Realities and Perspectives of Industrial R&D:
A Study of the Portuguese Reality in the European and Global Contexts

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Abstract
Most developed countries exhibit high rates of R&D performed in industry, but the situation is considerably different in medium income countries such as Portugal. Despite the lower levels of R&D, Portuguese firms have increased their competitiveness, and the country has been able to show remarkable levels of economic performance. This paper provides a framework to analyze the way in which R&D is performed in Portuguese firms, and how it contributes to their competitiveness and the overall performance of the Portuguese economy. The analysis will constantly take as a reference the situation that exists in more developed countries. We find that Portuguese firms are very likely to engage in search and exploration activities that are conducive to innovation. Most of these activities are informal, and are not either perceived, or reported, by firms as formal R&D. We interpret this feature within the conceptual framework of the emerging understanding of economic development which is based on learning dynamics. We conclude that the innovative performance of Portuguese firms should be measured and accounted for using innovation surveys and detailed case studies of sectors and representative firms.

1. Introduction
The relation between the scientific and technological ability of countries, and their capacity to sustain social economic development has been extensively discussed, and many authors argued that the national technological activities are expected to correlate with productivity and economic performance indicators [1-6]. Jones et al. [6] present empirical evidence showing that newly industrializing countries in Asia have been importers of technology and have not yet developed strong R&D capabilities. Therefore, these countries have not the foundations for a solid and sustainable development.

Additionally, many authors have argued that as economies are increasingly knowledge-based, the importance of creating and disseminating knowledge challenges the traditional ways of understanding the process of economic development, raising new questions about the mechanics of that process, the role of institutions such as enterprises and universities, and the suitability of current public policies to face this reality [7-13].

This paper analyses the contribution of the research conducted in the enterprise sector to sustainable economic and social development, and is structured into five sections, aiming at understanding the Portuguese situation, and is in five sections. Section 2 presents empirical evidence on R&D activities in OECD countries. Section 3 discusses why the social benefits of new knowledge are considerably higher than the advantages that directly benefit the agents who made the effort to create it, creating a conceptual rationale for public support for R&D. Finally, section 4 discusses the Portuguese situation, and the role of the state in the promotion of mechanisms for knowledge creation and diffusion.

2. R&D in Firms in OECD Countries
This section presents data related to R&D activities in the enterprise sector, and is divided in two sub-sections according to the aggregation level of the data. Sub-section 2.1 presents aggregated data for the OECD and G7 countries. Sub-section 2.2 presents data aggregated at a national level.
2.1 International Aggregate Analysis: OECD and G7 Countries

It is estimated that OECD countries allocated US$400 billions to R&D only in 1995, which represent 2.15 per cent of their GDP [14]. The main aggregate used for international comparisons of national R&D efforts is Gross Domestic Expenditure on R&D (GERD). GERD includes the expenditures in the higher education sector (HERD) and the business enterprise sector (BERD), as well as expenditures in other government institutions and non profit organisations. Figure 1 illustrates the evolution of BERD and GERD from 1981 to 1995 in all OECD countries. GERD increased 167% from 1981 to 1995, while HERD increased 180%. R&D expenditures in the enterprise sector are about 4 times higher than in the higher education sector for the aggregate of OECD countries.

An analysis of figure 1 raises some questions, such as: How can the evolution of R&D expenditures be explained in the context of social and economic evolution of the OECD countries? How far is the evolution of BERD related with the business cycles?

In terms of countries, the 133 US companies led the ranking of international firms with highest R&D expenditures. While the top 300 companies spent 12.8 % more in R&D in 1997 than in 1996, US companies raised total spending by 17%, with significant increases by companies of the electronics, engineering, IT and pharmaceutical sectors.

A sector analysis shows big differences in performance across sectors. Computing and electronics show some of the most striking increases. Microsoft raised R&D spending to £1,17bn in 1997, from £870m in 1996 and only £370m in 1994; Cisco, the leading US networking company, doubled R&D investment to £733m in 1997, in 199. Cisco spent only £54m. On the opposite side, the vehicle-manufacturing sector was one of the worst. Companies like General Motors and Ford cut spending in R&D by 8 and 7 per cent in 1997, but still rank in the top position in terms of R&D spending.

The top 10 in terms of R&D spending includes 6 companies from the electronic and electrical sector, and 4 companies from the vehicle

HERD raised about 3 times from 1981 to 1995, while in the enterprise sector the growth seems to be sensitive to the business cycle. In fact, the BERD grew much faster until the US recession up the early 90’s where growth became stagnant and even negative. On the other hand, HERD seems to suffer an incremental increase, irrespective of the business cycle.

A more detailed analysis can be derived from an analysis of R&D expenditures in different sectors. The most traditional way of comparing investment between companies is by measuring R&D intensity, which represents R&D as a percentage of total sales. Aggregate figures for R&D intensity of companies from different countries are frequently used to compare national performances. In such analysis the US, Japan and Germany.

A recent survey by the UK Department of Trade and Industry [15] recorded an unprecedented increase in the investment in R&D of international companies in 1997. The world’s top 300 companies spent $216bn on R&D, which represents an increase of 12.8% in comparison with 1996. Gaining competitive success through technological superiority seems to be a goal of these 300 companies, which strive for the advantages of new knowledge and innovation. Figures 2a and 2b present the recent evolution of R&D expenditures of top 300 international companies.

Figure 1 : HERD and BERD in OECD.

![Figure 1](HERD.png)

![Figure 2](Evolution.png)
engineering sector, which are ranked as follows: General Motors, Ford, Siemens (96-97 change of +11%), IBM (96-97 change of +9%), Hitachi (96-97 change of +2%), Toyota (96-97 change of +16%), Matsushita Electric Industrial (96-97 change of +9%), Daimler-Benz (96-97 change of +2%), Hewlett-Packard (96-97 change of +13%) and Ericsson (96-97 change of +39%).

2.2. National Analysis

A critical factor for S&T are human resources. Figure 3 shows the relation between the GERD per capita and the total R&D personnel per thousand labor force in 1995. Sweden, Japan, France, Germany are among the countries with both higher number of researchers per thousand labor force, and expenditures per capita, while Turkey, Mexico, Portugal, Spain and some other Eastern European Countries are in the opposite position.

One of the important benefits of research is the stream of new technical inventions that may be embodied in innovations. Patent data provide useful indications for measuring technical change and inventive input and output. Patenting trends can therefore serve as an indicator of national inventive activities. In this context, we consider an inventiveness coefficient, which represents the ratio between resident patent applications per 10,000 people. Figures 4 and 5 compare the inventiveness coefficient of some OECD countries and relate it with the GERD per capita, and with the percentage of GERD performed by the business enterprise sector.

Figure 5 shows the percentage of gross expenditures performed by the enterprise sector, as well as percentage of GDP in 1995, and shows that countries with highest percentages GDP devoted to research tend to have a higher percentage of GERD performed by the business sector. Although there is no fundament to establish a direct causality between state intervention in R&D and the performance of the enterprise sector, the analysis of figure 5a suggests that enterprises are prepared to perform better in contexts where the state has contributed to the establishment of a learning environment. In other words it means that the level of knowledge accumulation, and the education level of the human resources of a country are essential requisites to allow the development of research activities within enterprises.
3. Knowledge Spillovers

In the world of science and technology, there is a tendency to consider science as a public good and technology as a private good. Science rests on the publicly available scientific journals and is freely and rapidly disseminated throughout the scientific community and the society at large. Technology is associated with more practical applications exploited by the firms that engaged in its development, and is protected by patents or other instruments of privatising software.

David [16] proposes three types of alternatives to yield the conditions for the production of science or ‘non-rival software’. The first, patronage, consists on giving direct subsidies to producers, on the condition that the goods must be publicly available at virtually zero costs. The second, procurement, is based on the direct production of the goods by the government, awarding specific contracts to private agents whenever necessary. Finally, the third, property, is associated with the privatization of the non-rival software, awarding the producer monopolistic rights that yield returns large enough to cover the fixed costs of production. Specific legal instruments include patents, copyrights, and trade secrets.

Both patronage and procurement rely on a direct intervention of the government, by which the non-rival software remains non-excluded, and, therefore, effectively a public good. Property grants private producers on new knowledge exclusive property rights in the use of their creations. This yields the private incentives in which markets operate efficiently.

David [16] argues explicitly that, as a consequence, the market by itself does not have adequate mechanisms for the production of ideas, and that other institutional mechanisms are required for this purpose. Indeed, as Dosi [17] notes, the non-rivalry of ideas separates the costs of their creation from the benefits accruing to those who use them. In other words, the efforts that somebody has made to arrive at an idea may be inadequately rewarded by the beneficiaries of that idea.

Furthermore, the effort (or cost) of producing a new idea is usually high, especially in comparison to the cost of disseminating it. To make matters more complicated, making that effort does not even guarantee that an idea of any value will result; the production of ideas is highly contingent and its results are uncertain. According to Dasgupta and David [18], Nelson [19] was the first author to describe the economic implications of the uncertainties associated with the efforts to produce new ideas, as well as of the difficulty the creator experiences in retaining the benefits of a new idea. Specifically, Nelson studied the effort put into creating ideas represented by R&D carried out by companies. Even if a company succeeds in its R&D effort, Nelson says, the benefits of a new idea are shared by society in general. The data in Table 2, which compare the rates of individual and social return on investment in R&D, give an empirical demonstration of this argument. Rates of individual return, the benefits that the individual entity responsible for the R&D expenditure receives, are around 20-25%. Rates of social return (benefits to society in general) are around 50%.

Table 1: Compilation of Results on Private and Social Rates of Return on R&D: Firm and Industry Data
Table 1 confirm Nelson’s hypothesis, showing that the social benefits from effort put into creating ideas are indeed considerably higher (approximately double) than the advantages that accrue to the private agents who made that effort. This phenomenon, generally known in the literature as “knowledge spillover”, has been interpreted as the result of positive externalities associated with the performance of R&D and other inventive activities (e.g., design, engineering). Phenomena such as externalities are identified as “shortcomings of the market”, and indicate situations in which markets do not function effectively as a means of stimulating production. Using the concepts of the new growth theories, we are now in a position to reinterpret this phenomenon as the result of the non-rivalry and low transmission cost of ideas.

4. R&D in Portugal

In this section R&D activities performed in the enterprise sector are discussed taking as a reference the OECD context.

Overall, it is estimated that Portugal allocated 0.61% of its GDP to R&D activities in 1995, while the aggregate figure for the EU is 1.85% and for the OECD is 2.15% (OECD-MSTI, 1997) [14]. Regarding the rate of R&D performed by enterprises, Portugal presents a considerably different situation from developed countries. While in OECD industrial R&D expenditures are about 4 times the expenditures in the higher education sector (see figure 1), in Portugal this ratio is significantly different, since expenditures in industrial R&D represent only 1/3 of the expenditures in the higher education sector. Figure 7 illustrates the evolution of BERD and HERD from 1982 to 1996 in Portugal.

The OECD countries have very diverse situations in terms of share of GERD by sector, but Portugal is the OECD country with a lower percentage of GERD performed by the enterprise sector, as illustrated by figure 8.

Regarding personnel devoted to R&D the situation in Portugal is similar, since the number of people devoted to R&D in the enterprise sector is about 1/4 of similar figure in the higher education sector.

Figure 8: Percentage of GERD Performed by the Enterprise Sector (1995)

An analysis of the financing sources for R&D activities shows again that Portugal has a very peculiar situation in the OECD context since the share of financing from industry has decreased in the last decade, representing about 20% of the national total.
In terms of R&D output, the Portuguese situation is briefly described below considering bibliometric indicators and intellectual property protection for all sectors of activity.

Regarding the relative citation impact (number of citations divided by papers) which gives some measure of the quality of R&D activities in a country, Portugal ranks 22nd, as illustrated by table 2.

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<th>Country</th>
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<th>Number of papers</th>
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<tr>
<td>USA</td>
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<td>6,234,183</td>
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<td>Be. Netherlands</td>
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Table 2 : Ranking of Countries by Relative Citation Impact, 1992-96

In terms of intellectual property protection, in particular number of patents, Portugal presents the lower figures of the EU, with a ratio of patent applications per million labor force of 3, while the EU average is 207 [20]. The Portuguese share of patent applications in the EU is only 0.04. An analysis of the Portuguese situation in the European context suggests that the lower number of patent applications in Portugal reflect the low level of R&D performed by Portuguese enterprises.

SUMMARY

Empirical evidence presented shows that while most developed countries exhibit high rates of R&D performed in industry, in Portugal the situation is considerable different. Nevertheless, Portuguese firms have increased their competitiveness, and the country has been able to show remarkable levels of economic performance. Taking as a reference the situation that exists in more developed countries, we find that Portuguese firms are very likely to engage in search and exploration activities that are conducive to innovation. Therefore, the evidence reported suggests that most of these activities are informal, and are not either perceived, or reported, by firms as formal R&D. Despite the need for further research on this issue, we interpret this feature within the conceptual framework of the emerging understanding of economic development which is based on learning dynamics. We conclude that the innovative performance of Portuguese firms should be measured and accounted for using innovation surveys and detailed case studies of sectors and representative firms.

REFERENCES


