, there is a clear need for national formulation because different situation, institutions and structure of the economy in each country.

The focus of the Lisbon midterm review process should be placed on how to reach the numerical Lisbon targets in employment, R&D spending, schooling etc. rather than on analyzing the recent growth performance and suggesting new fields of economic policy measures. The main question is how to foster timely and successful implementation of measures that move the European economy closer to an improved macroeconomic outcome – ranging from better growth to higher employment and improved long-term competitiveness. Of course, an agreed theoretical blueprint of determinants of growth and TFP is crucial for addressing the right (intermediate-) targets and selecting the right instruments.

There seem to be two (conflicting) views on how a successful implementation of policies can be achieved:

One maintains that only a real economic crisis will produce the necessary acceptance for change, while the other calls for a pronounced upswing to facilitate reforms. Definitely, the first view cannot be a sensible guide for action as no politician will actively try to produce a (national) crisis, which would be very costly in macroeconomic terms. By comparison, an explicit growth strategy will not only generate more resources to spend on knowledge investment, ICT infrastructure etc., at the same time, changes and structural reforms necessary are always easier to implement in a growing economy, in particular at lower political cost. For example, the International Monetary Fund (IMF), (2004) recommends in a recent study to take advantage of recoveries for structural policies and states that (p. 132) "*in practice, it can be difficult to undertake fiscal adjustment and structural reforms simultaneously*". Structural reforms should be of high priority at times of favourable cyclical prospects and, therefore, for public finances. The first priority for the success of the Lisbon strategy must thus be a pronounced and sustained economic upturn and a European macroeconomic policy mix that makes this possible. How can we achieve this while making sure that those favourable economic conditions will be effectively used for implementing measures to reach the core structural Lisbon targets? Sequencing of measures to be implemented should be pragmatic and concentrate on reforms first which will boost private consumption and confidence.

In this respect, one has to bear in mind that many of the structural reforms necessary and policy measures to be implemented are quite costly and may require more fiscal leeway than currently foreseen under the Stability and Growth Pact - if we think for instance of investment in human capital or a higher share of R&D expenditure. It is also extremely important to get reforms to be undertaken accepted in society. A proposal which refers to an idea of the pioneering public-finance economist Richard Musgrave from Harvard for example suggests to exclude growth enhancing public expenditures (such as public investment) from the current budget. The idea behind this proposal is that those public expenditures that generate benefits to future generations do not have to be financed by current budgetary revenues but can be financed by debt – very similar to the arguments behind private investment decisions. Although a (credible) implementation of this proposal may be quite complicated the basic idea of generating focus on growth enhancing public expenditures and raising the share of such expenditures in public budgets is also part of the EU tool kit for improving the overall quality of public finances.

For each of the five domains of the Lisbon Strategy (employment, research and innovation, economic reform, social cohesion and sustainable development), the EU has set itself targets, sometimes numerical ones. Instead of complaining generally it is essential to talk at the European and national level at the same time about where a country stands numerically in comparison with the Lisbon targets. In the spirit of Kok (2003), there is a need to formulate clear national policies with targets reflecting those agreed at the EU level. Why is the employment ratio in country A only at 62%, what measures could we take to increase it? Why is the R&D ratio in country B only at 1,5%, why does the transposition rate of the Lisbon directives stand at only 60% in country C, why have only 70% of 22-year olds in country D completed upper secondary education, what measures…

Building a constructive atmosphere involving governments, academia, social partners and the civil society and creating a feeling of Europe moving forward in a socially accepted way would speed up the implementation of measures and strengthen consumer confidence urgently needed. Another advantage of addressing more precisely the numerical benchmarks would be to put targets into focus which can really be influenced by national governments, whereas the overall growth rate can only be influenced via those benchmarks very indirectly and, at best, in the medium-term. (Improved) overall economic performance should be looked at once all the numerical targets (benchmarks) set in the Lisbon strategy have been achieved.

As Kok et al. (2003) also stress clearly, the success stories of a number of Member States show that apart from a clear vision about to path to sustainable growth and social cohesion, strong political will and co-ordinated efforts of all actors and relevant social groups are crucial. A national growth strategy (or a strategy for each Lisbon domain) could be both a vehicle for a clear vision and a co-ordinating device for all actors. Such a strategy could work like the goal of EU-Membership worked for the new member states, qualification for EMU or many other similar experiences, as a general accepted anchor of targets to be achieved and of policies to be implemented.

References:

Blanchard, O. 2004. The Economic Future of Europe. NBER Working Paper 10310.

Barro, R. and Sala-i-Martin, X. 1995. Economic Growth. New York.
Bresser Pereira, L. C., J. M. Maravall and A. Przeworski. 1993. Economic reforms in new democracies: A social-democratic approach. Cambridge: Cambridge University Press.
Daly, K. 2004. Euroland's Secret Success Story. Goldman Sachs Global Economics Paper No. 102.
De Grauwe, P. Europe could use a little economic optimism. In: Financial Times, 10.06.2004.
Domar, E. 1946. Capital Expansion and Growth. In: Econometrica 14(1). 137-47.
Easterly, W. and Levine, R. 2002. It's Not Factor Accumulation: Stylized Facts and Growth Models. Banco Central de Chile. Working Paper No.164.
Fernandez, R. and D. Rodrik. 1991. Resistance to Reform: Status Quo Bias in the Presence of Individual-Specific Uncertainty. In: The American Economic Review 81(5). December. 1146-1155.
Flash Eurobarometer N. 153. The euro, two years later. December 2003.
Hausmann, R., L. Pritchett and D. Rodrik. 2004. Growth accelerations. NBER Working paper N. 10566.
International Monetary Fund. 2004. Fostering Structural Reforms in Industrial Countries. In: World Economic Outlook. 103-146.
Jones, C. 1999. The New Growth Evidence.
Jones, C. 2003. Growth and Ideas, Mimeo.
Kok, W. (Chairman). 2003. Jobs, Jobs, Jobs. Creating more employment in Europe. Report of the Employment Taskforce.
Mankiw, N. G. 1995. The Growth of Nations. In: Brookings Papers on Economic Activity (1). 275-326.
OECD, 2003a. Sources of Growth, Paris.
OECD, 2003b. The Policy Agenda for Growth, Paris.
OECD. 2004. Regulatory Reform in Germany: Consolidating Economic and Social Renewal. Paris.
Robinson, J. 1977. What Are the Questions? In: Journal of Economic Literature 15(4). December. 1318-1339.
Rodrik, D. 1996. Understanding Economic Policy Reform. In: Journal of Economic Literature 34(1). March. 9-41.
Sala-i-Martin, X. 2002. 15 Years of New Growth Economics: What Have We Learnt? Columbia University. Department of Economics Discussion Paper Series #0102-47. April.
Sapir, A., P. Aghion, G. Bertola, M. Hellwig, J. Pisani-Ferry, D. Rosati, J. Viñals and H. Wallace. 2003. An Agenda for a Growing Europe: Making the EU System Deliver, Brussels.

Tabellini, G. and C. Wyplosz. 2004. Supply-Side Policy Coordination in the European Union. Report prepared for the Conseil de l'Activité Economique.

Temple, J. 1999. The New Growth Evidence. In: Journal of Economic Literature 37(1). March. 112-156.

The Economist. Special Report. 19.06.2004. Europe v America. P. 75-77.

European Productivity Gaps: Is R&D the Solution?

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1. Introduction

Industrialization, and the association between technological advance and economic growth, brought Europe world economic leadership in the 19th century. However, in the course of the 20th century, European leadership was lost to the United States, as well as a number of dynamic Asian economies, of which Japan was the first to emerge in the process of modern economic growth. This loss of European leadership is commonly associated with another major technological change: the rise of the mass production system in the United States (e.g., David, 1975).

The process of European integration, started after the Second World War primarily as a way of achieving political stability and peace, became a major force towards the realization of economies of scale in the European economies, and hence as a way for Europe to benefit more than it had done before from the mass production system. This had its highpoint in the realization of the 'Europe 1992' program, which created a single European market, without limitations or the free trade of goods and services or the free mobility of people (Tsoukalis, 1997).

As a result of this and other factors related to the diffusion of technology, Europe was able to catch-up to the United States over the long postwar period (e.g., Abramovitz, 1979, Nelson and Wright, 1992, Pavitt and Soete, 1982), and close some of the productivity gap that had emerged in the first half of the 20th century (especially during the 1930s and 1940s). However, as we will document below, at the dawn of the 21st century Europe still faces a major productivity gap relative to the U.S.A. and other world economic leaders, such as Japan.

- This fact of a European backlog relative to especially the U.S.A. and the dynamic Asian economies, led European political leaders to formulate an ambitious goal for the first ten years of the new millennium. At the Lisbon Summit in 2000 the governments of the European Union (EU) agreed on the goal of the EU to become by 2010 "the most competitive and dynamic knowledge-based economy in the world, capable of sustainable economic growth with more and better jobs and greater social cohesion".[1] This overall goal of the Lisbon Process has been embedded in a set of policy guidelines that include the following elements:
- Preparing the transition to a knowledge-based economy through better polices for the information society and R&D;
- Stepping up the process of structural reform for competitiveness and innovation and completion of the single market;
- Combating social exclusion and modernizing the European social model by investing in people;
- Sustaining the healthy economic outlook and favourable growth prospects by continuing with an appropriate macroeconomic policy mix and improving the quality of public finance.

To realize these goals, the review of the Lisbon Process at the Barcelona Summit in 2002 has explicitly emphasized the importance of Research and Development (R&D). One of its main recommendations calls for an increase in European R&D expenditure with the target to reach 3% of European GDP by 2010, two thirds of this to take the form of business R&D.[2] The main argument behind this target appears to be the concern that even if in the EU knowledge-intensive industries have been partially successful in creating employment over the last decade, productivity developments have been far less favorable (especially if measured against the U.S.A.). This underperformance is seen as a threat for European competitiveness and economic growth in general and, more specifically, for the achievement of the Lisbon goals and for the growth of national incomes and living standards. A related concern is the fact that the EU performs relatively low in input (business R&D) and output indicators (such as patents) of innovative activity. Public policy, with the aim to promote investment in business R&D, is therefore

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[1] Presidency Conclusions, Lisbon European Council, 23 and 24 March 2002, para. 5.
[2] Cf. Presidency Conclusions, Barcelona European Council, 15 and 16 March 2002 para. 47. For a review of the progress of the Lisbon Process up to then see *The Lisbon Strategy. Making Change Happen*, Communication from the Commission to the Spring European Council in Barcelona, COM(2002) 14 final, 15.1.2002.

seen as a key measure to prevent long-term economic decline (European Commission, 2002, Economic Policy Committee, 2002).[3]

As we argue below there is indeed major evidence that links R&D to productivity performance. Also, the adoption of the Barcelona target should contribute to close the gap in R&D intensities between the EU and the U.S. economies. However, the extent to which it can contribute to offset the productivity gap between the EU and the U.S.A. remains to be seen. On the one hand, as pointed out in the official documents as well, regulatory and other institutional differences might play important roles. On the other hand, the EU's trading partners will also benefit from increased European R&D by a higher R&D content of exports. Thus, for relative productivity, achieving the Barcelona target is not a zero-sum game. Based on a simulation exercise, which uses results from the literature and from a longitudinal dataset, the paper tries to assess this issue. It starts with a short discussion on the link between R&D and productivity growth. Section 3 presents an overview of the existing productivity gap between the EU and the U.S.A. and its development over time and sectors. Section 4 provides and discusses the simulation results. A conclusion sums up the main findings and puts them into the perspective of the debate.

2. The Link between R&D and Productivity

Economic theorists have accepted the positive link between technological change, productivity and economic growth for a long time. Process innovation provides opportunities for cost reduction. Product innovation enhances either the range of available intermediate inputs for the production process, increasing real output, or increases the availability of consumer products with corresponding welfare gains. Indeed, in modern economies, the inputs of capital and labor alone cannot account for a large part of output growth in modern economies (Solow, 1957). The concept of 'total factor productivity' (TFP) has been widely used as a measure to explain this residual (see Nadiri, 1970).

In a rich empirical tradition of work on productivity growth (e.g., Griliches, 1979), the total factor productivity residual has been related to the accumulation of a 'knowledge stock', which is not accounted for in the measurement of the conventional capital stock but increases output via innovation and technological change. R&D expenditures have been suggested as a way of measuring this knowledge stock, and this has led to a range of works relating R&D expenditures

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[3] See also *Productivity. The Key to Competitiveness of European Economies and Enterprises*, Communication from the Commission to the Council and the European Parliament COM(2002) 262 final, 21.05.2002.

to total factor productivity growth. This is consistent with the notion in 'new growth theory' of non-convexities of R&D and knowledge in output, which results in self-sustaining growth (as in Romer, 1986, 1990).

An important issue in this literature is the idea that R&D not only provides productivity benefits for the firms that undertake it, but also for other firms in similar or somehow related lines of business. This is the notion of R&D spillovers, indicating that the impact of innovation and technology is felt widely rather than being a private pay-off. In this context, Griliches (1979, 1993) pointed to the distinction between knowledge and rent spillovers. **Pure '**knowledge spillovers' are externalities arising from the public goods characteristics of technology and research without the need to engage in economic transactions. These externalities can arise from learning, observation and copying such as 'reverse engineering' and 'patenting around'. Other transmission channels result from formal and informal contacts and networks of scientists, professionals, clients and customers, which go beyond market transactions (Mansfield, 1985). Rent spillovers, on the other hand, are defined by a shift of innovation rents from the producer to the user of a certain technology due to competitive market pressures. From the perspective of the whole economy, this constitutes an unwanted measurement error in attributing productivity increases to the wrong entity and can in principle corrected by using adjusted output deflators (Triplett, 1996). Yet for an individual firm, industry or country, such effects result in real benefits with corresponding productivity increases. Empirically, however, both notions are somewhat difficult to separate, as market interaction can facilitate the exchange of technological knowledge. To reflect the different mechanisms of spillover transmission and absorption the empirical literature uses basically three different weighting schemes to aggregate a stock of indirect, spillover-related R&D. Tansaction-based weights emphasise to some extent the rent spillover component. Usually these are derived from interindustry sales (e.g. van Meijl, 1995), investment flows (e.g. Sveikauskas, 1981) or from a full input-output framework (e.g. Terleckyj, 1974, 1982, Wolff and Nadiri, 1993 or Sakurai *et al.*, 1996). In contrast, weighting by technological distance measures accounts for the fact that the absorption of knowledge spillovers is mediated by the technological proximity between receiver and transmitter. Such distance may be measured by the type of performed R&D (Goto and Suzuki, 1989), the qualifications of researchers (Adams, 1990), the distribution of patents between patent classes (Jaffe, 1986) or patent classifications and citations (Verspagen, 1997a,b). Technology flow matrices in a sense combine the two concepts of technological and 'market' proximity by identifying originators and (potential) users of a technology or an innovation. Scherer's user-producer matrix as well as the Yale matrix have been derived from patent statistics (Scherer, 1982, Putnam and Evenson, 1994).[4] Many empirical studies have found indeed a relatively high influence of R&D and related spillovers to productivity growth but the results depend in some measure on the construction of the spillover variable.[5] The findings that market transactions and technological closeness matter for productivity imply an extension of any meaningful empirical analysis to the global level, at least to the major trading partners. There is no *a priori* reason why international spillovers should be modelled differently than domestic spillovers. The total technology content of a product or a sector that matters for productivity contains the R&D performed by itself as well as the technology acquired by inputs from both domestic and foreign sources. For that reason, besides the more static advantages of getting an expanded set of inputs at lower cost (including frontier-technology), international trade is an important source for long-term development and catching-up (Fagerberg, 1987, Abramovitz, 1986). Especially small open economies can benefit disproportionately from international spillovers, not only in a development context (Coe et al., 2002) but also amongst developed countries as shown by Coe and Helpman (1995).[6] In fact it may be argued that the potential of the global R&D stock for catching-up should be *relatively* high for developed economies that already have a high level of absorptive capacities and would yield *comparatively* marginal benefits from investment in education and other social capabilities (Archibughi and Mitchie, 1998).

3. European Performance Relative to the World Economic Leaders

The eagerness of European policy makers to bring Europe to the economic frontier of the world is obviously rooted in the feeling that Europe is behind relative to the U.S.A. and other leading countries in the world in terms of technology and productivity. The aim of this section is to document the European gap in this respect. We focus on the manufacturing industry, which we subdivide into 21 sectors, documented in Table 1. The sources of the data are the OECD STAN database, and various parts of the Groningen Growth and Development database. The newest version of the STAN database, using the ISIC rev. 3 classification,

[4] The intermediate position of technology flow matrices is confirmed by van Pottelsberghe (1997), who applies the different weights to the same dataset. Moreover, these results vindicate the approach of most empirical studies to use one and the same matrix across different countries.

[5] See Cincera and van Pottelsberghe (2001), Mohnen (2002) and Los and Verspagen (2003) for recent in-depth reviews of the empirical spillover literature.

[6] Also the simulation results of Verspagen (1997b) exhibit to some degree a relatively high contribution to productivity growth for the smaller economies in the sample.

covers the period from1980 to 1998, while the older version of it, using the ISIC rev. 2 classification covers the period from1970 to 1994. Merging these editions and accounting for the different classification schemes we obtain a dataset that covers the period from 1973 from 1997. We derive the growth rates of total factor productivity from this database, in the way that is described in more detail below. We use additional data on hours worked per person, unit value ratios (for value added) and value added deflators from the GGDC database to set up a benchmark of total factor productivity *levels relative to the U.S.A.* for 1997 (on the general nature of the data, see, e.g., Van Ark, 1996).[7] The TFP growth rates derived from STAN are used to retrapolate this benchmark on a yearly basis to the early 1970s. Because the STAN database has some serious holes in terms of the coverage for some countries, we focus on only four European countries, and compare these to the U.S.A.. The four European countries are Germany, France, Italy and the United Kingdom. We use employment (in number of jobs) as our indicator of labor input in the total factor productivity growth rate calculations. In this part of the calculations, no correction for hours worked is made, because the data on hours in the GGDC database is not available for a large part of the period we are interested in. Value added is our output indicator, and a constructed capital stock is taken as the only other production factor. The capital stock is constructed on the basis of the investment time series, using a perpetual inventory method (with a depreciation rate equal to 0.15). We have to resort to using aggregate purchasing power parities for the capital stocks supplied by the Penn World Tables, because the GGDC database does not supply sectoral data on capital stocks (or investment flows). In summary, the 1997 benchmark of total factor productivity levels is based on state-of-the art methods that take into account differences between sectors in terms of unit value ratios and hours worked, but the growth rates that are used to retrapolate this benchmark are based on more rough measures.

[7] The specific way in which this is done involves retrapolating the 1997 unit value ratios in the GGDC database to 1990 by means of the value added deflators.

Table 1: Sectors in the Analysis

ISIC rev.2	ISIC rev.3	Short description
31	15-16	Food, beverages & tobacco
32	17-19	Textiles, apparel & leather
33	20	Wood products & furniture
34	21-22	Paper, paper products & printing
351+352	24	Industrial chemicals, drugs & medicines
353+354	23	Petroleum & coal products
355+356	25	Rubber & plastic products
36	26	Non-metallic mineral products
37	27	Iron & steel, non-ferrous metals
381	28	Metal products
3825	30	Office & computing machinery
382-3825	29	Non-electrical machinery
3832	32	Radio, TV & communication equipment
383-3832	31	Electrical apparatus, nec
3841	351	Shipbuilding & repairing
3843	34	Motor vehicles
3845	353	Aircraft
3842+3844+3849	352, 359	Other transport
385	33	Professional goods
39	36-37	Other manufacturing

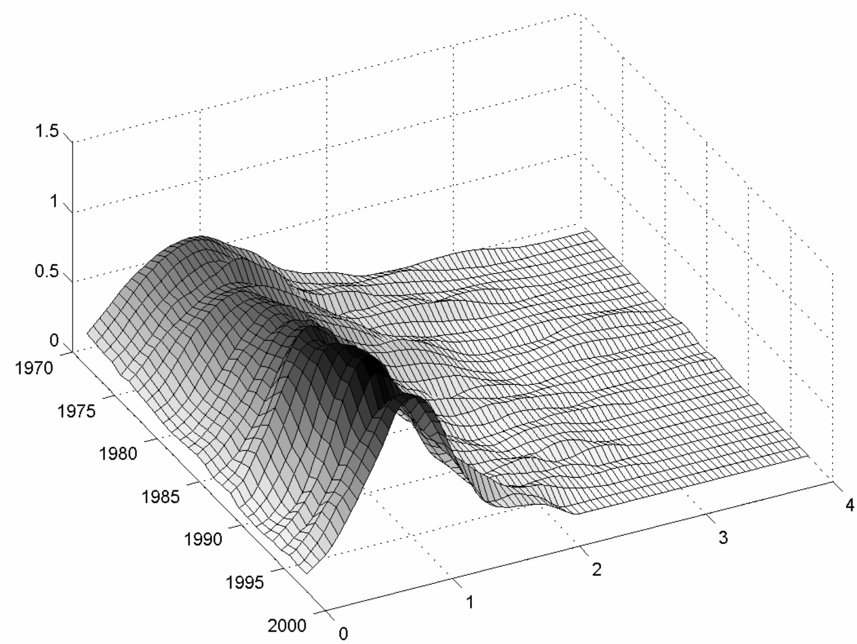
Chart 1 describes the evolution of total factor productivity gaps (ratios) in manufacturing sectors between the European countries and the U.S.A. A value larger than one indicates a European lead. The vertical axis of these figures gives the frequency of sectors with the specific value of the gap displayed on the horizontal axis. Thus, a peak in the plotted surface points to a cluster of sectors at the specific value of the productivity gap. The distribution displayed in the figure is smoothed using a so-called kernel density estimation method (see Härdle, 1990).[8] The raw data consist of the value of the productivity gap for each of the 21 sectors in the four countries (hence there are 84 observations for each year) for the period specified in the graphs. The kernel density estimates can be seen as smoothed histograms (one for every year) of these values. Peaks in the figure indicate that relatively many sectors cluster at the value of the productivity gap displayed on the horizontal axis below. The value 1 on the horizontal axis demarcates the difference

[8] We use Stata's kdensity function, with the default Epanechnikov kernel.

between European productivity leadership (>1) and a European productivity backlog (<1). In chart 1, it is obvious that on average, the European countries indeed face a productivity gap relative to the U.S.A., although it is a relatively small one.[9] The peak (modal value) of the density plot in 1997 lies at a value of 90% (0.9), i.e., where the European countries trail 10% behind U.S. productivity. 53% of the total density (sectors) has a 10% or higher backlog, i.e. is found to the left of the peak for 1997. 36% of the density is found in the right tail that represents European sectors leading over the U.S.A. in terms of total factor productivity (values larger than 1).

[9] Our four European countries display above-EU average productivity, so that the results in this section must be seen as a lower boundary to the gap of the total EU.

Chart 1: Kernel Density Estimates of the Distribution of Total Factor Productivity Gaps of four European Countries vs. the United States (The Horizontal Axis Indicates the Ratio of European Productivity over U.S. Productivity.)



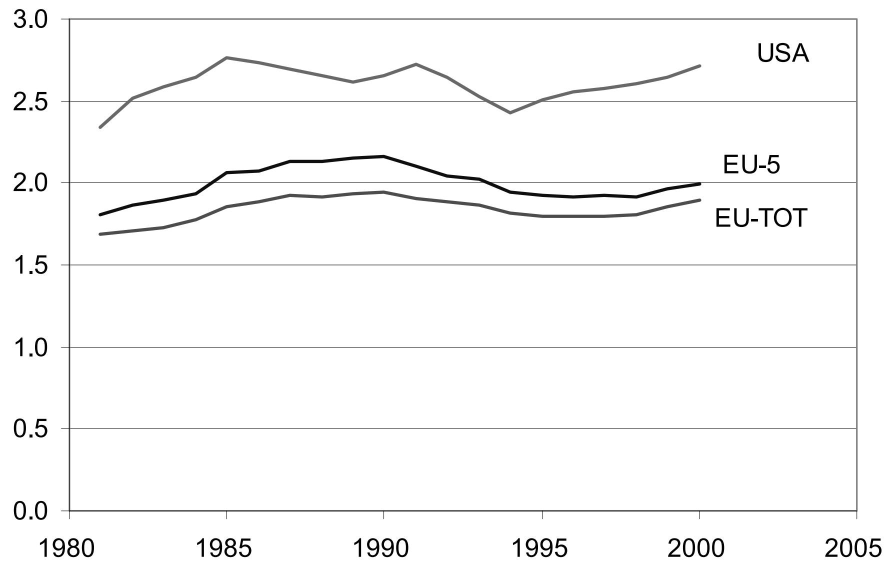
Over time, the evolution is one in which the distribution becomes more narrow and peaked, but the overall centre of the distribution does not shift very much. In the early 1970s, the peak lies at 85%, i.e., a somewhat larger European backlog, but at the same time, a larger fraction (48%) of the total density is found at values larger than one (i.e., a European lead). The early periods also show a relatively long trail of sectors on the right hand side, which corresponds to a limited number of European sectors that operate at the 'leading edge' of productivity. This 'leading edge' largely disappears over the 30-year period in the graph, until we have the relatively narrow and peaked distribution of the late 1990s.

4. R&D in Europe and the Global Economy: Reality and the Barcelona R&D Target

The large majority of R&D in the world is carried out by firms, universities and public or semi-public research organizations. Chart 2 shows the total R&D intensity in Europe, on the one hand, and U.S.A. on the other hand. R&D intensity is defined as total R&D as a % of GDP. Over the period 1980-2000, this value fluctuates between 2 ½percent and 3% in the U.S.A., while it is almost a full percentage point lower in the European Union[10] (all averages across countries are calculated as weighted averages). For the four European countries identified in the previous section, the value is slightly higher than the EU-average: it fluctuates around 2%. Chart 2 thus supports the impression of European backlog in R&D that led to the Barcelona target of a 3 % R&D intensity. In order to achieve this target, and given the value of GDP in the year 2000, Europe's R&D effort in that year would need to be expanded by (roughly) one third. Obviously, this is a large increase, and one may put question marks to the possibility to achieve this, especially so in times of a downturn in the world business cycle, as well as more than a year having passed since the Barcelona meeting, without clear policy measures aimed at stimulating R&D extra having been undertaken in many European countries.

[10] The European Union is defined as EU-16 over the complete period.

Chart 2: R&D Intensity (Total R&D as Percents of GDP)



While we believe that the Barcelona R&D targets will be rather hard to achieve, we undertake the analysis in the remainder of this paper under the assumption that it will indeed be possible to achieve these targets. The aim of this analysis is to assess the impact that increased R&D intensity may have on the productivity gaps facing the European economy.

5. Assessing the Impact of "Barcelona" on European Productivity Gaps

The empirical and theoretical literature on R&D and productivity provides a practical framework to assess the impact of increased R&D efforts in Europe on technology gaps between Europe and the U.S.A.. In this assessment, account will have to be taken of the fact that R&D does not only have an impact in the firm/sector where it is undertaken, but also, partly spills over to other sectors in the domestic and foreign economy. Viewed in this way, much of the increased R&D efforts as a result of 'Barcelona' will be absorbed within the EU itself due to the nature of the integration of European economies. However, it will also add to the technology content of exports to the main non-European competitors with the potential to generate productivity increases there. The aim of this section is to employ a simulation exercise to assess the net effect of the mechanisms on the productivity gaps identified in Section 3 above.

The methodology that will be used in this section is based on a theoretical framework in which scale economies play no role. An important debate in the "new growth" literature is about the role of technology in scale effects. The early endogenous growth models in, e.g., Romer (1986, 1990) or Grossman and Helpman (1991) lead to the conclusion that an increase in the knowledge stock of a country (in whichever way we may measure this) will lead to an increase in the growth *rate*. This represents a mechanism of strong scale economies, in which, *ceteris paribus*, large countries are at an advantage. Jones (1995) argues that the empirical data do not support such strong effects of scale economies related to knowledge and R&D stocks. Instead, Jones (1995) proposes a model in which the growth rate of an economy depends on the growth rate of population, i.e., the growth of (human) resources that can be put into the development of new knowledge (so called semi-endogenous growth).

Although the so called Jones-Critique of strong scale effects has led to a debate in which the possibility of some form of scale economies related to knowledge and R&D has not been ruled out, we proceed here to implement a model that is rooted in an earlier empirical approach (e.g., Griliches, 1979) in which the level of total factor productivity depends on the level of the knowledge stock, and the rate of growth of total factor productivity thus depends on the growth of a knowledge (or R&D capital) stock. The reason for adopting this relatively conservative approach is that this model can still be considered as the main theoretical workhorse for the empirical work in this area. Moreover, since an important part of our calculations will take the form of extrapolating on the basis of increased R&D stocks in Europe, a model incorporating scale effects that have not been empirically verified over a large range of the relevant variables may be too optimistic in assessing the increased productivity effects.

For the calculation of productivity effects we use the concept of 'direct and indirect' R&D from the spillovers literature. We take the same sectors as above, and focus on business R&D only. The method we employ will be to add one-third to the R&D stocks of European sectors. The 3% Barcelona R&D intensity target actually implies a somewhat larger multiplication factor, but in light of the above discussion, we feel that this is a too ambitious target.[11] This implies that current R&D levels in Europe increase by (roughly) 33% (taking GDP as given, something we will do for all analysis in this section). We assume that the distribution of R&D over private and non-private sources does not change, i.e., that the one-third increase applies to both types of R&D.

We take 1997 as the reference year (this is the most recent year for which disaggregated R&D stocks can be calculated for the countries in our sample).

[11] The calculated effects are linear in the growth rates.

Because our R&D stocks are simply summations over time (taking into account also knowledge depreciation), a once-and-for-all multiplication of R&D investment by 1.33 also implies a multiplication of the R&D stocks by 1.33. We therefore perform a simulation in which all European R&D stocks are multiplied by 1.33 and compare the total factor productivity levels implied by this to the levels implied by the actual 1997 R&D stocks.

From the 'direct' R&D stocks, we calculate domestically and internationally acquired 'indirect' R&D stocks (see appendix for mathematical details). For the construction of these we rely on a weighting scheme developed by Verspagen (1997a). This scheme uses patent statistics, and is based on co-classification of patents in terms of their technological class. When a patent is classified in more than a single technology class, and these classes 'belong to' different industries, this is taken as a spillover from one sector (where the main technology class of the patent is) to another sector (where the supplementary technology class of the patent is). In this way, a matrix can be set up that gives the share of all patents generated in a sector that spillover to all other sectors. In Verspagen (1997b) these weights were used to construct domestic and foreign indirect R&D stocks, and the results were applied to an estimation of the impact of R&D and R&D spillovers on total factor productivity. We use the elasticities obtained in Verspagen (1997b), and documented in table 3, in the simulation exercises in this section. In addition to these 'technology weights', domestic indirect R&D is weighted by the share of domestic producers on the market; 'imported' R&D is weighed by the share of foreign producers (broken down at the country level). TFP growth is simply given as the sum of the three components (own sector R&D, domestic indirect R&D from other sectors, foreign indirect R&D), weighted by their output elasticities.

Table 2: Empirical Coefficients (Output Elasticities) used in the Simulations

	OwnR&D	Domestic indirect R&D	Foreign indirect R&D
High-tech (Radio, TV & communication equipment; office & computing machinery; professional goods; aircraft)	0.177	0.025	0.061
Medium-tech (Industrial chemicals, drugs & medicines; non-electrical machinery; electrical apparatus)	0.078	0.022	0.032
Low-tech (Food, beverages & tobacco; textiles, apparel & leather; wood products & furniture; paper, paper products & printing; petroleum & coal products; rubber & plastic products; non-metallic mineral products; iron & steel, non-ferrous metals; metal products; shipbuilding & repairing; motor vehicles; other transport; other manufacturing)	0.084	0.040	0.045

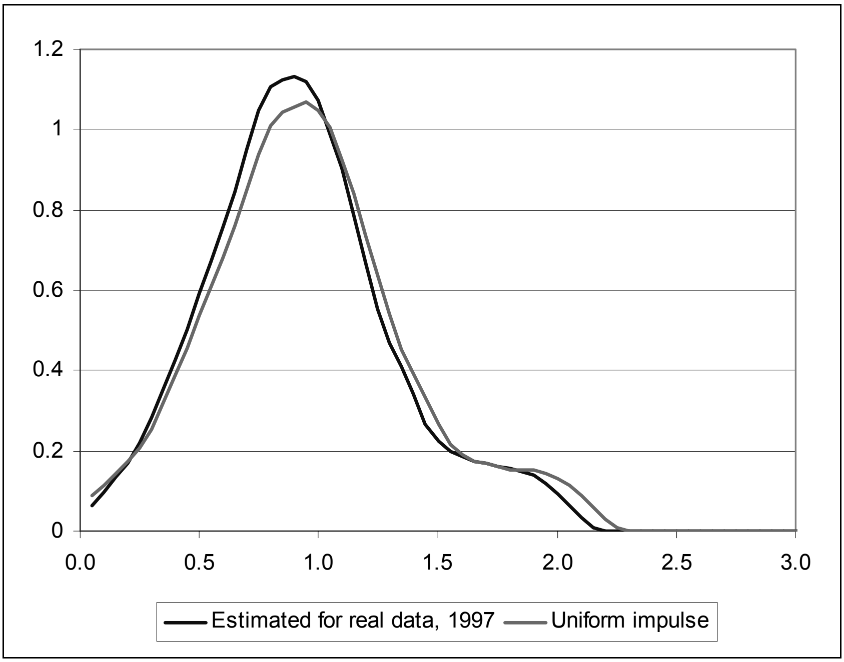
Table 3 documents the productivity effects in the four European countries and the U.S.A. for the various simulation experiments. Our first experiment, described above, is to multiply all European R&D stocks by 1.33, the value associated with the Barcelona target. This corresponds to an 'untargeted' or uniform R&D impulse, i.e., one in which all sectors increase R&D expenditures by the same proportional rate. The effect of this is to raise total factor productivity levels in Europe across the 21 sectors of our analysis by an average of 4.4%, with a relatively narrow variation (standard deviation equal to 1.0%-points) over the sectors. The U.S.A. also benefits from this European R&D policy, and realizes a projected 0.6% increase in total factor productivity levels (with a standard deviation equal to half this value). Thus, both European and U.S.A. levels of productivity may be expected to rise across the board of manufacturing sectors as a result of the Barcelona targets, if and when successfully achieved.

Table 3: Average Growth Rates over Sectors of Total Factor Productivity in Simulation Experiments (Standard Deviations between Brackets)

	Growth of productivity relative to base case (1997 real data)		
Description of simulation experiment	EU-4	U.S.A.	Ratio increase EU to U.S.A.
Uniform R&D impulse in EU	4.4% (1.0%)	0.6% (0.3%)	7.3
Targeted high-tech R&D impulse in EU	8.0% (12.5%)	1.5% (1.9%)	5.3
Targeted medium-tech R&D impulse in EU	8.9% (4.1%)	2.5% (1.1%)	3.6
Targeted low-tech R&D impulse in EU	13.3% (11.6%)	0.4% (0.6%)	33.3

The result is, obviously, a reduction in European technology gaps. This is documented in chart 3, which gives the kernel density estimations for the first simulation experiment and the real data for 1997. The latter is taken from chart 1 (last year), but is now reproduced in a 2-dimensional format. The evenness of the impact of increased R&D across sectors is evident from the almost parallel shift of the density curve. The peak (modal value) of the distribution shifts to the right, and is now found at a value of 0.95, i.e., where European productivity lags behind US productivity 5%-points. 41% of the total density is now found in the domain where European productivity leads over U.S.A. productivity (to the right of 1 on the horizontal axis). Although this is a clear improvement of the European situation, it does not represent a very clear take-over of the U.S.A. by Europe. In other words, although the increased R&D levels as a result of the Barcelona targets are beneficial for European industry, they do not seem to lead to the targeted European productivity leadership.

Chart 3: Kernel Density Estimates for real Productivity Gaps (1997) and Simulated Gaps (a European R&D Impulse Uniformly distributed over Sectors)



In order to compare the impact of the different sectoral R&D stocks on the distribution of European productivity gaps, we also document the results of some other thought-experiments, in which only a number of sectoral R&D stocks are varied at the same time. In these experiments, we employ the commonly used distinction between high-tech, medium-tech and low-tech sectors. This classification is based on average R&D intensity across the OECD countries, and is documented in Table 2 in the specific way in which it was used here. Note that because our level of disaggregation of sectors does not completely correspond to the usual scheme, we had to change some of the usual definitions. The most notable of these changes is that we merge pharmaceuticals (normally considered as a high-tech sector) with chemicals (normally considered as a medium-tech sector), and treat the resulting sector as a medium-tech sector.

In the sectoral experiments, we employ a broad reasoning that corresponds to "putting all money on one card". This means that we still start from a one-third increase in total R&D efforts (stocks), but now put these additional expenditures into a single of the three broad sectoral classifications (low-, medium or high-tech). In order to find the multiplication factor of R&D stocks that corresponds to this, we use the following formula:

$$\frac{R_{L,t+1}+R_{M,t+1}+R_{H,t+1}}{R_{L,t}+R_{M,t}+R_{H,t}}=\frac{R_{L,t+1}}{R_{L,t}}\sigma_{L,t}+\frac{R_{M,t+1}}{R_{M,t}}\sigma_{M,t}+\frac{R_{H,t+1}}{R_{H,t}}\sigma_{H,t}=1.33,$$

where R represents R&D stocks, the subscripts *H*, *M* and *L* indicate high-tech, medium-tech and low-tech, respectively, the subscripts t and t+1 indicate before and after experiment periods, and σ indicates a share in total R&D. A 'focused' R&D impulse is calculated using this formula, by setting the ratio $R_{i,t+1}/R_{i,t}$ to 1 (i.e., no change) for the two sectoral classes on which the R&D impulse is *not* focused, and then solving for the same ratio for the sectoral class on which the R&D is focused. For example, in case of an R&D impulse focused on low-tech, this yields

$$\frac{R_{L,t+1}}{R_{L,t}}=\frac{0.33}{\sigma_{L,t}}+1.$$

This shows that we can calculate the ratio at which R&D stocks in the focused sectoral class must be increased as a function of the targeted overall increase (one third, or 0.33) and the share of the sectoral class in total R&D stocks. For sectoral classes that represent a small (large) share in total stocks, a large (small) proportionate increase is necessary to accommodate the increase of total R&D by one third.

Chart 4 and 5 document the sectoral distribution of total R&D stocks for the broad aggregates used in the experiments. Obviously, the low-tech R&D stocks make up the smallest part of total R&D stocks in both the EU-4 and the U.S.A., accounting for approximately 10% at the end of the period. In the U.S.A., the medium-tech sectors are somewhat smaller than in Europe, and the reverse holds (by implication) for the high-tech sectors. We use the EU-4 shares in 1997 to calculate the implied multiplication factors for the high-, medium and low-tech sectors according to the above formula. This yields a factor of 5.0, 3.5 and 11.4, respectively. It must be noted that these factors are quite high, especially so for low-tech sectors, and hence it is not very realistic to assume that such a focused R&D strategy could ever be actually implemented. The calculations using these multiplication factors are, however, intended to illustrate the differences in sectoral impact, rather than to make actual predictions of what could happen.

Table 3 shows that the largest productivity effects of increased R&D are to be expected from the medium-tech sectors. For the focused low-tech R&D impulse, an average 13.3% total factor productivity increase in Europe is found, while this value is almost 0.4% in the U.S.A. (as a result of increased European R&D).

Moreover, the effects of increasing high-tech R&D are highly variable over sectors, as indicated by the fact that standard deviation is larger than the mean (this is less so the case for medium- and low-tech sectors). The ratio of the increase of productivity in Europe and the U.S.A. is highest for the focused low-tech impulse, indicating that in this sectoral class, increased European R&D efforts are 'appropriated' to the largest extent.

Chart 4: Percentual Distribution of R&D Stocks in High-, Medium- and Low-Tech Sectors

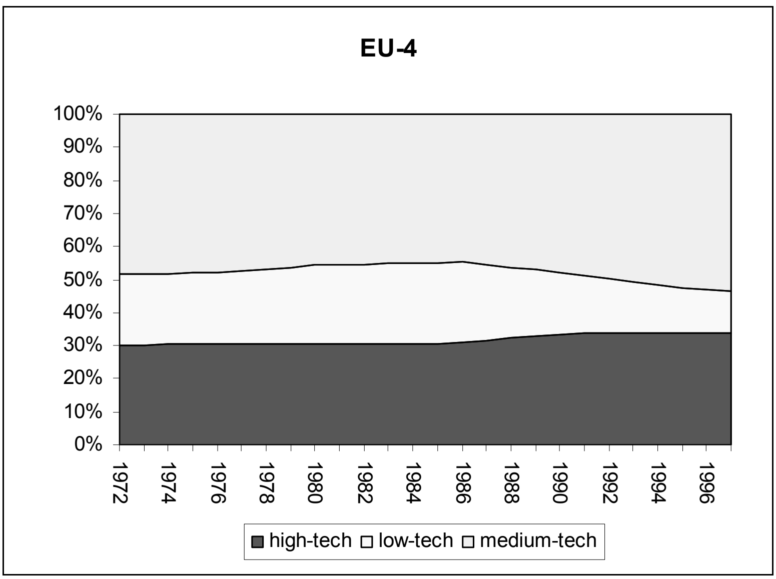


Chart 6 shows the effects in terms of the distribution of total factor productivity gaps over sectors for the focused high-tech impulse. The latter is compared against two different baseline cases, i.e., the kernel density estimate of the productivity gaps resulting in the first experiment (uniform R&D impulse), and the empirical observation for 1997. While the uniform R&D impulse shifts the kernel estimate almost in a parallel fashion, this is much less the case for the focused high-tech R&D impulse. For the focused high-tech R&D impulse, the peak of the distribution actually shifts slightly to the left, to a value of 0.85 (15% European productivity backlog). 42% of the total density lies to the right of the value 1 in case of the focused high-tech R&D impulse, indicating that, overall, there is a rightward shift of the distribution (the value is 36% for the empirically observed distribution). But what is most striking in the case of the focused high-tech impulse is that a small number of sectors on the right hand side of the distribution benefits most. This 'leading edge' of European sectors gains relatively much as a result of a targeted high-tech impulse.

The focused medium-tech impulse is displayed in chart 7. Here we note a shift of the kernel density that is almost equal to the case of a uniform R&D impulse, and almost exactly parallel to the empirically observed density. The peak of the distribution stays, however, at a value of 0.9 (10% productivity back log for Europe), which is also the empirically observed peak. In this case, 44% of the total density lies to the right of 1 (European productivity lead).

Chart 5: Percentual Distribution of R&D Stocks in High-, Medium- and Low-tech Sectors, EU-4

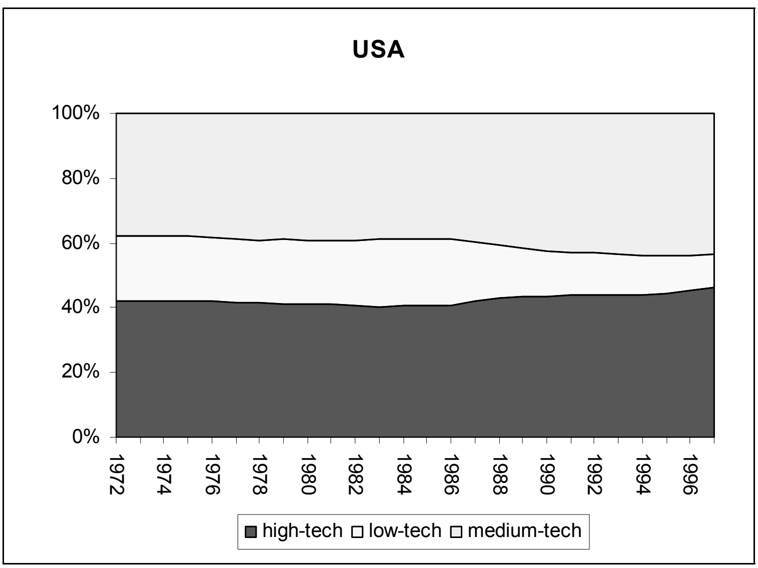
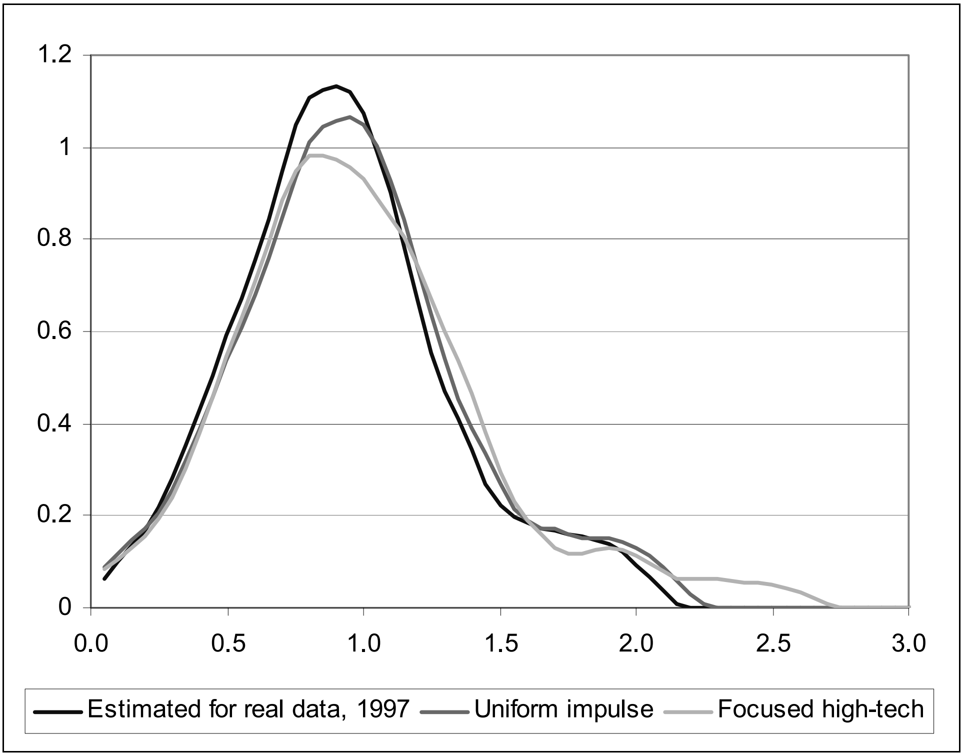


Chart 6: Kernel Density Estimates for Simulated Productivity Gaps (a European R&D Impulse Focused on High-Tech Sectors



Finally, chart 8 displays the result of a focused low-tech R&D impulse. In comparison to the two earlier focused R&D impulses (high-tech and medium-tech), the effects are more dramatic for low-tech. We observe a relatively strong shift of the part of the distribution that is immediately to the right of the peak, while the peak itself (by implication, because the total density is constant) shifts downwardly relatively much. Also the 'leading edge' European sectors (to the far right) shift relatively much as a result of the focused low-tech R&D impulse. The fraction of the density that lies to the right of the value 1 is 51% in case of the focused low-tech impulse, and the peak of the distribution occurs at 0.95 (5% European productivity backlog).

Summarizing, it seems indeed to be the case that R&D policies aimed at different sectors may have different effects in terms of the distribution of productivity effects over sectors. Perhaps surprisingly, the most dramatic effects are associated to R&D in low-tech, while medium-tech sectors have the most evenly distributed impact.

Chart 7: Kernel Density Estimates for Simulated Productivity Gaps (a European R&D Impulse focused on Medium-Tech Sectors)

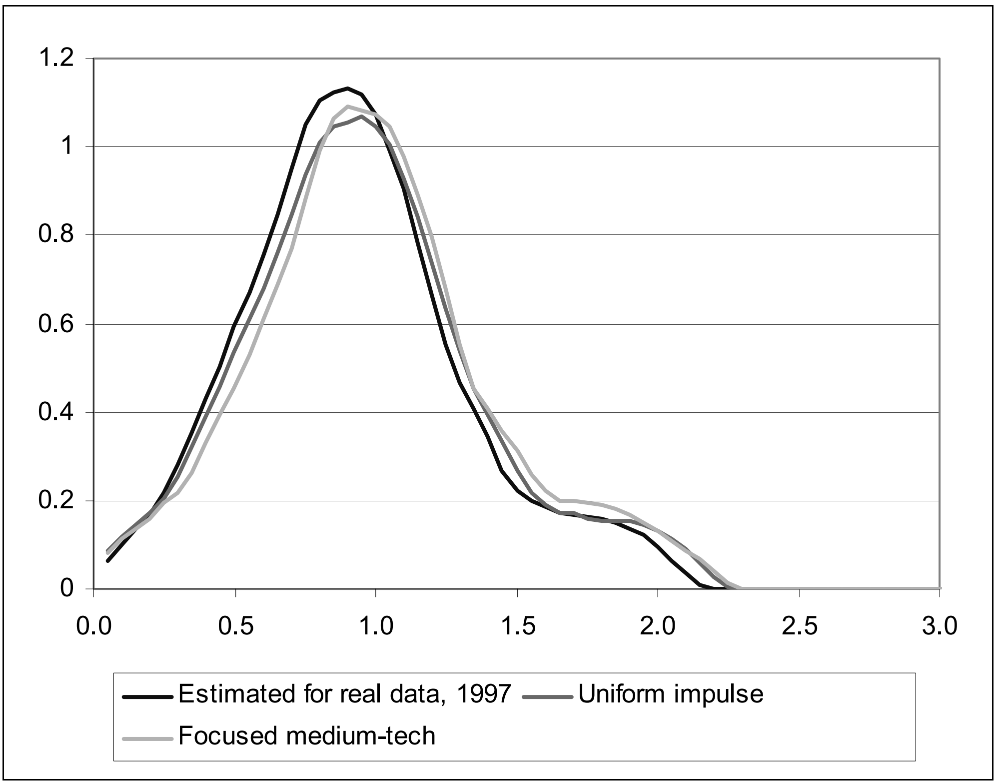
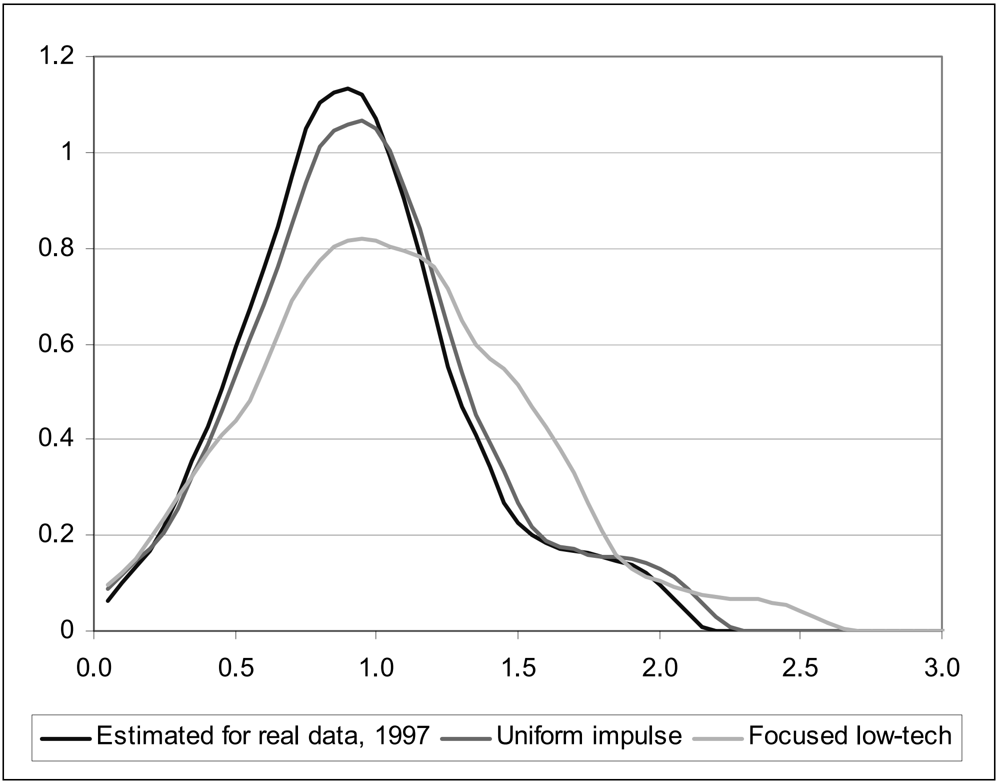


Chart 8: Kernel Density Estimates for Simulated Productivity Gaps (a European R&D Impulse Focused on Low-Tech Sectors)



6. Discussion and Conclusions

In this paper we have documented European total factor productivity gaps relative to the U.S.A. Although our method of calculating productivity levels in these countries is imperfect, it was shown that Europe indeed lags behind somewhat to the U.S.A. in terms of total factor productivity in many manufacturing industries. We discussed the European ambition, expressed at the Lisbon Summit, to become 'the most competitive and dynamic economy in the world'. For reason of the relationship between R&D and productivity, we were especially interested in the targets set in Barcelona for European R&D intensity. In an analysis of current R&D trends, it was concluded that these targets are indeed ambitious, implying an increase of European R&D intensity by one third.

We then proceeded to apply a simple simulation method, based on the empirical literature on R&D and productivity, to estimate the impact of the Barcelona targets, assuming they can successfully be implemented, on the productivity gaps in manufacturing industry between Europe and the U.S.A.. Our model makes many simplifying assumptions, but its main virtue is that it does take into account the indirect impact of R&D, in terms of spillovers, in other sectors and countries than where the R&D effort is originally made. Thus, it was shown that also the U.S.A. may expect to benefit from increased European R&D, although at relatively low rates. The net effect on European productivity gaps is expected to be positive from the European perspective, i.e., will lead to a catch-up of total factor productivity levels relative to the U.S.A..

However, the results also indicate that the expected effects are relatively small compared to the size of existing productivity gaps facing European industries. According to our estimates, which are to be looked as a rough indication of orders of magnitude, achievement of the Barcelona targets in a purely quantitative sense (i.e., *ceteris paribus* raising R&D intensity to 3% of GDP) will not put the European economy clearly in the lead in terms of productivity relatively to the U.S.A.. According to our simulations, a focused R&D impulse in low-tech industries can be expected to have the strongest effect, but it is unrealistic to assume that these sectors alone can achieve the Barcelona R&D target.

These results imply that, according to the estimations of our model, a policy solely aimed at increasing R&D expenditures, without paying any attention to the broad institutional context in which innovation and technological development take place, is not likely to succeed. Raising R&D expenditures may be one part of the story behind the European backlog, but factors such as absorptive capacity, interaction between researchers in public and private organizations, finding the right level of intellectual property rights protection, etc., may be just as important in achieving the Lisbon ambition. Our model does not have to say much on these factors (which can be argued to represent changes in the R&D elasticities that our models takes as given), but it does point out that more research on these issues may be useful, and that the story of regaining European technological and economic leadership may be a more complicated one that the Lisbon and Barcelona summits want us to believe.

References

Abramovitz, M.A. "Rapid Growth Potential and its Realization : The Experience of Capitalist Economies in the Postwar Period." In *Economic Growth and Resources, vol. 1 The major Issues, Proceedings of the fifth World Congress of the International Economic Association*, edited by E. Malinvaud, 1-51. London: Macmillan, 1979.

Abramovitz, M.A. "Catching up, forging ahead and falling behind," *Journal of Economic History*, 46 (1986): 385-406.
Adams, J.D. "Fundamental Stocks of Knowledge and Productivity Growth." *Journal of Political Economy*, 98 (1990): pp. 673-702.
Archibughi, D. and J. Mitchie. "Trade, Growth, and Technical Change: What are the Issues?" In *Trade, Growth and Technical Change*, edited by D. Archibugi and J. Michie, 1-15. Cambridge: Cambridge University Press, 1998.
Coe D. T. and E. Helpman. "International R&D spillovers," *European Economic Review*, 39 (1995): 859-887.
Coe D. T., E. Helpman E. and A. Hoffmaister. "North-South R&D Spillovers," *The Economic Journal*, 107 (2002): 134-49.
David, P. *Technical Choice, Innovation and Economic Growth*. Cambridge: Cambridge University Press, 1975.
Economic Policy Committee. Report on Research and Development. EPC/ECFIN/01/777-EN Final. Brussels, 22 January 2002.
European Commission. European Competitiveness Report 200. Commission Staff Working Paper, SEC(2002) 528. Luxembourg: Office for Official Publications of the European Communities, 2002.
Fagerberg, Jan. "A Technology Gap Approach to why Growth Rates Differ." *Research Policy*, 16 (1987): 87-99.
Goto, A. and K. Suzuki. "R&D Capital, Rate of Return on R&D Investment and Spillover of R&D in Japanese Manufacturing Industries." *Review of Economics and Statistics*, 71 (1989): 555-564.
Griliches, Z. "Issues in Assessing the Contribution of Research and Development to Productivity Growth." *The Bell Journal of Economics* 10 (1979): 92-116.
Griliches, Z. "The Search for R&D Spillovers." *Scandinavian Journal of Economics* 94 (1992): S29-S47.
Groningen Growth and Development Centre, *60-Industry Database*, http://www.ggdc.net
Groningen Growth and Development Centre, *ICOP Industry Database*, http://www.ggdc.net
Grossman, G.M., and E. Helpman. *Innovation and Growth in the Global Economy*. Cambridge MA: MIT Press, 1991.
Härdle, W. *Applied NonparametricRregression*. Vol. 19, *Econometric Society Monographs*. Cambridge: Cambridge University Press, 1990.
Jacobs, B., R. Nahuis and P.J.G. Tang. "Sectoral Productivity Growth and R&D Spillovers in the Netherlands." *De Economist*, 150 (2002): 181-210.
Jaffe, A.B. "Technological Opportunity and Spillovers of R&D: Evidence from Firms' Patents, Profits and Market Value." *American Economic Review* 76 (1986): 984-1001.
Jones, C. 1995. R&D Based Models of Economic Growth. *Journal of Political Economy* 103:759-784.

Los, B. and B. Verspagen. "Technology Spillovers and Their Impact on Productivity", forthcoming in "The Edward Elgar Companion on neo-Schumpeterian Economics", 2003.

Mansfield, E. "How Rapidly does New Industrial Technology Leak Out?" *Journal of Industrial Economics*, 34 (1985): 217-223.

Mohnen, P. "International R&D Spillovers and Economic Growth" In *Information technology, productivity, and economic growth: International evidence and implications for economic development*, edited by M. Pohjola, 50-71. Oxford: Oxford University Press, 2001.

Nadiri, M.I. "Some Approaches to the Theory and Measurement of Total Factor Productivity: A Survey." *Journal of Economic Literature* 9 (1970): 1137-1177.

Nelson, R.R., and G. Wright. "The Rise and Fall of American Technological Leadership: the Postwar era in an Historical Perspective." *Journal of Economic Literature* 30 (1992): 1931-1964.

Papaconstantinou, G., N. Sakurai and A. Wyckoff. 1996. Embodied Technology Diffusion: An Empirical Analysis for 10 OECD Sountries, STI working paper 1996/1, Paris: OECD, 1996.

Pavitt, K., and L. Soete. "International Differences in Economic Growth and the International Location of Innovation." In *Emerging Technologies: The Consequences for Economic Growth, Structural Change and Employment*, edited by H. Giersch, 105-133. Tuebingen: Mohr, 1982.

Putnam, J. and R.E. Evenson. Inter-Sectoral Technology Flows: Estimates from a patent Concordance with an application to Italy. Yale University, mimeo, 1994.

Romer, P. "Increasing Returns and Long Run Growth." *Journal of Political Economy* 94 (1986): 1002-1037.

Romer, P.M. "Endogenous Technological Change." *Journal of Political Economy* 98 (1990): S71-S102.

Sakurai, N., E. Ioannidis and G. Papaconstantinou. The Impact of R&D and Technology Diffusion on Productivity Growth: Evidence for 10 OECD Countries in 1970s and 1980s. STI working paper 1996/2. Paris: OECD, 1996.

Scherer, F. M. "Interindustry Technology Flows and Productivity Growth.“ *Review of Economics and Statistics*, 64 (1982): 627-34.

Solow, R.M. "Technical Progress and the Aggregate Production Function." *Review of Economics and Statistics* 39 (1957): 312-320.

Sveikauskas, L. "Technology Inputs and Multifactor Productivity Growth," *The Review of Economics and Statistics*, 63 (1981): 275-82.

Terleckyj, N.E. "Direct and Indirect Effects of Industrial Research and Development of Productivity Growth of Industries." In *NewDevelopments in Productivity Measurement and Analysis*, edited by J. Kendrick and B. Vaccara, Chicago: The University of Chicago Press, 1980.

Terleckyj, N.E. *Effects of R&D on the Productivity Growth of Industries: An*

Exploratory Study. Washington/DC: The National Planning Association, 1974.

Triplett, J.E. *High Tech Industry productivity and Hedonic Price Indexes*. Washington, D.C: Bureau of Economic Analysis, 1996.

Tsoukalis, L. *The New European Economy Revisited*. 3rd ed. Oxford: Oxford University Press, 1997.

Van Ark, B. "Sectoral Growth Accounting and Structural Change in Post-War Europe." In *Quantitative Aspects of Post-War European Economic Growth*, edited by B. van Ark and N. Crafts, 84-164. Cambridge: Cambridge University Press, 1996.

Van Meijl, H. *Endogenous Technological Change: The Case of Information Technology*, Ph.D. dissertation, University of Limburg, Maastricht: Universitaire Press, 1995.

Van Pottelsberghe de la Potterie, B. "Issues in Assessing the Impact of Interindustry R&D Spillovers." *Economic Systems Research*, 9 (1997): 331-56.

Van Pottelsberghe de la Potterie, B. and M. Cincera. "International R&D spillovers: a survey." *Cahiers Economiques de Bruxelles*, 169(2001).

Verspagen, B., 1997a, "Measuring Intersectoral Technology Spillovers: Estimates from the European and US Patent Office Databases." *Economic Systems Research*, 9 (1997): 47-65.

Verspagen, B., 1997b, "Estimating International Technology Spillovers Using Technology Flow Matrices." *Weltwirtschaftliches Archiv*, 133 (1997): 226-248.

Wolff, E.N. and M.I. Nadiri. "Spillover Effects, Linkage Structure, and Research and Development," *Structural Change and Economic Dynamics*, 4 (1993): 315-331.

Appendix – Data, Methods and Variables

The analysis draws on the OECD STAN, ANBERD and BITRA databases, merging their ISIC-Rev.2 and ISIC-Rev.3 versions for a longitudinal dataset, covering 21 industries in 7 countries for the period of 1973-1997 (table 1). These sectoral data are used to calculate both domestic and 'international', i.e. imported R&D stocks. To derive constant price series in U.S. dollars, implicit deflators from STAN and PPPs from the Penn World Tables were employed. The countries covered include the EU member states of France, Germany, Italy and the United Kingdom, as well as the United States. Japan is included as a country from/to which spillovers flow, but this country is not included in the productivity comparisons.

Following Verspagen (1997b) we start from an augmented Cobb-Douglas production function

$$Y_{ijt} = A_{ijt} K_{ijt}^{\alpha} L_{ijt}^{\beta} RD_{ijt}^{\rho} IRD_{ijt}^{\delta} IRF_{ijt}^{\phi} \tag{1.1}$$

where *Y* represents production, *A* the usual scale variable, and *K* and *L* capital and labour inputs respectively. *RD* is 'own', i.e. direct R&D, *IRD* is domestic indirect R&D, *IRF* is 'foreign', i.e. indirectly imported R&D. α, β, ρ, δ, ϕ are the relevant output elasticities. The indices *i*, *j* and *t* refer to country, sector and time. Neglecting indices, total factor productivity can be measured as a function of total R&D:

$$TFP \equiv Y / \left(K^{\alpha} L^{\beta} \right) \tag{1.2}$$

or, combining (1.1) and (1.2), in the form of growth rates:

$$\frac{\dot{TFP}}{TFP} = \rho \frac{\dot{RD}}{RD} + \delta \frac{\dot{IRD}}{IRD} + \phi \frac{\dot{IRF}}{IRF} \tag{1.3}$$

Capital stocks are constructed by applying the perpetual inventory method, that is

$$K_t = (1-\psi) K_{t-1} + I_t \tag{1.4}$$

with I being investment in fixed capital, the depreciation rate ψ set to 0.15 and an initial capital stock of 5 times I_{t+1} (assuming an initial growth rate of 5 per cent). The 'own' R&D stocks are constructed similarly using R&D expenditures.

For indirect domestic R&D, the sectoral R&D stocks are weighted by coefficients from a patent citation matrix based on EPO statistics (Verspagen, 1997a). For domestically acquired R&D we set their diagonal elements to zero to avoid double-counting. Finally, we weight with the share of domestic inputs; that is

$$IRD_{ik} = \sum_{j} \omega_{jk} \left(1 - m_{ij}\right) RD_{ij}, \qquad j \neq k \tag{1.5}$$

where ω_{jk} designates the share of sector j in sector k's citations and m_j stands for the import penetration of the domestic market. For imported R&D we keep the diagonal elements and aggregate as

$$IRF_{ik} = \sum_{h} \sum_{j} \omega_{jk} m_{ij} RD_{hj} s_{ihj} \tag{1.6}$$

using import penetration-weighted input coefficients, and RD_{hj}, the R&D stock of the export country h, being weighted by its import share in country i, s_{ihj}. We take this variable as a proxy for the degree of interaction between two countries (Verspagen, 1997b). The simulation uses hypothetical R&D stocks as explained in the main text and calculates corresponding indirect R&D as in (1.5) and (1.6). To calculate hypothetical TFP growth the elasticity estimates (as in table 3) by Verspagen (1997b), who uses a comparable set of OECD countries and sectors, were employed and fed into (1.3).

Comment on: Christoph Meister und Bart Verspagen, "European Productivity Gaps: Is R&D the Solution?"

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Christoph Meister and Bart Verspagen raise the question of whether R&D is *the* solution to productivity gaps in European manufacturing sectors relative to the U.S.A. Here we must be careful, because the correct answer depends on the precise reading of that question. Literally speaking, their answer is no. It is not *the* solution that can do the trick on its own. In a less literal sense, the answer could also be yes. The lower level of R&D is certainly *one* important cause for the European backlog in productivity relative to the U.S.A.. In conclusion, the Barcelona target of raising R&D levels to 3% of GDP appears both unrealistic and insufficient, but, as the paper shows, it is not misguided towards an invalid target. There are strong links between R&D and productivity growth and the general validity of the Barcelona target is demonstrated. The paper thus underpins the need for structural policies that are directed at the microeconomic sources of productivity growth, complementing the traditional focus on macroeconomic stability.

There are several distinctive features of your paper that I fully endorse. One of its major strengths is the comprehensive coverage of three different links of R&D to productivity, encompassing not just (i) the direct effects of own sector R&D, but also (ii) domestic indirect R&D from other sectors, and finally (iii) indirect R&D from international trade of goods. A second distinctive strength, which originates in a previous work of Bart Verspagen, is the use of co-classification of patents as weighting scheme for indirect R&D stocks in your technology flow matrice. I find that to be a very intriguing approach to capture a horizontal kind of spillovers as opposed to vertical supplier-relationships.

Another distinctive feature of your simulation model needs more explanation in order to avoid some confusion about the concept of Total Factor Productivity. In aggregate studies the standard approach is to adjust labor productivity by increases in the use of physical capital per worker and the upgrading of human capital so that TFP is somehow interpreted as a costless increase in output. In contrast, you define

TFP growth not as a residual, but positively as the sum of the above three R&D components weighted by their output elasticities. So your estimation follows the typical specification of the production function in microeconometric studies on the returns of R&D but additionally takes account of indirect spillover effects. The advantage is of course that TFP is no longer costless (like manna from heaven) but results from purposeful investment in R&D (either by oneself or by others).

What remains problematic, however, is to proceed in your analysis *as* if R&D were the only source of TFP growth. It is easy to imagine other, non-R&D related sources of technological progress. One example are smaller, incremental improvements that are not directly related to a formal R&D process and therefore not covered by the statistics. Second, and, even more important, investments in human capital can be expected to affect an economy's capacity to absorb domestic as well as international spillovers and thus the TFP growth rate. The upshot is, your model operates under the assumption that R&D is the only source of TFP growth. But interestingly, your simulation results show that even when the EU overtakes the U.S.A. in terms of R&D stocks, it will not be sufficient to close the current TFP gap.

More generally, I also wonder what the benefits are of your simulation compared to an outright econometric approach, where one estimates the output elasticity and then calculates the counterfactuals for the general as well as the focused rise in R&D expenditures according to the Barcelona target. Furthermore, I consider that multiplying the level of R&D stocks in low-tech industries by a factor of 11.4 is no more "illustrative" (as you claim) than it is unrealistic and implausible (as you admit in the paper). The problem is, that you implicitly assume an extreme endogeneity of innovation output. But under any realistic assumptions, and especially for low-tech industries, we must expect exogenous limitations of technological opportunity and thus of an industry's propensity to turn additional R&D into successful innovations (even if we include compensation for spillovers by the community).

Next, I want to put forward a few quibbling details: The first one is with respect to chart 1 – I find the three dimensional chart of Kernel density somehow missing its purpose. On the one hand it is difficult to read. Three dimensions and the frequency distribution of a ratio scale is quite confusing. On the other hand, I also want to know more, e.g. which sectors appear at what ends of the distribution, or how robust these gaps are over time. Maybe a summary table could provide more and better accessible information. Another quibbling question is about chart 2, in which you show slight but persistent difference in the R&D to GDP ratios between the 4 large EU economies (Germany, France, United Kingdom and Italy) and the EU total. Might not that be an indication for some scale effects of R&D in the sense of the "old" new-growth models – implying that large economies (or an integrated economic area) internalises more spillovers? (Of course, an alternative explanation might be the large size of the defense sector). I also recall that the current slow growth performance in the EU since the second half of the1990s is frequently attributed to the bad performance of its largest countries (except the United Kingdom but Germany and Italy in particular) – i.e. those that do more than average R&D. Finally, with respect to table 2 I must say that I critically missed any detailed discussion of the empirical coefficients that you use in the simulation.

At this point, I finally want to mention a new study undertaken by the National Institute in London and the Groningen Growth and Development Center, which deals precisely with the sources of EU productivity growth,[1] fitting perfectly to our focus in this session. Among the many empirical results of that study, I briefly report the following:

1. Their estimates for the gap of the EU relative to the U.S.A. in terms of labour productivity per hour worked in the year 2002 is 92%, which is quite different from the official EUROSTAT estimate of 87% (they say that this is due to the methodological differences in measuring U.S.A. labor input). This gap has increased: In 1995 the ratio was 96% and in 2000 it was 94%.
2. The main message of the report is that the growth slowdown of the EU and the widening productivity gap since the mid 1990s cannot be fully understood without adopting an industry perspective. To be precise, they say that the acceleration in US labour productivity growth from the mid 1990s is heavily concentrated in industries that either produce or intensively use the new information and communication technologies. The EU has not experienced the same growth spurt in these sectors and poorer performance is most apparent in ICT intensive using service sectors. They conclude that the U.S.A. is now dominant in high technology industries in manufacturing and intensive ICT users in services, while the experience in both regions is more similar in the other "non-ICT" industries, which generally experienced decelerating growth.

[1] O´Mahony, M., van Ark, B., EU productivity and competitiveness: An industry perspective. Can Europe resume the catching up process?, European Community, December, 2003.

R&D and Productivity

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1. Introduction

One of the central policy issues in the United Kingdom over the last ten years has been how far productivity lags behind levels in leading countries. A widely cited report by the McKinsey Global Institute found that manufacturing productivity in the United Kingdom was approximately 60% of that in the United States. Within the European Union, substantial differences in measured productivity exist across member countries.

Some of these productivity gaps may reflect measurement issues and lifestyle choices. For example, productivity per employee may be lower because Europeans have chosen to work fewer hours, so that labor productivity per hour is closer to, or in some cases higher than, levels in the United States. Similarly, labor productivity is a measure of the efficiency of only one factor of production and does not control for example for the use of physical capital. Employing measures of Total Factor Productivity (TFP) that, in principle, capture the efficiency of all factors of production yields somewhat different conclusions.

However productivity is measured, it is clear that there are substantial productivity gaps from the leading country within many manufacturing industries – whether this leading country is the United States, Japan or another industrialized nation. Since productivity is a key determinant of wages and ultimately living standards, a closing of the productivity gap seems to offer opportunities for welfare improvement. Within the United Kingdom, a Performance and Innovation Unit (PIU) has been established to investigate these issues, identify market failures, and consider policy options.

It is widely agreed that research & development (R&D) is an important driver of innovation and productivity growth, and one of the policy options that has received a lot of attention in the United Kingdom is a tax credit for R&D expenditures. Thus, in the year 2000, the UK government introduced a tax credit aimed at Small and Medium Enterprises (SMEs), including a provision for a eligible companies to deduct 150% of qualifying R&D from their taxable profits and additional provisions for companies not in profit. If the social returns to R&D exceed the private returns (as many authors argue), then there may be a case for some form of policy intervention to increase R&D and hence productivity growth. Whether this policy intervention should take the form of an R&D tax credit is, of course, a further issue which remains open to debate.[1]

This article reports the results of recent research, in which we provide theory and empirical evidence that much existing research may have underestimated the rate of return to R&D.[2] Undertaking R&D may not only result in innovation but also increases a firm's ability to understand and assimilate the discoveries of other firms – an idea referred to in the literature as "absorptive capacity" or the "second face of R&D". Every researcher knows a large part of one's own research time is spent on finding out what other people have already done! Translating this through to an international level, this suggests that, in economies behind the technology frontier, R&D may have an important part to play in catching up with the leaders. In so far as many existing studies focus solely on the effects of R&D on innovation, they may underestimate the social rate of return to R&D for economies (like the UK) that lie behind the technological frontier. In the next section, we develop this idea in further detail, before considering how to quantify to second face of R&D. We then discuss other considerations in addition to R&D which may influence countries' ability to assimilate ideas from the world technological frontier. A final section concludes.

2. The Two Faces of R&D

The idea that innovation is an important source of productivity growth and that monopoly profits provide the incentive for private agents to invest in the discovery of new technologies has a long intellectual lineage dating back to the writings of Joseph Schumpeter in the 1940s. These ideas have recently been formalised in the

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[1] For a detailed evaluation of R&D tax credits across a number of OECD economies, see Bloom, Griffith, and Van Reenen (2002).

[2] See Griffith, Redding and Van Reenen (2001, 2003, 2004).

endogenous growth literature, where innovation is modelled as the introduction of new product varieties or successively higher qualities of an existing product.

In emphasising innovation, it is important not to lose sight of the fact that imitation or technology transfer may result in substantial productivity growth in economies behind the technological frontier. Nathan Rosenberg argues that three of the great technical developments in European history – printing, gunpowder, and the compass – are all instances of successful technological transfer.[3] He goes on to say that it may be seriously argued that, historically, European receptivity to new technologies, and the capacity to assimilate them, whatever their origin has been, as important as inventiveness itself.[4]

However, technology transfer is not necessarily automatic and is contingent on levels of knowledge and expertise in the firm, industry, or country to which the technology is being transferred. This line of thought is closely linked to the idea that some knowledge is 'tacit' or hard to acquire without direct experience. By actively engageing in research and development in a particular intellectual or technological field, one acquires such tacit knowledge and can more easily understand and assimilate the discoveries of others. Even then, the transfer of technology may be far from automatic. Take the example of the jet engine: when plans were supplied by the British to the Americans during the Second World War, it took ten months for them to be redrawn to conform to American usage.[5]

This suggests a conceptual framework of the form shown in Figure 1. In all economies behind the technological frontier, innovation and technology transfer each constitute potential sources of productivity growth.[6] Investments in R&D may affect rates of productivity growth through either innovation and/or technology transfer.

If an economy already possesses the state of art technology, innovation provides the sole source of productivity growth. Investments in R&D now only affect productivity growth in so far as they generate innovations.

3. Quantifying the Two Faces of R&D

Griffith, Redding and Van Reenen (2004) implement the framework above using data on 14 sectors in 12 OECD countries since 1970. The identities of the industries and countries are listed in table 1. This required data on productivity growth, a measure of the potential for technology transfer, and a way of

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[3] Possibly in all three cases from China. See Rosenberg (1982), chapter 11.
[4] Rosenberg (1982), page 245.
[5] Arrow (1969), page 34.
[6] See also Cameron, Proudman and Redding (1998).

quantifying the contribution of R&D to innovation and technology transfer.

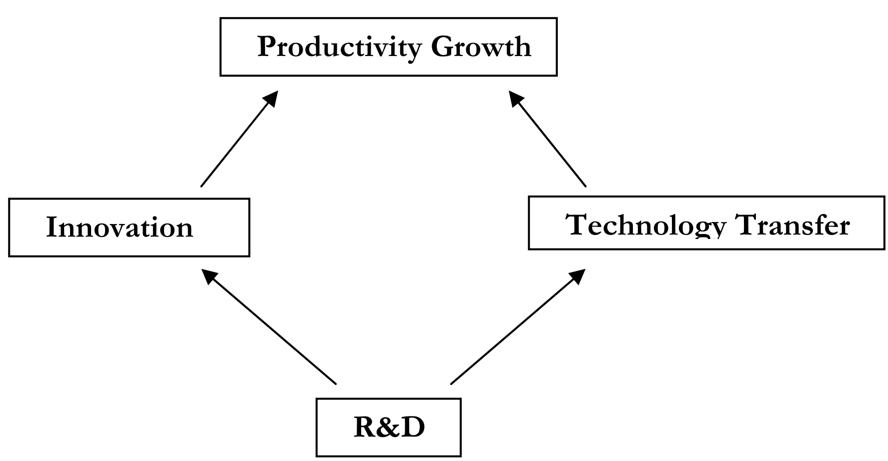
Our measure of productivity growth is based upon the idea that there is a production function determining the number of units of output produced for a given level of inputs of factors of production. This may be expressed mathematically in the following equation,

$$Output = TFP * F(Inputs)$$

Output will grow as conventional inputs grow (e.g. labour and capital). But it will also grow depending on how efficiently people and machines are used together. The measure of efficiency is called TFP for 'total factor productivity'.

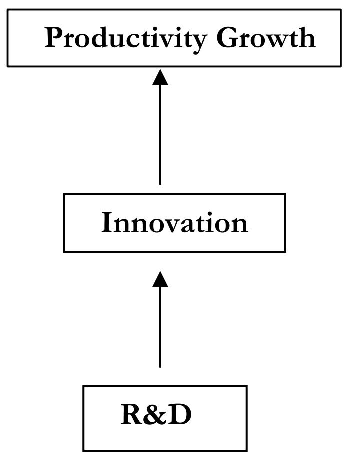
Table 1: Innovation, Technology Transfer and R&D

Panel A - An Economy behind the Technological Frontier



Panel B – an Economy that Already Possesses the State of the Art Technology

Table 2: List of Industries and Countries used in the Empirical Study



Industries

1) Food, beverages & tobacco (ISIC 31)
2) Textiles, apparel & leather (ISIC 32)
3) Wood products & furniture (ISIC 33)
4) Paper & printing (ISIC 34)
5) Chemical products (ISIC 35)
6) Non-metallic minerals (ISIC 36)
7) Primary metals (ISIC 37)
8) Fabricated metals (ISIC 38)
9) Metal products (ISIC 381)
10) Non-electrical machinery (ISIC 382)
11) Electrical machinery (ISIC 383)
12) Transport equipment (ISIC 384)
13) Instruments (ISIC 385)
14) Other manufacturing (ISIC 39)

Countries

1) Canada
2) Denmark
3) Finland
4) France
5) Germany
6) Italy
7) Japan
8) Netherlands
9) Norway
10) Sweden
11) United Kingdom
12) United States

The policy debate has largely been concerned with labor productivity (as measured for example by output per hour worked). While straightforward and intuitive, this is a measure of the productivity of one factor of production alone. Therefore, one cannot determine whether output per worker is high because of high levels of inputs (eg capital) or high levels of technical efficiency (TFP).

TFP itself provides a measure of the productivity of all factors of production. Under fairly general assumptions about the nature of the technological relationship (*F(.) above)* and market structures, one can derive measures of rates of productivity growth in individual industries of a particular country. These are based on index number theory and essentially compare the rate of growth of output with the rate of growth of factor inputs, where the rate of growth of each factor input is appropriately weighted.

We measure the potential for technology transfer by the distance between each economy's level of productivity in a particular industry and the level in the technological frontier in that industry (the "technology gap"). In principle, there are a number of ways in which one might model the technological frontier. One of the most natural is to treat the economy with the highest level of productivity in a particular industry as the frontier. Therefore in each industry, we calculate an economy's level of productivity relative to the productivity leader. Other things equal, the greater the distance between an economy's level of productivity and that in the leading economy, the greater the potential for technology transfer.

Similar techniques may be used to measure relative levels of productivity as were used to measure productivity growth. These essentially compare relative levels of output to relative levels of factor inputs, where factor inputs are weighted appropriately. In fact, a number of different measures of rates of growth and relative levels of productivity may be obtained depending upon exactly how one measures inputs of the factors of production and upon the assumptions one makes about market structure. We consider four measures of rates of growth and relative levels of productivity; these are listed in table 2 alongside the assumptions made about market structure and the way in which factor inputs are measured (e.g. how skilled the workforce is).

Table 3: Four Alternative Measures of Relative TFP

Each takes a different measure of inputs into the production process and makes a different assumption about market structure

(a) Market structure: perfect competition.
Labor input: hours worked
Capital input: no correction for degree of capacity utilization

(b) Market structure: perfect competition
Labor input: hours worked adjusted for skill composition of the workforce
Capital input: no correction for degree of capacity utilization

(c) Market structure: imperfect competition
Labor input: hours worked adjusted for skill composition of the workforce
Capital input: no correction for degree of capacity utilization

(d) Market structure: perfect competition
Labor input: hours worked adjusted for skill composition of the workforce
Capital input: correction for degree of capacity utilization

R&D activity is measured using data on the ratio of Business Enterprise R&D Expenditure to output. In order to assess the contribution of R&D activity to both innovation and technology transfer we modelled the growth in productivity as a function of R&D intensity, the productivity gap and many other factors. We allowed the effect of the gap to be different for industries with different R&D intensities. The results which emerged from the analysis were:-

- R&D generates productivity growth through innovation and so R&D activity has a direct effect on rates of productivity growth.

- Productivity growth was higher when the level of productivity in the leader is high relative to an economy's own productivity, suggesting a role for technology transfer and convergence within the OECD.

- A given size of the productivity gap has a greater effect on rates of productivity growth when R&D activity is high.

Across the four different measures of productivity growth, we find a role for R&D investment in stimulating both innovation and technology transfer. This provides support for the idea that there is an important second role of R&D in enabling agents to understand and assimilate existing technologies. It suggests that studies that focus on the innovative role of R&D investment alone may well underestimate the "true" rate of return to R&D in countries who are not technological leaders.

4. Not by Technology Alone…….

There are many other things that can affect effect productivity in addition to R&D. Perhaps the main alternative is human capital, and we allowed human capital to affect productivity growth through either innovation or technology transfer. We found countries which have invested more in schooling tend to absorb new technologies more quickly than countries endowed with less education. This is consistent with the findings of other, more aggregated studies.

Trade could stimulate faster innovation or learning through a number of routes. Imports from the technological leader will provide new knowledge embodied in the most technologically advanced new machines. Greater openness through lower tariffs could increase product market competition and force firms to adopt best practice in order to survive. Or trade with the less developed nations may push developed countries into defensive innovation.

We found some evidence that trade matters in addition to technology. Countries which were more open (especially to the technological leader) caught up faster. There appeared to be little role for trade in stimulating new innovations, however, trade seemed a way to adopt best practices rather than stimulate firms to come up with new ideas under the sun. For genuinely new products and processes higher R&D was the preferred method.

5. Conclusions

In this paper, we have argued that R&D drives productivity growth through both innovation and by facilitating the transfer of technology from the world technological frontier (absorptive capacity). Given that many countries, such as Britain, lie well behind the technological frontier one could ask why businesses are not doing more R&D since they get a big pay-off from it?

One reason is that the benefits of R&D are not really captured by those who do the R&D. As Flaubert [7]remarked in his dictionary "*Inventor*s - They all die in the hospice. Somebody else profits by their discoveries; it is not fair". But this problem is more endemic to R&D for innovation rather than R&D for learning. And it is an international problem (as firms learn from their international competitors as well as their national competitors). There is a big private incentive for companies to invest in something which boosts the speed at which they can catch up with the leaders.

The barriers to investing in R&D are more likely to come from the problems of raising finance or the lack of the appropriate skills necessary to turn R&D into innovation. On the first problem, the British government has targeted R&D tax credits at small firms where the financial problems are thought to be greatest. It has also encouraged various schemes to aid the start-up of high tech companies. But the amounts on offer are small relative to the gap in R&D. £150 million is earmarked for the R&D tax credit - compared to £7 billion in total R&D spend. It is overwhelmingly large firms who conduct R&D.

Since Britain's markets are relatively open to international trade, improving productivity through trade policy is less of an option than it would be in more protectionist countries.

The main area for UK improvement is almost certainly through increasing the skills infrastructure. The UK regularly comes near the bottom of the league tables of developed countries in mathematics and sends fewer of its young people to college than the U.S.A.. The best policy towards spreading technology is more likely to be in improving the environment for firms through better skills and greater competition rather than in an R&D policy per se.

[7] Dictionnaire des idées reçues

References

Arrow, K (1969) 'Classificatory Notes on the Production and Transmission of Technological Knowledge', *American Economic Review*, 59(2), Papers and Proceedings, 29–35.

Bloom, N, Griffith, R, and Van Reenen, J (2002) 'Do R&D Tax Credits Work? Evidence from a Panel of Countries 1979-97', *Journal of Public Economics*, 85, 1-31.

Cameron, G, Proudman, J, and Redding, S (1998) 'Productivity Convergence and International Openness', Chapter 6 in (eds) Proudman, J and Redding, S, *Openness and Growth*, Bank of England: London.

Griffith, R, Redding, S and Van Reenen, J (2001) 'Measuring the Cost-effectiveness of an R&D Tax Credit for the UK', *Fiscal Studies*, 22(3), 375-99.

Griffith, R, Redding, S and Van Reenen, J (2003) 'R&D and Absorptive Capacity: Theory and Empirical Evidence', *Scandinavian Journal of Economics*, 105(1), 99-118.

Griffith, R, Redding, S and Van Reenen, J (2004) 'Mapping the Two Faces of R&D: Productivity Growth in a Panel of OECD Industries', *Review of Economics and Statistics*, forthcoming.

Rosenberg, N (1982) *Inside the Black Box: Technology and Economics*, Cambridge University Press.

On the Determinants of Absorptive Capacity: Evidence from OECD Countries

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1. Introduction

It has long been recognised that international technology transfer in the form of knowledge spillovers is an important source of growth, and that the progress of both developed and developing nations may be determined in part by its extent (Gerschenkron, 1962). There does however appear to be large differences in how effective countries are in adopting foreign technology. Given that the bulk of new technology is created in a handful of the world's richest countries,[4] it is easy to see that differences in the ability of countries to take advantage of foreign technologies could be an important determinant of the world income distribution, which underlines the importance of identifying the major determinants of successful technology diffusion.

In this paper we add to the empirical literature on technology diffusion by

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[4]In 1990, 96% of the world's R&D expenditures took place in industrial countries (see Coe et al. 1997).

investigating the determinants of absorptive capacity in industrialized countries. In particular, we allow the absorption of foreign knowledge to be affected by variables that have been proposed in the theoretical literature. Our paper is related to two strands of the literature: namely, the literature dealing with trade-related knowledge spillovers and the literature on absorptive capacity.

A large and growing literature empirically investigating the role of trade in the diffusion of knowledge across countries has developed following the seminal contribution of Coe and Helpman 1995.[5] The approach adopted in empirical work has been to construct a "stock of knowledge" for each developed country and then measure access to this by weighting these stocks by some measure of the volume or share of bilateral trade. Using this approach evidence of knowledge spillovers on trading partners' rates of total factor productivity (TFP) or GDP growth have been found among developed countries (for example, Coe and Helpman, 1995) and from developed to developing countries (see Coe et al. 1997 for example).

The notion of absorptive capacity refers to the various factors that affect the ability of a country to take advantage of technology developed abroad.[6] Amongst the many determinants of absorptive capacity that have been proposed we analyze relative backwardness as proposed by Gerschenkron (1962) and Kuznets (1973), human capital, R&D expenditures and institutions as possible absorption barriers. The role of human capital in this context has been analyzed extensively in the empirical literature.[7] The general conclusion is that technology diffusion is positively affected by the availability of human capital. A small number of papers examine the impact of R&D on absorptive capacity. Griffith et al. (2000) use industry-level data from twelve OECD countries to study the main determinants of productivity dynamics and find that conditional on a certain productivity gap to the leader country, subsequent productivity growth in an industry is higher, the higher are its R&D expenditures. This is consistent with R&D playing a similar role to human capital. In a series of papers, Parente and Prescott (1994), (1999) and (2003) argue that absorptive capacity is to a large extent determined by institutional aspects that give rise to so called absorption barriers. That is, the costs of implementing new technologies faced by firms depend on the institutional setting. In particular, Parente and Prescott (1999), argue that monopoly rights may represent a barrier to the adoption of foreign technologies in the sense that industry insiders with monopoly rights to the current technology will resist the adoption of better production techniques. The greater the strength of protection granted to insiders, the greater the amount of resources that potential entrants with superior

[5]See Keller (2001) for a recent survey.

[6]Abramovitz (1986) discusses in detail the many factors that can be considered important for absorptive capacity.

[7]See for instance Benhabib and Spiegel (1994), Eaton and Kortum (1996), Engelbrecht (1997), Engelbrecht (2000) and Xu and Wang (2000).

technology have to spend in order to enter the industry. This suggests that more competitive economies are likely to be characterized by higher absorptive capacity.

In this paper we estimate the impact of foreign knowledge spillovers on growth using a method similar to Coe and Helpman (1995) for a sample of 21 OECD countries over the period 1973 to 1997. The paper differs from the previous literature by allowing the relationship between foreign knowledge spillovers and growth to depend on a third variable; absorptive capacity. Using a number of variables measuring absorptive capacity we employ threshold regression techniques to identify different regimes based on the level of absorptive capacity, with the impact of foreign knowledge spillovers on growth allowed to vary across regimes.

We find that human capital and in particular domestic R&D increases a country's absorptive capacity. Moreover, our results suggest that absorptive capacity depends on institutional variables as argued by Parente and Prescott (1994), (1999) and (2003). In particular, we find that countries with less regulated goods and labor markets tend to be characterized by a relatively higher absorptive capacity. We do not however find evidence that countries with relatively low initial levels of GDP per capita benefit more from spillovers than other countries. Thus, relative backwardness alone does not appear to facilitate foreign knowledge spillovers for our sample of industrialized countries.

The remainder of the paper is organized as follows: Section 2 gives an overview of the related literature. Section 3 discusses our empirical specification. Section 4 discusses our results and Section 5 concludes the paper.

2. Related Literature

In this paper we combine two strands of existing empirical literature, the literature on absorptive capacity and that on foreign knowledge stocks. A review of the literature shows that to date there has been little systematic analysis on the impact of absorptive capacity on foreign knowledge spillovers. In this section we begin by reviewing the existing (largely theoretical) literature on absorptive capacity before discussing the (largely empirical) literature on foreign knowledge spillovers.

It has long been recognized that international technology transfer is an important source of growth. Early theoretical contributions to the literature focused on the role of technology diffusion in the convergence process. Gerschenkron (1962) and Kuznets (1973) talked of the so-called "advantages of backwardness''. They argued that being a technological laggard had the advantage that it would be possible to ``borrow'' new technology from the leading edge countries. According to this argument we would expect that poorer countries gain more from foreign technology than richer countries. Others such as Abramovitz (1986), argued that in order to obtain such benefits other factors that affect the ability to adopt such technology needed to be in place, these factors being termed ``social capability'' or ``absorptive capacity''.

Abramovitz identifies a large number of factors that could be considered important for a country's absorptive capacity. Three general categories were identified; (1) Facilities for the diffusion of knowledge (for example channels of international technical communication, MNCs, the state of trade and of direct capital investment); (2)Conditions facilitating or hindering structural change in the composition of output, in the occupational and industrial distribution of the workforce, and in the geographical location of industry and population; (3) Macroeconomic and monetary conditions encouraging and sustaining capital investment and the level and growth of effective demand. Abramovitz also argued that the obstacles to change raised by vested interests, established positions, and customary relations among firms and between employers and employees may contribute to a country's absorptive capacity. As such a large number of factors may be considered important for a country's absorptive capacity. Despite this fact studies exist that consider a subset of such factors.

Two variables often associated with the idea that a firm or country needs to have a certain type of skill in order to be able to successfully adopt foreign technology are human capital and R&D expenditures (Keller, 1996, formalizes this idea). Such skills can come in the form of human capital (see Nelson, 1966) or in the form of R&D, as emphasized by Cohen. and Levinthal (1996). Cohen and Levinthal (1996) argue that in order to acquire outside technology a firm may itself need to invest in R&D. These authors argue that own R&D expenditures are critical for enabling the firm to understand and evaluate new technological trends and innovations.

A further aspect of absorptive capacity raised by Abramovitz has also been emphasized in the literature recently, namely institutional barriers to the adoption of new technology. Parente and Prescott (1994) argue that although the global pool of knowledge is readily accessible by each country, not all countries employ the best available technologies, because implementing new technologies and work practices involves costs. These costs are to some extent determined by institutional constraints such as the regulatory environment and competition policy. In their model, firms have to invest in order to increase the quality of their plants. However, the amount of investment required to achieve a certain level of quality depends on the institutional environment and therefore differs across countries. They find that even small variations in the costs imposed by the institutional environment give rise to large differences in income levels.

In a related paper, Parente and Prescott (1999) focus on monopoly rights as the main institutional feature that acts as a barrier to the adoption of foreign technologies. If industry insiders have monopoly rights to the current technology they will resist the adoption of better production techniques. The greater the strength of protection granted to the insiders, the greater the amount of resources that potential entrants with superior technology have to spend in order to enter the industry. Thus, more competitive economies are likely to benefit from spillovers to a larger extent.

Nelson and Phelps (2002) argue that the rate of technology absorption depends on the technology gap between the leading country and the follower. In this spirit, Benhabib and Spiegel (1994) and Engelbrecht (1997) include a human capital/productivity catch-up interaction term in regressions on the growth of either TFP or GDP, which also include a separate human capital variable to account for domestic innovation. Benhabib and Spiegel (1994) find that the interaction term is significant and has the expected sign only for developing countries, while the domestic innovation rate for these countries is negative but insignificant. The opposite result is found for the wealthiest third of countries. In contrast Engelbrecht (1997) finds that for OECD countries both variables enter significantly and with the expected sign. When including this interaction term, Engelbrecht (2000) finds for a sample of developing countries results similar to Benhabib and Spiegel (1994), namely a negative but insignificant coefficient on the education variable and a positive and significant coefficient on the interaction term. The results obtained suggest the sensible conclusion that for countries at lower levels of development general human capital accumulation is relatively more important, whereas for more developed countries embodied R&D spillovers and more specific human capital become crucial.

The development of theories of endogenous growth has revived the interest in the relationship between trade and growth and in to the role of foreign knowledge spillovers in growth. Recent theories of endogenous technological change provide a rationale for examining foreign knowledge spillovers through trade.[8] In a simple variant of these models, final output is produced using intermediate inputs, which may be horizontally or vertically differentiated. R&D affects output by increasing the number, or improving the quality, of available intermediates. In the absence of trade, a country's output is determined by its own cumulative past R&D. With trade a relationship between cumulative R&D and output remains, but the relevant measure is now the world R&D stock.[9]

From the theoretical literature, Coe et al. (1997) identify four channels through which international contacts may allow knowledge produced in one country to affect productivity and growth in others. First, they allow a country to employ intermediate and capital goods from abroad, which may enhance the productivity

[8] See for instance Romer (1986), Aghion and Howitt (1992), Grossman and Helpman (1991a) and (1991b).

[9] To date the literature has concentrated on the role of imports as a channel for foreign knowledge spillovers. Other channels are also likely to be important however, examples including exports, FDI, migration, technology licensing and electronic exchange.

of domestic resources. Second, by increasing communication between countries, they can encourage a more efficient employment of domestic resources through cross-border learning of production methods, product design, organizational structures and market conditions. Third, they can also assist countries inside the technological frontier in imitating the products of countries at the frontier. Finally, they can raise a country's productivity in the development of new technologies or the imitation of foreign technology.

An empirical literature has been in existence for some time examining knowledge spillovers among industries and firms within countries.[10] Recently, in response to the endogenous theories of trade and growth, a literature aiming to testing for the presence of international knowledge spillovers has emerged. The approach in empirical work has generally been to construct a stock a knowledge" based on past cumulative R&D for each country and then to measure the access of other countries to this by weighting these stocks by some measure of the volume or share of bilateral trade

This is the approach taken by Coe and Helpman (1995) who test for the presence of international knowledge spillovers among a sample of 22 developed countries over the period from 1971 to 1990. They study the extent to which a country's productivity depends upon both domestic and foreign knowledge stocks. The foreign knowledge stock is constructed using the weighted sum of trade partners' cumulative R&D spending. The weights used are bilateral import shares, since it is assumed that it is a country's imports that act as the conduit for knowledge spillovers and that the composition of imports is important (i.e. with whom a country trades). The import share weighted foreign knowledge stock is also interacted with the overall import share to examine the importance of the volume of trade as well as its composition. This specification is justified by referring to Grossman and Helpman (1991a), who relate productivity gains to trade volumes. The results suggest that both domestic and foreign knowledge stocks are important sources of productivity growth, although the former has a much larger impact on productivity in the larger countries. Smaller countries, it is argued, tend to be more open and benefit more from foreign knowledge than larger countries. A number of the results also suggest that foreign R&D capital stocks have stronger effects on domestic productivity the larger the share of imports in GDP. From these results Coe and Helpman (1995) conclude that a relationship between productivity and both the foreign and domestic knowledge stocks exists, with the countries gaining most from foreign knowledge being those that are more open to trade.

The results of Coe and Helpman (1995) have been controversial. Lichtenberg and van Pottelsberghe de la potterie (1998) alter the basic specification of Coe and Helpman's foreign knowledge variable to correct for an aggregation bias, while Keller (1998) re-examines the results of Coe and Helpman and in particular the

[10]See for example Terleckyj (1974) and Griliches (1984).

assertion that a country's benefit from knowledge created abroad is taken to be a trade weighted average of foreign countries knowledge stocks. He compares the estimated results of Coe and Helpman with those obtained from assigning bilateral trade partners randomly and finds that regressions based on simulated data generate on average larger estimated foreign knowledge spillovers, as well as a better fit in terms of R^2 , suggesting that the import composition of a country does not have a strong influence on the extent of foreign knowledge spillovers. Coe and Hoffmaister (1999) re-examine the work of Keller noting that the bilateral import shares constructed in the latter are similar to equal weights, or simple averages of trading partners knowledge stocks, suggesting that Keller's weights are not in fact random. Coe and Hoffmaister (1999) derive alternative sets of random weights that do not exhibit this property and find that using these weights the estimated foreign knowledge spillover estimates are extremely small and the equations explain less of the variation in productivity than when the true bilateral import shares are used.

Lumenga-Neso et al. (2002) extend the work of Coe and Helpman (1995) which considers ``direct'' foreign knowledge spillovers by considering also ``indirect'' foreign knowledge spillovers. Such ``indirect'' effects are based on the notion that a country can benefit from another country's knowledge stock even if they do not trade with each other as long as they both trade with a third country. The results of this study are stronger than those found in Coe and Helpman (1995) and show that "indirect" foreign knowledge spillovers are as important as "direct'' ones.

Coe et al (1997) adapt the analysis of Coe and Helpman to examine the extent of North-South R&D spillovers. They test for the presence of foreign knowledge spillovers from 22 developed countries to a sample of 77 developing countries over the period 1971-1990. The method used is similar to that in Coe and Helpman with the results suggesting that foreign knowledge spillovers from the North to the South are substantial. On average, a 1 percent increase in the knowledge stocks of the industrial countries raises productivity growth in developing countries by 0.06 percent. These results have been broadly supported by Engelbrecht (2000) and Falvey et al (2000).

3. Model Setup and Estimation

We begin our analysis by setting up a simple, empirically tractable model similar to those put forward extensively in the growth accounting literature. The model allows us to examine the importance of foreign knowledge spillovers for growth in a sample of OECD countries, and to examine whether the extent of such knowledge spillovers is influenced by several educational and institutional variables.

Consider a Cobb-Douglas production function with constant returns to scale and

Hicks neutral technological progress,

$$Y_{it} = A_{it}K_{it}^{\alpha}L_{it}^{1-\alpha}, \tag{1}$$

where Y_{it} refers to total production at time t in country i , K_{it} is physical capital and L_{it} refers to the labour input. Technological progress, that is the growth of A_{it} between period t and period $t+\tau$ will be assumed to depend on the changes of domestic and foreign stocks of R&D as in Coe and Helpman (1995),

$$\log A_{it+\tau} - \log A_{it} = \gamma_1(\log RD_{it+\tau}^{d} - \log RD_{it}^{d}) + \gamma_2(X_{it})(m_{it+\tau}\log RD_{it+\tau}^{f} - m_{it}\log RD_{it}^{f}), \tag{2}$$

where RD_{it}^{d} and RD_{it}^{f} are, respectively, the domestic and foreign R&D capital stock. As in Coe and Helpman (1995), the elasticity of labour-augmenting technology with respect to the foreign R&D capital stock is postulated to depend linearly on the the import share, m_{it} . We will further assume that the parameter capturing the absorption of knowledge, γ_2 , may depend on a set of economic and institutional variables (X_{it}). In principle, we assume that the diffusion of new technologies is a two stage process. In the first stage, knowledge is transmitted through trade flows, whilst in the second stage it is absorbed by the recipient country. Thus our empirical specification treats trade differently from the other determinants of absorptive capacity, since we assume that trade is necessary for the transmission of knowledge, but does not guarantee absorption.[11]

It should be noted that we will not consider human capital as a standard input of production as has occurred extensively in the growth literature (see for example Mankiw, 1992). Instead, in line with Nelson and Phelps (2002) and Benhabib and Spiegel (1994) and (2003), we will assume that human capital levels affect the ability of a nation to adopt foreign technology, and therefore human capital proxies will be incorporated to the set of variables affecting absorptive capacity in (2).

Using (1) and (2), the expression for the growth rate of income per capita between period t and period $t+\tau$ is given by

[11] An alternative view of the role of trade in this context is presented in Holmes and Schmitz (1995) who argue that international trade and foreign competition force domestic interest groups to adopt the most efficient technologies. Thus, international trade facilitates the adoption of new technologies, but for a different reason than in Coe and Helpman (1995).

$$\log y_{it+\tau} - \log y_{it} = \alpha(\log K_{it+\tau} - \log K_{it}) + \gamma_1(\log RD^d_{it+\tau} - \log RD^d_{it}) + \\ + \gamma_2(X_{it})(m_{it+\tau} \log RD^f_{it+\tau} - m_{it} \log RD^f_{it}) - \alpha(\log L_{it+\tau} - \log L_{it}), \quad (3)$$

where y_t denotes GDP per capita. Equation (3) is the specification that will be implemented empirically for different variables in X_{it} .

We will proceed by estimating (3) for a panel of 21 OECD countries assuming different specifications for the absorptive capacity parameter. The natural baseline estimation is given by assuming constant absorptive capacity, that is, $\gamma_2(X_{it}) = \gamma_2$. The countries included in the analysis are Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom and the United States. The yearly data, spanning the period from 1973 to 1997, were aggregated to five-year non-overlapping sub-periods. The panel has, thus, five observations per country and 105 observations in total. Details concerning data sources and computation of variables are given in the appendix. In all cases, a two-way fixed effects model was used in order to account for cross-country unmodeled heterogeneity and common shocks.

4. Estimation Results

The first column of table 1 presents the estimates of the baseline model. The null of constant returns to scale in the aggregate production function cannot be rejected by the data (the corresponding F -statistic equals 1.89 for the baseline model), and is therefore imposed in all estimations. The estimate of α is in line with those widely reported in the literature, and the significantly positive parameter attached to the change in domestic R&D, γ_1 , provides evidence on the importance of innovation-driven technological progress for a nation's growth performance. The parameter corresponding to the variable capturing foreign knowledge spillovers, γ_2 , however, although positive is not significant, suggesting that foreign knowledge spillovers are not an important source of growth.[12] Moreover, if the absorptive capacity parameter is assumed country-specific (while keeping the other two parameters equal across countries), none of the estimates appears 5% significant, and only the absorption parameter estimates for the United Kingdom and Norway

[12]Multicollinearity does not seem to play a major role in the lack of significance of the parameter estimate. The correlation between the domestic and foreign R&D variables, although significant at the 5% level is only 0.167.

are 10% significant and positive.[13]

The residuals of the baseline model present significant deviations from Gaussianity, as measured by the Jarque-Bera test statistic. The lack of normality seems to be caused by the observation corresponding to the deep recession experienced by Finland at the beginning of the nineties, for which the baseline model strongly overestimates the growth rate of GDP per capita. The second column of table 1 presents the estimation results if a dummy is included for this observation. The dummy is highly significant and negative, as expected, and the goodness of fit of the model increases enormously. Furthermore, the null of normal distribution of the residuals cannot be rejected now at any reasonable significance level. For all estimations reported henceforth, the dummy will be included.

Our hypothesis is that differences through time and across countries in variables representing the degree of absorptive capacity may be responsible for the lack of significance of the parameter estimates corresponding to foreign R&D spillovers. In order to obtain some evidence on the impact of the variables under consideration on absorptive capacity, we begin by modeling a level-dependent absorption parameter, where the absorptive capacity for foreign R&D depends upon the value of some other variable. The simplest way of assessing the influence of these variables on absorptive capacity is by dividing the sample according to the level of the variable being studied and estimating different absorption parameters for each sub-sample. The model we estimate is thus similar to (3) with

$$\gamma_2(X_{it}) = \sum_{k=1}^{\overline{K}} \gamma_{2,k} \mathrm{I}(X_{it} \in [q_{X,100(k-1)/\overline{K}}, q_{X,100k/\overline{K}})), \tag{4}$$

where $\mathcal{I}(\cdot)$ is the Heavyside function and $q_{X,n}$ is the n -th percentile of the distribution of X_{it} . The choice of regimes with equal number of observations is in principle unjustified, and we will later proceed to estimate and test optimal thresholds (in the sense of least square estimates). However, this simple method should help shed some light on the shape of the relationship between absorptive capacity and institutional and educational variables.

4.1 Relative Backwardness

We begin by exploring whether countries with comparatively low levels of per capita GDP benefit more from foreign R&D than rich countries. As such, we test the claim of Gerschenkron (1962) and Kuznets (1973) that technological laggards have the advantage that they can borrow technology from countries at the

[13] The goodness of fit of the model with country-specific absorptive capacities, as measured by the adjusted R^2 , is considerably smaller than the one of the baseline model.

technological frontier.

Table 2 reports the results for either real GDP per capita and or relative real GDP per capita as the variable that determines the absorption parameter. Relative GDP per capita is calculated with respect to the richest country in our sample, which is Switzerland. We obtain estimates for α and γ_1 that are similar to the baseline case. The equation is estimated with two regimes, as suggested by model selection criteria. The absorption parameter is found to be positive and significantly different from zero (at the 10 % level) in the first regime only. As such, the results suggest that foreign knowledge spillovers are important sources of growth in the most backward countries in our sample, but that there are no significant gains from knowledge spillovers in the most advanced countries in our sample.

The remaining columns in table 2 present the estimates of the model if the cutting point of the distribution of (relative) real GDP per capita is explicitly estimated. Maintaining the hypothesis of a two-regime absorption parameter, the $\gamma_2(X_{it})$ function used is

$$\gamma_2(X_{it}) = \gamma_{2,1}\mathcal{I}(X_{it} \leq \lambda) + \gamma_{2,2}\mathcal{I}(X_{it} > \lambda). \quad (5)$$

The threshold parameter λ will be estimated as

$$\hat{\lambda} = {}_{\tilde{\lambda}\in[q_{X,20},q_{X,80}]} \sum_i \sum_t [\hat{\varepsilon}_{i,t}(\tilde{\lambda})]^2,$$

that is, as the least squares threshold in the central 60% of the empirical distribution of X_{it} .[14]

Similar results are obtained when the threshold is estimated, with a positive and significant absorption parameter found in the low-income regime, but an insignificant coefficient found for the high-income regime. The threshold estimate for both, absolute and relative GDP per capita corresponds to the 78th percentile of the empirical distribution. For the models where the threshold was estimated, table 3 also presents the likelihood ratio test statistic for the null of linearity ($\gamma_{2,1} = \gamma_{2,2}$) together with the bootstrap p -value obtained using the methodology described in Hansen (2000).[15] Despite the differences in the absorption coefficient in the two regimes the null of parameter constancy across the regimes cannot be rejected at conventional levels of significance. Overall the results for backwardness suggest that there may be limited gains from foreign knowledge spillovers for relatively backward countries, but that backwardness doesn't appear to be a

[14]For more details on the techniques employed here see Hansen (1996) and Hansen (2000).

[15]The bootstrap distribution of the test statistic was computed using 500 replications of the procedure proposed in Hansen (2000).

sufficient condition for spillovers as suggested by Gerschenkron (1962). In what follows we address notion proposed by Abramovitz (1986) that factors other than backwardness may be needed in order to benefit from foreign knowledge.

4.2 Absorptive Capacity, Human Capital and R&D

As discussed in Section 2 human capital and domestic R&D are two additional determinants of absorptive capacity that have been proposed in the literature. The general idea is that a country has to have a well trained workforce and perform some R&D itself in order to successfully absorb foreign technology and knowledge.

Table 3 presents the parameter estimates using educational attainment and domestic R&D investment as the variables that trigger differences in absorptive capacity. The X variable in the second column is "Average years of secondary schooling in the total population over 25", and in the third column, "Average years of higher schooling in the total population over 25". Results for R&D investment as the X variable are reported in the fourth column.

Concerning the educational variables, in both cases, usual model selection criteria choose the two-regime specification ($\bar{K}$ =2) among models with the number of regimes ranging between two and four.[16] The estimates of α and γ_1 are largely unchanged by the inclusion of the break in the absorption parameter. The results indicate that significant absorptive capacity tends to be related to higher levels of educational attainment. The sub-sample specific absorption parameters are significantly different from each other (at the 10% significance level) for the case of secondary education, but the model with higher education fails to reject the null of equal parameters across regimes when using a standard F test.

A similar picture emerges for R&D investment. For this variable, model selection criteria indicate three regimes. The point estimates for α and γ_1 are once again largely unaffected by defining the absorption parameter as a function of R&D investment. According to the results in table 3 countries with relatively high R&D investment (i.e. in the high-regime) are characterized by a significantly larger absorption parameter than countries in the other two regimes.

The results are not qualitatively affected if the cutting points are estimated instead of being set *ad hoc*. When the threshold is estimated, the absorption parameter corresponding to the high education regime is also significant and

[16]This will be the range of models considered in the whole analysis. For the variables studied in the empirical analysis which present time variation, models with more regimes (up to ten) were also tried, but model selection criteria did not tend to choose models outside the range proposed.

positive, while the sub-sample belonging to the regime with low education levels is characterized by insignificant absorptive capacity. The same is true for R&D investment as an explanatory variable, with a positive and significant absorption parameter found for the high R&D investment regime and an insignificant parameter found in the low regime. The least squares estimate of the threshold for secondary schooling corresponds to the 35th percentile of the distribution of secondary schooling across countries in the period from 1976 to 1990 (approximately 2.37 years). For the case of higher education schooling, the estimate corresponds to the 53rd percentile of the distribution (approximately 0.43 years of higher education). For R&D investment, the threshold corresponds to the 70th percentile.

The evidence of a human capital dependent absorption parameter seems to be empirically observable when using secondary education as a proxy, suggesting that countries with higher levels of secondary schooling benefit to a greater extent from foreign knowledge. For higher education the LR test suggests that differences across regimes are not significant. For R&D investment the LR test indicates that linearity is rejected at a high level of significance showing that countries can benefit substantially from foreign knowledge spillovers by investing in R&D themselves.

4.3 Absorptive Capacity and Institutional Aspects

Parente and Prescott (2003) argue that market regulation that results in protecting the monopoly rights of industry insiders can act as a barrier to technology adoption. Intuitively, as long as firms are not threatened by the prospect that their competitors might introduce more productive technologies, the firms may prefer to stick to their current technology, although better ones are available. This is particularly likely since the adoption of new technology usually involves significant costs.

In order to test this view we include proxies for the intensity of regulation in X_{it} . We use data on regulatory indicators for product market regulation (collected in Nicoletti et al.,2000) for this purpose. The indicators measure restrictions on competition and private governance on a scale from 0 to 6 (from least to most restrictive). In our analysis, we employ summary indicators for product market regulation and indicators for barriers to entrepreneurship and employment protection.

We begin by analyzing an index of product market regulation (PMR). The summary index of regulation includes information on entry barriers, state control (in particular public ownership) and barriers to trade and investment. Entry barriers cover regulatory restrictions on the number of companies in potentially-competitive markets. The indicator for state control measures the size and scope of the public enterprise sector as well as regulatory features, such as price controls.

Table 4 presents the results of the estimation when the absorption parameter is postulated to depend upon the overall level of market regulation, as measured by PMR. Since this index includes some aspects related to the degree of openness and international competition (e.g. tariffs) that are in some sense already captured in the construction of the foreign R&D stocks, we repeat the estimation with the index of inward oriented product market regulation (IO-PMR).

Using a specification for the absorption parameter such as (4) with X_t = PMR (IO-PMR), AIC chooses for both cases a three-regime specification among those models ranging between two and four regimes. When product market regulation is measured by PMR, the absorption parameter is only positive and marginally significant for the sub-sample attached to low levels (corresponding to the first third of the empirical distribution of PMR) of market regulation. The evidence is stronger if IO-PMR is used as a measure; in this case the parameter corresponding to the sub-sample in the first third of the distribution of inward-oriented product market regulation is positive and 5% significant. Given that there are no significant results for the other regimes, a two-regime specification such as (5) was preferred for the endogenous estimation of the threshold value. The results of the model with a threshold level determined endogenously are presented in the third and fourth columns of table 4. The estimated value of the threshold for the case of PMR corresponds approximately to the 20th percentile of the distribution of the variable, and the picture drawn by the model is similar to that with exogenously set thresholds. The bootstrapped likelihood ratio test, however, cannot reject the null of no threshold effect in this variable. The estimate for the case of IO-PMR is the 33rd percentile of the empirical distribution of IO-PMR, so the results do not differ from the case with exogenous thresholds. The absorption parameter is positive and significant only in the sub-sample corresponding to low inward-oriented product market regulation, and the null of no threshold effect in the parameter is rejected at the 10% significance level.

Next, we isolate the effect of barriers to entrepreneurship (ENT), as an alternative variable that is of interest in this context. This is done because IO-PMR also includes information on public ownership which is not necessarily a restriction on competition per se. However, since one might argue that as long as the incumbent firms are protected by sufficiently high barriers to entry, they do not have an incentive to adopt more productive technologies.

We also analyze the impact of labor market institutions as a determinant of absorptive capacity since apart from firms with monopoly rights, unions are another group with vested interests that might potentially oppose the introduction of new (possibly labor-saving) technologies. Another reason why labor relations are important for the absorption of new technologies is that the introduction of new technologies typically involves some fixed costs and whether or not new technologies are implemented might depend on how these costs are shared between firms and workers. As a proxy for labor market institutions we use the index of employment protection regulation (EPL) from Nicoletti et al. (2000) and the data on union density (UD) from from Nickell et al. (2001).

Table 5 presents the results for ENT, EPL and UD.[17] The results presented complement those found for the product market regulation variables. In this case only EPL presents significant threshold effects (in the sense of rejection of the likelihood ratio test when the threshold was estimated endogenously) in the absorption parameter, with positive effects corresponding only to the sub-sample defined by observations of EPL in the first quartile of the distribution (the threshold estimate is roughly the 25th percentile of the empirical distribution of EPL). For UD the estimated threshold corresponds to the 50th percentile and is statistically significant. It appears that higher union density is associated with a higher absorptive capacity. Thus, we do not find that the bargaining power of unions acts as an adoption barrier in our sample.

For ENT the null of no threshold effects can not be rejected at conventional levels of significance although the point estimate for the absorption parameter is substantially larger for smaller values of the respective variables under consideration.

In short these findings appear to confirm that institutional aspects influence to some extent the absorptive capacity of a country. In particular, countries that are characterized by low degrees of product market regulation and employment protection are also characterized by a large degree of absorptive capacity. It has to be noted however that the statistical significance is not always overwhelming. Nevertheless, these results are in line with the ideas advocated by Parente and Prescott (2003) that institutional features that aim at protecting the vested interests of insiders can act as a barrier to technology absorption. In particular, countries that fall below the 33rd percentile of the empirical distribution of the index of inward oriented product market regulation can benefit from stronger spillovers than countries with more regulated product markets. The same is true for countries below the 25th percentile with regard to employment protection regulation. This suggests that countries need to achieve a certain minimum level of competitiveness in goods and labor markets in order to be able to take advantage of the global pool of knowledge.The bargaining power of unions on the other hand does not appear to be a significant absorption barrier.

[17] Data on EPL for Finland were not available, so the estimations including this variable are run excluding Finland from the sample. Similarly, Greece is dropped for the estimation with UD. There were also no available data on union density for Portugal in the period 1983 to 1987 and Spain in the period 1993 to 1997.

5. Concluding Remarks

This paper empirically evaluates the determinants of absorptive capacity in industrialized countries. In particular we analyze three broad groups of candidate variables that may affect the ability to benefit from foreign knowledge spillovers: relative backwardness, human capital and R&D expenditure and institutional variables related to absorption barriers.

According to our results, absorptive capacity appears to be increasing in human capital and domestic R&D. Moreover, we find some evidence in favor of the arguments presented in Parente and Prescott (2003) concerning the relevance of institutional variables. In our sample, countries with less regulated goods and labor markets tend to be characterized by high absorptive capacity. However, we find little evidence in favor of relative backwardness facilitating foreign knowledge spillovers. As such our results support the views of Abramovitz (1986) that it is not the ``advantages of backwardness'' that are important for international technology transfer, other factors need to be in place to be able to take advantage of such technology.

A - Data Description

The data on population, GDP per capita and the share of imports in GDP were taken from the World Bank's *World Development Indicators* Database. Education data was obtained from the Barro-Lee dataset (Barro and Lee, 2001). The source of the capital stock data is the OECD's *Economic Outlook* database for all countries except Portugal, whose data is taken from the European Commission's *AMECO* database. Domestic R&D stocks are constructed out of R&D flow data (source: Universidad Complutense, Madrid) using the perpetual inventory method as in Coe and Helpman (1995). A yearly depreciation rate of 5% was assumed for the computation of the stocks. Foreign R&D stocks for country i were computed, following Coe and Helpman (1995), as the import-share weighted averages of the domestic R&D of country i 's trade partners,

$$RD^f_{i,t} = \sum_{j \neq i} \frac{\eta_{ij,t}}{\eta_i} RD^d_{j,t},$$

where η_{ij} is the volume of imports of goods and services from country j to country i and η_i is the total volume of imports of country i from all countries in the sample. The data on trade flows are taken from the OECD's *International Trade by Commodity Statistic*.

Data on regulatory indicators, PMR, IO-PMR, ENT and EPL are from Nicoletti et al. (2000). The indicator for union density is taken from Nickell et al. (2001).

References

Abramovitz, M.: 1986, 'Catching Up, Forging Ahead, and Falling Behind'. *Journal of Economic History* **46**, 385–406. Aghion, P. and P. Howitt: 1992, 'A Model of Growth trough Creative Destruction'. *Econometrica* **60**, 323–351.

Barro, R. and J.W. Lee: 2001, 'International Data on Educational Attainment: Updates and Implications'. *Oxford Economic Papers* pp. 541–563.

Benhabib, J. and M. M. Spiegel: 1994, 'The Role of Human Capital in Economic Development. Evidence from Aggregate CrossCountry Data'. *Journal of Monetary Economics* **34**, 143–173.

Benhabib, J. and M. M. Spiegel: 2003, 'Human capital and technology diffusion'. In: P. Aghion and S. Durlauf (eds.): *Handbook of Economic Growth*. Amsterdam, forthcoming: North Holland.

Coe, D. and E. Helpman: 1995, 'International R&D Spillovers'. *European Economic Review* **39**, 859–887.

Coe, D., E. Helpman, and A. W. Hoffmaister: 1997, 'NorthSouth R&D Spillovers'. *Economic Journal* **107**, 134–150.

Coe, D. and A. W. Hoffmaister: 1999, 'Are There International R&D Spillovers Among Randomly Matched Trade Partners? A Response to Keller'. Working Paper 99/18, International Monetary Fund.

Cohen, W. and D. Levinthal: 1996, 'Innovation and Learning: The Two Faces of R&D'. *Economic Journal* **99**, 569–596.

Eaton, J. and S. Kortum: 1996, 'Measuring Technology Diffusion and the International Sources of Growth'. *Eastern Economic Journal* **22**, 401–410.

Engelbrecht, H. J.: 1997, 'International R&D Spillovers, Human Capital and Productivity in OECD Economies: An Empirical Investigation'. *European Economic Review* **41**, 1479–1488.

Engelbrecht, H. J.: 2000, 'Human Capital and International Knowledge Spillovers in TFP Growth of a Sample of Developing Countries: An Exploration of

Alternative Approaches'. *Applied Economics* **34**, 831–841.

Falvey, R. E., N. Foster, and D. Greenaway: 2000, 'North-South Trade, Knowledge Spillovers and Growth'. *Journal of Economic Integration* **17**, 650–670.

Gerschenkron, A.: 1962, *Economic Backwardness in Historical Perspective*. Cambridge, MA: Harvard University Press.

Griffith, R., S. Redding, and J. Van Reenen: 2000, 'Mapping Two Faces of R&D: Productivity Growth in a Panel of OECD Countries'. mimeo.

Griliches, Z.: 1984, *R&D, Patents and Productivity*. Chicago: University of Chicago Press.

Grossman, G. and E. Helpman: 1991a, *Innovation and Growth in the Global Economy*. Cambridge, MA: MIT Press.

Grossman, G. and E. Helpman: 1991b, 'Trade, Spillovers, and Growth'. *European Economic Review* **35**, 4517–526.

Hansen, B.: 1996, 'Inference when a nuisance parameter is not identified under the null hypothesis'. *Econometrica* **64**, 413–430.

Hansen, B.: 2000, 'Sample Splitting and Threshold Estimation'. *Econometrica* **68**, 575–603.

Holmes, T. J. and J. A. Schmitz: 1995, 'Resistance to New Technologies and Trade between Areas'. *Federal Reserve Bank of Minneapolis Quarterly Review* **19**, 2–17.

Keller, W.: 1996, 'Absorptive Capacity: On the Creation and Acquisition of Technology in Development'. *Journal of Development Economics* **49**, 199–227.

Keller, W.: 1998, 'Are International R&D Spillovers TradeRelated? Analyzing Spillovers Among Randomly Matched Trade Partners'. *European Economic Review* **42**, 1469–1481.

Keller, W.: 2001, 'International Technology Diffusion'. Working Paper 8573, NBER.

Kuznets, S.: 1973, 'Modern Economic Growth: Findings and Reflections'. *American Economic Review* **68**, 247–258.

Lichtenberg, F. R. and B. van Pottelsberghe de la Potterie: 1998, 'International R&D Spillovers: A Comment'. *European Economic Review* **82**, 942–963.

Lumenga-Neso, O., M. Olarreaga, and M. Schiff: 2002, 'On Indirect' TradeRelated R&D Spillovers'. mimeo.

Mankiw, G., D. Romer, and D. Weil: 1992, 'A Contribution to the Empirics of Economic Growth'. *Quarterly Journal of Economics* **107**, 407–437.

Nelson, R. and E. Phelps: 2002, 'Investment in Humans, Technological Diffusion and Economic Growth'. *American Economic Review* **56**, 69–75.

Nickell, S. J., L. Nunziata, W. Ochel, and G. Quintini: 2001, 'The Beveridge Curve'. Discussion Paper 502, CEP.

Nicoletti, G., S. Scarpetta, and O. Boylaud: 2000, 'Summary Indicators of Product Market Regulation with an Extension to Employment Protection Legislation'. Working Paper 226, OECD Economics Department.

Parente, S. L. and E. Prescott: 1994, 'Barriers to Technology Adoption and Development'. *Journal of Political Economy* **102**, 298–321.

Parente, S. L. and E. Prescott: 1999, 'Monopoly Rights: A Barrier to Riches'. *American Economic Review* **89**, 1216–1233.

Parente, S. L. and E. Prescott: 2003, *Barriers to Riches*. MIT Press.

Romer, P.: 1986, 'Increasing Returns and long run Growth'. *Journal of Political Economy* **94**, 1002–1037.

Terleckyj, N. E.: 1974, 'Effects of R&D on the Productivity Growth of Industries'. Report no. 140, National Planning Association, Washington DC.

Xu, B. and J. Wang: 2000, 'Trade, FDI and International Technology Diffusion'. *Journal of Economic Integration* **15**, 585–601.

Table 1: Baseline Model

Parameter	Baseline	Baseline with dummy
α	0.244* (0.145)	0.229 (0.144)
γ1	0.281** (0.127)	0.352*** (0.100)
γ2	0.014 (0.009)	0.014 (0.009)
Fin. rec. dummy	–	-0.200*** (0.038)
Obs	105	105
JB test	8.27***	0.606
R^2adj	0.397	0.506

The dependent variable is the 5-year log change of GDP per capita in all specifications. Robust standard errors in parenthesis.***(**)[*] stands for 1% (5%) [10%] significant. Estimation carried out assuming a two-way fixed effects error term. JB test stands for the Jarque-Bera test statistic for normal distribution of the residuals, $\chi^2(2)$ distributed under the null of Gaussian residuals.

Table 2: Absorptive capacity and backwardness: Estimation results

	Exogenous threshold		Estimated threshold	
Parameter	X=GDP p.c.	X=Relative GDP p.c.	X=GDP p.c.	X=Relative GDP p.c.
α	0.229 (0.146)	0.229 (0.146)	0.227 (0.143)	0.223 (0.144)
γ_1	0.343*** (0.096)	0.346*** (0.098)	0.337*** (0.101)	0.336*** (0.101)
$\gamma_{2,1}$	0.021* (0.012)	0.021* (0.012)	0.016* (0.009)	0.017* (0.010)
$\gamma_{2,2}$	0.006 (0.011)	0.006 (0.011)	-0.005 (0.018)	-0.006 (0.015)
λ	–	–	10.17	-0.48
LR test	–	–	1.39 (p-val: 0.32)	1.92 (p-val: 0.19)
Observations	105	105	105	105
JB test	0.55	0.53	0.51	0.45
R^2_{adj}	0.505	0.504	0.506	0.507

The dependent variable is the 5-year log change of GDP per capita in all specifications. Robust standard errors in parenthesis.***(**)[*] stands for 1% (5%) [10%] significant. Estimation carried out assuming a two-way fixed effects error term. JB test stands for the Jarque-Bera test statistic for normal distribution of the residuals, $\chi^2(2)$ distributed under the null of Gaussian residuals. The p-value for the likelihood ratio test statistic (LR) was computed using the bootstrap procedure in Hansen (2000) with 500 replications.

Table 3: Absorptive capacity, education levels and domestic R&D investment: Estimation results

	Exogenous threshold			Estimated threshold		
Parameter	X=Second. Educ.	X=Higher Educ.	X=Dom. R&D growth	X=Second. Educ.	X=Higher Educ.	X=Dom. R&D growth
α	0.243* (0.143)	0.248* (0.146)	0.215 (0.149)	0.250* (0.143)	0.251* (0.147)	0.216 (0.139)
γ_1	0.322*** (0.098)	0.345*** (0.099)	0.333*** (0.093)	0.331*** (0.096)	0.345*** (0.099)	0.324*** (0.089)
$\gamma_{2,1}$	0.009 (0.010)	0.008 (0.010)	0.011 (0.016)	0.005 (0.010)	0.008 (0.010)	0.010 (0.009)
$\gamma_{2,2}$	0.034** (0.015)	0.026* (0.014)	0.009 (0.012)	0.033** (0.014)	0.027* (0.015)	0.054*** (0.019)
$\gamma_{2,3}$	–	–	0.052*** (0.019)	–	–	–
λ	–	–	–	2.37	0.43	0.17
LR test	–	–	–	4.08 (p-val: 0.08)	1.89 (p-val: 0.26)	6.96 (p-val: 0.02)
Observations	105	105	105	105	105	105
JB test	1.13	0.94	0.82	1.31	0.89	0.91
R^2_{adj}	0.513	0.507	0.522	0.518	0.508	0.530

The dependent variable is the 5-year log change of GDP per capita in all specifications. Robust standard errors in parenthesis.$^{***(**)[*]}$ stands for 1% (5%) [10%] significant. Estimation carried out assuming a two-way fixed effects error term. JB test stands for the Jarque-Bera test statistic for normal distribution of the residuals, $\chi^2(2)$ distributed under the null of Gaussian residuals. The p-value for the likelihood ratio test statistic (LR) was computed using the bootstrap procedure in Hansen (2000) with 500 replications.

Table 4: Absorptive Capacity And Product Market Regulation: Estimation results

	Exogenous threshold		Estimated threshold	
Parameter	X=PMR	X=IO-PMR	X=PMR	X=IO-PMR
α	0.254* (0.15)	0.265* (0.15)	0.262* (0.14)	0.267* (0.15)
γ_1	0.321***(0.09)	0.320***(0.09)	0.319***(0.09)	0.322***(0.09)
$\gamma_{2,1}$	0.035* (0.02)	0.032** (0.01)	0.036* (0.02)	0.032** (0.01)
$\gamma_{2,2}$	0.003 (0.01)	-0.003 (0.01)	0.007 (0.01)	0.003 (0.01)
$\gamma_{2,3}$	0.009 (0.01)	0.007 (0.01)	–	–
λ	–	–	1.30	1.72
LR test	–	–	2.88 (p-val: 0.15)	3.69 (p-val: 0.10)
Obs	105	105	105	105
JB test	1.12	1.25	1.31	1.08
R^2_{adj}	0.506	0.511	0.518	0.516

The dependent variable is the 5-year log change of GDP per capita in all specifications. Robust standard errors in parenthesis.***(**)[*] stands for 1% (5%) [10%] significant. Estimation carried out assuming a two-way fixed effects error term. JB test stands for the Jarque-Bera test statistic for normal distribution of the residuals, $\chi^2(2)$ distributed under the null of Gaussian residuals. The p-value for the likelihood ratio test statistic (LR) was computed using the bootstrap procedure in Hansen (2000) with 500 replications.

Table 5: Absorptive Capacity, Barriers To Entrepreneurship And Employment Protection Legislation: Estimation Results

	Exogenous threshold			Estimated threshold		
Parameter	X=ENT	X=EPL	X=UD	X=ENT	X=EPL	X=UD
α	0.279* (0.153)	0.356** (0.151)	0.183 (0.151)	0.267* (0.149)	0.357** (0.147)	0.183 (0.151)
γ_1	0.321*** (0.092)	0.321*** (0.090)	0.353*** (0.098)	0.315*** (0.094)	0.320*** (0.088)	0.353*** (0.098)
$\gamma_{2,1}$	0.032* (0.019)	0.035* (0.018)	-0.011* (0.015)	0.032* (0.016)	0.035* (0.018)	-0.011* (0.015)
$\gamma_{2,2}$	-0.001 (0.015)	0.002 (0.011)	0.025**(0.011)	0.004 (0.011)	0.001 (0.001)	0.025**(0.011)
$\gamma_{2,3}$	0.014 (0.012)	0.004 (0.018)	0.015 (0.010)	–	–	–
λ	–	–	–	1.30	1.10	0.401
LR test	–	–	–	3.15 (p-val: 0.14)	4.07 (p-val: 0.08)	7.081 (p-val: 0.03)
Ob	105	100	98	105	100	98
JB test	1.37	1.19	0.982	1.16	1.24	0.982
R^2_{adj}	0.506	0.522	0.537	0.514	0.528	0.537

The dependent variable is the 5-year log change of GDP per capita in all specifications. Robust standard errors in parenthesis.$^{***(**)[*]}$ stands for 1% (5%) [10%] significant. Estimation carried out assuming a two-way fixed effects error term. JB test stands for the Jarque-Bera test statistic for normal distribution of the residuals, $\chi^2(2)$ distributed under the null of Gaussian residuals. The p-value for the likelihood ratio test statistic (LR) was computed using the bootstrap procedure in Hansen (2000) with 500 replications.

Comment on the Papers by Scharler et al. and by Redding et al.

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Both of these papers are related to the research field of endogenous growth and, more particularly, to the effects of inventions on economic growth.

In economics, *technological progress* means an increase in productivity, i.e. more output at the same-value of input. Part of it is caused by inventions (new products, new production technologies, or major changes of old technologies), part of it by learning-by-doing etc. Inventions can be rewarding to the inventor or to others who adopt the new creation. Inventions may be transferred, adapted, or imported. The (non-academic) literature as well as history are full of anecdotes on inventors who were unable to reap the profits that eventually arose from their ideas. A popular cartoon character, Gyro Gearloose, may serve as an example.

The presented papers contribute to several aspects of this general process:

1) improving the environment for inventions by investing into R&D (*research and development*)
2) importing the inventions created by others' R&D
3) improving the ability of adopting others' R&D

In the world of GRIFFITH, REDDING, VAN REENEN, technological progress is caused by own R&D and by "distance to a leading frontier economy". A lesser role is allotted to human capital, while the significance of trade (technology imports) remains low.

In the world of CRESPO-CUARESMA, FOSTER, SCHARLER, technological progress is caused by own R&D and by imported R&D. The reaction to imported R&D is analyzed in detail. Human capital *per se* is not considered. The significance of a "technology gap" to frontier economies remains low.

GRvR measure the technological progress by using a constructed TFP (*Total Factor Productivity*) variable. This variable is unobserved. Its construction relies on a production function specification. In that construction, measured inputs were modified. The dependent variable is a sophisticated construction.

CCFS measure technological progress by using GDP *per capita*. Increases in welfare that are not directly explained by labor quantity and physical capital are explained by R&D. The assumed production function is of a Cobb-Douglas type.

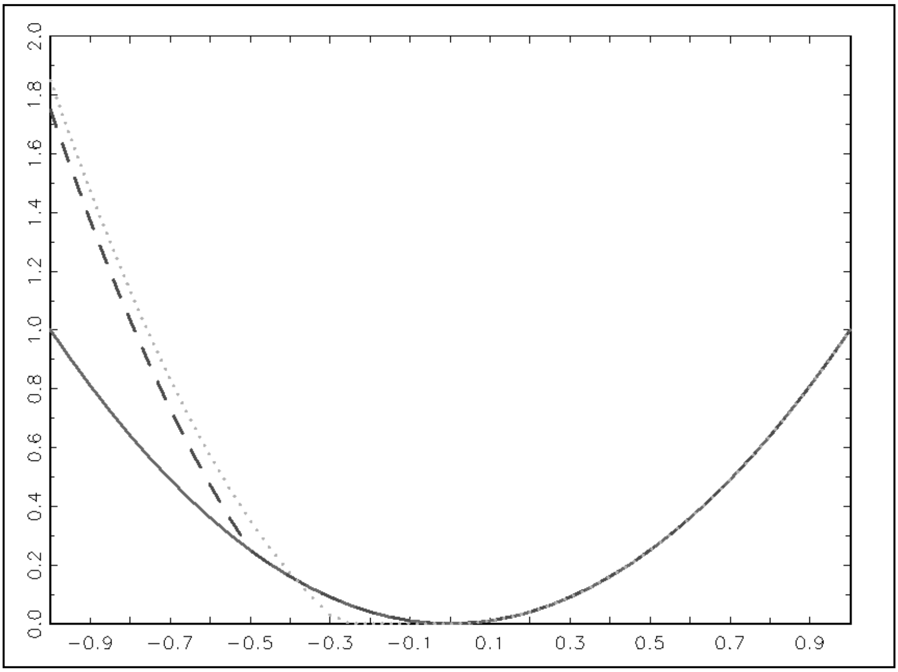
The dependent variable is a straightforwardly measured aggregate.

This evaluation of inherent sophistication should not be seen as a preference for the GRvR approach. Sophistication may be a virtue and it may be a problem. Simple techniques may succeed in highlighting features more clearly. Sophisticated constructions involve a larger risk due to potential weak points in the logical chain.

In more detail, I would like to concentrate on two features in the presented papers: firstly, the threshold model that was used by CCFS to characterize the slowdown in technological progress, as a point of satiation is approached; secondly, the inherent problem of time-series approaches in describing processes of economic convergence.

The threshold model relies on the main idea that convergence is faster while you are further away from the equilibrium. A good visual impression is provided by the curves in chart 1. A linear model corresponds to the movement of a particle in a parabolic cup, which obeys two kinds of forces: gravity and some `stochastic' perturbation that may be caused by filling the cup with some liquid or gas. A third force, inertia, can be represented in short-run autocorrelation corrections, in economic time-series models. To the left of the minimum, the particle tends to move right, while the tendency is reversed to the right of the minimum. Note that only the left side of the convergence mechanism is investigated in the paper.

Chart 1: Attraction Toward an Equilibrium in Linear and Broken Linear Models

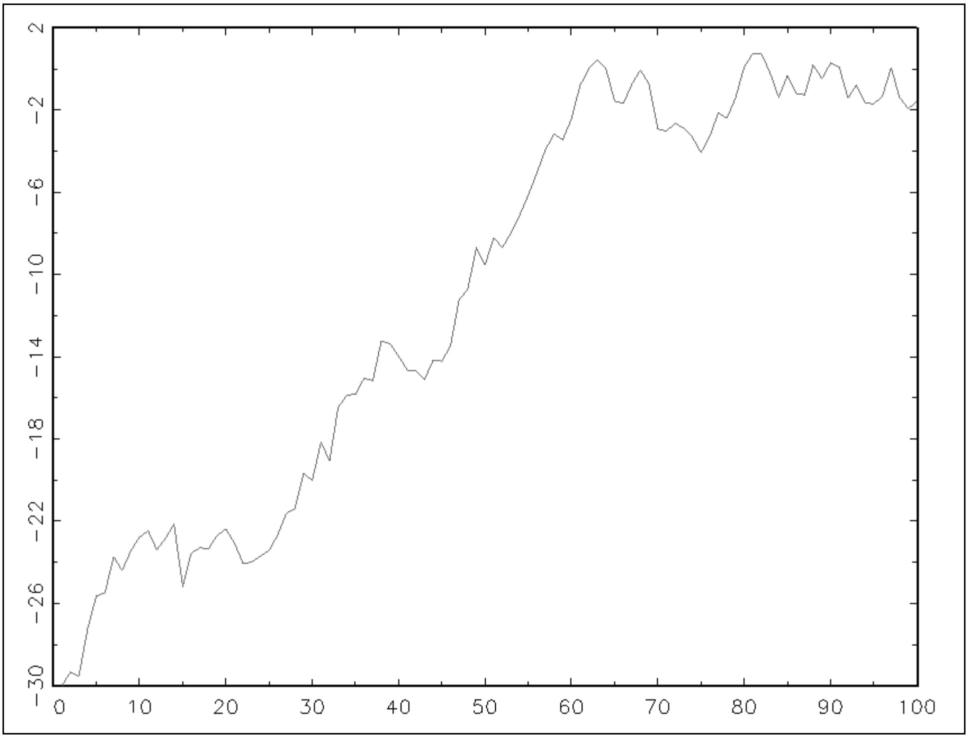


The solid curve depicts linear convergence, while the dashed one implies a threshold close to the equilibrium. The dotted curve is representative of a threshold process that is active only at a distance from the equilibrium. The curve is flat close to the bottom. In this case, there is a whole range of values that serves as an attractor, rather than a single point. It is a common misunderstanding that such an attractor area is equivalent to statistical expectation. Also for the dynamic behavior that is depicted by the dotted curve, usually a single point is the expected value for the position of the particle.

Another remark concerns the problem whether time-series models are able to describe economic convergence. It is obvious that some confusion has been introduced to the convergence literature, for example, by testing for cointegration in vector systems. It is often unclear whether cointegration indicates convergence or not. If two integrated processes are *not* cointegrated, there cannot be convergence. Trajectories may cross each other by chance, with no tendency to stay together from the time point of crossing. If two integrated processes are cointegrated, however, there cannot be convergence either. Their trajectories tend to develop in parallel movements, as some linear combination or simply their distance is stationary. It follows that, in the framework of time-series models, observed “convergence” is either a non-linear or a disequilibrium phenomenon.

High positive serial correlation and a starting value distant from the stationary equilibrium may lead to plausible modeling of disequilibrium phenomena (“convergence”) even for linear autoregressions. The chart shows a threshold linear autoregression with $\varphi = 0.99$ and $\varphi = 0.98$. The stationary mean is 0, while the process is started from $X_0 = -30$.

Chart 2: A Trajectory from a Treshold Autoregressive Process with Strong Serial Correleation, Started from a Disequilibrium Value



Note, however, that absorption may not imply convergence. A country may lead others by its larger R&D capital stock persistently.

It may be interesting to simulate a joint system of a vector of economies. This should be a recommendation to many authors of empirical papers. Following the identification of a plausible dynamic model and estimation of its free parameters, trajectories from the implied `reality' should be simulated by Monte Carlo methods. A simple visual comparison of the simulated trajectories and the observed data reveals most data features that have not been captured by the model. Such features, in turn, may provide a guideline for a potential revision of the modeling ideas.

Human Capital and Growth: Some Results for the OECD

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1. Introduction

One of the most distinctive features of the "new" theories of growth developed in recent years has been the broadening of the relevant concept of capital. While traditional neoclassical models focused almost exclusively on the accumulation of physical capital (equipment and structures), more recent contributions have attributed increasing importance to the accumulation of human capital and productive knowledge and to the interaction between these two factors.

The empirical evidence, however, has not always been consistent with the new theoretical models. In the case of human capital, in particular, some recent studies have produced discouraging results. Educational variables are often not significant or even enter with the "wrong" sign in growth regressions, particularly when these are estimated using differenced specifications or panel techniques. The accumulation of negative results in the literature has generated a growing scepticism about the role of schooling in the growth process and has even led some authors (see in particular Pritchett, 1999) to seriously consider the reasons why educational investment may not contribute to productivity growth.

An alternative hypothesis that has received considerable attention by researchers in the area is that such negative results could be due, at least in part, to the poor quality of the schooling data that have been used in empirical studies of the determinants of growth. This article summarizes the main results of a series of

[1] This article summarizes the results of a series of papers written in collaboration with R. Doménech. These studies have been financed by the European Fund for Regional Development, the OECD, Fundación Caixa Galicia and the Spanish Ministry of Science and Technology (through grants SEC99-1189 and SEC2002-01612).

papers that provide evidence in support of this hypothesis (de la Fuente and Doménech 2000, 2001a, 2001b and 2002). The paper is organized as follows. Sections 2 and 3 briefly survey the theoretical and empirical literature on growth and human capital and review the main educational data sets that have been used in this literature. Section 4 presents a new schooling series for a sample of 21 OECD countries that makes use of previously unexploited information. Section 5 discusses a series of indicators of the quality or information content of the existing schooling data sets that have been constructed using an extension of the technique proposed by Krueger and Lindhal (2001). Different specifications of an aggregate production function are then estimated with each of these schooling series. Finally, the results of the last two exercises are used to correct the bias induced by measurement error. With this correction, the contribution of investment in human capital to productivity growth is positive and quite sizable.

2. Human Capital and Growth: Theoretical Framework and Empirical Evidence

Theoretical models of human capital and growth are built around the hypothesis that knowledge and skills embodied in humans directly raise productivity and increase an economy's ability to develop and to adopt new technologies. In order to explore its implications and open the way for its empirical testing, this basic hypothesis is generally formalized in one of two (not mutually exclusive) ways. The simplest one involves introducing the stock of human capital (which will be denoted by H throughout this paper) as an additional input in an otherwise standard production function linking aggregate output to the stocks of productive inputs (generally employment and physical capital) and to an index of technical efficiency or Total Factor Productivity (TFP). The second possibility is to include H in the model as a determinant of the rate of technological progress (i.e. the rate of growth of TFP). This involves specifying a technical progress function that may include as additional arguments variables related to R&D investment and the gap between each country and the world technological frontier.

In what follows, I will refer to the first of these links between human capital and productivity as *level effects* (because the stock of human capital has a direct impact on the level of output) and to the second one as *rate effects* (because H affects the growth rate of output through TFP). Box 1 develops a simple model of growth with human capital that formalizes the preceding discussion and incorporates both effects.

Some recent theoretical models also suggest that the accumulation of human capital may give rise to important externalities that would justify corrective public interventions. The problem arises because some of the benefits of a more educated labor force will typically "leak out" and generate benefits that cannot be appropriated by those who undertake the relevant investment in the form of higher earnings, thereby driving a wedge between the private and social rates of return. Lucas (1988), for example, suggests that the average stock of human capital at the economy-wide level increases productivity at the firm level holding the firm's own stock of human capital constant. It is also commonly assumed that the rate effects of human capital through the technical progress function include a large externality component because it is difficult to appropriate privately the full economic value of new ideas. Azariadis and Drazen (1990) and implicitly Lucas (1988) as well, stress that younger cohorts are likely to benefit from the knowledge and skills accumulated by their elders, thus generating potentially important intergenerational externalities that operate both at home and in school. The literature also suggests that human capital can generate more diffuse "civic" externalities, as an increase in the educational level of the population may help reduce crime rates or contribute to the development of more effective institutions.

Box 1: A Descriptive Model of Human Capital and Growth

This box develops a simple model of growth and human capital that has two components: an aggregate production function and a technical progress function. The production function will be assumed to be of the Cobb-Douglas type:

$$(1)\ Y_{it} = A_{it}\, K_{it}^{\alpha_k} H_{it}^{\alpha_h} L_{it}^{\alpha_l}$$

where Y_{it} denotes the aggregate output of country *i* at time *t*, L_{it} is the level of employment, K_{it} the stock of physical capital, H_{it} the average stock of human capital per worker, and A_{it} an index of technical efficiency or total factor productivity (TFP) which summarizes the current state of the technology and, possibly, omitted factors such as geographical location, climate, institutions and endowments of natural resources. The coefficients a_i (with *i = k, h, l*) measure the elasticity of output with respect to the stocks of the different factors. An increase of 1% in the stock of human capital per worker, for instance, would increase output by a_h%, holding constant the stocks of the other factors and the level of technical efficiency.

Under the standard assumption that (1) displays constant returns to scale in capital, labour and total human capital, *LH*, (i.e. that $a_k + a_l = 1$) we can define a per capita production function that will relate average productivity to average schooling and to the stock of capital per worker. Letting $Q = Y/L$ denote output per worker, $Z = K/L$ the stock of capital per worker, and dividing both sides of (1) by total employment, *L*, we have:

$$(2)\ Q = AZ^{\alpha_k} H^{\alpha_h}$$

The technical progress function describes the determinants of the growth rate of total factor productivity. I will assume that country *i*'s TFP level can be written in the form:

$$(3) A_{it} = B_t X_{it}$$

where B_t denotes the world "technological frontier" (i.e. the maximum attainable level of efficiency in production given the current state of scientific and technological knowledge) and $X_{it} = A_{it}/B_t$ the "technological gap" between country *i* and the world frontier. It will be assumed that B_t grows at a constant and exogenous rate, *g*, and that the growth rate of X_{it} is given by

$$(4)\ \Delta x_{it} = \gamma_{io} - \lambda x_{it} + \gamma H_{it}$$

where x_{it} is the log of X_{it} and g_{io} a country fixed effect that helps control for omitted variables such as R&D investment. Notice that this specification incorporates a technological diffusion or catch-up effect. If $l > 0$, countries that are closer to the technological frontier will experience lower rates of TFP growth. As a result, relative TFP levels will tend to stabilize and their steady-state values will be partly determined by the level of schooling.

Empirical evidence

Empirical studies of the productivity effects of human capital (or more broadly, of the determinants of economic growth) have followed one of two alternative approaches. The first one involves the specification and estimation of an ad-hoc equation relating growth in total or per capita output to a set of variables that are thought to be relevant on the basis of informal theoretical considerations. The second approach is based on the estimation of a structural relation between the level of output or its growth rate and the relevant explanatory variables that is derived from an explicit theoretical model built around an aggregate production function and, possibly, a technical progress function of the type described in Box 1.

This basic framework for the "structural" analysis of the determinants of growth can give rise to a large number of empirical specifications. The production function can be estimated directly with the relevant variables expressed in levels or in growth rates when reliable data are available for the stocks of all the relevant production inputs. Alternatively, its parameters can be recovered from other specifications (*convergence* and *steady state equations*) that are designed for estimation when only data on investment flows (rather than factor stocks) are available. These specifications can be derived from production functions by replacing factor stocks or their growth rates by convenient approximations constructed using observed investment rates.

A large number of empirical studies have analyzed the relationship between human capital and growth with conflicting results using the different specifications I have just outlined.[2] While earlier studies on the subject generally produced positive results, the conclusions of a second group of more recent studies have been rather discouraging, as many of these studies failed to detect a significant positive correlation between the average level of schooling of the population and the level of productivity.[3] The main difference between the two sets of studies has to do with the use of econometric techniques that implicitly assign different weights to the cross-section and time-series variation in the data. While the first group of studies relied on cross-section data (working with a single observation per country that describes average behavior over a period of several decades), studies in the second group have used several observations per country, taken over shorter periods, and have employed panel techniques or differenced specifications that basically eliminate the cross-section variation in the data before proceeding to the estimation.

Although the estimation techniques used in the more recent studies have the important advantage that they control for unobservable differences across countries, they also have some disadvantages. Perhaps the main one is that they are more sensitive to measurement error in the data as errors tend to be greater in the

[2] Section 3 of the Appendix of de la Fuente and Ciccone (2002) contains a detailed survey of this literature.

[3] See in particular Landau (1983), Baumol et al (1989), Barro (1991) and Mankiw, Romer and Weil (1992) within the first group of studies and Kyriacou (1991), Knight et al (1993), Benhabib and Spiegel (1994), Pritchett (1999), Islam (1995) and Caselli et al (1996) within the second.

time-series than in the cross-section dimension because they tend to cancel out when we work with averages over long periods. This suggests, as I have already noted in the introduction, that a possible explanation of the negative results obtained in many recent studies has to do with the poor quality of the schooling data that have been used in the growth literature. As we will see in the next section, most of the international schooling databases contain important amounts of noise that can be traced back to various inconsistencies of the primary data used to construct them. The existence of this noise induces a downward bias in the estimation of the coefficients that measure the impact of human capital (that is a tendency to underestimate their values) because it generates spurious variability in the stock of human capital that is not matched by proportional changes in the level of productivity.

3. International Schooling Data Bases: a Brief Survey and Some Problems

Most governments gather information on a number of educational indicators through population censuses, labor force surveys and specialized studies and surveys. Various international organizations collect these data and compile comparative statistics that provide easily accessible and (supposedly) homogeneous information for a large number of countries. The most comprehensive regular source of international educational statistics is UNESCO's *Statistical Yearbook*. This publication provides reasonably complete yearly time series on school enrollment rates by level of education for most countries in the world and contains some data on the educational attainment of the adult population, government expenditures on education, teacher/pupil ratios and other variables of interest.[4]

The UNESCO enrollment series have been used in a large number of empirical studies of the link between education and productivity. In many cases this choice reflects the easy availability and broad coverage of these data rather than their theoretical suitability for the purpose of the study. Enrollment rates can probably be considered an acceptable, although imperfect, proxy for the flow of educational investment. On the other hand, this variable is not necessarily a good indicator of the existing stock of human capital since average educational attainment (which is often the more interesting variable from a theoretical point of view) responds to investment flows only gradually and with a very considerable lag.

[4] Other useful sources include the UN's *Demographic Yearbook*, which also reports educational attainment levels by age group and, in recent years, the OECD's annual report on education in its member countries *(Education at a Glance)*, which contains a great deal of information about the inputs and outputs of the educational system.

In an attempt to remedy these shortcomings, a number of researchers have constructed data sets that attempt to measure directly the educational stock embodied in the population or labor force of large samples of countries during a period of several decades. These data sets have generally been constructed by combining the available data on attainment levels with the UNESCO enrollment figures to obtain series of average years of schooling and the educational composition of the population or labor force. The best known attempts in this line are the work of Kyriacou (1991), the different versions of the Barro and Lee data set (1993, 1996, 2000) and the series constructed by World Bank researchers (Lau, Jamison and Louat (1991), Lau, Bhalla and Louat (1991) and Nehru, Swanson and Dubey (NSD), 1995).

In de la Fuente and Doménech (2000 and 2002) we briefly review the methodology used in these studies and compare the different data sets with each other, focusing in particular on the OECD where the quality of the available information should in principle be better than in developing countries. The analysis of the different series reveals very significant discrepancies among them in terms of the relative positions of many countries and implausible estimates or time profiles for at least some of them. Although the various studies generally coincide when comparisons are made across broad regions (e.g. the OECD vs. LDC's in various geographical areas), the discrepancies are very important when we focus on the group of industrialized economies. Another cause for concern is that existing estimates often display extremely large changes in attainment levels over periods as short as five years (particularly at the secondary and tertiary levels).

To a large extent, these problems have their origin in the deficiencies of the underlying primary data. As Behraman and Rosenzweig (1994) have noted, there are good reasons to worry about the accuracy and consistency of UNESCO's data on both attainment levels and enrollment rates. Our analysis of the different schooling data sets confirms this diagnostic and suggests that many of the problems detected in these data can be traced back to shortcomings of the primary statistics, which do not seem to be consistent, across countries or over time, in their treatment of vocational and technical training and other courses of study, and reflect at times the number of people who have started a certain level of education and, at others, those who have completed it.

4. A New Schooling Series for a Sample of Industrial Countries

Concerns about poor data quality and its implications for empirical estimates of the growth effects of human capital have motivated some recent studies that attempt to improve the signal to noise ratio in the schooling series by exploiting additional sources of information and introducing various corrections. This section summarizes the results of one of these studies (de la Fuente and Doménech, 2001b)[5] that constructs new schooling series for a sample of 21 OECD countries.[6]

To construct these series we first collected all the information we could find on the distribution of the adult population by educational level in OECD countries. We used both international publications and national sources (census reports and surveys, statistical yearbooks and unpublished data supplied by national governments and by the OECD). Next, we tried to reconstruct a plausible time profile of attainment in each country, using all the available data and a bit of common sense. For those countries for which reasonably complete series are available, we have relied primarily on national sources. For the rest, we start from the most plausible set of attainment estimates available around 1990 or 1995 (taken generally from OECD sources) and proceed backwards, trying to avoid unreasonable jumps in the series that can only reflect changes in classification criteria. The construction of the series involved in many cases subjective judgments to choose among alternative census or survey estimates when several are available. At times, we have also reinterpreted some of the data from international compilations as referring to somewhat broader or narrower schooling categories than the reported one.[7] Missing data points lying between available census observations are filled in by simple linear interpolation. Missing observations prior to the first census observation are estimated, whenever possible, by backward extrapolations that make use of census information on attainment levels disaggregated by age group.

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[5] This study extends and updates the series constructed in de la Fuente and Doménech (2000) for the same sample. Among other improvements, the revised series incorporate unpublished information supplied by the OECD and the national statistical institutes of about a dozen member states in response to a petition for assistance that was channeled through the Statistics and Indicators division of the OECD.

[6] A closely related paper, both in terms of its objectives and its methodology, is Cohen and Soto (2001). These authors construct a schooling data set for a much larger sample of countries using census and survey data from UNESCO, the OECD's in-house educational data base, and the websites of national statistical agencies, together with enrollment rates from UNESCO and other sources.

[7] Clearly, the construction of our series involves a fair amount of guesswork. Our „methodology" looks decidedly less scientific than the apparently more systematic estimation procedures used by other authors starting from supposedly homogeneous data. However, even a cursory examination of the data shows that there is no such homogeneity. Hence, we have found it preferable to rely on judgment to try to piece together the available information in a coherent manner than to take for granted the accuracy of the primary data. The results do look more plausible than most existing series, at least in terms of their time profile and, as I will show below, perform rather well in terms of a statistical indicator of data quality.

Table 1: Availability of Primary Data

	secondary attainment				university attainment		
	direct tot. observ.	*first observ.*	*last observ.*		*direct tot. obs.*	*first observ.*	*last observ.*
U.S.A.	24/24	1960	1995		24/24	1960	1995
Netherlands	12/24	1960	1995		12/24	1960	1995
Italy	15/24	1961	1999		5/8	1960	1998
Belgium	13/24	1961	1995		12/24	1960	1995
Spain	12/21	1960	1991		12/21	1960	1991
Greece	15/24	1961	1995		15/24	1961	1997
Portugal	12/21	1960	1991		8/21	1960	1991
France	12/21	1960	1989		12/21	1960	1990
Ireland	15/24	1961	1998		11/24	1961	1998
Sweden	9/24	1960	1995		9/24	1960	1995
Norway	15/24	1960	1998		9/24	1960	1998
Denmark	9/24	**1973**	1994		12/24	**1973**	1994
*Finland**	16/24	1960	1995		21/24	1970	1995
*Japan**	8/21	1960	1990		12/21	1960	1990
New Zealand	10/24	**1965**	1998		10/24	**1965**	1998
UK	6/21	1960	1993		10/21	1960	1991
Switzerland	15/24	1960	1995		15/24	1960	1995
Austria	11/24	1961	1995		7/24	1961	1995
Australia	11/24	**1965**	1997		11/24	**1966**	1997
W. Germany	11/24	**1970**	1995		17/24	1961	1995
United Germany	6/6	1991	1995		6/6	1991	1995
Canada	15/24	1961	1996		21/24	1960	1996

Data availability varies widely across countries. Table 1 shows the fraction of the reported data points that are correspond to "direct observations" (taken from census or survey reports) and the earliest and latest such observations available for secondary and higher attainment levels. The number of possible observations is typically either 21 or 24 for each level of schooling depending on whether the series ends in 1990 or 1995 (two sublevels and a total times seven or eight quinquennial observations). In the case of Italy, there seem to be no short higher education courses, so the number of possible observations at the university level drops to eight.

As can be seen in the table, for most of the countries in the sample we have enough primary information to reconstruct reasonable attainment series covering the whole sample period. The more problematic cases are highlighted using bold characters. In the case of Italy, the main problem is that much of the available information refers to the population over six years of age. For Denmark and

Germany (at the secondary level), the earliest available direct observation refers to 1970 or later. In these two cases, we have projected attainment rates backward to 1960 using the attainment growth rates reported in OECD (1974), but we are unsure of the reliability of this extrapolation.

Table 2: Average Years of Schooling of the Adult Population (Sample Average = 100 in Each Year)

	1960	**1965**	**1970**	**1975**	**1980**	**1985**	**1990**
West Germany	118.5	120.1	121.6	121.7	121.7	122.1	121.7
Australia	117.7	120.6	122.6	124.0	125.7	124.2	121.1
Canada	124.1	123.5	123.2	123.1	122.9	121.2	119.7
U.S.A.	126.3	126.1	125.4	124.5	123.1	121.0	119.1
Switzerland	124.8	124.2	123.6	120.5	117.8	116.1	114.9
New Zealand	125.1	123.4	121.7	119.6	117.5	115.4	113.8
Denmark	129.0	125.9	123.0	119.8	116.9	113.7	110.2
Austria	**107.7**	**105.4**	**103.5**	**103.2**	**104.1**	**105.9**	**106.3**
Japan	103.1	103.3	103.5	104.8	105.6	105.5	105.6
Norway	115.8	113.6	111.6	108.9	107.1	106.1	104.4
Finland	91.5	94.5	96.8	98.6	100.7	102.0	103.1
Netherlands	97.0	97.6	98.1	99.0	100.1	101.4	102.9
Sweden	96.2	95.5	95.0	96.1	97.2	98.4	99.8
UK	102.5	101.7	100.8	99.9	99.0	98.8	98.9
France	97.3	98.6	100.2	101.3	99.9	98.9	98.2
Belgium	92.5	93.3	94.1	94.4	94.8	94.7	94.7
Ireland	88.0	86.8	86.9	86.5	86.0	87.0	88.4
Italy	64.7	66.7	68.6	69.6	70.7	73.1	75.6
Greece	66.5	67.5	68.5	70.1	71.8	73.1	74.3
Spain	59.5	58.5	57.5	58.5	59.5	62.8	66.7
Portugal	52.3	53.2	54.0	56.0	58.0	59.0	60.2
avge. (in years)	*8.36*	*8.69*	*9.02*	*9.45*	*9.87*	*10.28*	*10.64*

After estimating the breakdown of the adult population by educational level, we have calculated the average number of years of schooling taking into account the theoretical duration of the different school cycles in each country. The results are summarized in table 2. The last row of the table shows the (unweighted) average years of schooling for the entire sample. This variable increases by 27.3% between 1960 and 1990 as a result of the important improvement in the educational level of the younger cohorts observed in practically all countries. The rest of the rows show the position of the different countries relative to the sample average in each period, which is normalized to 100, with the countries arranged in decreasing order by school attainment in 1990.

5. Attenuation Bias and a Quality Indicator for the Most Commonly Used Schooling Series

Measurement error generates a tendency to underestimate the impact of human capital on productivity. Box 2 discusses the origin of this *attenuation bias* and describes a technique that can be used to construct an indicator of the quality of different series that measure with error a common underlying variable. Intuitively, the bias arises because measurement error introduces "noise" that tends to hide the relationship between the variables of interest. The quality indicator, known as the *reliability ratio*, measures the importance of such noise relative to the true signal contained in each of the series and is constructed on the basis of an analysis of the capacity of each series to explain the behavior of the rest. This ratio is very useful, first because it provides an indicator of the informational content of each series, and second because the error in the estimation will be inversely proportional to its value. As a result, the reliability ratio can be used to correct the attenuation bias so as to obtain consistent estimators of the parameter of interest (i.e. estimators that are not biased in large samples).

Box 2: Attenuation Bias and the Reliability Ratio

The origin of the attenuation bias is the following one. Assume that the level of productivity, Q, is a linear function of the stock of human capital, H, given by

$$(1)\ Q = bH + u$$

where u is a random disturbance. Given this relationship, variations in the stock of human capital, H, will induce changes in Q, and the relative magnitude of the variations in these two variables will allow us to estimate the value of the coefficient b. Now, if H is measured with error, that is, if what we observe is not H itself but a noisy proxy for it, $P = H + \varepsilon$, where ε is a random measurement error, then part of the apparent variation in the stock of human capital (over time and across countries) will be due to measurement error --that is, it will be noise rather than true signal. Since such variations logically do not induce any response in Q, this variable will appear to be less sensible to H than it really is, thereby biasing toward zero the estimated value of b.

The size of the bias will be inversely related to the informational content of the series, as measured by its reliability ratio, r. This variable is defined as the ratio between the signal and the sum of signal and noise contained in the data, that is,

$$(2)\ r \equiv \frac{\operatorname{var} H}{\operatorname{var} P} = \frac{\operatorname{var} H}{\operatorname{var} H + \operatorname{var} \varepsilon}$$

where *var H* measures the signal contained in the series and *var e* the noise that distorts it.[8]

When several noisy proxies are available for a given variable, their respective reliability ratios can be estimated using the procedure proposed by Krueger and Lindhal (2001). Let $P_1 = H + \varepsilon_1$ and $P_2 = H + \varepsilon_2$ be two alternative proxies for the stock of human capital, H. It is easy to check that if the error terms of the two series, ε_1 and ε_2, are not correlated with each other, then the covariance between P_1 and P_2 can be used to estimate

[8] Notice that the denominator of the last expression given in (2) implicitly assumes that the measurement error term, ε ,is not correlated with H.

Box 2 — Continued

the variance of H, which is the only unknown magnitude in equation (2). It follows that, under this assumption, r_1 can be estimated as

$$(3)\ \hat{r}_1 = \frac{cov\,(P_1,P_2)}{var\,P_1}$$

which turns out to be the formula for the OLS estimator of the slope coefficient of a regression of P_2 on P_1. Hence, to estimate the reliability of P_1 we run a regression of the form $P_2 = c + r_1 P_1$.[9] Notice, however, that if the measurement errors of the two series are positively correlated ($Ee_1e_2 > 0$) as may be expected in many cases, $\hat{r}_1$ will overestimate the reliability ratio and hence understate the extent of the attenuation bias induced by measurement error.

In de la Fuente and Doménech (2002) we develop an extension of this procedure that can be used to construct a minimum-variance estimator of the reliability ratio whenever more than two noisy proxies are available for the same underlying variable, under the maintained assumption that measurement errors are uncorrelated across data sets. As in K&L, the reliability ratio r_k of a given series of average years of schooling (say S_k) is estimated by using S_k to try to explain alternative estimates of the same variable (S_j with $j \neq k$). The main difference is that, rather than running a set of independent pairwise regressions with different data sets, the efficient estimator of the reliability ratio for data set k can be obtained as the slope coefficient of a restricted SUR model of the form

$$(4)\ P_k = c_k + r_{jk} P_j + u_k \quad \text{for } k = 1..., K$$

where k denotes the "reference" data set and varies over the last available version of all data sets different from j. The reliability ratio of Barro and Lee's (2000) data set, for instance, is estimated by using these authors' estimate of average years of schooling as the explanatory variable in a set of regressions where the reference (dependent) variables are the average years of schooling estimated by Kyriacou (1991), NSD (1995), Cohen and Soto (2001) and ourselves. Other versions of the Barro and Lee data set, however, are not used as a reference because the correlation of measurement errors across the same family of schooling series is almost certainly very high and this will artificially inflate the estimated reliability ratio.

Under the assumption that measurement error is uncorrelated across families of data sets (i.e. that $E\varepsilon_j\varepsilon_k = 0$ for $j \neq k$ when j and k belong to different families) all the pairwise estimates of r_j obtained above will be consistent and so will be any weighted average of them,

$$(5)\ \bar{r}_j = \sum_k \omega_k \hat{r}_{jk} \text{ where } \sum_k \omega_k = 1.$$

To obtain the most efficient estimator of r_j, we choose the weights ω_k in (5) so as to minimize the variance of $\bar{r}_j$. The resulting estimator, which will be denoted by $\hat{r}_j$, can be approximated by imposing a common slope coefficient across the equations in (4) and estimating the system as a restricted SUR. Hence, we will refer to $\hat{r}_j$ as the *SUR reliability ratio*.

In de la Fuente and Doménech (2002) we use the procedure described in box 2 to construct an indicator of the information content of the series of years of

[9] Intuitively, regressing P_2 on P_1 gives us an idea of how well P_1 explains the true variable H because measurement error in the dependent variable (P_2 in this case) will be absorbed by the disturbance without generating any biases. Hence, it is almost as if we were regressing the true variable on P_1.

schooling most commonly used in the growth literature, restricting ourselves to the sample of 21 OECD countries covered by the data set described in the previous section. This indicator is constructed for several transformations of the series of average years of schooling after removing period means from all the series so as to eliminate fixed time effects. In particular, we estimate reliability ratios for years of schooling measured in levels *(S_{it})* and in logs *(s_{it})*, for average annual changes in both levels and logs measured across successive quinquennial observations (ΔS_{it} and Δs_{it}), and for log years of schooling measured in deviations from their country means *(s_{it} - s_i)*. Notice that Δs_{it} corresponds to annual growth rates and $s_{it} - s_i$ is the "within" transformation often used to remove fixed effects.

Table 3: SUR Estimates of Reliability Ratios, OECD Sample

	S_{it}	s_{it}	ΔS_{it}	Δs_{it}	s_{it}-s_i	$\Delta s_{it} - \Delta s_i$	*promedio*
D&D (2002)	0.754	0.775	0.337	0.769	0.917	0.246	*0.633*
C&S (2001)	0.806	0.912	0.330	0.467	0.547	0.185	*0.541*
D&D (2000)	0.720	0.761	0.100	0.550	0.818	0.074	*0.504*
Kyr. (1991)	0.723	0.600	0.024	0.065	0.111	0.026	*0.258*
B&L (2000)	0.707	0.603	-0.018	0.045	0.178	-0.016	*0.250*
B&L (1996)	0.559	0.516	-0.017	0.039	0.146	-0.007	*0.206*
B&L (1993)	0.526	0.436	-0.019	0.029	0.121	-0.017	*0.179*
NSD (1995)	0.278	0.330	-0.021	0.066	0.095	-0.115	*0.106*
promedio	*0.634*	*0.617*	*0.090*	*0.254*	*0.367*	*0.047*	*0.335*

Notes:
- All series are measured in deviations from their respective sample means in each period prior to estimation.
- Key: D&D = de la Fuente and Doménech; C&S = Cohen and Soto; Kyr. = Kyriacou; B&L = Barro and Lee; NSD = Nehru et al.

The results are shown in Table 3 with the different data sets arranged by decreasing average reliability ratios. The last row of the table shows the average value of the reliability ratio for each type of data transformation (taken across data sets), and the last column displays the average reliability ratio of each data set (taken across transformations). Our mean estimate of the reliability ratio for all the series and transformations is 0.335. Since this variable must lie between zero and one (with zero indicating that the series contains only noise and one that it is measured without error)[10] this result suggests that the average estimate of the coefficient of schooling in a growth equation is likely to suffer from a substantial downward bias, even without taking into account the further loss of signal that arises when additional regressors are included in these equations (see de la Fuente and Doménech, 2002). The bias will be smaller when the data are used in levels or logs, but is likely to be very large in fixed effects or differenced specifications. The average reliability ratio is only 0.254 for the data in quinquennial log differences, and 0.090 for level differences taken at the same frequency.

Our results indicate that the importance of measurement error varies significantly across data sets, although their precise ranking depends on the data transformation that is chosen. Two of the datasets most widely used in cross-country empirical work, those by Kyriacou (1991) and Barro and Lee (various years), perform relatively well when the data are used in levels but, as Krueger and Lindhal (2001) note, contain very little signal when the data is differenced. Recent efforts to increase the signal content of the schooling data seem to have been at least partially successful, although the attenuation bias continues to be potentially large even in these cases. Taking as a reference the average reliability ratio for the (1996) version of the Barro and Lee data set (0.206), the latest revision of these series by the same authors has increased their information content by 21%, while the estimates reported in Cohen and Soto (2001) and in de la Fuente and Doménech (2001) raise the estimated reliability ratio by 162% and 207% respectively.

6. Data Quality and Estimates of the Growth Effects of Human Capital

As we have seen in the previous section, the expected value of the attenuation bias is a decreasing function of the reliability ratio of the series used in the estimation. This suggests that the estimated value of the coefficient of human capital in a growth regression should increase with the quality of the schooling data. In de la Fuente and Doménech (2002) we show that this is indeed the case. We estimate various specifications of an aggregate production function using the different schooling series analyzed in the previous section as alternative proxies for the stock of human capital. We find that both the size and the significance of the

[10] This is true as long as the measurement error terms of the different series are uncorrelated with each other and with *H*. As can be seen in table 3, some of our estimates of the reliability ratio lie outside this interval, which implies some violation of this assumption. In de la Fuente and Domenéch (2002) we construct alternative estimates of reliability ratios under more general assumptions and find that the required corrections do not qualitatively change the results.

coefficient of schooling increase as expected with the reliability ratio. Finally, we exploit this correlation to construct a set of "meta-estimates" of the parameter of interest that correct for measurement error bias.[11]

a. Results with Different Schooling Series

The equations we estimate are derived from a Cobb-Douglas aggregate poduction function with constant returns to scale that includes as inputs the stock of physical capital, the level of employment and the average level of education of the adult population. This equation is estimated in levels (with the variables measured in logarithms), in levels with fixed country effects and in first differences. We also estimate a fourth specification in differences that includes fixed country effects and incorporates a process of technological diffusion or catch-up. In this specification, the rate of growth of TFP is directly proportional to the technological distance between each country and the US, and the fixed country effects capture permanent differences in TFP levels that will presumably reflect differences in R&D expenditure and other omitted variables.[12]

These specifications are estimated using quinquennial data for our usual OECD sample that cover the period 1960-90. All equations include fixed period effects (dummy variables for the different sample sub periods). The estimates of the coefficient that measures the elasticity of output with respect to the level of schooling (α_s) obtained with the different specifications and schooling series are shown in Table 4. The last two rows of the table show average coefficient values and *t* ratios for each data set computed across the different specifications, and the last column reports the average values of α_s and the corresponding *t* statistic computed across data sets for each specification.

[11] A meta-estimate is an estimate that is not obtained directly from the data but is constructed using other primary estimates.

[12] All specifications are derived from equation (2) in box 1 using average years of schooling *(S)* as a proxy for the stock of human capital *(H)*. The last specification also incorporates a technical progress function similar to equation (5) in the same box, except in that the stock of human capital is omitted. Hence, the estimated model does not allow for rate effects. We have tried to incorporate them but the results are not satisfactory. This problem arises frequently in the literature. See de la Fuente and Ciccone (2002) for a discussion of the reasons why it may be difficult to separate the rate and level effects of human capital.

Table 4: Alternative Estimates of the Human Capital Coefficient (α_s) Using Different Specifications and Schooling Series

	NSD	*KYR*	*B&L93*	*B&L96*	*B&L00*	*C&S*	*D&D00*	*D&D02*	*avge.*
levels	0.078	0.186	0.141	0.165	0.238	0.397	0.407	0.378	*0.249*
	(2.02)	(2.18)	(4.49)	(4.82)	(6.19)	(7.98)	(7.76)	(6.92)	*(5.30)*
fixed eff.	0.068	0.066	0.136	0.115	0.203	0.608	0.627	0.958	*0.348*
	(0.76)	(1.86)	(3.30)	(1.80)	(3.74)	(4.49)	(3.99)	(6.51)	*(3.31)*
differences	0.079	0.009	0.089	0.083	0.079	0.525	0.520	0.744	*0.266*
	(0.70)	(0.15)	(2.52)	(1.47)	(1.28)	(2.57)	(2.17)	(3.10)	*(1.75)*
catch-up	- 0.206	0.014	0.056	-0.007	-0.019	0.573	0.587	0.540	*0.192*
	(1.61)	(0.29)	(1.80)	(0.11)	(0.31)	(3.52)	(3.47)	(2.89)	*(1.24)*
average	*0.005*	*0.069*	*0.106*	*0.089*	*0.125*	*0.526*	*0.535*	*0.655*	
	(0.47)	*(1.12)*	*(3.03)*	*(2.00)*	*(2.73)*	*(4.64)*	*(4.35)*	*(4.86)*	

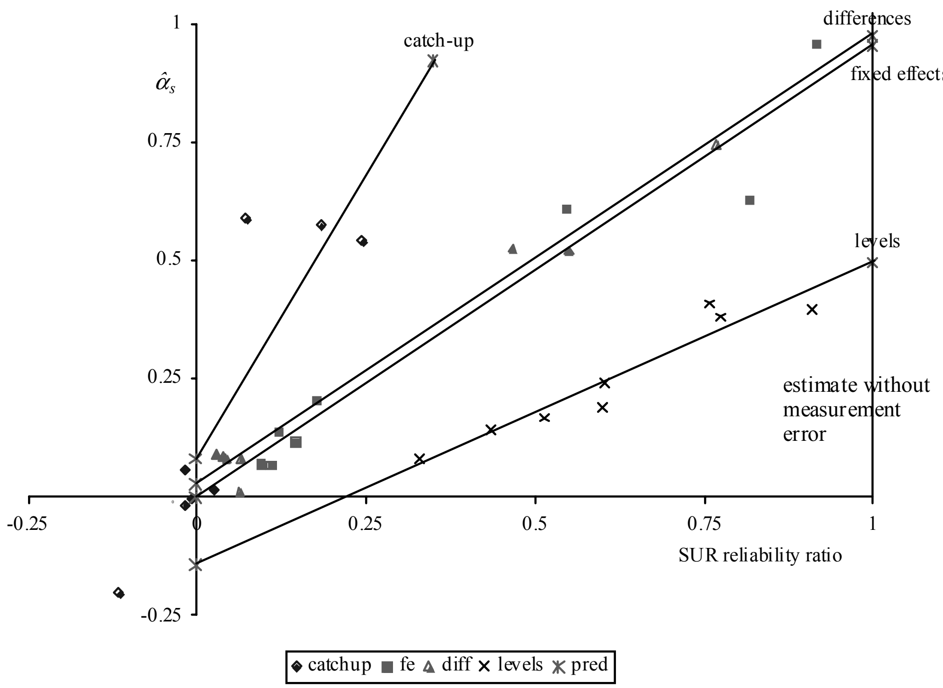
Key: see the notes to table 3.

The pattern of results that emerges as we change the source of the human capital data is consistent with our hypothesis about the importance of educational data quality for growth estimates. For all the data sets, the estimated value of α_S is positive and significant in the specification in levels without fixed country effects (first set of rows in the table), but the size and significance of the estimates increases appreciably as we move to the data sets with higher reliability ratios (that correspond to the last columns of the table). The differences are even sharper when the estimation is repeated with fixed country effects (second set of rows) or with the data in growth rates with or without a catch-up effect (third and fourth blocks). The results obtained with the Kyriacou, B&L and NSD data in growth rates are consistent with those reported by Kyriacou (1991), Benhabib and Spiegel (1994) and Pritchett (1999), who find insignificant (and sometimes negative) coefficients for human capital in an aggregate production function estimated with differenced data. On the other hand, our series and those of Cohen and Soto produce rather large and precise estimates of the human capital coefficient in most equations and, in the case of our preferred catch-up specification, yield plausible values of the remaining parameters of the model as well, with estimates of α_k close to the share of physical capital in national income and positive diffusion coefficients.

b. Correcting for Measurement Error Bias

The results summarized in table 4 strongly suggest that measurement error often induces a large downward bias in human capital coefficients. They also show that improvements in data quality reduce this bias and generate results that are generally more favorable to the view that investment in schooling contributes substantially to productivity growth. To make this point visually, chart 1 plots the various estimates of α_s given in table 4 against the corresponding SUR reliability ratios (taken from table 3), along with the regression lines fitted for each of the growth specifications estimated in the previous section. The scatter shows a clear positive correlation between these two variables within each specification and suggests that the true value of α_s is at least 0.50 (which is the prediction of the levels equation for $r = 1$).

Chart 1: Estimated α_s vs. SUR Reliability Ratio



As chart 1 suggests, it is possible to extrapolate the relationship between the reliability ratio and the estimated human capital coefficient that is observed across data sets to estimate the value of α_s that would be obtained in the absence of measurement error. In this manner, it is possible to construct meta-estimates of this parameter that will be free of attenuation bias, although this has to be done a bit more carefully than the chart suggests, at least when the growth equation includes additional regressors. In de la Fuente and Doménech (2002) we use a procedure of this type to obtain consistent meta-estimates of α_s. Working with the three linear specifications estimated above (that is, with all of them except for the catch-up model) and with three alternative assumptions about the nature of measurement error (and in particular about its correlation across data sets and with the remaining explanatory variables in the model), we obtain nine different estimates of α_s that range from 0.587 to 2.606 with an average value of 1.11.

These values are significantly higher than those obtained in the previous literature. The smallest of them is roughly twice as large as Mankiw, Romer and Weil's (1992) estimate of 1/3, which could probably have been considered a consensus value for this parameter a few years ago and has lately come to be seen as too optimistic in the light of recent negative results in the literature. Our estimates, by contrast, point to a considerably higher chart and suggest therefore that investment in human capital is an important growth factor whose effects have been underestimated in previous studies as a result of the poor quality of schooling data.

7. Conclusion

Existing data on educational attainment contain a considerable amount of noise that reflects various deficiencies of the primary data. In an attempt to increase the signal-to-noise ratio in these data, we have constructed new schooling series for a sample of OECD countries using previously unexploited information and an ad-hoc procedure that attempts to minimize the error generated by changes in classification criteria. We have also constructed statistical measures of the information content of the schooling data sets used in the growth literature. This indicator supports our view that the amount of measurement error in these data is rather large, and suggests that both our attainment series and those constructed by Cohen and Soto (2001) constitute a significant improvement over earlier sources.

The studies summarized in this paper were originally motivated by the view that weak data is likely to be one of the main reasons for the discouraging results obtained in the recent empirical literature on human capital and growth. Our results clearly support this hypothesis, as does recent work by Krueger and Lindhal (2001) and Cohen and Soto (2001), and suggest that the contribution of investment in education to productivity growth is sizable. Unlike several older data sets, our revised series produce positive and theoretically plausible results using a variety of growth specifications. More importantly, our analysis of the performance of different schooling data sets in a variety of production function specifications shows a clear tendency for human capital coefficients to rise and become more precise as the information content of the schooling data increases. We have extrapolated this relationship to construct estimates of the value of the coefficient that would be obtained with the correctly measured stock of human capital. The exercise suggests that the true value of the elasticity of output with respect to the stock of human capital is almost certainly above 0.50, that is, at least 50% higher than the most optimistic estimate of reference in the previous literature.

References

Azariadis, C. and A. Drazen (1990). "Threshold Externalities in Economic Development." *Quarterly Journal of Economics,* May, pp. 501-26.

Barro, R. (1991). "Economic Growth in a Cross Section of Countries." *Quarterly Journal of Economics* CVI (2), pp. 407-43.

Barro, R. and J-W. Lee (1993). "International Comparisons of Educational Attainment." *Journal of Monetary Economics* 32, pp. 363-94.

Barro, R. and J-W. Lee (1996). "International Measures of Schooling Years and Schooling Quality." *American Economic Review* 86(2), *Papers and Proceedings*, pp. 218-23.

Barro, R. and J-W. Lee (2000). "International data on educational attainment, updates and implications." NBER Working Paper no. 7911. (http://www.nber.org/papers/w7911).

Baumol, W., S.A. Batey Blackman and E. Wolf (1989). *Productivity and American Leadership: the Long View*. MIT Press.

Behrman, J. and M. Rosenzweig (1994). "Caveat emptor: cross-country data on education and the labor force." *Journal of Development Economics* 44, pp. 147-71.

Benhabib, J. and M. Spiegel (1994). "The Role of Human Capital in Economic Development: Evidence from Aggregate Cross-Country Data." *Journal of Monetary Economics* 34, pp. 143-73.

Caselli, F., G. Esquivel and F. Lefort (1996) "Reopening the convergence debate: a new look at cross-country growth empirics." *Journal of Economic Growth* 1(3), pp. 363-89.

Cohen, D. and M. Soto (2001). "Growth and human capital: good data, good results." CEPR Discussion Paper no. 3025.

De la Fuente, A. and A. Ciccone (D&C, 2002). "Human capital and growth in a global and knowledge-based economy." Report for the European Commission, DG for Employment and Social Affairs. (http://ideas.repec.org/e/pde52.html#papers)

De la Fuente, A. and R. Doménech (2000). "Human capital in growth regressions: how much difference does data quality make?" OECD Economics Department Working Paper no. 262, Paris.

De la Fuente, A. and R. Doménech (2001a). "Schooling data, technological diffusion and the neoclassical model." *American Economic Review* 91(2), *Papers and Proceedings*, pp. 323-27.

De la Fuente, A. and R. Doménech (2001b). "Educational attainment in the OECD, 1960-90." CEPR Discussion Paper no. 3390.

De la Fuente, A. and R. Doménech (2002). "Human capital in growth regressions: how much difference does data quality make? An update and further results." CEPR Discussion Paper no. 3587. (http://ideas.repec.org/e/pde52.html#papers)

Grossman, G. and Helpman, E. (1991). *Innovation and Growth in the Global Economy.* MIT Press, Cambridge, Mass.

Islam, N. (1995). "Growth empirics: a panel data approach." *Quarterly Journal of Economics* 110, pp. 1127-70.

Jones, C. (1996). "Human capital, ideas and economic growth." Mimeo, Standford University.

Knight, M., N. Loayza and D. Villanueva (1993). "Testing the neoclassical theory of economic growth: A panel data approach." *IMF Staff Papers* 40(3), pp. 512-41.

Krueger, A. and M. Lindahl (2001). "Education for growth: why and for whom?" *Journal of Economic Literature* XXXIX, pp. 1101-36.

Kyriacou, G. (1991). "Level and Growth Effects of Human Capital, A Cross-Country Study of the Convergence Hypothesis." Mimeo, NYU.

Landau, D. (1983). "Government Expenditure and Economic Growth: a Cross-Country Study." *Southern Economic Journal*, January, pp. 783-92.

Lau, L, D. Jamison, and F. Louat (1991). "Education and Productivity in Developing Countries: an Aggregate Production Function Approach." Report no. WPS 612, the World Bank.

Lau, L., S. Bhalla and F. Louat (1991). "Human and physical capital stock in developing countries: construction of data and trends." Draft mimeo, *World Development Report,* World Bank.

Lucas, R. (1988). "On the Mechanics of Economic Development." *Journal of Monetary Economics* 22, pp. 3-42.

Mankiw, G., D. Romer and D. Weil (1992). "A Contribution to the Empirics of Economic Growth." *Quartely Journal of Economics*, pp. 407-37.

Nehru, V., E. Swanson and A. Dubey (1995). "A New Database on Human Capital Stocks in Developing and Industrial Countries: Sources, Methodology and Results." *Journal of Development Economics*, 46, pp. 379-401.

OECD (1974). *Annuaire des Statistiques de l'Enseignement,* Vol. I, Paris.

Pritchett, L. (1999). "Where has all the education gone?" Mimeo, World Bank.

Romer, P. (1990). "Endogenous Technical Change." *Journal of Political Economy*, pp. S71-S102.

Steedman, H. (1996). "Measuring the quality of educational outputs: a note. Center for Economic Performance, Discussion Paper no. 302, LSE.

Convergence of Educational Attainment Levels in the OECD: More Data, More Problems?

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1. Introduction

Finding a robust positive partial correlation between long-run economic growth and measures of educational attainment across world economies (after conditioning upon some other determinants of growth) has proved to be an extraordinarily difficult task for growth empiricists. In their influential survey on the empirics of economic growth, Durlauf and Quah (1999) report results for 16 empirical studies that used different educational variables in the specification. Only eight of the parameter estimates reported in Durlauf and Quah (1999) are positive, and not always significant. More recent studies (not included in Durlauf and Quah, 1999) find evidence of a negative partial correlation between human capital variables and economic growth (Pritchett, 1996, Benhabib and Spiegel, 1994).

One of the usual explanations for the failure in finding robust positive partial correlations between educational attainment and growth is related to the quality of the data usually employed as a proxy of human capital. Krueger and Lindahl (2001) and de la Fuente and Doménech (2002) present comparisons of different datasets of educational attainment (including the three datasets that will be used in this study). Using simple estimates of the signal-to-noise ratio, both contributions reach the conclusion that the widely used Barro-Lee dataset (Barro and Lee, 1993, 2001) performs poorly if the data is used in first differences, and that more recent datasets improve considerably the informational content of human capital proxies.

This contribution will focus on the comparative dynamics of the dispersion of educational attainment across OECD countries for the period 1960-1990. The question that is being tackled is: did educational attainment levels converge across OECD economies, or do we observe divergence in human capital accumulation?

This issue is of major relevance, since convergence in educational levels has been often claimed to be one of the motors for productivity convergence among industrialized countries (see for example Wolff, 2000). The aim of this note is to investigate the patterns of σ-convergence and σ-divergence (in the terminology introduced by Barro and Sala-i-Martin, 1992, for income levels) in educational attainment levels across OECD countries. To the knowledge of the author, there exists no comparative research tackling such an issue for different data sources. Depending on the dataset used in order to study the problem, it will be shown that the answer to the question concerning whether convergence or divergence in schooling years took place in the OECD between 1960 and 1990 can be very different.

This note presents results for the datasets by Barro and Lee (2001), Cohen and Soto (2001) and de la Fuente and Doménech (2000), which lead to contradictory answers to the question posed above. The Barro-Lee dataset is probably the most widely used reference for educational attainment in the economic literature and the Cohen-Soto dataset ranks very well in terms of signal-to-noise ratio in the comparison carried out by de la Fuente and Doménech (2002). De la Fuente and Doménech (2000, 2001, 2002) present a new database of educational attainment for 21 OECD countries. Relying on the primary sources, they correct, among other things, for changes classification criteria that may have led to implausible developments in earlier datasets. It should be noticed that, while the Barro-Lee and de la Fuente-Doménech datasets report data at a five-year periodicity, the Cohen-Soto dataset has a single observation for each decade.

This note is structured as follows. In section two, a general picture of the dynamics of the distribution of educational attainment across OECD countries is given based on each dataset. Section three presents the results of convergence/divergence tests based on the test statistic proposed by Carree and Klomp (1997) and section four concludes.

2. The Distribution of Educational Attainment: A Comparison of Datasets

The variable whose distributional dynamics we are interested in is “Average years of schooling of the adult population (over 25 years)”. This variable is reported by the three datasets being studied, and its basic descriptive statistics are given in table 1 for the sample of 21 OECD countries (Australia, Austria, Belgium, Canada, Switzerland, Germany, Denmark, Spain, Finland, France, United Kingdom, Greece, Ireland, Italy, Japan, Netherlands, Norway, New Zealand, Portugal, Sweden and United States) for each period.

Table 1: Descriptive Statistics, Average Years of Schooling for Adult Population, OECD Countries

Barro-Lee Dataset

Year	Mean	Median	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis
1960	6.70	6.87	9.56	1.94	1.98	-0.57	2.81
1965	6.79	7.17	9.42	2.24	1.88	-0.59	2.93
1970	7.25	7.47	10.09	2.44	1.85	-0.71	3.37
1975	7.50	7.73	11.00	2.79	1.94	-0.49	3.20
1980	8.22	8.28	11.91	3.27	2.06	-0.45	3.22
1985	8.38	8.40	11.71	3.57	1.93	-0.55	3.44
1990	8.87	9.06	12.00	4.33	1.83	-0.67	3.30

Cohen-Soto Dataset

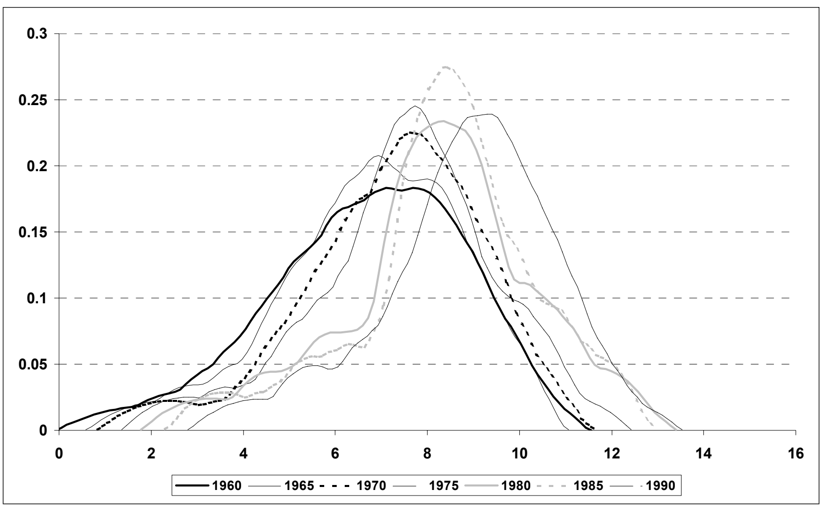
Year	Mean	Median	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis
1960	8.07	8.68	10.96	3.15	1.86	-0.86	3.45
1970	9.12	9.87	11.81	4.11	1.94	-0.85	3.18
1980	10.23	10.72	12.65	5.57	1.90	-0.77	2.86
1990	10.93	11.02	13.21	5.91	1.83	-1.01	3.72

de la Fuente-Domenech Dataset

Year	Mean	Median	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis
1960	8.36	8.57	10.78	4.37	1.95	-0.63	2.34
1965	8.69	8.84	10.96	4.62	1.99	-0.66	2.38
1970	9.02	9.10	11.32	4.87	2.02	-0.69	2.46
1975	9.45	9.57	11.76	5.29	2.03	-0.72	2.50
1980	9.87	9.94	12.41	5.73	2.03	-0.72	2.54
1985	10.28	10.48	12.76	6.06	1.99	-0.76	2.62
1990	10.64	10.97	12.95	6.41	1.90	-0.81	2.73

While all datasets present a steady increase on the average level of educational attainment for the countries in the sample, the dynamics of the distribution of schooling across OECD countries implied by the three datasets are very different. Charts 1 to 3 present the density estimates (using an Epanechnikov kernel) for each dataset and each year reported. All datasets present some degree of left skewness, with the Cohen-Soto dataset presenting the highest asymmetry.[1] The de la Fuente-Doménech dataset presents a quasi-twin peaked distribution (with a relatively high concentration of mass for values in the interval 4-8 years) which is more relevant for the most recent observations and is not directly observable in the other data collections.

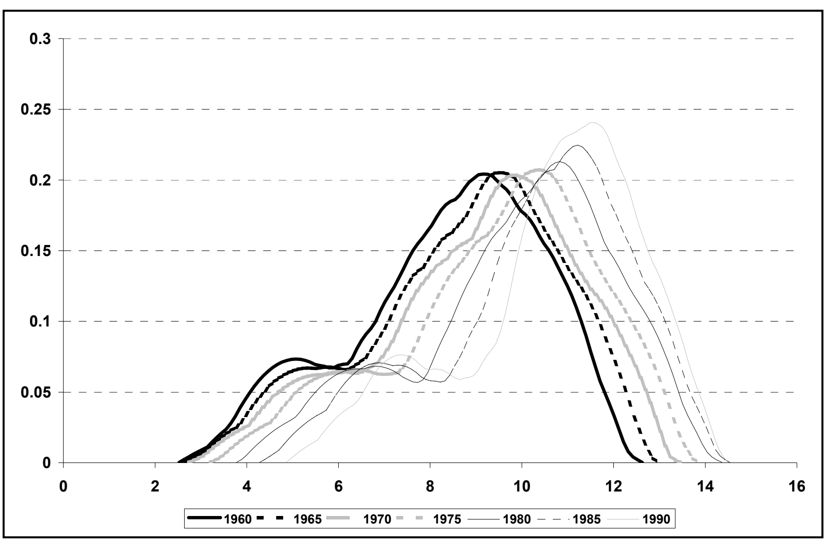
Chart 1: Kernel Desnity Estimates: Barro-Lee Dataset



[1] It should be noticed, however, that, independently of the dataset used, the overall shape of the distribution of the variable in each period is not significantly different from that of a Gaussian distribution when tested using the Jarque-Bera test.

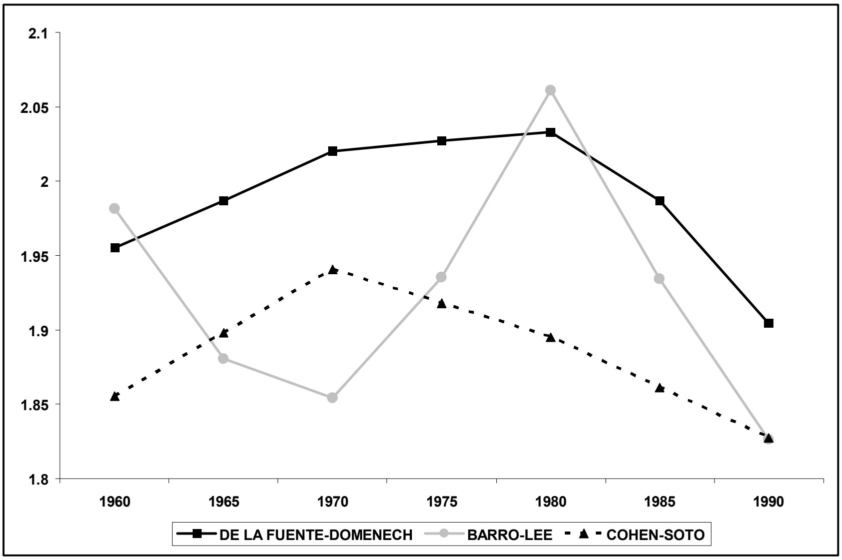
Chart 2: Kernel Density Estimates: Cohen-Soto Dataset

Chart 3: Kernel Density Estimates: de la Fuente-Doménech Dataset



The differences in terms of the dynamic behavior of the second moment of the distribution, and thus of the dispersion of educational levels across OECD countries, can be grasped from the charts in Table 1 and from chart 4, which plots the evolution of the cross-country standard deviation of years of schooling for the three datasets used in the study.[2]

Chart 4: Evolution of the Standard Deviation of Schooling Years



The dynamics of the dispersion of educational attainment in the OECD are extremely different depending on the source employed. The Barro-Lee dataset shows a relatively strong reduction of the cross-country standard deviation of years of schooling for the 1960s and 1980s, interrupted by a decade of divergence in the 1970s. The Cohen-Soto dataset, on the other hand, presents a slow path of continuous reduction in the dispersion of educational attainment since 1970, which was preceded by a decade of increase in the standard deviation of the variable. Finally, the de la Fuente-Doménech dataset only shows a decline in dispersion across OECD countries in the 1980s, with steady increases in the standard deviation of educational attainment in the 1960s and 1970s. To sum up, the only period for which all three datasets report the same type of dynamics in the dispersion measure is 1980-90, where all of them report convergence in schooling across OECD countries (in the sense of a reduction of the dispersion of educational attainment in the OECD). Notice that the dispersion dynamics in the Barro-Lee dataset are much more volatile than those resulting from the Cohen-Soto and de la Fuente-Doménech datasets.

The overall dynamics of educational attainment dispersion deliver thus a

[2] For the Cohen-Soto dataset, the observations corresponding to 1965, 1975 and 1985 were interpolated linearly.

completely different message depending on the dataset used to assess convergence in schooling for OECD countries. A further issue that needs to be tackled concerns the actual statistical significance of the changes in dispersion observed in the different data.

3. Testing for Convergence of Schooling Levels

In order to assess the statistical significance of the reductions and increases in the dispersion of educational attainment presented in table 1 and chart 4, the test introduced by Carree and Klomp (1997) will be used. Correcting an earlier proposal from Lichtenberg (1994), Carree and Klomp (1997) propose two different statistics to test for convergence. We will use the test statistic T_2, defined as

$$T_2 = (N-2.5)\ln\left[1+\frac{(\hat{\sigma}_1^2-\hat{\sigma}_T^2)}{4(\hat{\sigma}_1^2\hat{\sigma}_T^2-\hat{\sigma}_{1T}^2)}\right], \quad (1)$$

where $\hat{\sigma}_1^2$ is the variance of the variable being investigated in the initial period, $\hat{\sigma}_T^2$ is the variance of the variable in the final period, $\hat{\sigma}_{1T}$ is the covariance between the variable in the initial and final period, and N is the number of observations. Under the null hypothesis of equal dispersion in the initial and final periods, T_2 has a limiting $\chi^2(1)$ distribution.[3]

Table 2: Tests for σ-Convergence/Divergence

Period	Barro-Lee	Cohen-Soto	de la Fuente-Doménech
1960-65	3.28*	3.05*	1.02
1965-70	0.04		1.43
1970-75	0.50	0.70	0.05
1975-80	1.03		0.05
1980-85	4.78**	1.30	2.73*
1985-90	0.64		7.37***

*(**)[***] stands for 10% (5%) [1%] significant. The figures refer to the T_2 test statistic in Carree and Klomp (1997), $\chi^2(1)$ distributed under the null hypothesis of equal variance.

[3] The choice of T_2 over the other alternative put forward in Carree and Klomp (1997), T_3, can be easily justified as T_3 would require the estimation of an autoregressive parameter for the educational attainment data. Given the reduced size of the time dimension in the panel of OECD countries for the data available, inference based on this test statistic would render unreliable results.

Table 2 presents the results of the test for all subperiods and datasets. For the Barro-Lee dataset, the 1960-65 and 1980-85 periods present significant σ-convergence in educational attainment levels for OECD economies. This last period of significant convergence in schooling is also found in the de la Fuente-Doménech dataset, together with further convergence in the subperiod 1985-90. The Cohen-Soto dataset paints a very different picture concerning the evidence of changes in the dispersion of educational attainment. In this case, the only statistically significant change in dispersion takes place in the subperiod 1960-70, and it is in the direction of σ-divergence in educational attainment.

The results of the Carree and Klomp (1997) test emphasize thus the contradictory results obtained by the visual analysis of the evolution of the dispersion of educational attainment. Not only do the overall dynamics of dispersion differ extremely across datasets, but also the statistically significant changes do not coincide for the different data. There is no single period for which all three dataset offer a unified picture of significant change in the standard deviation of schooling, and for some cases the answer to whether convergence took place is answered completely differently depending on the dataset used. The experience in the 1960s is a clear example: while using the Barro-Lee dataset one would conclude that there was (10%) significant convergence in the period 1960-65, using the Cohen-Soto dataset the conclusion would be that the 1960s were marked by (10%) significant divergence in educational attainment in OECD countries, and the de la Fuente-Doménech dataset does not find any significant change in the second moment of the distribution in the whole decade.

4. Conclusions

This note shows that the answer to the question whether convergence of educational attainment levels across OECD countries happened in the period 1960-1990 depends strongly on the dataset used for the analysis. Three datasets were studied, including two of the most recently developed data collections on human capital variables (Cohen and Soto, 2001, and de la Fuente and Doménech, 2000, 2002) and the most widely used dataset on educational attainment in the empirical economic growth literature (Barro and Lee, 1993, 2001). It was shown that the dynamics of dispersion in educational attainment for OECD countries differ enormously across datasets, as do the results of the Carree and Klomp (1997) test of significance in the change of standard deviation between periods. The three datasets provide contradictory conclusions on both the existence and evolution of convergence of educational attainment in industrialized countries.

References

Barro, R. and J.W. Lee (1993). International measures of schooling years and schooling quality. *American Economic Review, Papers and Proceedings* 86, pp. 218-223.

Barro, R. and J.W. Lee (2001). International data on educational attainment: Updates and implications. *Oxford Economic Papers* 53, pp. 541-563.

Barro, R. and Sala-i-Martin, X. (1992). Convergence. *Journal of Political Economy* 100, pp. 223-251.

Benhabib, J. and M. Spiegel (1994). The role of human capital in economic development: Evidence from aggregate cross-country data. *Journal of Monetary Economics* 34, pp. 143-174.

Carree, M. A. and L. Klomp (1997). Testing the convergence hypothesis: A comment. *Review of Economics and Statistics* 79, pp. 683-686.

Cohen, D. and M. Soto (2001). Growth and human capital: good data, good results. *CEPR Discussion Paper 3025*.

De la Fuente, A. and R. Doménech (2000). Human capital in growth regressions: how much difference does data quality make? *CEPR Discussion Paper 2466* and *Economics Department Working Paper 262*, OECD, Paris.

De la Fuente, A. and R. Doménech (2001). Schooling data, technological diffusion and the neoclassical model. *American Economic Review*, *Papers and Proceeding*s 91, pp. 323-27.

De la Fuente, A. and R. Doménech (2002). Human capital in growth regressions: How much difference does data quality make? An update and further results. *CEPR Discussion Paper 3587.*

Durlauf, S. and D. Quah (1999). The new empirics of economic growth. Chapter 4 in *Handbook of Macroeconomics*, John B. Taylor and Michael
Woodford (eds.), North-Holland, 1999.

Krueger, A. and M. Lindahl (2001). Education for growth: why and for whom? *Journal of Economic Literature* XXXIX, pp. 1101-36.

Lichtemberg, F. L. (1994). Testing the convergence hypothesis. *Review of Economics and Statistics* 76, pp. 576-579.

Pritchett, L. (1996). Where has all the education gone? *World Bank Policy Research Working Paper 1581*, World Bank.

Wolff, E.N. (2000). Human capital investment and economic growth: exploring the cross-country evidence. *Structural Change and Economic Dynamics* 11, pp. 433–472.

Workforce Ageing and Economic Productivity: The Role of Supply and Demand of Labor: An Application to Austria

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1. Introduction

Population ageing currently receives high attention in economics, in particular with respect to its implications for the sustainability of social security systems such as the pension, health and elderly care system. In addition, population ageing will also affect other markets like the labor market, the markets for goods and services and capital markets (see e.g., Börsch-Supan, 2002). In this paper we focus on the labor market and consider the fact that population ageing will affect the quantity and the composition of the current workforce. It is now well accepted that in most industrialized countries, the economic output must be achieved by a smaller and an older labor force in the future. The question is then how this development might have an impact on the economic productivity as measured by output per worker.[2]

According to the view of many economists, an ageing population leads to negative consequences in terms of growth of output per capita for two reasons.

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[2]The recent development accounting literature (Hall and Jones, 1999) has stressed that only workers can contribute to production and therefore an understanding of differences in output per worker is more important than an understanding of differences in output per capita.

First, there is an accounting effect because a decreasing ratio of the working-age population to the total population increases the ratio of consumers to producers. This contributes negatively to growth of output per capita. Second, there might also exist behavioral effects on growth of output per worker, i.e., negative effects of an ageing population on economic productivity as measured by output per worker. It is the latter effect that we want to investigate in the current paper. In particular we shall study the sensitivity of projected economic productivity with respect to three key assumptions in the labor market. These include the projected labor force participation rates, the assumption of the age-productivity profile of workers and the degree of substitutability between labor of different ages. Hence, we focus on the supply side of the labor market and its interrelationship with the assumed labor demand function. In particular we investigate the role of the internal composition of the labor force as opposed to using only dependency ratios or broad age categories to simulate the macroeconomic implication of an ageing labor force.

Our aim is to present qualitative results and rough orders of magnitude rather than proposing detailed projections of the future development of economic productivity. We therefore follow the work of and and choose a pure labor economy as our theoretical framework to study the impact of labor force ageing on economic output. For our numerical simulations we use age-specific demographic data provided by Statistics Austria and age-specific labor market data provided by OECD.

A restrictive assumption in Blanchet (1992) is the production technology that allows for perfect substitutability between workers of different ages. Though the assumption on production technology was relaxed in Blanchet (2002) and a CES production function was applied instead, the study is restrictive since it only considers the effect of workforce ageing in a stable population. However, as is well known from recent studies in the economic growth literature relating differences of economic growth rates to changes in demographic structures (e.g. Higgins and Williamson, 1997), an analysis that restricts itself to steady states of the population distribution may be at best insufficient and at worst misleading in times of severe demographic changes. Since in many industrialized countries we will experience pronounced fluctuations of the working age population in the coming decades (caused by the baby boom generation which is expected to start retiring around 2020) a focus on transitional dynamics is essential.

We are aware of the fact that by focusing on a pure labor economy and ignoring physical capital we disregard one of the most important channels through which the negative impact of the labor force shrinkage on economic growth may be attenuated. As is well known in neoclassical growth theory, population decline increases the steady state capital labor ratio since less people have to be equipped with capital.[3] These effects are captured in general equilibrium models which

[3] As shown in Cutler et al. (1990, p.18), this „Solow effect" offsets the long-run dependency

commonly constitute the theoretical framework to study the economic consequences of population ageing. However, most of those models are restrictive with respect to the production technology which in most cases aggregates labor of all ages into one production factor. Since our aim is to introduce imperfect substitutability across age groups in the labor market and consider its implication on economic productivity during times of rapid labor force shrinkage and ageing, we regard (similarly to Lam, 1989, p.192) our assumption to concentrate on a pure labor economy as an `important departure for more complete models'.

The setup of the paper is as follows. In section 2 we go over the empirical and theoretical literature that has dealt with population~ ageing and economic productivity. Our theoretical framework is reviewed in section 3. In section 4 we present the demographic forecasts for Austria, outlining various scenarios for the size and structure of the labor supply development. Combining the labor force and demographic projections, we discuss the trends in the support ratio (the number of active to dependent population). We apply alternative assumptions about the substitutability, productivity and labor supply of workers of different ages to arrive at scenarios of economic productivity in Section~5. In Section~6 we summarize our findings.

2. Recent Studies on Economic Productivity and Demographics

2.1 Microeconomic Evidence

As evidenced in the recent literature it is a difficult task to unravel the impact of changing age composition of the workforce on aggregate productivity (Disney, 1996), Arnds and Bonin (2002, chapter 2). A common argument is that an ageing population is less entrepreneurial and ambitious and may therefore negatively affect economic productivity. On the other hand there is the argument by labor economists that a mature population embodies a greater stock of human capital and experience, measured by employment-specific acquired skills (tenure) and employment-independent experience. Testing for these competing hypotheses on the individual level is a difficult task since productivity is difficult to measure individually (see Skirbekk, 2004 and Johnson, 2002b) for a review of studies measuring individual productivity). In particular, there is the potential interaction

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effect on U.S. per capita consumption in the short run. On the other hand, it can be argued that significant proportions of excess savings may be invested abroad and not in the domestic capital stock so that the positive effects of higher capital intensity are of a smaller order of magnitude.

of cohort effects, age effects and other productivity effects (including company-specific production processes and organisational structures) which complicates the uncovering of the “pure” age effect on individual productivity. The general conclusion among these studies is that “a decline in performance may be falsely attributed to age, when in fact it may be due to skill obsolescence or a burn out phenomenon which may occur at any age and can be remedied through training practices” (Auer and Fortuny, 2002, chapter 7). Moreover, the assumption of competitive labor markets where workers are paid their marginal productivity is often violated (see Laezar, 1990). It is commonly argued that older workers are more expensive than younger workers because of higher remuneration, fringe benefits and social contributions. The fear is then that the relative price of labor will rise though its quality might even decline which would reduce the competitiveness of ageing economies.

2.2 Macroeconomic Evidence

While the relation between age and individual productivity is less clear cut, there has been recent evidence of a significant relation between changes in the adult population and aggregate productivity. In an econometric study on the experience of 18 industrialized countries, Beaudry and Collard (2003) have shown that over the period 1960 to 1974, adult population growth (i.e., of the population aged between 15 and 64) is found to exert only a small and insignificant effect on GDP per worker, and this effect turned negative for the period 1974 to 1996. Their results imply that a country with a yearly adult population growth of one per cent greater than the average would experience poorer growth in output per worker of approximately one per cent per year which compounded over 22 years corresponds to a difference of 25 per cent in labor productivity.[4] Recalling neoclassical growth theory (which implies that economies with a lower growth rate of adult population would accumulate more capital) the authors argue that those findings could be evidence of capital biased technological change and they continue to set up a simple growth model that incorporates those considerations. The study by Beaudry and Collard (2003) relates closely to the empirical evidence which has shown that input accumulation cannot explain the majority of cross-country differences in output per worker, but that the `residual', and therefore, total factor productivity must account for the differences, see e.g. Prescott (1998). In a recent paper Feyrer (2002) has shown that the age structure of the workforce has a significant impact on aggregate productivity (where he measured productivity as the Solow residual).

[4]These results are similar to earlier findings in Cutler et al. (1990) who found in a sample of 29 countries (whose labor productivity was at least 30 per cent of U.S. labor productivity) that a 1 percentage point decrease in the annual labor force growth rate raised productivity growth by 0.62 percentage points a year from 1960 to 1985.

In particular he found that workers aged 40 to 49 have a large positive effect on productivity and he uses his findings to explain the productivity slowdown in the US in the 70s and the boom in the 90s.[5] However, Feyrer (2002) does not present a definite mechanism through which demographic change operates although he argues that technology adoption is one of the driving factors that spurs growth and this might be related to demographics. A recent study by Kögel (2004) finds a significant and negative effect of the youth dependency ratio (the population below working age divided by the population of working age) on productivity and provides a theoretical model in the style of the life cycle model where he links a lower youth dependency ratio to higher savings -- hence more capital can be spent on technology, hence productivity will increase. A key paper which presents a theoretical framework for the argument that even a dramatic decline in population growth will not lead to a long-run slowdown in productivity is Dalgaard and Kreiner (2001). The authors allow for endogenous human capital in a basic R & D driven growth model and develop a theory of scale-invariant endogenous growth where population growth is neither necessary for, nor conducive to, economic growth.

Analyses of the relation between changes to the age structure of the population and aggregate measures of performance, such as technical progress or economic growth, can also provide insight about workers' productivity. Nishimura et al. (2002) investigate the impact of age structure on technical progress and value-added growth in Japanese industries for the years 1980 to 1998. They estimate the relation between technological progress and the employees' age structure and find that the relation between the share of educated workers older than 40 years and technological progress is positive in the 1980s, but turned negative in the 1990s. This may be due to a higher rate of technological change in the 1990s which shifted the productivity peak towards younger ages.

Further studies that estimated the macroeconomic effects of the age structure of the labor force include, e.g., Lindh and Malmberg (1999) and Malmberg (1994). In both studies, demographics is assumed to influence factor accumulation, as opposite to Feyrer (2002) and Kögel (2004) who regard the effect on productivity as the more important channel. While Lindh and Malmberg (1999) find an effect of the age composition of the labor force on growth of GDP per worker in OECD countries, Malmberg (1994) finds for Sweden such age structure effects on growth of GDP, on growth of GDP per capita, on growth of TFP (Total Factor Productivity) and on aggregate savings.

[5]More specifically, he found that a 5 per cent increase in the size of the cohort of 40 to 49 years old over a ten year period can lead to 1.7 per cent higher productivity growth in each year of the decade.

2.3 Projecting the Future Impact of Demographic Change on Economic Productivity

To project the future impact of an ageing labor force on macroeconomic variables, computational general equilibrium models (CGE models) are applied. In a recent study on labor market effects of population ageing, Börsch-Supan (2002) shows that about half of the decline (of 15 per cent) in per capita output that results from the decrease in the labor force until 2035 can be compensated by the induced higher capital intensity. However, as he mentions, on p. 42, *"... any possible age-structure related reduction in aggregate productivity ... would reduce the effect of higher capital intensity"*. He then concludes that an increase of productivity growth from 1.39 to 1.65 per cent would be necessary to maintain the per capita level of GDP as of 2000. Hence, strong productivity growth which in turn depends on increased capital intensity and human capital is necessary to keep up the consumption level if the labor force participation starts to decline.

A different approach -- more related to demographic accounting than applying sophisticated economic modelling -- to forecasting the effect of labor force ageing on economic productivity is taken in Blanchet (1992) and Blanchet (2002). Interacting fixed and exogenously chosen age-productivity profiles with alternative projected demographic structures and age-specific labor force participation, Blanchet (1992) shows that the effect of labor force ageing on economic productivity is moderate. To explain these results, the author refers to stable population theory which provides simple rules of thumb to assess the condition under which the average value of an age-dependent variable may be sensitive to changes in the population growth rate. In particular, he shows that a change in the population growth rate by one percentage point cannot have an aggregate impact of more than 20-25 per cent on any age-dependent phenomenon (see Appendix A where we apply the argument by Blanchet, 1992).

Aggregate economic productivity is not only determined by the change in individual-based productivity that works through a change in age composition of the workforce, but as we know from the theory of factor demand, the impact of labor force ageing and labor force shrinkage on economic productivity will depend on the substitutability of different factors of production. These include the substitution of capital for labor and the substitutability among workers of different age and education. As documented in Hamermesh (1993, chapter 3) the result of a relative decline in the supply of labor in a world consisting of homogeneous capital and labor would be declining interest rates and an increase in wage rates. However, the results are much less clear if one introduces more restrictive substitution patterns between workers disaggregated by age (Hamermesh, 1993, table 3.9).

Though Blanchet (2002) has taken up the role of imperfect substitutability of workers of different ages and its impact on economic productivity when population growth changes, his analysis is restrictive since he focused only on a stable population. However, to study the effect of imperfect substitutability between workers of different ages in times of population ageing it is necessary to focus on transitional dynamics. We therefore extend the analysis of Blanchet (1992) and investigate the time path of economic productivity in a pure labor economy where workers of different ages are not perfect substitutes. Hence, we concentrate on dynamic features of population ageing. In addition to studying the sensitivity of projected economic productivity with respect to the labor demand function we also investigate how future productivity will change depending on labor supply factors such as the individual age productivity profile and labor force participation rates.

3. Theoretical Framework

In the simulations presented in the following sections we want to analyse the sensitivity of the projected labor productivity with respect to alternative assumptions about future labor supply and the substitutability and productivity of the labor force at different ages. We assume that the output of a particular economy only depends on the input of labor and individuals aged 15 to 65 participate in the labor force according to the age-specific labor force participation rates given by the OECD labor market statistics.

We apply three different production functions. The first one is the *additive production function* which assumes perfect substitutability between labor at different ages. In this modelling framework the output at time t is given by

$$Y(t) = \sum_{x=15}^{60} \alpha_x \, {}_5L_x(t) \sum_{x=15}^{60} \alpha_x = 1, \tag{1}$$

where α_x indicates the productivity of the labor force at age x and ${}_5L_x$ indicates the labor force in the five year age interval $[x, x+5)$, i.e., the population at age x , ${}_5N_x(t)$, multiplied by the age-specific labor force participation rate ${}_x(t)$ where we distinguish between female and male labor force participation rates. Moreover, we also consider the *Cobb-Douglas production function*,

$$Y(t) = \prod_{x=15}^{60} {}_5L_x(t)^{\alpha_x} \sum_{x=15}^{60} \alpha_x = 1. \tag{2}$$

Alternatively, we assume a *constant elasticity of substitution production function* (CES) of the form

$$Y(t) = \left(\sum_{x=15}^{60} \alpha_x \, {}_5L_x(t)^{\rho} \right)^{\left(\frac{1}{\rho}\right)} \tag{3}$$

with $\sigma = \frac{1}{1-\rho}$ denoting the elasticity of substitution between labor force of different ages and $\rho \in (-\infty, 1]$. The additive and Cobb-Douglas production function are included in this general formulation and result if $\rho = 1$ and $\rho \to 0$, respectively. As already indicated in Blanchet (2002) the assumption of the CES production technology is restrictive as well. When workers from one age group are substituted by members of any other age group, the actual age difference does not matter. In reality one might assume that a person aged 25 can easily be substituted by another person aged 26 but not that easily by another person aged for instance 64. To take this into account we propose another kind of CES production function

$$\begin{aligned} Y(t) = \Bigg[& \alpha_{15} \left(\frac{3\, {}_5L_{15}(t) + {}_5L_{20}(t)}{4} \right)^{\rho} \\ & + \sum_{x=20}^{55} \alpha_x \left(\frac{{}_5L_{x-5}(t) + 2\, {}_5L_x(t) + {}_5L_{x+5}(t)}{4} \right)^{\rho} \\ & + \alpha_{60} \left(\frac{{}_5L_{55}(t) + 3\, {}_5L_{60}(t)}{4} \right)^{\rho} \Bigg]^{\left(\frac{1}{\rho}\right)} \end{aligned} \tag{4}$$

which we will call *fuzzy CES* in the following. The above function takes into consideration that the two neighbouring age groups are better substitutes than those age groups which are further away. Instead of just having one age group within each addend of the production function -- like in formula () -- we use a weighted average of three neighbouring age groups. For example, it is assumed that the elasticity of substitution of workers of different age is higher when they belong to consecutive age groups. This idea can be extended by combining for instance five age groups instead of three which would lead to an expression like

$$\alpha_x \left(\frac{{}_5L_{x-10}(t) + 2\, {}_5L_{x-5}(t) + 4\, {}_5L_x(t) + 2\, {}_5L_{x+5}(t) + {}_5\, L_{x+10}(t)}{10} \right)^{\rho}.$$

4. Demographic and Labor Supply Forecasts for Austria

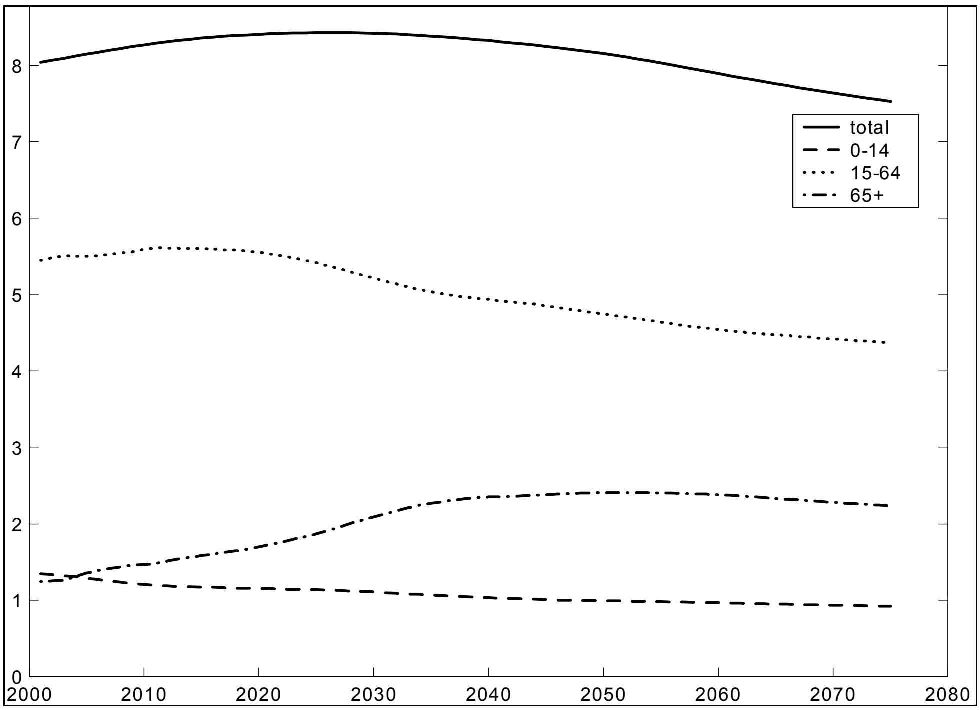
In the following we use the latest population projections released by Statistics Austria in 2003 covering the time interval from 2000 to 2075. These data contain single-year age groups and also single-year time steps.

4.1 Demographic Forecasts

To investigate the sensitivity of our results with respect to alternative demographic forecasts we apply three alternative variants of the population projections by Statistics Austria (Hanika, 2004). These include the main variant which assumes a constant fertility of 1.4 children per woman and an increase of the mean age at birth from 28.6 (2001) years to 31.0 years (2050). Life expectancy is assumed to increase from 75.8 years (2002) to 83.0 years (2050) for men and from 81.7 years (2002) to 88.0 years (2050) for women. Migration is assumed to increase in the short run from 90.000 (2001) to 95.000 (2006) and will remain until 2011 at a value of 94.000 persons, afterwards a further decrease to 87.000 (2016) and consequently 80.000 (2041) is assumed. Alternatively we also apply a high fertility/high migration and a low fertility/low migration variant. In the high and low fertility variants, the total period fertility rate is assumed to be 1.70 and 1.10, respectively, starting from 2015 onwards. Hence, the high fertility variant assumes that fertility will increase in the long run to values currently observed in the northern European countries, while the low variant reflects the situation currently prevalent in southern European countries. The mean age at birth is kept similar to the main variant. For the high fertility variant, life expectancy is assumed to increase to 87.0 years for men and 91.0 years for women until 2050. In the low fertility variant, a smaller increase in life expectancy up to 79.0 years for men and 85.0 years for women is assumed. For the high migration variant, migration is assumed to be about 10.000 more persons per year, while the low migration variant assumes about 10.000 persons less.

In chart 1 we plot the forecast of total population and of broad age groups (0-14, 15-64, 65+) between 2000 and 2075 for the main variant. While population is projected to increase during the first 3 decades of the century to reach a maximum of 8.43 millions in 2026, the number of the working age population (15 - 64 years) is projected to decrease much earlier. The shrinkage of the working age population is expected to set in already in 2012.

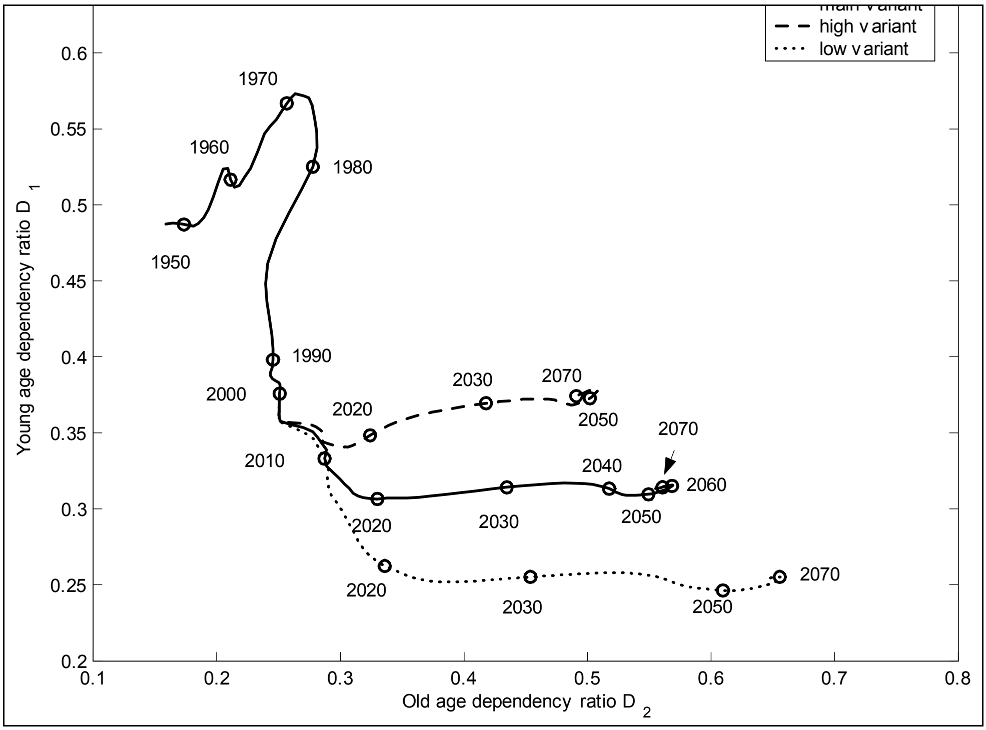
Chart 1: Forecast of Total Population and Broad Age Groups, Main Variant



In chart 2 we plot the historical path of old and young age dependency ratios as well as forecasts through 2070 under the main, low and high variant of the population projection.[6] Independent of the specific projection variant, Austria will experience a pronounced increase in its old age dependency ratio with the pace and the size of the increase being more pronounced in the low variant compared to the main and high variant.

[6]The young age dependency ratio is defined as the population below age 20 divided by the economically active population between ages 20 and 64, while the old age dependency ratio is defined as the population aged 65+ divided by the economically active population between ages 20 and 64.

Chart 2: Dependency Ratios 1947–2075, Main, High and Low Variant



4.2 Labor Supply Forecasts

We combine the three variants of the population projection with two variants of the labor force participation rates. In a benchmark model we assume that today's age and gender-specific labor force participation rates are kept constant over the whole projection time period. Alternatively we propose a scenario where we assume that the labor force participation rates will be adjusted to keep the size of the labor force constant at its maximum value obtained in 2012. This adjustment is made by assuming an increase in age-dependent labor force participation rates with the rates observed in northern European countries acting as an upper maximum. That means for each year we try to find a multiplier β_t such as

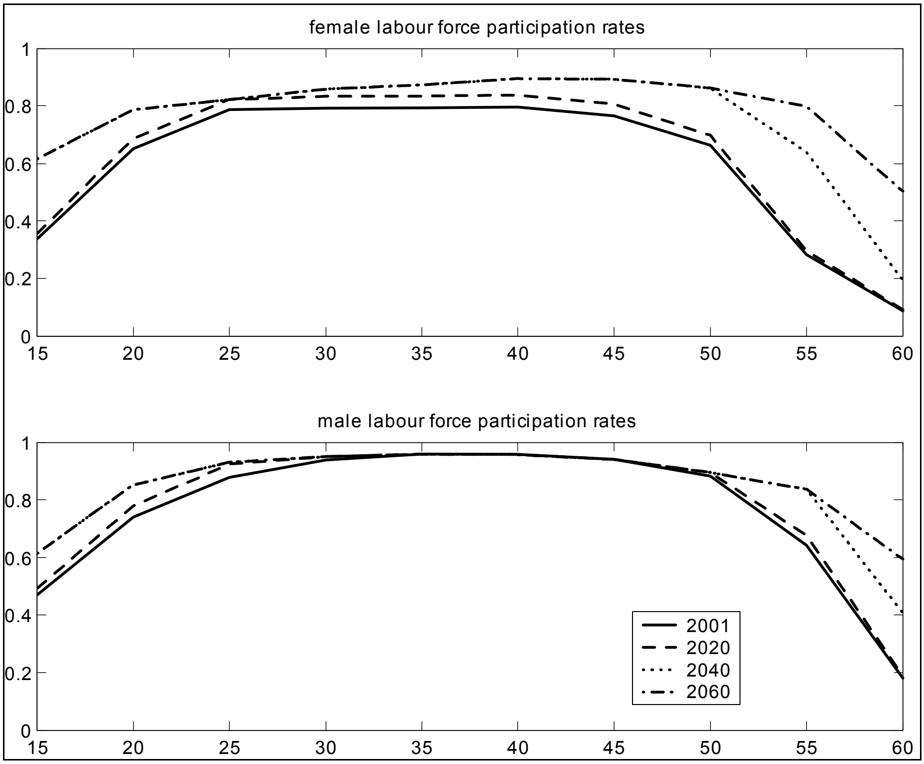
$$\sum_{x=15}^{60}\left(\min\left\{\overline{\mathrm{lfpr}_{f,x}},\beta_t\,\mathrm{lfpr}_{f,x}\right\}N_{f,x}(t)+\min\left\{\overline{\mathrm{lfpr}_{m,x}},\beta_t\,\mathrm{lfpr}_{m,x}\right\}N_{m,x}(t)\right)$$
$$=\sum_{x=15}^{60}\left(\mathrm{lfpr}_{f,x}\,N_{f,x}(2012)+\mathrm{lfpr}_{m,x}\,N_{m,x}(2012)\right), \qquad (5)$$

with $N_{f,x}(t)$ and $N_{m,x}(t)$ denoting the female and male population aged x to $x+5$. Moreover, f,x and m,x denote the current age and gender-specific labor force participation rates in Austria for women and men in 2012, and $\mathrm{lfpr}\overline{_{f,x}}$ and $\mathrm{lfpr}\overline{_{m,x}}$ are the maximum age and gender specific labor force participation rates observed in northern European countries. Hence, if it is not possible to find a β_t satisfying equation (5), then we use the maximum labor force participation rate for that year.

In chart (3) we plot the status-quo labor force participation rates (as of 2001) as well as the labor force participation rates resulting from the adjustment procedure just described and assuming the main variant of the population projection. To keep the size of the labor force constant at its maximum value obtained in 2012 requires a persistent increase in the labor force participation rate at younger and older ages for males and a persistent increase in the labor force participation rates at all ages for females.[7]

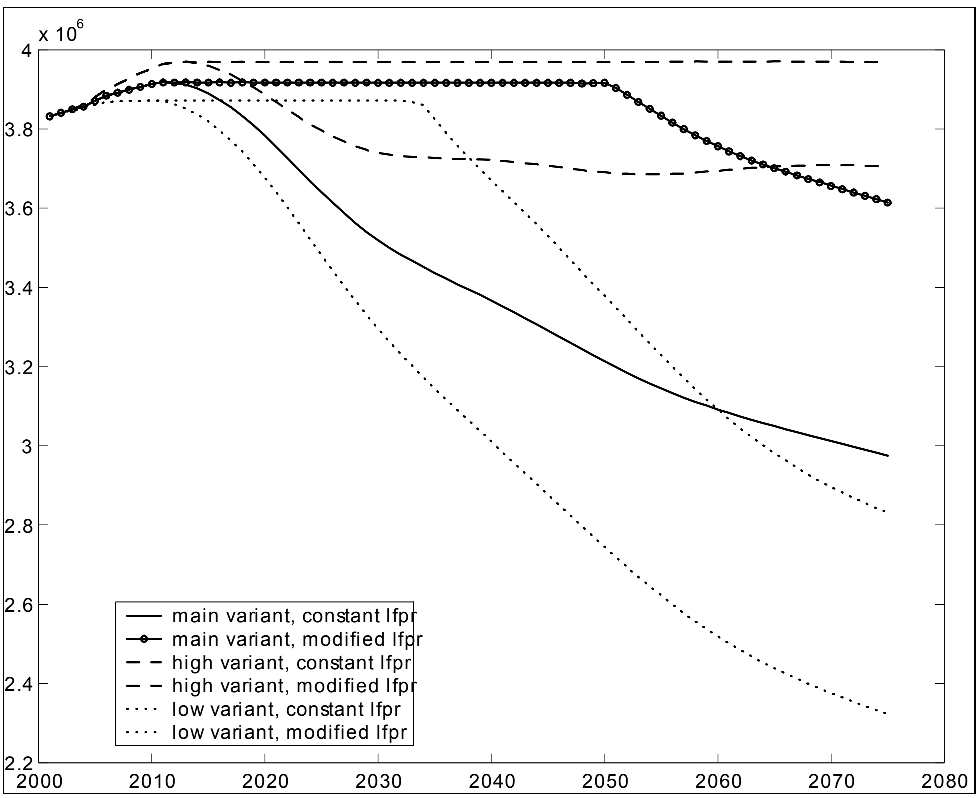
[7]Following the „lump-of-labor fallacy" it is often argued that an increase in labor force participation rates may cause additional labor market frictions (at least in the short run) since retirees are allegedly freeing jobs for others. However, the number of jobs in an economy is no fixed figure and cross-country patterns in the EU reveal no relation between employment rates of older workers and overall unemployment. On the other hand, an increase in the female labor force participation rate needs to be accompanied by family support measures, otherwise it would worsen the ageing effect since lower fertility could possibly result from the increase in female labor force participation.

Chart 3: Age-Specific Labor Force Participation Rates, Main Variant



We then interact the age-specific labor force participation rates with the three variants of the population projections yielding six alternative forecasts for the stock of future labor force (chart 4). Note that in the status quo scenario (and taking into consideration the main variant of the population projections) the labor force starts to shrink already in 2012. However, if we allow for an increase in labor force participation rates up to the point currently observed in northern European countries, the decline in the labor force can be held off until 2050. Thereafter such higher labor force participation rates can no longer counteract the shrinkage of the labor force that is caused by smaller cohorts entering working age. Similar dynamics also occur when the same calculations are based on the high fertility/high migration or low fertility/low migration variant. In the former case the maximum size of the labor force can even be maintained until the end of the projection period, while in the latter case adjustments of the labor force participation rates can only postpone the shrinkage of the labor force until the mid 2030s. Moreover, projections of labor force across alternative variants of population forecasting begin to diverge significantly around 2020. On the other hand, assumptions regarding the labor force participation are critical for projected labor force already in the coming decade. In summary, future projections of the quantity of the labor force are sensitive to the uncertainty in future population projections with the difference between the high and low variant (given constant labor force participation rates) being about 1.4 million workers in 2075. Only for the high population projection variant an adjustment of the labor fore participation rates towards values observed in northern European countries could counteract the shrinkage of the working population. For the median and low variant of the population projections such a scenario could not compensate for the shrinkage of the working population in the long run.

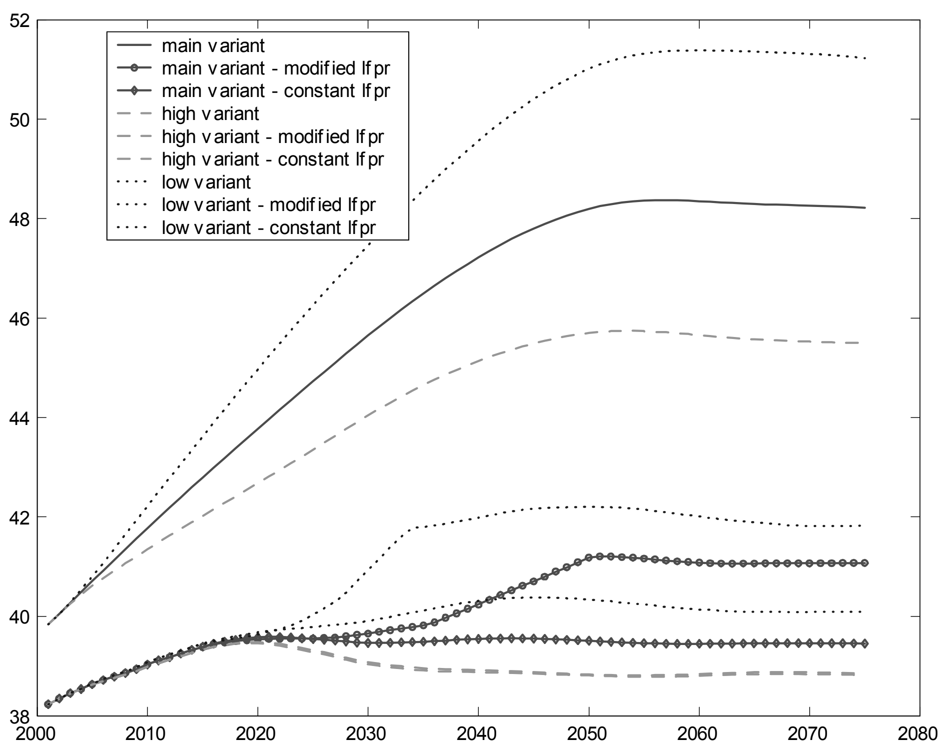
Chart 4: Projected Total Labor Force, Mean, High and Low Variant



In addition to a shrinking workforce, the Austrian economy will be faced with an ageing workforce. Chart 5 illustrates the mean age of the total population, the mean age of the labor force assuming that labor force participation rates are kept constant at the level of 2001, and the mean age of the labor force when labor force participation rates increase up to the maximum level of the northern European countries for the main variant, the high fertility/high migration variant, and for the low fertility/low migration variant.[8]

In case of the main variant, the mean age of the total population increases up to a value of 48.37 in 2057 before it levels off in the second half of the 21st century (chart 5), while ageing of the labor force reaches its maximum in 2021 with a mean age of the labor force of 39.6 years. Thereafter the mean age of the labor force remains nearly constant. (The slight rejuvenating effect of the labor force after 2021 can be explained by the retirement of the baby boom generation.) If age-specific labor force participation rates were increased to maintain the maximum size of the workforce as of 2012, there is a further increase of the mean age up to 41.2 years in 2051.

Chart 5: Mean Age of Total Population and Labor Force, Mean, High and Low Variant



[8] To compute the mean ages we assumed that the age of an individual belonging to the age-group $[x, x+n)$ is $x + n/2$.

In the high fertility/high migration variant, the mean age of the total population reaches its maximum in 2053 and always remains below 46 years. The mean age of the labor force reaches its maximum around 2020 at a level of about 39.5. Moreover, there is a clear decline in the mean age of the labor force after reaching the peak. The curves representing the two different labor force scenarios are almost identical because in case of high fertility and high migration the size of the working age population is rather big anyway. Therefore only small adjustments of the labor force participation rates are required. Finally, in the low fertility/low migration variant the mean age of the total population exceeds the previously mentioned variants. It peaks in 2060 at a level of 51.4 years. As a consequence, ageing of the labor force is also more pronounced. In case of adjusting the participation rates to maintain the size of the labor force, its mean age may rise up to 42.2 years in the year 2050.

In summary, purely demographic factors (in case of constant labor force participation rates) explain an ageing of the labor force that does not extend beyond 2021. Under constant labor force participation rates (as of 2001) the peak of workforce ageing is obtained around 2020, i.e., almost 40 years in advance of the peak of population ageing. Of course, ageing of the labor force will be more pronounced if we add to this natural ageing a process of artificial ageing due to a policy of increasing labor force participation rates at higher ages as suggested in our second scenario. An increase of the labor force participation rates towards the values observed in northern European countries would increase the age of the workforce by about 2 years until the mid 21st century.

4.3 Support Ratio

To compare the burden of demographic change in the past and the future we calculate alternative measures of the support ratio as introduced in .Cutler et al. (1990). The benchmark definition of the support ratio S relates the effective labor force $L1$ to the effective number of consumers $C1$:

$$S = L1/C1$$

where $L1 = \sum_{x=20}^{64} N_x$ and $C1 = \sum_{x=0}^{95+} N_x$. This definition assumes that people of every age have the same consumption needs and that all people aged 20 to 64 are in the labor force.

Alternatively we can apply a needs weighted consumption measure $C2 = \sum_{x=0}^{95+} s_x N_x$ where s_x indicates the weight for an individual at age x . We follow Cutler et al. (1990) and assume that $s_x = 0.72$ for people under 20,

$s_x = 1$ for people aged 20 to 64 and $s_x = 1.27$ for people 65 and over. The relative consumption needs are derived by considering three components (private nonmedical expenses, public education expenses, and medical care), and represent the relative demands for consumption of different age groups. For instance, young people show less private consumption but consume more education services whereas older people consume more health services.

For the labor force we consider one alternative measure in addition to $L1$. Similar to Cutler et al. (1990) we propose a measure $L2$ that takes variation of labor force participation and wages by age into account. We use the sex and age-specific labor force participation rates $\text{lpfr}_{f,x}, \text{lpfr}_{m,x}$ of 2001 (chart 3) and sex and age-specific mean earnings $w_{f,x}, w_{m,x}$ of 2001 (table 1) to estimate $L2 = \sum_{x=15}^{60} [w_{f,x} \text{lpfr}_{f,x}\ {}_5N_{f,x} + w_{m,x} \text{lpfr}_{m,x}\ {}_5N_{m,x}]$. This definition considers the fact that the earnings capacity of a society will differ depending on the underlying age distribution of the labor force.

Table 1: Gross Earnings of Employed Persons in Euro per Year in 2001

age group	15 – 19	20 – 29	30 – 39	40 – 49	50 – 59	60+
female	9889	16279	16324	19086	20077	13259
male	12175	21992	27752	30291	32427	41626

Out of these two alternative consumption and labor force measures we construct four alternative support ratios as plotted in chart 6. (All projections are based on the main variant of the population projection.) The general conclusion we may draw from these figures is the projection of a long-run decline in the support ratio which is caused by the decline of the labor force as compared to the total population. Note that we are currently at the beginning of this decline which will only come to a halt by the middle of the century. Ignoring the labor force participation rates and differences in consumption needs by age (i.e., applying the definition $L1/C1$) we observe a slight increase in the support ratio until 2010 due to the baby boom generation still being in its working ages while the old age dependency has not yet set in. The decline in the support ratio during the coming decades is not exceptional; the support ratio declined markedly in the late 1940s and 1950s before it recovered when the baby boom generation entered the labor market. However, the decline of the support ratio we expect in the future is indeed unique in terms of its persistence and magnitude. From chart 6 we may draw two further conclusions. First, the projected support ratio is more sensitive to alternative measures of the consumption measure than to alternative measures of the labor force. When we assume equal consumption needs for all people (C1), the support ratio drops by 14.1% (16.3%) for L1 (L2) between 2001 and 2050. When adjusting for consumption needs, the respective declines are much more pronounced: 18.6% (20.8%) for L1 (L2). Secondly, while the support ratio that considers needs weighted consumption falls below the corresponding ratios where we neglect those weights for the future, the opposite was true in the past. This reflects the fact of an increasing old age dependency burden as compared to the youth dependency burden we observed during the baby boom years.

In summary, in the worst scenario ($L2/C2$) the support ratio drops between 2001 and 2050 by 20.8% . This means that in 2050 the working population will need to be almost 21% more productive than in the year 2001 in order to keep per capita output the same. Put differently, this would require an annual productivity growth rate of about 0.4 percentage points between 2001 and 2050. Referring to estimates for long-term real productivity growth of about 1.4% (Börsch-Supan, 2002, p. 8) about one third of this growth rate would be taken up by the decrease in the labor force. In fact, the decline of the support ratio is steepest already in the first three decades between 2001 and 2035 implying that the productivity increase would need to be even bigger to preserve the 2001 level of output per capita during this period.

As our simulations indicate, the demographic burden -- as a consequence of workforce shrinkage and increased old age dependency -- is expected to rise during the next decades. It is therefore of interest to understand the potential of economic productivity (output per worker) to increase depending on the underlying labor demand function and labor supply conditions.

5. Economic Productivity Forecasts

To forecast economic productivity we multiply the age-dependent productivity schedule α_x with the distribution of the work force by age and divide by the total size of the labor force. In a first step we investigate the sensitivity of those projections if we assume equal productivity schedules across ages, i.e., $\alpha_x = \frac{1}{10}$, but vary the elasticity of substitution across age groups. We base this first set of simulations on the main variant of the population projection and the constant labor force participation scenario as of 2001. Next, we allow for alternative shapes of the age-productivity schedules and labor force participation to study the sensitivity with respect to labor supply as opposed to the labor demand function.

Applying equal productivity levels by age together with perfect substitutability of workers of different ages (i.e., an additive production function, $\rho = 1$) implies that output per worker will be independent of the projected changes in the size and composition of the labor force (chart 7). If we relax the assumption of perfect substitutability between workers of different ages, the change in the size and composition of the workforce will no longer be neutral for forecasts of output per worker. The lower the elasticity of substitution between workers of different ages (i.e., the lower the value of ρ), the more pronounced fluctuations of output per worker are to be expected. For instance, in case of $\rho = -1$, i.e., an elasticity of substitution of 0.5 , the change in the size and composition of the workforce would result in an increase of about 15 per cent of output per worker between 2000 and 2025.

The results are intuitive since output maximization for a CES type production function with equal productivity for all ages is achieved if the age distribution is uniform (see Appendix~B where we review the argument brought forward by Lam (1989, section 3.) As shown in Appendix C, the age distribution of the labor force is less uniform during the first decades of the century and then becomes more uniform as the baby boom generation moves through the ages of high labor force participation rates. Obviously, the sensitivity of the output with respect to the age distribution of the labor force is higher in case of a lower elasticity of substitution.

Chart 6: Actual and Projected Support Ratios (Relative to 2001). Four Alternative Measures, Main Variant of Population Projection

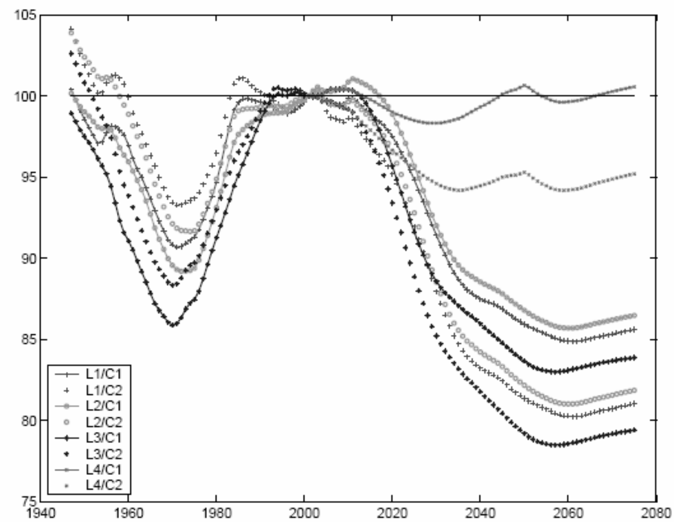
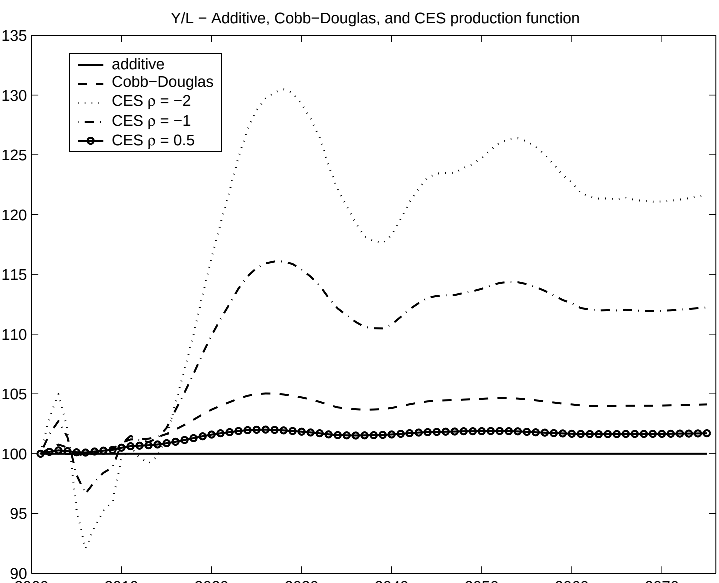
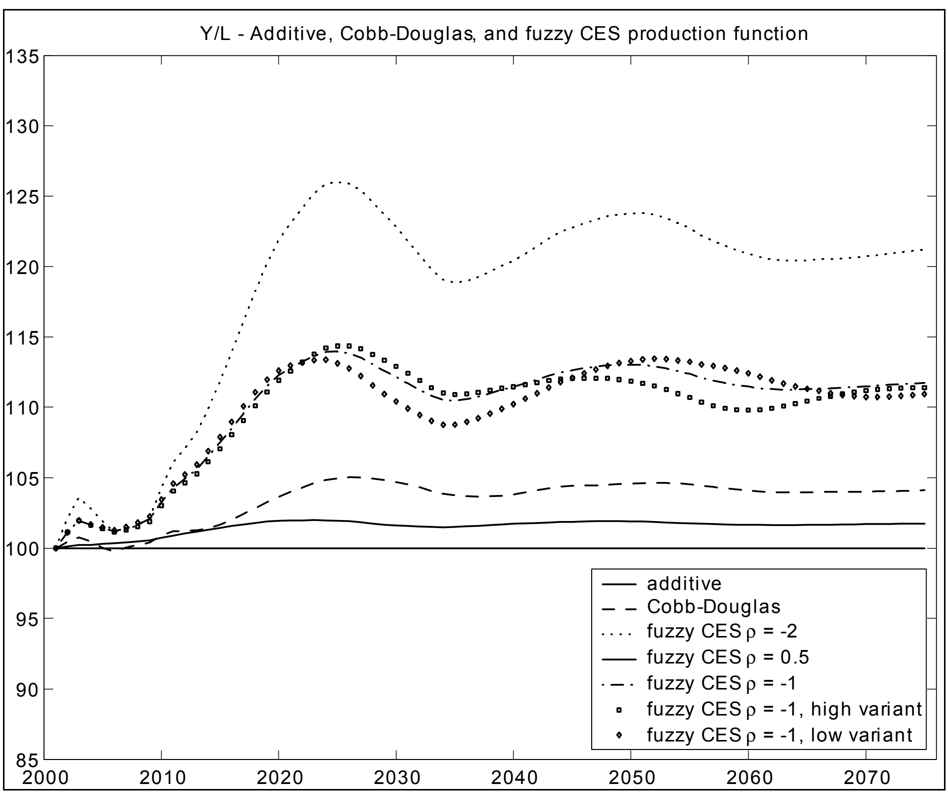


Chart 7: Projected Relative Output per Worker for Equal Productivity Schedule by Age and CES Type Labor Demand Functions, Main Variant and Constant Labor Force Participation Scenerio



As already noted in Blanchet (2002), the assumption of a CES type labor demand function may be unrealistic as well. We therefore introduce a fuzzy CES type production function as described in section 3. By allowing neighbouring age groups to be better substitutes than distant age groups the pattern of output per worker is smoothed (chart 8) and the peak of output per worker occurs about 3 years earlier and is slightly attenuated compared to chart 7. For the CES type labor demand function with $\rho = -1$ we also plot the projected output per worker if we apply the high and low variant of the population projections in addition to the main variant. The results are less sensitive to alternative demographic projections compared to alternative assumptions on the degree of substitutability between workers of different ages.

Chart 8: Projected Relative Output per Worker for Equal Productivity Schedule by Age and Fuzzy CES Type Labor Demand Functions, Main Variant and Constant Labor Participation Scenario



Up to now our results seem very optimistic. Though the labor force is projected to age and shrink, the relative output per worker is projected to increase. However, these results will depend on age-specific productivity schedules. We therefore alternatively assume a decreasing and a hump shaped pattern of age-specific productivity (chart 9). The qualitative shape of the age-productivity profiles is chosen to present two rather extreme scenarios but should also reflect some of the empirical findings. For instance, a hump shaped profile has been found in many empirical studies (see e.g. Börsch-Supan, 2002). We interact those age-productivity profiles with our forecasts of the age composition of the labor force given the main variant of the population projections and constant labor force participation rates and assuming different labor demand functions. In chart 10 we plot output per worker if we apply these alternative (rather extreme) age productivity profiles and assume either an additive or fuzzy CES production function with $\rho = -1$. From chart 10 we may draw the following three conclusions. Firstly, allowing productivity to vary by age the projected changes in the size and composition of the labor will have an effect on output per worker also in case of an additive production function that assumes perfect substitutability between workers of different ages. Combined with an ageing labor force, the assumption of decreasing productivity by age will lead to lower output per worker compared to a scenario with age-independent productivity.[9] Secondly, given a CES production function with an elasticity of substitution of 0.5 , the difference between the most optimistic (constant age-productivity profile) and most pessimistic (monotonically decreasing productivity) scenario is pretty constant over time at about 10% . Thirdly, the results are more sensitive to variations in age-specific productivity compared to alternative variants of the population projections.

[9] For the additive production function and assuming age-varying productivity, the optimal age structure, i.e., the age distribution that optimises output, is achieved if all workers are in the age group with the highest productivity. However, the concentration of the population distribution towards these ages (age 35–39 in case of the hump-shaped productivity profile and age 15–19 in case of the decreasing age productivity profile) declines over the next few decades.

Chart 9: Age Productivity Schedules

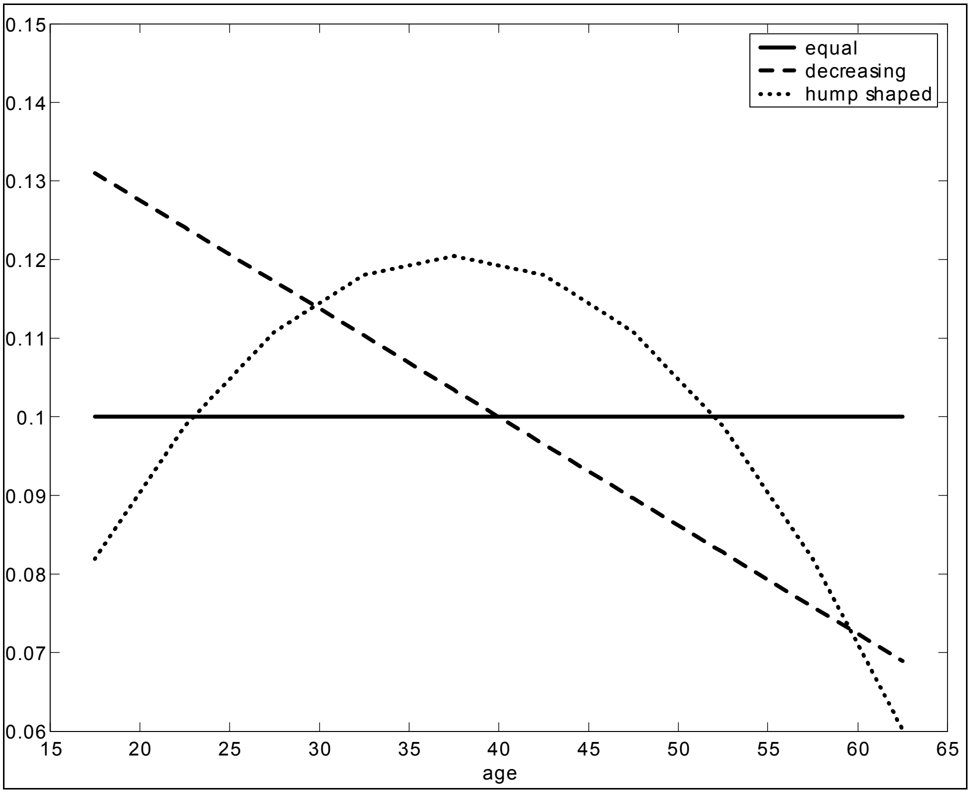
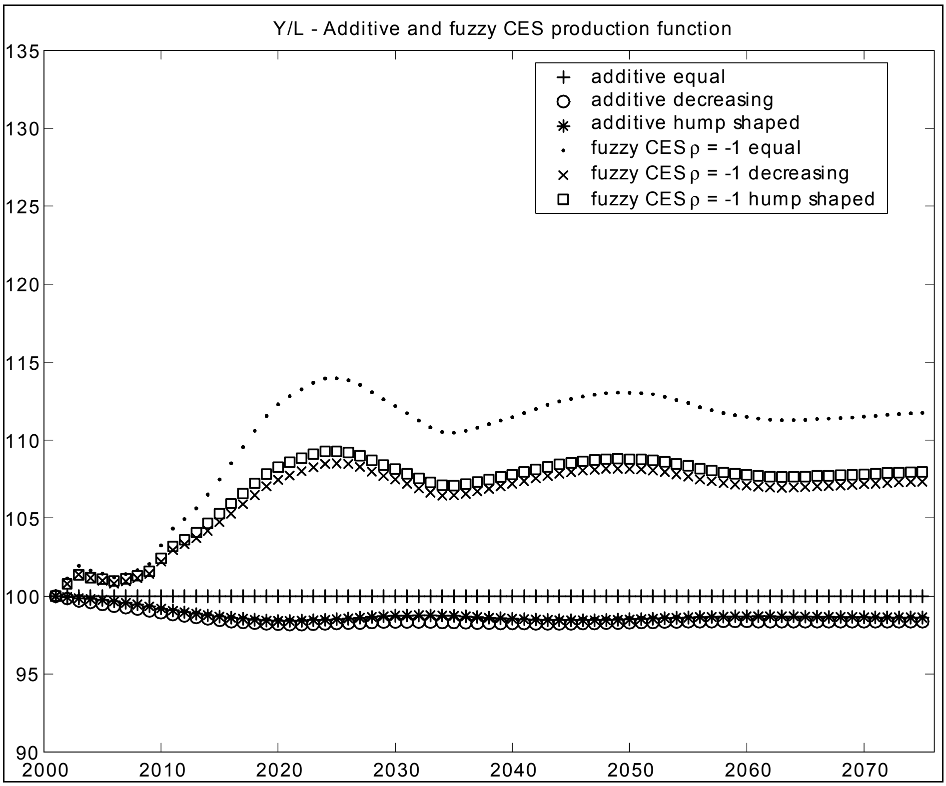
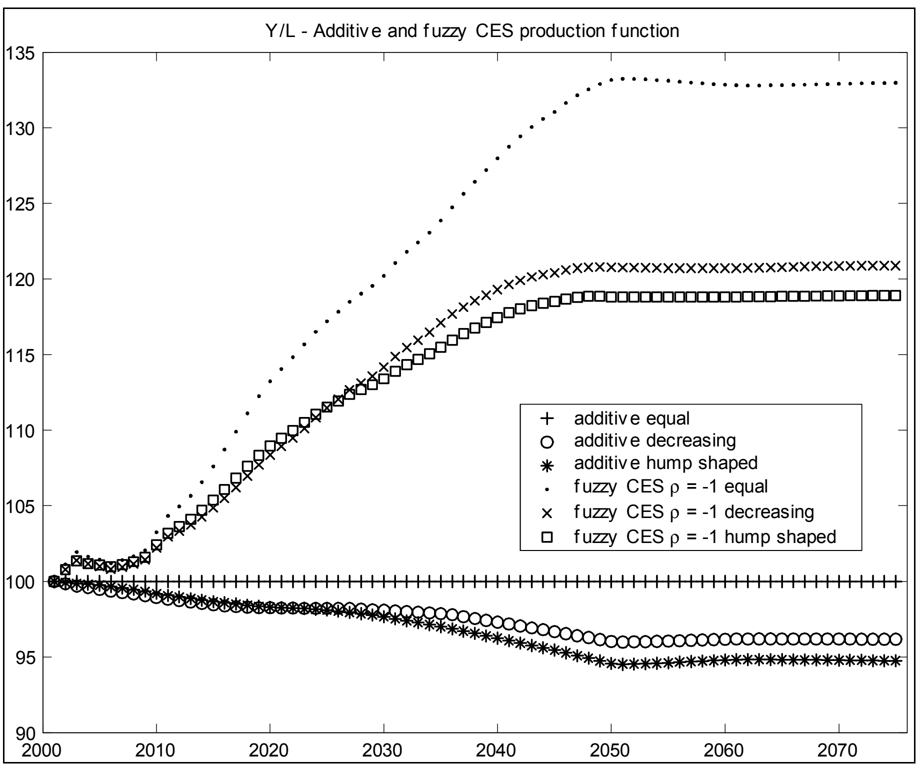


Chart 10: Projected Relative Output per Worker for Alternative Productivity Schedules by Age and Various Labor Demand Functions, Main Variant and Constant Labor Participation Scenario



To prevent labor productivity from falling when the shrinkage of the working age population sets in around 2020, we apply the labor force scenario introduced in section 4.2 assuming the main variant of the population projections. Similar to chart 10 we assume an additive or fuzzy CES labor demand function with $\rho = -1$ As illustrated in chart 11, if labor force participation rates are adjusted to approach the values observed in northern European countries, economic productivity can be sustained at its high level even after 2020 in case of the fuzzy CES type labor demand function. By increasing labor force participation rates at lower and older ages (cf. chart 3) we reduce the dissimilarity between the projected age distribution and the uniform age distribution, thereby increasing the level of output per worker in case of equal age-specific productivity levels (compare chart 14, Appendix C). Though a uniform age distribution does no longer constitute the maximizing age distribution if we allow for the hump-shaped or declining age productivity profiles (cf. Appendix B), the increase in the labor force participation rate at higher and lower ages reduces the dissimilarity between the projected and optimal age distribution in those latter two cases as well. The increase in economic productivity amounts to more than 30 per cent in case of the fuzzy CES production function with age-independent productivity levels, while the increase in the labor force participation rates does not change the negative impact of workforce ageing for the declining and hump-shaped age productivity profile in case of the additive production function.

Chart 11: Projected Relative Output per Worker for Alternative Productivity Schedules by Age and Various Labor Demand Functions, Main Variant and Modified Labor Force Participation Rate



6. Conclusion

The computational findings presented in this paper are based on the population projections released by Statistics Austria and on the labor force participation rates provided by the OECD labor market statistics. We combine three different variants of the population projections (main variant, high fertility/high migration, and low fertility/low migration), two different scenarios with respect to the labor force participation rates (retaining the participation rates of 2001 vs. smoothly converging to the maximum participation rates of the northern European countries), production functions with different elasticities of substitution among age-groups within the workforce, and three different age-productivity profiles. The international comparison reveals that at present, exploitation of the potential labor force is rather low in Austria. This high potential of workers offers an opportunity to compensate for the expected shrinkage of the labor force due to population ageing.[10] Nevertheless, an increased exploitation of the available labor force also intensifies ageing of the labor force. Whether this is advantageous in terms of output per worker depends on the underlying age-productivity profile and on the substitutability of workers of different age. However, investment in education of older workers may help to soften the negative impact of population ageing on labor productivity.

Our simulation results indicate that the degree of substitutability between workers at different ages markedly determines the projected relative productivity. In particular we show that in a pure labor economy, the assumption of imperfect substitution of workers at different ages implies an increase in relative economic productivity during the next two decades compared to a constant or declining economic productivity that results in case of the commonly applied additive labor demand function found in the literature. Given those results, it is surprising that most studies on the economics of ageing assume perfect substitutability of workers at different ages without discussing alternative labor demand functions. We may even conclude that given imperfect substitutability of workers at different ages the next two decades will offer both opportunity and challenge in terms of economic productivity. Of course, future work needs to verify the robustness of those results with respect to the inclusion of non-labor factors in the production function. Most importantly, future work needs to put more focus on estimating the elasticity of substitution between workers at different ages and possibly on how it may change over time as technological progress advances.

[10] As noted in Johnson (2002a), those behavioral factors, and in particular the rise in female employment, have dominated the purely demographic influence on the size of the workforce in post-war Europe as well.

A The Effect of Labor Force Ageing on Economic Productivity in a Stable Population

The average value of an age-specific variable $x(a)$ over ages a_1 to a_2 in a stable population that grows at rate n and has a survivorship function $s(a)$ can be written as:

$$\bar{x} = \frac{\int_{a_1}^{a_2} x(a)s(a)e^{-na}da}{\int_{a_1}^{a_2} s(a)e^{-na}da} \tag{7}$$

The logarithmic derivative of $\bar{x}$ is then equal to

$$dlog\bar{x} = \frac{d\bar{x}}{\bar{x}} = (-A_x + A)dn \tag{8}$$

where A is the mean age of the population and A_x is the mean age associated with the characteristic $x(a)$. If one limits the labor force participation to ages $[\alpha, \beta]$ it follows that $A - A_x$ is bounded in absolute values by $(\beta - \alpha)/2$, i.e., about 20 to 25 ages. Hence, a change of the population growth rate by 1 percentage point cannot have an aggregate impact of more than $20 - 25\%$.

B Output Maximization with CES Technology

Lam (1989, section 3) considers a CES production function $Y = [\alpha L_1^{\rho} + (1 - \alpha)L_2^{\rho}]^{1/\rho}$ which can be rewritten as $Y = L[\alpha\pi^{\rho} + (1 - \alpha)(1 - \pi)^{\rho}]^{1/\rho}$ with π denoting the proportion of the labor force in the young age group. It can be shown that for given values of ρ and α there exists a unique value of the share of the labor force in the young age group π that maximizes the value of total output, i.e., which equates the marginal products of the two ages of workers. More specifically, output per period attains a maximum when

$$\frac{\pi}{1-\pi} = \left[\frac{\alpha}{1-\alpha}\right]^{\sigma} \tag{9}$$

with $\sigma = 1/(1-\rho)$ denoting the elasticity of substitution between the young and old labor force age groups. From (9) it follows that if the two types of workers have equal productivity ($\alpha = 0.5$) output will be maximized when $\pi = 0.5$, i.e., when the age distribution of the labor force is uniform. If $\alpha \neq 0.5$, however, the elasticity of substitution will determine the division of labor that maximizes output. For instance, if $\alpha < 0.5$ the optimal value of π will be less than 0.5 since a greater proportion of older workers will be required to equate the marginal products of the two age groups. As the degree of substitutability increases, a higher ratio of older workers to younger workers is required to equilibrate their marginal products and the output maximizing value of π will decrease.

The above considerations can be applied to the labor demand function as given in (). Denoting by π_x and π_y the share of the labor force in age group x and y , the output maximization condition is:

$$\frac{\pi_x}{\pi_y} = \left[\frac{\alpha_x}{\alpha_y}\right]^{\sigma}. \tag{10}$$

For an age-independent productivity schedule $\alpha_x = \alpha_y$ we obtain that $\pi_x = \pi_y$ for any pair of ages x,y . In other words, a uniform age distribution within the labor force ensures maximum output per worker.

In case of age-dependent productivity - for instance decreasing or hump-shaped the optimal age distribution of the workforce will differ from the uniform age distribution. Formula (10) indicates that an optimal age-structure requires a higher share of those age-groups with higher productivity and a lower share of those with lower productivity. Thus the profile of the optimal age-structure looks similar to the chosen productivity profile (see charts 12 and 13). Moreover, the optimal age structure also depends on the elasticity of substitution. In both figures the curves representing a high elasticity are steeper than those for low elasticity. Therefore, in the latter case the share of workers with an average low age-specific productivity is relatively high because it is difficult to substitute them with workers from other age groups.

Chart 12: Optimal Age Structure – Decreasing Productivity

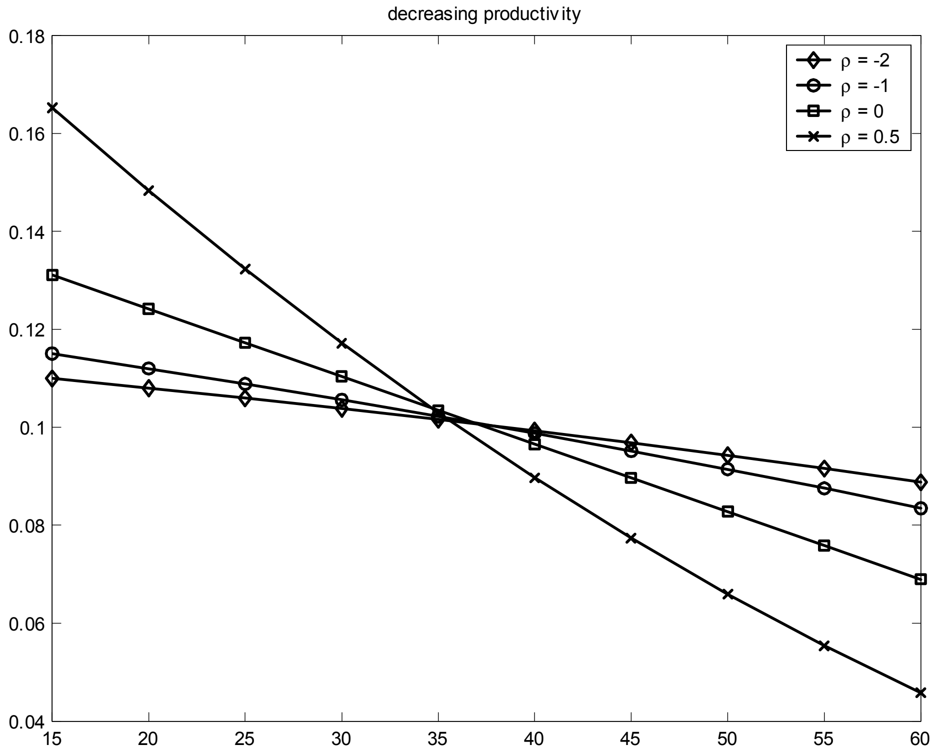
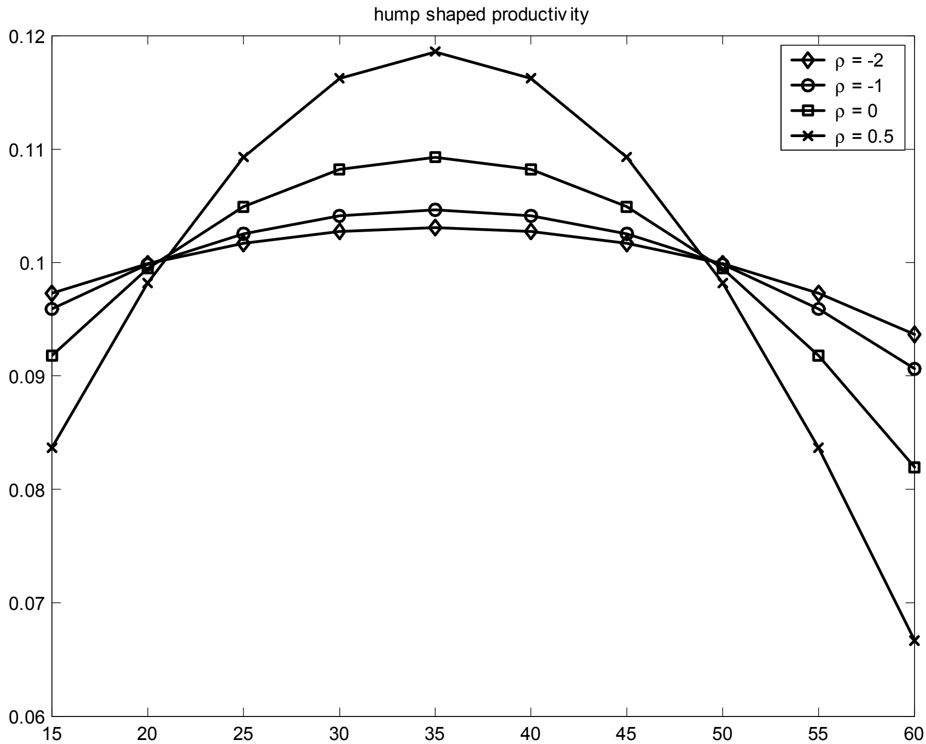


Chart 13: Optimal Age Structure – Hump Shaped Productivity



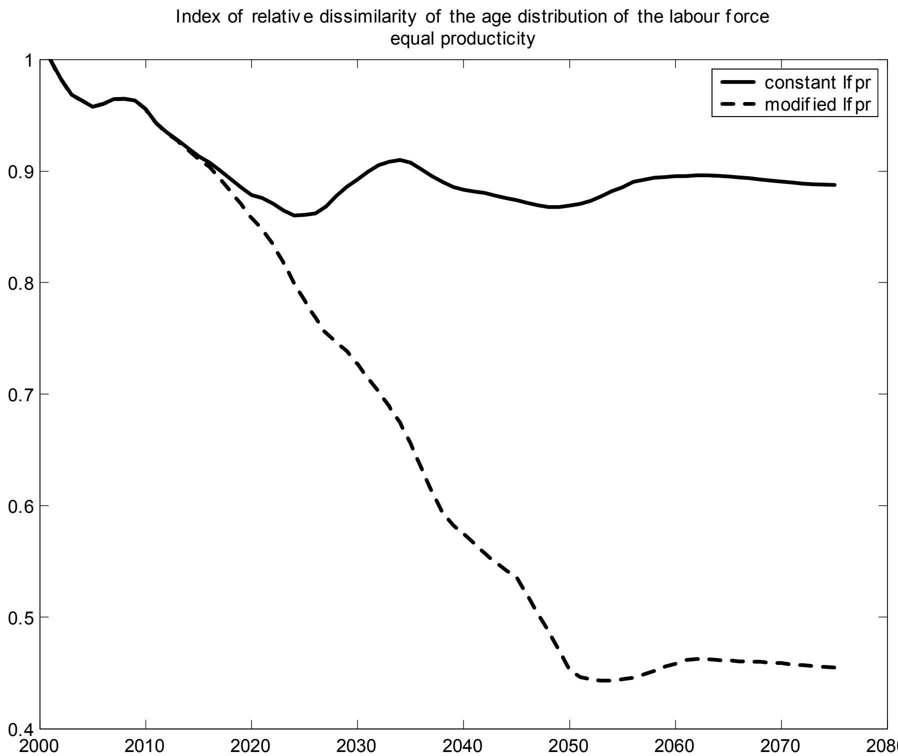
C Index of Dissimilarity of the Age Distribution of the Labor Force

As a measure of the dissimilarity between the uniform and the projected age distribution we calculate the index

$$0.5 \sum_x |\tilde{\pi}_x - \pi_x| \tag{11}$$

where $\tilde{\pi}_x$ denotes the actually observed share and π_x the optimal share of the five-year age groups of the labor force. The index of dissimilarity will result in a measure between 0 and 1, being closer to 1 the more dissimilar the projected age distribution is from the optimal age distribution. In the following we will use the relative dissimilarity which means that we multiply all dissimilarity values with a constant multiplier such that the index in year 2001 is always equal to 1. As shown in figure~ for an equal age-specific productivity, assuming constant labor force participation rates, the age distribution is more dissimilar to the uniform age distribution during the first decade of the 21st century whereafter the dissimilarity decreases and reaches its minimum value around 2025 which also corresponds to the peak in output per worker in figure~. If the labor force participation rates are increased to maintain the size of the labor force, the index of dissimilarity decreases even further until around 2055. Again, this perfectly corresponds to the increase in output per worker illustrated in chart 11.

Chart 14: Projected Index of Dissimiliarity between the Projected and Uniform Age Distribution of the Labor Force, Mean Variant



References

Arnds, P. and Bonin, H. (2002). Arbeitsmarkteffekte und finanzpolitische Folgen der demographischen Alterung in Deutschland. IZA Discussion Paper No. 667.

Auer, P. and Fortuny, M. (2002). Ageing of the Labour Force in OECD Countries:

Economic and Social Consequences. Employment Paper 2002/2, International Labour Office Geneva.

Beaudry, P. and Collard, F. (2003). Recent technological and economic change among industrialized countries: insights from population growth. *Scandinavian Journal of Economics*, 105(3):441–463.

Blanchet, D. (1992). Does an ageing labour force call for large adjustments in training or wage policies? In Johnson, P. and Zimmermann, K., editors, *Labor markets in an ageing Europe*. CEPR, Cambridge University Press.

Blanchet, D. (2002). Le vieillissement de la population active: ampleur et incidence. *Economie et Statistique*, 355–356:123–138.

Borsch-Supan, A. (2002). Labor market effects of population ageing. Discussion Paper 11-2002, Mannheim Institute of the Economics of Ageing.

Cutler, D., Poterba, J., Sheiner, L., and Summers, L. (1990). An ageing society: Opportunity or challenge? *Brookings Papers on Economic Activity*, 1990(1):1–56.

Dalgaard, C.-J. and Kreiner, C. (2001). Is declining productivity inevitable? *Journal of Economic Growth*, 2001(6):187–203.

Disney, R. (1996). Productivity, wages, and educational attainment: The impact of workforce ageing. In Disney, R., editor, *Can We Afford to Grow Older?*, pages 153–192, Cambridge. MIT Press.

Feyrer, J. D. (2002). Demographics and productivity. Mimeo, Dartmouth College.

Hall, R. and Jones, C. I. (1999). Why do some countries produce so much more output per worker than others? *Quarterly Journal of Economics*, 114:83–116.

Hamermesh, D. S. (1993). *Labor Demand*. Princeton University Press, Princeton.

Hamermesh, D. S. (2001). Older workers in the coming labor ”shortage:” implications of labor demand. preapred for the roundtable on the demand for older workers, The Brookings Institution, March 23 2001.

Hanika, A. (2004). Zukünftige Bevölkerungsentwicklung Osterreichs bis 2050 (2075). Statistische Nachrichten 1/2004.

Higgins, M. and Williamson, J. G. (1997). Age structure dynamics in Asia and dependence on foreign capital. *Population and Development Review*, 23:261–293.

Hofmann, A., Biehl, K., Fent, T., and Schimany, P. (2003). Working-Paper Demographie. Beirat fr Wirtschafts-und Sozialfragen.

Johnson, P. (2002a). Global Ageing: Historical Legacies and Economic Challenges. paper presented at the XIII Economic History Congress, Buenos Aires 2002.

Johnson, P. (2002b). The impact of ageing: the supply of labour and human capital. In H.Siebert, editor, *Economic Policy for Ageing Societies*, pages 111–130, Berlin. Springer.

Kögel, T. (2004). Youth dependency and total factor productivity. *Journal of Development Economics*, forthcoming.

Kotlikoff, L. J. and Wise, D. A. (1989). Employee retirement and a firm's pension plan. In Wise, D. A., editor, *The Economics of Ageing*, pages 16–60, Chicago. The University of Chicago Press.

Laezar, E. P. (1990). Adjusting to an ageing labor force. In Wise, D. A., editor, *Issues in the Economics of Ageing*, pages 287–316. The University of Chicago Press.

Lam, D. (1989). Population growth, age structure, and age-specific productivity: Does a uniform age distribution minimize lifetime wages? *Journal of Population Economics*, 2:189–210.

Lindh, T. and Malmberg, B. (1999). Age structure effects and growth in the OECD, 1950-90. *Journal of Population Economics*, 12:431–449.

Malmberg, B. (1994). Age structure effects on economic growth - Swedish evidence. *Scandinavian Economic History Review*, 42:279–295.

OECD (1998). Work force ageing: consequences and policy responses. Working paper AWP 4.1.

Prescott, E. (1998). Needed: A theory of total factor productivity. *International Economic Review*, 39:525–552.

Skirbekk, V. (2004). Age and individual productivity: A literature survey. *Vienna Yearbook of Population Research*, forthcoming.

Comment on: Prskawetz and Fent, "Workforce Ageing and Economic Productivity: the Role of Supply and Demand of Labor"

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1. It would have been useful to have had this paper several years ago when I prepared a review of economic impacts of population ageing. In prefacing these remarks,
a. I will discuss population ageing as a generic phenomenon, abstracting from the specific trends in Austria and
b. I will ignore my own advice and use the phrase "population ageing" sloppily to refer both to change in age structure and deceleration in aggregate rate of growth.

2. Throughout this paper, the authors abstract from capital. We are, in this paper, miles away from the neoclassical vision of an ageing society in which declining labor force causes the capital-output ratio to rise, corresponding to the declining productivity of capital (not enough workers to man the machines, i.e. the opposite to the situation that development economists worry about). The wage rate rises along with the marginal product of very scarce labor. The rate of return to capital declines as machines go looking for people to run them, in turn discouraging saving and encouraging net capital outflows, all of which combine to limit the rise in the capital-output ratio. It all sounds rather pleasant for us wage slaves: the only drawbacks of the ageing society, it would seem, are (i) the need to import foreign labor for those jobs, many of them unattractive, which cannot be compressed and (ii) the need constantly to remind the young that despite skyrocketing social contribution rates, their net wages are in fact rising.

3. To begin their argument, the authors assume first that individual worker productivity is equal at all ages. If the production function is additive, then average output per worker is a weighted average of (equal) age-specific productivity coefficients, so clearly age structure changes have no impact on average output per worker. What is less obvious (I confess that it had never occurred to me) is that even with a simple Cobb-Douglas production function, average output per worker

will be sensitive to changes in age structure. To see why, consider that output will be maximized when the marginal product of young workers is equal to marginal product of old workers, which would imply that the absolute number of workers in the two age groups is equal.

4. Starting with 2000:100, the authors calculate that in 2030, the average product of labor assuming a Cobb-Douglas production function might be 105; with a CES production function and an elasticity of substitution of –0,5 between workers of various ages, it would be closer to 115. This is because, disregarding a blip in the first decade, the index of dissimilarity of the labor force age distribution steadily declines until 2030. Parenthetically, this means that countries like Austria where workers are slow to enter the labor force and quick to leave it, are at a disadvantage.

5. The policy makers' nightmare, however, is not that an ageing labor force will give rise to a rising index of dissimilarity; it is that older workers may be less productive than young ones, thus damaging the competitiveness of their economies. Now, this immediately raises problems because it is firms, not countries, which compete, but let us leave that aside.

Age-profile of Productivity

6. Using reasonable individual age-productivity profiles, the authors find that, given a CES production function with an elasticity of substitution of -0,5 the difference between the most optimistic (constant age-productivity profile) and most pessimistic (monotonically decreasing productivity) scenarios is pretty constant over time at about 10%. In other words, once you are ten or fifteen years out, assuming individual productivity declines monotonically age with results in average labor productivity 10% lower than assuming that it is constant with age. The more likely assumption that individual productivity is hump-shaped, peaking at about 40, lies almost exactly in the middle, i.e. between the pessimistic assumption of a monotonic decrease and the optimistic one of a constant age-productivity profile.

7. A simple way of approaching the problem is to assume that old workers are just like young ones except they have to rest more. In a Cobb-Douglas economy, output would then be $Q = A\, K^{\alpha}\, (\beta L)^{1-\alpha}$ and the elasticity of output per worker Q/L with respect to β would be (1- α), just like its elasticity with respect to labor. Say that this is 0,67. Now, the mean age of the Austrian labor force, according to the most pessimistic projection given, will increase by 10 years between 2000 and

2050 and may increase far less. It is hard to imagine this change increasing the average "rest factor" by more than a quarter. So very roughly speaking, we might expect to see the average product of labor decline by perhaps 17%. Looked at differently and keeping in mind the 50-year time horizon, an increase in total productivity growth of 0.3 percentage points per year would be required to address this epidemic of idleness.

8. In the UK, about one-third of the adult population is now over 50; in 2020, about half will be. Say that the same applies to the labor force. Assume that productivity is flat until 50 and then falls to zero … in other words, workers under 50 shovel and workers over 50 simply lean on their shovels. (I should add that there is also the Sala-I-Martin thesis that older workers actually REDUCE the productivity of young ones!) Then the projected age structure change would reduce the average product of labor by precisely 25%.

9. These extreme and simplistic examples help to explain the gist of the results presented here: that age patterns of productivity, combined with the evolving age structure of the labor force, do not have much impact on average output per worker. And the most important variable appears to be the elasticity of substitution between workers of different ages.

10. To be added to this is uncertainty over whether individual productivity really does decline with age, a subject on which Vegard Skirbeck is an expert. As I read his synthesis, there is a fair bit of evidence that it does, but the case is not overwhelming.

Substitutability of Older and Younger Workers

11. The situation is likely to differ by sector. There are jobs for which physical strength or stamina are important; construction, for example. It seems clear that older workers will be at a disadvantage here. Note that in others, the balancing factor in the equation may not be productivity, but physical wear and tear … the elderly bus driver drives just as many passenger kilometers, but suffers more for it. In the former case, younger and older workers will be very poor substitutes and we can expect average output per worker to decline with aging. In the latter case, average worker productivity will not decline with ageing, just the satisfaction of the average worker. In neither case will worker training be of the slightest use. Note that I make the very restrictive assumption that there is no inter-sectoral mobility. In fact, the question of how many older workers will willingly take a step

down – IT workers becoming bartenders, for example – is an interesting one.

12. At the other end of the spectrum are jobs were physical strength or stamina are irrelevant but mental acuity and being up on the latest techniques are crucial – "knowledge jobs." Here, just as in the case of construction workers, older workers will be poor substitutes for younger ones because their skills will be out of date. But,

a. Subject to some limitations, training can address the problem.

b. Firm-specific knowledge, "networks," etc. are likely to be very important assets.

c. Sorting of workers into the functions they perform best is likely to occur very effectively.

For all three reasons, I conclude that ageing is unlikely to be a problem in "knowledge sectors." This is particularly true since there is an infinitely elastic supply of Third World workers to the "knowledge sectors," and with outsourcing – a much more revolutionary phenomenon than I think it is usually given credit for being – you do not even have to let them in the country.

13. Somewhere in between lies the great bulk of jobs, where stamina, mental faculties, acuity, networks, etc. are all somewhat important but not decisive.

Labor Market Rigidities

14. Whatever the age-profile of productivity, it would seem assured that countries with flexible labor markets are better adapted to respond to ageing. Those with seniority-based wage systems will find themselves in trouble, and it is a great irony that (in my casual observation) the more rigid the labor market, the louder the cries for "active ageing." I am, in fact, a critic of active ageing: Who WANTS old people in the labor force?

a. Not the old themselves, who show a marked inclination to retire as fast as they can unless they are in jobs with amenity value,

b. Not labor unions, whose membership is older than the labor force itself,

c. Not young workers, who see their chances for advancement choked off and who reply to surveys that they themselves hope to retire young,

d. Not governments, who operate under the "lump of labor" fallacy.

15. Issues that need attention:

a. *Baumol's "cost disease."* Will ageing lead to concentration of labor in relatively low-productivity sectors (low-end personal services, health care, etc.).

This is related to immigration and distribution.
b. *Impact of ageing on human capital formation decisions*. Do young workers, facing spiraling real wages, forgo human capital formation?
c. *Impact of ageing on technical progress / TFP and labor productivity*. Was Habbakuk right that necessity is the mother of invention (as Cutler et al.'s famous regression appears to indicate)? Or was Julian Simon right – vitality and so on will be lacking in a stagnant population?
d. *How does ageing bias technical progress?* Or will technical progress be absorbed into the health sector?
e. *Will labor scarcity and resistance to immigration draw less productive workers into the labor force?* This may be the dark, Ricardian side of policies to stir up potential workers.

These are just speculations. In closing, do not interpret what I said at the beginning, about ignoring capital, as a criticism; I think you have done quite the right thing to start off looking at a pure labor economy.

Is Human Capital the Solution to the Ageing and Growth Dilemma?[1]

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1. Introduction

When the population of industrialized countries is greying and the retired share of the population increases economic growth will most likely be retarded. The fiscal problem of providing for the elderly with a diminishing tax base may therefore be exacerbated by a decreasing growth potential. This paper discusses the potential to remedy this by increasing the level of human capital in these economies. The conclusion is that growth levels can probably be preserved by a broad approach consisting not only of increased education but also intensified and lengthened utilisation of available human capital combined with labor imports and increased fertility. Nevertheless the basic redistribution problem remains to be dealt with and cannot automatically be solved through growth promoting policies nor by pension reforms.

2. Ageing, Redistribution and Growth

There are obvious reasons why an ageing population should put downward pressure on economic growth rates. First, the increasing share of elderly will be expected to decrease the relative labor supply. Second, an increasing share of elderly will put pressure on budget deficits and should according to the life cycle hypothesis depress private savings in the economy. Thus, a downward pressure on

[1]This paper has been prepared for the "Workshop on Current Issues of Economic Growth", Vienna, arranged by the Oesterreichische Nationalbank - Central Bank of Austria, March 5, 2004.

the supply of both labor and capital could result in negative growth effects. But there are also more subtle ways in which an ageing population can depress growth. On the demand side an ageing population will tend to shift demand towards services rather than goods and in most countries this also entails a shift toward more public services. There are well known reasons (Baumol's disease) why a more service oriented economy may have a slower productivity growth. Public services as well as many transfers to the elderly are generally tax financed and thus the excess burden of tax wedges may increase. A shift towards more labor intensive services coinciding with decreasing labor supply would also be expected to raise compensation for labor relative to capital. With a booming labor market for relatively simple service jobs there is a risk that the demand for education becomes weaker, and thus eventually the human capital content of labor is reduced and further aggravates the slowing growth trend. The danger of getting into a negative feedback spiral through some or all of these mechanisms is not very far-fetched.

Furthermore, there is by now plenty of empirical evidence that the productivity slowdown in the 1970s to some extent can be linked to the ageing of the population that took place in most Western countries at that time and with a considerable lag hit Japan in the 1990s.[2] Large dependency ratios correlate with low growth, but there is little consensus on how different mechanisms will interact nor indeed on the quantitative impact of potential counteracting forces like longer working life as people become more healthy at higher ages, labor scarcity is eased by immigration, capital imports by ever more globalized capital markets, etc.

The purpose of this paper is not to build an extensive model of this complicated nexus, but to discuss the quantitative scope for rational policies to counteract the negative feedback pressures that may arise in an ageing economy. The second purpose is to argue that growth is a second order problem when facing the future ageing problem. The real challenge is the redistribution pressure that rising dependency ratios necessarily imply. While growth is still important in order to ameliorate the conflicts that this pressure gives rise to, the central dilemma will still be how to maintain a socially acceptable standard of living for the elderly and still invest sufficiently in the young.

The plan of this paper is to first lay out some theoretical points that I find important to keep in mind when discussing human capital and growth. That is done in Section 2. In Section 3 some quantitative exercises illustrate the empirical order of magnitude of the ageing problem. In Section 4 the redistribution dilemma is discussed in more detail. Section 5 finally concludes and summarizes.

[2] See Lindh and Malmberg (1999), Bloom and Sachs (1998), Bloom et al. (2000) for some examples. Kelley and Schmidt (1999) provide an overview and general discussion.

3. Human Capital and Productivity Growth

First of all, let us state the obvious. Without people there is no human capital. There is no such thing as raw labor, this is only a convenient abstraction for what is considered a common basic level of human capital possessed by all (or nearly all) adults. The exact meaning of adult may, however, differ considerably between cultures, time periods and even the specific productive activity. Thus, giving birth to and raising a child to a level where it can support itself is actually an act of human capital investment. The duration and requirements of bringing up and educating a child to a self-supporting individual are strongly dependent on the social context as well as the technology of production. Some of these costs are borne by the parents (maybe with some consumption motive being an important offset but also as a major part of the intergenerational transfer system), much of it by household production outside the market economy. In modern societies we generally find that a substantial part of the young child's education is financed and in general also provided by the public sector. By taxation of income this later yields a return that is sufficient to keep financing the system. If that was the complete story there is really no reason why the education of children could not be financed through ordinary credit markets. There would be no need for the public sector to intervene in this relation and some tax wedge inefficiencies could be avoided. Yet, almost universally we observe public provision of at least primary education, often also the secondary and in quite a lot of cases even important parts of the tertiary education.

Some kind of externality or market imperfection in the provision of education is therefore a natural hypothesis.[3] One such imperfection could be credit constraints, which have received a major part of the attention in the literature trying to explain how less inequality could be associated with higher growth (Aghion et al.1999). Indeed it is quite difficult to approach your local bank manager with a proposition for a loan to finance education putting up the child´s future income as collateral. Thus, a major part of the population would be excluded from education if parents had to pay the costs up front. But there have also been other suggestions of schooling externalities, such as the fostering of discipline, culture and generally civilized behavior, creating an environment where productivity may grow faster through a variety of potential mechanisms such as higher investment in both capital and human capital because of generally smaller risks, or by the cumulative effects of increasing knowledge production and technological change, or by creating virtuous circles where better health, political stability and so on permit individuals to realize their full economic potential. As some authors have suggested (Galor and

[3]It is conceivable though that social altruism actually extends beyond the parental altruism by protecting children's interest when they come into conflict with parental self-interest. Market failures is thus no *necessary* explanation for public provision of education.

Weil, 2000) a quality-quantity trade-off may become more advantageous once industrialization has started to provide economic opportunities outside the home for women. There are plenty of possibilities and a blossoming literature on how such processes could be started by the correct combination of institutions or even as an evolutionary process favoring families with stronger preferences for child quantity than child quality (Galor and Moav 2002), etc.

This is a fascinating research area in itself but it would lead too far to go into this further here.There is one aspect of the quality-quantity trade-off that is important although we still know rather little about it.

3.1 The Trade-off Between Costs for Investing in Human Capital and Social Return to those Investments

The costs for investing in human capital are shared by individuals and the public sector. The former are mainly in the form of opportunity costs either for the individual himself, abstaining from wage income during higher education, or in household production in the family for the parents while the individual goes through primary education. The latter costs are mainly teaching costs at different levels, sometimes offset to some extent by tuition fees. The private return to the individual accrues to him through wage income later in life (tied more or less tightly to pension benefits in retirement) but there is in general little or no accrual of returns to the parents, save the altruistic utility they get through the success of their children and---in some cultures---an old age insurance for those who happen to outlive their own productive capacity. The social return accrues in part through the direct channel of taxation of the higher income but in part also through positive externalities that educated people may have on their environment and the productivity of other factors of production in addition to the positive effects on their own welfare.

We can measure the income effect of education through its relative wage effect, which in turn depends on a number of other factors, like relative supply and demand for different factors of production. This observation simply means that the observed wages are related to marginal productivity and not average productivity, thus dependent on relative scarcity and comparative advantages as much as or more than its average effect on productivity growth.

To get at the latter effect we need to evaluate the effect at the macroeconomic level. There is by now a large literature following the lead of Barro and Lee (1993) in trying to estimate these effects on cross-country or country panel data. Although results are often ambiguous and there are quite a lot of dissenting voices a rather fair assessment of the literature is (Krueger and Lindahl, 2001) that increasing the average years of schooling in the population will give positive effects on growth as big as private returns or larger but with a non-linear effect with a maximum around

8 years of schooling. The size of these effects and whether the returns actually cover the costs is still an unresolved issue since it is far from clear to what extent the coefficients catch a correlation due to reverse causation. Bils and Klenow (2000) concludes from a simulation experiment that only about a third of the effect is causal from schooling to growth the rest is causal from growth to schooling. Most of the correlation is due to being able to afford more schooling rather than to its enhancing effect on growth.

Anyway, there is not much hard evidence that tertiary education in developed countries has any major positive causal effects on general productivity growth. That is not particularly surprising since a simple thought experiment immediately tells us that there must be decreasing returns in the length of education for an individual. Suppose somebody increases years of education up to the end of life. Obviously the cost of this is not offset by any income and thus the pecuniary return must necessarily be negative.[4]

From this we cannot draw the conclusion that education is no longer profitable in developed countries. But it seems to me that more sophisticated empirical approaches are needed in order to actually quantify the effects.[5] This is not the place to deepen that discussion, however, and I only use the state of research as a motive to attack the question in the title of this paper from another angle than direct measurement.

4. The Quantitative Impact of Human Capital on Growth

Instead of trying to answer the question how much impact years of education actually have, I approach the question what impact we would need in order to make the transition to the grey economy more painless. Thus I will treat a hypothetical question under a number of simplifying assumptions as a vehicle towards a better understanding of the possibilities inherent in a human capital approach to ageing problems.

It is instructive to start the investigation by looking at how the ratio of elderly 65+ to the working age population set to 20-64 is forecasted by the UN medium variant to develop up till 2050. I have chosen eight, as I believe, representative European countries in order not to clutter the graphs too much. Apart from Japan the rest of the developed world have less serious ageing problems than the worst European countries. The selection here therefore gives a fairly representative

[4]Two different qualifications should be noted. One is that human capital is also accumulated by learning-by-doing, a mechanism which may be self-financing. The other is that for some individuals a life of education may be welfare enhancing although it can never be so for all individuals.

[5]Better measurement is an important first step, as shown by de la Fuente (2004).

picture of the spread in forecasted elderly dependency ratios for the developed countries in the next 50 years.

The general trend in chart 2 is crystal clear, there will be fewer working age people available to support each elderly person. However, the magnitude of the problem is vastly different between the European nations I have chosen to illustrate this. While Ireland will do comparatively well, only doubling its dependency ratio between 1950 and 2050 Spain is projected to quadruple it. Expressed in another way there were five or more potential workers to support each elderly person in all these countries in the beginning of the 1950s, the number now lies between 3.3 and 5 potential workers per elderly person, and is expected to go down to 5 workers for two elderly (Ireland) or even down to 5 workers for 4 elderly (Spain). Also note that only a small part of this rise is behind us, most of it still lies ahead. Although this way to illustrate is crude, taking no account of actual participation rates, it gives the general flavor of the problem. Of course, not everybody between 20-64 can be expected to work, and there are a few people outside these age brackets that actually do work. Furthermore, the flattening out of the curves towards 2050 are based on UN assumptions that fertility will eventually rebound from its current low levels in these countries[6].

[6]These are the UN (2000) assumptions for the medium variant: Fertility in low-fertility countries is generally assumed to remain below replacement level during most of the projection period, reaching by 2045-2050 the fertility of the cohort of women born in the early 1960s or, if that information is lacking, reaching 1.7 children per woman if current fertility is below 1.5 children per woman or 1.9 children per woman if current fertility is equal to or higher than 1.5 children per woman.

Chart 1: The Elderly Dependency Ratios (the Population Aged 65+ Divided by the Population Aged between 20-64) as Estimated and Projected by the UN Population Division

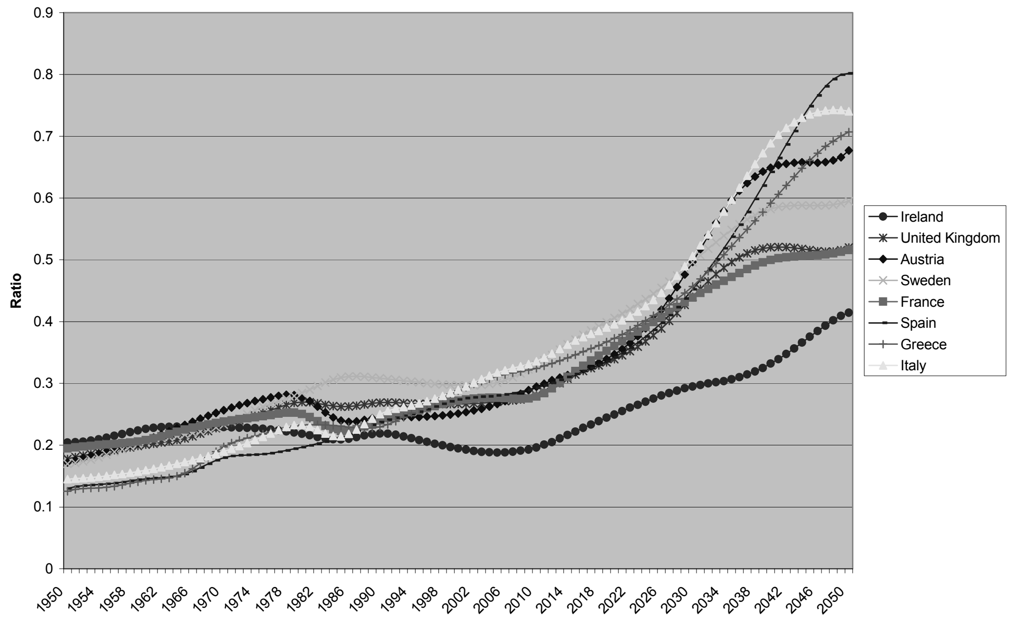
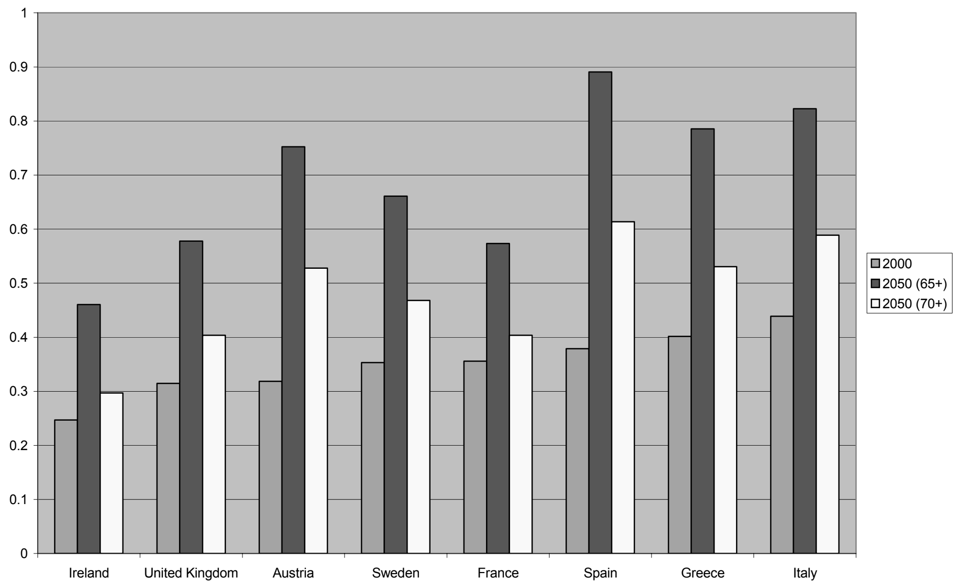


Table 1: Labor Force Active Percentages in Different Age Brackets

Activity rates	Greece	Spain	France	Ireland	Italy	Austria	Sweden	UK
15 to 24 years	38.1	42.9	35.6	51.1	38.1	56.1	40.7	63.6
25 to 34 years	82.9	83.1	87.1	85.7	75.4	86.2	83.3	84.8
35 to 44 years	80.2	79.7	88.1	78.0	78.9	87.9	88.8	85.4
45 to 54 years	69.7	68.8	83.8	70.2	67.5	80.7	88.3	82.0
55 to 64 years	40.6	40.9	31.6	46.3	28.6	31.4	68.4	52.8
65years above	5.4	1.7	1.1	8.0	3.2	3.0	5.0	5.3

Source: Eurostat 2003.

Chart 2: The Ratio of the Population 65+ to Persons Actively Working in 2000 and the Same Ratio in 2050 Assuming 0.9 Activity Rates in Each Age Group between 20 – 64 (Darker Shade) and Extending that Activity Rate up to 69 (Lighter Shade)



Source: UN (2000) and Eurostat (2003).

The next question is whether we can change the message of chart 2 by increasing labor force participation. In table 1 the 2000 activity rates in different age groups for our country sample are reported. Using these rates I convert the age groups in 2000 to labor and report the elderly dependency ratio of 65+ to labor in chart 4 compared to the same ratio in 2050 assuming a violently optimistic 90 percent labor force participation in all age groups 20-64. Even under this assumption elderly dependency rates will increase sharply although less dramatically.

What if we lengthen working life with another 5 years for 90 percent of the age group up to 70? Dependency rates will still increase but more moderately.

These experiments give us an idea of the sheer size of the ageing problem. More realistic assumptions on how labor participation could possibly increase must concede that it would be hard to raise participation among the young very much without interfering with education. Nor can we expect to raise participation in the age intervals above 60 anywhere close to 90 percent, since a substantial part of the labor force is simply worn out at these ages. Thus we must conclude that even massive mobilization of people able to work will only moderate and not fundamentally change the tendency for increasing elderly dependency ratios.

Now, what about education? How much do we need to increase the *efficient* labor force in order to keep the ratio of population or part of the population to labor units constant? Efficient labor meaning that we multiply the number of persons by a productivity factor making the actual productive capacity of the active population comparable at different points in time.

Now, let us get back to the question of whether human capital accumulation can solve the problem. Suppose that the efficiency of labor increases with education and we manage to achieve a general increase in education of say five years. I will assume that this increase is implemented by letting everybody not yet in active ages have five more years of education starting in 2000 and then go into the work force under the stylized assumption that participation rates remain the same except that the 15-24 rate now holds for the age group 20-29 instead and shifts five years for all other age groups but that working age is still cut off at 65. I.e. those 65 and above that are in fact still working are ignored. After 50 years the effect of this education change has diffused throughout the whole working population. Suppose that those five years of education increases the efficiency of labor by 100 x percent. If we standardize efficiency such that the active population in 2000 has an efficiency factor of 1 in each age group $A_{2000} = E_{2000}$. We then have an efficient labor force in 2050 which is $1+x$ times the active population and we can solve for the increase in efficiency needed to keep the *efficient elderly dependency rate* constant, i.e. $A_{2000} = E_{2050}$. If A is active population and E is the efficient labor we can solve x from the equation

$$1+x = \frac{A_{2000}}{E_{2000}} \cdot \frac{E_{2050}}{A_{2050}} = \frac{A_{2000}}{A_{2050}} \qquad (1)$$

This ignores that the active population might have an increasing efficiency trend due to already implemented increases in education and thus exaggerates the efficiency increase needed. On the other hand the calculation takes into account only the opportunity cost of education and not the teaching costs, so the numbers still give an indication of how much productive efficiency would have to increase as a result from these five years of education on average over the working life. In the remaining columns we compensate in the other direction by assuming activity rates of 90 percent for everybody 20-64 and 20-69 respectively, thus ignoring that five more years of education is hardly implementable without letting a substantial part of those below 30 to be outside the labor force.

Table 2: Solutions to Equation (1) Tabulating $1+x$ *for different assumptions on Participation Rates. Ratio 1 is if Current Participation Rates Hold in 2050 only Shifted 5 Years in the Age Distribution and Worklife Cut off at 65. Ratio 2 is if Participation Rates Increase to 90 Percent in Age Groups 20-64. Ratio 3 also adds the Group 65-69 as active up to Percent*

Country	ratio 1	ratio 2	ratio 3
Ireland	1.88	1.45	0.93
United Kingdom	2.16	1.81	1.27
France	2.34	1.80	1.27
Sweden	2.50	2.08	1.47
Austria	2.96	2.36	1.66
Greece	3.43	2.47	1.66
Italy	3.80	2.58	1.85
Spain	3.83	2.80	1.93

Estimates of the return to education varies quite a bit over countries but an average of around 10 percent per year of college education probably gives a rough figure for the average private return (when taxes and subsidies have been factored in) see OECD (2002). Thus the required increase in efficiency for the upper part of the countries in table 2 column 3 makes the private return level sufficient but for the lower part the efficiency increase has to be higher even though participation rates are at unrealistic 90 percent from 20 up to 69 years. Adding some extra years of active work, increasing labor force participation and perhaps increasing worked hours would still require larger efficiency gains than the private returns, and as remarked above this is very unlikely to be the case.

Refining these calculations in various ways, factoring in technical change, increased migration etc., it seems quite possible to bring down the impact of ageing in terms of efficient labor per retiree in various ways. Combining a range of different factors we may very well be able to preserve dependency ratios of efficient labor near today's dependency ratios, although it seems very unlikely that any one factor will do the trick by itself.

From these exercises I draw the conclusion that the answer to the question whether human capital can solve the growth problem just by increasing education is no with a high likelihood, while it does seem possible that in combination with higher utilisation of the human capital and support from higher capital intensity, some labor import and technological change, growth at least can be kept up to such an extent that living standards on average continue to rise in an ageing society.

However, this dodges the real dilemma with ageing. The number crunching exercises above were designed to illustrate the magnitude of the shift in the age distribution. After all, the standard of living in the ageing countries is so high that even at current productivity levels we would be able to support the (mostly stagnant or decreasing) population at a decent level in relation to what most of the inhabitants of this planet have to settle for. The real dilemma is the distribution of total income over different groups. That is the topic of the next section.

5. Growth and Distribution

There is by now a rather general consensus that ageing is likely to dampen growth rates in the economy for several reasons. A stagnating or decreasing work force in relation to the population will for pure accounting reasons bring down the growth rate of GDP per capita. On top of this we may add an expected decrease in domestic saving, downward pressure on the budget deficit, a shift in demand towards services with lower productivity growth, increasing time spent in education and so on. The debate is not so much about the direction of the ageing effect on growth but rather its magnitude, something that often boils down to a disagreement on what the reasonable rate of growth in total factor productivity might be.

Some formal framework aids in seeing exactly how the redistribution issue works. Let Y stand for GDP, P the total population and A the active working population (or labor force in terms of heads) while D is the dependent population.

$$\widehat{\left(\frac{Y}{P}\right)} = \hat{Y} - \hat{P} = \hat{Y} - \frac{1}{1+\delta}(\hat{A} + \delta\hat{D}) \tag{2}$$

where the hat denotes the logarithmic derivative or growth rate and δ is the dependency ratio. Let g be the growth rate of GDP per capita and y average labor productivity. Then we can rewrite

$$g = \hat{y} + \frac{\delta}{1+\delta}\left(\hat{A} - \hat{D}\right) = \hat{y} - \frac{\delta}{1+\delta}\hat{\delta} \tag{3}$$

and it is clear that an increasing dependency ratio will decrease the per capita growth rate at a constant growth of labor productivity. Moreover the difference $\hat{y} - g$ increases with the level of the dependency ratio. In standard specifications of production functions with constant returns

$$y = f(k) \quad \text{and} \quad \hat{y} = \alpha\hat{k} \tag{4}$$

where k is the capital intensity and α is the capital elasticity, a common stylized value being set to 0.3 or sometimes a third. The marginal conditions for optimizing profit are

$$f'(k) = r \quad \text{and} \quad f(k) - kf'(k) = w \tag{5}$$

and $f(\cdot)$ is a decreasing function so in steady state this Solow (1956) specification requires zero growth for a given interest rate, hence a time dependence with an exogenously given rate of growth is generally added (technological change)

$$y = f(k,t) \quad \text{and} \quad \hat{y} = \gamma + \alpha\hat{k} \tag{6}$$

If the active population is stagnating or decreasing very small or no new investment is required to make the capital intensity grow. However, to maintain equilibrium interest rates will have to go down and thus, in most models investment will go down to levels consistent with domestic or international savings decisions. In traditional Cass-Koopmans models where a representative agent optimizes consumption utility over an infinite horizon these savings decisions depend on the intertemporal elasticity of substitution and the difference between the subjective discount rate for future consumption and the rate of interest. While that type of model may be perfectly relevant for the analysis of steady-state economies, they are more or less useless for the analysis when the population age structure is out of balance, which, of course, is the case in ageing economies, and will continue to be the case for the rest of this century.

Overlapping generations models are then much more relevant, although still fairly intractable out of steady state. Blomquist and Wijkander (1994) show in a simple OLG framework that we can expect no stable relation between interest rates and household savings when we allow for baby booms that destabilize the age distribution. The pulse generated by these events will create a highly variable macroeconomic environment that generally disfavor large generations (by lower wages and lower interest rates), i.e. the Easterlin hypothesis (Easterlin 1968). That conclusion is, however, subject to the caveat that intergenerational transfer systems and policy may actually reverse the relation, something which seems to have happened in Sweden for example (Dahlberg and Nahum, 2003) while the original Easterlin hypothesis seems to be valid in the United States (Macunovich, 1998).

In the general pension debate it has been very much emphasized, in line with Samuelson (1958), that funded pension systems generate capital investment, the return of which both boost growth and support the old generation. In contrast PAYG systems only yield a return equal to population growth, which is negative for many developed countries in the future. This conventional view need qualifications in several dimensions. First of all, it is the growth in the labor force that yields the return in the PAYG system, more specifically it is the growth in the efficient labor force, meaning that human capital investments will increase returns in a PAYG system. Second, in modern economies national savings are actually much more dependent on budget deficits than on household saving, something that substantially weakens the link between private savings and capital investment. Third, in an open economy there is no direct link between national savings and capital investment, even if we empirically observe a home bias in this respect (Feldstein and Horioka, 1980), thus severing the link between national saving and national growth. Fifth, more capital investment is not necessarily growth increasing in a mature economy, it might very well be sub-optimal. In the Solow type model above there is an optimal level of capital intensity in steady state, while we in some of the endogenous growth models have non-decreasing returns to capital implying that capital externalities drive growth. But even in that case it is in general not welfare enhancing to boost capital investment indefinitely. In most endogenous growth models the growth generating mechanisms are furthermore tied to more immaterial investments in knowledge and human capital.

In this context I will therefore not pursue further how capital investment will affect future standards of living for the elderly, but only conclude that the conventional view that more investment is better is not necessarily relevant. Moreover, to the extent that it is relevant it implies that decreasing savings as the boomers retire can be expected to generate even more problems with growth and redistribution. Capital assets, also in the form of pension claims, are very unevenly distributed and capital returns from domestic production has to come out of the current value added anyway, in the form of taxes, decumulation of assets or capital returns. In a closed economy that implies that for capital returns to preserve the relative standard of living for the elderly as their relative numbers grow, the labor share of production need to decrease.

5.1 The Redistributive Dilemma

Let Y_A and Y_D denote the aggregate income that is disposable for consumption and saving for respective group. Note that this is not the conventional disposable income concept, but includes the government consumption and transfers, private and public, of the active population and the dependent population respectively. Thus we have

$$Y_A + Y_D = Y \tag{7}$$

in a closed economy. Using y_A and y_D for the average level of this income we can rewrite this as

$$y_A + y_D\delta = y \tag{8}$$

and denoting the ratio of dependent average income to active average income with $\beta = y_D/y_A$ we get

$$1 + \beta\delta = \frac{y}{y_A} \quad \text{or} \quad \beta\delta = \frac{y - y_A}{y_A} \tag{9}$$

Given that we do not want to change β it follows that an increasing dependency ratio necessarily increases the relative difference between value added per active and the income actually disposed by the active population. This conclusion holds, no matter how fast growth we have since

$$\hat{\beta} + \hat{\delta} = (\hat{y} - \hat{y}_A)\frac{y}{y_A} = (\hat{y} - \hat{y}_A)(1 + \beta\delta)$$

Thus even at much higher growth rates than today we cannot keep the relative standard of living of the dependents constant without decreasing the share that the active population gets from production. In a system where we have pay-as-you-go transfers to dependents this is quite obvious, but it holds also in a funded system in a closed economy where the capital share has to increase at the expense of the labor share. Since it is considered a stylized fact that labor and capital shares should be more or less constant in the long run this may not even be possible in a free market system. Since the dependency ratio may double or even quadruple very large changes in the relative share of income that the active population commands must take place unless we are prepared to accept changes of the same magnitude in the relative living standard of the dependents. In an open economy another way is opened by investing capital abroad today and bring it home again later. I will return to that possibility in more detail below.

Obviously it will in traditional welfare states be much easier politically to increase transfers to the dependents if growth is high enough to support increasing standards of living for everybody. In more liberal economies with less public parts of intergenerational transfers the same reasoning also goes through since increasing capital shares at the expense of decreasing wages are almost certain to lead to social disturbances and labor conflicts. In more traditional economies where intergenerational transfers take place within the family these obligations are much likelier to be honored if income grows fast enough that active earners can improve their standard of living and still support their parents at a reasonable level. In view of the magnitude of the changes in dependency ratios and the likelihood that growth will actually be depressed it does seem rather unlikely that we can wholly avoid increasing conflicts of interest between the young and the elderly but the intensity of the conflict will undoubtedly depend on the rate of productivity growth.

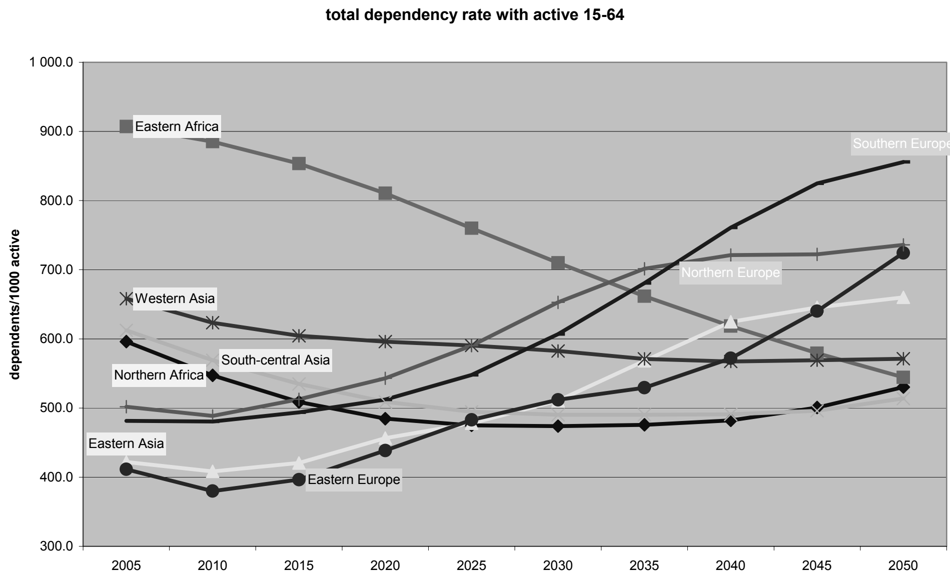
5.2 Open Economies and Financial Markets

Chart 6 shows some regional projections of dependency rates from UN (2000) medium variant using as active population the groups between 15 and 64 years old. While Europe and Eastern Asia have rising total dependency rates due to ageing and in spite of low birth rates the African and Asian regions have decreasing dependency rates due to ageing of the child cohorts and decreasing birth rates. In fact these regions are projected to hit about the same dependency rates in 2050 as we see in Europe today. Drawing on estimates of the correlation between age structure and GDP this can be predicted to generate high growth in regions with decreasing dependency ratios and low growth in the regions with rising dependency ratios (Malmberg and Lindh, 2004).

The figure immediately suggests that the dependency ratio of the world might not change that much and indeed the projection for the world dependency rate is stable between 0.5 and 0.6 which opens for the obvious idea that increased factor flows or trade between the currently developed world and the developing world have a potential for mutual advantages. In a recent article Hatton and Williamson (2003) analyze the case for African labor migration from this kind of perspective. Taylor and Williamson (1994) puts a similar perspective on 19th century capital flows to the US.

Without going into too much detailed modeling of comparative advantages and factor abundance it is rather obvious that during the baby boomer's middle age period we would expect the developed countries to exhibit a relative capital abundance making it advantageous in theory either to export capital to the developing world or exporting capital intensive goods and services in exchange for labor intensive goods or services or accepting labor migrants. What we observe is relatively small capital and labor flows, the former because of institutional instability and lack of financial markets, while the labor flows remain small because they are largely illegal. Thus the equilibration is left to trade which still is littered by trade restrictions from both sides in this exchange.

Chart 3: Regional Total Dependency Rates: the Population 0-14 years old Added to the Population 65+ and then Divided by the Population in Age Groups 15-64



Source: UN (2000).

This issue merits its own full blown study[7], so I will only note that further globalization and development of the international financial system can be a substitute for domestic investment both in capital and human capital. On the other hand to materialize this escape route may require not only investment in the capital structure of less developed economies but it may be even more important to invest in its human capital both in terms of health and education, see Bloom and Sevilla (2004).

5.3 Increasing Human Capital in the Very Long Run

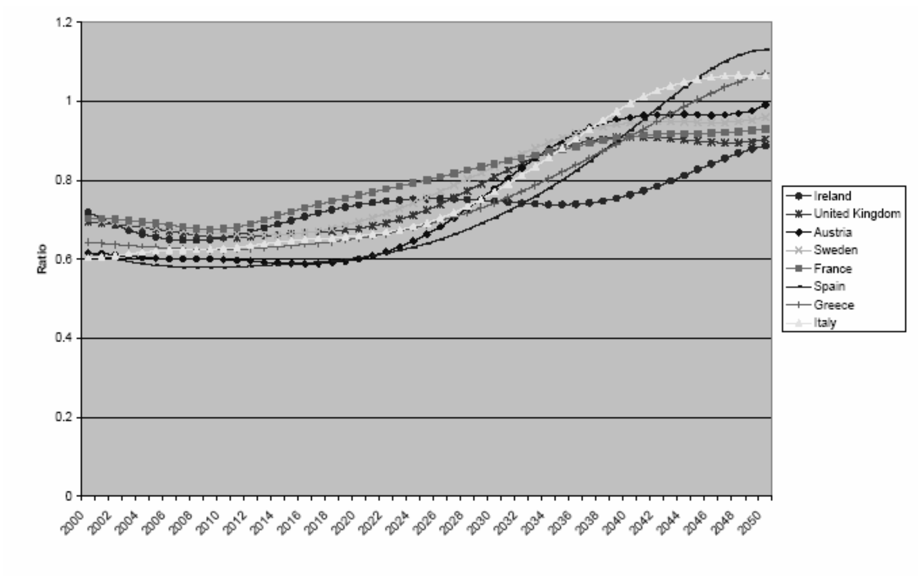
The preceding sections have discussed the scope for ameliorating the problems caused by increasing elderly dependency ratios by human capital accumulation and more intense use of the active human capital by lengthening work life and increasing participation rates. In chart 8 the total dependency rates are graphed for our selection of countries. The total dependency rates are, of course, higher than

[7] There are some studies of current account effects and age structure that are of interest in this connection, see e.g. Higgins 1998. There are also simulation exercises investigating these issues, e.g. OECD (1998) and Brooks (2003).

the elderly dependency rates, but increases less radically than the elderly dependency ratios and also appear much more homogeneous over the country sample since those countries who have the largest shares of elderly in chart 2 also are the countries with the lowest fertility and hence lowest shares of children.

So far I have avoided any explicit discussion of the other end of the dependent population distribution. The UN projections on which the calculations in Section 2 were based assumes that there will be a rebound in fertility as we get closer to 2050, but against the changes in economic life that we envisage as part of the solution to ageing this assumption seems unduly optimistic. If people on average will spend even longer time in education and have higher participation rates in the labor force and get a diminishing share in the production result the opportunity costs of having children are not likely to decrease. Even though it is often claimed that the decision to have children is mainly a question of social norms and have little to do with economic incentives I, as an economist, find it very unlikely to expect fertility to rise unless society increases the transfers and public consumption allowances for families with children. This, however, brings us into another dilemma because such a policy necessarily will have to compete politically with the transfers to the elderly which anyway have to increase, thus putting added pressure on the diminishing share of production that the active population can command.

Chart 4: Total Dependency Ratios (0-19 and 65+ Divided by Population 20-64)



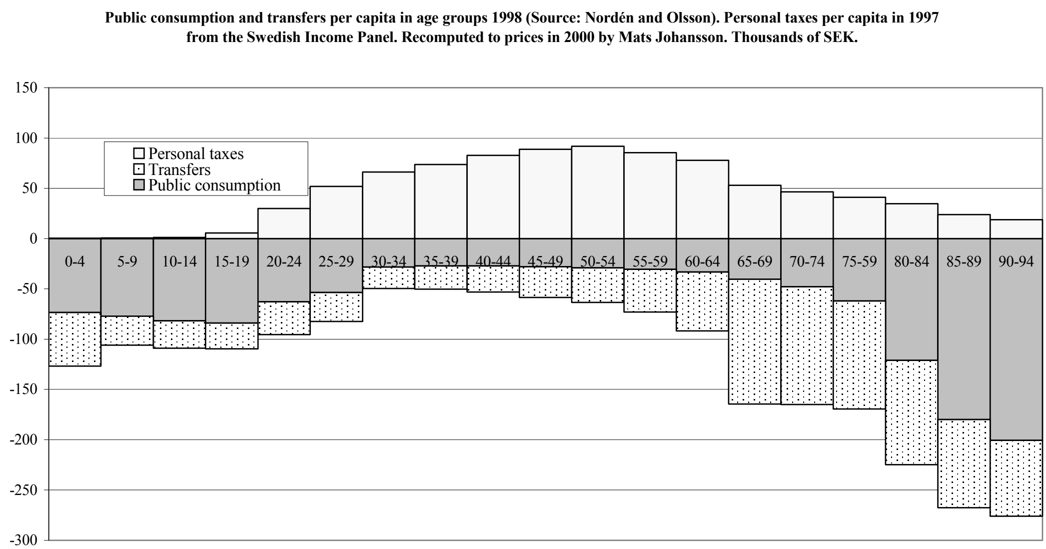
Source: UN (2000.)

In Sweden intergenerational transfers are to a large extent organized through the public sector and it is instructive to take a look at the age distribution of expenditure and revenues for the public sector in chart 10 (Lindh, 2003). With minor variations the pattern will be similar in most developed economies even if the levels of expenditure and transfers vary. The basic point is that taxes are mainly paid by the active part of the population (personal capital taxes are included here) but expenditure and transfers mainly go to the non-active part of the population. In fact we can compute that around 70-80 percent of all redistribution in Sweden consists of intergenerational transfers. In countries with smaller and less general welfare systems some of these intergenerational transfers are within the family rather than through the public sector and thus are less visible. However, the social strains may be even larger. When people live on average upwards of 80 years and have only one or two children a typical extended family in the future may consist of four living grandparents needing support from one or two households of middle aged pairs in their 50s expected to work at least another decade or two in order to save enough for their own pensions. Due to late births these families may very well have to support teenage children during education at the same time, and it may actually be fairly common to have some grand grandparent still alive.

A crucial question for the future, that I am not aware of any firm answers to, is then whether the rise in longevity actually can be balanced by a longer work life. Post-war history tells us that a considerable portion of potential growth in material well-being has been exchanged for more leisure and shorter work life. There are exceptions like Iceland but work force participation among the elderly has actually been decreasing in step with longer life expectancy. Is that only because pension systems have been designed to give incentives for early retirement? In many cases we can easily analyse existing systems to see that this is the case, but pensioners have in general had a much more advantageous real income growth than other groups. And a lot of them have chosen to retire early. We have little facts to base an assessment of whether this trend will reverse or not. Many are clearly not fit to keep working but exactly how many and to which degree their working abilities have decreased we know little about. More to the point, we really do not have any well founded idea about whether the baby boomers will turn out to be healthier and more long-lasting in work than their parents.

In Global Report on Ageing (Winter, 2004) the European Commissioner for Employment and Social Affairs, Anna Diamantopoulou use table 3 to make the point that the spread in participation rates above 55 is much too large to make it believable that it should not be possible to raise participation rates quite substantially, but whether it can reach Icelandic levels remains to be seen.

Chart 5: Age Distribution of Expenditures and Personal Tax Revenue in Sweden 1998



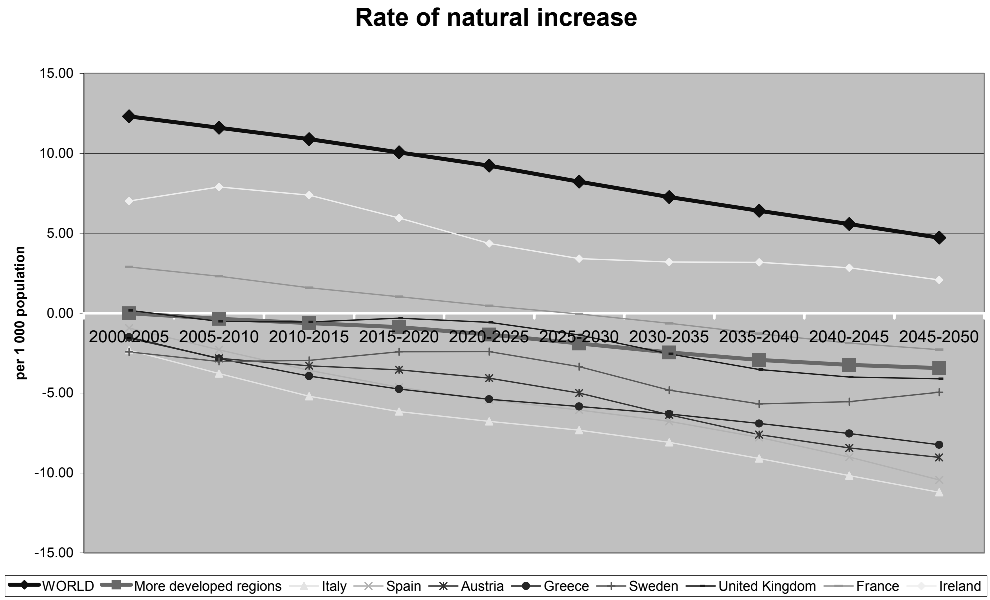
Source: Lindh (2003)

Table 3: Labor Force Participation Rates

	Aged 55-64		Aged 65+	
	1990	1999/2000	1990	1999/2000
Australia	44.1	46.9	4.9	5.7
Canada	49.3	51.2	6.8	6.0
Denmark	57.1	56.6	7.4	1.9
France	38.1	37.2	2.4	---
Germany	---	44.7	---	2.8
Iceland	82.7	87.1	30.5	21.6
Italy	35.9	28.3	3.4	3.4
Japan	64.7	66.5	24.3	22.6
Sweden	70.5	68.6	8.5	7.3
UK	53.0	52.1	5.5	5.4
U.S.	55.9	59.2	11.8	12.8

Source: International Labor Office (ILO), Key Indicators of the Labor Market, 2001-2002, (Geneva: ILO, 2002).

Chart 6: The Rate of Natural Increase in Population Projected by UN 2000, Medium Variant



In spite of the rebound in fertility that the UN projects will take place the rate of natural increase (birth rates less death rates) in the developed countries is trended downward. In chart 12 we see that most of our sample countries have an even stronger trend downwards, i.e. in spite of the projected fertility rebound the population will not be reproduced. In table 4 the total growth of population 2000-2050 is reported according to the medium and high fertility variants of the UN (2000) projections.

Table 4: Population Growth According to the UN (2000) High and Medium Fertility Scenarios

Population growth 2000-2050	Fertility		''Missing active millions''
	Medium variant	High variant	Medium variant
Ireland	39.7%	53.7%	3.206
Sweden	-12.0%	-5.2%	3.983
United Kingdom	-1.0%	7.6%	29.397
Greece	-15.4%	-9.4%	6.294
Italy	-25.3%	-19.9%	32.343
Spain	-21.6%	-16.2%	28.288
Austria	-20.1%	-14.2%	5.491
France	4.0%	13.8%	28.701

Even under high fertility scenarios most countries are projected to decrease their population. With a declining population the demographic momentum that results when smaller cohorts reach reproductive age and give birth to even smaller cohorts combined with decreasing mortality will, for fixed age boundaries of the active population, mean that the elderly dependency ratio will go on increasing in the latter half of this century as well.

Thus immigration becomes an important option to consider. The UN assumptions are very conservative: The future path of international migration is set on the basis of past international migration estimates and an assessment of the policy stance of countries with regard to future international migration flows:

"The future path of international migration is set on the basis of past international migration estimates and an assessment of the policy stance of countries with regard to future international migration flows."

Migration cannot be any stand-alone solution either to keep dependency ratios stable. The magnitude of migration that would be needed to keep dependency ratios stable only in this way is absolutely staggering---the third column in table 4 indicates the number of millions of people 20-64 which are missing in 2050 to keep the elderly dependency ratio constant, for these eight countries it sums to around 138 million. Because immigrants also grow older and tend to adapt their fertility to the standards of the recipient country the actual numbers of migrants needed are well above these numbers. In fact it can be shown that the migration flows have to be accelerating indefinitely if dependency rates are to be kept constant (Lindh 2004). But there should exist a potential to design migration policies to provide a productive basis for financing an increase in fertility that in the long run leads to a more well balanced population structure. Expressed in other words, import of human capital during an extended period of a few decades could provide the resources necessary to finance a domestic reproduction and education that in the very long run balances the population structure.

In order to do so, a number of conditions must be fulfilled. First and obviously there must be meaningful employment for the migrants. Importing human capital and support it by welfare is clearly suboptimal. Storesletten (2003) show that even at relatively low participation rates immigrants can be a fiscal bonus since the recipient country have not had to support them during childhood and adolescence.

Second and much more difficult this must be acceptable to the native population. Apart from purely xenophobic and irrational reasons there are at least for some parts of domestic labor reason to fear that unrestricted immigration may hurt them by increasing unemployment and lowering wages.

Third, much research indicates that only after a fairly long period of integration does immigrants reach levels of productivity comparable to the native population. Even if that conclusion still is a matter of debate---productivity measured by wages might as well be a case of discrimination---it is clearly the case that migrants tend to be much younger than the native population, mainly between 20 and 35 and thus it takes at least one or two decades before they reach their top incomes and then contributes the most to the fiscal balance.

Thus timing of migration matters, we would like to import middle aged people but they are not likely to move very much. Hence we should import more human capital a decade or two before the worst fiscal pressures start, presumably when the boomers reach ages around 80 and start to burden the health care system. But that is liable to cost us some supporting institutions that can sustain long-term immigration even at times when there is not full employment in the economy in the hope that they later will be better matched to the labor market.

6. Conclusions

Will growth be saved in the ageing society by increasing human capital investment? In the narrow sense of human capital investment, i.e. by increasing years of education this paper argues that it will only be a minor part of the solution since any realistic increase in efficiency through education falls far short of what is needed to keep relative living standards of the dependent and active population at anything near current levels. By focusing on the dependency ratio it is emphasized that the problem of ageing is not so much a question of the GDP level per se but of redistribution. No matter what the growth rate is, we either get a decrease in the relative standard of living of the elderly or we have to redistribute a sizable part of productivity growth from the active generation to the elderly. The point of having higher growth in that context is that it makes it easier and more acceptable to achieve the redistribution.

But we could take a broader approach to human capital formation and recognize that there are several margins at which it can be increased. First, by increasing utilization of the existing stock of human capital we can both redefine how productive the active generation is per capita and most important by lengthening work life we also redefine (and decrease) the dependent group. This is important especially if we allow education to become longer, since that in turn also increases the group of dependents.

Second, we can import human capital by immigration. By itself it is no long-term solution but with sensible policies it could help further in alleviating the fiscal problems of ageing. Unfortunately immigrants also get older and if they are really integrated into society (which is important in order to really help with the fiscal problems) they cannot very well be sent back to their home countries when they become dependent. Although long run on the usual time scale of economics, it is therefore still only a temporary remedy at the time scale of demography.

Third, the basic production of human capital starts with children and in the very long run a sustainable society where longevity into a dependent state of life has become a rule, and not an exception as previously in history, it becomes necessary to have a fertility high enough to reproduce labour (and the tax base) if the economy shall be able to support such massive cohorts of dependents. Fertility rates need not for the foreseeable future reach reproduction rates, since it can be combined with other measures, but in the very long run and at a global scale it should get much closer to total fertility rates around two than it is today in most developed countries.

Fourth, by taking advantage of the international division of labor and capital, national economies can become more independent of the domestic demography and thus ensure capital incomes even if profitable investment in diminishing economies with diminishing demand dries up. By allowing free movement of both capital and labor global differences in demography can be another important part of the solution of the ageing problem.

However, economic research on these issues today is hardly empirically precise enough to provide a reliable guide for the quantitative trade-offs between different measures that can be taken. Considering that the ageing that follows from the demographic transition and the continuing upward drift in longevity already is built into the world's demographic structure these are problems that will certainly not go away. Hopefully I have succeeded in demonstrating that ageing has only started.

The demographic momentum will not only disfavor the currently developed countries in this century but it will certainly favor some of the emerging and less developed economies to an extent that is likely to tip the economic power balance of the world. One would therefore expect this to be one of the defining issues of 21st century.

References

Aghion, P., Carolí, E. and García-Peñalosa, C. (1999), Inequality and Economic Growth: The Perspective of the New Growth Theories, *Journal of Economic Literature* 37(4), 1615-1660.

Barro, R. J. and Lee , J.-W. (1993), International Comparisons of Educational Attainment, *Journal of Monetary Economics* 32 (3), 363-394.

Bils, M. and Klenow, P. J. (2000), Does Schooling Cause Growth, *American Economic Review* 90(5), 1160-1183.

Blomquist, N.S. and Wijkander, H. (1994), Fertility Waves, Aggregate Savings and the Rate of Interest, *Journal of Population Economics* 7, 27-48.

Bloom, D.E., Canning, D. and Malaney, P.N. (2000), Population Dynamics and Economic Growth in Asia, *Population Development Review* 26, Sup-plement.

Bloom, D.E. and Sachs, J.D. (1998), Geography, Demography, and Economic Growth in Africa, Brookings Papers on Economic Activity (1998:2), 207-273.

Bloom, D.E. and Sevilla, J. (2004), Proÿts and People: On the Incentives of Business to Get Involved in the Fight Against AIDS, MIT Press.

Easterlin, R.A. (1968), Population, Labor Force, and Long Swings in Economic Growth: The American Experience, National Bureau of Economic Research, Columbia University Press, New York.

Feldstein, M.S. and Horioka, C.Y. (1980), Domestic Saving and International Capital Flows, *Economic Journal* 90(358), 314-329.

Higgins, M. (1998), Demography, National S avings, and International Capital Flows, *International Economic Review* 39(2), 343-369.

Lindh, T. and Malmberg, B. (1999), Age Structure Effects and Growth in the OECD, 1950-90, *Journal of Population Economics* 12(3), 431-449.

Macunovich, D.J. (1998), Relative Cohort Size and Inequality in the United States, *American Economic Review* 88(2), 259-264.

Malmberg, B. and Lindh, T. (2004), Demographically Based Global Income Forecasts up to the year 2050. Manuscript presented at the Symposium on Demographic Change and Global Income Growth in the 21st Century, Krusenberg, 7-9 January 2004.

OECD (1998), Maintaining Prosperity in an Ageing Society, OECD Publica-tions, Paris.

Samuelson, P.A. (1958) An Exact Consumption-Loan Model of Interest with or without the Social Contrivance of Money, *Journal of Political Economy* 66, 467-482.

Solow, R.M. (1956), A Contribution to the T heory of Economic Growth, *Quarterly Journal of Economics* 70(1), 65-94.

Storesletten, K. (2003), Fiscal Implications of Immigration-a Net Present Value Calculation, *Scandinavian Journal of Economics* 105(3), 487- 506.

Taylor, A.M. and Williamson, J.G. (1994), Capital Flows to the New World as an Intergenerational Transfer, *Journal of Political Economy* 102(2), 348-371.

Comment on: Thomas Lindh, "Is Human Capital the Solution to the Ageing and Growth Dilemma?"

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I hope for your understanding starting with a very personal observation. When being invited to discuss a paper in a seminar like this my usual aim is contributing from my experience at least a little. But this time, when I agreed to discuss the paper of Thomas Lindh I did not foresee that I will be given a very precious present: under the impression of last years fierce discussions on pension reform in this country and in some others I began writing on the macro-economics of population ageing – not for the sake of academia but as a guideline for policy-makers and politically interested people. And preparing for this particular workshop I found – with all due modesty – that Thomas Lindh's paper arrives at basically the same conclusions as I. Therefore I am going to underline his findings rather than criticizing it.

Let me summarize how I see his findings.

First: in dealing with the perspectives of demographic changes in the decades to come, it is imperative to see the strategic options and the consequences as an unprecedented macro-economic problem. The dimension of the problem would be misunderstood, and is not adequately understood in fact, at least in Austria so far, when assuming that a mere adjustment of some parameters of the public PAYG-system is sufficient to meet the challenge. A parametric reform is indispensable, of course, but if not complimented by a comprehensive macro-economic strategy it will be insufficient and be doomed to fail in the long run.

Second: no isolated line of remedy will be sufficient to cope with the magnitude and the complexity of the problem, rather a strategic combination of major approaches and of many societal adaptations in detail seems promising.

Of course, the main ingredients of that strategy will be

* lowering the dependency ratio by raising the activity rate,

* increasing productivity per capita by additional investment in human capital and by deepening capital intensity,

* the use of international opportunities to invest into the economies of demographically younger nations and to earn profits from such investments in order to partly support the social system of the "older" countries: outsourcing instead of immigration,

* a careful handling of the intergenerational redistribution problems that inevitably will occur.

The coordinated use of some more particular instruments to support the strategies will be necessary to stabilize the social system, at least to preserve the level of per capita welfare of today: among them not at least limits to the generosity of the pension system, measures to raise birth-rates in the longer term, fiscal and other measures influencing the savings rate and the efficiency of capital markets etc.

When this is clear even to policy makers - which seems not to be the case in Austria yet - there remain still very difficult problems in implementing a comprehensive strategy.

Some short comments on aspects discussed by Thomas Lindh:

There is widespread unanimity as to the necessary increase in participation rates in the population out of various sources: length of working life, higher female participation, immigration.

When thinking of possible sources of human capital, we should not neglect the potential of lowering the currently high unemployment. The unemployment rate in Western Europe this year is some 4 to 5 percent of the labor force above the level it has been during times of full employment in the early seventies, before growth rates shrank and the baby-boom generation entered the labor markets. As the ceteris-paribus-impact of ageing by 2030 will be decreasing the European GDP by some 10 to 15 percent, the consequence of integrating this unused part of the labor force would cover about one third of the problem. Certainly, the effects of a lower unemployment rate are not independent of higher participation rates caused by the other sources mentioned.

This leads me to the core of my support for Lindh's arguments: productivity and human capital. In various articles we find a long list of factors influencing labor productivity trends downward under the impact of ageing: lower savings rates, higher risk aversity, less innovative capacity, lower capacity to work because of diminishing physical condition and so on.

But there are also arguments that would suggest forces working in the positive direction:

* First and fundamentally: the extrapolation of past trends of the decades after the end of the baby-boom, i.e. since about the early seventies, is conducive in many instances to misleading conclusions, as the very same reason that has led to increasing unemployment and decreasing participation rates – the sharp swing from big cohorts to very small ones - now turns into the opposite and will create - even without strategic intervention - some capacity to reduce the problem. For example the relative shift from labor to capital income will be reversed and therefore the direction of technological progress. The increasing scarcities on the labor market in coming decades will more or less automatically increase labor productivity through enforced labor saving technological progress.

* Early retirement in recent years has been an unnecessary loss of human capital while not significantly raising the employment rates. A reversal of this trend will – accompanied by adequate measures in labor-market-, wage-, wage-taxation- and education policies result in an increase of GDP,

* Intergenerational differences in human capital embodied will most probably decrease as a result of improved education in the last decades

I am sure about a sufficient automatic reaction of technical progress in this direction, but I think such effects will offset at least partly the dampening influences on productivity growth.

This is all the more plausible as the increased cohorts of aged persons to some extent not only demand more labor and GDP for their needs but in themselves provide also specific capacity to meet such needs, think of personal care for handicapped older persons. The question is, will the market forces work sufficiently to balance the specific demands and supplies. Certainly not. But, again, this can be encouraged and supported.

Next point, and a very crucial one. Thomas Lindh summarizes his quantitative simulations ("number crunching") convincingly: "it seems possible that in combination with higher utilization of the human capital and support from higher capital intensity, some labor import and technological change, at least can be kept up to such an extent that living standards on average continue to rise in an ageing society."

He proceeds to the discussion of distributional problems.

I would like to stay here for a moment. For me, still the question remains, how could we generate enough increase in human capital and social capabilities?

Answer: by intensified and improved learning on all levels, in all organizations and at (nearly) all ages. I was impressed a year ago when at a WIFO symposium Gosta Espin Anderson exclaimed: if you wish to solve the ageing problem for the long run, invest in your children! There are three things to be done with priority: education, education and education. And I confess I have much more affection for this view than with the other calling for the "production" of more kids. (I myself have three of them, so I think, I am out of obligo).

Improving human capabilities is the central political question, because an adequate answer would ease the distributional problem uno actu. There are, however, not many indicators, that national policy so far has recognized the importance of this key to future problems.

As to distributional questions I could agree that overlapping intergenerational models may give some insight into the dynamics of redistributional needs. I, however, see the limits of such models; e.g. assigning the use of societal goods and services to particular cohorts. That leaves me not only with the conclusion that we have to try to get much more comprehensive insight into generational value developments.

But also with two final remarks:

- *First*, I am inclined to follow Nicholas Barr (The Welfare State as Piggy Bank, Oxford 2001) in arguing, that the demographic challenges before us do not call for a dismantling of the welfare state. To the contrary, they ask for a reinforcement of the state in the sense, that only the democratic state is legitimated to an authoritative and fair balance between the interests of succeeding generations and between social groups.

- *Second*, I doubt that our measure of welfare (GDP per capita) is adequate to think of the possible developments of well-being in our countries under the influence of ageing. I rather think that ageing will bring about - in the medium- and long-term - fundamental shifts in relative values: the trade-off between labor and leisure, between environment and production, between national and global interests, between the state and the civil society. Such developments will not be adequately assessed by the standard economic measure of welfare. Instead, I think, we have to try to enlarge our analyses to wider degrees of freedom in the option before us.

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The publication provides easy access to continuously updated information on the Austrian capital markets to the international investment community. The brochure is jointly edited by the OeNB and the Oesterreichische Kontrollbank AG (OeKB).

http://www2.oenb.at/english/engl_p.htm

Workshops – Proceedings of OeNB Workshops *recurrent*

The issues comprise papers presented at OeNB workshops at which national and international experts, including economists, researchers, politicians and journalists, discuss monetary and economic policy issues. Workshop proceedings are available in English only.

http://www2.oenb.at/english/engl_p.htm

Working Papers *recurrent*

The *Working Paper* series of the OeNB is designed to disseminate and provide a platform for discussion of work of OeNB economists or outside contributors on topics which are of special interest to the OeNB. To ensure the high quality of their content, the contributions are subjected to an international refereeing process. The opinions are strictly those of the authors and in no way commit the OeNB.

http://www2.oenb.at/english/engl_p.htm

HVW-Newsletter *quarterly*

The English-language *Newsletter* is only published on the Internet and informs an international readership about selected findings, research topics and activities of the Economic Analysis and Research Section of the OeNB. This publication addresses colleagues from other central banks or international institutions, economic policy researchers, decision makers and anyone with an interest in macroeconomics. Furthermore, the Newsletter offers information on publications, studies or working papers as well as events (conferences, lectures and workshops).

http://www.oenb.at/content/Newsletter--1150/index.xml.frame