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Innovation in the Business Sector

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ABSTRACT/RÉSUMÉ

INNOVATION IN THE BUSINESS SECTOR

This paper draws together the key findings from separate detailed analyses of the determinants of R&D, patenting and the commercial introduction of innovations in the business sector in order to identify the policies, institutions and framework factors that provide the most effective means of supporting innovation. The evidence suggests that there is a clear role for framework conditions, framework policies and specific science policies, both independently and in interaction with each other. Policies that raise the absorptive capacity of the economy (the capacity to understand and make use of new knowledge) are likely to have dual benefits, not only helping to stimulate new innovative activities, but also helping to maximise the benefits to be gained from the existing stock of knowledge. Potential policy trade-offs also need to be taken into account. Some policies that offer benefits for current innovation also have costs that could adversely affect future incentives to innovate. Others have trade-offs when considered in combination. Cross-country differences in the level of R&D intensity are shown to be closely correlated with cross-country differences in science policies and institutions. Framework conditions and policies have an important influence when accounting for cross-country differences in the rate of change of R&D intensities over time.

JEL Classification: O30, O38
Keywords: Innovation, R&D, patenting, innovation policies, framework conditions

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L'INNOVATION DANS LE SECTEUR DES ENTREPRISES

Ce document fait la synthèse des principales conclusions d'un certain nombre d'analyses détaillées sur les déterminants de la R&D, du brevetage et de l'introduction commerciale des innovations dans le secteur des entreprises, afin de pouvoir mettre en évidence les facteurs politiques, institutionnels et structurels qui offrent les meilleures conditions pour soutenir l'innovation. On constate que les conditions et politiques structurelles comme les politiques spécifiques de la science ont une importance évidente, tant isolément qu'en interaction les unes avec les autres. Les politiques qui visent à agir sur la capacité d'absorption de l'économie (c'est-à-dire à améliorer la capacité de comprendre les nouveaux savoirs et d'en faire usage) ont généralement un impact doublement positif : non seulement elles contribuent à stimuler de nouvelles activités d'innovation, mais elles aident en outre à maximiser le bénéfice que l'on peut tirer du stock de connaissances existantes. Il faut aussi tenir compte des éventuels inconvénients que peuvent avoir ces politiques. Certaines mesures de soutien aux innovations en cours ont aussi des coûts qui risquent de pénaliser les incitations à l'innovation dans l'avenir. D'autres ont des effets pervers si elles sont combinées. On démontre que les écarts d'intensité de R&D d'un pays à l'autre sont étroitement corrélés aux différences observées au niveau des politiques scientifiques et des établissements de recherche. Les conditions cadres et les politiques jouent un rôle non négligeable pour expliquer les différences d'un pays à l'autre dans le rythme d'évolution de l'intensité de R&D au fil du temps.

Classification JEL : O30, O38
Mots-clef : Innovation, R&D, politiques de l'innovation, conditions cadres

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INNOVATION IN THE BUSINESS SECTOR

by

Florence Jaumotte and Nigel Pain[1,2]

1. Introduction and summary

1.1 Key issues

1. Innovation has become a central concern of public policy. The perceived importance of innovation for long-run economic growth is such that many governments have introduced new policy targets for research and development (R&D) expenditures. It has also fostered the development and use of benchmarking indicators of national innovation performance in order to evaluate progress towards these targets. Support for the importance of innovation is provided by past work at the OECD, notably for the Growth Study (OECD, 2001 and 2003a). This identified a clear positive linkage between private sector R&D intensity and growth in per capita GDP. Other research has also shown the importance of the science infrastructure and foreign knowledge and innovations for productivity growth in both developed and developing economies.

2. The concept of innovation is extremely broad and encompasses a wide range of diverse activities. An implication of this is that many different policies can affect different stages of the innovation process, and can potentially do so in different ways. The objective of this paper is to draw together the key findings from Jaumotte and Pain (2005a, b and c) in order to help identify the policies, institutions and framework factors that can provide the most effective means of supporting innovation. Such policies need not be ones that are the most likely to favour the development of new innovative ideas. It is at least as important to ask whether optimal use is being made of the existing stock of knowledge as it is to ask how that stock can be expanded. A recognition of the dual effects that many policies can have on knowledge creation and knowledge diffusion, and a better understanding of the trade-offs that may be involved, should help in the design of procedures for evaluating how effectively the overall national policy framework supports innovation.

3. The justification for public policy interventions in the innovation process is that market failures mean that the level of innovation expenditure will otherwise be less than socially desirable. In particular, the ability of competitors and potential follow-on innovators to benefit from new knowledge can mean that

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1. The authors are members of Country Studies Division I and the Macroeconomic Analysis and Systems Management Division, respectively, of the Economics Department of the OECD. The authors are grateful to Mike Feiner, Jorgen Elmeskov, Pete Richardson, Peter Jarrett, Giuseppe Nicoletti, Sean Dougherty, Daniel Malkin, Dirk Pilat, Jerry Sheehan, Mosahid Khan and Christopher Heady for helpful comments and suggestions, and to Diane Scott for assistance in preparing the document.

2. This study was carried out as part of the ongoing work in the Economics Department on structural adjustment, economic growth and innovation, and was previously presented as part of a wider research report to Working Party 1 of the OECD Economic Policy Committee and to the OECD Committee for Science and Technology Policy. Other parts of that report are also available in the Economics Department Working Paper series, see Jaumotte and Pain (2005a, b and c).

the social rate of return to investments in knowledge exceeds the private rate of return. Even if this were not the case, imperfections in financial markets, the unavailability of skilled researchers, or simply a lack of awareness about research advances in other sectors and other countries can mean that worthwhile innovation expenditures will be foregone in the absence of policy intervention.

4. However, such interventions need not always be successful, and there is a risk that at times they can even act as a disincentive for innovation, if not carefully designed. For instance, measures to raise the necessary finance for public spending and tax reliefs for R&D may have economic costs and can involve substantial deadweight losses. The existence of support programmes for particular types of innovative activity may at times also lead to lobbying for changes in their scale and scope, independently of whether the original objectives of the programmes have been met.

5. The natural questions to ask are whether there are net benefits from the wide range of policies used by all governments to try and stimulate national innovation performance, how large they may be and which policies are most effective. The influence of specific policies for innovation has to be judged against the background of the wider framework conditions in each economy. For example, it would be surprising if the framework factors that are known to influence the timing and level of fixed capital expenditures by firms did not also have some influence on other types of corporate expenditure, such as R&D. In the absence of supportive framework conditions, there may be very little that specific innovation policies can achieve. But equally, supportive framework conditions may not suffice to promote innovation if specific science policies are not well designed and market failures remain.

6. This paper provides an overview of cross-country differences in innovation and discusses the extent to which they can be accounted for by particular policies. The analysis focuses on economy-wide framework conditions and policies, as well as a small number of widely used public policies for innovation -- fiscal incentives for R&D,[3] the promotion of basic research in the non-business sector, the encouragement of collaborative research, protection for intellectual property rights and education and labour market policies to improve the availability of human resources for science and technology.[4] The effectiveness of these policies is examined using new cross-country empirical estimates of the determinants of business sector research and development expenditures and also of patenting. The principal focus is on the business sector, both because it accounts for the largest single share of innovation activities in most OECD countries, and because it is expenditures in this sector which have been found to have the most direct long-run influences on economic growth (OECD, 2003a). The analyses of R&D and patenting are complemented by a separate cross-section analysis using data from the Third European Community Innovation Survey (CIS3) to identify the principal influences on the proportion of successful innovators and the share of turnover accounted for by new products.

7. An implicit assumption made in much of the wide range of literature on innovation policies is that more innovation-related activity is always better than less. In principle this need not be the case, especially if there is unnecessary duplication of research efforts. Equally, patents need not be of equal value to each other. Excessive patenting can also hamper cumulative innovation processes. What is important is to obtain the maximum benefits from the resources being used in the research process and address any market or policy failures that may be holding back the level of research that takes place.

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3. In this paper the term fiscal incentives represents all direct financial measures that have a specific budgetary cost for government. These include both direct public spending on private R&D as well as tax reliefs for R&D.

4. These policies are employed in many countries. They are also the ones for which it is easiest to obtain broadly comparable cross-country data over time. The exclusion of other policies from the analytical work should not be taken as a sign that they do not matter for innovation.

8. The remainder of the paper is as follows. Section 2 provides a short overview of some of the key cross-country differences in innovation indicators and policies for OECD economies, and discusses the extent to which they are connected to each other. The effectiveness of the key science-related policies and institutions is discussed in Section 3, and the importance of different framework conditions and framework policies is discussed in Section 4.

9. This summary paper is complemented by three other research papers describing the work referred to in greater detail. An overview of the existing literature about the effectiveness of selected public policies to support innovation is provided in Jaumotte and Pain (2005a). A detailed econometric analysis of the determinants of R&D and patenting and the occupational labour market for scientists and engineers is contained in Jaumotte and Pain (2005b), who make use of a panel data set for 19 OECD countries over the period from 1982 to 2001. The factors determining business sector demand for researchers and the wages they receive are explored in detail because of their significant effects on innovation expenditures and potential endogeneity to the other factors that also affect innovation. A separate econometric analysis of the principal policy influences on the eventual commercial introduction of innovations, as recorded in the CIS3, is contained in Jaumotte and Pain (2005c). This analysis draws on cross-sectional data for 1998-2000 for a sample of 16 European economies.

1.2 Main conclusions

10. The empirical analyses in the paper point to a number of clear conclusions. These are summarised below, as well as in Table 1 and Figures 1-2. The main analytical findings from the empirical analysis are that:

- There is a clear role for framework conditions, framework policies and specific science policies in supporting innovation, both independently and in interaction with each other.
- There is a positive empirical relationship between all the different stages of the innovation process -- research, development, patenting and implementation. Cross-country differences in R&D are significantly positively correlated with subsequent cross-country differences in patenting levels and the successful introduction of innovative products.
- Policies that raise the absorptive capacity of the economy (the capacity to understand and make use of new knowledge) have dual benefits, not only helping to stimulate new innovative activities, but also helping to maximise the benefits to be gained from the existing stock of knowledge.
- It is important to take account of potential policy trade-offs in evaluating the effectiveness of specific policies. Some policies that offer benefits for innovation also have costs that could adversely affect innovation. Others have trade-offs when considered in combination.

11. The most important findings concerning framework policies are:

- Reducing the strength of anti-competitive product market regulations provides a significant stimulus to business sector expenditure on R&D, reflecting higher incentives to innovate. Rigid regulations are also found to adversely affect the level of patenting and the proportion of firms who are successful innovators. A low level of restrictions on foreign direct investment is a helpful means of improving cross-border knowledge transfers.
- Ensuring stable macroeconomic conditions and low real interest rates helps to encourage the growth of innovation activity, all else being equal.
- The availability of internal and external finance is an important determinant of innovation expenditures, both at the research stage and during commercial development. Improved corporate

profitability and higher stock market capitalisation both have a positive effect on innovation expenditures. This implies that a wide range of additional policies could have an important indirect effect on research activities.

12. The main findings for the science policies considered are that:

- Policies and conditions that help to make knowledge more accessible can be very effective. Two examples stand out in the analysis in this paper -- the ability to obtain an enhanced understanding of ideas developed in other countries by accessing the foreign knowledge stock, and greater collaboration between the business and the non-business sectors. A package of measures to raise the availability of human resources for science and technology could, collectively, be very effective.
- Expanding research activities in public research organisations helps to support business sector research activities, although these benefits can be mitigated if it also acts to push up the wage costs of researchers in the business sector. Achieving a significant expansion in business and non-business research activities simultaneously will be difficult, unless accompanied by measures to raise the supply of human resources for science and technology. Even then, such a rise in research activities may be feasible only if spread out in time.

Table 1. **Long-run effects of a one standard deviation increase in policy and framework factors**[1]

Measured in percentage change of the dependent variable

	Business R&D spending	Total domestic patents
Science policies and institutions		
B-index[2]	-1¾	-6
Subsidies for private R&D / GDP ratio	¼	-3
Share of business funding in non-business R&D	8¼	2½
Non-business R&D / GDP ratio	7¼	3¾
IPR index	1½	8
USA real wage of researchers	-3¼	-¾
Years of education	1	¾
Economic conditions		
Profit / GDP ratio	5¼	4¼
Private sector credit / GDP ratio	-1½	-3¼
Equity financing / GDP ratio	5¾	10
Foreign R&D stock / GDP ratio	12¾	6
Openness	-5¾	-4¼
Import penetration	-¼	0
Real interest rate	-5	-2¾
Real exchange rate	-3	-1¾
Framework policies (decrease)		
Product market regulation	9	4¼
FDI restrictions	..	13
Employment protection legislation	1	6½

1) This table is taken from Table 8 of Jaumotte and Pain (2005b). The standard deviation is the average of within-country standard deviations, and the effects of a one standard deviation increase in policy and framework factors are evaluated at the sample mean of the variables.
2) The B-index is defined as one minus the rate of tax subsidy for R&D.
Source: OECD estimates

- Fiscal incentives can be effective, especially when firms face financial constraints, but their overall impact on innovation appears comparatively small. Tax reliefs for private R&D are found to provide a stronger stimulus, on average, than direct government subsidies. Account should also be taken of the potential costs of any fiscal offsets that might be needed if fiscal incentives for R&D were to be raised significantly, and the scope for activities to be re-labelled as R&D in order to qualify for support. However the empirical evidence does not suggest that, to date, more generous tax reliefs have led to a significant re-labelling of non-patentable activities as R&D.
- The case for further strengthening of intellectual property rights for patent holders in OECD countries appears weak, especially in those that already have comparatively strong patent protection.[5] The evidence suggests that it will lead to more patenting, but have almost no effect on R&D expenditures. It could also result in a lower level of labour efficiency in the business sector. Excessively strong intellectual property rights can be counterproductive, reducing, but not eliminating, the benefits of enhanced product market competition.

13. The analysis in the paper also highlights the potential importance for innovation performance of policies that affect the location of internationally mobile researchers and research activities. Comparatively little quantitative analysis has been undertaken about the determinants of either the migration of highly skilled researchers or the determinants of the international location of R&D facilities. The increasing role that both play in the diffusion of knowledge across national borders, and in determining the availability of resources for innovation in home and host countries, suggests that an improved understanding of location choices would be worthwhile.

14. A further point that should be emphasised is the need for patience when considering innovation policies. Many of the concepts involved and many of the objectives of policy are difficult to measure, and the time taken for the level of innovation activities to change substantially can be lengthy. The difficulties of predicting the sources of new ideas, and the frequent uncertainty of their commercial applications at the time of discovery suggests that policies should be directed, as far as possible, to creating a favourable research environment. Information about the existing body of knowledge has to be available and accessible to potential users, and the skills and incentives required to make best use of it have to exist.

15. The overall impact of different policies and institutions on R&D and patenting is shown in Table 1, which reports the impact of a one standard deviation change in each factor, evaluated at the sample mean.[6] Figures 1 and 2 use the estimated equations to provide an indication of the extent to which particular factors account for the cross-country dispersion of R&D intensity in 2000, and the differences in the growth rate of R&D intensity between 1991 and 2000. During this period there was little aggregate change in OECD business sector R&D as a share of OECD GDP, despite the diversity of changes within individual countries.[7]

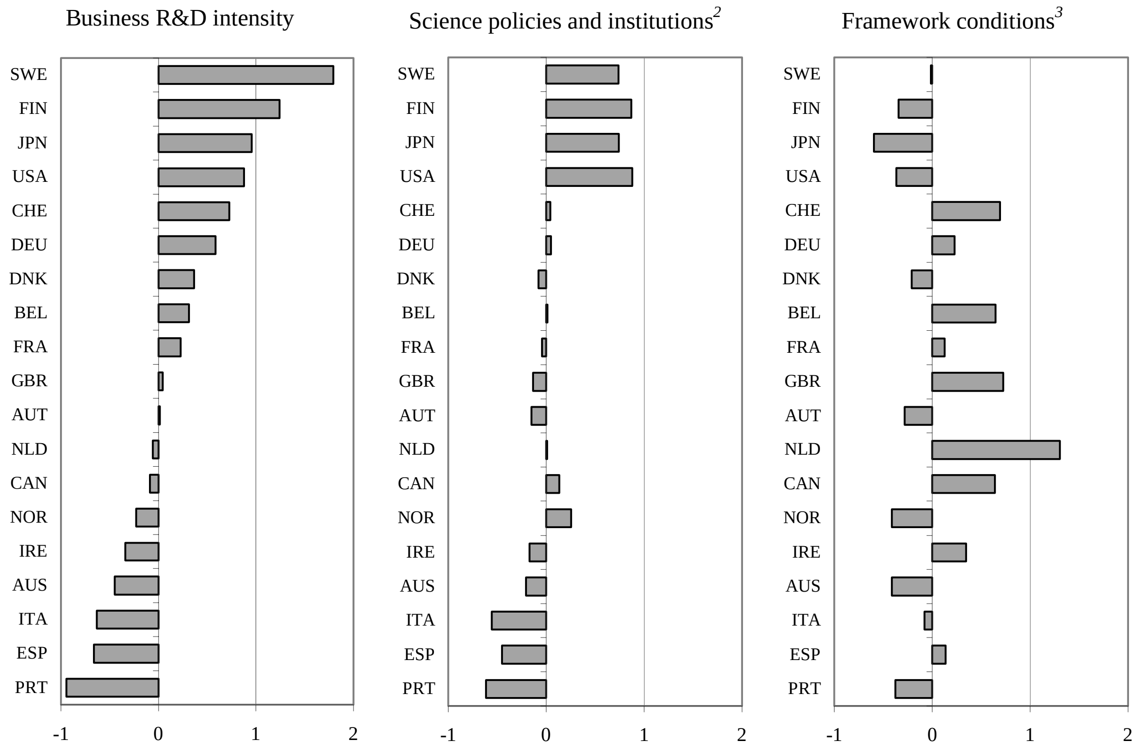
5. As discussed elsewhere in the paper, patent protection has many dimensions. The aggregate index used in the empirical analyses does not enable distinct conclusions to be drawn for different dimensions of patent protection, such as the enforcement of patent rights and the types of activities that are patentable.

6. The use of average within-country sample standard deviations is necessary because of the scale of differences in some factors across countries and the feasible extent to which some policies may be changed. Calculations with the cross-country standard deviation, whether evaluated using the full sample of observations or a cross-section at a particular point in time, can be especially problematic when using indicator variables whose upper or lower limit is bounded.

7. The countries shown in Figures 1 and 2 are those for which sufficient data existed over time to enable them to be included in the panel data sets used by Jaumotte and Pain. (2005b).

Figure 1. **Contribution of science policies and framework conditions to cross-country differences in business R&D intensity, 2000**

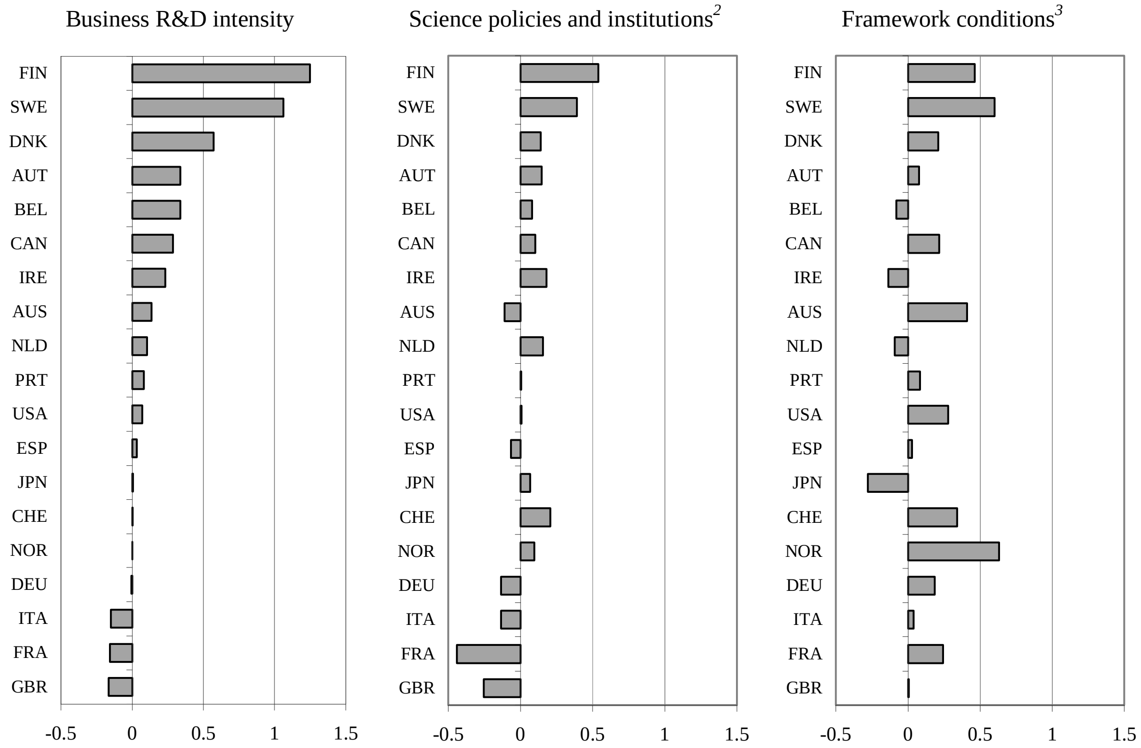
Measured in percentage point deviation of R&D intensity relative to average OECD R&D intensity[1]



1) The contributions have been calculated based on the long-run parameters from the equation reported in column 3 of Table 3 in Jaumotte and Pain (2005b). The OECD average refers to the unweighted geometric average of the OECD countries included in the sample (due to the logarithmic regression model).
2) Science policies include R&D tax incentives, subsidies for private R&D, business funding of non-business R&D, non-business R&D intensity, intellectual property rights, the share of scientists in total dependent employment and absorptive capacity (see definition in Jaumotte and Pain (2005b)).
3) Framework conditions include financial factors, real interest rates, real exchange rates, foreign exposure (foreign R&D stock and openness), import penetration, and product market regulation.
Source: OECD estimates.

Figure 2. **Contribution of science policies and framework conditions to growth in R&D intensity, 1991-2000**

Measured in percentage point deviation of R&D intensity between 1991 and 2000[1]



1) The contributions have been calculated based on the long-run parameters from the equations reported in column 1 of Table 6 and in column 3 of Table 3 in Jaumotte and Pain (2005b).
2) Science policies include R&D tax incentives, subsidies for private R&D, business funding of non-business R&D, non-business R&D intensity, intellectual property rights and absorptive capacity (see definition in Jaumotte and Pain (2005b)).
3) Framework conditions include financial factors, real interest rates, real exchange rates, foreign exposure (foreign R&D stock and openness), import penetration, product market regulation, employment protection legislation, human capital and the domestic economy-wide average wage.
Source: OECD estimates.

16. The main message from Figure 1 is that cross-country differences in the level of R&D intensity are closely correlated with the estimated cross-country differences in science policies and institutions.[8] Framework conditions and policies are equally, and sometimes more, important for some countries, especially those that are comparatively open to external trade. Figure 2 suggests that framework conditions and policies are relatively more important than science policies and institutions for determining cross-country differences in the rate of growth of R&D over time.

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8. Figure 1 shows the contribution of each of the main influences to the percentage point deviation in R&D intensity from the OECD average in 2000. These calculations should be seen as illustrative of the principal influences rather than precise estimates as they are based only on the long-run parameters from the econometric results in Jaumotte and Pain (2005b). The difference between the actual deviations and the (multiplicative) contributions shown in the Figure reflects additional dynamic effects, country-specific fixed effects and the unexplained component of national R&D intensities. The calculations may also be sensitive to the choice of time period. The OECD average refers to the geometric average of the countries included in the sample. It is used as a convenient means of summarising the estimation results and cross-country differences. This does not mean that the OECD average need be the most relevant benchmark for all countries when setting policy objectives.

17. It is also clear from the Figures that country-specific factors can play an important role in determining national innovation performance. Such idiosyncrasies imply that framework and science policies can differ in their effectiveness across countries. This is something that cannot be captured fully in an empirical approach of the kind used in this paper. It suggests that country-specific policy recommendations should seek to take account of differences in the characteristics of national innovation systems, and the efficacy of policy delivery, as well as the average differences in particular policies and institutions brought out in the econometric analysis.[9] Consideration might also need to be given to the overall policy mix, especially if innovation policies have multiple objectives. Some policies may work well together even if they are not particularly beneficial in isolation.

Box. Industry composition and cross-country differences in R&D intensity

A common method of estimating the sources of cross-country differences in R&D intensities is to decompose the change in aggregate R&D intensity into two components, one representing the differences between countries within individual sectors, and the other representing differences stemming from differences in the sectoral mix across economies. Recent examples of exercises of this type can be found for Canada (ab Iorweth, 2005) and the United Kingdom (Griffith and Harrison, 2003; Abramovsky *et al*., 2004).

The rationale for such decompositions is that economies may have similar levels of intensity in particular industries but very different aggregate R&D intensities, reflecting differences in the importance of each industry in each economy. For example, countries in which pharmaceuticals have a higher share in total value added are likely to have a higher level of R&D intensity, all else equal, The opposite is likely to be true for economies with large natural resource-based industries with comparatively low R&D intensities.

The findings from such studies vary across country pairs. The estimates in ab Iorweth (2005) suggest that between a quarter and a third of the aggregate differences in R&D intensity between Canada and the United States can be accounted for by different industrial structures. In contrast, Griffith and Harrison (2003) estimate that almost all of the gap in R&D intensity between the United Kingdom and the United States can be accounted for by within sector differences. Abramovsky *et al.* (2004) estimate that half of the differences in business sector R&D intensity between the United Kingdom and Germany can be attributed to differences in industrial structure.

Given such findings, it might be surprising that this issue is not discussed in greater detail in this paper. Yet even if such findings were important, the policy implications would be unclear, especially for governments seeking to raise the aggregate rate of R&D intensity in their economies. Estimates of this type are just accounting estimates of differences in R&D intensity. They do not provide an indication of whether, at the margin, there are worthwhile innovation projects being foregone because of policy or institutional failures, nor an indication of the most appropriate policies to draw on in order to raise innovation activities.

A second limitation of the accounting approach is that it can be very sensitive to the level of detail used. Typically, the proportion of the gap in R&D intensities explained by differences in industrial composition has been found to rise as the extent of disaggregation rises. Inclusion of service sector industries can have a marked bearing on the outcome of any study, both because of their high share in value added and because of their comparatively low R&D intensity.

A third limitation of the accounting approach is that it is more appropriate for understanding differences at a fixed point in time, rather than over time. In part this is because the share of individual sectors in total value added is endogenous, as R&D can be an important determinant of productivity growth and hence output growth. Griffith and Harrison (2003) find that almost all the differences in business sector R&D intensities between the United Kingdom and the United States over the period 1981-2000 stem from within industry differences. Yet for individual sub-periods, the contribution of the within industry effect is found to be much smaller.

Despite these limitations, it would still seem prudent to include an indicator of cross-country differences in industrial structure in any empirical analysis. Yet when a measure of the share of the high-tech sector in total value-

9. Cross-country differences in industrial structure and average firm size may also be important in understanding differences in R&D intensities. Countries can have similar intensities in each industry and still have a different aggregate intensity if the shares of industry value added in GDP are different. Jaumotte and Pain (2005c) use CIS3 data to highlight a number of differences between innovation performance in manufacturing and services and innovation in large and small firms. But the share of value added accounted for by high-tech industries was found to be insignificant in the empirical analysis of aggregate business sector R&D, once other factors are taken into account (Jaumotte and Pain, 2005b). This issue is discussed further in the Box.

added was included in the R&D model of Jaumotte and Pain (2005b, Table 2), it was found to have a positive, but statistically insignificant coefficient. A similar finding was also obtained in many of the estimates reported by Falk (2004).

The most likely explanation for this empirical result is that panel data models typically include fixed country effects. In effect, this type of model seeks to explain the factors accounting for fluctuations in R&D intensity (or patenting per capita) around the sample mean for each country. As many of the policy and institutional factors accounting for such fluctuations are already included in the model, there is not necessarily any remaining role for the (fairly constant) industrial structure effects. Instead, their impact is likely to be one of the factors picked up by the fixed effect. Common movements over time across countries in the share of high-tech industries in total value added will also be picked up by the annual time dummies also included in the model. So it is not possible to conclude that differences in industrial structure are unimportant from the regressions reported in the paper. However, it is unlikely from the reported decompositions of the estimated effects that they play a large role in explaining differences across OECD countries. Such a conclusion appears consistent with much of the recent evidence from accounting-type studies.

2. Cross-country differences in innovative activity

2.1 What is innovation?

18. Formally, innovation is considered to be the successful development and application of new knowledge.[10] As such, innovation is distinct from invention. This strict definition emphasises that innovation requires much more than greater inputs into the research process. Fixed capital investments are often necessary to be able to produce and utilise new products and processes, as are workforce training and organisational restructuring. In practice, it is convenient to view innovation as a process that encompasses many different activities, ranging from initial research (R&D) through to the development of prototypes and the registration of inventions (patents) and eventual commercial applications. This process is rarely linear (Romer, 2005). Many ideas may not come to fruition. Patents may be taken out on inventions arising from outside the formal R&D process. Commercial innovations can include many ideas, such as designs and trademarks which are not reflected in either patents or R&D. But in practice, the empirical work for this paper suggests that there are positive linkages between each stage of the innovation process. So policies that affect R&D will also have some impact, in years to come, on the level of patenting and the commercial introduction of innovative products, although they are not the only driving factors.

19. The remainder of this section provides a short overview of cross-country differences in a number of key indicators of innovative activity, together with an indication of how they have changed over time. A detailed account of recent science policy initiatives can be found in OECD (2004b). Where appropriate information is included for the largest possible number of OECD economies. In some cases the absence of particular data series led to some countries being omitted from the detailed econometric analyses.[11]

2.2 Research and development

20. The share of R&D expenditures in GDP is one of the most widely used indicators to compare the research activities of different countries. The principal focus of this paper is on R&D performed by the

10. A more detailed definition of innovation and research activities can be found in OECD (1997). Innovations can be organisational as well as technological; only the latter are considered in this paper.

11. As far as possible the data for the innovation indicators have been adjusted to correct for breaks in coverage and classification changes.

business sector. Not only does this represent the single largest share of national R&D, but it is also the major source of the cross-country dispersion in aggregate R&D expenditures. Figure 3 shows one measure of business R&D intensity, based on the ratio of business sector R&D to GDP. On average across OECD countries, about 1.4% of GDP was spent on business performed R&D in 2001. The countries with the highest R&D intensities were Sweden, Japan, Finland, the United States and Switzerland; those with the lowest were the economies of southern Europe and Mexico.

21. Business R&D intensity rose in most countries between the early 1980s and the late 1990s. The growth rate was especially strong in Finland, Sweden, Iceland and Denmark. On the other hand, negative or slow growth was observed in several countries that started with a relatively high R&D intensity at the beginning of the 1980s. Figure 4 indicates that there has been little significant convergence in cross-country business R&D intensity between 1981 and 2001. On average, business R&D intensity grew faster in the 1980s than since 1990.

22. There is a positive cross-country correlation between the shares of business and non-business R&D in GDP. Figure 5 shows the average shares of business and non-business R&D in GDP over 1996-2000. The correlation between the two series highlights the possibility that there may be particular institutional or structural features in many economies which tend to either stimulate or hold back both kinds of investment in R&D. The GDP share of non-business R&D is larger than, or of a similar magnitude to, business R&D in about a third of the countries; amongst those countries included in the econometric analyses, examples include Portugal, Australia, Iceland, Spain and Italy.

23. The evolution of non-business R&D intensity over time is shown in Figure 6. In the OECD as a whole, non-business R&D intensity was close to 0.7% of GDP in 2001, approximately half the size of business sector R&D. In most countries the share of non-business R&D in GDP in 2001 was little different from the share in the early 1980s. Iceland and, to a lesser extent, Finland, Portugal and Greece are notable exceptions. The growth of non-business R&D slowed sharply in the late 1980s and early 1990s, helped by reduced defence-related expenditures in some countries, but has since recovered, driven by an expansion of R&D undertaken in the education sector.[12]

24. A key component of R&D spending, and a key input in the innovation process, is R&D personnel, especially researchers.[13] The share of business sector researchers in economy-wide dependent employment is shown in Figure 7. On average in 2001, about ½ per cent of dependent employees were classified as being in an R&D occupation in the business sector, just under two-thirds of whom were researchers. The ranking of countries in Figure 7 is broadly similar to that based on business R&D intensity, even though wage expenditures account for only around one-half of all business sector expenditure on R&D. Countries which had high growth rates in the share of researchers over the period shown also had high growth rates of R&D intensity.

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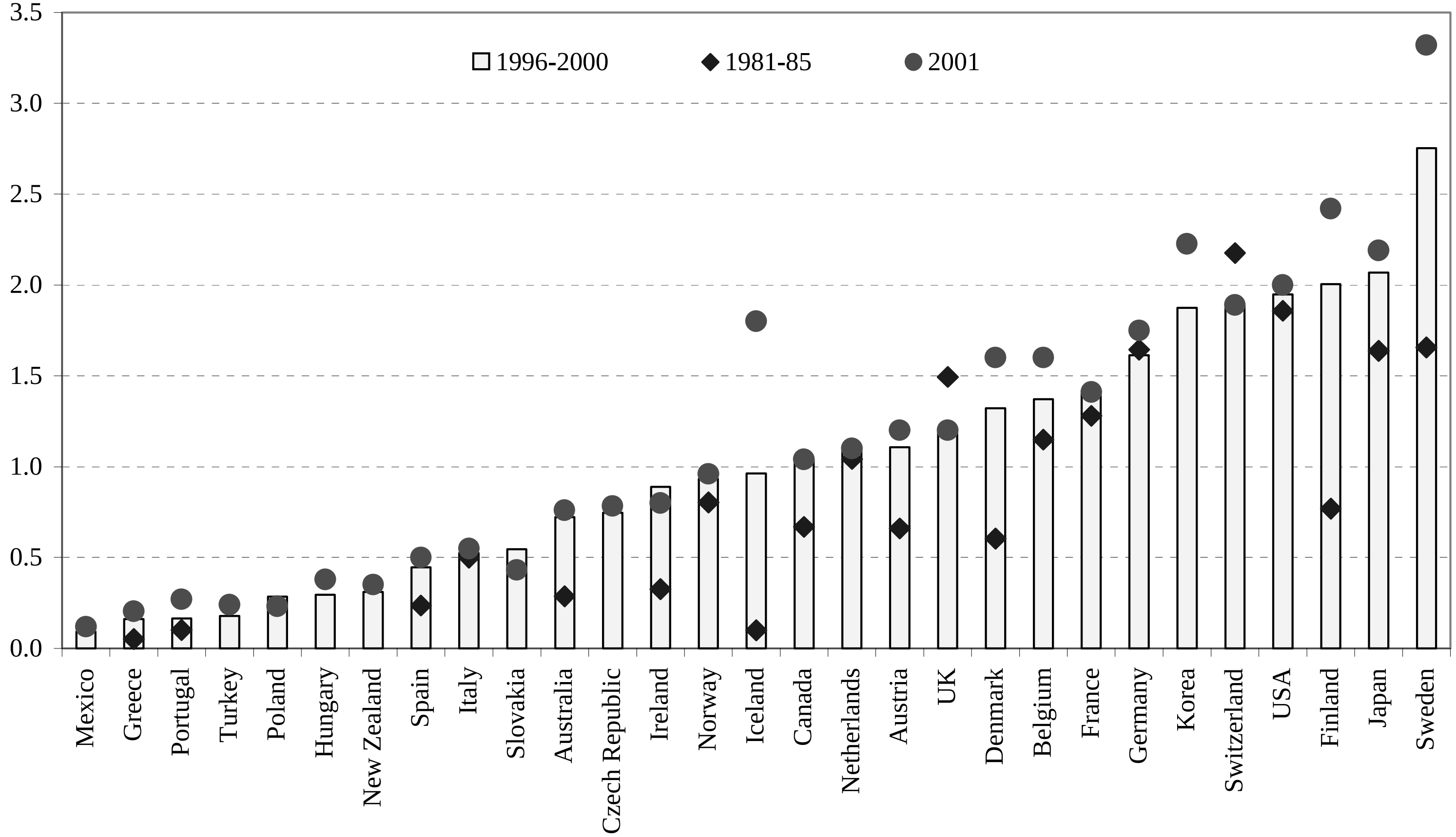
12. The sectoral classification of particular types of research institutions may differ across countries.

13. R&D personnel include, in addition to researchers, technicians and support staff.

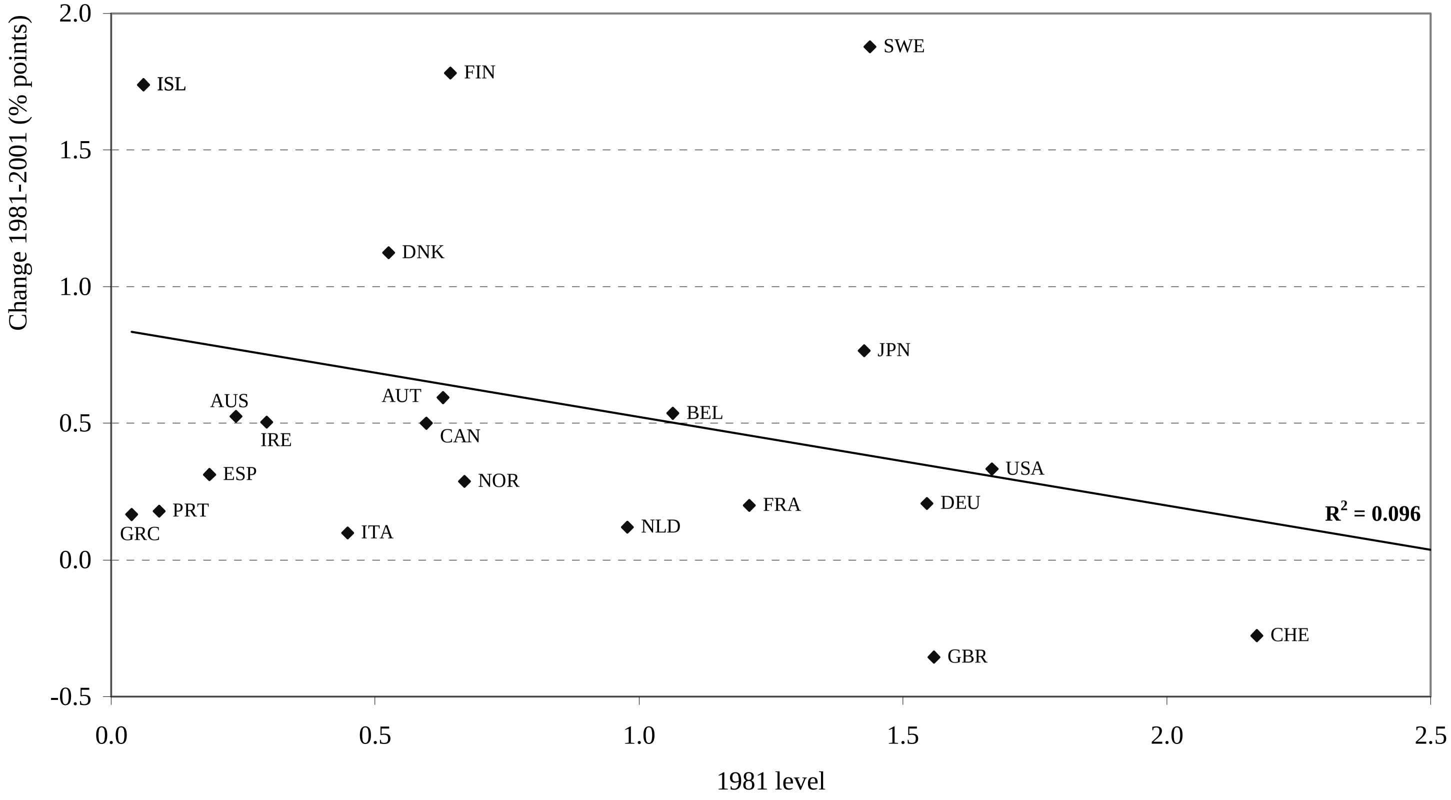
Figure 3. **Business Sector R&D Intensity**

% of GDP, average per annum



Source: OECD Main Science and Technology Indicators database and R&D database.

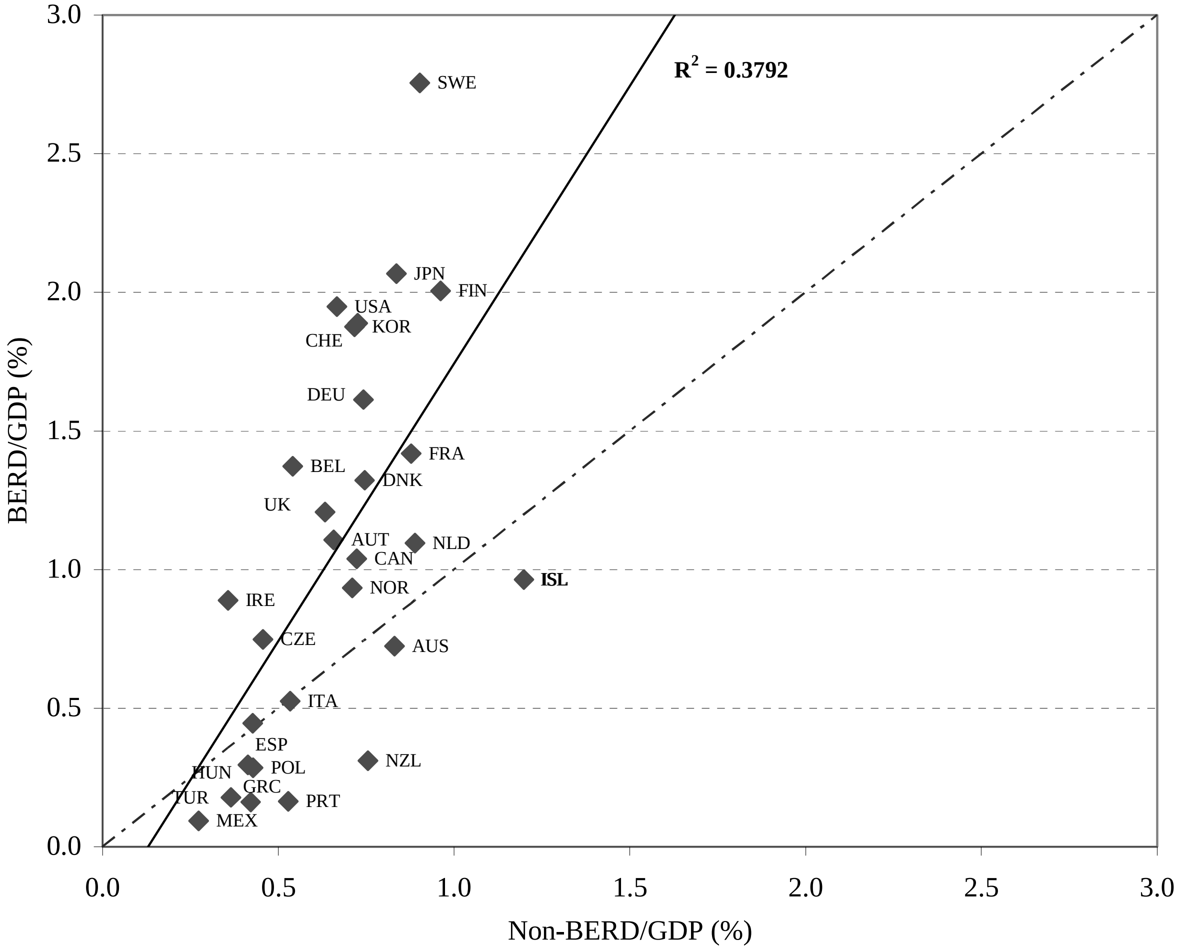
Figure 4. **Convergence in Business Sector R&D Intensity**



Source: OECD Main Science and Technology Indicators database and R&D database.

Figure 5. **Business and Non-business R&D Intensity, 1996-2000**[1]

Average per annum

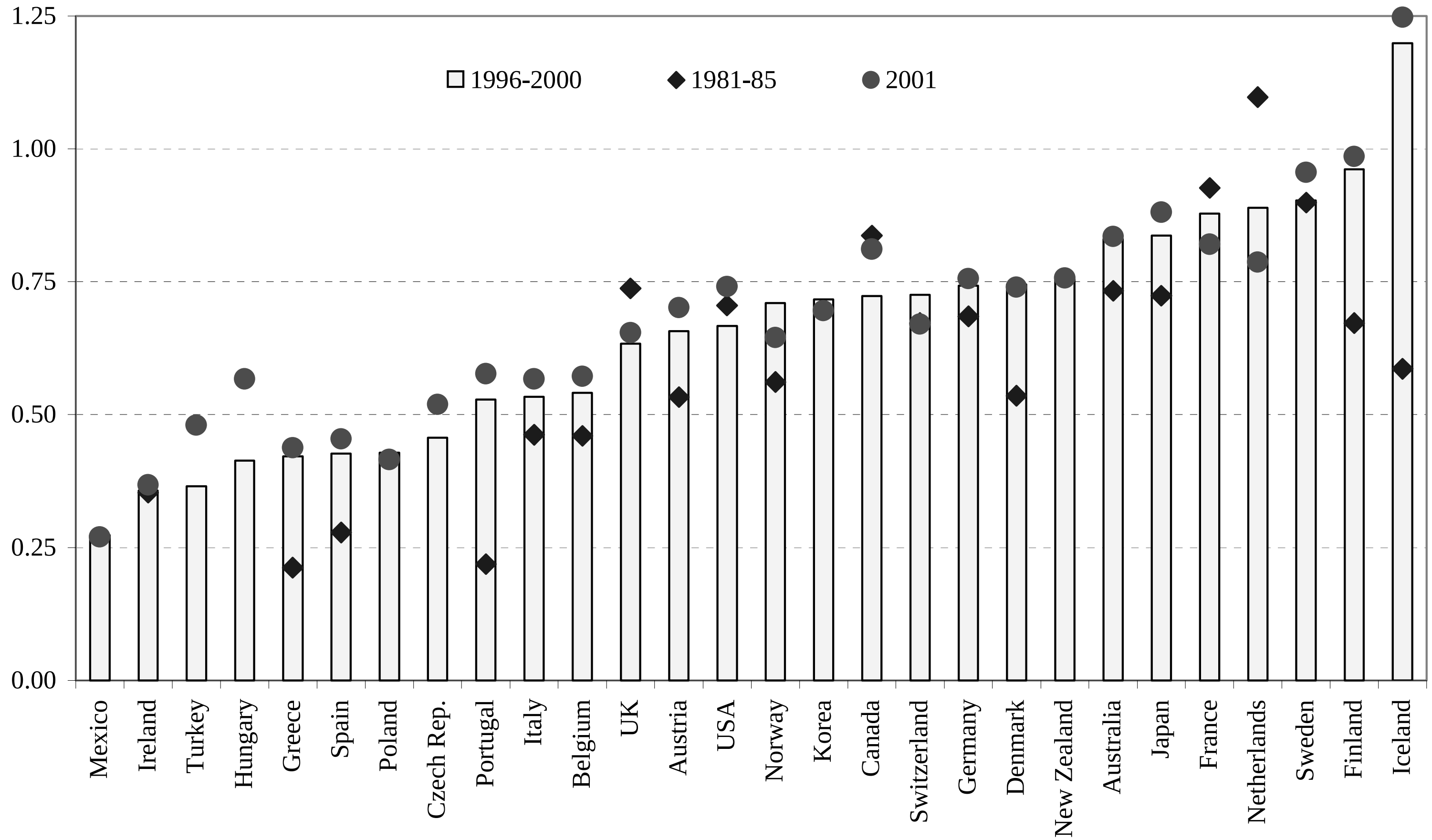


1) The regression line excludes Iceland, which is an important outlier.

Source: OECD Main Science and Technology Indicators database and R&D database.

Figure 6. **Non-Business R&D Intensity**

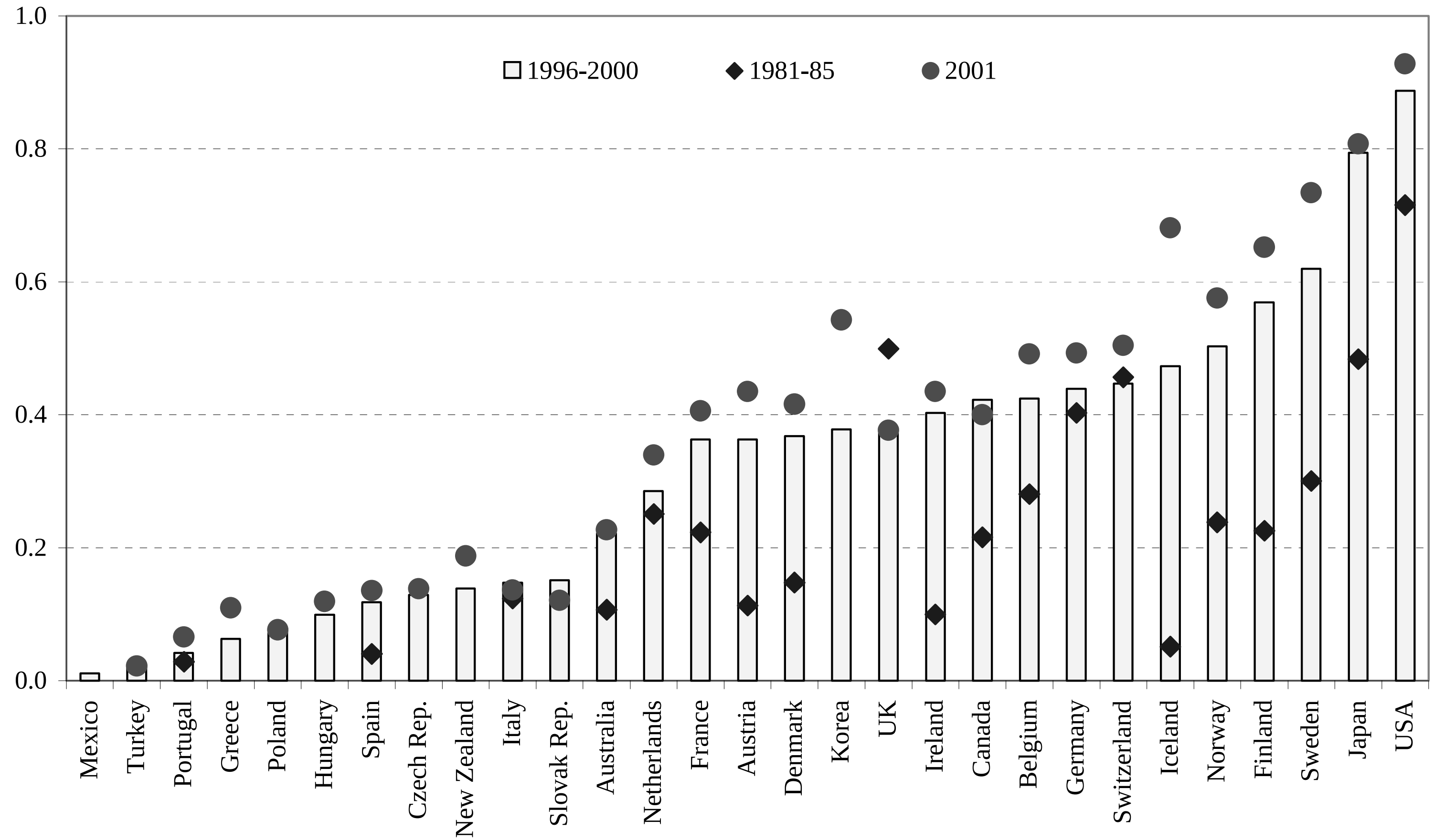
% of GDP, average per annum



Source: OECD Main Science and Technology Indicators database and R&D database.

Figure 7. **Business Sector Researchers**

% of total dependent employment, average per annum



Source: OECD Main Science and Technology Indicators database and OECD Analytical Database.

25. R&D-related indicators are an imperfect measure of innovative performance. Many other types of expenditure help to lead to successful commercial development of innovations, including fixed investment and training. Information on these other sources of spending is available for a subset of European countries from the Community Innovation Survey. This shows that intramural R&D accounts for a small fraction of total innovation spending, especially in small firms and in service sectors (Figure 8).[14] A further limitation of R&D data is that they may not reflect the productivity of the resources used, particularly if returns to scale are not constant and/or market competition is imperfect. The limitations of input measures as proxies for innovation underline the importance of looking at direct output measures.

2.3 Patents

26. The most commonly used measure of innovation output is patents. These can be purely domestic patents, patents taken out in a larger regional market, or patents that are taken out in several countries with different patent regimes. The latter, referred to as patent families, are likely to have a higher (and more uniform) value since the patentee is willing to take on the additional costs and delay related to the extension of protection to other countries.[15] However they may exclude a significant part of valuable innovation output. Different measures of patents can thus provide useful information and two are used in the econometric work in the paper.

27. Figure 9 shows a measure of domestic (or regional) patents per million of working-age population for each country.[16] Patents per capita have clearly increased in all countries over the past two decades. The comparison of levels is affected by differences in procedures and standards across patenting offices. For example, in Japan, a different patent application had (until recently) to be submitted for each claim; in other countries multiple claims can be made in each application.[17] This helps to explain the much larger level of patenting applications in Japan. Countries with the highest patents per capita are typically ones with high levels of business R&D intensity. Two exceptions are Iceland and Korea, who appear to have a low patenting propensity relative to their R&D spending.

28. The OECD indicator of triadic patents is one specific type of patent family, covering patents that have been applied for at the European Patent Office and Japanese Patent Office and applied for and granted at the United States Patent and Trademark Office (OECD, 2004a). This shows a similar picture to the previous measure of patenting (Figure 10), although, as would be expected, the levels of patenting are lower in all countries. Again, with the exceptions of Iceland and Korea, the countries with the highest patents per capita are those who have the highest business R&D intensity. Triadic patents per million US$ spent on R&D at 2000 prices, are shown in Figure 11. This is one possible indicator of the efficiency of R&D expenditures. Switzerland, the Netherlands and Germany are the three countries with the three highest ratios of patenting to R&D expenditure. New Zealand is notable for having a comparatively high ratio of patents per million dollars of R&D expenditure, even though the aggregate R&D intensity is comparatively low.

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14. The figure compares the frequency of intramural R&D spending with the frequency of other types of innovation spending. The frequency of a type of spending is defined as the ratio of the proportion of firms undertaking that type of spending to the sum of the proportions of firms undertaking each type of innovation spending. A firm can undertake simultaneously various types of innovation spending.

15. Moreover, comparability across countries is enhanced by the fact that the patent numbers are less likely to be affected by the specific characteristics of national patent offices.

16. For the European countries, the measure of patents is based on patents applied for at the European Patent Office (EPO). This may understate the level of purely national patents, as some of these are unlikely to go to the EPO.

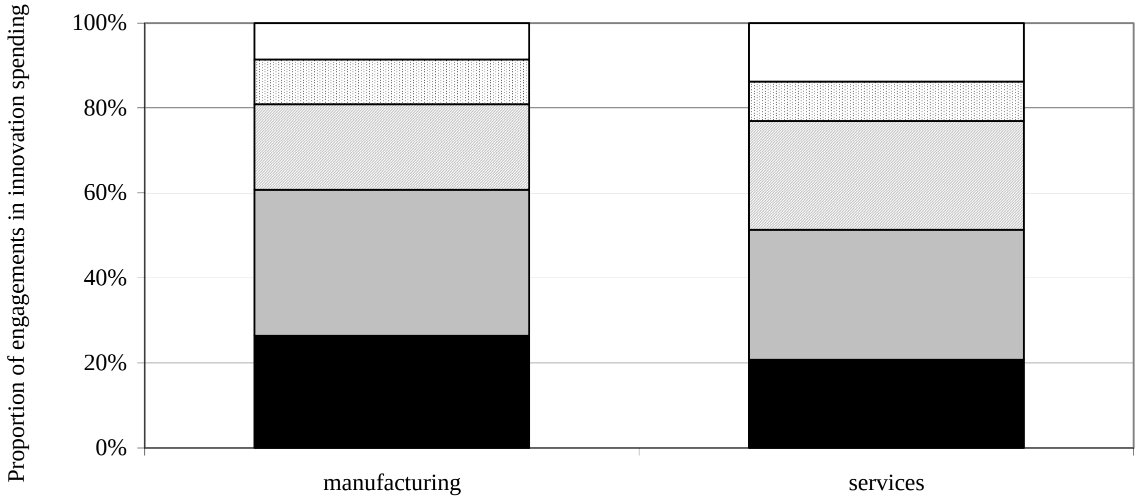
17. The claim defines the monopoly rights that the applicant is attempting to obtain for the invention. Further details are given in OECD (2004a).

Figure 8. **Composition of innovation spending[1]**

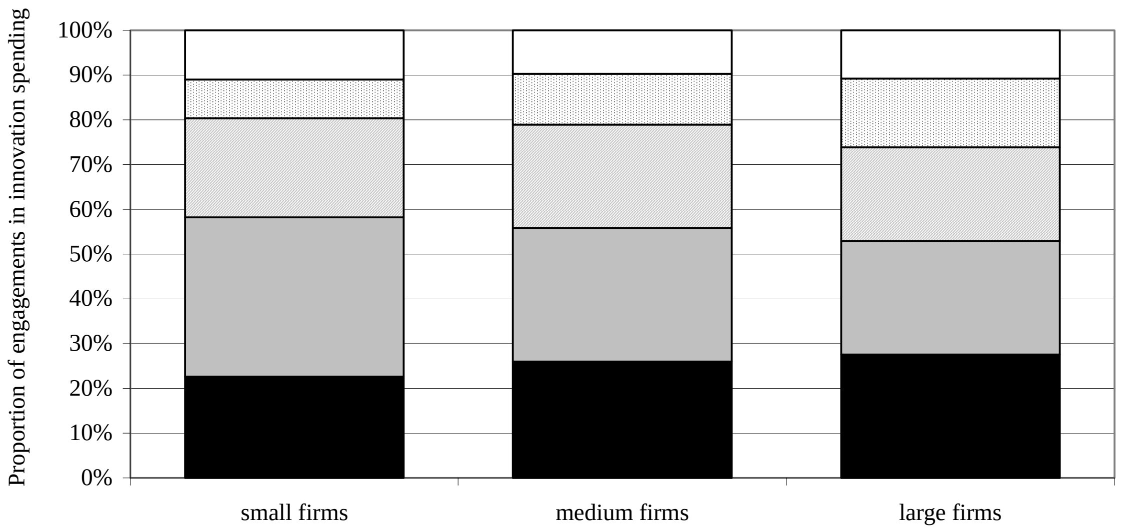
Community Innovation Survey countries, 1998-2000

■ intramural R&D ▩ machinery ▢ training ▒ extramural R&D □ external knowledge

Panel A: **Manufacturing versus services[2]**



Panel B: **By firm size[3]**

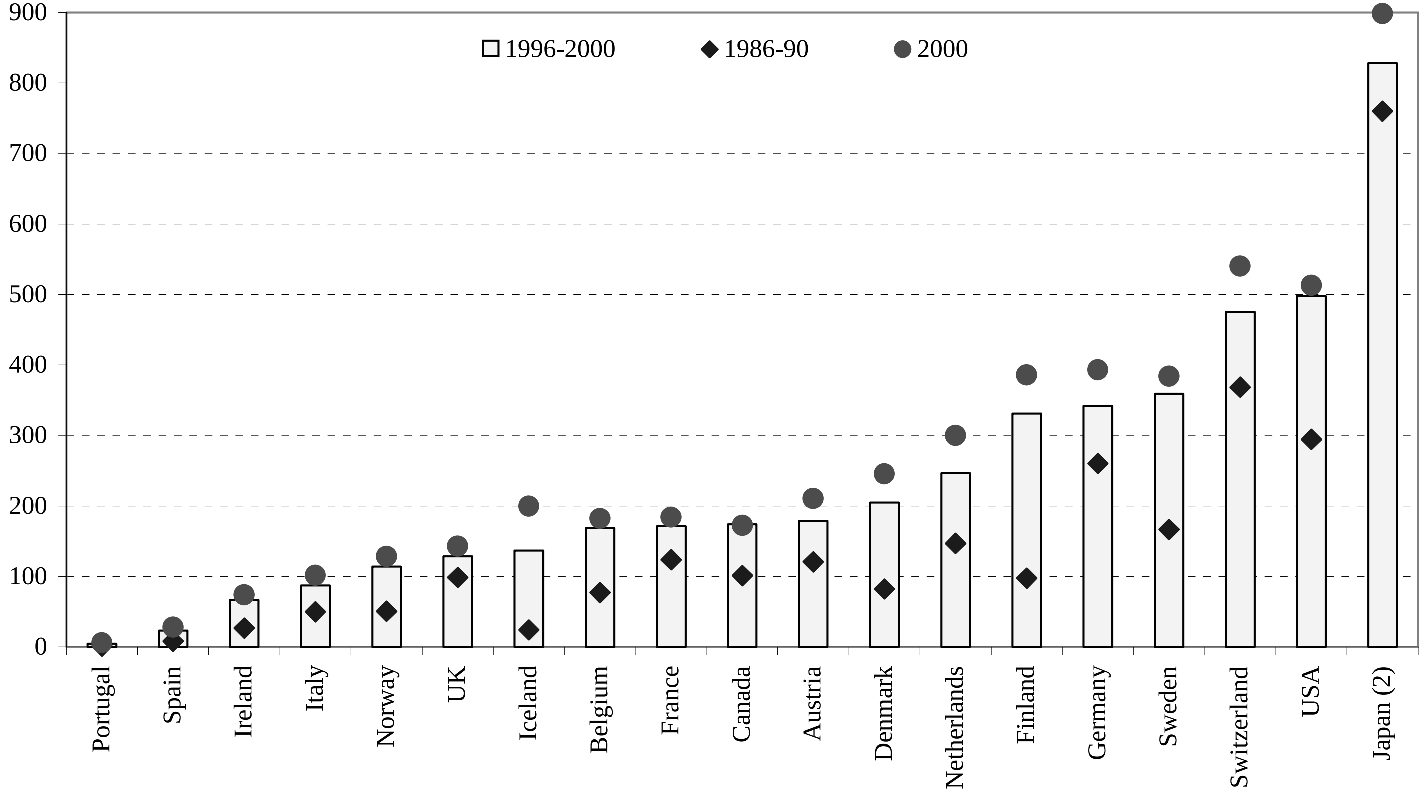


1. The proportion of engagements in innovation spending is calculated as the ratio of the proportion of firms engaging in a specific type of innovation spending to the sum of the proportions of firms engaging in the various types of innovation spending. Firms can engage in multiple forms of spending.
2. The sectoral aggregates are calculated by taking a weighted average of the individual countries' observations for the sector and using as country weight the country's share in the total population of firms working in the sector in all included countries.
3. The size class aggregates are calculated by taking a weighted average of the individual countries' observations for the size class and using as country weight the country's share in the total population of firms working in the size class in all included countries.

Source: Community Innovation Survey 3 (European Commission).

Figure 9. **Total Patents per million of working age population**[1]

Average per annum; residency of inventor



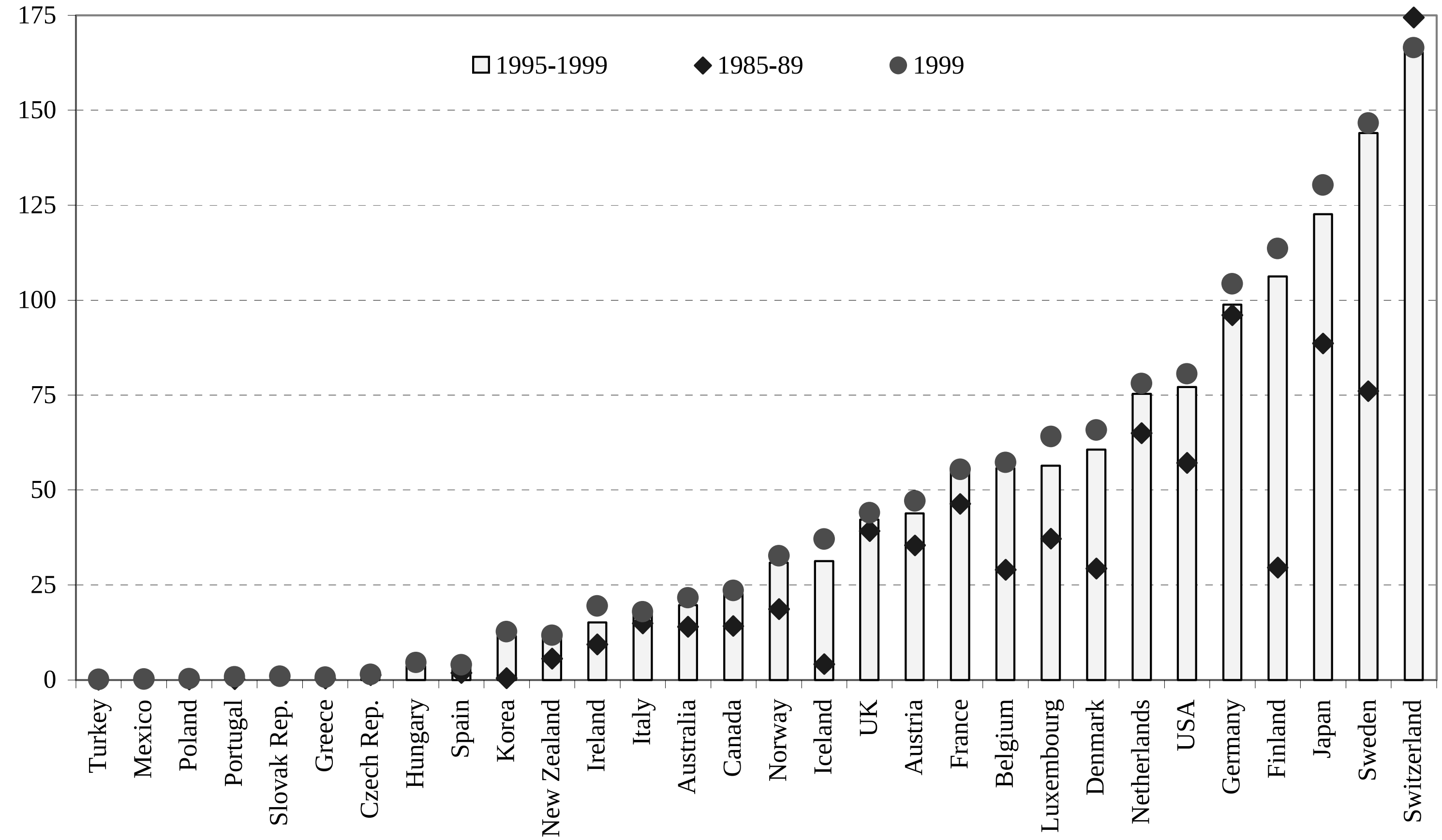
1) Total patents are patent applications at the EPO for European countries, patent applications at the JPO for Japan, and patent grants (based on priority dates) at the USPTO for the United States and Canada. Australia is not included in the figure because comparable data on patent applications at the Australian patent office were not readily available.

2) As explained in Section 2.3 of the main text, the level of patent applications at the JPO is much larger because a different application has to be filed for each claim. The patent applications for Japan were divided by five to fit the scale of the figure. Their level is not comparable with the level of patent applications of other countries.

Source: OECD Patent database; JPO and Maskus and McDaniel (1999) for data on Japan.

Figure 10. **Triadic Patents per million of working age population**

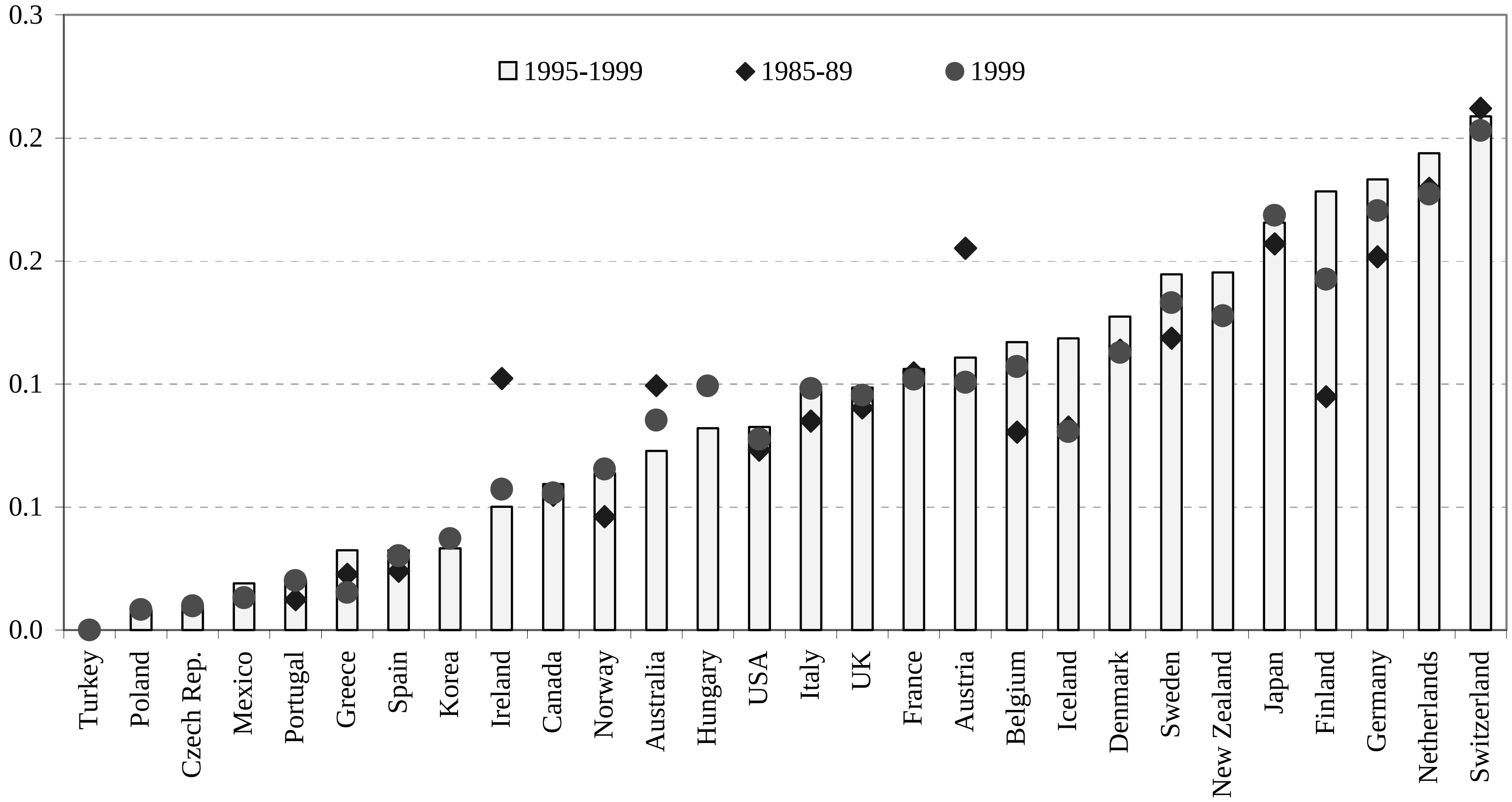
Average per annum; residency of inventor



Source: OECD Patent database.

Figure 11. **Triadic Patents per million of business R&D spending**

2000 PPP-adjusted R&D spending, average per annum



Source: OECD Patent database and Main Science and Technology Indicators Database. R&D deflated using national GDP deflators.
The patent data include patents taken out by all sectors; R&D includes only R&D by business.

2.4 Evidence from the European Community Innovation Survey

29. Patents capture only a part of innovation output. Many inventions are not patented. Companies can, and frequently do, choose to keep commercially sensitive information secret. Other inventions can be protected by trademarks, design registrations and copyrights. The propensity to patent for any given level of inventions may also vary according to the costs of patenting. Using information from the Community Innovation Survey (CIS3), Figure 12 shows for a subset of European countries that the use of patent applications as a means of protection is small relative to the total use made of protection methods.[18] This is especially true in services and for small firms, suggesting that indicators based on patents will tend to underestimate innovation for these categories. An additional limitation is that patents are only an intermediate measure of research output; many may never be implemented commercially. So it is also useful for assessments of innovation performance to examine data on the actual implementation of innovations. The CIS3 provides this for a subset of sixteen European countries.[19]

30. Innovation is defined in the CIS as the successful introduction of a new or significantly improved product or process. Two different indicators of this can be constructed. The first measures the share of firms who are successful innovators; the second measures the share of new products in turnover. Figures 13 and 14 show the values of these indicators for the period 1998-2000. In Figure 13, the proportion of successful innovative firms is compared with the proportion of firms having engaged in spending on intramural (intra-company) R&D. There does not appear to be a strong cross-country correlation between innovative success and intramural R&D.

31. The share of new products in turnover provides a further measure of innovation performance (Figure 14). This indicator embodies information about the number of innovations per successful firm, but may also reflect differences in market structure, intensity of competition and the diffusion of innovations. It is interesting to note that the ranking of some countries shifts radically compared with the ranking based on the proportion of successful innovative firms. As discussed below, cross-country differences in this measure of innovation have little correlation with those on the other measures of innovation.

32. The CIS also provides information about the relative importance of true innovations and imitations for the subset of product innovations. A "true" innovation is the introduction of a product which is new both to the enterprise and to the market. Imitation refers to the introduction of products which are new only to the enterprise, not to the market. On average 45% of successful product innovators are imitators (Figure 15). While true innovation is likely to be the eventual driver of long-term productivity growth, the rate of diffusion and imitation have a key effect on the speed at which new knowledge spreads to the whole economy. The countries with the highest proportion of successful product innovators also have a high diffusion rate, as proxied by the extent of imitation.

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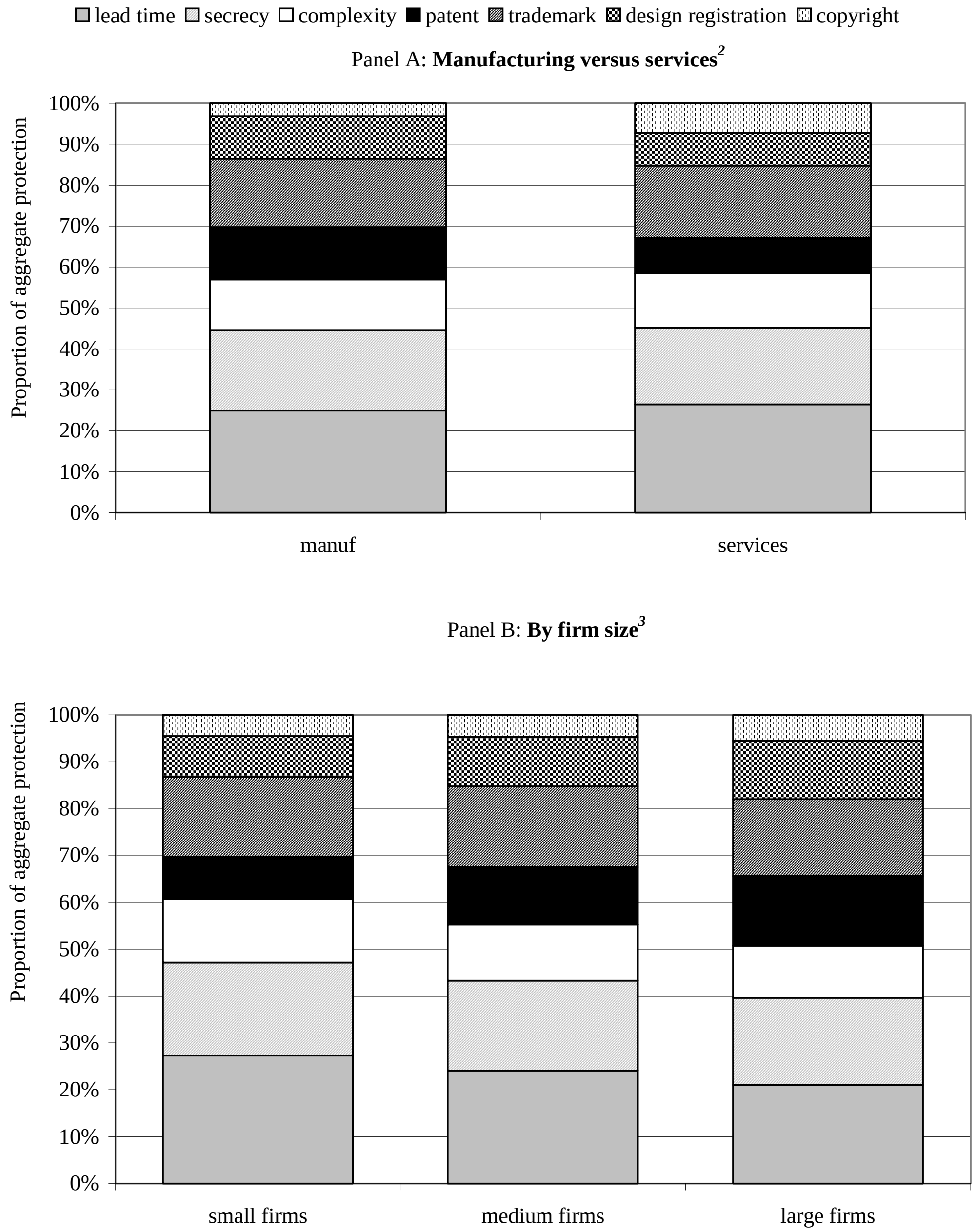
18. The frequency of the use of a particular mode of protection is defined as the ratio of the proportion of firms using that mode of protection to the sum of the proportions of firms using each mode of protection. A firm can make use of several modes of protection at a time.

19. Care has to be taken when interpreting cross-country comparisons made with the aggregated data in CIS, as there are differences in the sample sizes used in the respective national components of the survey, as well as in the national response rates. This issue is discussed further in Jaumotte and Pain (2005c).

Figure 12. **Choice of protection method**[1]

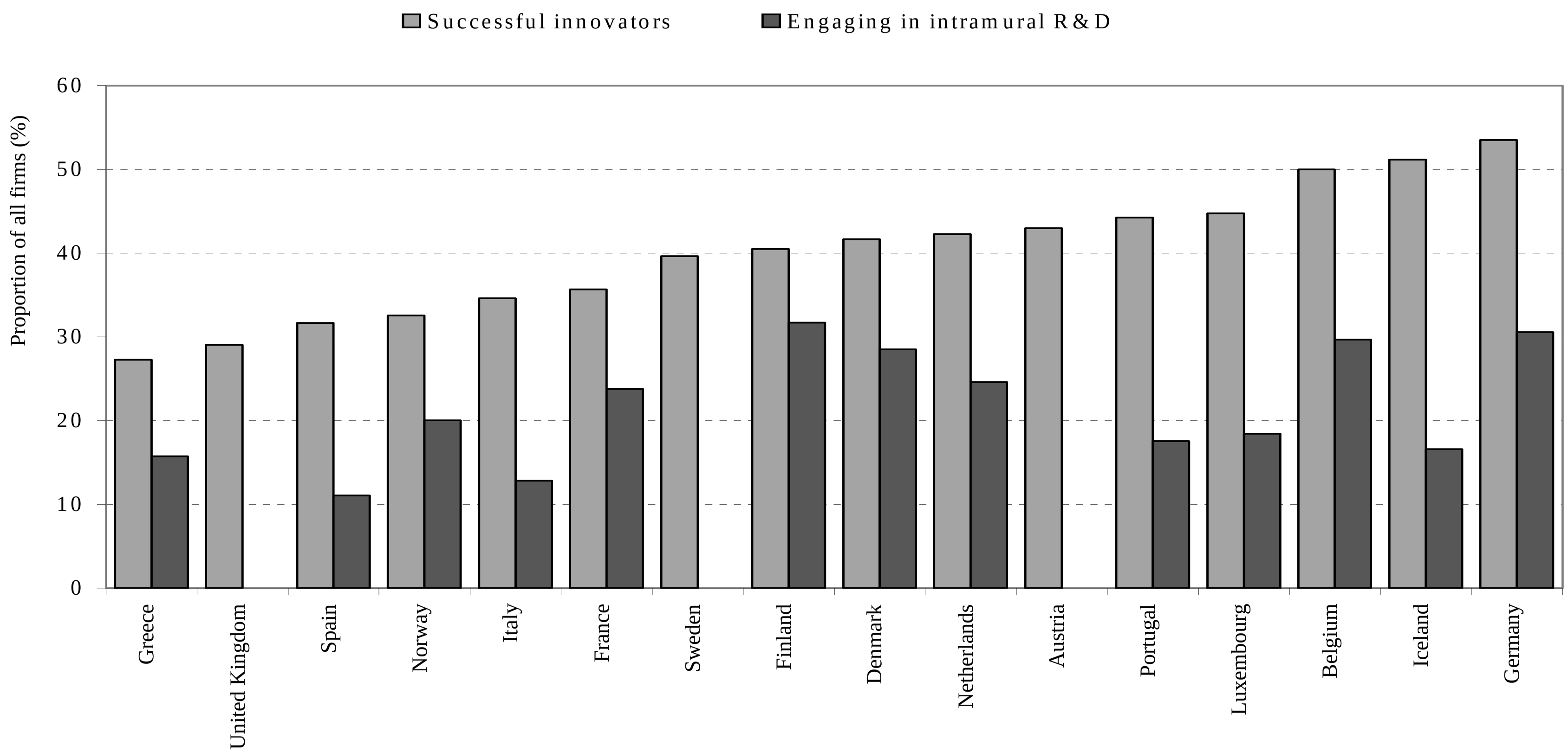
Community Innovation Survey countries, 1998-2000



1. The proportion of a specific type of protection in aggregate protection is calculated as the ratio of the proportion of firms using this specific type of protection to the sum of the proportions of firms using the various types of protection. Firms can use different forms of protection.
2. The sectoral aggregates are calculated by taking a weighted average of the individual countries' observations for the sector and using as country weight the country's share in the total population of firms working in the sector in all included countries.
3. The size class aggregates are calculated by taking a weighted average of the individual countries' observations for the size class and using as country weight the country's share in the total population of firms working in the size class in all included countries.

Source: Community Innovation Survey 3 (European Commission).

Figure 13. **Comparison of countries' innovative performance by various measures, 1998-2000**[1]

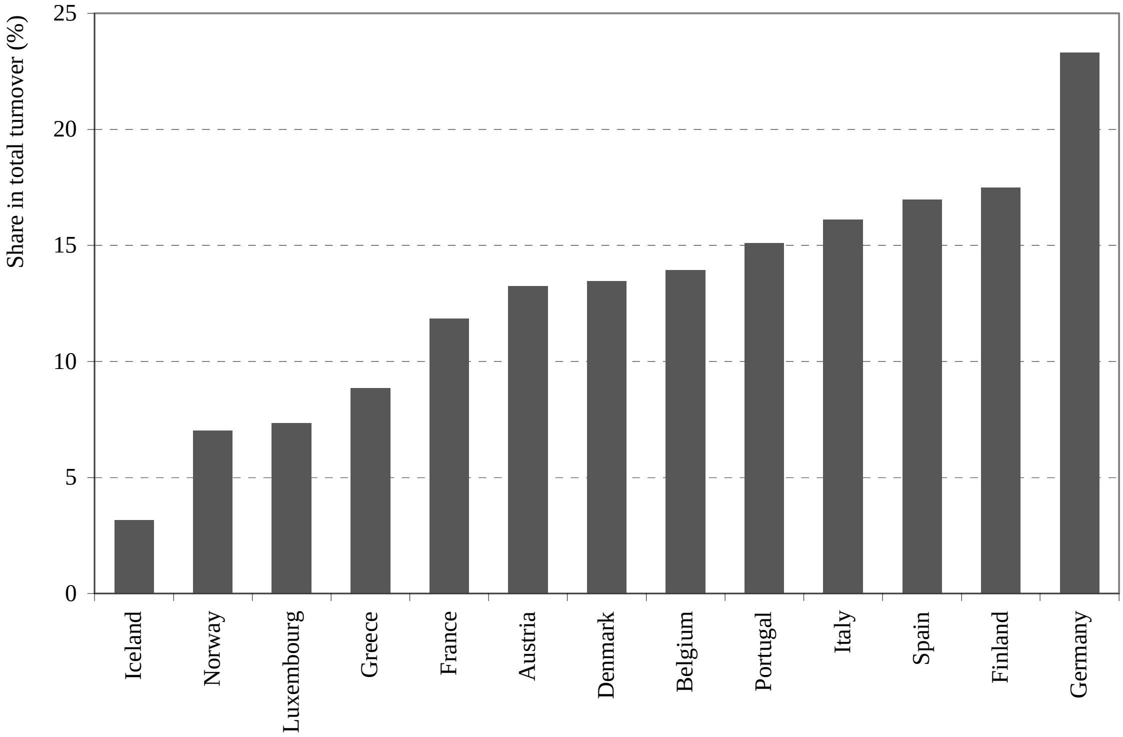


1) Care has to be taken when interpreting cross-country comparisons made with the aggregated data in CIS, as there are differences in the sample size used in the respective national surveys. For Austria, Sweden, and the United Kingdom, no data are available on the proportion of fims which engage in intramural R&D.

Source: Community Innovation Survey 3 (European Commission).

Figure 14. **Share of new products in turnover**[1]

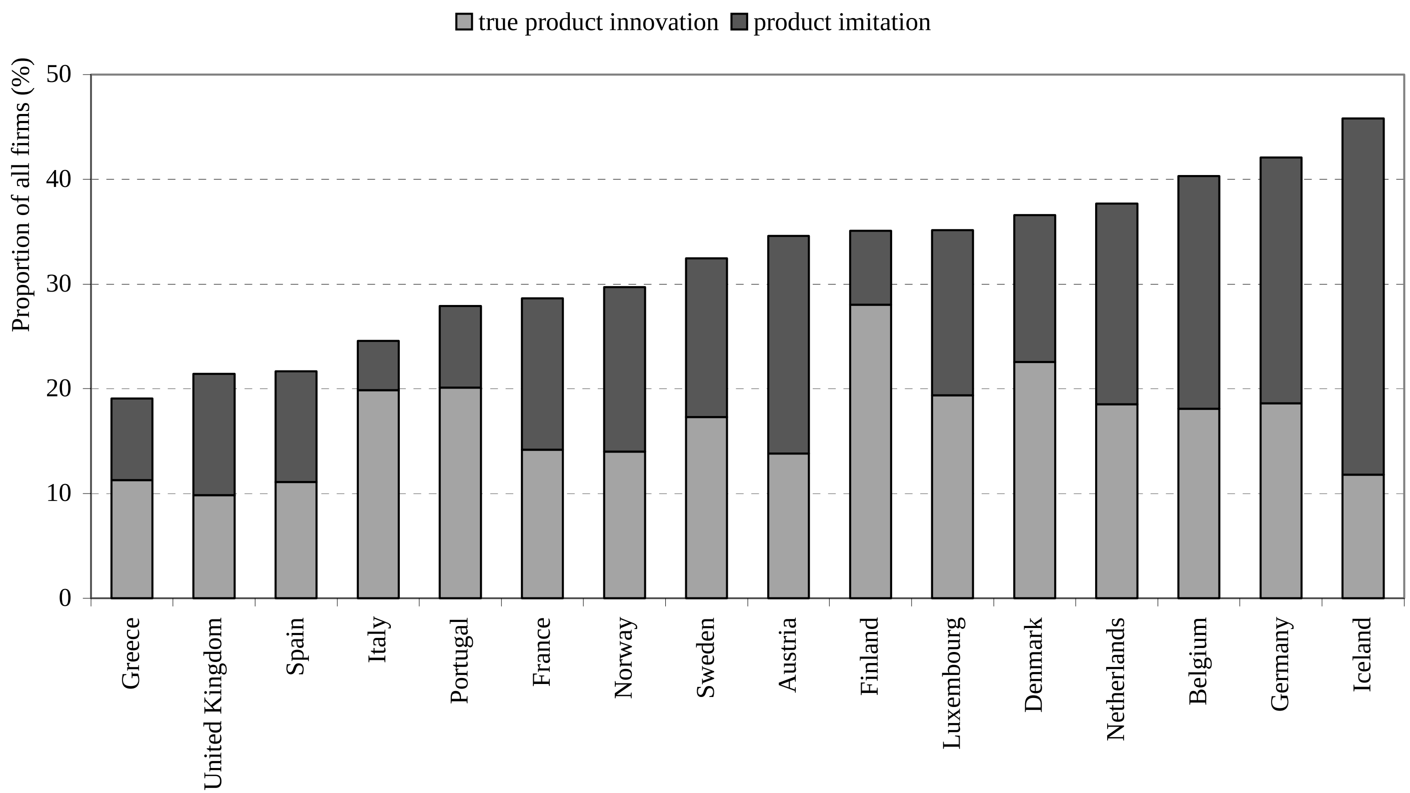
1998-2000



1. Care has to be taken when interpreting cross-country comparisons made with the aggregated data in CIS, as there are differences in the sample size used in the respective national components of the survey.
Source: Community Innovation Survey 3 (European Commission).

Figure 15. **Pure innovation and imitation**[1]

1998-2000



1. Care has to be taken when interpreting cross-country comparisons made with the aggregated data in CIS, as there are differences in the sample size used in the respective national components of the survey. Pure innovation refers to the proportion of firms which have introduced a product new to the market.
Imitation refers to the proportion of firms which have introduced a product new to the enterprise but not new to the market.
Data on the distinction between pure innovation and imitation are available only for product innovations, and not for process innovations.
Source: Community Innovation Survey 3 (European Commission).

2.5 How closely related are individual innovation indicators?

33. A preliminary exercise to the broader empirical analysis is to understand the possible linkages between different measures of innovation and to establish whether there are clear differences in the relative performance of countries when evaluated using different indicators of innovation. The ranking of a sample of twenty countries according to their R&D intensity, the share of R&D personnel in total dependent employment and triadic patents per million of working age population is reported in Table 2.

34. Both business and non-business R&D intensity make significant contributions to cross-country differences in aggregate R&D intensity, with the former especially important. The correlation between total R&D intensity and business R&D intensity is almost one, compared with 0.73 for non-business R&D intensity. The ranking of countries according to their shares of scientists and R&D employees in total dependent employment, and according to the number of triadic patent applications per capita also appear closely related, with one or two exceptions. After taking a simple average of the rankings by total R&D intensity, the scientists share and triadic patents, the average ranking of countries is not very different from the simple ranking based on total R&D intensity.

35. Although it should be kept in mind that this way of presenting the information is only a qualitative representation and does not take account of the scale of differences between countries, the basic message is also found in the econometric analysis undertaken of cross-country differences in patenting per capita. This shows that there is a strong positive association between R&D intensity, both in the business and non-business sector, and subsequent levels of patenting.[20]

36. A comparison between R&D, patenting and survey-based measures of innovative activity is reported in Table 3, using the subset of European countries participating in the CIS. Four indicators of innovation spending and methods of protecting innovations are used -- the proportions of firms engaged in R&D or who have made a patent application, and the proportions of firms who have made at least one type of innovation expenditure and made use of at least one means of protecting their innovation.[21] The rank correlations between economy-wide R&D and patenting and the survey measures of their use is high. But the correlation between economy-wide R&D and the survey indicator of all types of innovation spending is much lower, reflecting the importance of other types of innovation spending.

37. The rank correlation of the proportion of successful innovators with economy-wide R&D intensity is about 40%, but increases to 60% when the CIS indicator of aggregate innovation spending is used. However, the rank correlation of the share of new products in turnover with the proportion of successful innovators is close to zero. So the factors that affect the chances of making a successful innovation may not be the same as those affecting the commercial value of that innovation. The share of new products in turnover is only weakly correlated with the other CIS3 indicators of innovation.

20. This evidence is discussed in Section 3 of Jaumotte and Pain (2005b).

21. Innovation expenditures include investment and training expenditures necessary for the introduction of innovations, as well as R&D. Protection methods also include secrecy, lead-time, product complexity, trademarks, copyrights and design registration.

Table 2. **Comparison of innovation performance by various criteria, 2001**[1]

	Total R&D intensity	Business R&D intensity	Non-business R&D intensity	Scientists share[2]	R&D employees share[2]	Triadic patents (1999)	Average indicator[3]
Sweden	1	1	3	3	*2*	2	2.0
Finland	2	2	2	5	*1*	4	3.7
Japan	3	3	4	2	*6*	3	2.7
Iceland	4	6	1	4	*5*	13	7.0
United States	5	4	11	1		6	4.0
Switzerland	6	5	13	7	*3*	1	4.7
Germany	7	7	9	8	*8*	5	6.7
Denmark	8	8	10	12	*4*	8	9.3
France	9	10	6	13	*9*	10	10.7
Belgium	10	9	17	9	*7*	9	9.3
Austria	11	11	12	10	*10*	11	10.7
Canada	12	14	7	14	*14*	15	13.7
Netherlands	13	13	8	16	*12*	7	12.0
United Kingdom	14	12	14	15	*15*	12	13.7
Norway	15	15	15	6	*11*	14	11.7
Australia	16	17	5	17	*16*	16	16.3
Ireland	17	16	20	11	*13*	17	15.0
Italy	18	18	18	18	*17*	18	18.0
Spain	19	19	19	19	*18*	19	19.0
Portugal	20	20	16	20	*19*	20	20.0
Correlation with Total R&D intensity	1	0.99	0.73	0.85	0.94	0.87	0.97

1) The comparison is based on rank orders according to the various criteria. Rankings are a rough measure of cross-country differences. A possible refinement would be to use deviations from the country mean expressed in multiples of the standard deviation of countries' observations around the mean. Countries in the table are ordered by decreasing level of total R&D intensity.
2) The employment of scientists and R&D personnel is expressed as a share of total dependent employment. There are no published data for this measure of the R&D employee share for the United States and thus the ranking for this criterion is not perfectly comparable because only 19 countries are included instead of 20.
3) The average is the simple arithmetic average of the rankings for total R&D intensity, the scientists share and triadic patents.
Source: OECD Main Science and Technology Indicators database, R&D database and Patent database.

Table 3. **Comparison of macroeconomic indicators and survey-based indicators of innovation performance, 1998-2000**[1]

	Macroeconomic indicators		CIS indicators of innovation spending and protection				CIS measures of implementation of innovation	
Country	Business R&D intensity (2001)	Triadic patents (1999)	*Proportion of firms engaging in intramural R&D*	*Innovation spending index*[2]	Proportion of firms applying for a patent	Aggregate protection index[3]	Proportion of successful innovators	*Share of new products in turnover*
Sweden	1	1			1	2	9	
Finland	2	2	*1*	*3*	4	3	8	*2*
Iceland	3	10	*9*	*10*	14	14	2	*12*
Germany	4	3	*2*	*1*	3	5	1	*1*
Denmark	5	5	*4*	*5*	8	10	7	*7*
Belgium	6	6	*3*	*2*	6	6	3	*6*
France	7	7	*6*	*7*	2	7	10	*10*
Austria	8	8			5	4	5	*8*
United kingdom	9	9			11	1	14	
Netherlands	10	4	*5*	*6*	9	9	6	*9*
Norway	11	11	*7*	*8*	7	8	12	*11*
Italy	12	12	*10*	*9*	10	11	11	*4*
Spain	13	13	*11*	*11*	12	13	13	*3*
Portugal	14	14	*8*	*4*	13	12	4	*5*
Correlation with Business R&D intensity	1.00	0.81	0.69	0.42	0.57	0.46	0.38	0.00
Correlation with triadic patents	0.81	1.00	0.91	0.65	0.75	0.64	0.27	0.18
Correlation with % successful innovators	0.38	0.27	0.45	0.61	0.06	-0.14	1.00	0.03
Correlation with share new products in turnover	0.00	0.18	0.27	0.44	0.16	0.25	0.03	1.00
Number of countries	14	14	11	11	14	14	14	12

1. Care has to be taken when interpreting cross-country comparisons made with the aggregated data in CIS, as there are differences in the sample size used in the respective national components of the survey. A number of indicators (in italics) are available only for a subset of countries so that the ranks of countries cannot be directly compared across all indicators, though their rank-ordering can be compared. Countries in the table are ordered by decreasing level of business R&D intensity.

2. The innovation spending index is calculated as the arithmetic average of the proportions of firms engaging in the various types of innovation spending.
3. The aggregate protection index is calculated as the arithmetic average of the proportions of firms using the various types of protection.
Source: OECD Main Science and Technology Indicators database, R&D database and Patent database; Community Innovation Survey 3 (European Commission).

3. The influence of specific science policies on innovation

3.1 Do fiscal incentives for R&D work?

38. All OECD countries provide fiscal incentives to encourage private sector innovative activity, either through direct government funding of private sector R&D, or via tax incentives for private sector R&D expenditures. Specific programmes may also be established to provide financial support to particular types of firms, such as small businesses, that are believed to face capital market constraints. Direct government funding allows public subsidies to be used to finance research activities that are thought to offer high social, but low private, rates of return. It may also be a more effective means than tax reliefs for supporting young firms that have relatively little taxable income and face borrowing difficulties. The use of tax incentives broadens the range of different market-driven research activities that may be undertaken, and may be less prone to capture than direct funding schemes, but it also increases the possibility that research efforts will be duplicated unnecessarily, or that research of little social value will be undertaken. Both direct funding and tax incentives can also involve deadweight losses.

39. An increasing number of countries have some form of special tax treatment for expenditure on R&D. Existing work at the OECD has developed a comparative cross-country measure of the generosity of tax incentives for R&D known as the 'B-index" (OECD, 2003b). This index is intended to represent the present value of pre-tax income necessary to cover the initial cost of R&D investment and to pay corporate income tax. The index is calculated for representative large and small firms using information on the depreciation allowances, tax credits and other specific allowances in national tax systems. The amount of tax subsidy per unit of R&D is given by 1 minus the B-index.[22] One limitation of this measure is that no account is taken of possible cross-country differences in the extent to which available tax reliefs are applied for by innovating firms.[23] It should also be noted that a summary measure of this kind may not capture fully all the cross-country differences in the design of tax reliefs (OECD, 2003b).

40. Cross-country differences in the use of tax incentives and direct fiscal subsidies for private R&D in the latter half of the 1990s are shown in Figure 16. It is of interest to note that many of the countries with the highest R&D intensities had comparatively low levels of tax incentives during this period. Changes in the mix of direct government funding and tax incentives between the first half of the 1980s and the latter half of the 1990s are shown in Figure 17.[24] During this period the use of direct grants to institutions and individual firms became less important in almost all of the economies shown, with the exception of Finland, Switzerland, Spain and Portugal. Government funding represented a little over one-fifth of business R&D expenditure in the OECD as a whole in 1981; by 2001 this proportion had declined by almost two-thirds. Two key factors behind this change have been a reduction in direct support for defence-related research and the need in many countries for budgetary consolidation.

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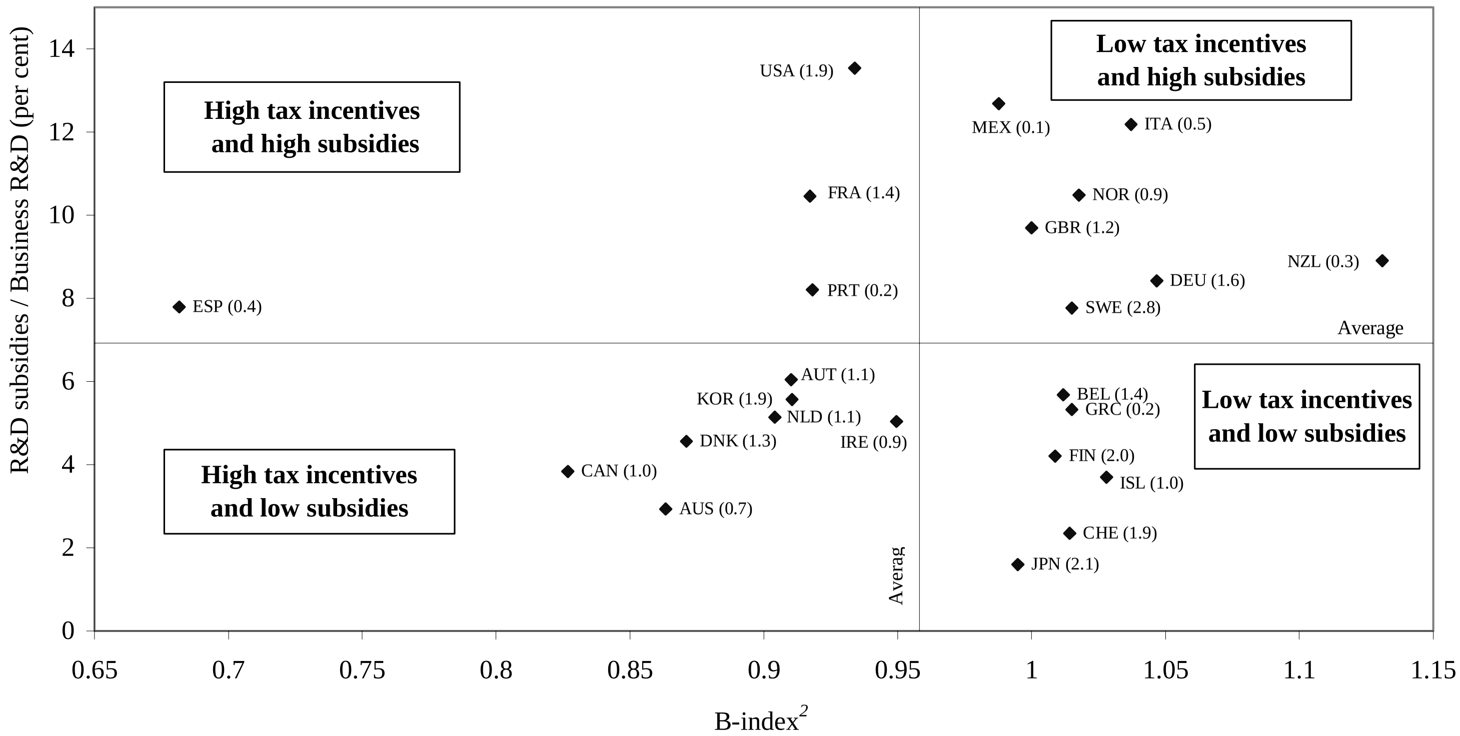
22. Algebraically, the B-index is equivalent to $\left[\dfrac{1-A_{it}^{d}-A_{it}^{c}}{1-\upsilon_{it}}\right]$ where A^d and A^c denote the present value of depreciation allowances and tax credits and υ the marginal rate of corporation tax.

23. This may help to explain why Spain, which has the most generous tax measures for R&D undertaken by a representative firm, also has one of the lowest levels of R&D intensity in the countries shown.

24. This uses data up to the end of 2000. Since that time a number of the countries shown have introduced new tax reliefs for R&D and in some others government funding for R&D has risen slightly (OECD, 2004). The countries with the largest reductions in the B-index between 2000 and 2004 were Norway, Spain, Portugal, Japan and the United Kingdom.

Figure 16. **The state of tax and subsidisation policies in the late 1990s**

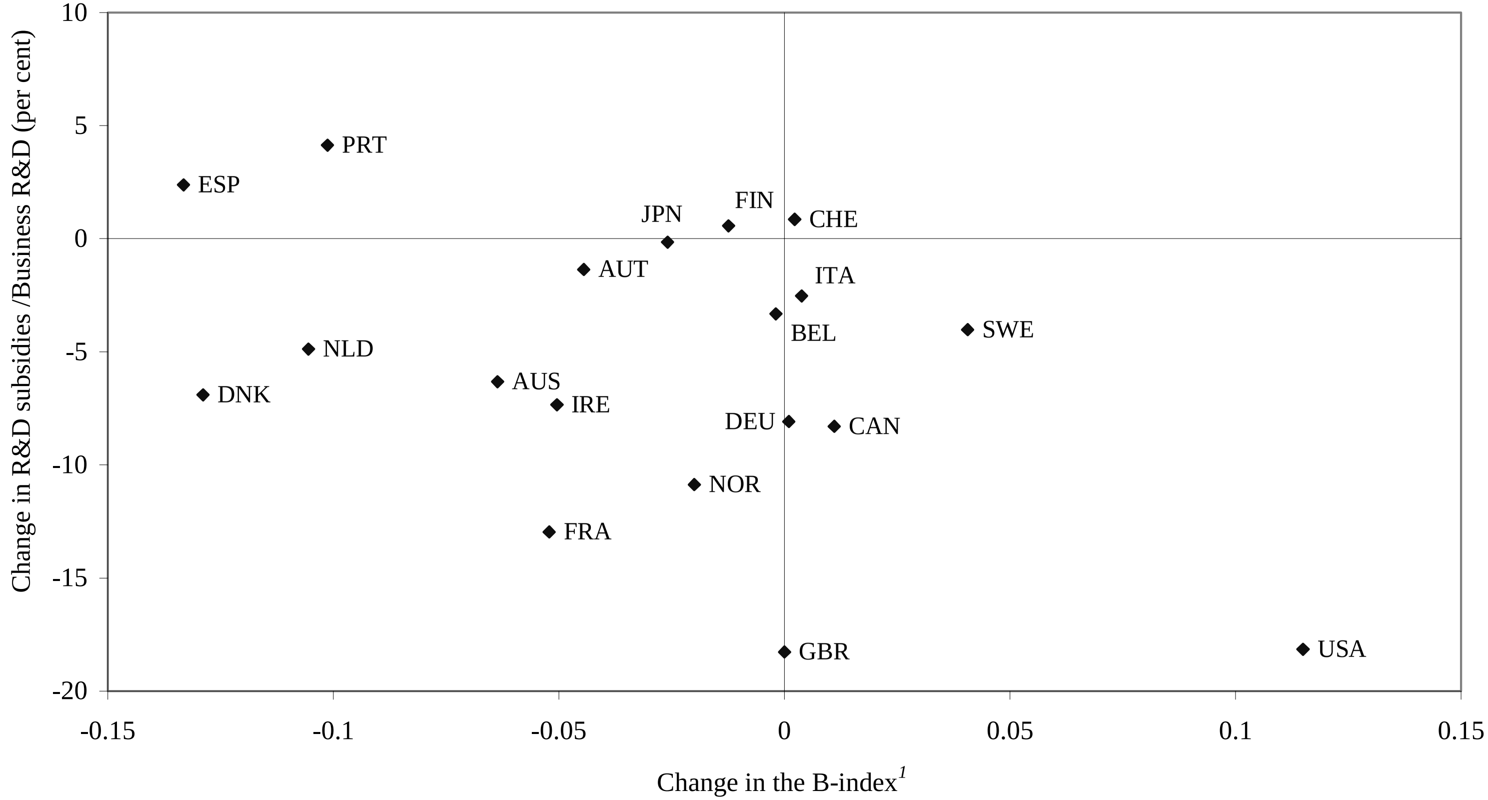
Average per annum, 1996-2000



1) The numbers in parentheses are the average business R&D intensities in 1996-2000.
2) The B-index is defined as one minus the rate of tax subsidy for R&D.
Source: OECD Main Science and Technology Indicators database for data on R&D subsidies; OECD, STI/EAS Division for data on the B-index.

Figure 17. **Changes in tax and subsidisation policies**

Average per annum 1996-2000 versus Average per annum 1981-1985



1) The B-index is defined as one minus the rate of tax subsidy for R&D.

Source: OECD Main Science and Technology Indicators database for data on R&D subsidies; OECD, STI/EAS Division for data on the B-index.

41. Evaluating the effectiveness of government fiscal incentives is difficult. Judgements are required about whether the supported research would still have been successful, or even undertaken at all, if funding had not been available, and also about the additional private sector resources that the funding has generated. Account also needs to be taken of the wider spillover benefits that any supported research may have for subsequent researchers. A significant proportion of direct funding of R&D by government is for wider socio-economic purposes, such as defence, space missions and health-related research.[25] Such expenditures may have few direct spillover benefits for other research activities, but still be of high social value. The indirect benefits that do result may occur at too long a lag to be picked up in an econometric analysis. Evaluation of such programmes is especially difficult, given the difficulties that sometimes arise in identifying the sums of money involved and the extent to which outcomes are kept secret.

42. Although the take-up and wider costs of tax incentives may be harder to monitor than the take-up of direct grants, existing empirical evidence does suggest that tax incentives help to raise the level of innovative activity undertaken compared to what might otherwise have happened.[26] But there is little consensus about the effectiveness of direct subsidies and specific funding schemes for companies.[27] Studies using country-level or industry-level data have been found to be more likely to report evidence of positive effects from fiscal incentives than studies with micro-econometric data, possibly because the higher level of aggregation is more likely to capture any wider inter-sectoral spillover benefits from the supported research.

43. The empirical work undertaken on cross-country differences in R&D and patenting in this paper suggests the effect of subsidies on innovative activity depends on initial conditions.[28] Holding all other factors constant, higher direct subsidies are found to have a small positive effect on R&D, especially when the corporate profit share is low. On such occasions, the availability of funding from the government can help to alleviate potential financial constraints. At other times, higher subsidies are found to reduce innovative activity. As reported in Table 1, when evaluated at the sample mean, a one standard deviation rise in subsidies (approximately 0.04% of GDP for the average country) is estimated to have only a small positive effect on the real level of R&D expenditure, while reducing the level of patenting by close to 3%.[29] A possible explanation for the latter result is that some types of research undertaken directly for the government are more likely to be kept secret rather than made publicly available through patenting.[30]

44. More generous tax reliefs for R&D are more frequently found to have a positive impact on the amounts of both R&D and patenting than higher levels of direct funding. However, their importance is found to vary considerably according to the remaining factors that are controlled for in any regression. In a simple baseline model of the kind used in a number of recent empirical studies, see for example Bloom *et al.* (2002), a permanent 10% reduction in the B-index (sample mean value = 0.95) is estimated to raise

25. On average in 2001, a little over one-quarter of total government budget appropriations or outlays for R&D were committed to defence research (approximately 0.2% of OECD GDP) and just under one-fifth were devoted to health research.

26. Interpretation of such results needs to bear in mind the possibility that the existence of tax reliefs raises the incentive to report expenditures as R&D.

27. This is discussed in greater detail in Section 2 of Jaumotte and Pain (2005a).

28. These studies are described in Jaumotte and Pain (2005b).

29. Table 3 is a simplified version of Table 8 in Jaumotte and Pain (2005b).

30. It may also be the case on occasion that a condition for public financial report is that the resulting research activities, and research tools, are made freely available to others.

the level of R&D spending by over 8%.[31] There are reasons for thinking this may be an upper bound of the effectiveness of tax reliefs for R&D; after additional control variables are included and account is taken of the wider effects of policy changes, the impact of the reduction in the B-index falls to less than 5%.[32]

45. Further evidence that public funding can help to support innovation is found in the empirical work using the data from the European Community Innovation Survey.[33] The findings suggest that public funding has a significant positive correlation with the proportion of firms that are innovators and also with the share of turnover accounted for by new products. An increase of one percentage point in the proportion of firms receiving public funding is found to correspond to a rise of 0.4 percentage points in the proportion of innovating firms who are successful and a rise of 0.7 percentage points in the share of new innovative products in turnover.

46. As few details are available in the CIS about the types of public funding received, it is not possible to tell whether the principal benefits are associated with direct fiscal support or tax incentives, or whether support intended to help firms bring products to the market is more important than incentives for them to undertake research. The positive impact found from public funding appears to be robust to alternative estimation techniques, and also to the inclusion of controls for firm size. However, it cannot be excluded that the observed effects come about because governments persistently fund firms with a proven record for successful research.

47. Thus the empirical analyses in this paper provide some support for the use of fiscal incentives to support innovation. Taken together, the results imply that recent changes in the mix of public funding for private R&D, with reduced use of grants and a more extensive use of tax incentives, should have provided a positive stimulus to private sector R&D in the OECD as a whole, other things being equal.[34]

48. The importance of scientists and engineers for the innovation process suggests that it might be worthwhile to undertake further analysis of the relative merits of directing tax incentives at R&D employment rather than aggregate R&D expenditure. Although this is beyond the scope of the present paper, tax incentives of this kind are used in the Netherlands, and this may provide a useful case study for further analysis of this issue.[35]

49. The effects of fiscal incentives found in the econometric work for this paper are partial effects. A complete evaluation of fiscal support schemes would also need to consider that all of the incentives for R&D involve budgetary costs for the public sector. These need to be balanced by offsetting changes in other fiscal instruments which will also have economic effects. Even if fiscal instruments are effective, the wider question remains as to whether the gains from supporting innovation are greater than the potential gains from supporting other activities, or the (deadweight) costs of raising the necessary revenues.

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31. This change implies that the amount of tax subsidy per unit of R&D would have risen from 0.05 (1-0.95) to 0.145. Assuming that all business sector R&D benefited from this subsidy, then with an average business sector R&D intensity of 1.4% of GDP this change would involve a potential budgetary cost of up to 0.13% of GDP.

32. This is because the estimated price (user cost) elasticity of R&D in the latter specification is lower than in the former, see Tables 2 and 3 in Jaumotte and Pain (2005b).

33. This is discussed in detail in Section 5 of Jaumotte and Pain (2005c).

34 . This does not mean that countries should eliminate grants completely and use only tax incentives for stimulating all aspects of the innovation process, especially for financing basic research in the public sector.

35. This is discussed further in Section 2 of Jaumotte and Pain (2005a).

50. In some cases it may also be worth considering changes in the design of policy programmes to learn from experiences in other countries. Mistakes are sometimes made when picking specific projects or companies for targeted fiscal assistance. Opening up funding programmes to a wider field of potential applicants, peer reviewing applications and making support conditional on plans for effective public dissemination of the results may all prove worthwhile on occasion.

3.2 What are the benefits from expanding non-business sector R&D and collaborative research?

51. Basic research performed in universities and other public research organisations (PROs) has long been an important source of significant scientific and technological advances. Such research is often undertaken with little or no idea of the potential commercial applications, or the length of time that might be required for commercialisation, making it necessary for it to be supported by public funding. Universities also play an important role in the supply of human resources for science and technology.

52. Although detailed studies of individual innovations reveal the important role played by such public research, the long and variable lags between discovery and development can at times make it difficult for econometric studies to identify any significant effects. Company surveys, such as the CIS, also suggest that a relatively small proportion of firms regard universities and other public research organisations as an important information source. However, this could reflect a lack of awareness about the research being undertaken and about the opportunities available for collaboration, rather than a sign that contacts with universities and key research personnel are not highly valued.

53. There is some empirical evidence suggesting that co-operation between public research organisations and industries can stimulate private sector R&D, but that the benefits need not be felt by all types of firms. Those in industries where the frontier technology is rapidly changing often value specialist advice and inputs from PROs more than others. Geographical proximity has also been shown to matter for knowledge transfers, possibly because of the enhanced opportunities to transfer tacit as well as codified knowledge.[36]

54. In addition to supporting the generation of new knowledge, science policies also seek to encourage the dissemination of new knowledge from the public sector to the private sector. Examples of such policies include moves to encourage public research organisations to make more active use of their intellectual property, and measures to promote the development of research partnerships between industry and PROs. Funding structures have also been changed in many countries, with less emphasis being given to funding of institutions and more to competition for funding to undertake either specific projects or work in certain research fields. Such measures are intended to help improve the diffusion of knowledge to the private sector, although they are not without potential costs. For example, firms without collaborative agreements may find it harder to access knowledge than before. Equally, a more active management of IPRs may slow the speed at which details of new research findings are placed in the public domain -- patenting takes longer than presenting research at conferences -- and also may raise the costs of using knowledge.

55. The econometric work for this paper indicates that research in the non-business sector is an important component of innovation, both directly, as reflected in patenting, and indirectly through its wider effects on private sector activities. Even though an expansion in public sector research can help to push up wage costs for the business sector, this is more than offset by a positive impact on the labour efficiency of business sector researchers. An increase of 1 standard deviation in the share of non-business R&D in GDP (an increase of 0.06 percentage points for the average economy) raises business sector R&D by over 7% and total patenting by close to 4%.

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36. These studies are discussed in more detail in Section 3 of Jaumotte and Pain (2005a).

56. A decomposition of the factors accounting for cross-country differences in R&D intensity also indicates the scale of the potential gains that might result from a higher level of R&D in the non-business sector. In two economies, Sweden and Finland, an above-average share of non-business R&D in GDP is estimated to raise business sector R&D intensity by around 25% above the OECD average (a change equivalent to just under 0.4% of GDP). In contrast, a below average share of non-business R&D in GDP is estimated to reduce business sector R&D intensity by around 25% below the OECD average in Spain and Ireland.

57. One indicator of the extent of research collaboration between business and public research organisations is the share of non-business R&D expenditure financed by industry. This has edged up steadily over time in almost all countries, as shown in Figure 18. The empirical work suggests that higher funding shares provide an additional stimulus to private sector innovation, over and above the direct effects from higher R&D spending in the non-business sector. This is especially so when the level of funding by business is a comparatively low level of the internal funds that companies have to finance their own expenditures. Evaluated at the sample mean, an increase of 1 standard deviation in the share of non-business R&D funded by the private sector (an increase of 1.4 percentage points for the average economy) will eventually raise business sector R&D by over 8% and total patenting by close to 2½ per cent.

58. The evidence from the analytical work using the European CIS suggests that enhanced collaboration with the public sector also raises the share of turnover accounted for by new products, although it does not have a significant impact on the proportion of firms who are successful innovators. One interpretation of these findings is that the principal benefits from collaboration may be enjoyed by the firms who collaborate, rather than by the business sector as a whole.

59. These findings shed new light on one surprising result in the analysis for the OECD Growth Study (OECD, 2003a); higher levels of public sector R&D were found to have a negative impact on growth after controlling for the effect of business sector R&D. The analysis in this paper shows that business sector R&D will already embody many of the effects that come from public sector R&D.

3.3 Should intellectual property rights be strengthened further?

60. Legal protection for the intellectual property rights of innovators is widely seen as an important means of stimulating innovation. Yet judgements over the appropriate strength of IP protection are finely balanced, and evidence of the efficacy of IP policies is far from clear. The general tendency of IP policy in most countries is to offer ever greater protection for the rights of IP holders. This is especially so for patents. Legislative changes have made patent rights easier to enforce, broadened the range of innovations that can be patented and lengthened the period over which patents may be granted. These changes have been complemented by the moves to encourage more active management of intellectual property by universities and other public research organisations.

61. There has been a gradual convergence over time in the strength of IP protection in most OECD countries, as can be seen from Figure 19.[37] Countries with a comparatively weak level of protection in the mid-1980s have typically done the most since then to strengthen the rights of IP holders. By 2000, the United States, Austria and Germany were the three countries with the highest index scores.

37. The data in this chart are based on updated estimates of the index of intellectual property rights originally published in Ginarte and Park (1997). The index is based on a weighted average of country scores for a number of criteria - the extent of coverage, membership in international patent agreements, duration of protection, provisions for loss of protection and enforcement mechanisms. The index reflects the rights of patent holders; it is not necessarily reflective of the rights of the holders of other types of intellectual property, such as copyrights and trademarks.

62. In the absence of formal protection, many inventors may choose to reveal nothing about their inventions. Enhanced protection of intellectual property rights (IPRs) is intended to foster innovation by providing incentives for inventors to undertake research and subsequently disclose information about their inventions. Disclosure of information about new research is beneficial, not least because it may prevent unnecessary duplication of research efforts. In return for disclosure, IP mechanisms such as patents and copyright allow inventors to have exclusive use of their innovations for a fixed period, after which it becomes freely available to all potential users. But the social costs of such protection can be high; for example, patent holders, if they so choose, have monopoly rights to the use of inventions during the lifetime of the patent. Thus the net impact of enhanced IP protection is ambiguous. Patent holders can enter into licensing agreements with potential users, but even these can have deadweight costs unless perfect price discrimination is possible.[38] Compulsory licensing may also be imposed at times, especially when an innovation has high social, but limited private, benefits. Again, care is needed to ensure that incentives to innovate are not adversely affected.

63. The design of intellectual property systems becomes especially difficult in fields where the research process is cumulative. New inventions often build on a number of existing ideas. Strong protection for the innovators of first generation products can easily be counterproductive if it limits access to necessary knowledge or research tools for follow-on innovators, or allows patenting to be used as a strategic barrier to potential competitors. Such concerns are particularly acute in fields such as biotechnology and information technology. The difficulties of predicting the source of new ideas provides one reason why it may be preferable for the costs of entry into the innovation process to be kept to a minimum.

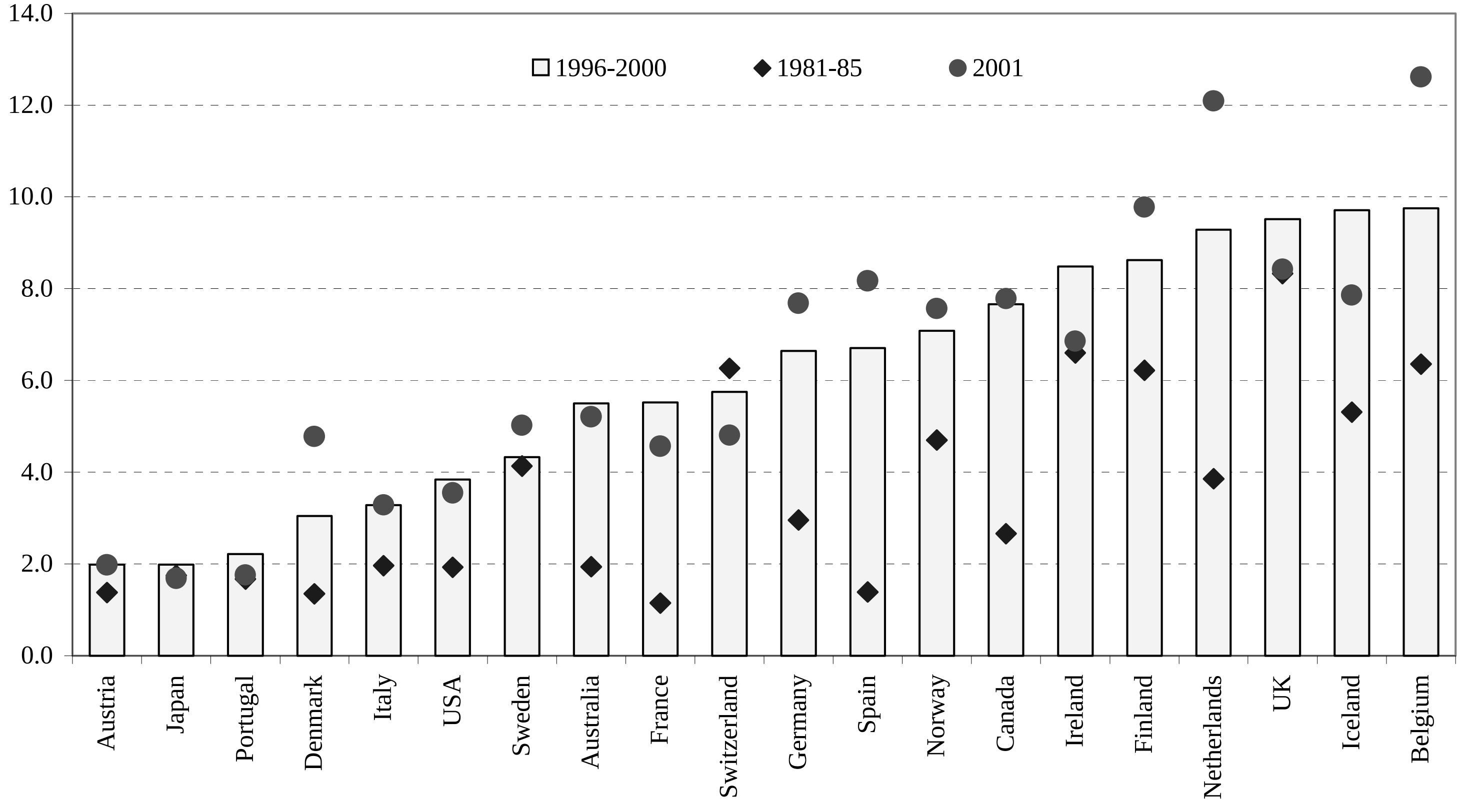
64. Strong IP protection also poses challenges for competition policy. Commercial agreements such as cross-licensing arrangements and “patent pools” are common in industries in which a large number of patented inventions have to be used to develop new products. Potential entrants without patents may find it difficult to join such agreements. It is difficult to determine whether this represents anti-competitive behaviour by patent holders or simply an efficient (and legal) exercise of intellectual property rights.

65. The overall picture that emerges from the extant empirical literature is that the relationship between the IP system, patenting and innovative activity is a complex one. Some studies have found evidence that cross-country differences in patenting are positively related to cross-country differences in the strength of IP protection. Others have suggested that the benefits of stronger IP protection are positive only when IP protection is initially weak. Company surveys indicate that patenting is the most important means of IP protection in only a few industries, such as pharmaceuticals and scientific equipment. A majority of companies in other industries make use of alternative protection methods, such as secrecy and lead-time. However, such methods may be less likely to favour the diffusion of knowledge than patents.

66. The main conclusion that emerges from the econometric estimates in this paper is that stronger IP protection has a substantial positive effect on patenting, but only a limited effect on R&D. Evaluated at the sample mean, an increase of 1 standard deviation in the IPR index is estimated to raise the number of patents by 8% and R&D expenditure by between 1-1½ per cent. In both cases the amount of research activity per researcher is slightly lower than it was before the change, implying that stronger IPRs can reduce the labour efficiency of researchers. The empirical work also suggests that there may be important interactions between the IPR index and some measures of product market competition, with stronger IP protection offsetting some of the beneficial effects of enhanced competition. However, the magnitude of these effects is difficult to pin down precisely. As most OECD economies now offer strong protection for many kinds of intellectual property, remaining differences typically account for only a small fraction of cross-country differences in R&D intensity.

38. These issues are discussed further in Section 4 of Jaumotte and Pain (2005a).

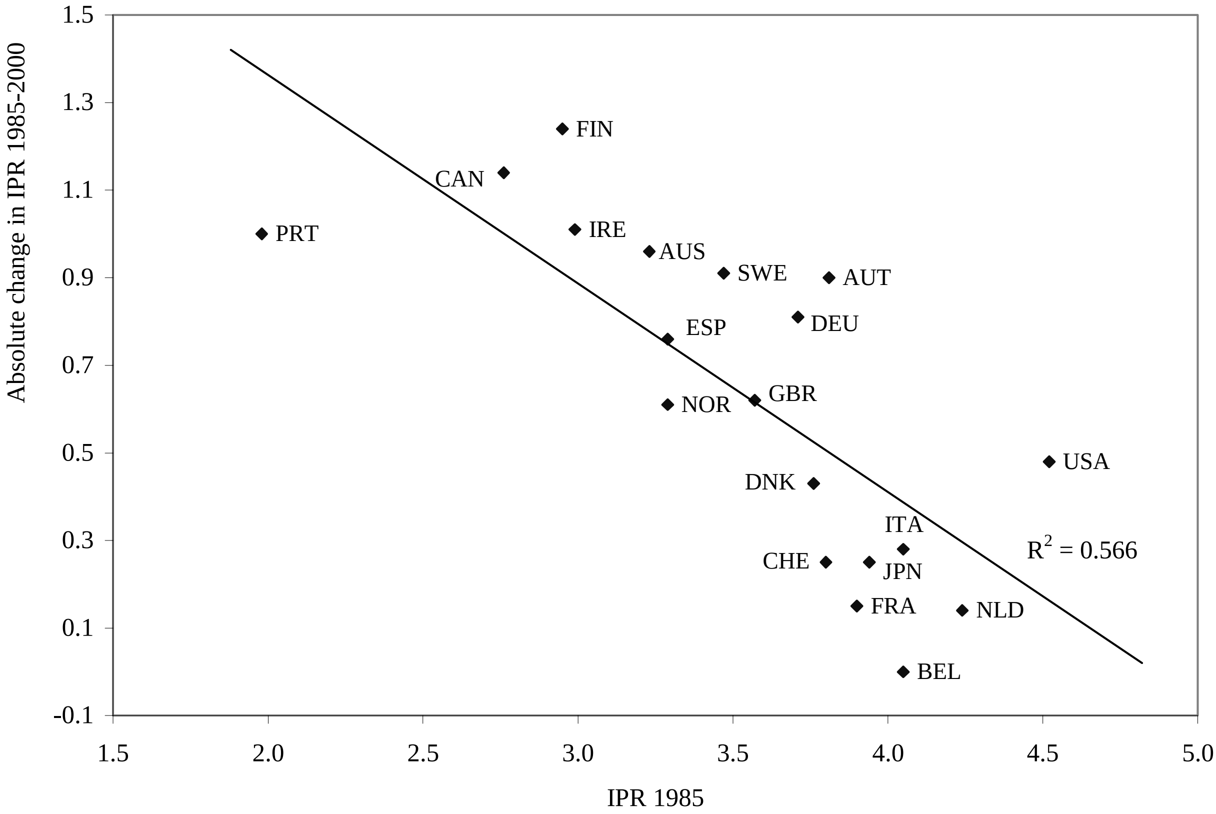
Figure 18. **Business funding of non-business sector R&D**
% points, average per annum



1. The last observed value is 2000 instead of 2001 for Australia, Ireland, and Switzerland; for Italy, the last observed value is 1996.
Source: OECD Main Science and Technology Indicators database.

Figure 19. **Convergence in intellectual property rights (Park index)**

1985-2000



Source: Park and Wagh (2002) and Ginarte and Park (1997).

67. Taken in conjunction with existing research, the evidence from the analysis in this paper suggests that there are benefits from having protection for IP rights. This does not imply that such rights should be increased without limit, especially if they reduce the beneficial effects of product market competition. Stronger patent regimes help to direct innovation towards patentable activities; such activities need not offer the greatest benefits for society as a whole.

3.4 How important are education and labour market policies?

68. Education and labour market policies are key influences on the availability of human resources for science and technology and hence on the level of innovative activity that takes place. Skilled researchers play a dual role in the innovation process, helping in the discovery of new inventions as well as in maximising the benefits that can be obtained from existing knowledge. However, at any point in time there is only a limited supply of trained scientists and engineers available to perform R&D related activities. It takes time for potential new researchers to acquire the necessary human capital and many existing graduates choose to work in other professions, or migrate elsewhere.

69. This raises two issues for innovation policies and policy targets.[39] Many countries currently have specific targets that imply a significant expansion in national R&D expenditures as a share of GDP over the coming years. These are unlikely to be met, and the increased expenditure be used effectively, without substantial increases in the numbers of researchers employed.[40] A second issue is that an increase in innovative activities in one part of the economy may have adverse consequences for the level of innovation in other parts. One example is provided by increased public funding for public research organisations. If this results in a higher demand for researchers and the short-run supply of researchers is fixed, wages will rise and the real resources available for innovation in the private sector may be reduced.

70. The econometric work in this paper demonstrates the importance of skilled researchers for all stages of the innovation process. In particular, the evidence on the determinants of R&D suggests that a higher share of scientists and engineers in total employment helps to raise national absorptive capacity -- the extent to which productive use can be made of new ideas resulting from the diffusion of knowledge developed in other countries. Evaluated at the sample mean, the estimates imply that a rise of 1 standard deviation in the share of business sector scientists and engineers in total dependent employment (roughly equivalent to a rise of 0.07% of total employment) is associated with a rise of 12% in business R&D expenditure. Evidence obtained from the European CIS data also shows that the proportion of firms who are successful innovators is significantly negatively correlated across countries and sectors with the proportion of firms who report a lack of qualified personnel.

71. In a detailed accounting exercise using the estimated coefficients from the R&D model and data for the year 2000, deviations in national R&D intensities from the OECD average are shown to be positively correlated with deviations in the share of scientists from the OECD average, as might be expected. In four countries, the United States, Japan, Sweden and Finland, the above-average employment share of scientists is shown to be reflected in a level of R&D intensity 40% or more above the OECD average.[41] This is a partial effect; raising the level of scientists and engineers in the business sector may have offsetting effects elsewhere. For example, the accounting exercise confirms that there are few countries that benefit significantly from both an above average share of non-business R&D in GDP and an above average share of private sector researchers in total employment. This emphasises the importance of taking a further step to explore the factors that influence the availability of scientists for the private sector.

72. The relationships estimated for the employment and wages of business sector researchers enable preliminary assessments to be made of the interactions between the demand and supply of researchers as business R&D spending and public policies change.[42] Among the key findings are that the demand for researchers is negatively related to their real wages, with the price elasticity estimated to be between –0.6 and –0.7%, and that the wages of researchers respond positively to changes in average economy-wide wages. The findings imply that the supply of skilled researchers may be responsive to changes in relative wages, at least in the long run. A separate finding is that in the short run, labour demand is less sensitive to the economic cycle than is total expenditure on R&D, suggesting that the main effects of changing cyclical conditions are on the non-labour inputs used in the research process.

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39. These issues are discussed further in Section 6 of Jaumotte and Pain (2005a).

40. It is also possible that they can be met through significant growth in the real wages of scientists and engineers. In this case there would be little change in the real resources devoted to R&D.

41. This estimate includes the direct impact of a higher number of scientists and also the indirect impact of such a change on national absorptive capacity -- defined here in terms of the benefits received from the diffusion of knowledge from other countries.

42. A more complete account of the empirical work is in Section 4 of Jaumotte and Pain (2005b).

73. Taken together, the econometric results confirm that an expansion in publicly funded and performed R&D will raise the real wages of researchers employed in the private sector. A rise of one standard deviation in the share of non-business R&D in GDP (an increase of 0.06% of GDP for the average economy) is found to raise the real wages of researchers by between 1-3%, depending on the specification of the particular model used.

74. Finally, the estimated wage equations provide indirect evidence of the extent to which the availability of skilled researchers may be affected by international labour mobility. An increase of 1% in the real wages of researchers in the United States is found to lead to an increase of between ½-1 per cent in researchers' wages in other countries as well. This results in a small reduction in the level of innovative activities because of the decline in the number of researchers employed induced by higher real wages.

4. How important are framework factors for innovation?

75. The OECD Growth Study identified a number of important framework conditions and policy settings that could help to support private sector fixed capital investment. These included macroeconomic stability, well developed financial markets, pro-competitive regulations in labour and product markets and openness to international trade. Similar factors may also help to determine knowledge capital.

4.1 The macroeconomic framework

76. Enhanced macroeconomic stability allows firms to plan more effectively for the long-term. Strong and stable rates of output growth also provide favourable conditions for firms seeking to introduce new products or to undertake significant organisational changes. Further benefits may arise if the macroeconomic framework helps to maintain low and stable rates of inflation and limit cyclical pressures on the level (and volatility) of real interest rates.

77. The estimated R&D specification demonstrates the clear importance of macroeconomic factors for understanding the evolution of business R&D expenditure. Strong output growth and low inflation are both found to have a positive influence on the rate of growth of R&D, suggesting that a stability-oriented macroeconomic framework provides a business environment that is conducive to innovation. Factors which help to lower the level of real interest rates can also help to stimulate innovation because of the impact this has on the user cost of R&D capital. Evaluated at the sample mean, the estimated parameters of the model imply that a 1 standard deviation reduction in real interest rates (a change of just over 1½ percentage points) will raise R&D expenditure by almost 5%, and the total level of patents by close to 3%.

78. While theoretical models raise the possibility that the timing or the level of innovation could be affected by uncertainty over future economic conditions, the empirical work for this study was inconclusive. No significant effects were found when (backward-looking) measures of output and inflation volatility were added to the R&D model.

4.2 Financial factors

79. A growing number of empirical studies have shown that the scale of financial market development and well-functioning financial systems can have an important impact on long-run economic growth. In particular, they can help to ease the external financial constraints faced by firms who want to make long-term investments. Evidence of both these effects was found in the OECD Growth Study (OECD, 2003).

80. Other studies suggest that similar issues arise for investment in research and development. R&D projects are inherently more risky than others, given their long and uncertain payback period, and the

likelihood of asymmetric information between prospective borrowers and lenders is high. External investors will require a premium to compensate for the agency costs arising from the risks of adverse selection and moral hazard. In these circumstances the availability of adequate internal finance, as reflected in profitability and cash-flow, is likely to be an especially important source of finance for expenditure on innovative activities. In the absence of sufficient cash-flow, some projects may never go ahead at all.

81. The likelihood of financial constraints is especially high for (potential) new entrants into the research process, since they have no history of successful research and often only limited means of internal finance. The possibility that this may lead to under-investment in R&D has led to policy programmes targeting fiscal support directly at small firms, and also to measures designed to encourage the development of venture capital markets. The effectiveness of such programmes appears mixed, although some studies suggest that public funding can act as a mark of quality for private investors, reducing the marginal cost of external funds for supported firms.

82. Cross-country differences in financial development and profits are shown in Figure 20. Changes over time in the share of equity financing in an aggregated measure of financial development[43] are shown in Figure 21. In almost all countries equity financing has become more important relative to credit financing over time.

83. The econometric analysis in this paper suggests that the scale of financial development, stock market capitalisation and the share of corporate profits in GDP all have significant positive effects on R&D expenditures. However the impact from greater financial market development on R&D is found to lessen when the corporate profit share is high, indicating that a greater availability of internal finance is likely to reduce the need to obtain external finance. Stock market capitalisation is found to have an additional significant positive effect on patenting in addition to the effects it has through research and development, suggesting that equity-based financial systems may provide more favourable conditions for firms seeking to raise external finance for innovation.[44] Financial liquidity, as reflected in the profit share and changes in tax incentives for R&D, is also found to have a significant effect on the hiring of researchers in the business sector.

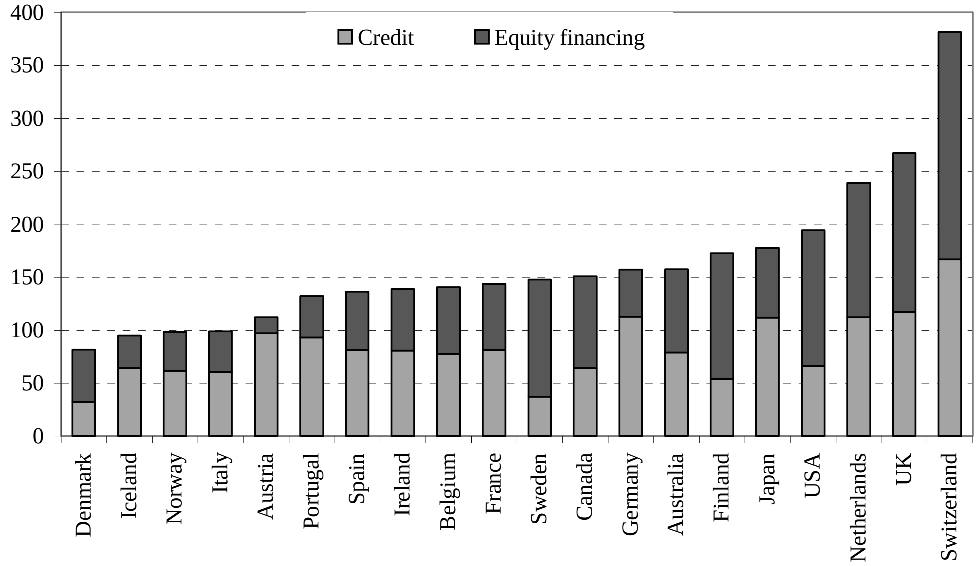
84. Taking all these diverse influences together, a one standard deviation rise in the profit share of GDP is estimated to raise the level of R&D expenditure by over 5%, and total patents by over 4%. A rise of 1 standard deviation in the ratio of stock market capitalisation to GDP (equivalent to an increase of 26-27% of GDP for the average country) is estimated to raise R&D by almost 6%, and total patents by 10%. Perhaps surprisingly, an increase in the ratio of private sector credit to GDP is found to have a small negative impact on both R&D and patenting. It is not immediately clear what generates this result. However it is consistent with the evidence found when using the CIS3 data. This suggested that the proportion of firms citing a lack of finance as a constraint on innovation has a positive cross-country association with the ratio of private sector credit to GDP.

43. The term ‘financial development’ is used to describe the sum of stock market capitalisation plus credit provided to the private sector by deposit money banks. Both are expressed as a proportion of GDP.

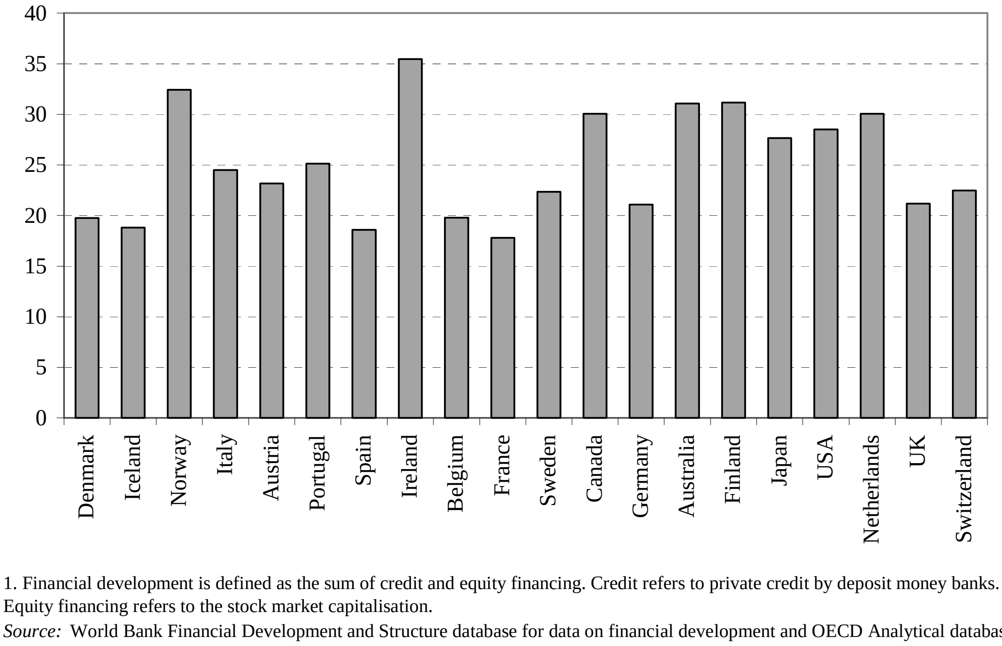
44. Measures of venture capital were not included in the empirical work on R&D in Jaumotte and Pain (2005b), reflecting the relatively short time span over which data are available. However, work using the CIS3 suggests that cross-country differences in the provision of venture capital are significantly negatively correlated with the number of firms citing finance as an obstacle to innovation (Jaumotte and Pain, 2005c)..

Figure 20. **Financial factors**

Panel A: Financial development / GDP[1]
Average 1996-2000, in per cent



Panel B: Profits / GDP
Average 1996-2000, in per cent

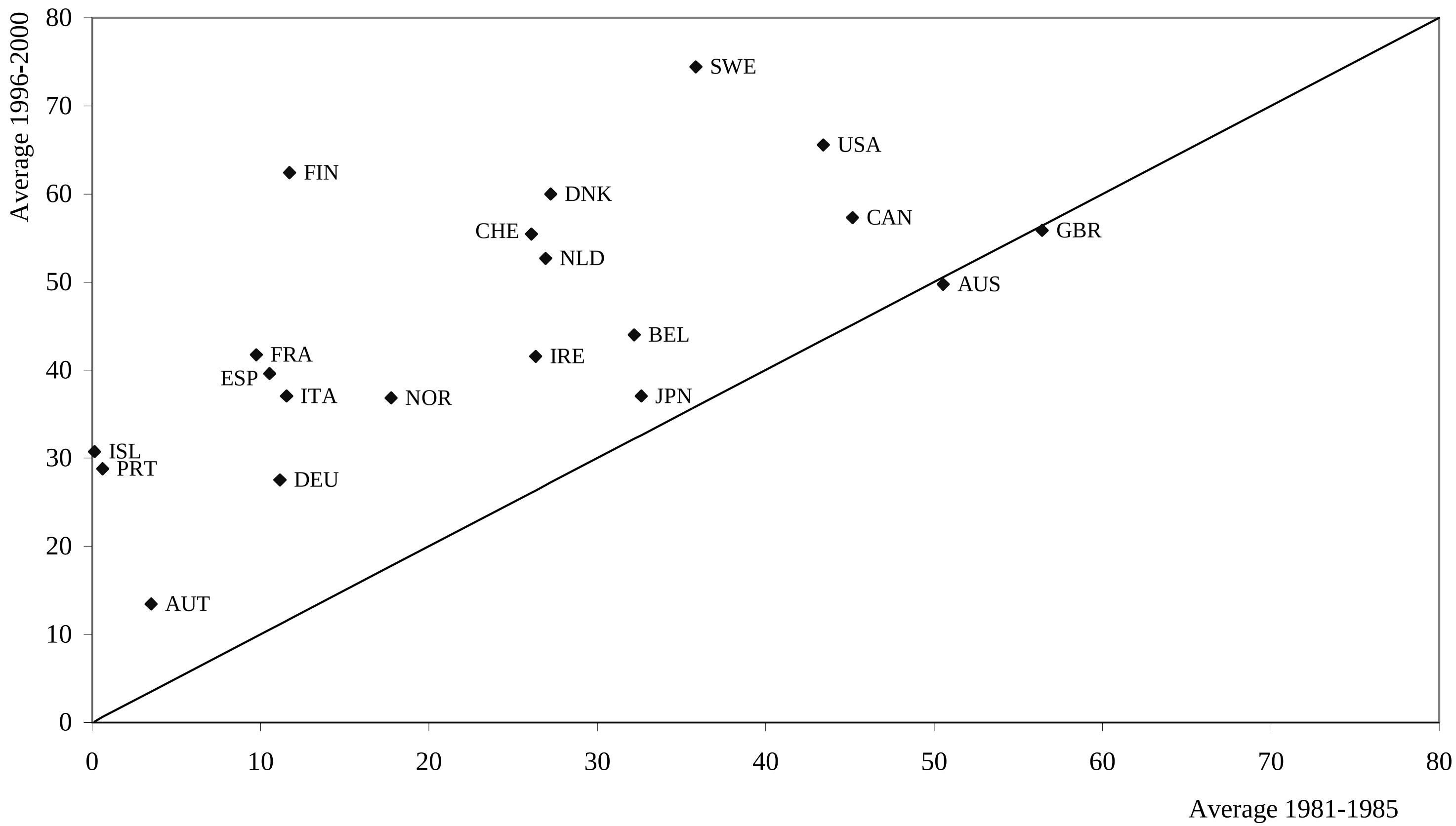


1. Financial development is defined as the sum of credit and equity financing. Credit refers to private credit by deposit money banks. Equity financing refers to the stock market capitalisation.

Source: World Bank Financial Development and Structure database for data on financial development and OECD Analytical database for data on profits.

Figure 21. **Evolution of the share of equity financing in financial development**[1]

Average per annum 1996-2000 versus Average per annum 1981-1985



1. Financial development is defined as the sum of credit and equity financing. Equity financing refers to the stock market capitalisation.
Source: World Bank Financial Development and Structure database.

85. While the effects on innovation from changes in profits and stock market capitalisation appear sizeable, in practice these factors account for only a small proportion of cross-country differences in R&D intensity in many countries when evaluated using data for the year 2000. When all the financial factors are combined together, Switzerland, the United Kingdom and Norway are the three countries which are found to have the most favourable financing conditions; in all three, financial factors are estimated to raise R&D intensity by more than 10% above the OECD average.[45] Austria and Denmark are the two countries found to have the least favourable combination of financial factors, with these lowering R&D intensity by over 10% relative to the OECD average.[46]

86. Additional evidence of the potential importance of financing constraints is obtained in the empirical analysis using the European CIS, with a lack of private financing found to have a significant negative relationship with the share of turnover accounted for by new products. An increase of 1 percentage point in the proportion of firms citing the lack of financing as an impediment to innovation reduces the share of new products in turnover by just over 1½ percentage points, although it does not have a clear effect on the proportion of firms who are successful innovators. This evidence suggests that financing difficulties do not necessarily stop innovations from occurring, but may hamper the scale of their commercial development. Small firms in the manufacturing sector appear more likely to report financing difficulties than do medium-sized and large firms, and all firms in service industries.

87. The importance of the financial variables for innovation highlights the possibility that other policies may have an indirect impact on innovation through their impact on profitability or financial development. Analysis of this is beyond the scope of the present paper. But it does reinforce the importance of the need for a full analysis of the costs and benefits of specific tax incentives for R&D by taking into account the alternative uses to which the funds might be put.

4.3 Product and labour market regulations

88. The expected impact of changes in product and labour market regulations is theoretically ambiguous. Dynamic models of product market competition and innovation often suggest that there is a hump-shaped relationship between them. When competition is growing from a low level, incumbent firms have incentives to innovate to try and escape from competition and potential competitors have incentives to innovate to catch-up or surpass the technologies of incumbent firms. But at high levels of competition the expected rents to be earned from further innovation may be sufficiently low to eliminate any incentive for incumbents to make further innovations. The aggregate level of innovation could even decline if potential entrants judge that it is no longer worthwhile to invest in frontier technologies. The strength of protection for IP rights can also affect this trade-off since it affects the speed at which information about frontier technologies is diffused from incumbents to competitors. An indicator of cross-country differences in product market regulation in non-manufacturing industries, and changes over time, is shown in Figure 22.[47]

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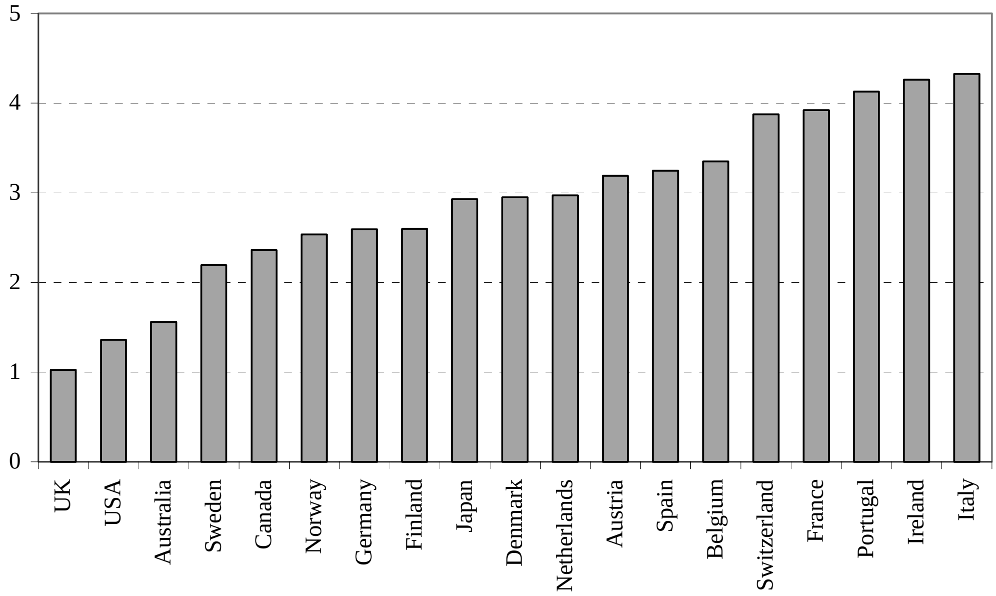
45. The effects for Norway stem in part from the inclusion of oil profits in total corporate profits.

46 . It should be noted that the differences in some financial indicators such as stock market capitalisation may reflect in part different propensities for different types of firms, such as R&D performing and non-R&D performing firms, to be quoted in the stock market. In such cases R&D performing firms need not face an external financing constraint even if aggregate stock market capitalisation is low relative to GDP.

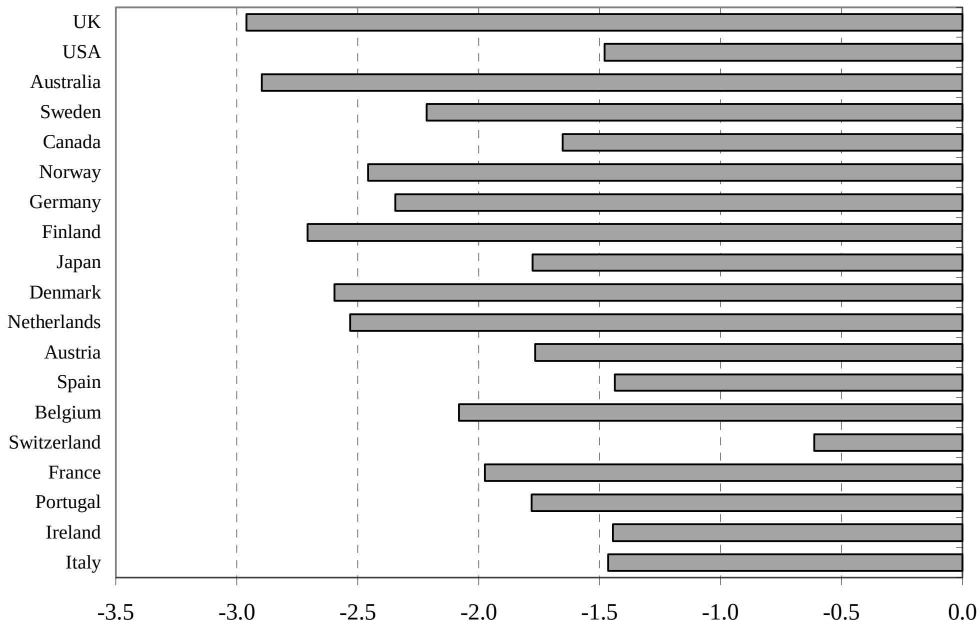
47. The empirical analysis of R&D and patenting in Jaumotte and Pain (2005b) uses the non-manufacturing indicators as a measure of the strength of economy-wide product market regulations. For the analysis of the CIS3 data in Jaumotte and Pain (2005c) use is made of a survey-based measure based on the proportion of firms in different sectors citing rigid regulations and standards as an obstacle to innovation. These two different measures are shown to be significantly correlated with each other.

Figure 22. **PMR index**[1]

Panel A: Cross-country comparison in 1998



Panel B: Change between 1985 and 1998



1. This OECD index of product market regulation covers 7 non-manufacturing sectors for which time-series data are available.
Source: Nicoletti and Scarpetta (2003).

89. Employment protection can also have dual effects. It can help to create mismatches between the demand and supply of researchers, potentially adding to wage pressures, and slow necessary workplace reorganisations needed to implement new innovations. But it can also be an advantage for certain types of innovation, especially process innovations, by reducing turnover and thereby allowing firms to make better use of the specific competencies of their workforce.

90. The econometric work in this paper suggests that less stringent product market regulations primarily help to raise R&D intensity, whereas reduced employment protection mainly boosts patenting.[48] The explanation for the latter effect is provided by the work on the CIS3 data which suggests that process innovations are less likely to be patented, and also that more stringent employment protection raises the share of process innovations in total innovation. Evaluated at the sample mean, a one standard deviation decline in the stringency of product market regulations (equivalent to a change of 0.84 in the index for an average country) is estimated to raise R&D expenditure by almost 9%, and the total level of patents by over 4%. A one standard deviation decline in the strength of employment protection is estimated to raise R&D expenditure by less than 1%, but to raise total patents by just over 6½ per cent. The latter result reflects two separate effects; weaker EPL raises patenting directly for any given level of R&D, and also reduces the real wages of researchers slightly, helping to raise employment and, consequently, absorptive capacity.

91. Differences in the stringency of regulations can also result in national R&D intensities deviating markedly from the OECD average level. The estimated long-run relationship for R&D suggests that the low level of product market regulation in Australia, the United Kingdom and United States helps to raise their R&D intensity by 10% or more above the OECD average. In contrast, heavy regulation reduces R&D intensity in Ireland, Italy and Portugal, by over 8% relative to the OECD average.

92. The analysis using the CIS survey data provides a mixed picture of the potential effects of regulations. The number of firms who report that rigid regulations and standards are an impediment to innovation is found to be negatively correlated with the proportion of firms that succeed in introducing innovations. This is especially so for firms who are introducing new products to the market. Those who are imitating existing products appear less affected than companies introducing completely new products. In contrast, the number of firms citing rigid regulations and standards is positively associated with the share of turnover accounted for by new products, especially in service industries. One interpretation of these mixed findings is that firms who innovate have market power when anti-competitive regulations are high.

4.4 International openness

93. Many cross-country studies of economic growth emphasise the importance of the diffusion of both codified and tacit knowledge across national borders. This can occur in many different ways, including the transfer of information about new technologies, ideas and working practices through imported goods and services, from inward direct investment and from international labour mobility. Equally, national companies can access information abroad through exporting or by establishing affiliates in other countries. Other things being equal, more open economies will have a greater exposure to the foreign knowledge stock at any point in time, although they may not be able to benefit from this if they have only a small domestic research base. A further effect of enhanced openness is that it provides a stimulus to product market competition. As discussed above, the empirical evidence suggests that this should be favourable for innovation on average, although theoretical models suggest that this need not always be the case.

48. The variable is the employment protection indicator used recently in the OECD empirical work on labour force participation.

94. A number of existing studies suggest that the benefits of foreign knowledge diffuse more rapidly through the direct transmission of ideas rather than through trade in goods and services that embody them. So the international mobility of skilled researchers and multinational firms may be especially important channels for knowledge transfer. In many OECD economies the share of business sector R&D funded and performed by foreign-owned firms is rising steadily over time (OECD, 1999 and 2004). This suggests that national innovation performance may be affected, in at least some countries, by policies that influence the location of internationally mobile research activities and the opportunities for national firms to benefit from the knowledge they can bring.

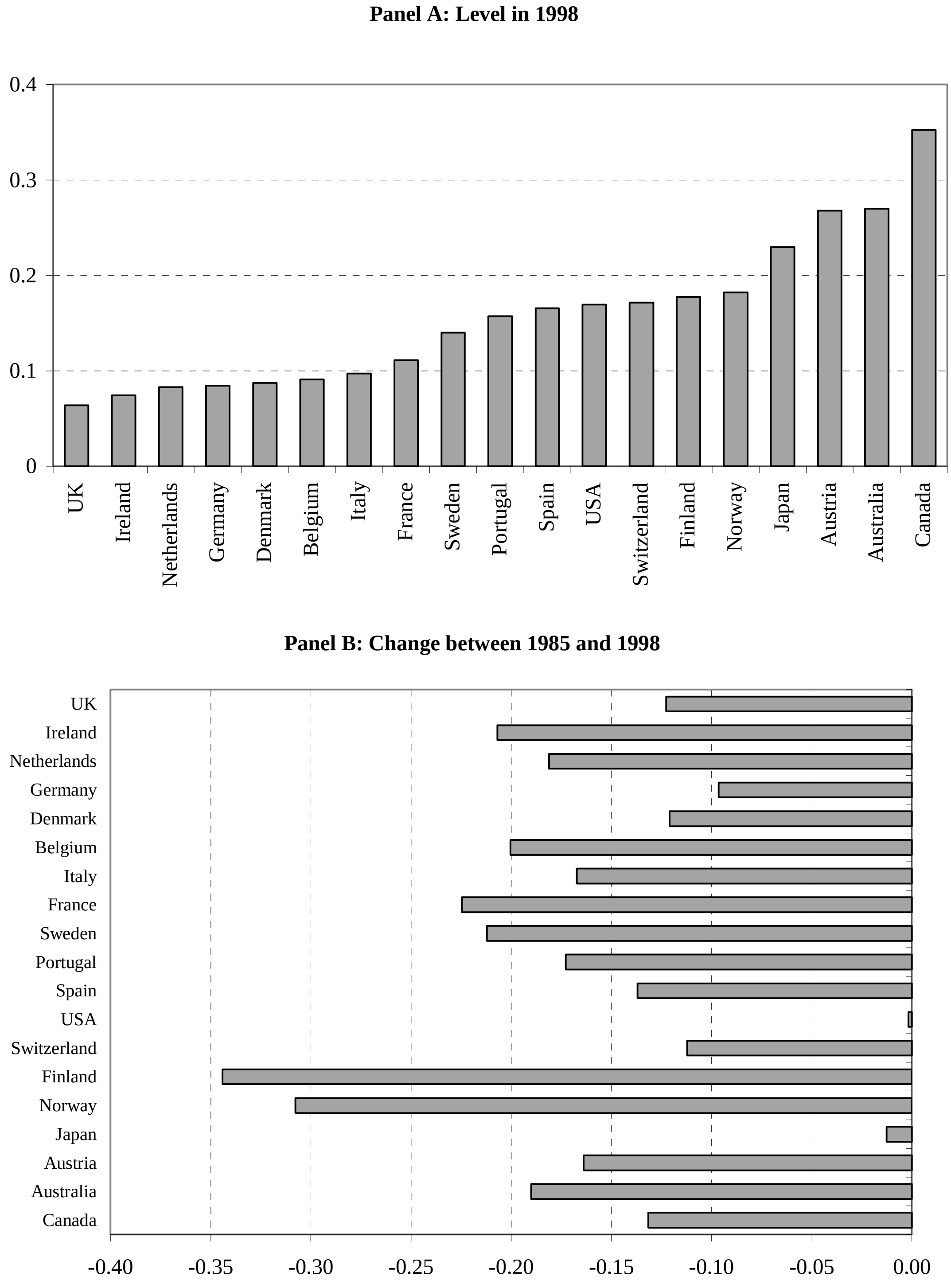
95. The empirical work in this paper highlights a number of different effects from greater openness on innovation. The most important effects are found to come from a measure of the foreign knowledge stock, constructed as a weighted average of business sector R&D stocks in each country's trading partners.[49] This is shown to have a significant positive effect on the level of domestic R&D expenditure, an effect enhanced when absorptive capacity, as measured by the share of scientists and engineers in total employment, is high. The interaction of the foreign knowledge stock with a size-adjusted measure of trade openness is also found to have a significant impact on labour efficiency in the model of the occupational labour market for researchers. Evaluated at the sample mean, an increase of 1 standard deviation in the ratio of the foreign R&D stock to domestic GDP is estimated to raise domestic R&D by almost 13%, and total domestic patents by close to 6%, suggesting that the rate of knowledge diffusion across international borders is an important determinant of national innovation efforts.

96. The positive effects of diffusion are offset partially by a finding of significant negative effects from openness itself, whether measured using the ratio of exports and imports to GDP, or by import penetration. These two findings suggest that greater openness helps to make new knowledge accessible, but reduces the ability to undertake domestic innovation. The accounting decomposition of the findings in the estimated R&D equation suggests that the countries who receive the greatest benefits from international openness are Ireland, the Netherlands, Switzerland and Belgium.

97. The potential importance of foreign direct investment (FDI) for innovation is explored in two ways in the paper. The cross-country indicator developed by the OECD to quantify the barriers facing potential inward investors was included in the estimated models for both R&D and patents. Cross-country differences in the level of restrictions and their evolution over time are shown in Figure 23. It was not possible to identify any significant effects from the FDI measure in the R&D equation. However, in the patents model, restrictions on FDI were found to have an important negative effect. Evaluated at the sample mean, a decrease of 1 standard deviation in the FDI indicator (a relaxation of barriers to investment) is estimated to raise total patents by 13%.

49. The weights on each partner country are based on the ratio of bilateral imports from that partner country scaled by GDP in the partner country.

Figure 23. **Index of FDI restrictions**



Source: Golub (2003).

98. A more direct test of the potential benefits from the activities of the foreign affiliates of multinational companies is provided in a separate stand-alone analysis for a smaller sample of OECD countries over a shorter time period (1992-2001) in Jaumotte and Pain (2005b). After controlling for fixed country effects and common time effects across countries, the growth in the level of R&D expenditures undertaken by the foreign affiliates of US-owned parent companies is found to have a significant positive effect on the rate of growth of business sector R&D in the host country. A second finding is that the growth of the level of R&D expenditures undertaken by foreign-owned affiliates in the United States has a significant negative effect on the rate of growth of business sector R&D in the home country.[50] The coefficient on the inward R&D term is greater than that on the outward R&D term, implying that if inward and outward R&D grow at the same rate, the net effect will be to enhance the rate of growth of business sector R&D in all countries.

99. These findings are preliminary and from a relatively short sample period. They do not provide conclusive evidence that foreign direct investment has a permanent effect on national R&D intensities. But they do indicate that inward FDI is one means by which knowledge is diffused to host economies and that outward FDI is a means of sourcing technologies and knowledge from elsewhere, relocating some research activities that might previously have taken place in the home economy.

100. The importance of international spillovers does not imply that countries would be better off by simply using the research of others rather than attempting to maximise their own innovation efforts. If all countries adopted such a view, global welfare would clearly be adversely affected. But even for individual countries there would be a cost. The empirical results in the paper show that absorptive capacity matters for maximising the benefits from using the stock of international knowledge. In the absence of trained scientists and engineers, whether in the private sector or in public research organisations, the extent of international spillovers would be greatly reduced. This provides one indication of the potential complementarities between science policies and the stimulus to innovation provided by favourable framework conditions.

4.5 The real exchange rate

101. A growing number of empirical studies have shown that movements in exchange rates can have a significant impact on fixed investment. This occurs through a number of channels, including the product market competition that firms face from foreign companies and the location decisions of internationally mobile companies. Exchange rate movements also affect profitability, depending on the share of total revenues derived by exporting, the ratio of imported inputs in production and the extent to which firms choose to absorb currency fluctuations in their profit margins.

102. The impact of exchange rate movements on R&D activities has not been widely examined in the existing empirical literature on innovation, although a small number of papers have suggested that they can have significant effects. Many of the potential effects can operate in different directions. Greater competition following an exchange rate appreciation could stimulate innovation by domestic firms in order to try and escape competition by improving product quality or variety. But it could equally well provide an incentive for some firms to move operations abroad because of changes in the relative costs of producing in different locations. Others may simply try and retain their market share (in volume terms) by lowering their profit margins, thus reducing the finance available for R&D.

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50. These effects also hold when the United States is included in the sample. In this case the relevant variables are the total R&D of all foreign affiliates from the sample countries in the United States and the total R&D of all US-owned foreign affiliates in the sample countries.

103. As the regression models already include a number of controls for profitability and market competition, the inclusion of separate exchange rate terms is more likely to capture potential location influences than anything else. The empirical results find a significant negative impact from both changes and the level of the real exchange rate in the R&D model. Evaluated at the sample mean, an increase of 1 standard deviation in the real exchange rate is estimated to eventually lower R&D expenditure by just over 3% and total patenting by just under 2%, approximately two-thirds of the effects induced by a 1 standard deviation rise in real interest rates.

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