# Assessing the influence and impact of R&D institutions by mapping international scientific networks: the case of INESC Porto

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**Abstract:** Studies about the influence and impact of knowledge-producing organisations' (*e.g.*, universities or *R&D* institutions) have been addressed by means of strict economic analysis, stressing their economic impact in a local, regional or national extent. In the present study, an alternative methodology is put forward in order to evaluate the international scientific impact and influence of a knowledge-producing and -diffusing institution. Two main branches of the literature, dealing with the measurability of the economic impact of *R&D* organisations and their knowledge flows, are surveyed: standard economic studies, and scientometrics and bibliometrics analyses. With the aim of implementing an approach closer to the latter methods, we map the international scientific network of a knowledge-producing organisation using social network analysis statistical tools and thus assess the international impact and influence of such institution. Using INESC Porto – a Portuguese private non-profit organisation, recognised as being of public interest, due to its R&D activities – as our case study, we analyse the dynamics of its scientific production over the last two decades, attributing special attention to the international scientific co-authorships' evolution, outlining the architecture of the knowledge network and its changing pattern. Additionally, focusing on the most prolific scientific areas of INESC Porto, and resorting to published scientific work recorded in the Science Citation Index (SCI) of the Institute for Scientific Information (ISI), we trace citations and infer over INESC Porto's international scientific influence and impact.

**Keywords:** scientific network, knowledge network, international impact, scientometrics, social network analysis

**JEL Codes:** C81, J24, O32

**Course Code:** MEGI.FEP.UP.PT

## 1. Motivations and research aims

It is broadly recognised how R&D research and innovation breakthroughs have the potential to deeply expand or even alter economic growth, which at the end have a strong influence over world-changing dynamics, favouring countries that support knowledge research and innovation (Martin, 1998). The flow of ideas and technologies from universities and R&D institutions has therefore profound consequences over several economic variables. The truth is that international economic activity is increasingly technology-driven and knowledge-based, and this has been forcing firms to produce stronger linkages with innovative knowledge-based institutions, who, by their turn, also seek scientific partnerships to better respond to the higher innovative technology or knowledge demand (Grandstrand et al., 1997; Langlais, 1997; Brusoni et al. 2000; Meyer, 2000b; Meyer, 2004). The importance of such linkages with Research and Development (R&D) and innovation-based organisations has long been defended and reasoned due to their influence over the regional, national and international economic growth (Kuznets, 1966; Martin, 1998). These different-leveled impacts have for long time attracted and challenged researchers within economic science.

Traditionally, the measurability of the economic impact of an university or a R&D organisation was based on several economic variables, such as new jobs created after the public/private investment in R&D projects (cf., Beeson and Montgomery, 1990; Huggins and Cooke, 1997; Gagnol and Héraud, 2001; Cox and Taylor, 2006; Swenson and Eathington, 2007; Barrios et al., 2008), revenues, productivity, worker efficiency (cf., Love and McNicoll, 1988; Newlands, 2003; Harloe and Perry, 2004; Bilbao-Osorio and Rodríguez-Pose, 2004; Braunerhjelm, 2008), and, public health or environmental impact (cf., Hedrick et al., 1990; Simha, 2005). These types of studies assessed such impact mainly through this institutions' influence on the evolution and composition of the Gross Domestic Product (GDP) and were usually associated to the need for backing or justifying public funds allocation (cf., Martin, 1998; Bessette, 2003; Bilbao-Osorio, and Rodríguez-Pose, 2004; Barrios et al., 2008). Such studies are in fact largely related to a branch of the neo-classical growth theory, or more generally, mainstream economics (e.g., Bayoumi et al., 1996).

In contrast with the economic dimension, the knowledge dimension of the influence and impact of R&D organisations is in general much poorly developed. Notwithstanding, several attempts were conducted to study the combining backward expenditures-related linkages and the forward knowledge-related linkages of Universities and R&D organisations (e.g., Felsenstein, 1996; Huggins and Cooke, 1997; Newlands, 2003; Harloe and Perry, 2004; Buxton et al., 2004; Tavoletti, 2007). However, these attempts failed to capture the whole

nature of knowledge flows that goes beyond expenditures linkages.

Scientometrics and bibliometrics approaches are increasingly used by several authors to assess the evolution and structure of scientific knowledge and R&D output (e.g., Meyer, 2004; Wagner and Leydesdorff, 2005; Dietz and Bozeman, 2005; Adams, 2006; Hussler and Ronde, 2007). Normally, studies within this research field (Meyer, 2000b; Meyer, 2004; Wagner and Leydesdorff, 2005) aim to appraise the scientific output of individuals, journals and even organisations (e.g., effective publication in internationally refereed journals, high citation scores) by surveying and analyzing co-authorships and citation indexes. According to Wagner and Leydersdorff (2005), authors within this research field are interested in the increase of the interconnectedness of scientists (e.g., Okubo et al., 1992; Luukkonen et al., 1993; Zitt et al., 2000; Glänzel, 2001; Cantner and Graf, 2006), in figuring out patterns of collaboration in general (e.g., Chung and Cox, 1990; Gibbons et al., 1994; Katz and Martin, 1997; Dietz and Bozeman, 2005; Hussler and Ronde, 2007;) and of international linkages in particular (e.g., Stichweh, 1996; Schott, 1998), and further analysing implications of linkages for funding and outcomes (e.g. Van den Berghe et al., 1998; Wagner et al., 2000; Advisory Council of Canada, 2001; Carmona et al., 2005; Adams, 2006). Although scientometrics and bibliometrics studies embrace a much wider perspective of the linkages/networks of R&D institutions at the regional, national and international context than the standard economic studies, to the best of our knowledge, these studies did not make use of scientometric tools to analyse the influence and impact of R&D institutions. In the present work we aim to contribute to fill this gap. As such, we use scientometrics and bibliometrics approaches to assess the influence and impact of an R&D organisation, complementing therefore traditional economic approaches, and providing a more embracing perspective of knowledge flows. To accomplish such endeavour we resort to social network analysis statistical tools, addressing the main goal of our study which is to map the scientific network of an R&D institution and therefore to evaluate its international influence and impact.

## 2. Assessing the impact and influence of R&D organisations – a literature review

The purpose of this section is to review the two literature branches that fundament the goal pursued by our present work.. Thus, in a first section (Section 2.1.) we devote some attention to the traditional approach of economic studies. Further (Section 2.2.), we link this field of study with scientometrics and bibliometrics literature, which use measurability and relatedness tools to trace knowledge networks. These two sections are complemented by a third one (Section 2.3.), which synthesize those two literature branches, reasoning how the analysis of the production and diffusion of scientific output may contribute to evaluate the international influence and impact of a R&D institution.

### 2.1. Assessing the influence and impact of knowledge-producing organisations - the standard approach of economic studies

It is generally recognised (albeit less empirically proved) the significant role that R&D institutions or knowledge producing organisations have in today's global economic development, by generating valuable returns in terms of economic growth and productivity (cf., Denison, 1968; Romer 1990: Steinnes, 1987; Dosi, 1988; Feller, 1990; Trajtenberg 1990; Lichtenberg, 1993; Felsenstein, 1996; Bilbao-Osorio and Rodríguez-Pose, 2004).

Economic studies on the methods to measure the impact of a university (and less of a research organisation) at the national or regional economic level have proliferated. Generally, instruments to measure the economic impact of R&D producers are mainly focused on the public funding directed for scientific research, in order to evaluate the usage of public money, i.e., the economic relevance of research (Bailetti and Callahan, 1992; Bozeman and Melkers, 1993; Felsenstein, 1996; Martin, 1998; Bessette, 2003). The focus is thus to evaluate the relevance of activities or outputs, undertaken by universities or R&D institutions, namely the production of skills, know-how, patents, technology transfer and licensing activities, consultancy and spin-offs, new jobs formation, new firms formation, and so on (e.g., Smilor et al., 1990; Bozeman and Melkers, 1993; Goddard et al., 1994; Coe and Helpman, 1995; Felsenstein, 1996; Verspagen, 1997; Bessette, 2003).

Updating the survey of Felsenstein (1996) on the economic impact literature of universities and R&D institutions (cf. Table 1), we might distinguish four main approaches: (i) the proposition of correlation between concentrations of high-technology activities and various location factors that favour spatial clustering; (ii) the evaluation of the role of universities in the economic growth process; (iii) the studies of impact assessment in a strictly economic sense; and (iv) studies that introduce backward expenditures-related linkages combined with forward knowledge-related linkages of universities and R&D institutions.

The first approach, suggested in the work of Felsenstein (1996), includes studies that assess the relationship between the presence of the university or R&D institution and the agglomeration of advanced technological production engines, depicting a 'seeding' effect of these organisations in the local economy, when, for instance, spillovers or spin-offs are produced (e.g., Markusen et al., 1986; Steinnes, 1987; Malecki, 1987; Davelaar and Nijkamp, 1989; Bania et al., 1992). In these studies, the university is one of the most relevant location factors, such as wage rates, amenity aspects, close firms-universities links or metropolitan attractiveness, which contribute to suggest geographically localised effects of university research (Felsenstein, 1996).

As presented by Felsenstein (1996), the second approach – the role of universities in the economic growth process – deals specifically with issues of university-induced growth, i.e., in local labour markets (e.g., Beeson and Montgomery, 1990; Bluestone, 1993;

Bilbao-Osorio and Rodríguez-Pose, 2004; Swenson and Eathington, 2007; Barrios et al., 2008), in new firm formation rates (e.g., Bania et al., 1990), in the development of the local service sector (e.g., Hedrick et al., 1990), or by influencing the human capital effect over the investment patterns of local industry (e.g., Florax, 1992; Love and McNicoll, 1988; Huggins and Cooke, 1997; Newlands, 2003; Steinacker, 2005; Tavoletti, 2007; Braunerhjelm, 2008). In these cases, aggregate models are used from place-based data (cities, metropolitan areas, countries, regions), which find the presence of the university to have a positive effect (Felsenstein, 1996).

The third approach – studies of impact in a strictly economic sense – includes the case of studies that attempt to estimate local economic development impacts, ranging from specific, individual, organisational-centered reports or more academic-type contributions (Felsenstein, 1996). Within this approach, Felsenstein (1996) distinguish three variants: (i) accountability-type studies, which include thoroughly analysis of various kinds of direct impacts (in employment, income and sales) of the university in the economy (e.g., Caffrey and Isaacs, 1971; Moore and Suffrin, 1974; Elliot and Meisel, 1987, Link, 1999; Bessette, 2003); (ii) the regional economic impact studies, which use input-output analysis instruments, econometric modelling and coefficients, focusing on regional change induced by the university presence; (iii) and, finally, demand-side analysis to university impact by using Keynesian-type income-expenditure multipliers, where the scale of this kind of approach is micro, depicting mainly the relationships of the university with the local economy.

Finally, the forth approach draws on the results of Felsenstein (1996), who conceptualises the university as an organisation that, on one side, receives inputs from households, government and firms, paying its staff, equipments, services, and so on (backward linkages of the university with the local economy), and, on the other side, produces outputs like human capital formation or knowledge production (forward linkages, knowledge-related impacts).

**Table 1: Summarising the main approaches on the economic impact of universities and R&D institutions**

| Approaches | | Mechanisms / Methods | Results | Authors |
|---|---|---|---|---|
| **Correlation between concentration of high-technology activities and various location factors which favour clustering** | | Empirical analysis to urban location factors, such as university presence, wage rates, amenity aspects, close firms-universities links or metropolitan attractiveness | • Relationship between the presence of the university and the concentration of advanced technological production;<br>• Geographically localised effects of university research | Markusen *et al.*, 1986; Steinnes, 1987; Malecki, 1987; Davelaar and Nijkamp, 1989; Bania *et al.*, 1992; Audretsch and Feldman, 1996 |
| **The role of universities in the economic growth process** | ***The influence of universities on the local labour market*** | Aggregate models using specific place-based data | Positive influence of the university presence | Beeson and Montgomery, 1990; Bluestone, 1993; Huggins and Cooke, 1997; Gagnol and Héraud, 2001; Rego, 2004; Bilbao-Osorio and Rodríguez-Pose, 2004; Simha, 2005; Cox and Taylor, 2006; Swenson and Eathington, 2007; Barrios *et al.*, 2008 |
| | ***The influence of universities on the rate of formation of new firm*** | | | Bania *et al.*, 1990 |
| | ***The influence of universities on the development of the local service sector*** | | | Hedrick *et al.*, 1990 |
| | ***The human capital effect over the investment patterns of local industry*** | | | Florax, 1992; Love and McNicoll, 1988; Huggins and Cooke, 1997; Helpman, 1997; Martin, 1998; Forrant, 2001; Gagnol and Héraud, 2001; Bessette, 2003; Newlands, 2003; Harloe and Perry, 2004; Bilbao-Osorio and Rodríguez-Pose, 2004; Simha, 2005; Steinacker, 2005; Cox and Taylor, 2006; Tavoletti, 2007; Braunerhjelm, 2008 |
| | | | | |
| **Studies of impact in a strictly economic sense** | ***Accountability-type studies*** | University-generated data for expenditure and payroll; surveys on staff and student spending patterns; derivation of income multiplier | Estimation of effects generated by the university on the components of the urban economy with which it has contact; namely, local businesses, local households and local government | Caffrey and Isaacs, 1971; Moore and Suffrin, 1974; Moore, 1979; Rosen *et al.*, 1985; Elliot and Meisel, 1987, Link, 1999; Bessette, 2003 |

| Approaches | | Mechanisms / Methods | Results | Authors |
|---|---|---|---|---|
| | ***Regional economic impact studies*** | Stock regional economic analysis tools – mainly input-output and econometric modelling and imports/exports coefficients | University is viewed as a change-inducing factor; disturbances analysis to final demand connected to the university – for example, increased/decreased enrolment, employment or purchasing | Dorsett and Weiler, 1982; Rosen *et al.*, 1985; Elliot and Meisel, 1987; Goldstein, 1989-90; Zelder and Sichel, 1992; Beck *et al.*, 1993; Helpman, 1997; Martin, 1998; Bilbao-Osorio and Rodríguez-Pose, 2004; Felsenstein, 1996 |
| | ***Demand-side analysis by using Keynesian-type income-expenditure multipliers*** | Econometric models using Keynesian-type income-expenditure multipliers | Income, output and employment effects arising from the expenditure of faculty, staff and students | Brownrigg, 1973; Armstrong, 1993 |
| **Studies combining backward expenditures-related linkages and forward knowledge-related linkages** | | • Micro case study analysis;<br>• Input and output econometric model;<br>• Econometric and statistical descriptive analysis | • The university functioning as an export-base sector in the local economy;<br>• Implications to the demand side and the know-how supplied | Felsenstein, 1996; Huggins and Cooke, 1997; Newlands, 2003; Harloe and Perry, 2004; Buxton *et al.*, 2004; Tavoletti, 2007 |

*Source*: Adapted from Felsenstein (1996)

To sum up, the traditional economic impact studies are, in brief, case studies, with a micro level analysis length, descriptive, focusing on local, regional or national economic implications of the presence of a university or a R&D organisation. In specific cases, they attempt to analyse the knowledge-related impacts basically by suggesting the importance of this kind of organisations when offering knowledge-related services. Hence, these studies do not offer a clear picture of the relevance of R&D organisations as knowledge-diffusing actors and how this dimension of conductors and boosters of knowledge flows has also implications in R&D itself, and in economic progress at the limit. Section 2.2. specifically addresses this gap in the literature of the influence and impact of R&D organisations since it introduces a method commonly used to study knowledge output, namely by means of scientometrics statistical tools.

## 2.2. Assessing the international influence and impact of knowledge-diffusing organisations – the innovativeness of scientometrics approaches

There exists a literature stream that has addressed the evaluation of the scientific production and diffusion resulted from R&D institutions in terms of publication, namely in international refereed journals, making use of scientometrics and bibliometrics instruments (cf., Conroy and Dusansky, 1995; Scott and Mitias, 1996; Smith et al., 1998; Kalaitzidakis et al., 2003; Meyer, 2004).

Bibliometrics is commonly associated with quantitative measurements of documentary materials, used to analyse the structures of scientific and research areas, and to appraise research activity and the usage of scientific information (Persson, 2001). Bibliometrics has been specifically applied in a large number of contexts, which include science studies, research evaluation, knowledge management, environmental scanning, trend analysis, and the optimization of library and information resources (Persson, 2001). Consequently, scientometrics and bibliometrics approaches have been increasingly used by several authors to assess the evolution and structure of scientific knowledge and R&D output (e.g., Meyer, 2004; Dietz and Bozeman, 2005; Teixeira, 2006; Adams, 2006; Abramo and D'Angelo, 2007).

Normally, studies within this research field have been basically conducted from three perspectives (cf., Table 2), as Wagner and Leydersdorff (2005) have highlighted: on one hand, scientometric analysis is concerned over the increase in the interconnectedness of scientists (e.g., Okubo et al., 1992; Luukkonen et al., 1993; Zitt, et al., 2000; Glänzel, 2001; Cantner and Graf, 2006); in another hand, a literature branch is focused on social sciences analysis of collaboration in general (e.g., Chung and Cox, 1990; Gibbons et al., 1994; Katz and Martin, 1997; Dietz and Bozeman, 2005; Hussler and Ronde, 2007;) and international linkages in particular (e.g., Stichweh, 1996; Schott, 1998; Jaffe and Trajtenberg, 1999; Hu and Jaffe, 2003; Verspagen and Werker, 2004); and finally, empirical research present policy analysis of the implications of linkages for funding and outcomes (e.g. Van den Berghe et al., 1998; Wagner et al., 2000; Advisory Council of Canada, 2001; Carmona et al., 2005; Adams, 2006). However, as a result of our literature analysis, a fourth type of approach can also be added to this synthesis, i.e., the studies that address the implications of scientometrics' tools usage (e.g., Aguillo et al., 2006; Aksnes, and Taxt, 2006; Abramo and D'Angelo, 2007; Blanchard, 2007).

The studies in the area of scientometrics are undoubtedly becoming more and more frequent, and the interests moving forward investigation are several: the willingness to infer on the probability of national or international publications (e.g., Teixeira, 2006), the studies of the paths of the academic careers (e.g., Bozeman et al., 2001), or the impact the citations indicators may produce (e.g., Smith et al., 1998; Meyer, 2004; Verspagen and Werker, 2004; Wagner and Leydesdorff, 2005). Further, the pioneering work on the geography of knowledge flows by Jaffe et al. (1993) gave rise to a series of studies that aimed to track specifically the flows of knowledge (Allen, 1977; Cantwell, 2006),

like the case of the studies on international knowledge flows by Jaffe and Trajtenberg (1999), or the one by Hu and Jaffe (2003). Another perspective values the strands of knowledge not only because of their own inherent quality, but because their value is partially determined by a web of social relationships (Podolny and Stuart, 1995).

**Table 2: Summarising the main approaches in scientometrics and bibliometrics literature**

| Approaches | Scientometric analysis of the increase in the interconnectedness of scientists | Social sciences analysis of… | | Policy analysis of the implications of linkages for funding and outcomes | Implications of scientometrics tools usage |
|---|---|---|---|---|---|
| | | *…collaboration* | *…international linkages* | | |
| **Authors** | Okubo *et al.*, 1992; Luukkonen *et al.*, 1993; Zitt, *et al.*, 2000; Glänzel, 2001; Cantner and Graf, 2006 | Chung and Cox, 1990; Cox and Chung, 1991; Gibbons *et al.*, 1994; Katz and Martin, 1997; Agrawal and Henderson, 2002; Carayol and Roux, 2003; Calvert and Patel, 2003; Bozeman and Corley, 2004; Meyer, 2004; Adams *et al.*, 2005; Dietz and Bozeman, 2005; Aksnes, 2006; Hussler and Ronde, 2007; Ramlogan *et al.*, 2007 | Stichweh, 1996; Schott, 1998; Jaffe and Trajtenberg, 1999; Hu and Jaffe, 2003; Verspagen and Werker, 2004 | Podolny and Stuart, 1995; Van den Berghe *et al.*, 1998; Henderson *et al.*, 1998; Wagner *et al.*, 2000; Advisory Council of Canada, 2001; Bozeman *et al.*, 2001; Leydesdorff and Meyer, 2003; Sampat *et al.*, 2003; Coronado *et al.*, 2004; MacGarvie, 2005; Wagner and Leydesdorff, 2005; Carmona *et al.*, 2005; Teixeira, 2006; Adams, 2006; Hong, 2008 | Aguillo *et al.*, 2006; Aksnes, and Taxt, 2006; Abramo and D'Angelo, 2007; Blanchard, 2007 |

*Source*: Adapted from Wagner and Leydersdorff (2005)

The role of a research-intensive university in the knowledge transference process is also studied by Agrawal and Henderson (2002), recovering the work of Henderson et al. (1998) that suggested a decrease in the quality of patenting when a increase in university-based patenting was produced, but which is confronted with the findings of the study by Sampat et al. (2003). When replicating the same methodology but extending the time frame, Sampat et al. (2003) discovered that the university patents did not loose their quality, though there has clearly been a longer time lag before they attract a comparable number of citations and that were valuable for continuing innovation. However, patenting has become progressively more important in recent years, and this tendency is likely to be fostered in years to come (Cantwell, 2006).

In the specific case of citations patterns (cf., Cox and Chung, 1991; Coronado et al., 2004; Meyer, 2004; Wagner and Leydesdorff, 2005; Aksnes, 2006; Abramo and D'Angelo, 2007), it is argued how important it is to measure patent and publication citations in order to better comprehend the linkages between science and technology pushers, and, at the limit, with firms (Meyer, 2000b; Stephan and Audretsch, 2000; Meyer, 2004). The method of patent citation analysis, a bibliometric instrument, is a mixture of citations of scientific references and patents, motivated by a necessity to have science-related knowledge inputs in the new exploratory work or invention, forcing a stronger interaction between science and technology, and clarifying the main scientific contributions (Meyer, 2000b; Meyer, 2004). Like Meyer stated, patent citations may be understood as information flows, a science and technology interplay, that is to say, reciprocal knowledge transfer (Meyer, 2000a; Meyer, 2000b; Stephan and Audretsch, 2000; Meyer, 2004).

The Science Citation Index (SCI), organised by the Institute for Scientific Information (ISI), is regarded in this context of citation analysis as one of the best research sources to analyse international co-authorships, interconnectedness of researchers that basically foster the diffusion of scientific capacity (Wagner and Leydesdorff, 2005). According to Wagner and Leydesdorff (2005), international co-authorship occurs when a scientific output has more than one author, and at least two are from different countries. Price (1963), Stichweh (1996), and again Wagner and Leydesdorff (2005), actually address this phenomenon of increased international scientific interplay as result of science's inner differentiation on specialised disciplines that naturally seek dynamic interactions to enrich scientific output of any kind (Bush and Hattery, 1956). But these authors also explain this phenomenon as a consequence of geographic proximity and historical determinants, as pointed out also by Zit et al. (2000), when instead the dispersion of information and communications' technologies is a relevant factor emphasized by Gibbons et al. (2004).

Undoubtedly, proximity and innovative-favourable local milieus, that is to say, innovative clusters, are considered

by literature to support knowledge diffusion and knowledge spillovers (cf., Feldman, 1994; Saxenian, 1994; Audretsch, 1998; Antonelli, 1999; Carayole and Roux, 2003; MacGarvie, 2005), thus stimulating the process of the network formation from this interrelationship milieu (Balconi et al., 2002; Carayole and Roux, 2003; Casson and Della Giusta, 2008). Concluding, it should be stated that though scientometrics and bibliometrics studies embrace a wider perspective over the linkages/networks of R&D institutions at the regional, national and international context than the standard economic studies, to the best of our knowledge, these studies did not make use of the bibliometric tools to analyse the influence and impact of R&D institutions. Our goal in this work, therefore, is to make use of the potential that scientometrics has to offer when measuring the production/diffusion of knowledge of an R&D organisation, and through this means obtaining the map of its influence at the international level.

### 2.3. Relationship between production/diffusion of scientific knowledge and the influence of R&D organisations

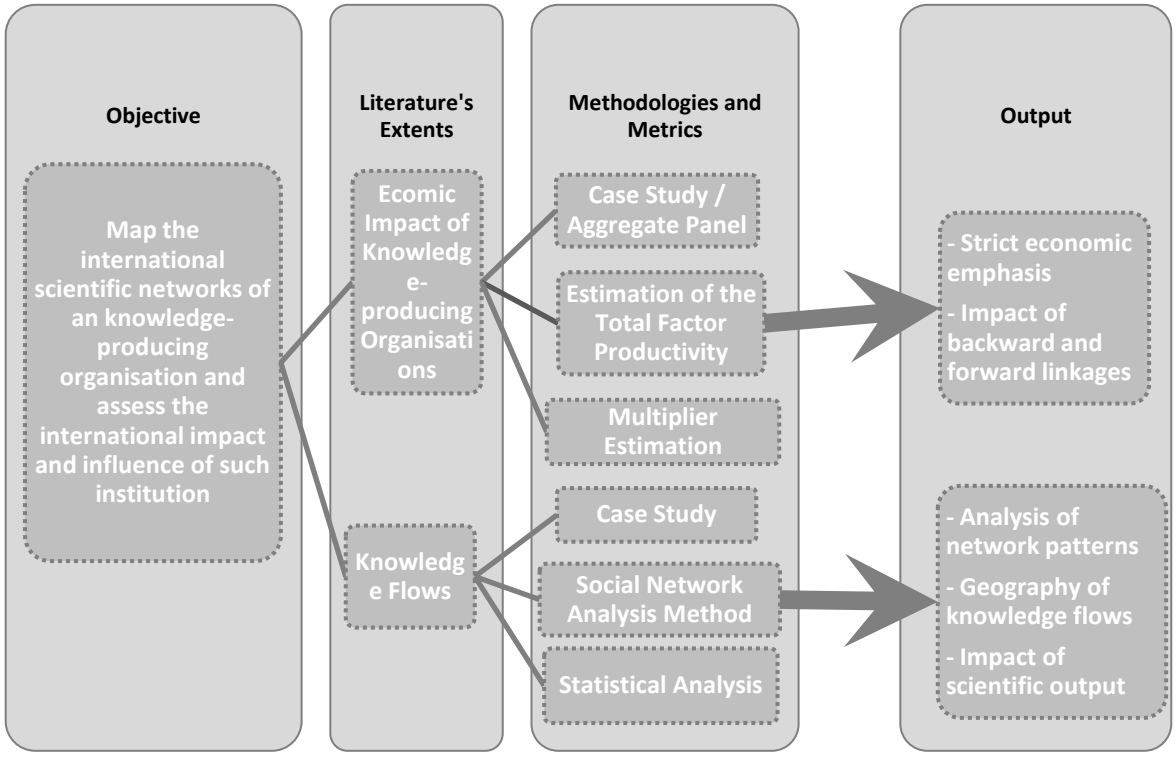
R&D organisations have been gaining a decisive entrepreneurial orientation in today's economy, leading or having a strong influence over certain technological areas, where innovation and knowledge transference's processes are critical (Stephan and Audretsch, 2000; Cowan and Jonard, 2001; Meyer, 2004; Cantwell, 2006; Casson and Della Giusta, 2008). The publication productivity, the patent productivity, the interconnectedness of scientists, the collaborative behaviours and the wider diversity of network ties and social capital have been analysed in a variety of ways, which solidifies the perception of the R&D organisations as being specific enablers and boosters in the production and diffusion of scientific knowledge (cf., Stephan and Audretsch, 2000; Cowan and Jonard, 2001; Dietz and Bozeman, 2005; Cantwell, 2006; Casson and Della Giusta, 2008). Universities, R&D organisations and firms, through partnerships and collaborations, create technological opportunities, foster additionally learning networks and facilitate progress (Stephan and Audretsch, 2000; Beaver, 2001; Cantwell, 2006; Adams, 2006; Casson and Della Giusta, 2008).

At this point, it becomes relevant to highlight, in one hand, the limitations that the methodology normally associated to the economic impact of knowledge-producing organisations' literature branch has, and, in another hand, evidencing the contribution scientometrics and a social network analysis statistical method brings within the knowledge flows' literature branch. A thoroughly analysis of four scientific papers was performed in order to better fundament the choice made in terms of the application of the methodology for the present study. Figure 1 presents a synthesis-scheme to the analysis of those four scientific papers, namely the works of Martin (1998), and from Cox and Taylor (2006), representing the economic impact of knowledge-producing organisations' literature, and the works of Cantner and Graf (2006), and by Hussler and Rondé (2007), which are within the knowledge flows' literature scope.

Succinctly, the first literature path brings us to methodologies that replicate case studies or present aggregate data, estimating, for instance, the Total Factor Productivity (e.g., Martin, 1998), or the total impact by means of a multiplier formula (e.g., Cox and Taylor, 2006). In this case, the scope of analysis is focused on strict economic effects, namely multiplier effects, evaluating the impact of backward-related and forward-related linkages of knowledge-producing organisations. As far as the knowledge flows' literature branch is concerned, the application of case studies' methodologies through the use of social network analysis methods and statistical analysis (e.g., Cantner and Graf, 2006; Hussler and Rondé, 2007) deliver results ranging from the appraisement of network patterns, to the geography of knowledge flows, and the assertion of the scientific output's impact. Among this literature branch, to the best of our knowledge, no scientific contribution was produced, exploring social network analysis statistical methods in order to infer over the international impact and influence of a knowledge-producing organisation, namely a university or a R&D institution. It is the aim of the present work to fill this gap and introduce this methodology to address the evaluation of international impact of knowledge-producing and -diffusing organisations.

The works from Cantner and Graf (2006) and from Hussler and Rondé (2007), notwithstanding presenting case studies about R&D hubs, namely Jena and the University Louis Pasteur, respectively, where it was intended to picture their learning networks and figure out their core competencies when tracing knowledge flows through the use of social network analysis methods – in fact, despite this exercise, there was no direct inference over the influence this type of organisation has within the network it operates.
The present work aims exactly to bridge the economic impact literature's branch with the one devoted to scientometric analysis of knowledge flows using for its empirical implementation the case of INESC Porto and thus addressing the literature gap identified above. Hence, our goal in this work is to make use of the potential that scientometrics has to offer regarding the measurement of the production/diffusion of knowledge of an R&D organisation, and thus obtaining the map of INESC Porto's knowledge-producing and diffusing behaviour, its impact and influence over the international knowledge network it operates, methodology that is further explored in the next section.

**Figure 1: Synthesis of the commonly-used methodologies**




*Source*: Adapted from Martin (1998), Cox and Taylor (2006), Cantner and Graf (2006), and Hussler and Rondé (2007)

## 3. Methodology

In the present study, we aim to analyse the international scientific impact and influence of a knowledge-producing organization. Specifically, we seek to answer the following questions:

***i.*** *Has the network of scientific production of INESC Porto been enlarging over time its geographical scope? Or putting it in other terms, has INESC Porto extended its international influence?*

1.a. Is the scientific output of INESC Porto's researchers increasingly international?

1.b. Is INESC Porto scientific production increasingly cited at the world level or it is mainly locally cited?

***ii.*** *Does the scientific influence of INESC Porto differ according to its different areas of expertise (e.g., energy, Information and Communication Technologies (ICT's), optical-electronics)?*

Answering these questions call for an encompassing approach requiring that we move beyond strict, materialistic perspectives of organisations' impact and influence. Therefore, to carry out such endeavour, as stressed earlier, it is advisable resorting to a combination of scientometric and social network analyses.

Therefore, the research work is conducted in two separated though interrelated stages, which roughly addresses our two main research questions. First, we constructed a bibliographic database containing all the published and unpublished works (including both papers and communications in workshops and conferences; 1464 entries in total, at 14th April 2008) by INESC Porto's researchers. This database includes also information regarding the number of authors, authors' affiliation, research areas, and, when applicable, the source of publication (e.g., journal, book, etc.). Consequently, this dataset enables to assess the main trends of INESC Porto's scientific production. The time frame of the analysis is the last 23 years of INESC Porto existence, in which we trace its knowledge production and diffusion. Based on the dynamics of international co-authorships, we are able to map and trace international collaborations' patterns and thus infer over INESC Porto's geographical influence scope, i.e., its international influence (Research Question i.a.). In a second stage, resorting to the information available in the Institute for Scientific Information (ISI), namely in the Science Citation Index (SCI), we assess the geographical pattern of the citations of INESC Porto's scientific production. This enables us to evaluate in what extent INESC Porto scientific production has been increasingly cited at the world level (Research Question i.b.). Finally,

combining citation matrixes and scientific areas, it is possible, by means os social netword analysis, to depict the scientific influence of INESC Porto according to its different areas of expertise (e.g., energy, Information and Communication Technologies (ICT's), optical-electronics) (Research Question ii.).

In the present study, and following the work by Ramlogan et al. (2007), we use Pajek software, developed by mathematicians from the University of Ljubljana (de Nooy et al., 2005) to analyse and visualise the interrelationships within the network governed by INESC Porto, our case study, exploring the core linkages and the knowledge clusters with the best performances.

Objectively, a social network analysis method is the appropriate method for depicting the knowledge flows of a network by means of relatedness measures (cf., Wagner and Leydesdorff, 2005; Cantner and Graf, 2006; Hussler and Rondé, 2007; Ramlogan et al., 2007). The social network analysis method gives importance to relationships between interacting units, defining linkages that characterise a network (Wassermann and Faust, 1994). Social network analysis, combined with scientometric tools, is in fact one of the often chosen method to assess a knowledge-producing and diffusing network (Wagner and Leydesdorff, 2005; Cantner and Graf, 2006).

## 4. Provisional chronogram of the research work

| | Sept | Oct | Nov | Dec | Jan |
|---|---|---|---|---|---|
| Literature survey | | | | | |
| INESC Porto dataset - data collection and analysis | | | | | |
| ISI dataset - data collection and analysis | | | | | |
| 1st public defence (the 26th October) | | | | | |
| Discussion of the results – 1st draft | | | | | |
| Final submission (the 22nd December) | | | | | |
| Final public defence (the 16th/17th January) | | | | | |

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