# Which Portuguese firms are more innovative? The importance of multinationals and exporters*

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## Abstract

*In this study we test the trade Global Engagement hypothesis in which firms more globally engaged – either multinationals or exporters – are more innovative. The test is applied to 4815 Portuguese enterprises´ data for the period 2002-2004 through the use of the fourth Portuguese Community Innovation Survey. We estimated several Knowledge Production Functions assuming that knowledge outputs result from the combination of some knowledge inputs with the flow of ideas coming from existing stock of knowledge. We found that more internationally exposed firms create more knowledge output, than their domestic counterparts; indeed, more globalized firms use more inputs and have the opportunity to use a larger stock of knowledge. Notwithstand, the observed superiority of more internationally exposed firms is also the result of their globalized nature, not directly connected with knowledge inputs or information flows.*

**Keywords:** Multinational firms, exporting, knowledge-production functions, Portugal

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[*] This work contains statistical data from the Comunnity Innovation Survey 4 for Portugal. The data is used under the permission of GPEARI/MCTES but does not imply the endorsement of GPEARI/MCTES in relation to the interpretation or analysis of the statistical data.

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## 1. Introduction

Since different firms create different levels of knowledge two related questions arise: (i) which firms are more innovative? (ii) is there any connection between this issue and firms´ level of global engagement?

A firms’ innovation level is linked to firm or industry characteristics such as size, market concentration or orientation and technological characteristics. According to Oszomer *et al*. (1997), the firm strategic posture, organisation and environmental structure and even the uncertainty level interact and contribute to the level of a firms’ innovativeness.

On the other hand, some models (e.g., Jones, 2002) assume that the stock of knowledge is a public good, equally and freely available to all enterprises worldwide. In contrast, Grossman and Helpman (1991) and Parente and Prescott (1994) present models in which firms have to face costs and difficulties in adopting new technological knowledge. Those barriers differ across time and countries, suggesting that external trade may influence technological knowledge adoption. Nowadays it is common to accept that the existing stock of knowledge is appropriated and profited from quite differently by various enterprises. This learning ability of firms is a decisive factor in explaining different innovative performances, even more important than different facilities for the acquisition of inputs.

In this line of reasoning, more globally engaged firms may obtain larger stocks of ideas through their foreign sources such as international suppliers and customers or, in the case of multinationals, through their internal worldwide pool of information. In addition, higher exposure to foreign markets could reduce costs associated with the adoption of new technologies. Lederman (2009) calls this the Global Engagement hypothesis, after which “importing” foreign know-how through licensing, foreign investment or exporting activities are positively correlated with innovation and, especially, product innovation. Moreover, this hypothesis also assumes that trade protectionism raises costs of global engagement, adding difficulty to innovation. Additionally, he assumes that the density of knowledge available to local firms spurs innovation, and that more globally engaged firms have a higher knowledge density available to work with.

The existence of a positive relationship between the level and growth of technological knowledge and foreign exposure has been documented in several papers, using firm-level data (e.g., Alvarez and Robertson, 2004 for Mexican and Chilean enterprises or Cassiman and Veugelers, 1999 for Belgian firms). There is a general agreement that this positive connection results from the highly competitive pressure of international markets, which requires constant updating and adaptation. Nevertheless, in a surprising conclusion Silva and Leitão (2007a) found that between 1995 and 1997 Portuguese industrial firms with high export intensity were less capable of innovating. They explained that the majority of high export intensity firms belonged to clothing and footwear industries and worked on an outsourcing basis, adopting a low-price strategy which did not rely on product innovation. A similar result was also found by Cassey (2004) in the Malaysian manufacturing sector.

Criscuolo *et al*. (2005) for UK firms and Wagner (2006) for German firms, developed a new approach to test the global engagement hypothesis. These authors use the Knowledge Production Function (KPF) as a theoretical framework to study the innovation *versus* international engagement connection. They also use the Community Innovation Survey (CIS) as database for this purpose. This methodology assumes that knowledge outputs result from the combination of knowledge inputs and of the flow of ideas coming from the existing knowledge stock. This framework is superior to other approaches to the extend that allows to estimate several versions of the KPF[1]. By doing so it is possible to evaluate which factors really matter in regard to the innovative performance of firms.

[1] Hamermesh (2006, p.376) refers that: "the credibility of a new finding that is based on carefully analysing two data sets is far more than twice that of a result based only on one".

This paper aims to test the global engagement hypothesis for Portuguese firms using the KPF approach and CIS as the database for the period 2002-2004. Our analysis yields a set of results that indicate a confirmation of the previous vision. We find that more international engaged firms report much more knowledge output, whatever measure is used.

Despite of the lack of data on two consecutive CIS Portuguese reports, which would have enabled a panel data analysis, the use of suitable econometric models allowed us to understand that: (i) much of the higher knowledge output created in globally engaged Portuguese firms was the product of both higher knowledge inputs and informational flows used; (ii) and also of a superior efficiency in their use, as suggested by the KPF approach. Our findings also provide evidence that existing knowledge is not uniformly accessible to Portuguese firms. Moreover, for the first time, this study estimates the contribution of distinct knowledge inputs and knowledge information sources to the innovation ability of Portuguese firms.

The paper is organized as follows. Section 2 describes the theoretical foundations of KPF that support our empirical studies and reviews the empirical studies on the subject. Section 3 presents the main statistics for CIS 4 in Portugal, by distinguishing the actual differences between purely domestic and globalized firms. Section 4 discusses the main econometric and estimation issues. Section 5 presents estimation results. Section 6 performs an exercise of innovation accounting using the estimates obtained and the actual differences in data. Section 7 concludes the paper.

## 2. Innovation factors and empirical literature

### 2.1. International factors of innovation: theory and modelling approach

In line with Coe and Helpman (1995), we know that the benefits of innovation are much more evenly distributed than the expenditures on innovative R&D. This is a sign of the importance of global technological diffusion. Technological knowledge can be diffused internationally by several ways: Foreign Direct Investment (FDI), labour mobility, communication patterns and imitation. In the latter case, international trade is the vehicle through which diffusion occurs.

Based on Grossman and Helpman (1991) and Parente and Prescott (1994), we assume that firms face barriers to adopt foreign technological knowledge. These authors argued that the reduction of the differences among countries' economic growth rely on the ability to reduce barriers to technology adoption, and they assume that greater trade openness favours weakening the resistance to technology adoption. It is also assumed that barriers are reduced by FDI. Additional channels to technological diffusion are imports of intermediate inputs, that incorporate new technological knowledge, and exports, which increase the firms' market and in that way expand firms' return on innovative efforts.

Alternatively, following the conceptual framework of Silva and Leitão (2007b), innovation is the result of an interactive and non-linear process between firms and their global environment. In a certain way, innovation is "a collective learning process" (Silva and Leitão, 2007b, p. 2) in which organizational and environmental factors affect the firm specific innovative ability. This so-called "systematic approach" of innovation process allows a new vision for the role performed by external partners, and of the importance on the information flows that disseminate knowledge within the system.

Roper *et al*. (2008) hold that innovation is a recursive process that involves three phases: sourcing the existing knowledge, transforming it into new products or processes and finally exploiting the innovation in order to generate more added value. They regard the innovation process as a value chain, although also a risky one. It is important, then, to consider the motivational input for innovation activities.

On the other hand, the fact that different firms produce different amounts of new knowledge has opened the possibility to use "knowledge production functions" (KPF) or "innovation production function" in a very similar way to a production function for goods and services (e.g., Geroski, 1990; Love and Roper, 1999; Roper *et al*., 2008). In the KPF framework, production of new output knowledge relies on the competitive environment in which each firm acts. Moreover, the KPF framework also relies on the assumption that new knowledge depends on two types of inputs: Innovation input activities like R&D activities (which allow the emergence of knowledge) and the flow of ideas from the knowledge stock.

Using the approach followed by Criscuolo *et al*. (2005), which is in line with Griliches (1979) and Romer (1990), we can write the KPF in the simpler Cobb-Douglas form:

$$\Delta K_i = H_i^{\lambda} K_i^{\varphi}. \tag{1}$$

The creation of new ideas, the change of the knowledge stock ($\Delta K_i$) depends on the investment in the process of knowledge creation (*H*), human capital or R&D activities, and on the existing knowledge stock from which ideas can be generated, *K*, through the knowledge information flows. Parameters $\lambda$ and $\varphi$ represent, respectively, the elasticity of new idea creation on knowledge investment and from the existing knowledge stock. Subscripting *K* in (1) means that firms have different access to the existing knowledge stock, since each existing idea might not be equally crucial to all firms. Besides, as firms can learn from their internal knowledge stock and from other external sources, it is essential to identify distinct channels through which firms are encouraged to innovate, and especially those that carry international technology spillovers.

Following Criscuolo *et al*. (2005) and Wagner (2006), a second KPF version is presented:

$$\Delta K_i = f\left(H_i, K_{ii}, K_{i\_i}, X_i\right) \tag{2}$$

This version of the KPF assumes that changes in the knowledge stock depend on: (i) *H* – the investment in the process of knowledge creation (R&D activities or other non-R&D investments); (ii) $X_i$ – a vector of other determinants such as size, industry or sector; (iii).$K_{ii}$ –

the flow of ideas to firm *i* from within; (iv) $K_{i\_i}$ – the flow of ideas to firm *i* from outside the firm. In this case, *K* is thus decomposed into two different components.

Woerter and Roper (2008) argued that the innovation output of a firm *i* in a time *t* ($I_{it}$) reflects R&D investments, other knowledge sources, the expansion of markets and additional factors. They also proposed a KPF conceptual framework by using:

$$I_{it} = \phi_0 + \phi_1 XMG_{it-j} + \phi_2 HMG_{it-j} + \phi_3 K_{it} + \phi_4 RI_{it} + \phi_5 IND_i + \phi_6 TDUM_t + \nu_i + \varepsilon_{it} \quad (3)$$

In (3), the independent variables are, respectively, export-market growth, *XMG*, home-market growth, *HMG*, the availability of existing knowledge stock, *K* such as in equation (1), firms internal resources, *RI*, industry resources, *IND*, that may affect post innovation returns and control dummy variables, *TDUM*. They studied the Irish and the Swiss cases and concluded that the probability a firm to innovate depended mainly on its innovation ability and less on the market demand.

In an integrated approach, Mancusi (2008) investigated the role of domestic firms' prior R&D to conclude that knowledge accumulation within the firms increases their absorptive capacity and enhances international spillover effects. These hypotheses rely on Cohen and Levinthal (1990), who argue that firms' ability to recognize, assimilate and apply external knowledge is critical to their innovative performance and that absorptive ability is a function of a firms' previous investment in R&D.

### 2.2. Empirical studies on innovation and foreign exposure

There are several empirical papers that study the specific connection between the level of global engagement of firms and their innovative performance. Using logit models for Brazilian firms, Braga and Willmore (1991) found that the probability of innovating by firms was increased by their foreign property and by their exporter orientation: "The coefficient of the export dummy is highly significant and quite large in each equation, evidence that the competitive pressure of producing for foreign markets demands greater access to imported technology, encourages technological effort and increases the utilisation of modern methods of quality control" (p.429).

In a study on the choice between internal and external technology acquisition for Belgian firms, Cassiman and Veugelers (1999) found, using logit models, that "All else equal, a firm that exports 10% more of its production has a 3.74% higher probability of being an innovating firm. Competitive pressure in international markets could account for the fact that constant innovation is the only way to hold on to international market share" (p.71).

Also using logit models, Alvarez and Robertson (2004) found that Chilean and Mexican exporting firms had higher probability of process, packing, product and organizational administration innovations (the exceptions were innovations in product designs and in foreign licenses purchase). They also showed that those effects were not linear and relied on exports destination, as exports to more developed markets were associated with a higher probability of innovating. Moreover, they found a significant, but smaller role for foreign capital.

Using probit models, Blind and Jungmittag (2004) found, for German services firms, that exporting increased innovation propensity by about 50%, both for product and process innovations. Hellebrandt (2007) in an overview of the U.K. CIS data, reported that exporting firms are far more likely to innovate, namely in the group of firms exporting beyond Europe.

Using KPF and CIS data for the U.K. firms in a more proficuous approach, Criscuolo *et al*. (2005) found, through probit and tobit models, that globally engaged firms did generate more innovative outputs. Moreover, they also found that higher innovative capacity was related to superior use of knowledge inputs, and especially to higher learning from more knowledge sources. Wagner (2006) adopted this approach for German firms and confirmed the previous results, reinforcing the thesis that the importance of the knowledge sources varies with the type of innovation performed.

## 3. Data issues on innovation in Portuguese firms: summary statistics

The Portuguese CIS is part of a European Union-wide survey which reports firms' answers to: output of innovation efforts (in product, process, organizational and marketing innovations), inputs of innovation, sources of information-knowledge for innovation efforts, partnerships between firms and other institutions, obstacles to innovation and effects of innovation. It is a voluntary postal survey and covers the manufacturing and the service sectors. CIS follows the OECD and EUROSTAT (2005) Oslo Manual which guides each national survey.

We use the fourth survey carried out in Portugal (CIS 4) conducted in 2005.[2] It is the last one available for researchers and unhappily, it was not possible to access to more than one wave of these Portuguese surveys. 7,370 firms (representative of a population of 27,797 firms) were queried about their innovative activity in period 2002-2004. 74.3% of the firms answered, in a total of 5,475.[3]

According to the OCES report (2006), 40% of Portuguese firms surveyed had innovation activities, on products or processes. If we also include innovations on organizational and marketing levels this number reaches 62%. Considering firms' personnel numbers (we could only use the group dimension of firms),[4] the percentage of innovative firms increases with the dimension of firms, measured by the number of workers.[5]

[2] Two previous statistical problems arise from the sample design of CIS: one is non-response and the related bias, the other is that the survey is conducted at enterprise level (or firm level that we use as synonymous) and each firm can have more than one business establishment. Eventually it would be of interest to have establishment data. Nevertheless, these situations are common to all national CIS and therefore we did not distinguish between firm and establishment units.

[3] The CIS is a voluntary survey but in the Portuguese CIS 4 the overall response rate was higher than those obtained, for example, in CIS 4 for the U.K. (42%).

[4] This variable has four dimensions: 4 – large enterprises have more than 249 workers, 3 – medium enterprises have from 50 until 249 workers, 2 – small enterprises have less than 50 workers but more than 9, 1 – micro enterprises with less than 10 workers.

[5] On average, enterprises spent about 2% of their global turnover in innovation input. The portion of innovative firms is greater than 75% for R&D services, communications, technical analysis, chemical and petrol, but in other sectors it is lower than 30%: apparel, textiles and leather industries. Of all innovators, 10% had received public financing or even public subsidies.

The CIS 4 allows us to know if an enterprise belongs to a foreign group,[6] or not, because firms are asked if they are part of a group of enterprises and in which country is located the head office of that group. The CIS 4 does not ask Portuguese firms if they are Portuguese multinational parents with subsidiaries abroad; therefore unabling us to study the performance of those type of firms. At the other hand, CIS 4 surveys if an enterprise exports or not, but it does not report the export intensity, although, for exporters it allows us to split export destinations between EU countries and other destinations.

Thus, given the data availability, we created four levels for global engagement of Portuguese firms:[7] (i) Global Multinationals (*GM*), which are subsidiaries[8] (of foreign firms) located in Portugal and that export – being the group of more globalized firms in the data, (ii) Internal Multinationals (*IM*), which are subsidiaries of foreign firms located in Portugal but do not export, (iii) Exporters (*EXP*), which do not belong to foreign group and export; and, (iv) Purely Domestic (*DOM*) which do not export nor are part of a multinational. Our CIS 4 benchmark sample has 4,815 enterprises: 353 *GM* (7.3% of the sample), 131 *IM* (2.7%), 1,904 *EXP* (39.5%) and 2,427 *DOM* enterprises (50.4%).

Table 1 shows that there are clear basic differences in overall performance across these four groups: average "size" (measured by classes of employment level), average output growth (2002-2004) and average output level (2004) are highest for *GM*, followed by *IM* and *EXP*, all far above the *DOM* firms. Given the limitations of the data employed we are not able to compute "labour productivity of firms" as we have no access to the exact number of workers. We can, nevertheless, divide each of the four groups average turnover by each firms' group labour dimension (average size) and obtain a proxy for labour efficiency. The global

[6] According with CIS definition "Group is a bunch of firms linked by legal and financial ties".
[7] Data does not allow us to recognize which Portuguese firms have foreign direct investment what would permit a wider analysis of global engagement.
[8] Subsidiaries are defined by Birkinshaw (1997) as "an operational unit controled by the Multinational headquarters and located outside the home country".

results have the same pattern: *GM* and *IM* have “labour productivity” levels four times higher than *DOM* enterprises; *EXP* almost double the performance of *DOM* enterprises.

**Table 1 - Summary statistics on Overall Performance**

| Sub-sample | “Average Size” | Average Output (thousand of €) | Average Output growth 2002-2004 (%) | Output / “Size” (thousand of €) |
|---|---|---|---|---|
| *GM* | 3.03 | 67,424 | 15.45 | 22,252 |
| *EXP* | 2.46 | 23,848 | 11.40 | 9,694 |
| *IM* | 2.80 | 59,653 | 13.29 | 21,305 |
| *DOM* | 2.22 | 12,453 | -16.28 | 5,609 |
| All | 2.39 | 22,301 | 2.65 | 9,331 |

Source: Own calculations

There is also a certain heterogeneity in the distribution of each type of firm through the 35 different two-digit code of economic activity. *GM* firms are mainly concentrated in wholesale retail, services to enterprises and manufacture of vehicles, trailers and semi-trialers. *EXP* firms concentrate in the previous sectors and also on manufacture of textiles, manufacture of wearing apparel and dressing and dyeing of fur. More than half of *IM* firms concentrate in services to enterprises and insurance companies.

### Knowledge output

In line with Pavitt (1982), the use of several knowledge output measures occurs due to the assumption that there is no single measure to assess innovation activities.

Table 2 shows the higher knowledge output level of more internationally engaged firms in comparison with the poorer performance of *DOM*. Whatever measure is used, IM firms are better than DOM firms; EXP are better than IM and DOM firms and GM are better than all.

**Table 2 - Knowledge Outputs (mean values)**

| Sub-sample | Innovation Product or Process | Product Innovation | Process Innovation | IPPOM | Innovation protection | Novel Sales (thousand of €) |
|---|---|---|---|---|---|---|
| *GM* | 66% | 48% | 60% | 83% | 27% | 7,570 |
| *EXP* | 50% | 33% | 41% | 69% | 21% | 2,164 |

| | | | | | | |
|---|---|---|---|---|---|---|
| *IM* | 48% | 31% | 37% | 77% | 21% | 2,442 |
| *DOM* | 33% | 17% | 29% | 53% | 10% | 878 |
| All | 43% | 27% | 36% | 62% | 16% | 1,921 |

Source: Own calculations
Notes: values are the percentages of firms that report that type of innovation in comparison with all the firms of the group.

"Innovation of Product or Process"[9] is an indicator that takes value one if an enterprise undertakes any product or process innovation (excluding purely organizational innovations).[10] According to the third Oslo Manual of OECD and Eurostat (2005) the definition of innovation refers to new products or services for each enterprise but not necessarily to the market. It states "The minimum requirement for an innovation is that the product, process, marketing method or organization method must be new to the firm" (Oslo Manual, p. 46). *DOM* firms report only half of the innovations undertaken by *GM* and only two thirds of those produced by *EXP*. Splitting innovation into innovation in products and innovation in processes, the higher differences between domestic and more globally engaged firms are observed in respect to products. Meanwhile, *DOM* firms present almost the double of process innovations in comparison with their own product innovations.

If we add Organizational Innovation (as a result of strategic decisions of each firm) and Innovation of Marketing (design, distribution, pricing and promotion) to the previous components, we obtain the second knowledge output measure and the largest one[11]: aggregating the queries on firms´ Innovation on Product, Process, Organization and Marketing (IPPOM).Differences between groups are reduced and *IM* becomes the second more innovative group, overcoming *EXP*.

"Innovation protection" is a binary variable that is equal to one if the enterprise either applied for patents or trademarks and copyrights for industrial design. *DOM* enterprises only

[9] This is a composite variable that aggregates the answers to product innovation and process innovation.
[10] See Appendix Table for detailed definitions of the variables used and the CIS questions associated.
[11] Although not used in the following sections of this paper.

mention a third of the protection measures undertaken by *GM* and only half of the protections done by *EXP*.

Finally, knowledge output is measured by "Novel Sales" (sales of new and improved products, either in the firm or in the market the firm belongs to). Only 25% of sample firms reported Novel Sales. DOM enterprises present a knowledge level output that is a ninth part of GM and a third part of EXP' performance.

**Knowledge input**

Concerning knowledge inputs, the same patterns of differentials are observed: more globally engaged enterprises use more inputs in producing new ideas. Knowledge inputs are captured by R&D expenses and non-R&D expenses. Intramural R&D expenses refer to the creative work of personnel guiding the knowledge increase and to investment spending in buildings and specific equipment for R&D activities. Extramural R&D expenses refers to the acquisition of R&D from both public or private institutions. Non-R&D expenses may include the acquisition of equipment, machinery, software and hardware specifically to produce new products or services, and also expenses for other external knowledge – buying or licensing of patents or rights.

As reported in Table 3, for *Intramural R&D expenses*, *GM* presents a seven times higher level and *EXP* a three times higher level than *DOM* firms. The differences for Extramural R&D are even more pronounced. *EXP* firms present higher R&D expenses than *IM* but in what concerns Non-R&D expenses their position is inverted. In total Innovation Expenses the differences between the groups of firms are quite similar[12].

**Table 3 - Knowledge Inputs (mean values)**

| Sub-sample | Intramural R&D (thousand | Extramural R&D | Non R&D expenses | Total Innovation expenses | Innovation effort intensity | Personnel training (% of |
|---|---|---|---|---|---|---|

[12] In Portugal, the non R&D expenses in innovation account for three quarters of all innovation expenses.

| | of €) | (thousand of €) | (thousand of €) | (thousand of €) | (%) | firms) |
|---|---|---|---|---|---|---|
| *GM* | 163 | 94 | 607 | 864 | 1.28% | 57.5% |
| *EXP* | 63 | 21 | 260 | 344 | 1.44% | 33.6% |
| *IM* | 20 | 8 | 274 | 302 | 0.50% | 40.5% |
| *DOM* | 23 | 6 | 102 | 131 | 1.05% | 25.7% |
| All | 49 | 18 | 207 | 274 | 1.22% | 32.8% |

Source: Own calculations
Notes: Innovation effort intensity means the ratio of Total innovation expenses on turnover.
Personnel training is a variable equal to one if the employees receive internal or external training specifically oriented to the development and introduction of new products or processes or of highly improved ones.

Given the possibility that the superiority of more global enterprises may reflect their greater size, we also study the behaviour of "Innovation Effort Intensity" that represents the share of total Innovation Expenses in each firm´s turnover. In contrast with previous results we find that, on one hand *EXP* firms show the highest innovation effort intensity and on the other hand *DOM* firms present an unexpected high value compared to *IM* and *GM* firms. This may be explained by the fact that both *GM* and *IM* firms may rely on their parent company innovation efforts.

In light of the unavailability of data on R&D personnel, we used the percentage of firms, of each group, that reported internal or external personnel training especifically oriented to the development and introduction of new products or processes. More than 50% of all *GM* firms report to achieve that type of personnel training, but only a quarter of *DOM* firms report having personnel training for Innovation.

**Sources of knowledge information**

Given the fact that not all of the variation in knowledge outputs can be accounted for by variation in knowledge inputs, it is important to study how and where firms get information on knowledge improvements, and how important those sources are. In CIS 4, each innovative enterprise was asked to report where came from any valuable information for innovation and which was the importance of that source: high (code 3), medium (code 2), low (code 1) or null (code 0).

Table 4 shows the mean values of these answers, considering the information origin: Internal to enterprises (including all information internal to the enterprise or to the group), from Suppliers and Clients ("Vertical type"), from Universities and Polytechnic schools and other interface organisations, from Government laboratories and institutions, from Competitors, from "Free access sources" including information obtained in Conferences, Scientific publications, Professional meetings and finally from Private Consulting.

**Table 4 - Knowledge Flows (mean values), values in units**

| Sub-sample | Internal | Suppliers | Clients | Universities | Government | Competitors | Conferences | Scientif | Professional | Consultants | All sources |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *GM* | 0.88 | 1.13 | 0.98 | 0.73 | 0.66 | 1.18 | 1.26 | 1.14 | 1.14 | 0.90 | 1.00 |
| *EXP* | 0.76 | 0.89 | 0.85 | 0.59 | 0.53 | 0.64 | 0.90 | 0.95 | 0.90 | 0.63 | 0.90 |
| *IM* | 0.62 | 0.87 | 0.82 | 0.39 | 0.38 | 0.82 | 0.69 | 0.75 | 0.72 | 0.53 | 0.67 |
| *DOM* | 0.53 | 0.61 | 0.59 | 0.29 | 0.25 | 0.61 | 0.61 | 0.60 | 0.55 | 0.38 | 0.50 |
| All | 0.65 | 0.77 | 0.73 | 0.44 | 0.40 | 0.79 | 0.77 | 0.79 | 0.74 | 0.52 | 0.59 |

Source: Own calculations

Notes: Each variable is a categorical indicator of how important a different knowledge source is to the enterprise's innovation activity. Each of them takes four possible values: 0, 1, 2, 3; higher values have greater importance as an information source. For each cell, there is the mean of each sub-sample. "All sources" represent the average of all types of sources. In the table we report the mean values for each group of firms.

In general, *GM* learn two times more and *EXP* learn 1.8 times more than *DOM* firms. The difference is even more evident in learning from Universities and Government institutions. On the other hand, *DOM* firms have their "highest" level of learning in clients and suppliers and their lowest level in the "formal sources" as Government and Universities.

### Overall knowledge statistics

The four groups of firms differ in all three areas of knowledge production functions: knowledge outputs, knowledge inputs and access to flows from existing knowledge. These results confirm that firms use and exploit differently the existing stock of knowledge and flows.

The data of Table 5 also show that more global engaged firms have higher “knowledge output productivity”. Using “novel sales per intramural R&D expenses” *GM* display an “innovation productivity” four times higher than *DOM* firms and that represents the double of the level of *EXP*. This suggests that innovation resources may have different efficiency depending on firms global engagement level.

**Table 5 - Knowledge Output Productivity**

| Sub-sample | Novel Sales per Intramural R&D Expenses (€) | Novel Sales per Total Innovation Expenses (€) |
|---|---|---|
| *GM* | 56 | 9 |
| *EXP* | 26 | 6 |
| *IM* | 44 | 8 |
| *DOM* | 14 | 6 |
| All | 23 | 7 |

Source: Own calculations

CIS also allows us to know if a firm participates in active innovation projects with other firms or non-commercial institutions. Firms were also encouraged to state which collaboration partner was the most crucial from a list of other firms in the group, suppliers, clients, competitors, private consulting, universities and polytechnic schools, governmental laboratories and public R&D institutions. 528 firms answered this question. Suppliers (25% of all answers), other enterprises of the same group (23%) and clients (18%) were the most cited sources of co-operation. Looking at the partnerships made by *EXP* the most crucial partners were clients and suppliers, each indicating 23% of all co-operation agreements. This could mean that exporting firms learn more (in knowledge terms) from their clients and suppliers.

On the other hand, it was possible to recognize that the lack of information was the main obstacle firms faced concerning innovation ability. The shortage of market information, the lack of innovation partnerships and scarcity of skilled personnel were also handicaps for more innovation. Concerning with the usefulness of innovation as perceived by the respondents, there was a clear majority of answers identifying labour cost reduction and higher flexibility in production as the most important effects, suggesting the possibility of productivity improvements.

## 4. Estimation issues and econometric strategies

At the estimation level, given the different nature of the three measures of knowledge output, different econometric estimators were required. *Innovation – Product or Process* and *Innovation Protection* are binary variables assuming only zero or one values, but *Novel Sales* is continuous non-negative, although frequently assuming zero values.

For the two binary variables *Innovation – Product or Process* and *Innovation Protection* we estimate several KPF versions using probits (and also using logits, although not reported). We report the marginal effects on the dependent variable, at the mean values of the regressors and we also present the standard errors of marginal effects. The purpose is to report the effect of a unit increase in the independent variable studied, on the probability that the dependent variable equals one, *ceteris paribus*. Estimations are compute using maximum likelihood method.

Endogeneity may be important in these estimations. Some regressors, namely those connected with knowledge inputs, may be correlated with the regression error term. Some unobserved determinants of innovation success can also affect knowledge level inputs. It can result from certain unobserved firm fixed effects, like a highly-valued R&D culture or a high propensity for new ideas and organizational changes. It can also arise from time-varying effects, like a high (but short run) firm managerial talent or a country-favourable innovation policy. In order to minimize those handicaps, we use a common set of control variables for all estimations: in particular, industry and service dummies and size (measured by the some categories of level of employment).[13] Furthermore, our global-engagement regressors have the advantage that may proxy for unobserved firm effects such as firms' managerial ability. We could not employ other recommended strategies to deal with endogeneity, such as instrumental variables or panel data methods due to limitations of data availability (e.g. R&D personnel and other CIS data wave were not available).[14]

With regard to the fourth innovation measure, *Novel Sales*, given the fact that this variable is a continuous non–negative but equals zero for many firms, we estimate KPF using the tobit model (censored regression model). As in many censored regression models, a change in a certain independent variable has two kinds of effects: a change in the mean of the dependent variable, given that it is already observed and also a change in the probability of the dependent variable to be observed (given the fact it was not yet). In order to obtain the marginal effects of interest we use the McDonald and Moffit (1980) decomposition to report marginal effects conditional on positive Novel Sales, that is to say, the former kind of effect. In order to perform it in *Stata 10* we followed Cong (2001) and Kang (2007).

Estimation of KPF raises some measurement issues that have been previously discussed in Criscuolo *et al*. (2005). Possible measurement errors in regressand (output knowledge) and regressors (input and knowledge flows) may arise. Moreover, the answers on the survey may be question and context dependent. Nevertheless, the richness of our data plus the fact that it is direct data and importance-weighted gives us the possibility to control for many possible biases from the omission of relevant variables in KPF specification.

## 5. Estimation results

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[13] We were not allowed to access the real number of employees but only to the four dimension groups of total firms´ employment: dimension 1 (5 to 9 employees), dimension 2 (10 to 49), dimension 3 (50 to 249) and dimension 4 (more than 250 employees).

[14] GPEARI/MCTES denied the hand out of those data invoking confidentiality issues.

Tables 6 to 8 report the estimates of three KPF versions that are associated with the three different measures of knowledge output that we use, respectively: *Innovation – product or process, Innovation Protection and Novel Sales*. For each version of KPF function we estimate five different specifications, always reporting marginal effects of the regressors on the dependent variable. In all specifications the variable *DOM* is excluded as a regressor and by doing so these firms become our reference group in all analysis.

The first specification, regression 1, uses as independent variables, the three global engagement levels: *GM, EXP, IM*. Next, we consider as additional independent variables either *Intramural R&D* or *Total Innovation Expenses*, in regressions 2 and 4, respectively. Finally, regressions 3 and 5 include additionally ten independent variables that capture knowledge information flows. In all regressions we use (although not reported, for brevity) as control variables 35 two-digit industry or service dummies and 4 classes of firm size to help control cross-firm differences that may impact firm´ innovative performance.

**5.1. Estimates of KPF for "Innovation – product or process".**

Table 6, reports the estimates for the five different specifications used to study the Knowledge Production Function for *Innovation -Products* or *Processes.*

In column 1, the estimates show that all globalization indicators are statistically significant,[15] positive and their values suggest that more globalized firms have a higher probability to innovate than less globalized ones. We detect that *GM* are 26 percentage points (pp) more likely to innovate than the omitted *DOM* firms. For exporters the advantage over *DOM* is of 15 pp. In column 2 we add one knowledge input indicator, *Intramural R&D.* It is positive and statistically significant. Coefficients of the global engagement indicators are now slightly reduced, which means that differences in the dependent variable (*Innovation – products or processes*) are not mainly explained by this knowledge input differences. Using

[15] As validated by Z and log likelihood tests.

an alternative knowledge input indicator, in column 4, the global engagement indicators are reduced by two thirds suggesting that *Total expenses in innovation* are more significant in explaining innovative performance.

**Table 6 - Estimates of KPF for "Innovation – product or process".**

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| *GM* | 0.261<br>(0.0004) | 0.240<br>(0.028) | 0.188<br>(0.052) | 0.070<br>(0.011) | 0.180<br>(0.052) |
| *EXP* | 0.154<br>(0.016) | 0.148<br>(0.016) | 0.043*<br>(0.029) | 0.056<br>(0.009) | 0.045 **<br>(0.030) |
| *IM* | 0.083<br>(0.046) | 0.077*<br>(0.046) | 0.158*<br>(0.079) | 0.021+<br>(0.019) | 0.141*<br>(0.080) |
| *Intramural R&D* | | 0.0012<br>(0.0002) | 0.00002*<br>(0.0001) | | |
| *Total expenses in Innovation* | | | | 0.0011<br>(0.0003) | 0.0003<br>(0.0003) |
| *Internal Info.* | | | 0.289<br>(0.022) | | 0.294<br>(0.023) |
| *Clients Info.* | | | 0.101<br>(0.020) | | 0.102<br>(0.021) |
| *Supply Info.* | | | 0.234<br>(0.020) | | 0.231<br>(0.021) |
| *Private Consulting Info.* | | | - 0.096+<br>(0.017) | | -0.012+<br>(0.017) |
| *University & Polytechnic Info.* | | | 0.066<br>(0.022) | | 0.064<br>(0.023) |
| *Government Info.* | | | 0.068+<br>(0.021) | | 0.0006+<br>(0.022) |
| *Conferences, Exhibitions Info.* | | | 0.066<br>(0.020) | | 0.065<br>(0.021) |
| *Scientific Info.* | | | 0.050<br>(0.019) | | 0.051*<br>(0.021) |
| *Professional Info.* | | | 0.029<br>(0.017) | | 0.018+<br>(0.017) |
| *Competitors Info.* | | | 0.086<br>(0.017) | | 0.086<br>(0.018) |
| Observations | 4815 | 4815 | 4815 | 4815 | 4815 |
| LR chi2 | 300 | 462 | 5042 | 319 | 5072 |
| Prob > Chi2 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |

Source: Own calculations

Notes: Each column is a different estimated specification and for each line we report the marginal effects for that regressor as estimated by probit. We compute the estimation of marginal effects at the mean values of the regressors. All specifications include additional control variables: two digit industry / service dummies and employment size (both not reported). If nothing is mentioned all estimates are statistically significant at 1% level.
*****: statistical significance at 10%
******: statistical significance at 5%
+: not statistically significant

Column 3 reports the regressions that include the 10 variables capturing knowledge information–flows. Overall, the estimates confirm the hypothesis that information knowledge flows contribute positively to the innovation output. Eight in ten sources of knowledge information considered are statistically significant, with special relevance for internal sources, suppliers and clients. The coefficients of international engagement are now even smaller than in regression 2; *GM* coefficient is reduced in about one quarter and *EXP* coefficient is reduced in about two thirds. The later suggests that EXP firms´ access and use of information knowledge flows may be particularly relevant to their innovation output. Information from universities and "free sources" are significant but with minor impact. On the other hand, information from government institutions and private consulting are neither statistical nor economic relevant.

In column 5 the regression uses *Total expenses in innovation* as an alternative knowledge input indicator and generally the estimates confirm the results found in regression 3. Overall all these regression results confirm the global engagement hypothesis.

### 5.2. Estimates of KPF for "Innovation protection".

Table 7, reports the estimates for the five different specifications used to study the Knowledge Production Function for *Innovation Protection* (patent appliances, utility model appliances, trademarks and copyrights).

In the first specification (column 1) we run *Innovation Protection* on globalization indicators and control variables. Estimates show that all globalization indicators are positive, statistically significant and their values reveal that more globalized firms have a higher probability to protect innovations than less globalized ones. The coefficient on *GM* indicates that those firms are 14 pp more likely to protect innovations relative to the omitted purely domestic firms. *EXP* firms are 10 percentage points more likely to protect innovations than the domestic enterprises. In column 2, the regression adds *Intramural R&D* which is positive and statistically significant. In column 4, we regression uses an alternative variable, *Total expenses on Innovation*, but as in the previous case the coefficients of the international indicators are almost unchanged, which means that differences in the dependent variable (*Innovation Protection*) are not mainly explained by input differences.

Once we add in the ten knowledge information-flow variables one can see that the coefficients of global engagement present a slight decrease (column 3 and 5). Moreover, only Private consulting, Professional and Government Information are statistically significant. These two facts clearly suggest that the information-flow variables have a small role in explaining firms´ ability to protect innovation. Moreover, not reported control variables, especially industry dummies, have now an important weight in the explanation of the actual variation across firms.

Overall all these regression results still confirm the global engagement hypothesis. However, the *protection of innovation* is not so dependent of the global engagement of firms as found in the *innovation – product or process.*

**Table 7 - Estimates of Knowledge Production Function for "Innovation Protection"**

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| *GM* | 0.136<br>(0.027) | 0.129<br>(0.027) | 0.090<br>(0.026) | 0.132<br>(0.027) | 0.092<br>(0.025) |
| *EXP* | 0.107<br>(0.012) | 0.104<br>(0.012) | 0.080<br>(0.012) | 0.106<br>(0.012) | 0.082<br>(0.012) |
| *IM* | 0.096<br>(0.040) | 0.101<br>(0.041) | 0.0921<br>(0.041) | 0.096<br>(0.040) | 0.088<br>(0.040) |
| *Intramural R&D* | | 0.00011<br>(0.00002) | 0.00007<br>(0.00002) | | |
| *Total expenses in Innovation* | | | | 0.000004 | 0.000015 |

| | | | | | |
|---|---|---|---|---|---|
| | | | | (0.0000) | (0.0000) |
| *Internal Info.* | | | 0.002+<br>(0.009) | | 0.0001+<br>(0.009) |
| *Clients Info.* | | | 0.0041+<br>(0.008) | | 0.003+<br>(0.008) |
| *Supply Info.* | | | 0.010+<br>(0.009) | | 0.012**<br>(0.009) |
| *Private Consulting Info.* | | | 0.013<br>(0.006) | | 0.013<br>(0.006) |
| *University & Polytechnic Info.* | | | 0.0044+<br>(0.007) | | 0.0056+<br>(0.007) |
| *Government Info.* | | | 0.012*<br>(0.007) | | 0.011*<br>(0.007) |
| *Conferences, Exhibitions Info.* | | | 0.007+<br>(0.008) | | 0.007+<br>(0.008) |
| *Scientific Info.* | | | 0.004+<br>(0.004) | | 0.004+<br>(0.007) |
| *Professional Info.* | | | 0.014<br>(0.007) | | 0.016<br>(0.007) |
| *Competitors Info.* | | | 0.070+<br>(0.007) | | 0.006+<br>(0.007) |
| Observations | 4815 | 4815 | 4815 | 4815 | 4815 |
| LR chi2 | 200 | 244 | 411 | 207 | 389 |
| Prob > chi2 | 0,0000 | 0,0000 | 0,0000 | 0,0000 | 0,0000 |

Source: Own calculations
Notes: see notes in Table 6.

### 5.3. Estimates of KPF for "Novel Sales"

Table 8, reports the estimates for the five different specifications used to study the Knowledge Production Function for *Novel Sales.*

**Table 8 - Estimates of Knowledge production function for Novel Sales,** Unit: €

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| *GM* | 7.076.513<br>(902.987) | 6.904.537<br>(901.453) | 3.875.123<br>(694.632) | 6.741.780<br>(882.830) | 3.794.555<br>(689.590) |
| *EXP* | 3.560.770<br>(413.613) | 3.489.630<br>(409.310) | 1.497.470<br>(360.408) | 3.452.112<br>(407.210) | 1.488.026<br>(359.235) |
| *IM* | 2.230.214<br>(1.206.050) | 2.328.929<br>(1.201.207) | 1.867.307<br>(1.056.455 | 2.233.451<br>(1.190.348) | 1.793.377<br>(1.049.345) |
| *Intramural R&D (thousand €)* | | 1.097 | 647 | | |

| | | | | | |
|---|---|---|---|---|---|
| | | (177) | (140) | | |
| *Total Innovation Expenses (thousand €)* | | | | 299<br>(42) | 167<br>(31) |
| *Internal Info.* | | | 1.087.227<br>(225.979) | | 1.074.594<br>(225.315) |
| *Clients Info.* | | | 385.833<br>(207.034) | | 325.993<br>(206.375) |
| *Supply Info.* | | | 1.213.207<br>(217.425) | | 1.258.270<br>(217.702) |
| *Private Consulting Info.* | | | -1.445<br>(150.036) | | -16.320<br>(149.685) |
| *University & Polytechnic Info.* | | | 449.083<br>(177.388) | | 459.885<br>(176.821) |
| *Government Info.* | | | 344.934<br>(176.040) | | 297.197<br>(177.321) |
| *Conferences, Exhibitions Info.* | | | 538.172<br>(205.620) | | 541.285<br>(197.821) |
| *Scientific Info.* | | | 875.500<br>(198.455) | | 869.846<br>(162.345) |
| *Professional Info.* | | | 110.040<br>(162.677) | | 124.799<br>(161.021) |
| *Competitors Info* | | | 300.050**<br>(170.020) | | 285.450**<br>(170.210) |
| Observations | 4815 | 4815 | 4815 | 4815 | 4815 |
| LR chi2 | 263 | 302 | 1318 | 311 | 1320 |
| Prob > chi2 | 0,0000 | 0,0000 | 0,0000 | 0,0000 | 0,0000 |

Source: Own calculations

Notes: Each column is a different estimated specification and for each line we report the marginal effects for that regressor as estimated by tobit. For each specification we present the marginal effects conditional on non-zero values for Novel Sales. See also notes in Table 6.

In regression 1 the three globalization indicators are positive and statistically significant and their values reveal that more globalized firms generate more *Novel Sales* than less globalized ones, which is in line with the conclusions obtained in the other two KPF versions. The estimates show that, conditional of *Novel Sales* being non-zero, the transformation of a *DOM* firm to a *GM* firm generated, ceteris paribus and in average, a surplus of seven millions euros of *Novel Sales.* For exporters this advantage is of three and a half million euros. In column 2 we add *Intramural R&D expenses*. It is positive and statistically significant. In column 4 we use the alternative knowledge input indicator. The results show that, conditional on *Novel Sales* being non-zero, each additional euro spent in *Intramural R&D* has the ability to generate four times more new sales than each euro spent in *Total Innovation Expenses*. This suggests that *Total innovation expenses* are less effective to generate *Novel Sales* than firms´ own R&D expenses.

In regressions 3 and 5 the coefficients of all knowledge information-flow variables are statistically significant and they have positive impact on *Novel Sales* with the exception of private consulting information. The global engagement indicators fall by 50% once the knowledge informational-flow variables are introduced. The most relevant informational flows are suppliers, internal information and scientific sources. Free sources are also vital. The impact of clients is inferior to that found in two previous KPF versions.

Bearing in mind estimates in Tables 6, 7 and 8, we can state that the subsidiaries of multinationals present higher propensity to innovate than exporters. Indeed, looking at columns 3 and 5, we observe that *IM* coefficients are systematically higher than *EXP* coefficients.

## 6. Innovation accounting

This section presents an attempt to evaluate the relative importance of knowledge inputs and of knowledge information flows, in explaining differences on knowledge output between groups of firms with different levels of global engagement. In general, innovation accounting tries to establish how much of the higher innovation-output level, of more global firms[16], is explained by: (i) their higher use of the knowledge input *Intramural R&D expenses*[17], (ii) their higher ability to access and use knowledge flows, iii) their globalized nature and is left

[16] In comparison with *DOM* firms.
[17] Although not reported – for brevity - we also tested the alternative knowledge input indicator – *Total innovation expenses* – with similar results.

unexplained by (i) and (ii)[18]. Table 9 presents innovation accounting statistics[19] for each of the three Innovation output indicators used in this paper.

As an example, looking for *Innovation- product or process*, we observe in Table 6 (column 1) an estimate suggesting that *GM* firms have a 26 p.p. higher probability to innovate than *DOM* firms. The innovation accounting splits this advantage of *GM* firms in terms of the share due to differences, between *GM* and *DOM* firms, in *Intramural R&D expenses* and the share due to differences in the use of knowledge information flows. For that purpose we multiply the estimates in Table 6 (column 3) to the actual differences observed both in *Intramural R&D expenses* (Table 3) and in the use of knowledge information flows (Table 4). Appendix B presents the procedures used to compute these values that are later reported in Table 9 (column 1, rows 1 to 3).[20]

**Table 9 – Innovation accounting statistics**

| | Innovation | Innovation Protection | Novel Sales |
|---|---|---|---|
| Actual difference between GM and DOM firms (Table 2) | 33p.p. | 17p.p. | 6.692.000€ |
| Estimated difference between GM and DOM firms (Tables 6, 7 and 8) | 26p.p. | 14p.p. | 7.076.000€ |
| GM Share of Intramural R&D expenses | 1% | 7% | 1% |
| GM Share of Knowledge Information-Flows | 141% | 8% | 36% |
| GM Share left unexplained | 72% | 66% | 54% |
| Actual difference between EXP and DOM firms (Table 2) | 17p.p. | 11p.p. | 1.286.000€ |
| Estimated difference between EXP and DOM firms (Tables 6, 7 and 8) | 15p.p. | 11p.p. | 3.561.000€ |
| EXP Share of Intramural | < 1% | 4% | 0.2% |
| EXP. Share of Information-Flows | 144% | 8% | 41% |
| EXP Share left unexplained | 28% | 52% | 42% |

[18] Eventually, meaning the high efficiency connected with the nature of more globalized firms in translating *Intramural R&D expenses* and knowledge information flows into innovation outputs.
[19] In these statistics we do not consider the estimates of the usual control variables. For this reason the sum of the shares is not equivalent to 100%.
[20] Although not reported, for brevity, similar procedures and computations are made for *Innovation Protection* and *Novel Sales*.

| | | | |
|---|---|---|---|
| IM Share of Intramural | Not significant | Not significant | -0.2% |
| IM Share of Information-Flows | Not significant | Not significant | 37% |
| IM Share left unexplained | Not significant | Not significant | 67% |

Source: Own calculations
Notes: The shares do not add up to 100% because the effects associated with control variables are not considered.

Looking at values reported in Table 9 several conclusions arise. Firstly, our Knowledge Production Function estimates seem to explain properly the differences, in actual data, between the different groups of firms as estimated differences are similar to their actual values. In what respects the innovation accounting of the *Innovation – product and process,* similar results for *GM* and *EXP* firms arise. For both groups, the use of knowledge information flows explains most of their superior innovation output. In the case of the *Innovation Protection* variable the share of *Intramural R&D expenses* is higher than that found in the other two innovation functions, but is still small. In turn, the globalized nature of *GM* and *EXP* firms is the most important factor for their superior innovation output. As for *Novel Sales*, both *GM* and *EXP* firms show similar patterns of innovation accounting. Their superior innovation output is mainly due to their use of information flows and their globalized nature, in almost equal terms.

Moreover, it is noticed that, knowledge information flows are clearly more important than *Intramural R&D expenses,* for all the KPF versions. Although not reported while computing innovation accounting, we notice that the importance of each knowledge information flow varies across the three KPF versions. On the one hand, suppliers, clients and internal sources are dominant for *Innovation – product or process*; on the other hand, for *Innovation Protection* private consultants and government have greater importance. In what concerns *Novel Sales*, suppliers and internal sources, together with scientific sources are the most significant.

## 7. Concluding remarks

In line with a recent trend in trade literature, this paper applies, for the first time to Portuguese firms, a new way to assess the relationship between innovation performance and the international exposure of firms. To our known, there are only two similar previous studies, using data for the U.K. and German firms, which concluded that more internationally engaged firms are more innovative.

This study uses a Knowledge Production Function framework and data from the European Community Innovation Survey, 2002-2004, for Portuguese firms to test those alleged and expected connections, known in the literature as the Global Engagement hypothesis. We argue that the test confirms that hypothesis.

This study shows that Portuguese firms that are more globally engaged have a higher ability to innovate. Moreover, as the level of global engagement rises that superiority increases – *GM* firms are the better in all knowledge output indicators. These results arise from their higher use of knowledge inputs – *Intramural R&D expenses or Total Innovation Expenses* - from their greater access to a larger stock of ideas – knowledge information flows- and from their globalized nature. Those results where consistently confirmed in each of the three knowledge production functions used to test the Global Engagement hypothesis: *Innovation – product or process; Innovation Protection* and *Novel Sales.*

This study also finds that the access to knowledge information flows has systematically an higher impact on innovation ability than knowledge inputs, which is in line with previous studies. In the same line, our study reveals that the importance of knowledge information sources varies with both the type of innovation output indicator considered and the level of global engagement of firms. In fact, Portuguese firms access to the global knowledge stock through three main channels: their internal pool of information (especially for Multinational enterprises), their market contacts with clients, suppliers (especially for Exporters) and competitors and also their wider access to free information sources such as scientific publications, fairs, conferences or professional activities.

On the other hand, those outcomes allowed us to uncover the weakness of some models that argued knowledge was a public and free good, always available to the world. In fact, in our study, we could also verify that existing knowledge stock is not uniformly accessible through the world, and that more engaged firms have both more access to it and higher capacity for taking advantage of it. This logic is often called the "paradox of openness" (Laursen and Salter, 2005) in the sense that, at one hand, the innovation creation requires firms´ "openness", resulting in additional importance for the ability to access and adopt others' ideas – knowledge information flows - but, at the other hand, in order to apply and profit from those innovations, firms also need to obtain returns from their innovative ideas, which in turn requires their own internal effort and appropriability capacity.

We are conscious that there are also other organizational and environmental aspects that Knowledge Production Function framework does not capture and which may be of importance in explaining the alleged innovation superiority of the most global engaged firms. Nevertheless, in spite of both data and methodological handicaps, our findings may contribute to a better understanding of new ideas creation process, and in this context to the understanding of what is so special about more globally engaged firms', given their superior ability to develop and use more knowledge.

Future developments on this area of research could explore the determinants of the differences in productivity between more and less globalized firms. In fact, assuming that one of the main causes of the differences between firms´ productivity are different innovative abilities, the present study could also serve to raise the interest in future analysis connecting productivity and global engagement levels of Portuguese firms.

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## Appendix A: Survey Questions in CIS 4

### 1. Measures of Knowledge Outputs

| Variable name | Question in CIS 4 |
|---|---|
| Product Innovation | During the three year period 2002-2004, did your enterprise introduce any technologically new or significantly improved products (goods or services) which were new to your firm? |
| Process Innovation | During the three year period 2002-2004, did your enterprise introduce any technologically new or improved processes for producing or supplying products which were new to your firm? |
| Novel Sales | Please estimate how your turnover in 2004 was distributed between products (goods or services) introduced during the period 2002-2004 which were:<br>New to your firm + Significantly improved (% of total turnover) |
| Innovation Protection | During the period 2002-2004, did your enterprise apply for any patent, utility model or registered any trademark or copyright? |

### 2. Measures of Knowledge Inputs

| Variable name | Question in CIS 4 |
|---|---|
| Intramural R&D | Please tick if expenditure in the category [of] Intramural research and experimental development (R&D); [and if so ticked], please estimate innovative expenditure in 2004, including personnel and related investment expenditures (no depreciation) |
| Extramural R&D | Please tick if expenditure in the category [of] Extramural research and experimental development (R&D); [and if so ticked], please estimate innovative expenditure in 2004, excluding machinery, software and other external knowledge |
| Total Innovation expenses | Please estimate innovative expenditure in 2004, in Intramural R&D, Extramural R&D and other non-R&D as machinery, software and other external knowledge. |

### 3. Measures of Knowledge Flows

| Variable name | Question in CIS 4: Sources of Information for Innovation Activities. Please indicate the sources of knowledge or information used in your technological innovation activities, and their importance during the period 2002-2004. |
|---|---|
| Internal Information | Self Within the enterprise or from Group Other enterprises within the enterprise group |
| Vertical Information | Suppliers of equipment, materials, components or software<br>Clients or customers |
| Information from competitors | Competitors |
| Commercial Information | Private Consultants and R&D enterprises |
| Free Information | Professional conferences, meetings, trade associations fairs, exhibitions |
| Information from Schools | Universities and Polytechnic schools |
| Information from Government | Government research organizations and offices |

## Appendix B: Innovation Accounting for *GM* firms and *Innovation- product or process*

| | Estimates of KPF | Actual differences between GM and DOM firms | (3) = (1) x (2) | Share<br>(4) = (3) : 0.262 |
|---|---|---|---|---|

| | (1) | (2) | | |
|---|---|---|---|---|
| Estimated difference between *GM* and *DOM* firms | | | | 0.262 |
| Intramural R&D expenses (thousands of euros) | 0.00002 | 163 – 23 = 140 | 0.0028 | 0.011 |
| Internal Information | 0.289 | 0.88 – 0.53 = 0.35 | 0. 101 | 0.388 |
| Clients Information | 0.101 | 0.98 – 0.59 = 0.39 | 0.039 | 0.149 |
| Suppliers Information | 0.234 | 1.13 – 0.61 = 0.52 | 0.122 | 0.466 |
| Private Consulting Information | -0.096 | 0.90 – 0.38 = 0.52 | - 0.050 | 0.191 |
| University and Polytechnic Information | 0.066 | 0.73 – 0.29 = 0.44 | 0.029 | 0,111 |
| Government Information | 0.068 | 0.66 – 0.25 = 0.41 | 0.028 | 0.107 |
| Conferences and Exhibition Information | 0.066 | 1.26 – 0.61 = 0.55 | 0.036 | 0.137 |
| Scientific Information | 0.050 | 1.14 – 0.60 = 0.54 | 0.027 | 0.103 |
| Professional Information | 0.029 | 1.14 – 0.55 = 0.59 | 0.017 | 0.065 |
| Competitors Information | 0.086 | 1.18 – 0.61 = 0.57 | 0.049 | 0.187 |
| All knowledge information flows | - | | 0.369 | 1.41 |
| *GM* nature - left unexplained by knowledge inputs and information flows | 0.188 | | 0.188 | 0.72 |
| Total contributions | | | | 0.011 + 1,41 + 0.72 = 2.14 |

Note 1: This table combines the coefficient estimates of Table 8 with differences between the mean values of Tables 2, 3 and 4 to calculate what explains the actual differences in *Innovation – product or process* between *GM* firms and purely domestic ones. In order to perform it we split the effects of *Intramural R&D expenses*, the effects of all Knowledge information flows and the effect of *GM* nature that was left unexplained by the previous factors.

Note 2: The shares do not add up to 100% because the effects associated with control variables are not considered.