FEP WORKING PAPERS
FEP WORKING PAPERS

RESEARCH WORK IN PROGRESS

N. 319, MARCH 2009

DETERMINANTS OF THE INTERNATIONAL INFLUENCE OF A R&D ORGANISATION: A BIBLIOMETRIC APPROACH

AURORA A.C. TEIXEIRA[1]
JOSÉ SEQUEIRA[2]

[1] CEF.UP, INESC PORTO, FACULDADE DE ECONOMIA, UNIVERSIDADE DO PORTO
[2] PORTO VIVO - SOCIEDADE DE REABILITAÇÃO URBANA (SRU), INESC PORTO

Determinants of the international influence of a R&D organisation: a bibliometric approach

Aurora A. C. Teixeira

CEFUP, Faculdade de Economia, Universidade do Porto; INESC Porto

José Sequeira

Porto Vivo - Sociedade de Reabilitação Urbana (SRU); INESC Porto

Abstract

Traditionally, studies on the influence and impact of knowledge-producing organisations have been addressed by means of strict economic analysis, stressing their economic impact to 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. We introduce a new methodology, based on scientometric and bibliometric tools, which complement traditional assessments by considering the influence of a R&D institution when looking at the scientific production undertaken and the recognition of its relevance by its international peer community. Focusing on the most prolific scientific areas of INESC Porto, and resorting to published scientific work recorded in the *Science Citation Index* (SCI), we show that INESC Porto has enlarged its international scientific network. The logit estimations demonstrate that the wide geographical influence of INESC Porto scientific research is a result not of its international positioning in terms of co-authorships, but rather a result of the quality of its scientific output.

Keywords: Impact and influence assessment methods; R&D Institutions; Bibliometrics, Scientometrics; knowledge network; INESC Porto

JEL-Codes: O39; C81; L31

1. Introduction

It is broadly recognised how Research and Development (R&D) and innovation breakthroughs have the potential to deeply expand or even alter economic growth, which in the end has 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 therefore has profound consequences over several economic variables. The truth is that international economic activity is increasingly technology-driven and knowledge-based, and this has forced firms to produce stronger linkages with innovative knowledge-based institutions, which in 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 regional, national and international economic growth (Kuznets, 1966; Martin, 1998). These different-levelled 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 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 institution's influence on the evolution and composition of the Gross Domestic Product (GDP) and were usually associated with 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 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, more poorly developed. Notwithstanding, several attempts have been made 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 have failed to capture the whole nature of knowledge flows that goes beyond expenditures linkages.

Scientometric and bibliometric approaches are increasingly used by several authors to assess the evolution, productivity, 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 analysing 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 scientometric and bibliometric studies embrace a much wider perspective of the linkages/networks of R&D institutions in the regional, national and international context than 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 towards filling this gap. As such, we use scientometric and bibliometric approaches to assess the influence and impact of an R&D organisation, therefore complementing traditional economic approaches, and providing a more embracing perspective of knowledge flows. To accomplish such endeavour we resort to multivariate logit models, addressing the main goal of our study which is to evaluate the organisation's international influence and impact.

We structure the present paper as follows. In the next section, we review the two main branches of literature in analysis: the standard economic approaches and the bibliometric and scientometric approaches. The methodology is further detailed in Section 3. Based on the most prolific units of INESC Porto in terms of scientific output, in Section 4, we use a logit

model to assess the determinants of INESC Porto's international influence. Finally, in Conclusions, we address the main results and highlight the contributions of the methodology to the literature.

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

It is generally recognised (albeit less empirically proved) that R&D or knowledge producing organisations play a significant role in today's global economic development, by generating valuable returns in terms of economic growth and productivity (cf., Denison, 1968; Romer 1986: Steinnes, 1987; Dosi, 1988; Feller, 1990; Trajtenberg 1990; Lichtenberg, 1993; Felsenstein, 1996; Bilbao-Osorio and Rodríguez-Pose, 2004; Marginson and van der Wende, 2007).

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. These studies usually present alternative models that best evaluate public and private support to R&D (Scherer, 1982; Felsenstein, 1996; Martin, 1998). 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 job creation, new firms' creation, 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 expenditure-related linkages combined with forward knowledge-related linkages of universities and R&D institutions.

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 of urban location factors, such as university presence, wage rates, amenity aspects, close firm-university links or metropolitan attractiveness	• Relationship between the presence of the university and the concentration of advanced technological production; • 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; Teixeira and Costa, 2006
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; Garlick *et al.*, 2006; Swenson and Eathington, 2007; Barrios *et al.*, 2008
	The influence of universities on the rate of creation of new firms			Bania *et al.*, 1990; Schutte, 1999 ; Garlick *et al.*, 2006
	The influence of universities on the development of the local service sector			Hedrick *et al.*, 1990; Garlick *et al.*, 2006
	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; MSTHE, 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
	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; disturbance analysis of 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; Felsenstein, 1996, Helpman, 1997; Martin, 1998; Schutte, 1999 ; Simonyi, 1999; Silva *el al.*, 2000; Bilbao-Osorio and Rodríguez-Pose, 2004;
	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 expenditure-related linkages and forward knowledge-related linkages		• Micro case study analysis; • Input and output econometric model; • Econometric and statistical descriptive analysis	• The university functioning as an export-base sector in the local economy; • Implications to the demand side and the know-how supplied	Felsenstein, 1996; Huggins and Cooke, 1997; Oosterlinck, 2001; Newlands, 2003; Harloe and Perry, 2004; Buxton *et al.*, 2004; Silva and Santos, 2006; Tavoletti, 2007

Source: Adapted from Felsenstein (1996)

To sum up, the traditional economic impact studies have this characteristic of estimating the impact of knowledge-producing organisations by using methods that rely essentially on economic variables, tested in econometric models and statistically analysed. These studies are, in brief, case studies, with a micro- or meso-level analysis length; they are descriptive and focus on the 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 organisation 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 or how the dimension of conductors and boosters of knowledge flows also has implications on R&D itself, and on economic progress at the limit.

There is a literature stream that has addressed the evaluation of the scientific production and diffusion resulting from R&D institutions in terms of publication, namely in international refereed journals, making use of bibliometric and scientometric instruments (*cf.*, Conroy and Dusansky, 1995; Scott and Mitias, 1996; Smith *et al.*, 1998; Kalaitzidakis *et al.*, 2003; Meyer, 2004). Despite mapping knowledge networks, and therefore serving part of our main goal in the present research work, generally, bibliometric and scientometric studies do not consider the economic dimension of knowledge production and diffusion, which certainly substantiates itself in the medium-, long-term. That is why we find it relevant to address this literature branch and further explore its contribution to our study, by complementing traditional economic impact studies of R&D organisations.

According to Pritchard and Wittig (1981), bibliometric methods have been used for more than a century, while Sengupta (1992) specifies that Campbell (1896) was the first author to produce the first bibliometric work, making use of statistical methods to study subject diffusion in publications. In the literature review conducted by Hood and Wilson (2001), two definitions are recovered for bibliometrics that complement each other, one presented by Pritchard (1969: 348), who defines it as "the application of mathematical and statistical methods to books and other media of communication", and the other given by Fairthorne (1969: 341), who widens the notion of the "quantitative treatment of the properties of recorded discourse and behaviour appertaining to it". But White and McCain (1989: 119) also have their own definition, presenting bibliometrics as "the quantitative study of literatures as they are reflected in bibliographies [providing] evolutionary models of science, technology, and scholarship." Bibliometrics is therefore 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 (Hood and Wilson, 2001; 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 optimisation of library and information resources (Persson, 2001). Consequently, scientometric and bibliometric 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).

On the other hand, the term 'scientometrics' is more recent; according to Hood and Wilson (2001), it was first employed by Nalimov and Mulchenko (1969) in Russian (in which the equivalent term is '*naukometriya'*) to describe the study of all aspects of the literature of science and technology, its growth, structure, interrelationships and productivity, and is closely related to bibliometrics. The term became more widespread with the foundation of the homonymous journal, *Scientometrics*, by Tibor Braun, in Hungary, in 1978 (Hood and Wilson, 2001). At present, bibliometrics and scientometrics refer to the study of the dynamics of disciplines as reflected in the production of their literature, terms used consequently to describe analogous and overlapping methodologies (Hood and Wilson, 2001). Hence, according to Leydesdorff (2001), scientometrics is the claim that scientific developments, when conducted through an organised knowledge production and control, are amenable to measurement. As a matter of fact, scientometrics is fairly indistinguishable from bibliometrics, with plenty of bibliometric research about literature output (Hood and Wilson, 2001), having been published in the journal *Scientometrics*, while it also comprehends research work dealing with quantitative aspects of the science of science, communication in science, science policy, practices of researchers, socio-organisational structures, research and development management, the role of science and technology in the national economy, governmental policies towards science and technology, and much more (Hood and Wilson, 2001; Wilson, 2001). Summing up, the definition given by Tague-Sutcliffe (1992: 1) can be recovered here:

> Scientometrics is the study of the quantitative aspects of science as a discipline or economic activity. It is part of the sociology of science and has application to science policy-making. It involves quantitative studies of scientific activities, including, among others, publication, and so overlaps bibliometrics to some extent.

According to Archambault and Gagné (2004), the main kinds of indicator used within bibliometrics include publication count (i), citations and their impact factor (ii), and co-

citation or co-word analysis (iii). Specifically, publication count (i), as an indicator of the productivity of a scientific field of study in terms of the output delivered in journals, that is to say, as the number of articles published, may clarify the output intensity or the degree of specialisation of a specific field (Archambault and Gagné, 2004), may be used for the evaluation and comparison of the research performance of individual researchers, departments, and research institutions (Garfield *et al.*, 1978; Adam, 2002; Bornmann *et al.*, 2008), as well as to assess at the limit the scientific impact of nations (May, 1997; King, 2004; Bornmann *et al.*, 2008). As far as citations and impact factor are concerned (ii), these indicators purposely address the assessment of the scientific impact of research, through the number of citations spread in internationally learned journals and, for instance, recorded and compiled in Thomson Reuters (Archambault and Gagné, 2004). Furthermore, co-citation-based indicators (iii) may be used to map research activity by means of bibliographic coupling, generating knowledge webs from the analysis of co-citations and/or co-words, which will create mappings (using time as a variable, and, as an example, depicting the evolution of scientific emerging fields), multifaceted representations of research fields, and related linkages of the fields of study themselves or of the actors performing within them (Archambault and Gagné, 2004). At present, the most commonly used gauge of the research impact of publications is the total number of citations attributed by articles to a scholar, institution or country, regardless of the unit of analysis, in a given period (Westney, 1998; van Leeuwen, 2001; van Raan, 2003; Archambault and Gagné, 2004), allowing citation rates to be an important indicator of scientific success because of their quantitativeness and objectiveness, therefore complementing qualitative methods of research evaluation, as for the case of peer review (Garfield and Welljamsdorof, 1992; Daniel, 2005; Bornmann *et al.*, 2008).

As defined by Smith (1981: 83), "a citation implies a relationship between a part or the whole of the cited document and a part or the whole of the citing document", and bibliometrics uses citation analysis specifically to study these relationships. Smith (1981: 85) continues, interpreting citations as "signposts left behind after information has been utilised and as such provide data by which one may build pictures of user behaviour without ever confronting the user himself." Citation convention is actually a matter of controversy, as Cozzens (1989) points out, since their application may be due to the need to sustain the persuasive argument of the knowledge claims in the citing document, but may also be interpreted as some kind of reward or acknowledgement instrument. Self-citations, within this framework, may cause

even more controversy, if one interprets them as biases of indicators to research evaluation studies (Smith, 1981; Schwarz *et al.*, 1998). Nonetheless, as defended by Glänzel and Schoepflin (1999), the application of citation-based indicators by the scientific community of a country or organisation will give a symptomatic picture of the research performance of the community under consideration.

Several authors (*cf.*, Weinstock, 1971; Smith, 1981; Garfield and Welljamsdorof, 1992) present reasons for the convention of citations in scientific documents, which can be confirmed in Table 2, according to the relevance or to more positive or negative acknowledgement conduct.

Table 2: Listing reasons given in the literature for the usage of citations

Attributing citations		**by relevance**		
		relevant	*less relevant*	*irrelevant*
by acknowledgment	*positive*	• Paying homage to pioneers • Correcting one's own work	• Providing leads to poorly disseminated, poorly indexed, or non cited work	• Identifying original publications in which an idea or concept was discussed • Identifying original publications or other work describing an eponymic concept or term
	neutral	• Identifying methodology, equipment, *etc.* • Substantiating claims • Authenticating data and classes of facts – physical constants, *etc.*	• Giving credit for related work (homage to peer) • Providing background reading	• Alerting to forthcoming work
	negative	• Correcting the work of others	• Criticising previous work • Disclaiming work or ideas of others (negative claim)	• Disputing priority claims of others (negative homage)

Source: Adapted from Weinstock (1971), and Garfield and Welljamsdorof (1992)

Smith (1981) also underlines assumptions as far as citation analysis is concerned, namely, (i) that citing a document implies using that document, but what is often proven is that only a small percentage of what is read and found useful is in fact cited; (ii) citing a document (from an author, a journal, *etc.*) evidences merit given to that document, in terms of quality, significance or impact, but, as Table 2 shows, and Thorne (1977) has also highlighted, documents can be cited for reasons irrelevant to their merit; (iii) citations are made of the best works, but accessibility of a document is often a serious barrier, because of its format, place of origin, age or even language; (iv) though there is the assumption of content interrelationship between two bibliographically coupled documents, nothing in fact guarantees a relationship between their contents through citations; (v) and, finally, the assumption that all citations are equal, but the fact is that, as demonstrated in Table 2, there are several reasons sustaining the usage of citations.

Additionally, a similar listing may be identified in the works of Garfield (1977, 1986), and developed also by Smith (1981), when tracing reasons for not citing a scientific document, which may be related to (i) the lack of relevance of the topic, (ii) unawareness of relevant published works, suggesting here some kind of arbitrariness in the selection of the bibliography, as Kochen (1974) points out, (iii) wilful unawareness, that is to say, deliberate plagiarism, (iv) disregard for other scholars' researches, (v) obsolescence or 'natural' obliteration, (vi) or due to the disappearance of authors that use the specific cited information, contributing to the extinction of some topics. Furthermore, the decrease in the citation impact is a reflection of obsolescence, an evolutionary process that substitutes cited work with more recent and more relevant findings (Garfield, 1977, 1986). However, in the case of a breakthrough, all cited knowledge is immediately superseded, and, in this case, the literature faces a revolutionary process (Garfield, 1977, 1986). But a third type of obliteration in literature can also come about, in which relevant knowledge becomes current or common, which is the case of obliteration by incorporation, when literature absorbs the author's thought as eponymy (Garfield, 1977, 1986). Garfield (1977, 1986) still considers five main factors that directly influence citation impact, namely, (i) the subject matter and within the subject, the 'level of abstraction', (ii) the paper's age, (iii) the paper's 'social status' (because of the author(s) and/or the journal), (iv) the document type, and (v) the observation period.

Despite the benefits that bibliometrics and scientometrics bring to our study, through the correlation between bibliometric data and scientific knowledge growth (Kuhn, 1962; Price, 1965; Leydesdorff, 2001), by being the best tool to issue relevant topics like performance or hierarchies (*cf.*, Schubert and Braun, 1996; Bornmann *et al.*, 2008), tracing science mappings and their developments (*cf.*, Burt, 1983; Leydesdorff, 2001), or even knowledge / actor-networks (*cf.*, Leydesdorff, 2001), limitations in their usage must also be highlighted. Bibliometrics and scientometrics presently play a strong role in assessing and comparing the research performance and impact of scholars, research groups, R&D institutions and nations, but drawbacks are identified within this literature scope and alternative solutions are also presented. This is the case of Bornman *et al.* (2008), when evidencing that bibliometric analysis commonly uses an arithmetic mean value in the evaluation of research performance as a measure of central tendency (Kostoff, 2002; van Raan, 2004), but which has to be balanced by the recognition of the most prolific researchers, for instance (Daniel and Fisch, 1990; Bornman *et al.*, 2008). On the other hand, a citations' count of a research group also has its limitations (*cf.*, Schubert and Braun, 1996; Kostoff, 2002, Bornman *et al.*, 2008),

which according to Schubert and Braun (1996) may be transposed by setting reference standards to the comparative appraisal of research performance, in terms of field of research, journals and related records. Lawani (1986), for instance, identified a strong relationship between the number of co-authors in a scientific paper and its citation counts, evidencing that the higher the number of co-authors, the higher the number of citations.

As Moed (2005a) argues, citation impact, for instance, is nothing less than a quantitative concept, with limited significance, which must be addressed taking into account the universe of citing publications, that is to say, the database that we operate on should be comparative in nature, in order to relate the outcomes of our case study with those of similar entities. In this perspective, the level of aggregation must be fully identified and comprehended (Moed, 2005a; Moed, 2005b; Bornmann *et al.*, 2008), because it is important whether we are evaluating and/or comparing the research performance of individual researchers, departments, research institutions (*cf.*, Garfield *et al.*, 1978; Adam, 2002) or even, at another level, the scientific impact of nations (*cf.*, May, 1997; King, 2004). Schwarz *et al.* (1998) also recognise how citations deliver a reasonably valid measure at aggregate levels, and are a pragmatic way of tracing general characteristics of research structure, the visibility of results, and the positioning of a scholar, institution or country in the research community. However, Schwarz *et al.* (1998) highlight how the indicativeness of results from citation analysis should be further assessed by experts, for instance, through the means of peer review. From a quantitative and bibliometric point of view, the common usage of an arithmetic mean value as a measure of central tendency may erase or at least disguise the true importance, for instance, of the most prolific researchers, and this aspect must also be taken into account (Bornmann *et al.*, 2008).

Moreover, the concepts of 'intellectual influence' and 'contribution to scholarly progress', as Moed (2005a) evokes, could only be better assessed by analysing the cognitive contents of the data studied since those concepts are fundamentally of a theoretical and qualitative nature. Analysing citations from a reference list can also be misinterpreted, since their real influence over the scientific output may be vague or implicit (*cf.*, Schubert and Braun, 1996; Kostoff, 2002), merely acknowledgeable of a reverential author considered within a specific research field as producer of an influential work, remarking, therefore, how unrelated the concepts of 'citation impact' and 'intellectual influence' may be (Moed, 2005a; Bornmann *et al.*, 2008). A reference may be interpreted purely as the registration of the intellectual property of a knowledge claim, but does not necessarily reflect acceptance or rejection of such a claim,

since it rather acknowledges by whom and in which work the claim was presented (Bornmann *et al.*, 2008). Citation analysis may also lead to the recognition of systematic biases that emerge naturally and commonly between authors and groups of authors, and which we must also take into consideration when interpreting (Bornmann *et al.*, 2008). Succinctly, when performing citation analysis, a constructive, qualitative, evaluative framework should be put into action in order to allow a substantive assessment of the contents of the data under analysis (Uren *et al.*, 2006), avoiding looking at it simply as a quantitative indicator (Garfield, 1972; Lawani, 1986; Garfield and Welljamsdorof, 1992; Daniel, 2005), to further comprehend and identify fully possible biases, distortions, or measurement 'errors' (Smith, 1981; Moed, 2005a; Bornmann *et al.*, 2008).

Studies within bibliometrics and scientometrics research field (*cf.*, Meyer, 2000b; Meyer, 2004; Wagner and Leydesdorff, 2005; Moed, 2005b) 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 analysing co-authorships and citation indexes. At the extent of this literature, research has basically been conducted from three perspectives (*cf.*, Table 3), as Wagner and Leydersdorff (2005) have highlighted: on the 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); on the other hand, a literature branch is focused on a 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 presents 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 summary, *i.e.*, the studies that address the implications of scientometric tools' usage (*e.g.*, Aguillo *et al.*, 2006; Aksnes and Taxt, 2006; Abramo and D'Angelo, 2007; Blanchard, 2007).

Studies in the area of scientometrics are undoubtedly becoming more and more frequent, and the interests moving investigation forward are several: the willingness to infer on the probability of national or international publications (*e.g.*, Teixeira, 2006), the studies of the paths of academic careers (*e.g.*, Bozeman *et al.*, 2001), or the impact the citation indicators

may produce (*e.g.*, Smith *et al.*, 1998; Meyer, 2004; Verspagen and Werker, 2004; Wagner and Leydesdorff, 2005). Further to this, 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 the flows of knowledge specifically (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 3: Summarising the main approaches in scientometric and bibliometric 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 scientometric 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; Moed, 2005b; Wagner and Leydesdorff, 2005; Carmona *et al.*, 2005; Adams, 2006; Marques *et al.*, 2006; Teixeira, 2006; Hong, 2008; Horta, 2008	Garfield *et al.*, 1978; May, 1997; Vincent and Ross, 2000; Leydesdorff, 2001; Adam, 2002; King, 2004; Moed, 2005; Aguillo *et al.*, 2006; Aksnes, and Taxt, 2006; Abramo and D'Angelo, 2007; Blanchard, 2007; Bornmann *et al.*, 2008

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), which suggested a decrease in the quality of patenting when an 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 lose their quality, though there was clearly a longer time lag before they attracted a comparable number of citations and before they 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 citation 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). Actually, the method of patent citation analysis, a bibliometric instrument, was pioneered by Francis Narin and his research group, when tracking citations of patents from public funded research in scientific papers (*cf.*, Narin *et al.*, 1995; Narin *et al.*, 1997). This method has become useful when trying to clarify the scientific activity that may foster connection between firms and science (Godin, 1993; Godin, 1995; Stephan and Audretsch, 2000; Meyer, 2004). In fact, patent citations are 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). As 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 Institute for Scientific Information (ISI), which was launched in 1964 and is now part of Thomson Reuters business units, organises the *Arts and Humanities Citation Index* (A&HCI), the *Social Sciences Citation Index* (SSCI), and, specifically, the *Science Citation Index* (SCI), which has long been the most common tool for measuring citations and which is regarded in this context of citation analysis as one of the best research sources to analyse reference patterns, international co-authorships, and interconnectedness of researchers that basically foster the diffusion of scientific capacity (Wagner and Leydesdorff, 2005; Bornmann *et al.*, 2008). 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 a 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 Zitt *et al.* (2000), when, instead, the dispersion of information and communication technologies is a relevant factor emphasised 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). Here the seminar work of Carayole and Roux (2003) is of relevance when studying the self-organising network formation and selection, following the previous theoretical suggestions that pointed out the importance of the role of information, knowledge and technology diffusion within issues of innovation dynamics (*e.g.*, David and Foray, 1994; Valente, 1996; Cowan and Jonard, 2001; Young, 2002), even introducing concepts of stability (*e.g.*, Watts, 2001; Jackson and Watts, 2002; Young, 1993; Kandori *et al.*, 1993) and efficiency that will model endogenously emerging structures (*cf.*, Jackson and Wolinski, 1996), but also enriching their contribution when using a preferential meeting process by reasons of neighbourhood. Furthermore, Carayole and Roux (2003) also remind us that a branch of the literature emerged in Physics, focusing on the structures of large networks (*e.g.*, Barabási and Albert, 1999, 2000; Watts and Strogatz 1998; Newman *et al.*, 2001), which highlighted that despite the large number of network agents, and taking into consideration the 'six degrees of separation' of Milgram (1967), the distance between them is usually small.

Concluding, it should be stated that though scientometric and bibliometric studies embrace a wider perspective over the linkages/networks of R&D institutions in the regional, national and international context than 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/organisations. Scientometric and bibliometric studies are devoted basically to the interconnectedness of scientists, network formation, national and international collaboration patterns, and in the implications, development, and impact of scientometric tools' usage. Our goal in this work is therefore to make use of the potential that scientometrics has to offer when measuring the production/diffusion of knowledge of an R&D organisation, and thus understand the determinants of its influence at the international level.

Summarising, the traditional 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 (Figure 1). As far as the literature branch of knowledge flows 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) delivers results ranging from the appraisement of network patterns, to the geography of knowledge flows, and the assertion of the scientific output's impact. Within this literature branch, to the best of our knowledge, no scientific contribution has been produced by exploring bibliometric tools in order to infer over the international impact and influence of a knowledge-producing organisation, namely a university or R&D institution. It is the aim of the present work to fill this gap and introduce this methodology to address the determinants of international influence of knowledge-producing and -diffusing organisations.

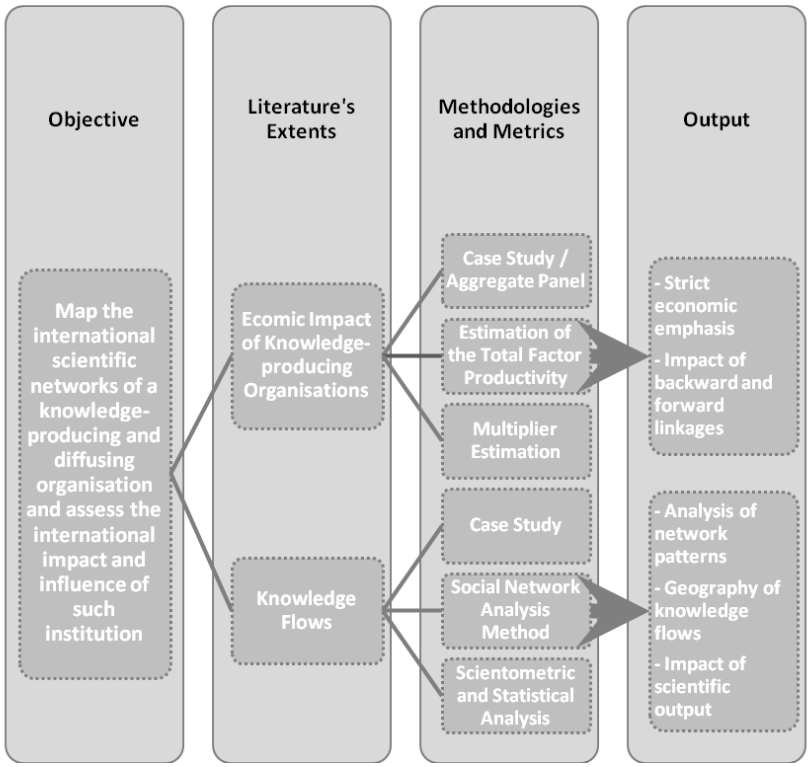

Figure 1: Summary of the commonly-used methodologies within economic impact literature and knowledge flows literature

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

As a matter of fact, the works of Cantner and Graf (2006) and Hussler and Rondé (2007) present case studies on R&D hubs, namely Jena and the University Louis Pasteur, respectively, in which the aim was to picture their learning networks and figure out their core competencies when tracing knowledge flows through the use of social network analysis methods. However, despite this exercise, there was no direct inference over the influence this

type of organisation has within the network it operates, nor was a special emphasis even traced to the international dimension of the relationships that form the network itself.

3. Assessing the impact and influence of R&D organisations – methodological considerations

The Institute for Systems and Computer Engineering of Porto (*Instituto de Engenharia de Sistemas e Computadores do Porto* – INESC Porto) was established on 18th December, 1998, after a restructuring of INESC, which had had several centres throughout Portugal, and one specifically in Porto, since May 1985 (INESC Porto, 2008b). This reform was a result of the local specialisation of each centre, and their growing autonomy, which led to the appearance of new institutions (for instance, INESC Porto), centrally connected to INESC, and now with the responsibility of coordinating the national strategic progress of each of these new-born institutions (INESC Porto, 2008b). INESC Porto was then constituted as a private non-profit association by two founders, the University of Porto and the Faculty of Engineering of the University of Porto, which were later joined, in 2006, by the Faculty of Sciences of the University of Porto and the Polytechnic Institute of Porto (INESC Porto, 2008b).

Regarded as an Institution of Public Interest, in 2002, INESC Porto was made an Associated Laboratory by the Ministry of Science and Technology (INESC Porto, 2008b, 2008c). This latter distinction may be understood as an expression of the importance this institution holds within the Portuguese scientific community, placing it among a very selective group of Portuguese research institutions that develop valuable areas of expertise (INESC Porto, 2008c).

INESC Porto integrates six working units (Figure 2), with a common support services infrastructure, promoting scientific research and technological development in the following areas of activity: Telecommunications and Multimedia, Information Systems, Power Systems, Manufacturing Systems, and Electronics and Optoelectronics, aimed at promoting innovation and internationalisation (INESC Porto, 2008c). Considered to be a medium-size research and technology institution, INESC Porto runs with an annual budget of approximately 8 Million Euros (INESC Porto, 2008c) to support a structure of 318 members (72 of whom are internal staff), according to a report from INESC Porto's Human Resources Department, dated 30th September, 2008.

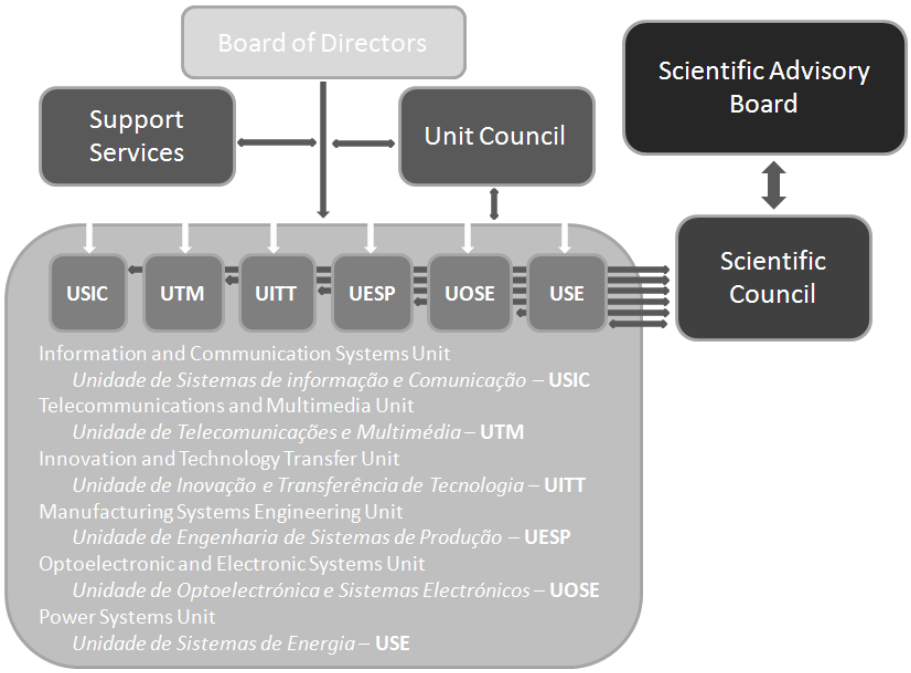

Figure 2: The organogram of INESC Porto

Source: Adapted from INESC Porto (2008b)

The recent analysis of the activities of INESC Porto made by an international Scientific Advisory Board (INESC Porto, 2008c) indicated that its strengths lie in its team of collaborators and in the strong research accomplishments it has made in key technology areas. Hence, we conclude that INESC Porto constitutes a pertinent and valuable unit of analysis for conducting a study on the international influence of R&D, knowledge-based institutions, since it combines fundamental preconditions for conducting the present research work, namely, outstanding scientific output developed during more than a decade, and within an international collaboration framework of co-authorship, integrating different research fields.

In order to conduct this research, we first collected and refined bibliographic data from a dataset named SACA (*Sistema de Arquivo e Controlo de Artigos* – Archive System of Articles Control), organised internally by INESC Porto. This dataset contains all published and unpublished scientific work, that is to say, internationally as well as nationally published papers, book chapters, international conference proceedings, and communications in workshops or at conferences. On 14th April 2008, when the data was gathered, 1488 entries were counted, but out of these, 62 papers were duplicated or triplicated, corresponding to the same paper but presented at different conference venues, and published again in an international journal, for instance, therefore leaving 1426 papers for further analysis (Table 4). Afterwards, the data collected from SACA was thoroughly reviewed and it constituted the basis for another database that was then built to register the affiliations of the authors that

teamed up, in a local, national or international framework, in order to deliver INESC Porto's scientific output. Since each paper is, to our study, a unit of research, all the information concerning it was gathered in the same worksheet line. This new database that we have built specifically,includes information regarding the number of authors of each paper or scientific output, the authors' affiliation and their country of origin, and, finally, the source of publication (*e.g.*, international or national journal, book, conference proceedings, *etc.*). Consequently, this dataset enables us to assess the main geographical trends and co-authorship patterns of INESC Porto's scientific production.[1] We obtained 845 valid papers which we were able to access, either through the SACA search engine or through an online one, such as Google.com, Google Scholar or Thomson Reuters' Web of Knowledge.

When compiling a dataset of citations from INESC Porto's publications in Thomson Reuters' Web of Knowledge, 352 papers with INESC Porto's affiliation were identified, but 125 did not match the records in SACA. Since 38 papers out of those 125 new papers identified were cited, we decided to add only these 38 to our database from INESC Porto's scientific production and work them in terms of co-authorships as well, given that they would also be considered in terms of citations' impact. We arrived, then, at a total number of 883 papers that cover a timeline, which begins in 1979[2] and ends in 2008. Since only after 1996 are a significant number of papers reported as being published or presented at conferences, we have decided to neglect 41 papers from the period 1979-1995, and 16 papers dating from 2008.[3] In the end, 826 documents constitute our final study sample from INESC Porto's scientific output, in terms of affiliation's mapping (*cf.*, Table 4).

[1] During the process of assembling the information related to authors' affiliations, it was not possible to access 571 papers, since they were not available through SACA, or through Thomson Reuters, or through any other online search engine (like Google.com or Google Scholar). It was also not possible to access a printing copy since there is no material and centralised recording area of the papers produced in INESC Porto. Nevertheless, 845 entries were considered valid and thoroughly worked on, since 10 papers were also excluded. Specifically, as far as these 10 papers are concerned, in 5 cases none of their authors had written as belonging to INESC Porto and they were not recognised as having this affiliation. Two papers proved to have different authors from the ones originally identified in SACA, and one of these was from authors with no affiliation in INESC Porto whatsoever. The remaining three papers had no record in the journals that were identified in SACA and were, therefore, not accessible. It should be added that 14 papers within the 845 had authors with no written affiliation in INESC Porto, though that affiliation was confirmed by INESC Porto internally afterwards. Therefore, after this confirmation, we decided to accept these entries into our study. Entries where authors identified in the paper did not correspond to the ones introduced in SACA were also accepted. In the latter case, we corrected the information retrieved from SACA by using the authors as presented in the published paper.

[2] A paper from 1979 is the oldest record presented in SACA, though there is also a record dating from 1983, two years before the creation of INESC Porto's centre.

[3] We recall that we collected this data from SACA on 14th April 2008, and therefore these 16 papers were the ones available at the time.

In our dataset, we defined as relevant variables for each paper the authors and their affiliations, their countries of origin and the publishing information. All the 1397 papers (which include papers to which we had access and papers that were not accessible for affiliation's handling) are distributed among the working units of INESC Porto, as shown in Figure 3.[4]

Table 4: Data synopsis of the three databases created (1996-2007)

Source	Databases		
	INESC Porto's Database	**INESC Porto's International Co-authorships Database**	**INESC Porto's Citations Database**
	INESC Porto/SACA Thomson Reuters	INESC Porto/SACA Thomson Reuters	Thomson Reuters
Total Records (nr. papers)	1.488	246	352
Total Records Revised (nr. papers)	1.397	246	347
Workable Sample (nr. papers)	826	246	246
INESC Porto's Cited Papers (nr. papers)	-	-	142 (120 papers are cited by at least one foreign affiliated author)
Total Citations (nr. papers)	-	-	754
Networking Linkages (nr. connections)	-	1.239	13.035
International Share[1] (%)	29,8%	100%	48,8%[2]
First Accessed	2008.04.14	2008.11.30	2008.10.11
Last Accessed	2008.10.01	2008.11.30	2008.11.03

Note: [1] The denominator is the 'workable sample'; [2] Ratio of the papers cited by at least one foreign affiliated author (120) to workable sample (246).

A descriptive analysis of our database indicates that, comparatively, UOSE is, undoubtedly, the most prolific unit, with 519 papers, from which communications at conferences account for 309 (59.3%) presentations, and 184 (35.5%) papers were published in international refereed journals. UTM follows with 366 papers, distributed mainly between communications at conferences or workshops (145 papers, 36.6% of the total) and publications in book chapters and conference proceedings (173 papers, 47.3% of the total), while papers presented in international refereed journals account for 46 (representing 12.6% of the corresponding total). The USE is the third most fruitful unit in INESC Porto, with a total of 272 papers – 174 (64%) of which were included in book chapters or conference proceedings, and an amount of 60 papers (22.1%) were published in international journals. The UESP has 190 papers in the

[4] A note here must be highlighted since we recall that each paper may be counted in one, two or three conferences, and also the same paper can be published in conference proceedings or in an international refereed journal, for instance – therefore, we should emphasise how the production of knowledge may lead to the maximisation of the means within our reach for the diffusion of that same knowledge.

SACA database, from which 136 (71.6%) were presented at conferences and 32 (16.8%) were published in international refereed journals. USIC has 42 papers, 22 (52.5%) are part of book chapters or conference proceedings, and, finally, UITT, with 8 papers, had 3 presented at conferences and another 2 published in international journals.

Globally, Figure 3 shows an increase in the overall scientific output of INESC Porto, which may be more positively perceived when considering the type of publication, namely in internationally refereed journals, which accounted for 59 scientific articles in the period of 1996-1999, reaching 77 papers during the time period of 2000-2003, and more than doubling in the period of 2004-2007, when the papers published in learned journals amounted to 192. This upward tendency for the publication in international refereed journals is actually followed by all INESC Porto's working units, when considering the time periods, though the reading of Figure 4 gives us another perception of the evolution of publication. In terms of proportions, Figure 4 shows us how INESC Porto diminished publication overall, as far as international journals are concerned, from the period 1996-1999 to the period 2000-2003, but doubled its share in the 2004-2007 phase, when this kind of publication accounted for 30.4% of all papers produced. It is also interesting to highlight the fact that the share of book chapters has declined over the years, while conference presentations continue to represent around 40% of INESC Porto's overall output. Nevertheless, this pattern does not fit each INESC Porto's working unit, since, for instance, the weight of book chapters is higher in units like USE, USIC and UTM, though with different tendencies, getting weaker in USE and even weaker in UTM, but stronger in USIC. And as far as the percentage of papers published in international journals is concerned, here the increase in their relevance for units like UESP, USE and UTM is evident, while in UOSE the share lowers in the period 2000-2003 and recovers to 40% in the next four-year period, while it sinks in the case of USIC to 7.7%. Conferences, on the other hand, lose importance in the case of UESP and UOSE, and get stronger in USE, USIC, and more obviously in the case of UTM. This analysis of the data permits us to conclude that the relevance of UOSE, USE and UTM in terms of scientific production among INESC Porto's units is enormous in quantitative and qualitative terms and, at the limit, representative for the assessment of INESC Porto's scientific performance. This explains the closer analysis of these working units in terms of publication and diffusion of knowledge, depicting their evolution patterns, and on how they differentiate from one another. In a first stage, we trace INESC Porto's knowledge production resorting to statistical analysis of the data we collected from SACA and afterwards we conducted the search to confirm the affiliations of every author. With this data, it was possible to create another

database linking each INESC Porto's author with a foreign co-author for all the papers that had international co-authorships. This new dataset grouped 1239 connections resulting from 246 papers with international collaborations (*cf.*, Table 4). Consequently, based on the dynamics of international co-authorships, we were able to map and trace international collaboration patterns and thus infer over INESC Porto's geographical scope of influence, *i.e.*, its international interconnectedness and influence. In a second stage, resorting to the information over citations available from Thomson Reuters, namely in the Science Citation Index (SCI), we assessed the geographical pattern of the citations of INESC Porto's scientific production. For this purpose, we also built a citations' dataset with the authors of each paper cited from INESC Porto (a total of 142 papers) in correlation to the papers and the authors citing them (a total of 754 papers), thus also creating a link between every affiliation, which resulted in 13,035 citations' linkages (*cf.*, Table 4). We used Thomson Reuters database, inheritor of the Institute for Scientific Information (ISI), since literature within the bibliometrics range consider it to be the main resource for citation analysis, which has therefore become the most broadly used in assessing research performance (Archambault and Gagné, 2004; Bornmann *et al.*, 2008).[5] This enables us to evaluate to what extent INESC Porto scientific production has been increasingly cited at the world level. Combining citation matrixes and scientific areas, it was possible to depict the international scientific influence of INESC Porto according to its different areas of expertise, and assess the determinants of INESC Porto's international influence and impact.

[5] The high *status quo* of Thomson Scientific among literature results from the selection criteria evoked to restrict its databases essentially to internationally oriented journals, and highly-cited book series and conference proceedings, which address preconditions like having a peer review committee, high publication frequency, the facilitation of an English abstract (*cf.*, Braun *et al.*, 2000), and citation count, since this is perceived, as evidenced above, as an indicator of usefulness, quality and/or impact of a journal (Archambault and Gagné, 2004; Bornmann *et al.*, 2008; Neuhaus and Daniel, 2008). Because of its tendency to have only the highest-impact peer-reviewed journals, this is also referenced as one of the biggest limitations in its usage, since only a fraction of the scientific work is acknowledged here (Nederhof and Zwaan, 1991; Hicks, 1999; Archambault and Gagné, 2004; Neuhaus and Daniel, 2008), and several scientific fields are even neglected, such as, computer science, engineering, and mathematics, where journal literature is less developed (Moed, 2005; Bornmann *et al.*, 2008). Therefore, several authors claim that Thomson Reuters databases, accessed in the Web of Knowledge, should be complemented by other datasets offered online, in the World Wide Web, as is the case of Scopus from Elsevier, Google Scholar, and Cite-Seer, or even by discipline-oriented databases, such as Chemical Abstracts, MathSciNet, and PsycINFO (*cf.*, Neuhaus and Daniel, 2008). Actually, the main advantage of combining different data sources is coverage, since only Scopus accounts for 15,000 peer-reviewed journal titles (Neuhaus and Daniel, 2008). Nevertheless, Thomson Reuters databases cover nearly 10,000 learned journals (Katz and Hicks, 1998; Archambault and Gagné, 2004; Neuhaus and Daniel, 2008). As a matter of fact, as suggested by Garfield (1996), around 2,000 journals account for roughly 85% of published articles and 95% of cited articles are included in the Science Citation Index. This is, therefore, a strong indicator of the validity of this data source for our study.

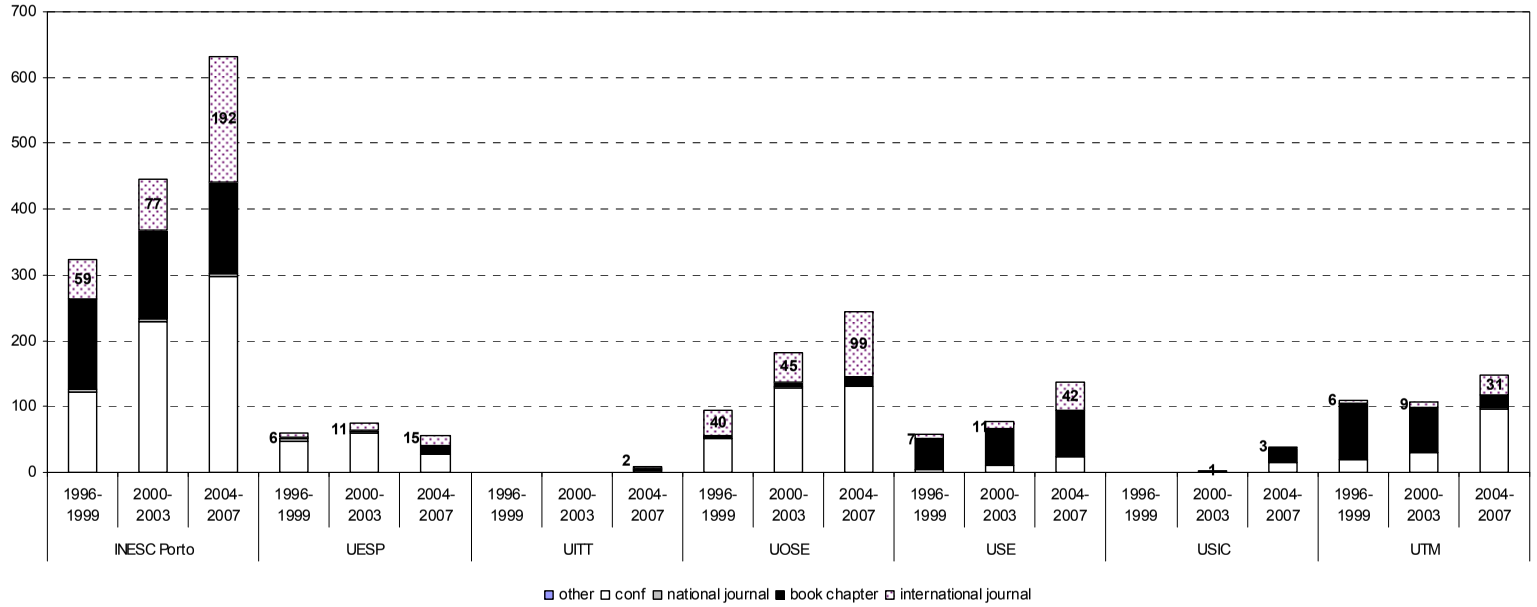

Figure 3: Distribution of the scientific output of INESC Porto per four-year periods, and per working unit, in number of papers

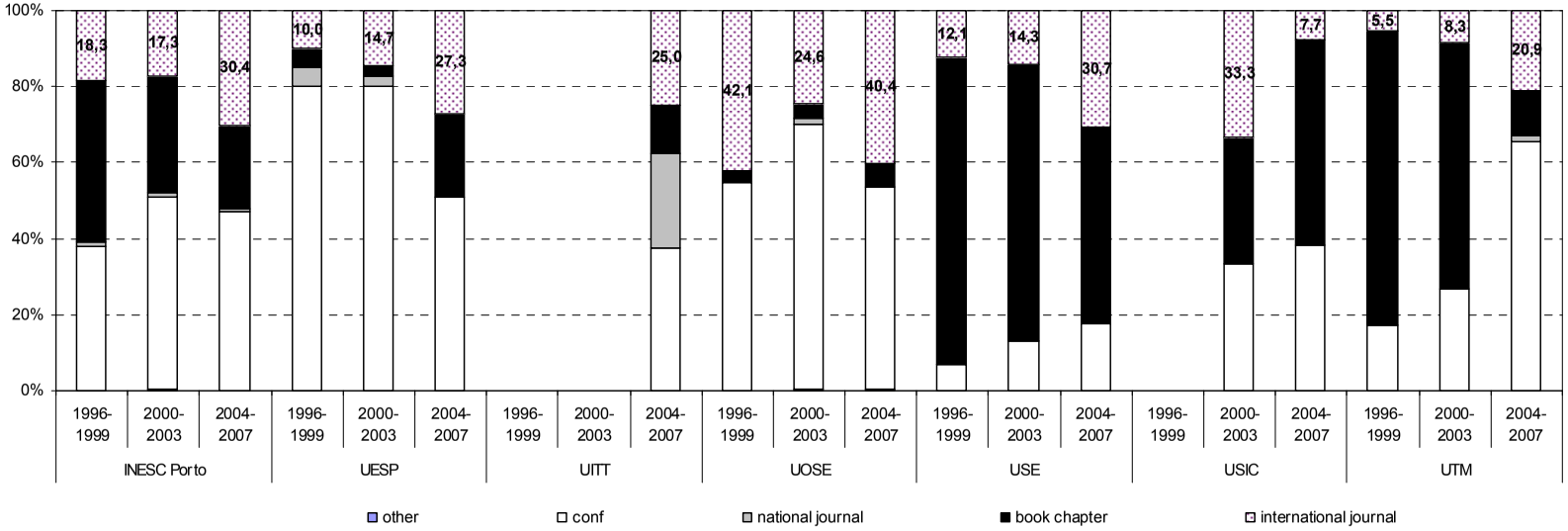

Figure 4: Scientific output's percentage of INESC Porto and its working units by type of publication, per four-year periods

4. Explaining the (international) influence of INESC Porto. A logit model of the propensity for (international) citations of INESC Porto's scientific production

The geographical mapping of co-authorships and citations showed some interesting patterns, both for INESC Porto as a whole and its most prolific units (Sequeira and Teixeira, 2009). It would be illuminating to evaluate which determinants affect the propensity of citations of INESC Porto's scientific work, that is, to understand which factors matter most in explaining the influence (global citations), in particular, the international influence (citations for authors with a foreign affiliation) of this knowledge based and producing institution.

One objective measure of the influence of a publication, and in a broader way, a scientific producing institution (*e.g.*, universities, R&D institutes), over future research is the frequency with which the study, or studies published/produced by such institutions, is/are cited in subsequent publications (Smith *et al.*, 1998; Sampat *et al.*, 2003; Meyer, 2004; Wagner and Leydesdorff, 2005; Filion and Pless, 2008). Previous studies (*e.g.*, Westney, 1998; van Leeuwen, 2001; van Raan, 2003; Archambault and Gagné, 2004) have demonstrated that the frequency with which a publication is cited varies greatly. Our objective in this section is to determine whether variables associated with an article's structural characteristics - namely number of authors, author, type of article (published in international journal *versus* published in book chapters, conference proceedings, *etc.*), year of publication -, the international features – presence of co-authors affiliated in foreign institutions, and country of origin of the foreign institution in which the co-author is affiliated -, and the scientific area of the papers – proxied by the INESC Porto's unit of the corresponding paper (UOSE – optoelectronics; USE – Energy; UTM – Multimedia; Others).

The nature of the data relative to the variable we aim to explain – cited (1) or not cited (0) – dictates the choice of estimation model. Conventional econometric techniques, in a context involving a discrete dependent variable, do not comprise a valid option. In fact, the premises that are necessary in the hypothesis testing of conventional regressions are necessarily violated – it is not reasonable to assume, for instance, that the error distribution will be regular. Furthermore, in a multiple regression analysis, the predicted values cannot be interpreted as probabilities – they are not necessarily restricted to the interval between 0 and 1. The approach adopted, therefore, falls within the general probabilistic models.

Prob (event j occurs) = Prob (Y=j) = F[relevant effects: parameters].

In the model of probability of (foreign) citation of the INESC Porto's papers, there is a set of factors, mentioned above, such as the characteristics of the article, its international features, and scientific area, included in vector X, that tend to explain the result (citation), such that:

$\Pr ob(Y = 1) = F(X, \beta)$ *and* $\Pr ob(Y = 0) = 1 - F(X, \beta)$.

The set of β parameters reflects the impact of the alterations operating on X on the probability of 'citation'. The problem at this stage is to build an appropriate model for the right-hand side of the equation. The base requisite is that the model should produce predictions that are consistent with the underlying theory. For a given vector of regressors, we expect that

$\lim_{\beta'X \to +\infty} \Pr ob(Y = 1) = 1$ *and* $\lim_{\beta'X \to -\infty} \Pr ob(Y = 1) = 0$.

Partially for reasons of mathematical convenience, the logistic distribution, $\Pr ob(Y = 1) = \frac{1}{1 + e^{-\beta'X}}$, has been used in many applications (Greene, 2000).

When rearranged according to *log odds*, or the probability ratio of an event occurring in contrast with the probability of non-occurrence of that same event, the expression is also called the *logit* model. The probabilistic model is a regression of the type:

$E(Y \setminus X) = 0[1 - F(\beta'X)] + 1[F(\beta'X)] = F(\beta'X)$.

Whatever the distribution used, it should be noted that the model's parameters, like those of a non-linear model, are not necessarily the marginal effects. Generally speaking, $\frac{\partial E(Y \setminus X)}{\partial X} = \frac{dF(\beta'X)}{d(\beta'X)}\beta = f(\beta'X)\beta$, where *f(.)* is the density function which corresponds to the cumulative distribution function, *F(.)*.

For the logistic distribution, $\frac{d\Lambda(\beta'X)}{d(\beta'X)} = \frac{e^{\beta'X}}{(1 + e^{\beta'X})^2} = \Lambda(\beta'X)[1 - \Lambda(\beta'X)]$. Thus, in the *logit* model, $\frac{\partial E[Y \setminus X]}{\partial X} = \Lambda(\beta'X)[1 - \Lambda(\beta'X)]\beta$.

It is obvious that these values vary in accordance with the values of X. In the interpretation of the estimated model, it is useful to calculate that value of the mean of the regressor and, when necessary, of other relevant values.

In logistic regression, the model's parameters are estimated using the maximum likelihood method (ML). That is, given the assumptions regarding the error distribution, the coefficients that make the observed results more 'probable' are selected.

According to the available literature (*e.g.*, Weinstock, 1971; Garfield and Welljamsdorof, 1992; Teixeira, 2006; Filion and Pless, 2008), the articles' characteristics, namely their size (number of authors), scientific area, tend to partially explain the corresponding propensity to be cited. Furthermore, we aim at assessing the importance of having foreign-affiliated co-authors and the country of affiliation of those co-authors in the propensity for being cited, and thus evaluate the the papers' potential for international influence, and therefore that of the research institution (INESC Porto). Thus, we can assume that, if the paper that is cited, namely cited by foreign affiliated authors, has foreign affiliated co-authors, all else constant, the probability of being cited in global terms or cited by foreign authors would be higher.

Thus, we propose that the empirical assessment of the propensity for INESC Porto's papers to be cited should be based on the estimation of the following general logistic regression:

$$P(cited) = \frac{1}{1+e^{-Z}}; \; with \; Z = \beta_0 + \underbrace{\beta_1 \ln nr\_authors + \beta_2 type\_paper + \beta_3 Period}_{structural\ characteristics\ of\ the\ paper} + \\ + \underbrace{\beta_4 Foreign\_coauthor + \beta_5 Country\_foreign\_coauthor}_{International\ features} + \beta_6 Scientific\_area + \varepsilon_i$$

So as to obtain a more direct reading of the logistic coefficients, the equation of the logistic model should be rearranged, such that the logistic model is rewritten in terms of the odds of the event occurring.

Writing the logistic model in terms of the odds, we obtain the *logit* model

$$\log\left(\frac{\Pr ob(cited)}{\Pr ob(notcited)}\right) = \beta_0 + \underbrace{\beta_1 \ln nr\_authors + \beta_2 type\_paper + \beta_3 Period}_{structural\ characteristics\ of\ the\ paper} + \\ + \underbrace{\beta_4 Foreign\_coauthor + \beta_5 Country\_foreign\_coauthor}_{International\ features} + \beta_6 Scientific\_area + \varepsilon_i$$

The logistic coefficient can be interpreted as a variation of the *log odds* associated with a unitary variation in the independent variable. Where *e* raised to the power β_i is the factor by which the *odds* are altered when the i^{th} independent variable increases by a unit. If β_i is positive, this factor will be greater than 1, which means the *odds* have increased; if β_i is negative, the factor will be less than 1, which means that the *odds* have decreased. When β_i is 0, the factor is equal to 1, which leaves the *odds* unchanged. For example, if the estimate of β_4 shows up positive and significant for the conventional levels of statistical significance (that is, 1%, 5% or 10%), it will mean that, all else constant, the probability of citation ratio in contrast with the probability of non-citation increases when the affiliation of the papers' co-authors is foreign (that is from a country other than Portugal).

The estimates for the βs are presented in the next table, for the three alternative models which cover the different types of citation. The first model concerns global citations, which include citations by Portuguese (and INESC Porto) affiliated authors. The second model includes citations by at least one foreign affiliated author. The third and final model is only concerned with citations by exclusively foreign affiliated authors. It is to be expected, therefore, given the different degrees of international influence of scientific production – global; global excluding citations by exclusively national affiliated authors; and international (citations only by foreign affiliated authors) -, that the relative importance of the various potential determinants of citations will also be different.

Table 5: Assessing the (international) influence of INESC Porto - estimation of the logit model with the dependent variable being the ratio of the log odds of (foreign) citations

			Model 1: citations	Model 2: at least one foreign	Model 3: cited only by foreign
Article's structural characteristics	Number of authors (ln)		0.214	0.007	-0.086
	Type of article (dummy=1 if published in international journal; 0 otherwise)		2.227***	3.459***	3.342***
	Year of publication (ln)		-83.683	-188.048***	61.676
International features	Foreign co-authors (dummy=1 if at least one of the co-authors is affiliated in an international institution; 0 otherwise)		-0.689*	-0.597	0.300
	Country of origin of the foreign co author (default: other remaining countries)	Germany	-18.242	-17.766	-16.897
		Russia	0.524	-0.454	0.351
		Spain	0.156	0.168	-18.541
		UK	-0.224	0.063	0.778*
		USA	0.739	0.692	-1.308
Scientific area – Unit (default: UOSE)	USE		-1.263***	-0.978***	0.319
	UTM		-1.581***	-1.351***	-1.073*
	UESP, UITT, USIC		-1.045***	-0.713*	0.705
Constant			663.861	1426.060***	-474.054
N			883	883	883
Cited			142	120	47
Other			741	763	836
Goodness of fit					
Hosmer-Lemeshow Test (significance)			12.058 (0.149)	8.075 (0.426)	7.844 (0.449)
Nagelkerke R^2			0.383	0.450	0.293
Corrected			84.9	88.6	94.8

Note: statistically significant at *** 1%; **5%; *10%

The models present a reasonable quality of adjustment. On the one hand, the percentage of correctly attributed estimated observations (between the categories 'cited' and 'not cited') is

high, varying between 85% and 95%. Furthermore, the Hosmer and Lemeshow test indicates the *non-rejection* of the null hypothesis that the model predicts reality adequately.

It is interesting to report that the 'size' of the paper, proxied by the number of authors, does not significantly affect the odds of being cited, both in general terms (Model 1 and 2) and by exclusively internationally affiliated authors (Model 3). The newness of the paper, proxied by its year of publication, has a negative impact on the odds of citation when we exclude the citations made by authors affiliated in national (Portuguese) institutions (Model 2). As reported in previous similar studies on citation patterns/propensity (*e.g.*, Weinstock, 1971; Smith, 1981; Garfield and Welljamsdorof, 1992; Moed *et al.*, 1998; Teixeira, 2006; Filion and Pless, 2008), the scientific area is an important determinant of citations. In fact, being a paper from the Optoelectronic and Electronic Systems - UOSE (default unit) – means, on average, all the remaining factors being constant, a much higher degree of global and international influence (proxied by the odds of citations) than a paper published by Power Systems (USE), Telecommunications and Multimedia (UTM), Information and Communication (USIC), Innovation and Technology Transfer (UITT), or Manufacturing Systems Engineering (UESP). In the case of citations made exclusively by authors affiliated in foreign institutions (Model 3), Power Systems and the set of the remaining scientific areas cease to emerge with a degree of influence statistically different to that of the Optoelectronic and Electronic Systems.

Regardless of the degree of a paper's international influence when the paper is published in an international journal with referee, in comparison with papers published in book chapters or conference proceedings, the probability of citation ratio *versus* the probability of non-citation (the odds) is 9 ($e^{2,227}$) (global influence) to 32 ($e^{3,459}$) (international influence excluding citation exclusively from nationally affiliated authors) times higher. This indicates that the 'quality' of the paper published is a truly important predictor of the (international) influence of the scientific production undertaken at INESC Porto.

The literature (*e.g.*, Burt, 1983; Leydesdorff, 2001; Balconi *et al.*, 2002; Carayole and Roux, 2003; Casson and Della Giusta, 2008; Filion and Pless, 2008) usually gives a lot of credit to the importance of foreign networking, namely through the capability to produce scientific publishable papers in co-authorship with authors from institutions of other countries, in particular those highly ranked in scientific terms (the USA, the UK and Germany, to name but a few). Quite unexpectedly, we observe that to have a paper which is co-authored with researchers affiliated in a foreign institution has a negative and significant impact on INESC Porto's global influence, that is on the (log) odds of global citations, and has no impact

whatsoever on international influence. Moreover, the country of affiliation of co-authors seems not to have any impact on the influence of INESC Porto. Notwithstanding, in the case of the strictly international influence (Model 3), we find that being a paper with UK affiliated co-authors has a positive and significant impact on the odds of citation by exclusively foreign affiliated authors.

The evidence gathered tends to imply that papers from INESC Porto which have foreign affiliated co-authors are not necessarily more cited, both in global terms and in strictly international terms. Interestingly, the same evidence seems to indicate that the scientific global and international influence of INESC Porto is to a greater extent dependent on the intrinsic quality of the research produced rather than on being part of an international network of co-authorships. Although being capable of establishing (dense) networks with authors from other countries might reveal, *per se*, an indicator of the influence and impact of R&D institutions (Sequeira and Teixeira, 2009), the likelihood of these institutions constituting an effective source of international relevant scientific work for the area in which it performs the corresponding activity does not depend on such networks but rather on the quality of the scientific research it produces.

5. Conclusion

In the present study, we addressed the topic of assessing the impact and international influence of a knowledge-producing and -diffusing institution. We moved away from (aiming at complementing) the standard economic impact literature and methods, as we argue that the impact and influence of knowledge-producing and -diffusing institutions are not restricted to economic related outcomes but, and more importantly, embrace rather intangible and wide ranging knowledge and information impacts, which frequently go beyond local or regional boundaries. We proposed a methodology, largely implemented within scientometric and bibliometric areas, which is based on the analyses of the patterns and evolution of an organisation's co-authorships and citations. Our bibliometric-based method, instead of the local focus that characterises traditional assessment methods, has an international scope.

Given the significant scientific output recorded, specifically in international refereed journals, and a broad collaborative group of co-authors, inclusively with foreign affiliations, we decided to use INESC Porto, a Portuguese research and development organisation, as our case study. Resorting to our bibliometric based methods, we assessed INESC Porto's international influence and impact.

Besides its international focus, standing therefore at a wider level of analysis, our methodology has presented a new insight into the assessment of knowledge flows, which goes beyond useful but narrow economic outcomes, measuring the influence that an R&D organisation (in this case, INESC Porto) has created within the global scientific area in which it operates.

More specifically, we described how INESC Porto's knowledge network has evolved over a time span of twelve years, focusing the analysis, on the one hand, on the organisation's co-authorship framework, and on the other, quantifying citation patterns on a worldwide scale. Notwithstanding the foreign collaborative pattern of INESC Porto's scientific production, and despite the broad recognition of its scientific accomplishments, we showed, based on a multivariate econometric model, that international peer acknowledgement derives not from those straight collaborative and clusterised patterns of international teamwork (co-authorships) but from the intrinsic quality of the scientific output produced.

References

Abramo, Giovanni, and D'Angelo, Ciriaco Andrea (2007), Measuring science: Irresistible temptations, easy shortcuts and dangerous consequences, *Current Science*, Vol. 93, Nr. 6, pp. 762–766.

Adam, D. (2002), The counting house, *Nature*, Vol. 415, Nr. 6873, pp. 726–729.

Adams, J. D. (2006), Learning, internal research, and spillovers, *The Economics of Innovation and New Technology*, Vol. 15, Nr. 1, pp. 5-36.

Adams, James D., Black, Grant C., Clemmons, J. Roger, and Stephan, Paula E. (2005), Scientific teams and institutional collaborations: Evidence from U.S. universities, 1981–1999, *Research Policy*, Vol. 34, Nr. 3, pp. 259–285.

Agrawal, A., and Henderson, R. (2002), Putting Patents in Context: Exploring Knowledge Transfer from MIT, *Management Science*, Vol. 48, Nr. 1, pp. 44–60.

Aguillo, Isidro F., Granadino, Begoña, Ortega, José L., and Prieto, José A. (2006), Scientific Research Activity and Communication Measured With Cybermetrics Indicators, *Journal of the American Society for Information Science and Technology*, Vol. 57, Nr. 10, pp. 1296–1302.

Aksnes, Dag W. (2006), Citation Rates and Perceptions of Scientific Contribution, *Journal of the American Society for Information Science and Technology*, Vol. 57, Nr. 2, pp. 169–185.

Aksnes, Dag W., and Taxt, Randi Elisabeth (2006), Peer reviews and bibliometric indicators: a comparative study at a Norwegian university, *Research Evaluation*, Vol. 13, Nr. 1, pp. 33–41.

Allen, T. (1977), *Managing the Flow of Technology*, MIT Press, Cambridge, MA.

Antonelli, C. (1999), *The Microdynamics of Technological Change*, Routledge, London.

Archambault, Éric, and Gagné, Étienne Vignola (2004), *The Use of Bibliometrics in the Social Sciences and Humanities*, Final Report, Quebec, Canada: Science-Metrix.

Armstrong, H. W. (1993), The local income and employment impact of Lancaster University, *Urban Studies*, Vol. 30, Nr. 10, pp. 1653–1668.

Asai, Isao (1981), Adjusted Age Distribution and its Application to Impact Factor and Immediacy Index, *Journal of the American Society for Information Science*, Vol. 32, Nr. 3, pp. 172-174.

Audretsch, D. B. (1998), Agglomeration and the location of innovative activity, *Oxford Review of Economic Policy*, Vol. 14, Nr. 2, pp. 18-29.

Audretsch, D. B., and Feldman, M. P. (1996), R&D spillovers and the geography of innovation and production, *American Economic Review*, Vol. 86, Nr 3, pp. 630–640.

Bailetti, A., and Callahan, J. (1992), Assessing the Impact of University Interactions on an R&D Organisation, *R&D Management*, Vol. 22, Nr. 2, pp. 145–158.

Balconi, M., Breschi, S., and Lissoni, F. (2002), *Networks of inventors and the location of university research: an exploration of Italian data*, CESPRI, Working Paper nr. 127.

Bania, N., Clakins, L. N., and Dalenberg, D. R. (1992), The effects of regional science and technology policy on the geographical distribution of industrial R&D laboratories, *Journal of Regional Science*, Vol. 32, Nr. , pp. 209–228.

Bania, N., Eberts, R., and Fogarty, M. S. (1990), *Universities and the start-up of new companies: can we generalize from Route 128 and Silicon Valley?*, Working Paper Series, The Centre for Regional Economic Issues, Case Western Reserve University, Cleveland, Ohio.

Barabási, A. L., and Albert, R. (1999), Emergence of scaling in random networks, *Science*, Vol. 286, Nr. 5439, pp. 509-512.

Barabási, A. L., and Albert, R. (2000), Topology of evolving networks: Local events and universality, *Physical Review Letters*, Vol. 85, Nr. 24, pp. 5234-5237.

Barrios, Salvador, Mas, Matilde, Navajas, Elena, and Quesada, Javier (2008), Mapping the ICT in EU Regions: Location, Employment, Factors of Attractiveness and Economic Impact, European Commission, *JRC Scientific and Technical Reports EU 23067*, pp. 1–113.

Bayoumi, T., Coe, D. T., and Helpman, E. (1996), R&D spillovers and global growth, *Working Paper no. 79*, The Canadian Institute for Advanced Research, Toronto.

Beaver, D. (2001), Reflections on scientific collaboration (and its study): past, present and future, *Scientometrics*, Vol. 52, Nr. 3, pp. 365–377.

Beck, R., Curry, P., Elliot, D., Levin, Meisel J., Vinson, R., and Wagner, M. (1993) *The economic impact of Southern Illinois University*, Revised Internal Report, Department of Economics, Southern Illinois University, Edwardsville, IL, USA.

Beeson, P., and Montgomery, E. (1990), The effects of colleges and universities on local labour markets, *NBER Working Paper Nr. 3280*, Cambridge MA, USA.

Bessette, Russell W. (2003), Measuring the Economic Impact of University-Based Research, *Journal of Technology Transfer*, Vol. 28, pp. 355–361.

Bilbao-Osorio, B., and Rodríguez-Pose, A. (2004), From R&D to Innovation and Economic Growth in the EU, *Growth and Change*, Vol. 35, Nr. 4, pp. 434–455.

Blanchard, Antoine (2007), Understanding and customizing stopword lists for enhanced patent mapping, *World Patent Information*, Vol. 29, pp. 308–316.

Bluestone, Barry (1993), UMASS / Boston, An Economic Impact Analysis, *Report 140*, University of Massachusets, Boston: USA.

Bornmann, Lutz, Mutz, Rüdiger, Neuhaus, Christoph, and Daniel, Hans-Dieter (2008), Citation counts for research evaluation: standards of good practice for analyzing bibliometric data and presenting and interpreting results, *Ethics in Science and Environmental Politics*, Vol. 8, Nr. 1, pp. 93–102.

Bozeman, Barry, and Melkers, J. (1993), *Evaluating R&D Impacts: Methods & Practice, Boston*, MA: Kluwer Academic Publishers.

Bozeman, Barry, Dietz, J., and Gaughan, M. (2001), Scientific and technical human capital: an alternative model for research evaluation, *International Journal of Technology Management*, Vol. 22, Nr. 7/8, pp. 636–655.

Bozeman, Barry, and Corley, Elizabeth (2004), Scientists' collaboration strategies: implications for scientific and technical human capital, *Research Policy*, Vol. 33, Nr. 4, pp. 599–616.

Bozeman, Barry, Dietz, James S., and Gaughan, Monica (2001), Scientific and Technical Human Capital: An Alternative Model for Research Evaluation, *International Journal of Technology Management*, Vol. 22, Nr. 7-8, pp. 716–740.

Braun, T., and Glänzel, W. (1995), On a Source of Error in Computing Journal Impact Factors, *Chemical Intelligencer*, Vol. 1, pp. 31-32.

Braun, T., Glänzel, W., and Schubert, A. (2000), How balanced is the Science Citation Index's journal coverage? A preliminary overview of macro level statistical data, In Cronin, B., Atkins, H. B. (eds), *The Web of Knowledge: A Festschrift in Honor of Eugene Garfield*, Medford, NJ: Information Today, pp. 251–277.

Braunerhjelm, Pontus (2008), Specialization of Regions and Universities: The New *Versus* the Old, *Industry & Innovation*, Vol. 15, Nr. 3, pp. 253–275.

Brownrigg, M. (1973), The economic impact of a new university, *Scottish Journal of Political Economy*, Vol. 20, Nr, 2, pp. 123–139.

Brusoni, S., Prencipe, A., and Pavitt, K. (2000), Knowledge Specialization and the Boundaries of the Firm: Why Do Firms Know More Than They Make?, *Administrative Science Quarterly*, Vol. 46, Nr. 4, pp. 597-621.

Bush, G. P., and Hattery, L. H. (1956), Teamwork and creativity in research, *Science Quarterly*, Vol. 1, Nr. 3, Special Issue on the Administration of Research, pp. 361–372.

Buxton, Martin, Hanney, Steve, and Jones, Teri (2004), Estimating the economic value to societies of the impact of health research: a critical review, *Bulletin of the World Health Organisation*, Vol. 82, Nr. 10, pp. 733–739.

Caffrey, B., and Isaacs, P. (1971), *Estimating the Impact of a College or University on the Local Economy*, Washington, D.C., American Council on Education.

Calvert, J., and Patel, P. (2003), University-industry research collaborations in the UK: bibliometric trends, *Science and Public Policy*, Vol. 30, Nr. 2, pp. 85–96.

Campbell, F. B. F. (1896), *The Theory of the National and International Bibliography: with Special Reference to the Introduction of System in the Record of Modern Literature*, London, England: Library Bureau.

Cantner, Uwe, and Graf, Holger (2006), The network of innovators in Jena: An application of social network analysis, *Research Policy*, Vol. 35, Nr. 4, pp. 463–480.

Cantwell, John (Ed.) (2006), *The Economics of Patents. The Patent System and The Measurement of Invention*, The International Library of Critical Writings in Economics 197, Vol. I, Northampton, MA, USA: Elgar.

Carayole, Nicolas, and Roux, Pascale (2003), Self-Organizing Innovation Networks: When do Small Worlds Emerge?, *Working Papers of GRES - Cahiers du GRES*, Groupement de Recherches Economiques et Sociales, Nr. 2003-08.

Carmona, Salvador, García-Ferrer, Antonio, and Poncela, Pilar (2005), From Zero to Infinity: The Use of Impact Factors in the Evaluation of Economic Research in Spain, *Instituto de Empresa Business School Working Paper*, WP05-22.

Casson, Mark, and Della Giusta, Marina (Eds.) (2008), *The Economics of Networks*, The International Library of Critical Writings in Economics, Northampton, MA, USA: Elgar.

Chung, Kee H., and Cox, Raymond A. K. (1990), Patterns of Productivity in the Finance Literature: A Study of the Bibliometric Distributions, *The Journal of Finance*, Vol. 45, Nr. 1, pp. 301–309.

Coe, David T., and Helpman, Elhanan (1995), International R&D Spillovers, *European Economic Review*, Vol. 39, Nr. 5, pp. 859–887.

Conroy, M., and Dusansky, R. (1995), The productivity of economics departments in the U.S.: publications in the core journals, *Journal of Economic Literature*, Vol. 33, Nr. 4, pp. 1966–1971.

Coronado, Daniel, Acosta, Manuel, and León, Dolores (2004), Regional Planning of R&D and Science-Technology Interactions in Andalucia: A Bibliometric Analysis of Patent Documents, *European Planning Studies*, Vol. 12, Nr. 8, pp. 1075–1095.

Cowan, R., and Jonard, N. (2001), Knowledge creation, knowledge diffusion and network structure, in A. Kirman and J.B. Zimmermann (Eds.), *Economies with Heterogenous Interacting Agents*, Springer.

Cox, Raymond A. K., and Chung, Kee H. (1991), Patterns of Research Output and Author Concentration in the Economics Literature, *The Review of Economics and Statistics*, Vol. 73, Nr. 4, pp. 740-747.

Cox, Sue, and Taylor, Jim (2006), The Impact of a Business School on Regional Economic Development: a Case Study, *Local Economy*, Vol. 21, Nr. 2, pp. 117–135.

Cozzens, Susan E. (1989), What Do Citations Count? The Rhetoric-First Model, *Scientometrics*, Vol. 15, Nr. 5–6, pp. 437–447.

Daniel, Hans-Dieter (2005), Publications as a measure of scientific advancement and of scientists' productivity, *Learned Publishing*, Vol. 18, Nr. 2, pp. 143–148.

Daniel, Hans-Dieter, and Fisch, R. (1990), Research performance evaluation in the German university sector, *Scientometrics*, Vol. 19, Nr. 5–6, pp. 349–361.

Davelaar, E. J., and Nijkamp, P. (1989), The role of the metropolitan milieu as an incubation centre for technological innovations: a Dutch case study, *Urban Studies*, Vol. 26, Nr. 5, pp. 517–525.

David, P. A., and Foray, D. (1994), Percolation structures, Markov random fields and the economics of EDI standard diffusion, in Pogorel (Ed.), *Global Telecommunication Strategies and Technological Changes*, North-Holland, Amsterdam, pp. 135-170.

Denison, E. F. (1968), Measuring the economic contribution of education and the 'residual' to economic growth, in Bowman, M. J. (Eds.), *Readings in the Economics of Education*, Paris: UNESCO, pp. 315–317.

Dietz, James S., and Bozeman, Barry (2005), Academic careers, patents, and productivity: industry experience as scientific and technical human capital, *Research Policy*, Vol. 34, pp. 349–367.

Dorsett, R. A., and Weiler, W. C. (1982), The impact of an institution's federal research grants on the economy of its state, *Journal of Higher Education*, Vol. 53, Nr. 4, pp. 419–428.

Dosi, G. (1988), Sources, procedures and microeconomic effects of innovation, *Journal of Economic Literature*, Vol. 26, Nr. 3, pp. 1120–1171.

Elliot, D. S., and Meisel, J. B. (1987), *The economic impact study of Southern Illinois University at Edwardsville on the St Louis metropolitan area, 1986*, Department of Economics, Southern Illinois University at Edwardsville.

Evangelista, R., Iammarino, S., Mastrostefano, V., and Silvani, A. (2002), Looking for regional systems of innovation: Evidence from the Italian innovation survey, *Regional Studies*, Vol. 36, Nr. 2, pp. 173–186.

Fairthorne, R. A. (1969), Empirical hyperbolic distributions (Bradford-Zipf-Mandelbrot) for bibliometric description and prediction, *Journal of Documentation*, Vol. 25, Nr. 4, pp. 319–343.

Feldman, M. P. (1994), The university and economic development: the case of John Hopkins University and Baltimore, *Economic Development Quarterly*, Vol. 8, Nr. 1, pp. 67–76.

Feller, Irwin (1990), Universities as engines of R&D-based economic growth: they think they can, *Research Policy*, Vol. 19, Nr. 4, pp. 335–348.

Felsenstein, D. (1996), The university in the metropolitan arena: impacts and public policy implications, *Urban Studies*, Vol. 33, Nr. 9, pp. 1565–1580.

Filion, Kristian, and Pless, I. Barry (2008), Factors related to the frequency of citation of epidemiologic publications, *Epidemiologic Perspectives & Innovations*, Vol. 5, Nr. 3 (doi:10.1186/1742-5573-5-3).

Florax, R. (1992), *The University: A Regional Booster?*, Aldershot: Avebury.

Forrant, Robert (2001), Pulling Together in Lowell: The University and the Regional Development Process, *European Planning Studies*, Vol. 9, Nr. 5, pp. 613–628.

Gagnol, Laurent, and Héraud, Jean-Alain (2001), Impact Économique Régional d'un Pôle Universitaire: Application au Cas Strasbourgeois, *Working Paper BETA*, Université Louis Pasteur, Strasbourg.

Garfield, Eugene (1972), Citation analysis as a tool in journal evaluation: journals can be ranked by frequency and impact of citations for science policy studies, *Science*, Vol. 178, Nr. 4060, pp. 471–479.

Garfield, Eugene (1977), "The 'Obliteration Phenomenon' In Science – And the Advantage of Being Obliterated!", In *Essays Of An Information Scientist*, Chapter 2, Philadelphia, USA: ISI Press.

Garfield, Eugene (1979), *Citation Indexing-Its Theory and Application in Science, Technology, and Humanities*, New York, USA: Wiley.

Garfield, Eugene (1986), "Uses And Misuses of Citation Frequency", In *Essays of an Information Scientist*, Chapter 8, Philadelphia, USA: ISI Press.

Garfield, Eugene (1996), *SCI Journal Citation Reports: A Bibliometric Analysis of Science Journals in the ISI Database*, Philadelphia, Pennsylvania: Institute for Scientific Information, Inc.

Garfield, Eugene (1996), The significant scientific literature appears in a small core of journals, *The Scientist*, Vol. 10, Nr.17, pp. 13.

Garfield, Eugene, and Welljamsdorof, A. (1992), Citation data: their use as quantitative indicators for science and technology evaluation and policy-making, *Science & Public Policy*, Vol. 19, Nr, 5, pp. 321–327.

Garfield, Eugene, and Welljamsdorof, A. (1992), Citation data: their use as quantitative indicators for science and technology evaluation and policy-making, *Science & Public Policy*, Vol. 19, Nr. 5, pp. 321–327.

Garfield, Eugene, Malin, M. V., and Small, H. (1978), Citation data as science indicators, In: Elkana, Y., Lederberg, J., Merton, R. K., Thackray, A., and Zuckerman, H. (Eds), *Toward a metric of science: the advent of science indicators*, New York: John Wiley, pp. 179–207.

Garlick, Steve, Davies, Gordon, Polèse, Mario, and Kitagawa, Fumi (2006), *Supporting the Contribution of Higher Education Institutions to Regional Development - Peer Review Report: Atlantic Canada*, Paris: Organisation for Economic Co-operation and Development.

Gibbons, Michael, Limoges, Camille, and Nowotny, Helga (1994), *The new production of knowledge: The dynamics of science and research in contemporary societies*, Sage Publications, London.

Glänzel, W., and Schoepflin, U. (1995), A Bibliometric Study on Ageing and Reception Processes of Scientific Literature, *Journal Of Information Science*, Vol. 21, Nr. 1, pp. 37-53.

Glänzel, W., and Schoepflin, U. (1999), A Bibliometric Study of Reference Literature in the Sciences and Social Sciences, *Information Processing and Management*, Vol. 35, Nr. 1, pp. 31-44.

Glänzel, W., Schubert, A., and Czerwon, H.-J. (1999), A Bibliometric Analysis of International Scientific Cooperation of the European Union (1985-1995), *Scientometrics*, Vol. 45, Nr. 2, pp. 185–202.

Glänzel, Wolfgang (2001), National characteristics in international scientific co-authorship relations, *Scientometrics*, Vol. 51, Nr. 1, pp. 69-115.

Goddard, J., Charles, D., Pike, A., Potts, G., and Bradley, D. (1994), *Universities and Communities*, Committee of Vice Chancellors and Principals of the Universities of the United Kingdom, London, and Centre for Urban and Regional Development Studies, University of Newcastle.

Godin, B. (1993), *The relationship between science and technology: a bibliometric analysis of papers and patents in innovative firms,* unpublished D. Phil thesis, University of Sussex.

Godin, B. (1995), Research and the practice of publication in industries, R*esearch Policy*, Vol. 25, Nr. 4, pp. 587-606.

Goldstein, H. A. (1989–90), Estimating the regional economic impact of universities: an application of input-output analysis, *Planning for Higher Education*, Vol. 18, Nr. 1, pp. 51–64.

Grandstrand, O., Patel, P., and Pavitt, K. (1997), Multi-technology corporations: why they have 'distribute' rather than 'distinctive core' capabilities, *California Management Review*, Vol. 39, Nr. 4, pp. 8-25.

Greene, W. H. (2000), *Econometric Analysis*, 4th edition, New Jersey: Prentice Hall.

Harloe, Michael, and Perry, Beth (2004), Universities, Localities and Regional Development: The Emergence of the 'Mode 2' University ?, *International Journal of Urban and Regional Research*, Vol. 28, Nr. 1, pp. 212–223.

Hedrick, D. W, Henson, S. E., and Mack, R. S. (1990), The effects of universities on local retail, service and F.I.R.E. employment: some cross-sectional evidence, *Growth and Change*, Vol. 21, Nr. 3, pp. 9–20.

Helpman, Elhanan (1997), R&D and Productivity: the International Connection, *NBER Working Paper Series*, Working Paper 6101.

Henderson, R., Jaffe, A. B., and Trajtenberg, M. (1998), Universities as a source of commercial technology: a detailed analysis of university patenting, 1965-1988, *Review of Economics and Statistics*, Vol. 80, Nr. 1, pp. 119–127.

Hicks, D. (1999), The difficulty of achieving full coverage of international social science literature and the bibliometric consequences, *Scientometrics*, Vol. 44, Nr. 2, pp. 193–215.

Hong, Wei (2008), Decline of the centre: The decentralizing process of knowledge transfer of Chinese universities from 1985 to 2004, *Research Policy*, Vol. 37, Nr. 4, pp. 580–595.

Hood, William W., and Wilson, Concepción S. (2001), The literature of bibliometrics, scientometrics, and informetrics, *Scientometrics*, Vol. 52, Nr. 2, pp. 291–314.

Horta, Hugo (2008), On Improving the University Research Base: The Technical University of Lisbon Case in Perspective, *Higher Education Policy*, Vol. 21, pp. 123–146.

Hu, Albert G.Z., and Jaffe, Adam B. (2003), Patent citations and international knowledge flow: the cases of Korea and Taiwan, *International Journal of Industrial Organisation*, Vol. 21, Nr. 6, pp. 849–880.

Huggins, Robert, and Cooke, Philip (1997), The economic impact of Cardiff University: innovation, learning and job generation, *GeoJournal*, Vol. 41, Nr. 4, pp. 325–337.

Hussler, Caroline, and Rondé, Patrick (2007), The impact of cognitive communities on the diffusion of academic knowledge: Evidence from the networks of inventors of a French university, *Research Policy*, Vol. 36, Nr. 2, pp. 288–302.

INESC Porto (2008a), *Activity Plan of INESC Porto Units*, Porto, Portugal: INESC Porto.

INESC Porto (2008b), *Manual de Acolhimento do INESC Porto*, Porto, Portugal: INESC Porto.

INESC Porto (2008c), *Scientific Advisory Board Report*, Porto, Portugal: INESC Porto.

Jackson, M. O., and Watts, A. (2002), The evolution of social and economic networks, *Journal of Economic Theory*, Vol. 106, Nr. 2, pp. 265–295.

Jackson, M.O., and Wolinsky, A. (1996), A strategic model of social and economic networks, *Journal of Economic Theory*, Vol. 71, Nr. 1, pp. 44–74.

Jaffe, Adam B., Trajtenberg, M., and Henderson, R. (1993), Geographic Localization of Knowledge Spillovers as Evidenced by Patent Citations, *The Quarterly Journal of Economics*, Vol. 108, Nr. 3, pp. 577-98.

Jaffe, Adam B., and Trajtenberg, Manuel (1999), International Knowledge Flows: Evidence From Patent Citations, *Economics of Innovation and New Technology*, Vol. 8, Nr. 1, pp. 105–136.

Kalaitzidakis, P., Mamuneas, T. P. and Stengos, T. (2003), Rankings of academic journals and institutions in economics, *Journal of the European Economic Association*, Vol. 1, Nr. 6, pp. 1346–1366.

Kandori, M., Mailath, G., and Rob, R. (1993), Learning, mutation and long run equilibria in games, *Econometrica*, Vol. 61, Nr. 1, pp. 29–56.

Katz, J. S., and Hicks, D. (1998), Indicators for Systems of Innovation - a Bibliometrics-based Approach, Oslo: STEP Group, *IDEA Paper Series*, Vol. IV, Nr. 12, pp. 66.

Katz, Sylvan, and Martin, B. R. (1997), What is 'research collaboration'?, *Research Policy*, Vol. 26, Nr. 1, pp. 1–18.

King, David A. (2004), The scientific impact of nations: what different countries get for their research spending, *Nature*, Vol. 430, Nr. 6997, pp. 311–316.

Kochen, Manfred (1974), *Principles of Information Retrieval*, Los Angeles: Melville, pp. 74.

Kopcsa, Alexander, and Schiebel, Edgar (1998), Science And Technology Mapping: A New Iteration Model For Representing Multidimensional Relationships, *Journal of the American Society for Information Science*, Vol. 49, Nr. 1, pp. 7–17.

Kostoff, R. N. (2002), Citation analysis of research performer quality, *Scientometrics*, Vol. 53, Nr. 1, pp. 49–71.

Kuhn, Thomas Samuel (1962), *The Structure of Scientific Revolutions*, Chicago: University of Chicago Press.

Kuznets, Simon (1966), *Modern Economic Growth*, New Haven: Yale University Press.

Langlais, R. N. (1997), Transaction costs economics in real time, *Industrial and Corporate Change*, Vol. 1, Nr. 1, pp. 99–127.

Lawani, S. M. (1986), Some bibliometric correlates of quality in scientific research, *Scientometrics*, Vol. 9, Nr. 1–2, pp. 13–25.

Leydesdorff, Loet (2001), *The Challenge of Scientometrics: The Development, Measurement, and Self-Organisation os Scientific Communications*, Second Edition, USA: Universal Publishers.

Leydesdorff, Loet, and Meyer, Martin (2003), The Triple Helix of university-industry-government relations, *Scientometrics*, Vol. 58, Nr. 2, pp. 191–203.

Lichtenberg, F. R. (1993), R&D investment and international productivity differences, *NBER Working Paper N. 4161.*

Link, A. N. (1999), A Suggested Method for Assessing the Economic Impacts of University R&D: Including Identifying Roles for Technology Transfer Officers, *Journal of the Association of University Technology Managers*, Vol. 11, pp. 1–17.

Love, J. H., and McNicoll, I. H. (1988), The Regional Economic Impact of Overseas Students in the UK: A Case Study of Three Scottish Universities, *Regional Studies*, Vol. 22, Nr.1, pp. 11–18.

Luukkonen, Terttu, Tijssen, R. J. W., Persson, O., and Sivertsen, G. (1993), The measurement of international scientific collaboration, *Scientometrics*, Vol. 28, Nr. 1, pp. 15-36.

MacGarvie, Megan (2005), The determinants of international knowledge diffusion as measured by patent citations, *Economics Letters*, Vol. 87, Nr. 1, pp. 121–126.

Malecki, E. J. (1987), The R&D location decision of the firm and 'creative' regions, *Technovation*, Vol.6, Nr. 3, pp. 205–222.

Marginson, Simon, and van der Wende, Marijk (2007), *Globalisation and Higher Education*, Education Working Paper No. 8, Paris: Organisation for Economic Co-operation and Development.

Markusen, A. R., Hall, P., and Glasmeier, A. (1986), *High-tech America: The What, How, Where and Why of the Sunrise Industries*, Boston: Allen and Unwin.

Marques, J. P. C., Caraça, J. M. G., and Diz, H. (2006), How can university–industry–government interactions change the innovation scenario in Portugal?—the case of the University of Coimbra, *Technovation*, Vol. 26, Nr. 4, pp. 534–542.

Martin, Fernand (1998), The economic impact of Canadian university R&D, *Research Policy*, Vol. 27, pp. 677–687.

May, Robert M. (1997), The scientific wealth of nations, *Science*, Vol. 275, Nr. 5301, pp. 793–796.

Merton, Robert K. (1968), The Matthew Effect in Science, *Science*, Vol. 159, Nr. 3810, pp. 56-63.

Merton, Robert K. (1988), The Matthew Effect in Science, II: Cumulative advantage and the symbolism of intellectual property, *Isis*, Vol. 79, Nr. 4, pp. 606-623.

Merton, Robert K. (1995), The Thomas Theorem and the Matthew Effect, *Social Factors*, Vol. 74, Nr. 2, pp. 379-422.

Meyer, M. (2000a), Does science push technology? Patents citing scientific literature, *Research Policy*, Vol. 29, Nr. 3, pp. 409–434,

Meyer, M. (2000b), What is special about patent citations? Differences between scientific and parent citations. *Scientometrics*, Vol. 49, Nr. 1, pp. 93–123.

Meyer, M. (2004), Measuring the Impact of Science, *Engineering Management Conference, 2004. Proceedings, 2004 IEEE International*, Vol. 1, pp. 377–381.

Milgram, S. (1967), The small world problem, *Psychology Today*, Vol. 2, pp. 60–67.

Ministry of Science, Technology and Higher Education – MSTHE (2006), *Tertiary Education in Portugal – Background Report*, Lisbon: Organisation for Economic Co-operation and Development.

Moed, H. F., and Van Leeuwen, Th. N. (1995), Improving the Accuracy of the Institute for Scientific Information's Journal Impact Factor*, Journal of the American Society for Information Science*, Vol. 46, Nr. 6, pp. 461-467.

Moed, H. F., and Van Leeuwen, Th. N. (1996), Impact Factors Can Mislead, *Nature*, Vol. 381, Nr. 6579.

Moed, H. F., Van Leeuwen, Th. N., and Reedijk, J. (1998), A New Classification System to Describe the Ageing of Scientific Journals and their Impact Factors, *Journal of Documentation*, Vol. 54, Nr. 4, pp. 387-419.

Moed, Henk F. (2005a), *Citation Analysis in Research Evaluation*, Dordrecht, The Netherlands: Springer.

Moed, Henk F. (2005b), Citation analysis of scientific journals and journal impact measures, *Current Science*, Vol. 89, Nr. 12, pp. 1990–1996.

Moore, C. L., and Suffrin, S. C. (1974), Syracuse University : the impact of a nonprofit institution on regional income, *Growth and Change*, Vol. 51, Nr. 1, pp. 36–40.

Moore, G. A. (1979), Local income generation and regional income redistribution in a system of public higher education, *Journal of Higher Education*, Vol. 50, Nr. 3, pp. 334–348.

Nalimov, V. V., and Mulchenko, Z. M. (1969), *Naukometriya, Izuchenie Razvitiya Nauki kak Informatsionnogo Protsessa* [Scientometrics, Study of the Development of Science as an Information Process], Moscow: Nauka (English translation: 1971, Washington, D.C.: Foreign Technology Division, U.S. Air Force Systems Command, Wright-Patterson AFB, Ohio, NTIS Report Nr. AD735–634).

Narin, F., Hamilton, K. S., and Olivastro, D. (1995), Linkage between agency supported research and patented industrial technology, *Research Evaluation*, Vol. 5, Nr. 3, pp. 183–187.

Narin, F., Hamilton, K. S., and Olivastro, D. **(**1997), The increasing linkage between U.S. technology and public science, *Research Policy*, Vol. 26, Nr. 3, pp. 317-330.

Nederhof, A. J., and Zwaan R. A. (1991), Quality Judgments of Journals as Indicators of Research Performance in the Humanities and the Social and Behavioural Sciences, *Journal of the American Society for Information Science*, Vol. 42, Nr. 5, pp. 332–340.

Neuhaus, Christoph, and Daniel, Hans-Dieter (2008), Data sources for performing citation analysis: an overview, *Journal of Documentation*, Vol. 64, Nr. 2, pp. 193–210.

Newlands, David (2003), The Role of Universities in Learning Regions, Paper presented at the 43rd European Regional Science Association Congress, Paper Nr. 398.

Newman, M. E. J., Watts, D. J., and Strogatz, S. H. (2001), Random graphs models of social networks, *PNAS – Proceedings of the National Academy of Science*, Nr. 99, pp. 2566-2572.

Okubo, Y., Miquel, J. F., Frigoletto, L., and Doré, J.C. (1992), Structure of international collaboration in science: Typology of countries through multivariate techniques using a link indicator, *Scientometrics*, Vol. 25, Nr. 2, pp. 321-351.

Oosterlinck, A. (2001), *University/Industry Knowledge Management: A University Perspective*, Paris: Organisation for Economic Co-operation and Development.

Persson, Olle (2001), All author citations *versus* first author citations, *Scientometrics*, Vol. 50, Nr. 2, pp. 339-344.

Pinski, G., and Narin, F. (1976), Citation Influence for Journal Aggregates of Scientific Publications: Theory, with Application to the Literature of Physics, *Information Processing and Management*, Vol. 12, Nr. 5, pp. 297-312.

Podolny, Joel M., and Stuart, Toby E. (1995), A Role-Based Ecology of Technological Change, *The American Journal of Sociology*, Vol. 100, Nr. 5, pp. 1224–1260.

Price, Derek J. de Solla (1963), *Little Science, Big Science*, Columbia University Press, New York.

Price, Derek J. de Solla (1965), Networks of Scientific Papers, *Science*, Vol. 149, Nr. 3683, pp. 510–515.

Pritchard, A. (1969), Statistical bibliography or bibliometrics?, *Journal of Documentation*, Vol. 25, Nr. 4, pp. 348–349.

Pritchard, A., and Wittig, G. R. (1981)**,** *Bibliometrics: a bibliography and index*, Volume 1: 1874-1959, Watford, Hertfordshire, England: ALLM Books.

Ramlogan, Ronnie, Mina, Andrea, Tampubolon, Gindo, and Metcalfe, J. Stanley (2007), Networks of knowledge: The distributed nature of medical innovation, *Scientometrics*, Vol. 70, Nr. 2, pp. 459–489.

Rego, Maria (2004), Universities and economically depressed regions: how strong is the influence of the University of Évora on the human capital of the region?, Paper presented at the 44th European Regional Science Association Congress.

Romer, P. (1986), Increasing returns and long-run growth, *Journal of Political Economy*, Vol. 94, Nr. 5, pp. 1002–1037.

Rosen, M. I., Strang, W. A., and Kramer, J. (1985), The University of Wisconsin –Madison and the local and state economies: a second look, *Monograph Nr. 20*, Graduate School of Business, University of Wisconsin, Madison.

Sampat, Bhaven N., Mowery, David C., Ziedonis, Arvids A. (2003), Changes in university patent quality after the Bayh–Dole act: a re-examination, *International Journal of Industrial Organisation*, Vol. 21, Nr. 9, pp. 1371–1390.

Saxenian, A. (1994), *Regional Advantage: Culture and Competition in Silicon Valley and Route 128*, Harvard University Press, Cambridge.

Scherer, F. M. (1982), Inter-industry technology flows in the United States, *Research Policy*, Vol. 11, Nr. 4, pp. 227–245.

Schildt, Henri A., and Mattsson, Juha T. (2006), A dense network sub-grouping algorithm for co-citation analysis and its implementation in the software tool *Sitkis*, *Scientometrics*, Vol. 67, Nr. 1, pp. 143–163.

Schott, Thomas (1998), Ties between centre and periphery in the scientific world system: accumulation of rewards, dominance and self-reliance in the centre, *Journal of World Systems Research*, Vol. 4.

Schubert, A., and Braun, T. (1996), Cross-field normalization of scientometric indicators, *Scientometrics*, Vol. 36, Nr. 3, pp. 311–324.

Schubert, A., and Glänzel, W. (1986), Mean Response Time – A New Indicator of Journal Citation Speed with Application to Physics Journals, *Czechoslovak Journal of Physics,* Vol. 36, Nr. 1, pp. 121-125.

Schutte, Frits (1999), The University-Industry Relations of an Entrepreneurial University: the Case of the University of Twente, *Higher Education in Europe*, Vol. 24, No. 1, pp. 47–65.

Schwarz, A. Winkel, Schwarz, S., Tijssen, R. J. W. (1998), Research and Research Impact of a Technical University – A Bibliometric Study, *Scientometrics*, Vol. 41, Nr. 3, pp. 371-388.

Scott, L., and Mitias, P. (1996), Trends in rankings of economics departments in the U.S.: an update, *Economic Inquiry*, Vol. 34, Nr. 2, pp. 378–400.

Sengupta, I. N. (1992), Bibliometrics, informetrics, scientometrics and librametrics: an overview, *Libri*, Vol. 42, Nr. 2, pp. 75–98.

Siegfried, John J., Sanderson, Allen R., and McHenry, Peter (2007), The economic impact of colleges and universities, *Economics of Education Review*, Vol. 26, pp. 546–558.

Silva, João Albino, and Santos, Sérgio (2006), Using Input-output Analysis to Estimate the Regional Economic Impact of Universities: A Case Study, *Proceedings of the Internacional EcoMod Conference: Regional and Urban Modelling*, Brussels, Belgium, 1-3 June.

Silva, João Albino, Santos, Sérgio, and Gomes, Luís (2000), *O Impacte do Ensino Superior Público na Região do Algarve 2000*, Faro: Fundação para o Desenvolvimento da Universidade do Algarve.

Simha, O. Robert (2005), The Economic Impact Of Eight Research Universities On The Boston Region, *Tertiary Education and Management*, Vol. 11, pp. 269–278.

Simonyi, Agnes (1999), ***The Evaluation of University-Region Relationships*** [1], *European Journal of Education*, Vol. 34, Nr. 3, pp. 335–341.

Smilor, R. W., Gibson, D. V. and Dietrich, G. B. (1990), University spin-out companies: technology start-ups from UT-Austin, *Journal of Business Venturing*, Vol. 5, Nr. 1, pp. 63–76.

Smith, K. (Ed.), Ekeland, A, Iversen, E, Kaloudis, A, Patel, P, and Narula, R (1998), Science, Technology and Innovation Indicators – A Guide for Policy-Makers*, IDEA Paper Series Nr. 5*, Oslo: STEP Group.

Smith, Linda C. (1981), Citation analysis, *Library Trends*, Vol. 30, Nr. 1, pp. 83–106.

Steinacker, Annette (2005), The Economic Effect of Urban Colleges on their Surrounding Communities, *Urban Studies*, Vol. 42, Nr. 7, pp. 1161–1175.

Steinnes, D. M. (1987), On understanding and evaluating the university's evolving economic development role, *Economic Development Quarterly*, Vol. 1, pp. 214–225.

Stephan, Paula E., and Audretsch, David B. (Eds.) (2000), *The Economics of Science and Innovation*, The International Library of Critical Writings in Economics, Vol. I, Northampton, MA, USA: Elgar.

Stichweh, Rudolf (1996), Science in the system of world society, Social Science Information, Vol. 35, Nr. 2, pp. 327–340.

Swenson, David, and Eathington, Liesl (2007), *The Economic Impacts of Iowa State University in Fiscal 2006*, Iowa State University.

Tague-Sutcliffe, J. M. (1992), An introduction to informetrics, *Information Processing and Management*, Vol. 28, Nr. 1, pp. 1–3.

Tavoletti, Ernesto (2007), Assessing the Regional Economic Impact of Higher Education Institutions: An Application to the University of Cardiff, *Transition Studies Review*, Vol. 14, Nr.3, pp. 507–522.

Teixeira, Aurora A. C. (2006), Vinte anos (1985-2005) dos *Working Papers* da FEP: um estudo sobre a respectiva probabilidade de publicação nacional e internacional, *Working Paper FEP*, CEMPRE, Faculdade de Economia, Universidade do Porto, Portugal.

Teixeira, Aurora A. C., and Costa, Joana (2006), What type of firm forges closer innovation linkages with Portuguese Universities?, *Notas Económicas*, Nr. 24, pp. 22–47.

Thorne, Frederick C. (1977), The Citation Index: Another Case of Spurious Validity, *Journal of Clinical Psychology*, Vol. 33, Nr. 4, pp. 1157–1161.

Tomer, C. (1986), A Statistical Assessment of Two Measures of Citation: The Impact Factor and the Immediacy Index, *Information Processing and Management*, Vol. 22, Nr. 3, pp. 251-258.

Trajtenberg, M. (1990), *Economic analysis of product innovation*, Cambridge: Cambridge University Press.

Uren, Victoria, Shum, Simon Buckingham, Bachler, Michelle, and Li, Gangmin (2006), Sensemaking tools for understanding research literatures: Design, implementation and user evaluation, *International Journal of Human-Computer Studies*, Vol. 64, Nr. 5, pp. 420–445.

Valente, T. (1996), Social network thresholds in the diffusion of innovations, *Social Networks*, Vol. 18, Nr. 1, pp. 69-89.

Van den Berghe, Herman, Houben, Josee A., de Bruin, Renger E., Moed, Henk F., Kint, Andre, Luwel, Marc, and Spruyt, Eric H. J. (1998), Bibliometric Indicators of University Research Performance in Flanders, *Journal of the American Society for Information Science*, Vol. 49, Nr. 1, pp. 59-67.

Van Leeuwen, Th. N., van der Wurff, L. J., and van Raan, A. F. J. (2001), The use of combined bibliometric methods in research funding policy, *Research Evaluation*, Vol. 10, Nr. 3, pp. 195–201.

Van Leeuwen, Th. N., Moed, H. F., and Reedijk, J. (1997), *JACS* Still Topping *Angewandte Chemie*: Beware Of Erroneous Impact Factors, *Chemical Intelligencer*, Vol. 3, pp. 32-36.

van Raan, A. F. J. (2003), The use of bibliometric analysis in research performance assessment and monitoring of interdisciplinary scientific developments, *Technikfolgenabschätzung*, Vol. 12, Nr. 1, pp. 20–29. English translation available on the 1st December, 2008, at: http://www.itas.fzk.de/tatup/031/raan03a.htm.

van Raan, A. F. J. (2004), Measuring science. Capita selecta of current main issues, In: Moed, H. F., Glänzel, W., and Schmoch, U. (eds), *Handbook of quantitative science and technology research. The use of publication and patent statistics in studies of S&T systems*, Dordrecht, The Netherlands: Kluwer, pp. 19–50.

Verspagen, Bart (1997), European 'Regional Clubs': Do they exist, and where are they heading? On economic and technological differences between european regions, *Maastricht Economic Research Institute on Innovation and Technology MERIT, mimeo.*

Verspagen, Bart, and Werker, Claudia (2004), Keith Pavitt and the Invisible College of the Economics of Technology and Innovation, *Research Policy*, Vol. 33, Nr. 9, pp. 1419–1431.

Vincent, Annette, and Ross, Dianne (2000), On Evaluation of Faculty Research Impact of Citation Analysis, *The Journal of Applied Business Research*, Vol. 16, Nr. 2, pp. 1–14.

Wagner, Caroline S., and Leydesdorff, Loet (2005), Mapping Global Science Using International Co-authorships: A Comparison of 1990 and 2000, *International Journal of Technology and Globalization*, Vol. 1, Nr. 2, pp. 185–208.

Wagner, Caroline S., Yezril, Allison, and Hassell, Scott (2000), *International Cooperation in Research and Development: An Update to an Inventory of U.S. Government Spending*, RAND, Santa Monica.

Wassermann, S., and Faust, K. (1994), *Social Network Analysis: Methods and Applications*, Cambridge University Press, Cambridge.

Watts, A. (2001), A dynamic model of network formation, *Games and Economic Behaviour*, Vol. 34, Nr. 2, pp. 331–341.

Watts, D. J., and Strogatz, S. H. (1998), Collective dynamics of 'small worlds' networks, *Nature*, Vol. 393, Nr. 6684, pp. 440–442.

Weinstock, N. (1971), Citation Indexes, In Kent A. (Ed.). *Encyclopedia of Library and Information Science*, New York: Marcel Dekker, Vol. 5, pp. 16-41.

Westney, L. C. H. (1998), Historical Rankings of Science and Technology: A Citationist Perspective, *The Journal of the Association for History and Computing*, Vol. 1, Nr. 1.

White, H. D., and McCain, K. W. (1989), Bibliometrics, In: M. E. Williams (Ed.), *Annual Review of Information Science and Technology,* Vol. 24, Amsterdam, The Netherlands: Elsevier Science Publishers B. V. for the American Society for Information Science, pp. 119-186.

Wilson, C. S. (2001), Informetrics, In: M. E. Williams (Ed.), *Annual Review of Information Science and Technology,* Vol. 34, Medford, NJ: Information Today, Inc. for the American Society for Information Science, pp. 3–143.

Young, H. P. (1993), The evolution of conventions, *Econometrica*, Vol. 61, Nr. 1, pp. 57–84.

Young, H. P. (2002), The diffusion of innovations in social networks, *Santa Fe Institute Working Paper*, Nr. 02-04-018, USA.

Zelder. R. E., and Sichel, W. (1992), *The impact of Western Michigan University on the Kalamazoo County Economy*, Department of Economics, Western Michigan University, MI.

Zitt, Michel, Bassecoulard, E., and Okubo, Y. (2000), Shadows of the past in international cooperation: Collaboration profiles of the top 5 producers of science, *Scientometrics*, Vol. 47, Nr. 3, pp. 627–657.

Recent FEP Working Papers

Nº 318	José Sequeira and Aurora A.C. Teixeira, "*Assessing the influence of R&D institutions by mapping international scientific networks: the case of INESC Porto"*, March 2009
Nº 317	João Loureiro, Manuel M. F. Martins and Ana Paula Ribeiro, "*Cape Verde: The Case for Euroization"*, March 2009
Nº 316	Ester Gomes da Silva and Aurora A.C. Teixeira, "*Does structure influence growth? A panel data econometric assessment of 'relatively less developed' countries, 1979-2003"*, March 2009
Nº 315	Mário A. P. M. Silva, "*A Model of Growth with Intertemporal Knowledge Externalities, Augmented with Contemporaneous Knowledge Externalities"*, March 2009
Nº 314	Mariana Lopes and Aurora A.C. Teixeira, "*Open Innovation in firms located in an intermediate technology developed country"*, March 2009
Nº 313	Ester Gomes da Silva, "*Capital services estimates in Portuguese industries, 1977-2003"*, February 2009
Nº 312	Jorge M. S. Valente, Maria R. A. Moreira, Alok Singh and Rui A. F. S. Alves, "*Genetic algorithms for single machine scheduling with quadratic earliness and tardiness costs"*, February 2009
Nº 311	Abel Costa Fernandes, "*Explaining Government Spending: a Cointegration Approach"*, February 2009
Nº 310	João Correia-da-Silva, "*Uncertain delivery in markets for lemons"*, January 2009
Nº 309	Ana Paula Ribeiro, "*Interactions between Labor Market Reforms and Monetary Policy under Slowly Changing Habits"*, January 2009
Nº 308	Argentino Pessoa and Mário Rui Silva, "*Environment Based Innovation: Policy Questions"*, January 2009
Nº 307	Inês Drumond and José Jorge, "*Basel II Capital Requirements, Firms' Heterogeneity, and the Business Cycle"*, January 2009
Nº 306	Adelaide Maria Figueiredo, Fernanda Otília Figueiredo and Natália Pimenta Monteiro, "*Labor adjustments in privatized firms: a Statis approach"*, December 2008
Nº 305	Manuela A. D. Aguiar and Sofia B. S. D. Castro, "*Chaotic and deterministic switching in a two-person game"*, December 2008
Nº 304	Ana Pinto Borges and João Correia-da-Silva, "*Using Cost Observation to Regulate Bureaucratic Firms"*, December 2008
Nº 303	Miguel Fonseca, "*The Investment Development Path Hypothesis: a Panel Data Approach to the Portuguese Case"*, December 2008
Nº 302	Alexandre Almeida, Cristina Santos and Mário Rui Silva, "*Bridging Science to Economy: The Role of Science and Technologic Parks in Innovation Strategies in "Follower" Regions"*, November 2008
Nº 301	Alexandre Almeida, António Figueiredo and Mário Rui Silva, "*From Concept to Policy: Building Regional Innovation Systems in Follower Regions"*, November 2008
Nº 300	Pedro Quelhas Brito, "*Conceptualizing and illustrating the digital lifestyle of youth"*, October 2008
Nº 299	Argentino Pessoa, "*Tourism and Regional Competitiveness: the Case of the Portuguese Douro Valley"*, October 2008
Nº 298	Aurora A.C. Teixeira and Todd Davey, "*Attitudes of Higher Education students to new venture creation: a preliminary approach to the Portuguese case"*, October 2008
Nº 297	Carlos Brito, "*Uma Abordagem Relacional ao Valor da Marca"*, October 2008
Nº 296	Pedro Rui M. Gil, Paulo Brito and Óscar Afonso, "*A Model of Quality Ladders with Horizontal Entry"*, October 2008
Nº 295	Maria Manuel Pinho, "*The political economy of public spending composition: evidence from a panel of OECD countries"*, October 2008
Nº 294	Pedro Cosme da Costa Vieira, "*O Subsídio de Desemprego e a Relação Negativa entre Salário e Risco de Falência: Uma Teoria em Equilíbrio Parcial"*, October 2008
Nº 293	Cristina Santos, Alexandre Almeida and Aurora A.C. Teixeira, "*Searching for clusters*

	in tourism. A quantitative methodological proposal", September 2008
Nº 292	Alexandre Almeida and Aurora A.C. Teixeira, "*One size does not fit all… An economic development perspective on the asymmetric impact of Patents on R&D"*, September 2008
Nº 291	Paula Neto, António Brandão and António Cerqueira, "*The Impact of FDI, Cross Border Mergers and Acquisitions and Greenfield Investments on Economic Growth"*, September 2008
Nº 290	Cosme, P., "*Integrating fire risk into the management of forests"*, September 2008
Nº 289	Cosme, P., "*A comment on efficiency gains and myopic antitrust authority in a dynamic merger game"*, September 2008
Nº 288	Moreira, R., "*Workart – A Gestão e a Arte"* (1st Prize of the 2nd Edition of FEP/AEFEP- Applied Research in Economics and Management), August 2008
Nº 287	Vasco Leite, Sofia B.S.D. Castro and João Correia-da-Silva, "*The core periphery model with asymmetric inter-regional and intra-regional trade costs"*, August 2008
Nº 286	Jorge M. S. Valente and Maria R. A. Moreira, "*Greedy randomized dispatching heuristics for the single machine scheduling problem with quadratic earliness and tardiness penalties"*, August 2008
Nº 285	Patricia Teixeira Lopes and Rui Couto Viana, "*The transition to IFRS: disclosures by Portuguese listed companies"*, August 2008
Nº 284	Argentino Pessoa, "*Educational Reform in Developing Countries: Private Involvement and Partnerships"*, July 2008
Nº 283	Pedro Rui Mazeda Gil and Óscar Afonso, "*Technological-Knowledge Dynamics in Lab-Equipment Models of Quality Ladders"*, July 2008
Nº 282	Filipe J. Sousa and Luís M. de Castro, "*How is the relationship significance brought about? A critical realist approach"*, July 2008
Nº 281	Paula Neto; António Brandão and António Cerqueira, "*The Macroeconomic Determinants of Cross Border Mergers and Acquisitions and Greenfield Investments"*, June 2008
Nº 280	Octávio Figueiredo, Paulo Guimarães and Douglas Woodward, "*Vertical Disintegration in Marshallian Industrial Districts"*, June 2008
Nº 279	Jorge M. S. Valente, "*Beam search heuristics for quadratic earliness and tardiness scheduling"*, June 2008
Nº 278	Nuno Torres and Óscar Afonso, "*Re-evaluating the impact of natural resources on economic growth"*, June 2008
Nº 277	Inês Drumond, "*Bank Capital Requirements, Business Cycle Fluctuations and the Basel Accords: A Synthesis"*, June 2008
Nº 276	Pedro Rui Mazeda Gil, "*Stylized Facts and Other Empirical Evidence on Firm Dynamics, Business Cycle and Growth"*, May 2008
Nº 275	Teresa Dieguez and Aurora A.C. Teixeira, "*ICTs and Family Physicians Human Capital Upgrading. Delightful Chimera or Harsh Reality?"*, May 2008
Nº 274	Teresa M. Fernandes, João F. Proença and P.K. Kannan, "*The Relationships in Marketing: Contribution of a Historical Perspective"*, May 2008
Nº 273	Paulo Guimarães, Octávio Figueiredo and Douglas Woodward, "*Dartboard Tests for the Location Quotient"*, April 2008
Nº 272	Rui Leite and Óscar Afonso, "*Effects of learning-by-doing, technology-adoption costs and wage inequality"*, April 2008
Nº 271	Aurora A.C. Teixeira, "*National Systems of Innovation: a bibliometric appraisal"*, April 2008

Editor: Sandra Silva (sandras@fep.up.pt)
Download available at:
http://www.fep.up.pt/investigacao/workingpapers/workingpapers.htm
also in http://ideas.repec.org/PaperSeries.html

www.fep.up.pt

Faculdade de Economia da Universidade do Porto
Rua Dr. Roberto Frias, 4200-464 Porto | Tel. 225 571 100
Tel. 225571100 | www.fep.up.pt