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# R&D and Productivity

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## 1. Introduction

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

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

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

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

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

## 2. The Two Faces of R&D

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

[1] For a detailed evaluation of R&D tax credits across a number of OECD economies, see Bloom, Griffith, and Van Reenen (2002).
[2] See Griffith, Redding and Van Reenen (2001, 2003, 2004).

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

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

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

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

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

## 3. Quantifying the Two Faces of R&D

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

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

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

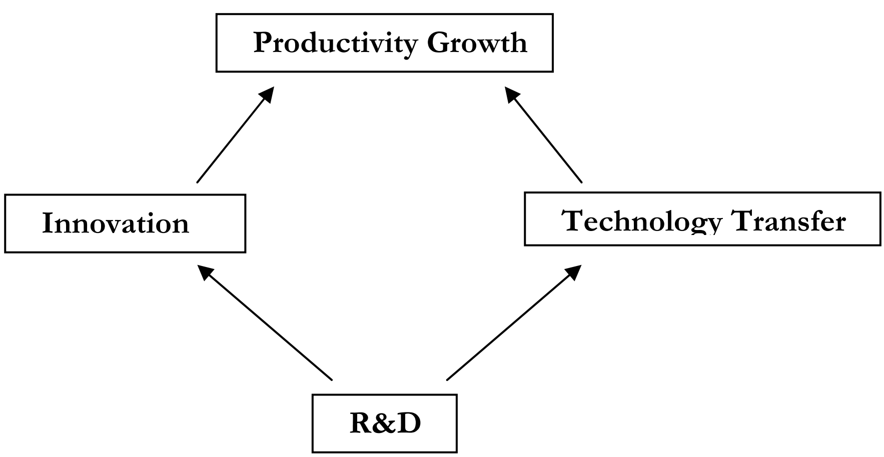
Our measure of productivity growth is based upon the idea that there is a production function determining the number of units of output produced for a given level of inputs of factors of production. This may be expressed mathematically in the following equation,

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

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

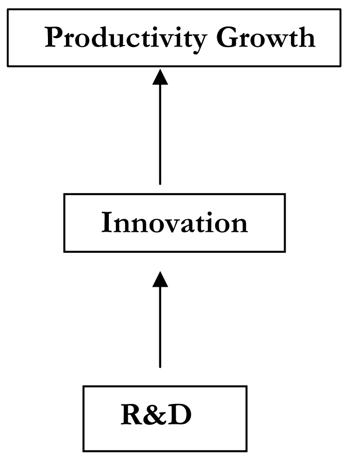
*Table 1: Innovation, Technology Transfer and R&D*

**Panel A - An Economy behind the Technological Frontier**



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

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




## Industries

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

## Countries

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

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

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

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

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

*Table 3: Four Alternative Measures of Relative TFP*

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

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

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

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

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

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

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

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

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

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

## 4. Not by Technology Alone…….

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

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

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

## 5. Conclusions

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

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

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

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

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

[7] Dictionnaire des idées reçues

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