An International Comparison of Selected Innovation Drivers

Lothar Funk and

Axel Plünnecke*

Contrary to the post-war period where growth and catching-up with the United States could largely be achieved through accumulation of production factors and from assimilating existing technologies, once European countries had moved closer to the technology frontier,[1] innovation has become the main engine of growth. In other words, the balance between imitation and innovation has shifted in favour of the second. At the heart of this ability to innovate lie all those factors that lead either to the introduction of new products (product innovation) or to the introduction of new production processes (process innovation). Additionally, a greater proportion of that innovation is radical rather than incremental (OECD 2004c, 82). According to the Sapir Report, "growth becomes driven by innovation at the frontier and fast adaptation to technical progress" (Sapir et al. 2004, 38).

The current study tries to shed some light on this hypothesis by analysing the 22 most important OECD countries within the last decade in order to answer the question, whether the economies at the technological frontier that had the highest rates of economic growth in recent years have indeed the best frameworks to innovate. Even if different international organizations – European Commission and OECD, for example – have conducted a range of very useful benchmarking exercises in the area of innovation[2] (European Commission 2004a; OECD 2004b), this question has not been analysed in depth by now to our knowledge.

Our study uses the United States as the benchmark economy.[3] The position of the US as the most technologically advanced country (European Commission 2004b, 174–177) results from the fact that it, in common with many European countries, has high hourly productivity rates, whilst it has, at the same time and in contrast to many European states, higher work volumes (Sapir et al. 2004, 34–35). Obviously, the trade-off between productivity and work volumes that is so apparent in much of Europe does not arise in the US.[4]

Our analysis demonstrates that, for countries at the technological frontier, the existing conditions for innovation have a significant effect on current growth rates. Human resources, financing possibilities as well as the institutional regulation of product and labour markets have a prominent position amongst those factors that influence innovation. At the technological frontier, those countries with high rates of growth also distinguish themselves from those with low rates of growth on important measures of innovation. Significant differences between the two groups of countries exist in the numbers of university graduates (including those in particularly important subjects, such as mathematics, sciences and technology – in short MST subjects), the availability of venture capital, the amount invested in information and communication technologies (ICT), the general conditions in which firms operate as well as in their demographic developments. Even if the other indicators of innovation are considered, it can be shown that the average ranking on such measures is correlated with economic growth rates after the end of the boom in the new economy.

Theoretical and methodological background

In contrast to traditional growth explanations, "modern theories emphasize research inputs and human

* Lothar Funk, University of Applied Sciences in Düsseldorf (lothar.funk@fh-duesseldorf.de); Axel Plünnecke, Cologne Institute for Economic Research IW (Pluennecke@iwkoeln.de).
This study is part of a research project by the Roman Herzog Institutes.

[1] Several European countries were able, above all in the immediate post-War decades, to pursue successfully a process of catching up. It was, thereby, possible to reach the technological frontier in important areas. However, the growth that is attributable to catching up came to an end, at the latest, at the beginning of the 1980s when the easy gains from imitating and incrementally improving existing technologies were exhausted and demand became saturated for the output of leading industries. A decrease in the importance both of imitating successful economies and of simple incremental innovations for economic growth are inextricably linked with the ending of catching up process (see Sapir et al. 2004, 35–37).

[2] Such benchmarks show the position of various national economies across a range of measures of innovation; they do not, however, provide an overall ranking based on those indicators that are most relevant for economic growth.

[3] Above all, we choose Germany as the base country, as it was the laggard among the countries analysed here. If growth rates over the last ten years are averaged out, then Germany, with, in real terms, an annualized growth rate in per capita GDP of only 1.2 percent, is last amongst 22 OECD countries.

[4] The US and other successful economies have managed to increase their productivity rates, despite increasing their rates of employment. This also applies to the low-skilled in the US. This implies that the US has obviously been more successful at transforming inventions in basic science into growth-enhancing innovations. High rates of hourly productivity alone are no indication of being a technological frontrunner. Several European countries, of which Germany is a good example, have high levels of labour productivity per hour; at the same time, however, they exhibit low levels of employment. Other countries that have higher employment levels have lower hourly productivity rates.

capital as the key drivers for long-run growth. They stress not only the importance of 'own' innovation but also the capacity to imitate and to absorb externally available know-how. Institutional factors and framework conditions are seen as an important part of the 'innovative system' in which innovative firms operate" (European Commission 2004, 175). There appears to be an emerging consensus that a narrow view of innovation ("science should somehow cause innovation") is inappropriate (Arnold and Thuriaux 2002, 1) and needs to be replaced by a broader view of innovation.

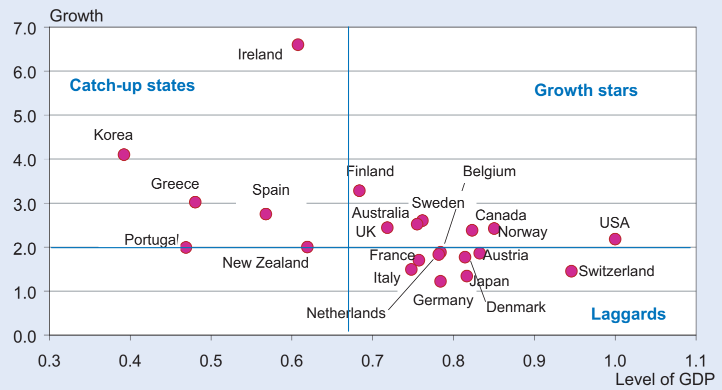
"Innovation is a fundamentally economic process. Schumpeter called innovation 'a new combination of factors of production'. This can be the result of an invention. But it can equally involve the exploitation of new natural resources, copying an idea from a distant market, or describing an old product in a new way. *Entrepreneurship – the act of making innovations – is not something related to science and research, but about changing the rules of the game in economic competition*. Exploiting an invention is, therefore, an important special case of innovation, but it is not the general case. Economists see innovative activity as a driver of economic development because it provokes imitation. Innovation forces competitors to react – often in creative ways involving improvement and 'innovating around' the first innovator's design to erode the 'supernormal' profit of the original innovator. Innovations give rise to changes in the economy, which may be several times larger than the effect of the original innovator. *The main driver of economic growth is therefore the process by which change diffuses through the economy"* (Arnold and Thuriaux 2002, 2).

In other words, an economy's "national innovation capacity" is appropriately defined "as the ability of a nation to not only produce new ideas but also to commercialize a flow of innovative technologies over the longer term" (European Commission 2004, 175). It is vital that conditions for innovation and diffusion are approached as a whole (Arnold and Thuriaux 2003, 8). In the words of Jan Fagerberg (2003, 17): "Innovation processes are inter-temporal by nature. Current innovations depend on past innovations, and future innovations will depend on current innovations. This means that there may be a strong aspect of path dependency in innovation processes. Radical innovations open up new paths for future innovation activities and can dramatically influence what can be done profitably. Consequently: innovation and diffusion should be seen as an integrated process. It does not make sense to separate innovation and diffusion policy because a number of innovations occur in the wake of radical innovation and these only achieve economic impact as part of the diffusion process. What is important for innovation policy is to approach innovation as an integrated whole...; it is important to get on the bandwagon early, because as time goes by requirements become increasingly difficult to meet and unless one can jump on early it may be difficult to catch up at all because of the accumulated advantages associated with path dependency."

The arguments mentioned above have important repercussions for analysing the preconditions and effects of innovation empirically, as the incentive to engage in innovative investments, which involve risky experimentation and learning in particular at the technological frontier, is itself strongly affected by the economic environment (Sapir et al. 2004, 38). At least three implications result from such a broad perspective of innovation: firstly, it appears reasonable to link the rates of economic growth of countries to the conditions for innovation and diffusion, as is quite common nowadays (see e.g. Acemoglu et al. 2002; Fagerberg 2005; Fehn 2004). Secondly, although in each and every country there will be specific factors at work (see e.g. Boyer 2004), these will not be in focus here. Rather we will attempt to single out some general factors related to innovation capacity that may be of interest when debating the differences across countries in economic performance. These important innovation dimensions are human resources, financing conditions and more general framework conditions, for example in product and labour markets. The factors of innovation in this study are clearly multidimensional and, therefore, rather difficult to handle. Hence, we shall identify four reliable innovation input indicators for each of the three dimensions, express these in a comparable format and weigh them together, giving each indicator and dimension an equal weight in the calculation of the composite ranking indicator, which will be computed as an average rank of the single indicators in this article. Admittedly, there is an element of arbitrariness involved in such a calculation. This analysis may, for example, have a problem of omitted variable bias, which is, however, alleviated by using several different indicators for each dimension. Moreover, it would of course have been preferable to have prior knowledge about the true weights to use. Lacking such information, it appeared least arbitrary to give each variable equal weight. Finally, it should be noted that the general approach we adopt here will – in line with the broad definition of innovation we follow – not only measures the direct effects of innovation activity (understood in a narrow sense as technological progress) on output but also indirect effects on output, such as reductions of technical inefficiency and improvements in allocative efficiency that cannot be separated empirically (see van Ark 2003, 10–13).

Figure 1

LEVEL OF ECONOMIC DEVELOPMENT AND ECONOMIC GROWTH[a)]



a) Average yearly growth rates in per capita gross domestic product over the period 1994 to 2004 in per cent and relative per capita gross domestic product in 1994 (USA = 1) in 22 OECD countries.

Source: Own calculations based on Eurostat (2005).

Innovation at the technological frontier: Catch-up states, growth stars and laggards

A recent study (Acemoglu et al. 2002) shows that the closer a country finds itself to the global cutting edge of technology, the more important radical innovations combined with fast adaptation to technical progress in all sectors become for economic growth. The basic conditions that promote the flow of radical innovations are of particular importance. By contrast, the importance of the ability to imitate others is severely reduced. According to this approach, the factors affecting innovation are of relatively little importance for economic growth in countries that are a long way from the technological frontier (catch-up countries); however, in national economies that are close to this technological frontier these factors are of decisive importance for growth. The following empirical analysis is based on this general empirical approach.

Per capita gross domestic product (GDP) will be a proxy for the technological advancement of a country. The US will be defined as the benchmark for technological advancement. Therefore, the US GDP per capita will be normalized to 1. In connection with their growth rates over the last ten years, the 22 OECD countries considered here can be grouped into three categories (Figure 1).

- **States that are catching up**: in the first group, countries can be found that have a relatively low level of per capita GDP and, at the same time, exhibit real GDP growth rates of more than 2 percent. These countries, such as Ireland, South Korea, Greece and Spain, can be described as states that are catching up. What also distinguishes these countries from most other countries is the fact that their rates of per capita GDP were less than two thirds of the US's level in 1994. This group of countries can profit significantly from imitating more successful economies and by incremental innovation.
- **Growth stars**: a second group of countries is characterized, firstly, by real GDP growth rates of over 2 per cent and, secondly, by already high levels of per capita GDP. This group can be described as growth stars. Over the last decade, Finland, Sweden, Australia, the UK, Norway, Canada and the US have belonged to this group. These states have, despite a relatively high technological level, high rates of economic growth.
- **Laggards**: a third group of countries, which are characterized by growth rates of less than 2 per cent, can be described as laggards. Belgium, Austria, the Netherlands, Denmark, France, Italy, Switzerland, Japan and Germany belong to this group. These countries are, because of their high levels of per capita GDP, undoubtedly highly developed economies. They, therefore, find themselves largely at the technological frontier. They have not, however, been able to take sufficient advantage of the opportunities for growth that have existed over the last decade.

Conditions for innovation

The growth stars as well as the laggards are, as groups of countries that are operating at the technological frontier, more dependent on radical innovations and fast adaptation to technical progress in all sectors for economic growth. This raises a couple of main questions. Firstly, what are the conditions that have the most favourable effects on growth? Secondly, did those economies that had the highest rates of growth between 1994 and 2004 have the best frameworks for innovation and did countries which offer better conditions for innovation exhibit higher rates of growth in the later years of the period? By considering more recent years, influences will be excluded that, firstly, may have promoted innovation during the boom in the area of information and communication technologies (ICT) (the so-called new economy boom), but that may distort evaluations of the innovation factors in the medium term.

From a theoretical perspective, variations, in particular, in conditions for radical innovation play a central role in explaining the differences in growth rates between countries. These conditions cover:

Human resources. In the case of human capital, a paper by Aghion, Meghier and Vandenrusche (2003) demonstrates that, for 19 OECD countries between 1960 and 2000, the impact of the share of the population that is highly skilled on economic growth increases as the distance to technological frontier declines.

Financing possibilities. The role of finance and investment for innovation and growth is shown in papers by Levine (1997) and by Bassanini and Scarpetta (2002). The latter show that technological change – embodied by new ICT capital goods – has been a primary source of output and productivity growth in ICT-using sectors.

Table 1

An international comparison of human resources

Country	Persons with a tertiary education as a percentage of the population aged between 25 and 64		Persons with post-graduate research qualifications[a] as a percentage of the population aged between 25 and 64		Graduates in MST[b] per 100,000 employees aged between 25 and 34		Expenditure on education as a percentage of GDP	
	in %	Rank	in %	Rank	Value	Rank	in %	Rank
Growth stars								
Finland	33	4	1.9	4	1,785	2	5.8	11
Australia	31	6	1.3	8	1,659	4	6.0	8
Sweden	33	4	2.8	1	1,267	8	6.5	4
Norway	31	6	1.1	11	703	16	6.4	5
UK	27	11	1.6	6	1,727	3	5.5	13
Canada	43	1	n.a.	n.a.	855[c]	12	6.1	7
US	38	2	1.3	8	928	11	7.3	2
Laggards								
Denmark	27	10	0.9	14	799	14	7.1	3
Austria	14	20	1.7	5	528	20	5.8	11
Belgium	28	9	1.1	11	674	18	6.4	5
Netherlands	24	15	1.3	8	653	19	4.9	18
France	24	15	1.4	7	1,609	5	6.0	8
Italy	10	21	0.5	20	703	16	5.3	15
Germany	23	18	2.0	3	721	15	5.3	15
Japan	36	3	0.7	18	1,074	9	4.6	20
Switzerland	25	13	2.6	2	838[c]	13	5.3	15
Catch-up states								
Ireland	25	13	0.8	17	1,514	6	4.5	21
Korea	26	12	0.9	14	1,788	1	8.2	1
Greece	18	19	0.7	18	n.a.	n.a.	4.1	22
Spain	24	15	1.0	13	935	10	4.9	18
Portugal	9	22	n.a.	n.a.	n.a.	n.a.	5.9	10
New Zealand	30	8	0.9	14	1,497	7	5.5	13
Average values on the measures of human resources for the three groups of countries								
Growth stars	34	1	1.7	1	1,275	1	6.2	1
Laggards	23	2	1.4	2	844	2	5.6	2
Catch-up states	22	3	0.9	3	n.a.	n.a.	5.5	3

The data relate mostly to 2002.
[a] Those who have successfully completed a post-graduate research degree. – [b] Graduates of mathematics, engineering, the life sciences and technology. Values for Canada are for 2000 and for Switzerland are for 1998. – [c] 2000.

Source: OECD (12004e).

General framework conditions. The role of regulations for innovation and growth is shown in papers by Scarpetta and Tressel (2004) and by Nicoletti and Scarpetta (2003). There is evidence that high labour adjustment costs can have a strong negative impact on productivity. Such costs can, in particular, reduce incentives for innovation and the adoption of new technologies, and lead to lower productivity performance, when institutional settings do not allow wages or internal training to offset high hiring and firing costs. Reforms promoting private governance and competition tend to boost productivity. Both privatisation and market-entry liberalisation are estimated to have a positive impact on productivity.

As mentioned above, the performance of an innovation system cannot sensibly be explained by one solitary factor. Therefore, in order to evaluate the forces that promote innovation within a national economy, it is necessary to look at a bundle of factors as explained above. Due to the research design, it will not be possible, here, to cover the measures of the output of innovation that do not include the effects of research and development on the national economy. In other words, measures such as the number of new patents will not be discussed here. This paper aims to elaborate the link between basic input factors within an innovation system and economic growth per capita.

Human resources

The share of the population that is highly qualified is of particular importance for the ability to innovate, as mentioned above (Aghion et al. 2003). If the technological distance to the leading national economies is great, then the share of the population that is highly qualified has, empirically, hardly any role to play in influencing economic growth. This is because imitation and incremental innovation dominate. The share of the population that is highly qualified, the share of the population with a post-graduate research qualification, the numbers of successful candidates in mathematics, sciences and technology, and investments in education are important measures that can be used as indicators of a national economy's human resources.

If the three groups of countries are considered, it can be shown that the group of growth stars performs considerably better on these measures of human capital than the average for the group of laggards (Table 1). The share of the population aged between 25 and 64 that has a tertiary education is, at 34 percent in the former group of countries, nearly a third higher than the figure for the laggards. Similarly, the number of graduates in mathematics, sciences and technology per 100,000 employees aged between 25 and 34 is considerably higher amongst growth stars than it is amongst the laggards. Moreover, the former group of countries have a higher share of graduates who have completed post-graduate research degrees amongst those of typical graduating age. Indeed, the growth stars invest more, as a percentage of GDP, in education than the laggards.

The performance of the growth stars and the laggards differs significantly on the indicator measuring "persons with a tertiary education" and on the "MST" indicator. However, there is no significant difference between growth stars and laggards on investments in education and the share of the population with a doctorate.[5]

Financing possibilities

Technological advancement has been regarded, for a very long time, as a significant driver of growth; this is especially true in more recent growth theories that use two-sector models of the economy (Romer 1990; Grossman and Helpman 1991; Aghion and Howitt 1992). In such models, the goods sector of the economy manufactures products, and the factors of production (capital, labour and technological knowledge) are utilized. In the area of research and development (R&D), capital, labour and existing technological knowledge are similarly used; here, however, new technological knowledge is the output. By investing more in this sector, a higher rate of growth can be achieved; market imperfections can, however, lead to a sub-optimal supply of R&D (Romer 1996).

Expenditure on R&D as a percentage of GDP and the investment in ICT represent important indicators of investment and, therefore, the financing of innovations; this is particularly true for governments' promotion of research and knowledge in the area of basic science. This is, to a large extent, supported by governments and is carried out at universities and other research institutes (BMBF 2004, 167). One reason for the role of government in this area might be that free market mechanisms do not generate enough of such "products" because of their public-goods character. Moreover, state subsidies can fundamentally improve

[5] The p-value of the t-test that the means for the two groups are different is, for investments in education, 0.1 and, for the share of the population with a doctorate, 0.375.

Table 2

An international comparison of financing conditions

Country	Share of GDP spent on R&D[a)] (2002)		Tax relief per R&D dollar spent in large firms[b)] (2001)		Share of GDP that is available as venture capital (1998–2001)		Share of fixed-capital investments that is spent on ICT[c)] (2000)	
	in %	Rank	in US$	Rank	in %	Rank	in %	Rank
Growth stars								
Finland	3.46[d)]	2	–0.01	13	0.138	8	17.5	10
Australia	1.54	16	0.20	3	0.093	14	19.9	6
Sweden	4.27[e)g)]	1	–0.01	13	0.207	5	21.6	3
Norway	1.67	15	–0.02	18	0.125	10	n.a.	n.a.
UK	1.88	14	0.10	8	0.219	4	22.8	2
Canada	1.91	12	0.17	4	0.251	2	21.4	4
US	2.67[h)]	5	0.07	10	0.492	1	30.1	1
Laggards								
Denmark	2.52	7	0.11	7	0.082	16	19.1	7
Austria	1.93	11	0.12	6	0.044	21	12.8	16
Belgium	2.17[e)]	10	–0.01	13	0.172	7	17.5	10
Netherlands	1.89[e)]	13	0.10	8	0.241	3	20.9	5
France	2.20	9	0.06	11	0.119	11	12.6	17
Italy	1.11[e)]	19	–0.03	21	0.076	17	16.1	12
Germany	2.52	7	–0.02	18	0.127	9	17.6	9
Japan	3.12	3	0.01	12	0.020	22	17.8	8
Switzerland	2.57[d)]	6	–0.01	13	0.085	15	n.,a	n,a,
Catch-up states								
Ireland	1.15[e)]	18	n.a.	n.a.	0.114	12	14.6	15
Korea	2.91[f)]	4	0.13	5	0.202	6	n.a.	n.a.
Greece	0.65[e)]	22	–0.01	13	0.059	20	15.7	13
Spain	1.03	20	0.44	1	0.095	13	15.5	14
Portugal	0.93	21	0.34	2	0.066	19	11.4	18
New Zealand	1.18[e)]	17	–0.02	18	0.069	18	n.a.	n.a.
Average values of the financing measures for the three different groups								
Growth stars	2.49	1	0.07	2	0.218	1	22.2	1
Laggards	2.22	2	0.04	3	0.107	2	16.8	2
Catch-up states	1.31	3	0.18	1	0.101	3	n.a.	n.a.

[a)] Research and development. – [b)] Equivalent to the tax relief on every dollar spent on R&D in large companies. – [c)] Information and Communication Technologies. – [d)] 2000. – [e)] 2001. – [f)] R&D expenditures in the humanities and the social sciences have been excluded. – [g)] Underestimated values. – [h)] So-called capital expenditures have been excluded.

Source: OECD, 2004b; Cologne Institute for Economic Research IW.

the sub-optimal supply of innovations. However, for political-economic reasons and because of the risks of inefficient demands for subsidies so funding should be treated with care; this becomes increasingly important as the tasks of R&D become more application oriented (Farhauer and Henke 2002). A large amount of venture capital (even if it represents only a relatively small percentage of GDP) can, most readily, enable radical innovations which, as a result of the current structural changes in economies, obviously have a greater effect on growth than incremental innovations do.

Moreover, venture capital can increase the rate at which new companies are founded. Such companies, amongst other things, make a significant contribution to innovation as they are able to choose the most productive combination of factors of production. Unlike established companies, new firms do not have any costs associated with adaptation (for example, training, redundancies) when they introduce new technologies and production methods. The establishment of new companies also exerts competitive pressures on existing ones; the latter are then spurred on to create innovations (OECD 2004c, 88).

If an examination is made of the extent to which the growth stars and the laggards differ on the measures of financing and investment, the means across all four indicators are better for the growth stars than the laggards. The differences in average values for investments in ICT and venture capital are statistically significant.[6]

In the availability of venture capital in the early and expansionary phases the growth stars dominate.

[6] The p-value of the t-test on mean equivalence is, for tax relief on R&D, 0.4, and, for investments in R&D, just under 0.6; this indicates that there are no statistically significant differences between the two groups on these two measures.

Younger firms have there a far better climate in which to fund their expansions from external sources. For the growth stars, venture capital amounted to, on average, 0.218 per cent of GDP between 1998 and 2001. In the laggard countries, not even half that amount was available to establish new companies. These latter countries had to be satisfied with venture capital that amounted to approximately 0.1 per cent of GDP only. More recently, the group of growth stars have also invested in new ICT; these not only contribute towards higher productivity and growth, but also represent an important infrastructure for the wide diffusion of advanced technologies (OECD 2004c, 77). Whilst, for the growth stars, investment in ICT amounted to, on average, 22.2 percent of their fixed investment, this figure was a mere 16.8 per cent for the laggards.

Despite the fact that, on average, the growth stars perform better on indicators that measure investments in R&D and tax relief on R&D, there are states with low rates of growth that perform well on such indicators, and there are also states that have high rates of growth with relatively poor records in these areas. For instance, Switzerland, Japan, Germany, Denmark and France, which are all laggards, invest more in R&D than Canada, the UK, Norway and Australia, which are growth stars. Similarly, Austria, Denmark and the Netherlands, which are laggards, offer far greater tax relief on investments in R&D than Finland, Sweden and Norway, which belong to the group of growth stars.

General framework conditions

The general conditions for companies are of great importance for the potential success of new technologies as such investments are associated with great uncertainties. These risks can, in general, be managed better in a situation in which there are fewer labour-market regulations. Flexible markets, furthermore, create incentives for highly qualified young people to use their knowledge to create new knowledge; this means that they will not use their knowledge in socially unproductive rent seeking (Murphy, Shleifer and Vishny 1991).

Nonetheless, the growth stars Finland, Sweden and Norway have higher levels of labour-market regulation than many other growth stars. These latter countries are, however, typical small open economies with particularly high trade openness and labour demand elasticities that may be, due to lower insider power to set wages above market-clearing levels, not directly comparable in this respect with larger economies (Brandt et al. 2005, 65).

However, the other regulatory conditions for companies are better in the growth stars. A ranking of the conditions for firms (Matthes and Schröder 2005), which is based on World Bank data (World Bank 2004) and which does not take into consideration labour market flexibility, shows that the growth stars perform significantly better than the laggards and those states that are catching up. This measure covers data on the founding of companies, the registration of homes and property, the availability of credit, the disclosure requirements of public limited companies, the extent to which contracts are upheld, and the laws on insolvency.

Equally, the age structure of the population is of great importance for the willingness to innovate, as a younger population shifts the political majority in the direction of more innovative production methods (Gehrig 2000, 570–571). Of particular importance for the renewal of human capital is the ratio of pupils and students to the total number of employees. This indicator shows how strongly the basis of human capital as a share of total employment is being refreshed. It is, first and foremost, demographic developments that influence these factors. States whose populations are aging quickly have a paucity of younger people who, as carriers of newly created knowledge, are particularly important in driving radical innovations. A demographically more favourable age structure creates more impetus for innovation when the education system is of a high quality so that those starting work for the first time have a high level of competence. The results of the PISA studies for OECD countries in literacy, mathematics and the natural sciences are important measures of the quality of the education system (OECD 2004d).

To sum up, the growth stars perform on net better in their general conditions for innovation than both the laggards and those states that are catching up (Table 3). The growth stars exhibit significantly better averages for indicators that measure the general product, capital market and bureaucracy environments in which firms operate and that capture demographic developments.[7]

[7] The p-value of the t-test on mean equivalence is, for labour-market regulation, 0.122, and, for the quality of the education system as measured by PISA, 0.394. This means that the growth stars and laggards are not significantly different on these two measures.

Table 3

An international comparison of general framework conditions

Country	Labour market regulation (2003)		Conditions for companies[a] (2004)		Ratio of pupils and students to employees[b]		PISA results[c] (2003)	
	Index[d]	Rank	Index	Rank	in %	Rank	Value	Rank
Growth stars								
Finland	2.1	11	52.3	7	63	9	545	1
Australia	1.5	6	55.8	5	80	1	525	5
Sweden	2.6	17	52.6	6	64	7	510	10
Norway	2.6	17	59.2	2	59	13	493	16
UK	1.1	2	58.0	3	74	3	n.a.	n.a.
Canada	1.1	2	50.2	9	n.a.	n.a.	526	4
US	0.7	1	57.2	4	64	7	490	17
Laggards								
Denmark	1.8	8	45.9	14	56	14	494	15
Austria	2.2	12	44.6	17	52	19	496	14
Belgium	2.5	15	44.6	17	74	3	515	8
Netherlands	2.3	13	49.0	10	54	15	525	5
France	2.9	19	43.5	19	65	6	506	12
Italy	2.4	14	39.2	20	54	15	476	19
Germany	2.5	15	44.8	16	53	17	499	13
Japan	1.8	8	51.4	8	44	20	527	3
Switzerland	1.6	7	47.1	13	44	20	513	9
Catch-up states								
Ireland	1.3	4	48.4	11	70	5	508	11
Korea	2.0	10	44.9	15	61	10	538	2
Greece	2.9	19	31.3	22	60	11	466	21
Spain	3.1	21	47.4	12	60	11	484	18
Portugal	3.5	22	34.0	21	53	17	471	20
New Zealand	1.3	4	59.3	1	77	2	522	7
Average values for the measures of general conditions								
Growth stars	1.7	1	55.0	1	67	1	515	1
Laggards	2.2	2	45.6	2	55	3	506	2
Catch-up states	2.4	3	44.2	3	63	2	498	3

[a] Without labour market regulation. Range of the index: median of the individual measures = 50. – [b] Employees aged between 25 and 64. – [c] Results in literacy, mathematics and the natural sciences. OECD average = 500. – [d] Range of the index: from 0 (few regulations) to 6 (highly regulated).

Source: OECD, 2004a; 2004d; 2004e; Matthes/Schröder, 2004; Cologne Institute for Economic Research IW.

Overall evaluation of the drivers of innovation

If the average values for all the measures are considered, Canada performs the best. Then follow the US, the UK, Sweden, Finland and Australia (Table 4). It is only Norway from the group of growth stars that does not occupy a leading position. The national economies with a high per capita real income level and low levels of economic growth (the laggards) are positioned at the bottom of the list. From this group, Belgium performs the best. It is followed by Denmark, the Netherlands, Japan, Switzerland, France, Germany, Austria, and, well behind the other countries, Italy. The group of catch-up states is led by Korea, New Zealand and Ireland. These three countries perform better than the majority of the laggards. The catch-up states Spain, Portugal and Greece follow a long way behind, and are near the foot of the list.

Finally, the core hypothesis of this evaluation should be assessed. According to that hypothesis, the conditions for innovation should have a strong effect on the growth rates of those states that are close to the technological frontier. In other words, as explained in the basic theoretical approach above (Acemoglu et al. 2002), conditions for radical innovations are of significant importance for growth stars and laggards. Figure 2 supports this hypothesis. The average position for all of the measures of innovation used here (which mainly portray the conditions for innovation between 2000 and 2003) has a statistically significant effect on the growth rate in per capita GDP between 2000 and 2004.

The current study aims at selecting, according to theoretical considerations, indicators from a range of innovation benchmarks provided by the OECD; the selected measures can then be used in an analysis to

Table 4

The composite ranking of 22 OECD countries

Country	Average rank
Canada	5.7
US	5.8
UK	6.2
Sweden	6.6
Finland	6.8
Australia	6.8
Korea	7.3
New Zealand	9.9
Belgium	10.5
Denmark	10.8
Netherlands	11.0
Japan	11.2
Switzerland	11.5
France	11.6
Norway	11.7
Ireland	12.1
Germany	12.9
Spain	13.8
Austria	14.3
Portugal	17.2
Italy	17.4
Greece	18.2
The data relate to 2002.	

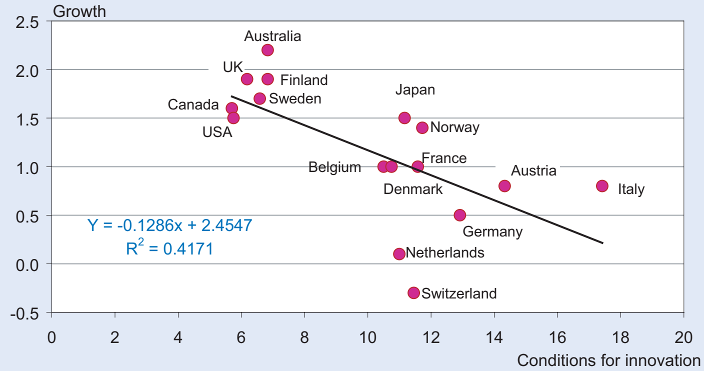
Source: Own calculation.

determine whether or not there is a statistical relationship between the country's average rank on such indicators and its macro-economic growth rate. If the measure of human capital alone were selected, the R2 measure would take an even higher value. It can, therefore, be tentatively concluded that human capital plays a particularly important role in innovation and growth.

It can, however, certainly be argued that those growth stars between 1994 and 2004 were also the fastest growing national economies between 2000 and 2004. The categorization of states according to their growth rates would appear, therefore, not to have been affected by the ebb and flow of the new economy. Those countries that grew strongly over the whole time period considered here had, at the start of this millennium, good conditions for innovation, and were also able between 2000 and 2004 to achieve a higher rate of growth than those states that, on the innovation measures, had worse values.

Figure 2

CONDITIONS FOR INNOVATION AND ECONOMIC GROWTH[a)]



a) Growth in per capita GDP between 2000 and 2004 in per cent and conditions for innovation of countries at the technological frontier.

Source: Own calculations based on Eurostat (2005).

Final remarks

The 22 OECD countries in the current study grew, on average, by 2.4 percent. Leading positions were taken by Ireland and South Korea, which because of their relatively low starting positions in 1994 were, to a large extent, still able to profit from a process of catching up. This catching up was characterized, first and foremost, by investments in already existing and predominantly labour-intensive technologies. Such a strategy is, however, no option for countries at the technological frontier. In highly developed industrial countries, the ability to innovate and a fast diffusion of these innovations as well as adaptation to technical progress plays, in comparison to imitation, an increasingly important role.

If Germany or, indeed, any other highly developed country with a poor growth record wants to increase its growth potential, it needs to improve the conditions for innovations at the technological frontier and the fast diffusion of these innovations. Improvements in human capital and the de-regulation of product markets should be of the highest priority. In particular, the government bureaucracy (including economically not sound subsidies) must be reduced considerably. In addition, more venture capital should be made available, and incentives to invest in ICT should be increased. A further level-headed de-regulation of the labour market and improved incentives in the welfare state so that innovators can find workers that match their new technologies more quickly could make an additional contribution to an improvement in performance on growth and innovation.

References

Acemoglu, D., P. Aghion and F. Zilibotti (2002), "Distance to Frontier, Selection and Economic Growth", *NBER Working Paper*, no. 9066, Cambridge MA.

Aghion, P and P. Howitt (1992), "A Model of Growth through Creative Destruction", *Econometrica* 60, 323–51.

Aghion, P., C. Meghier and J. Vandenrusche (2003), *Growth, Education and Distance to the Technological Frontier*, mimeo.

Arnold, E. and B. Thuriaux (2003), "Introduction", in European Commission, ed., *Future directions of innovation policy in Europe*, Brussels, 1–10.

Bassanini, A. and S. Scarpetta (2002), "Growth, Technological Change, and ICT Diffusion: Recent Evidence from OECD Countries", *Oxford Review of Economic Policy* 18, 324–44.

Baumol, W.J. (2004), *Education for Innovation: Entrepreneurial Breakthroughs vs. Corporate Incremental Improvements*, mimeo.

BMBF – Bundesministerium für Bildung und Forschung (2004), *Technologie und Qualifikation für neue Märkte*, Bonn and Berlin.

Boyer, R. (2004), "New Growth Regimes, But Still Institutional Diversity", *Socio-Economic Review* 2, 1–32.

Brandt, N., J.-M. Burniaux and R. Duval (2005), "Assessing the OECD Jobs Strategy: Past Developments and Reforms", *OECD Economics Department Working Paper*, no. 429, Paris.

European Commission (2004a), *Benchmarking Enterprise Policy*, Brussels.

European Commission (2004b), *The EU Economy: 2004 Review*, Brussels.

Eurostat, 2005, NewCronos, URL: http://europa.eu.int/comm/eurostat/newcronos/reference /display.do?screen= welcomeref&open=/&product=EU_MAIN_TREE&depth=1&language=de (accessed 20 January 2005).

Fagerberg,. J. (2003), "The Innovative Society", in European Commission, ed., *Future directions of innovation policy in Europe*, Brussels, 16–19.

Fagerberg, J. (2005), "The Dynamics of Technology, Growth and Trade: A Schumpeterian Perspective", in Hanusch, H. and A. Pyka, eds., *Elgar Companion to Neo-Schumpeterian Economics*, Edward Elgar, Cheltenham, in press.

Farhauer, O. and Henke, K.-D. (2002), "Wachstumstheoretische Konzeptionen und wirtschaftspolitische Folgerungen", *Das Wirtschaftsstudium* 31, 582–90.

Fehn, R. (2004), "Strukturwandel und europäische Wirtschaftsverfassung: Gibt es einen Zielkonflikt zwischen Effizienz und Sicherheit?", in Schäfer,W., ed., *Zukunftsprobleme der europäischen Wirtschaftsverfassung*, Duncker & Humblot, Berlin, 87–121.

Gehrig, T. P. (2000), "Zur Politischen Ökonomie des Technischen Fortschritts", in Külp, B. and V. Vanberg, eds., *Freiheit und wettbewerbliche Ordnung. Gedenkband zur Erinnerung an Walter Eucken*, Freiburg, 561–77.

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

Levine, R. (1997), "Financial Development and Economic Growth: Views and Agenda", *Journal of Economic Literature* 35, 688–726.

Matthes, J. and C. Schröder (2004), "Business Regulation in International Comparison – Aggregating World Bank 'Doing Business' Data", *CESifo Forum* 6, no. 1, 42–49.

Murphy, K. M., A. Shleifer and R. W. Vishny (1991), "The Allocation of Talent: Implications for Growth", *Quarterly Journal of Economics* 106, 503–30.

Nicoletti, G. and S. Scarpetta (2003), "Regulation, Productivity and Growth: OECD evidence", *OECD Economics Department Working Papers*, no. 347, Paris.

OECD (2004a), *Employment Outlook*, Paris.

OECD (2004b), *OECD Science, Technology and Industry Scoreboard 2003*, Paris, http://www1.oecd.org/publications/e-book/92-2003-04-1-7294 [Download: 11-22-2004].

OECD (2004c), *Wirtschaftsbericht Deutschland*, Paris.

OECD (2004d), *Lernen für die Welt von morgen. Erste Ergebnisse von PISA 2003*, Paris.

OECD (2004e), *Education at a Glance*, Paris.

OECD (2004f), OECD-Education Database, URL: http://www1.oecd.org/scripts/cde/members/EDU_UOEAuthenticate.asp [Download: 1-20-2005].

Romer, P. M. (1990), Endogenous Technological Change, *Journal of Political Economy* 98, 71–102.

Romer, D. (1996), *Advanced Macroeconomics*, McGraw Hill, New York.

Sapir, A., P. Aghion, G. Bertola, M. Hellwig, J. Pisani-Ferry, D. Rosati, J. Vinals and H. Wallace (2004), *An Agenda for a Growing Europe. The Sapir Report*, Oxford University Press, Oxford.

Scarpetta, S. and T. Tressel (2004), "Boosting Productivity via Innovation and Adoption of New Technologies: Any Role for Labor Market Institutions?", *Policy Research Working Paper Series*, no. 3273, The World Bank.

Van Ark, B. (2003), "The Productivity Problem of the Dutch Economy: Implications for Economic and Social Policies and Business Strategy", *Research Memorandum GD-66*, Groningen Growth and Development Centre, Groningen.

World Bank (2004), *Doing Business in 2005 – Removing Obstacles to Growth*, Washington DC.