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ASSESSING THE INFLUENCE OF R&D INSTITUTIONS BY MAPPING INTERNATIONAL SCIENTIFIC NETWORKS:

THE CASE OF INESC PORTO

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

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Abstract

Although scientometric and bibliometric studies embrace a much wider perspective of the linkages/networks of R&D institutions than standard economic studies, to the best of our knowledge, these studies have not yet made use of scientometric tools to analyse the influence and impact of R&D institutions. Moreover, the international perspective has so far been neglected both in standard and bibliometric studies.

Based on networks of 1239 foreign co-authorships and 13035 foreign citation linkages, we demonstrate that INESC Porto international influence has considerably expanded since 2003, a year that coincided with the implementation of an internal policy of granting monetary prizes to publications in scientific international journals. In terms of co-authorship, the network of INESC Porto more than duplicated (13 countries in the initial period to 27 in 2004-07). In terms of citations, INESC Porto's network encompassed almost 40 countries during the whole period (1996-2007). Its more prolific units (optoelectronics, energy and multimedia) presented a rather distinct pattern both in terms of size and evolution of the corresponding network boundaries. The network size of foreign co-authorships was not much different between the three units by the beginning of the 2000s (around 10 countries) but it evolved quite distinctly. The most remarkable pattern was registered by the multimedia (UTM) unit, whose network size rose exponentially to 21 countries in 2004-07. This contrasted with the decline (down to 8 countries) of the energy (USE) unit. The citation network of the optoelectronic unit (UOSE) was by far the largest, until 2003, involving 34 distinct countries, which contrasted with the size of USE (12 countries) and UTM (1 country). But again, after 2003, the size of the citation network of USE and UTM converged spectacularly to that of UOSE's, reaching in the last period 21 and 16, respectively.

The influence of INESC Porto reaches all five continents, especially when we consider citation networks. Indeed, excluding the citations from authors affiliated in Portuguese institutions, those that most cite INESC Porto's (and UOSE's) works are affiliated in institutions located in China, the UK and the US. The scientific works produced by USE influences mostly authors affiliated in institutions located in India, China and Spain, whereas for UTM the corresponding countries are the US, Germany and Italy.

We infer from the evidence analysed that not only did the boundaries of INESC Porto's scientific network substantially enlarge in the period of analysis (1996-2007) but its 'quality' also evidenced a positive evolution, with authors affiliated in institutions located in the scientific frontier countries citing works of INESC Porto (and its units).

Keywords: Bibliometrics, Knowledge networks; R&D Institutions

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 has therefore profound consequences over several economic variables. The truth is that international economic activity is increasingly technology-driven and knowledge-based, and this has been forcing firms to produce stronger linkages with innovative knowledge-based institutions, 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 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 many years, attracted and challenged researchers within economic science.

Traditionally, the measurability of the economic impact of a university or R&D organisation was based on several economic variables, such as new jobs created after the public/private investment in R&D projects (cf., Beeson and Montgomery, 1990; Huggins and Cooke, 1997; Gagnol and Héraud, 2001; Cox and Taylor, 2006; Swenson and Eathington, 2007; Barrios et al., 2008), revenues, productivity, worker efficiency (cf., Love and McNicoll, 1988; Newlands, 2003; Harloe and Perry, 2004; Bilbao-Osorio and Rodríguez-Pose, 2004; Braunerhjelm, 2008), and public health or environmental impact (cf., Hedrick et al., 1990; Simha, 2005). These types of studies assessed such impact mainly through this 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 the neo-classical growth theory, or more generally, mainstream economics (e.g., Bayoumi et al., 1996).

In contrast with the economic dimension, the knowledge dimension of the influence and impact of R&D organisations is, in general, much 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 expenditure 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 do 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 a R&D organisation, therefore complementing traditional economic approaches, and providing a more embracing perspective of knowledge flows. To accomplish such endeavour we resort to geographical descriptive statistics, addressing the main goal of our study, which is to map the scientific network of a R&D organisation and therefore to evaluate its 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. In Section 4, a comprehensive account of INESC Porto's scientific production by area of expertise is given and the net of international linkages is presented. Moreover, the most prolific units of INESC Porto are analysed in terms of scientific output, by employing descriptive geographical methods to assess the scope and importance of INESC Porto's international influence. Finally, in Conclusions, we address the main results and highlight some limitations of the present study, as well as the contributions our methodology brings 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 jobs 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.

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

As presented by Felsenstein (1996), the second approach – the role of universities in the economic growth process – deals specifically with issues of university-induced growth, i.e., in local labour markets (e.g., Beeson and Montgomery, 1990; Bluestone, 1993; Bilbao-Osorio and Rodríguez-Pose, 2004; Swenson and Eathington, 2007; Barrios et al., 2008), in new firm creation rates (e.g., Bania et al., 1990), in the development of the local service sector (e.g., Hedrick et al., 1990), or by influencing the human capital effect over the investment patterns of local industry (e.g., Florax, 1992; Love and McNicoll, 1988; Huggins and Cooke, 1997; Newlands, 2003; Steinacker, 2005; Tavoletti, 2007; Braunerhjelm, 2008). In these cases, aggregate models are used from place-based data (cities, metropolitan areas, countries, regions), which find the presence of the university to have a positive effect (Felsenstein, 1996).

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

Finally, the fourth approach draws on the results of Felsenstein (1996), who conceptualises the university as an organisation that, on the one hand, receives inputs from households, government and firms, paying its staff, equipment, services, and other kinds of costs (backward linkages of the university with the local economy), and, on the other hand, produces outputs such as human capital creation or knowledge production (forward linkages, knowledge-related impacts). Other more recent authors (e.g., Huggins and Cooke, 1997; Oosterlinck, 2001; Newlands, 2003; Harloe and Perry, 2004; Buxton et al., 2004; Tavoletti, 2007), adopt this approach in analysing knowledge production activities, such as consultancy, R&D, analytical and trouble-shooting services, or even non-market values' outputs, and the intangible assets, which result from the presence and influence of the university at the local and regional levels.

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 new firm creation			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 import/export 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	Econometric models using Keynesian-type income-	Income, output and employment effects arising from the	Brownrigg, 1973; Armstrong, 1993

Approaches	Mechanisms / Methods	Results	Authors
Keynesian-type income-expenditure multipliers	expenditure multipliers	expenditure of faculty, staff and students	
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, 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 and how this dimension of conductors and boosters of knowledge flows also has implications on R&D itself, and on economic progress at the limit.

There is another 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). Though 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 a medium-, long-term. That is why we find it relevant to address this branch of literature and further explore its contribution to our study, by complementing the 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 also White and McCain (1989: 119) 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' research, (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 indentified 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).

Actually, numerous authors identify limitations to bibliometrics, which can be compiled in a list. Pinski and Narin (1976) point out, for instance, the fact that there is no normalisation for reference practices in the different scientific disciplines, whereas a bias favouring journals with large papers is also identified by Pinski and Narin (1976), since, for example, review journals tend to have higher impact factors. Moreover, one can not clearly differentiate the nature and merits of the citing journals (Tomer, 1986). Also, citation frequency is a matter of age bias, as stressed by several authors (Asai, 1981; Glänzel and Schoepflin, 1995; Moed *et al.*, 1998). On the other hand, there is no suggestion in literature of the deviations from the citation impact statistic instrument (*cf.*, Schubert and Glänzel, 1986). Some authors (*e.g.*, Glänzel and Schoepflin, 1995; Moed *et al.*, 1998) reveal that it is not often that the average time for a scientific paper to reach a peak in citations is two years. For Moed *et al.* (1998), the description of citation patterns should not anchor only on one single measure. As Moed and van Leeuwen (1995, 1996) reveal, impact factors may be inaccurate in some cases, due to the fact that the concept of citable document is not adequately operationalised. Finally, errors in the calculation of impact factors may be due to incorrect identification in references (Braun and Glänzel, 1995; van Leeuwen *et al.*, 1997).

Schwarz *et al.* (1998) also emphasise problems of data coverage and consistency when interpreting statistical indicators from a general-purpose database like the SCI (*Science Citation Index*), for instance, from Thomson Reuters. Schwarz *et al.* (1998) mention the fact that the observation period may be too short, failing to depict all the citations accumulated over the years; also, one has to consider the distorting Matthew effect in citations' behaviour (*cf.*, Merton, 1968, 1988, 1995), which infers that cited authors will continue to be cited; moreover, low or no citation rates do not diminish a paper, since there are reasons, as pointed out previously, for not citing or delaying doing so. Also important is how papers that develop useful and new measurement techniques have higher citation scores compared to those presenting research results by using established and well-known methods. Schwarz *et al.* (1998) also recover the fact that self-citation (and/or friendship citation) practices vary between scientific fields of study. When scientific work gets to be considered 'classic', then it may lose explicit citations. Finally, utterly disregarding works not published in indexed journals has its consequence over analysis.

As stressed above, normally, studies within the bibliometric and scientometric 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 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 obtain the map of its influence at the international level.

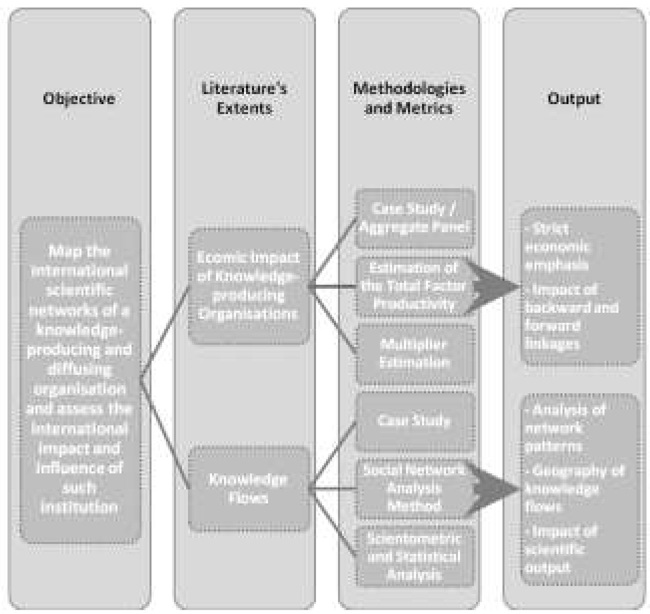


Figure 1: Synthesis of the commonly-used methodologies within economic impact literature and knowledge flow literature

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

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

3.1. Description of INESC Porto

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 integrates six working units (*cf.*, Figure 2), with a common support services infrastructure, which pursue, in an overall scope, innovation and internationalisation by means of strategic partnerships, reassuring institutional and economic sustainability (INESC Porto, 2008b, 2008c), and which are identified as follows:[1] Information and Communication Systems Unit (*Unidade de Sistemas de Informação e Comunicação* – USIC); Telecommunications and Multimedia Unit (*Unidade de Telecomunicações e Multimédia*

[1] From here onwards, we will identify each working unit of INESC Porto by its acronyms in Portuguese, since these are the names by which they are most commonly identified and recognised.

– UTM); Innovation and Technology Transfer Unit (*Unidade de Inovação e Transferência de Tecnologia* – UITT); Manufacturing Systems Engineering Unit (*Unidade de Engenharia de Sistemas de Produção* – UESP); Optoelectronic and Electronic Systems Unit (*Unidade de Optoelectrónica e Sistemas Electrónicos* – UOSE); Power Systems Unit (*Unidade de Sistemas de Energia* – USE).

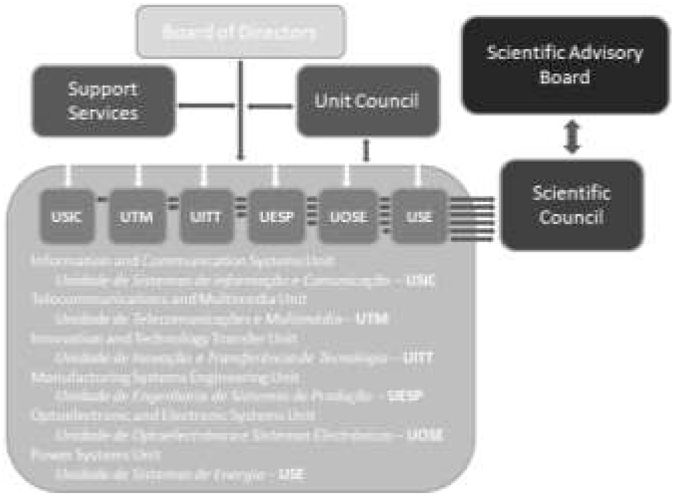


Figure 2: The organogram of INESC Porto

Source: Adapted from INESC Porto (2008b)

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. INESC Porto's scientific capability has been recognised internationally in academic circles, also becoming a player in the international technology market (INESC Porto, 2008c). Its success has been proven by awards given, by the visible magnetism of international scholars and students, and by targeting even the world market with successful high-tech startups (INESC Porto, 2008c).

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 joins together fundamental preconditions for conducting the present research work: outstanding scientific output developed during over a decade, and within an international collaboration framework of co-authorship, integrating different research fields.

3.2. Data gathering considerations and some descriptive account

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 (*cf.* 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. 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, nor 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 at INESC Porto. Nevertheless, 845 entries were considered valid and thoroughly worked on, since 10 papers were also excluded.[2]

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

[2] 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 revealed to have different authors from the ones originally indentified in SACA, and one of these was by authors with no affiliation with INESC Porto whatsoever. The remaining three papers had no record in the journals that were identified in SACA and were, therefore, not accessible. As indicated previously, 845 papers were valid since it was possible to have access to their contents, whether through the SACA search engine or through one online, like Google.com, Google Scholar or Thomson Reuters' Web of Knowledge. Furthermore, it should be added that 14 papers within these 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.

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[3] 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.[4] 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).

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.[5]

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

	Databases		
Source	**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 (no. papers)	1.488	246	352
Total Records Revised (no. papers)	1.397	246	347
Workable Sample (no. papers)	826	246	246
INESC Porto's Cited Papers (no. papers)	-	-	142 (120 papers are cited by at least one foreign affiliated author)
Total Citations (no. papers)	-	-	754
Networking Linkages (no. 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).

[3] 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.

[4] 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.

[5] 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.

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). 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 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 how they differentiate from one another.

Hence, 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 a 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.

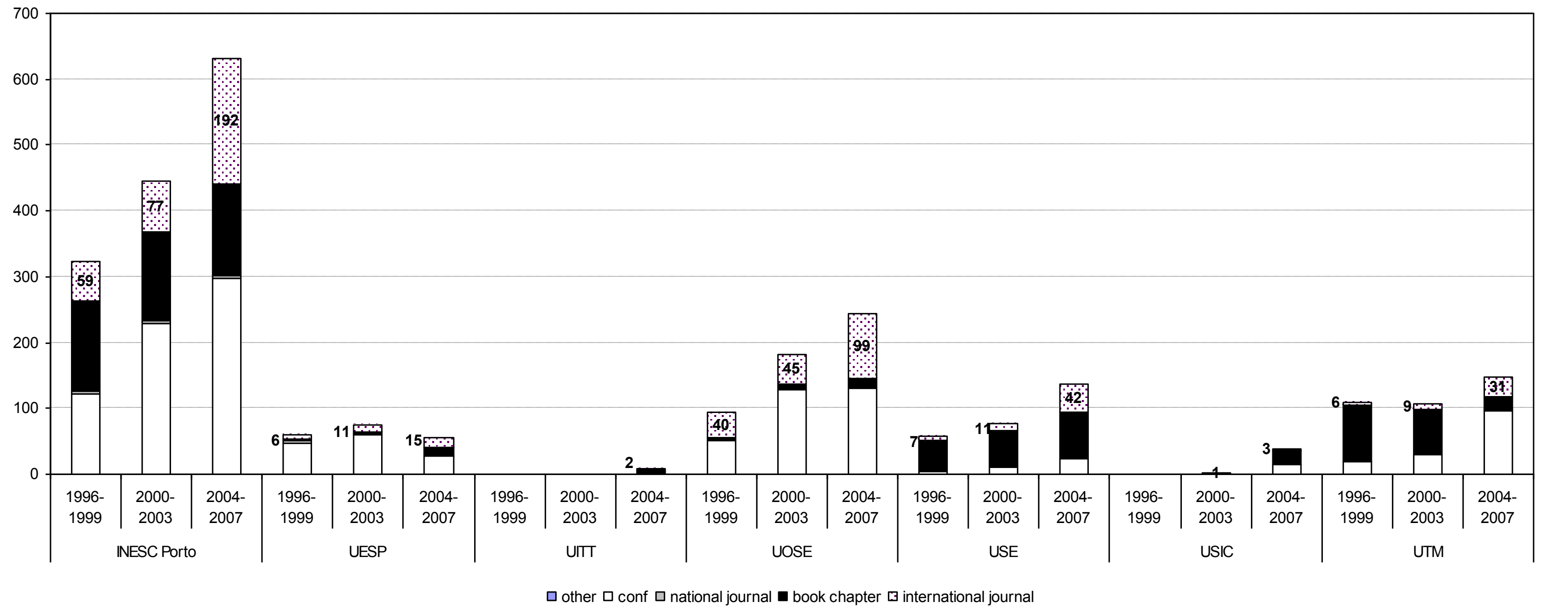


Figure 3: Distribution of the scientific output of INESC Porto per four-year periods, and per working unit, in number of papers

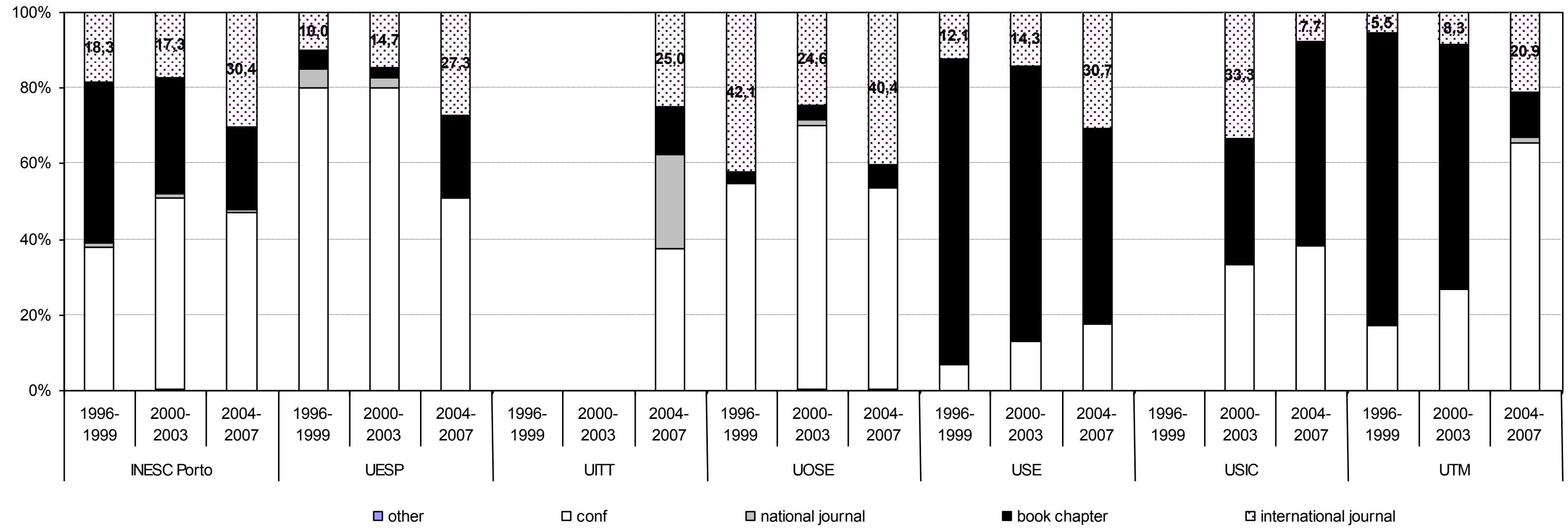


Figure 4: Scientific output's percentage of INESC Porto and its working units by type of publication, per four-year periods

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). This enables us to evaluate to what extent INESC Porto's 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.

4. The geographical scope and evolution of INESC Porto's scientific production. Mapping its influence through co-authorship and citation networks

4.1. Scientific co-authorships networks

When analysing INESC Porto's dataset of papers accessed, we may picture its scientific production in terms of international co-authorship behaviour, as summarised in Table 5. From the 826 papers produced by INESC Porto's scientific collaborators, the proportion of internationally co-authored papers published in international learned journals represents 35.2%, which means that the majority of papers published in this type of publication (64.8%) are of Portuguese origin. Nonetheless, publications in international journals account for 50.2% of the total output of INESC Porto in terms of foreign co-authored papers.

Table 5: Foreign co-authored papers of INESC Porto

	Proportion (%) of foreign co-authored papers in each type of paper	Distribution (%) of foreign co-authored papers by type
Conferences	19.7	21.0
National Journal	0.0	0.0
Book Chapter / Conference Proceedings	21.2	28.8
International Journal	35.2	50.2

By considering Figure 5, one can understand how the international collaboration in terms of publication has been increasing since 1996 at INESC Porto. In the last period of analysis, namely between 2004 and 2007, 27.4% of all scientific output produced had at least one foreign co-author, when in the first period of analysis (1996-1999) it represented just 21%. This positive outlook contrasts, however, with the reality of each working unit, such as UOSE, where the presence of an international co-author is stronger overall (32.1%), but which decreased in the four-year period, from 1996-1999 with an amount of 41.7% of foreign co-authorships, and dropped to an amount of just 26.3% by 2004-2007. USE, in turn, stays around the global average of the period, at 26.8% of papers with foreign co-authorships, while UTM has a much more impressive performance, with the share of papers with international co-authors jumping from 11.5%, in the period of 1996-1999, to 38% in the more recent period of 2004-2007.

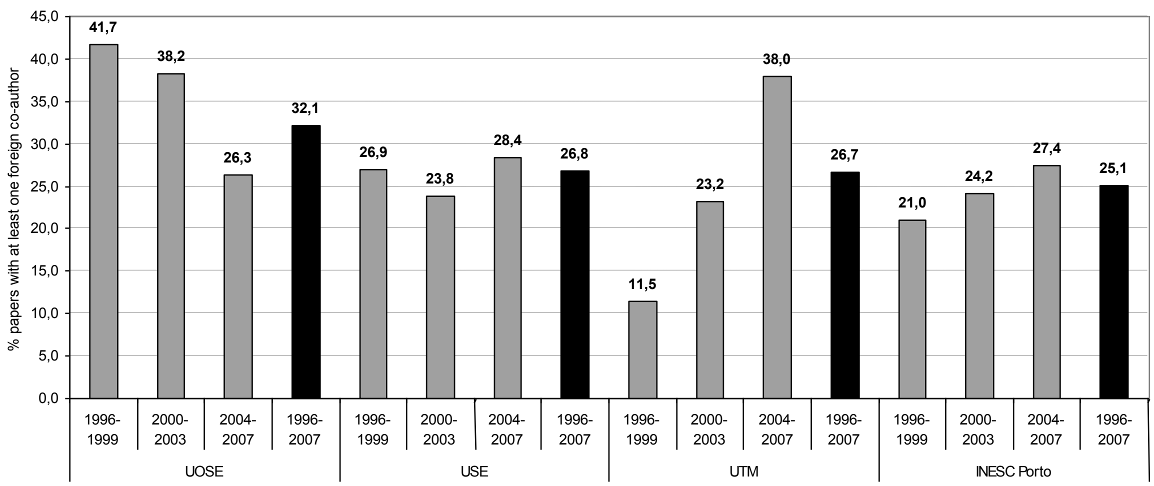


Figure 5: Percentage of papers with at least one foreign author

If we look at the evolution of the scientific publication of INESC Porto by type of publication, as shown in Figure 6, it is visible how the pattern is very different between its working units. Publications presented at conferences are the gross of the final output for UOSE and UTM, while USE has a big share of book chapters and conference proceedings, while in terms of publications in international academic journals, the figures are more positive for UOSE and USE, representing 32.8% and 22.9% of the overall output for the period 1996-2007 respectively, while UTM has a more timid record during the years, becoming more positive after 2004, and reaching a final 1996-2007 average of 12.9%.

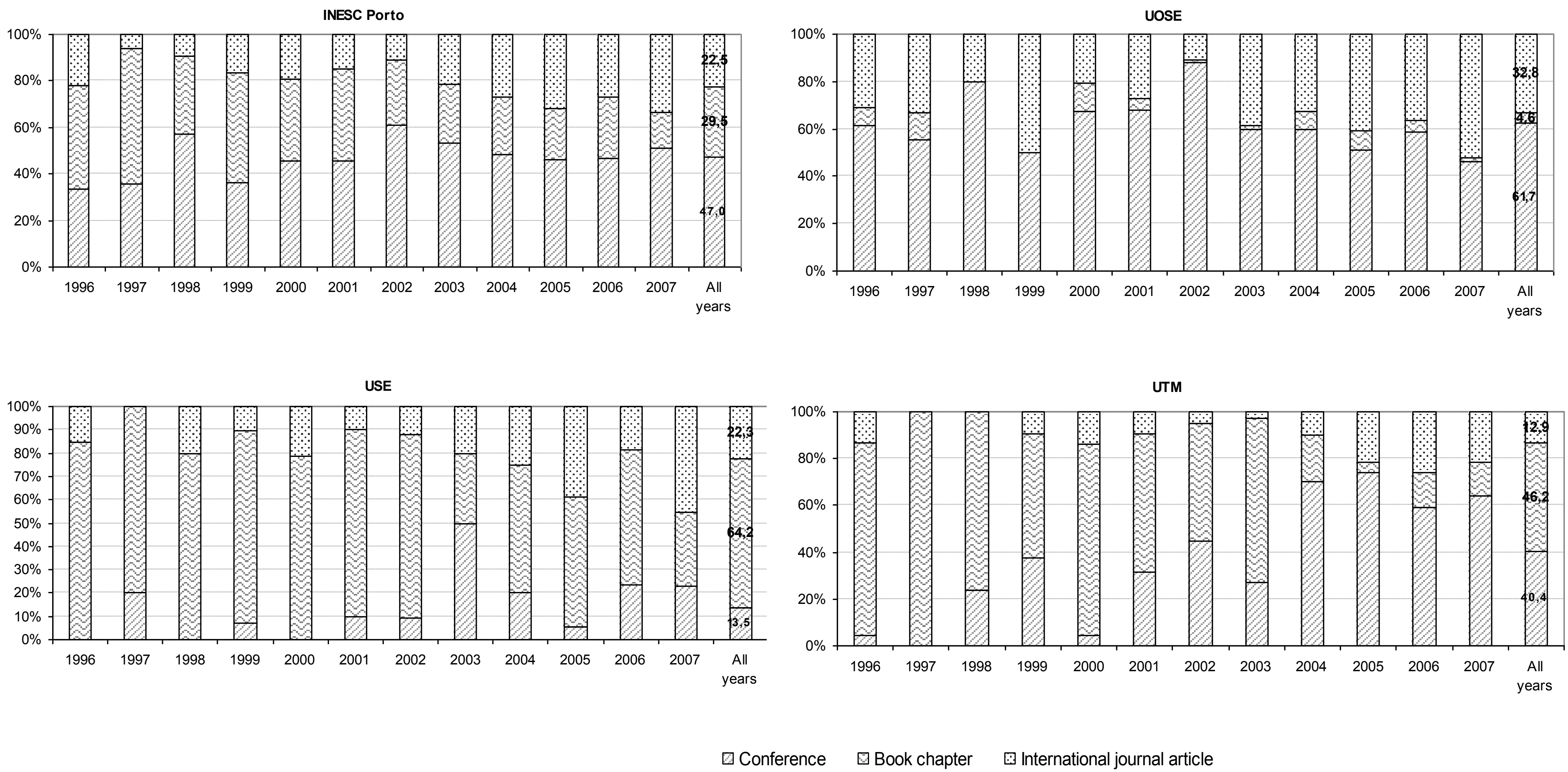


Figure 6: Evolution of scientific output by type of publication in INESC Porto

We may conclude, therefore, that INESC Porto has been improving its success in publication when accounting more and more for an growing share in scientific output that gets to be published in international journals, namely from 2003 onwards (*cf.*, Figure 6). Internationalisation of the scientific production of INESC Porto is, consequently, a reality, to which all working units contribute, but with greater relevance, it should be highlighted, in UOSE and USE.

When analysing the presence of the foreign countries that contribute to the scientific achievements of INESC Porto (*cf.*, Table 6), it becomes evident that the UK (14.1%), Spain (11.4%), the USA (11.1%), Brazil (8.4%) and Germany (7.2%) are the core partners of INESC Porto's international network (*cf.*, Table 6, Figure 7). As a matter of fact, the existence of straight connections, as far as scientific production is concerned, with this group of countries, leads us to recall Bush and Hattery (1956), Price (1963), Stichweh (1996), Zitt *et al.* (2000), and even Wagner and Leydesdorff (2005), authors that explained international scientific interplay because of geographic proximity and historical determinants, reasons that seem to be highly adequate in the present case.

Nevertheless, the picture is slightly different when we focus on the most prolific working units. Recovering the work by Archambault and Gagné (2004), which highlights the fact that evaluating the output intensity, that is to say, by counting the number of articles published by researchers, departments, and research institutions, this may indicate the degree of specialisation of a specific field and assess its research performance. Consequently, we decided to conduct a refinement of our analysis, by focusing on the scientific output of UOSE, USE and UTM. As far as the optoelectronics unit (UOSE) is concerned, 72.3% of its internationally co-authored papers are jointly produced with (co)authored affiliates in five core countries, namely the USA (23.4%), the UK (14.9%), Brazil (12.8%), Spain (12.8%) and Russia (8.5%). USE also develops 69.6% of its scientific R&D output in a hub formed by five countries, to be exact, Spain (19%), Brazil (15.2%), Greece (15.2%), Venezuela (11.4%) and Macau (8.9%). UTM, on the other hand, does not have such a high concentration in its five main partner countries, since these represent 55.7% of its overall production in international co-authorship. Regarding the telecommunications and multimedia unit, the UK represents 18.1% of co-authorship, while Germany represents 13.4%, which are then followed by France (8.7%), Italy (8.1%) and Austria (7.4%).

We may identify, as a result, some international scientific clusters with which INESC Porto directly interacts, one formed in Europe, where the UK, Spain, Germany, Russia, France and Finland are the most important players at stake, and another one in America, where the USA is of high relevance, following, in a significant degree of relevance, Brazil and Venezuela, in South America (*cf.*, Figure 7).

Table 6: The most representative countries contributing to INESC Porto's scientific production

	UOSE	USE	UTM	INESC Porto
Austria			[5%; 9%]	< 5%
Belgium	< 5%			
Bosnia Herzegovina		[5%; 9%]		
Brazil	>=10%	>=10%	< 5%	[5%; 9%]
Canada	< 5%			
Finland	[5%; 9%]		[5%; 9%]	[5%; 9%]
France	[5%; 9%]	[5%; 9%]	[5%; 9%]	[5%; 9%]
Germany			>=10%	[5%; 9%]
Greece		>=10%		< 5%
Ireland		< 5%		
Italy			[5%; 9%]	< 5%
Macau		[5%; 9%]		
Russia	[5%; 9%]			
Spain	>=10%	>=10%	[5%; 9%]	>=10%
Switzerland	[5%; 9%]			
The Netherlands			< 5%	
UK	>=10%	[5%; 9%]	>=10%	>=10%
USA	>=10%	>=10%	[5%; 9%]	>=10%
Venezuela		>=10%		

Legend:

- >=10%
- [5%; 9%]
- < 5%

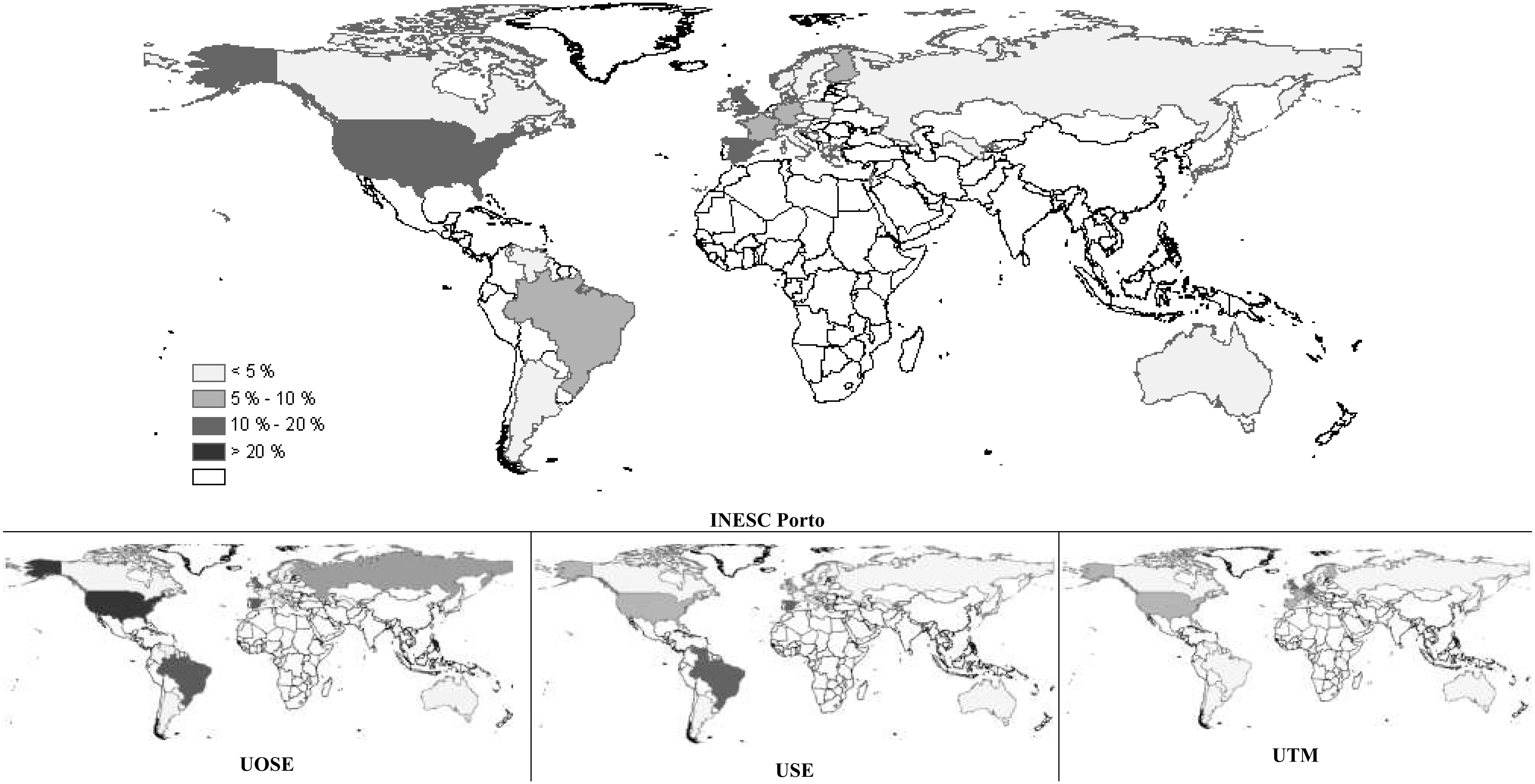


Figure 7: Country's affiliation of foreign co-authors (in % of total), 1996-2007

Source: Authors' computations – see Tables A1-A4 in Appendix

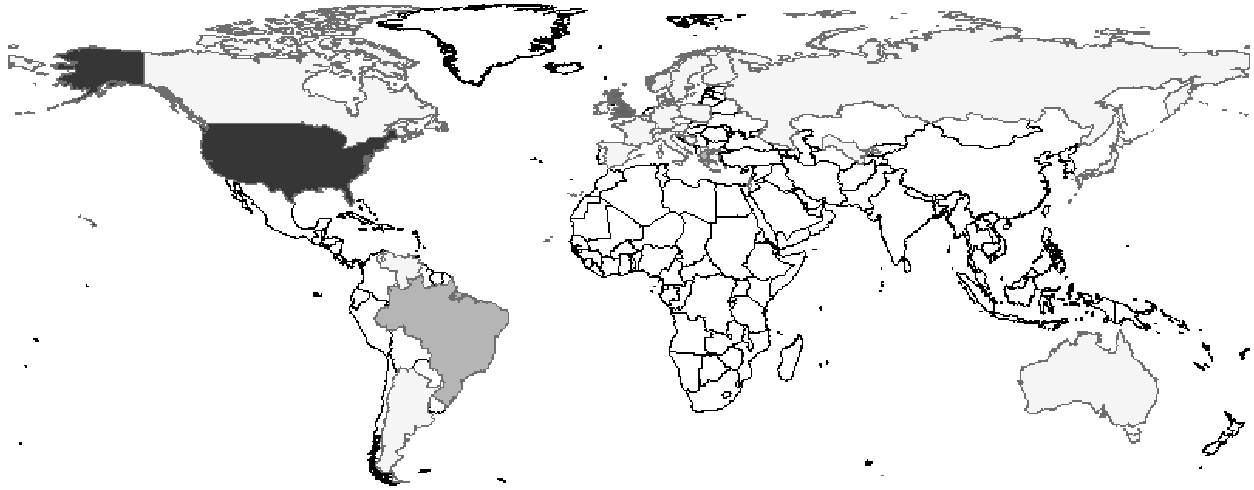
When analysing these foreign linkages through the time frame of 1996 to 2007 in blocks of four-year periods, this dynamic enrichment of the analysis shows us how there are countries with which INESC Porto has been losing its connection, others that are entering its sphere of scientific collaboration, and even the specific case of Brazil, which has maintained a stable collaborative pattern over the years (*cf.*, Figure 8). As a matter of fact, Brazil is not just a core player, as far as the overall scientific production of INESC Porto is concerned, but it is also a stable partner within its international scientific relationships, keeping a net contribution to co-authorship of *ca.* 5% to 10%, between 1996 and 2007 (*cf.*, Figure 8), the reason for which may be much anchored on previous works that have studied networks' dynamics (*e.g.*, Watts, 2001; Jackson and Watts, 2002; Young, 1993; Kandori *et al.*, 1993).

As far as the countries that are losing presence in INESC Porto's international network are concerned, we may highlight the cases of Greece (which drops from a share of participation in co-authorship of about 7%, in the period 1996-1999, down to a contribution of 4% in the period 2004-2007), the UK (which progressively loses it share, coming from 18.6% in the first period of years, and reaching 2004-2007 with a collaboration of exactly 12.9%), and the USA (which falls drastically from the first position in terms of co-authorship in the first period of analysis, when its share was 23.3%, and reaches 2004-2007 accounting of 9.5%). Macau, specifically, had a strong share of collaborative presence during the first period of analysis, amounting to 16.3%, but vanishes from record in the following periods.

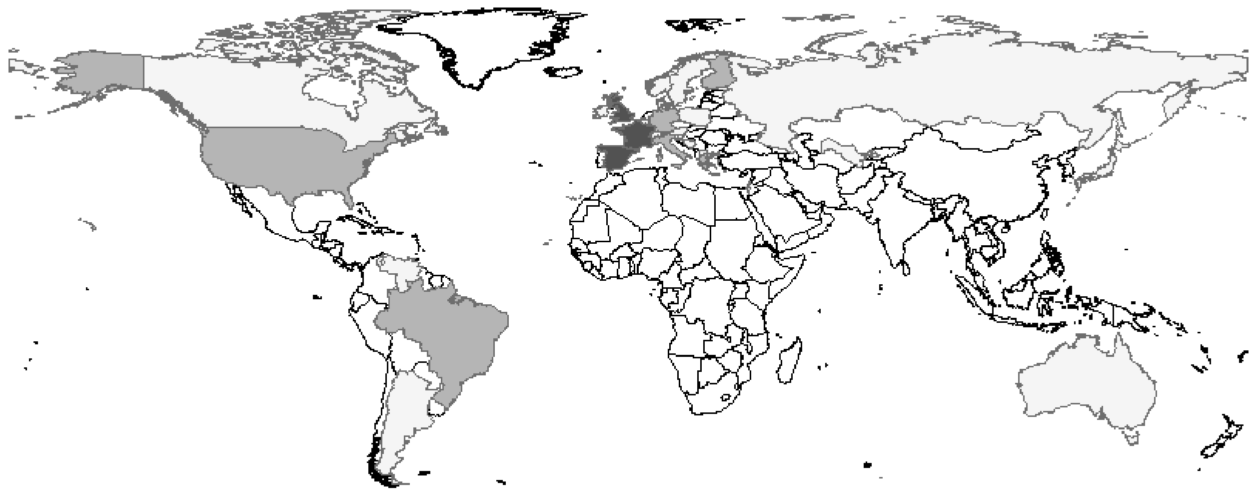
A much more positive outlook is delivered by Germany, Finland and Spain (*cf.*, Figure 8). Germany, specifically, has been moving positively inside INESC Porto's international network, coming from a share in co-authorship participation of 2.3%, in the period 1996-1999, to steadily reach a collaborative rate of 9% at the end of the period under analysis. Also positive is the case of Finland, which enters the network in the period of 2000-2003, and reaches 2004-2007 with a share of 6% for the scientific collaboration of INESC Porto.

The case of Spain is also of relevance, since it comes from a participation rate of 2.3% in the first period, and becomes a partner with stronger collaborative behaviour in the last two periods of analysis, (though the figure was about 16.7% in 2000-2003, and declined to 10.9% , in 2004-2007).

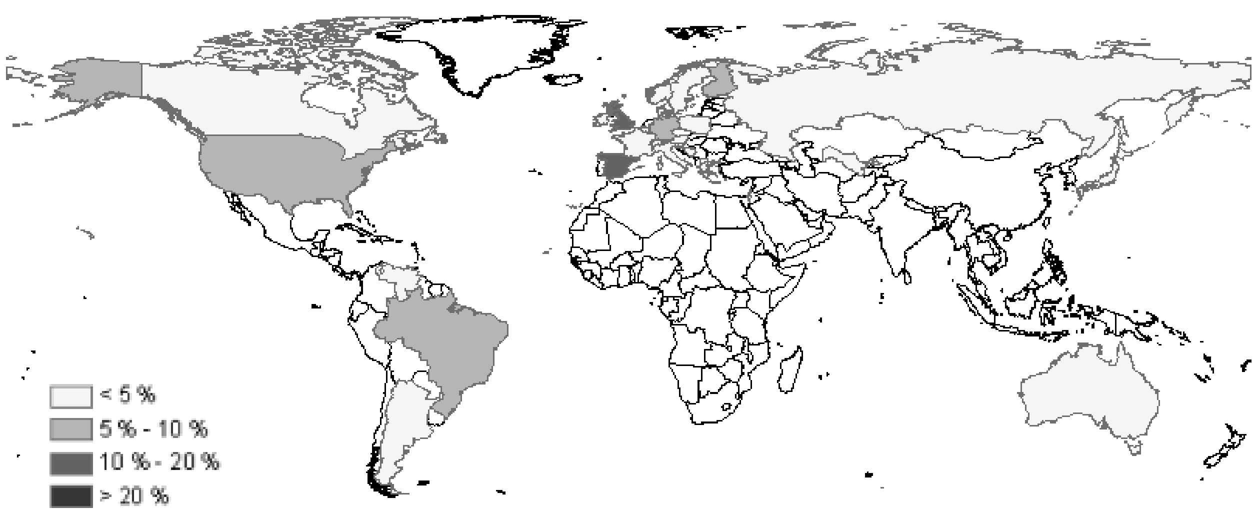
INESC Porto



1996-1999



2000-2003



2004-2007

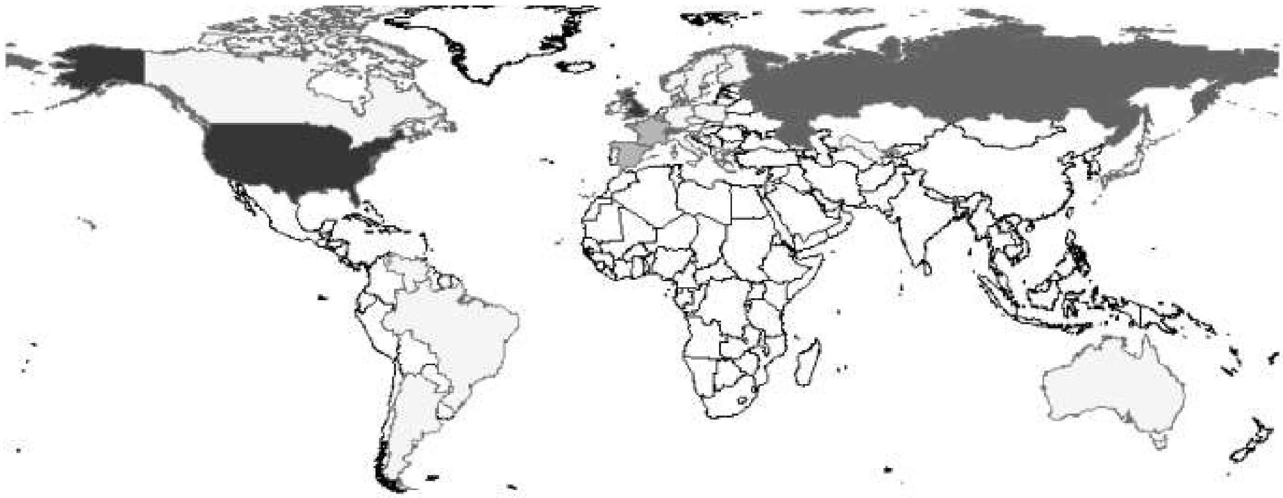
Figure 8: Country's affiliation of foreign co-authors (in % of total), for INESC Porto, per four-year periods
Source: Authors' computations - see Table A1 in Appendix

France is a case of a low contributor to the scientific production of INESC Porto, in the period of 1996-1999, but its input in this international network becomes stronger in the second period of analysis, reaching a share of 11.1% (the third place in the ranking of co-authorship for this period), and then declines in the last period, between 2003-2007, when its share falls back to a participation that amounts to 4% (*cf.*, Figure 8). With less relevance, but announcing a growing trend, are the cases of Austria and Canada, which only enter the network in the second period of analysis, and even Venezuela, which arrives at the network in the last period (*cf.*, Figure 8). These three countries present a participation in the co-authorship framework that almost reaches a 5% share, namely, Austria presents 4.5% in the last period, Canada gets 4.5%, and Venezuela also reaches 4.5% in 2004-2007.

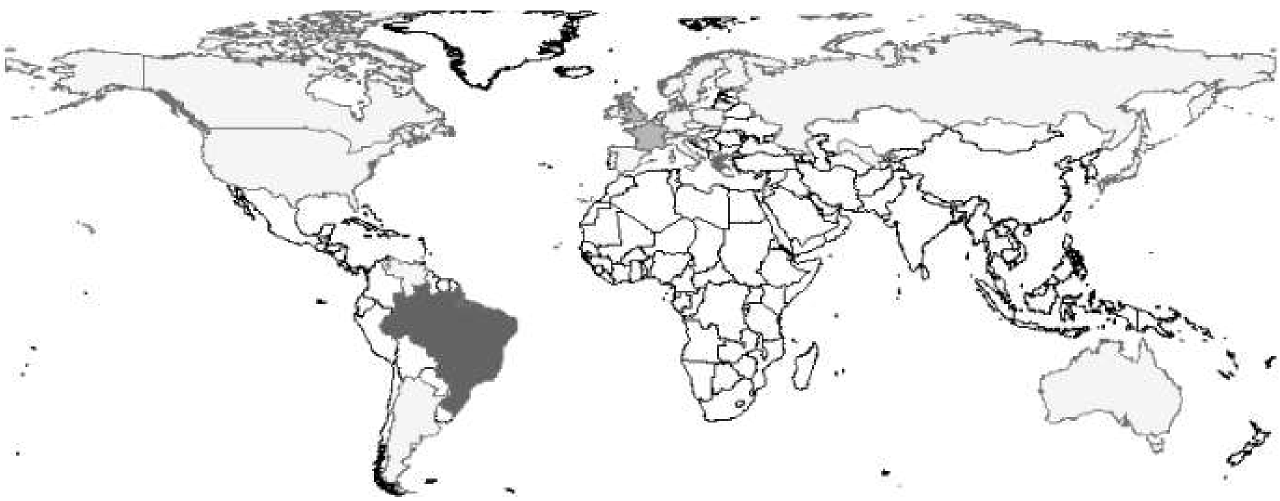
When considering the international co-authorship behaviour of the main scientific output deliverers of INESC Porto, namely UOSE, USE and UTM, it is evident how they all have specific evolution patterns of their own international network, strongly differentiated from the one identified as that of INESC Porto as a whole (*cf.*, Figures 9-11).

Starting with UOSE, the USA is the most important partner country in its specific scientific network, though stronger in proportion in the first period (accounting then for about 36.8%), its co-authorships' share has declined to 15.6%, between 2000-2003, and recovered afterwards to 23.3%, in the last period (*cf.*, Figure 9). Regarding Brazil, the second largest contributor to INESC Porto's co-authorship network, despite entering the network only in 2000-2003, its net input in this period reached a total of 12.5%, and this figure improved in the latest period when it summed 18.6%. At a lower level of relevance, but still having a positive outlook, is the case of Canada, which enters the network in the period of 2000-2003, accounting for 3.1% of the total international co-authorship output, but increasing this proportion in the last period, reaching 7%. As a counter-tendency, we find countries like the UK, Switzerland, and Finland, which have decreased their participation in the international co-authorship network of UOSE. The UK, in particular, had the largest fall, from 26.3%, in the first period, to 11.6% in the latest. Switzerland accounted for 10.5% of co-authorship share in the first period of analysis, disappears from record in the second period, and then reappears in UOSE international network, in 2004-2007, with a participation of 7%. Finland has also registered a strong decline in co-authorship, from 15.6%, in 2000-2003, to 2.3%, in 2004-2007.

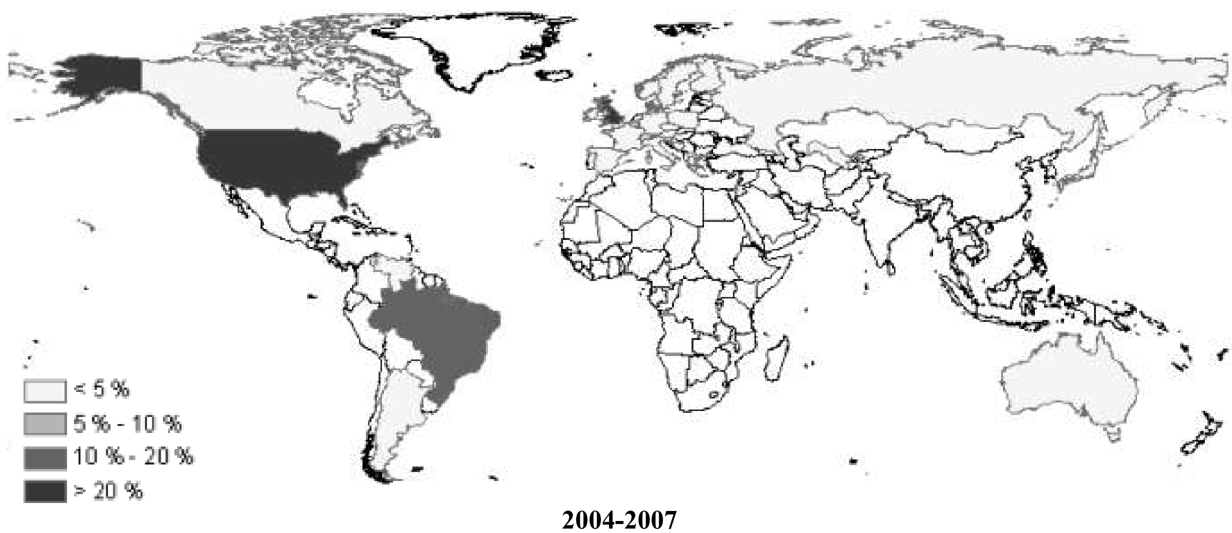
UOSE



1996-1999



2000-2003



2004-2007

Figure 9: Country's affiliation of foreign co-authors (in % of total), for UOSE, per four-year periods

Source: Authors' computations - see Table A2 in Appendix

The collaborative rate of France and Russia must also be emphasised; they present steady co-authorship participation, the former at the average level of 5% along the time frame of analysis, and the latter reaching the average rate of almost 9% for the three periods. A special note still has to be made in the case of Spain, which begins its participation in co-authorships with UOSE at a level of 5.3%, climbs afterwards to 28.1%, between 2000 and 2003, and then falls back to 4.7% in the latest period (*cf.*, Figure 9).

Regarding USE, this dynamic analysis also shows us a particular pattern in terms of co-authorships (*cf.*, Figure 10). Concerning the partners that are losing collaborative share, one must highlight countries such as Greece, Bosnia and Herzegovina, and the UK. Specifically, Greece had strong participation in the two first periods, accounting then for 13.3% and 22.7%, respectively, but fell in the last period down to 9.8%. Bosnia and Herzegovina entered USE international scientific network during the period of 2000-2003, with a share of 13.6% (ranking third in the international partners of USE), but its contribution to USE scientific production fell in the last four-year period to an amount of 4.9%.

Finally, the UK had a share of scientific collaboration of 6.7% and 9.1% in the first two periods, but this share shrank to 4.9%. The cases of France and Macau are different, but also vey important to highlight, namely because these countries have disappeared from USE's international collaborative network. France vanishes from record in the last four-year period of analysis, after being a partner country at a 5% to 10% level. Brazil is an important country in USE's network, having a share in co-authorship of 20% in the first period, dropping in the second period to 4.5%, but recovering again in the last four-year period to 19.5%.

Countries that have gradually been gaining weight, as far as USE's international relationships are concerned, are the USA and Spain. The USA entered the network in the second period of analysis, with 4.5%, and gets to 2004-2007 with 7.3%, while Spain also accounted for 18.2% of co-authorships in the second period, and in 2004-2007 this figure was already at 26.8%.

USE

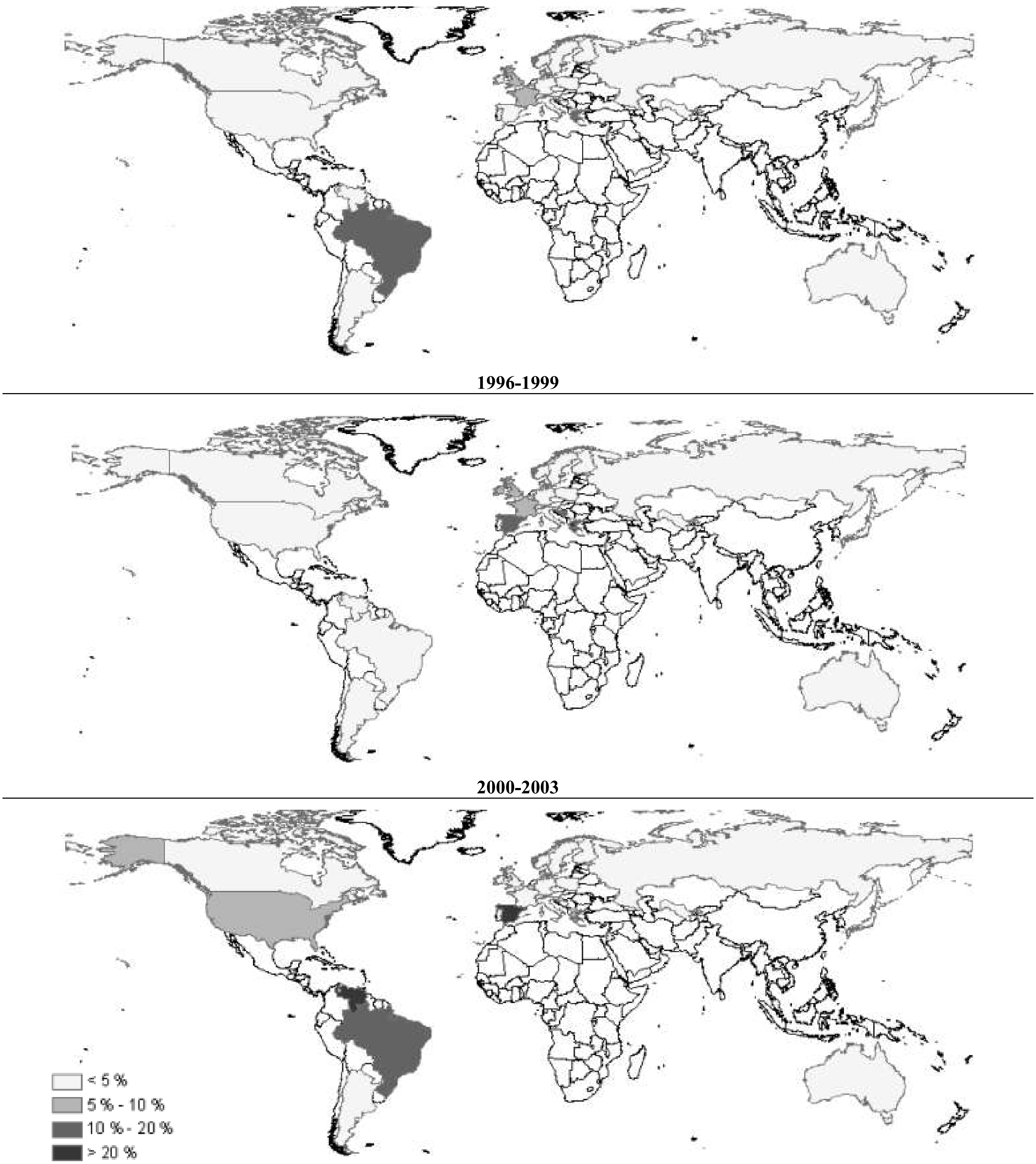
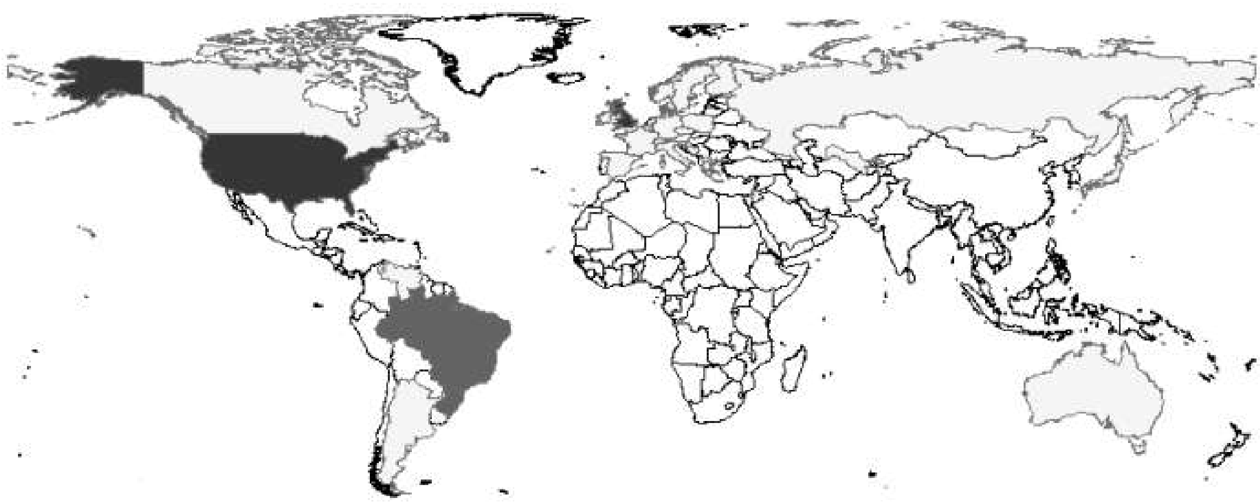


Figure 10: Country's affiliation of foreign co-authors (in % of total), for USE, per four-year periods
Source: Authors' computations - see Table A3 in Appendix

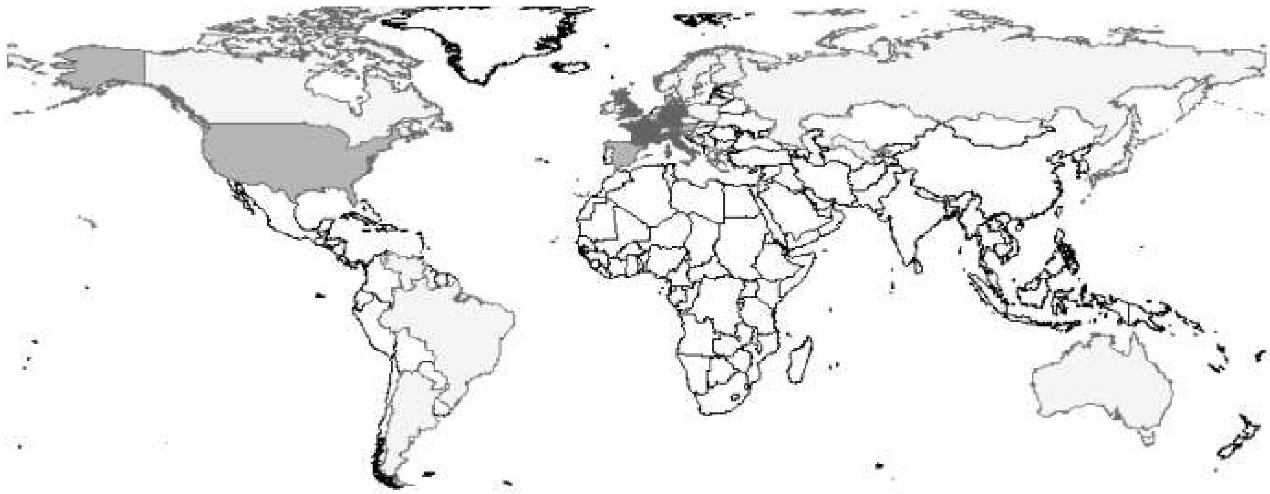
As far as the telecommunications and multimedia unit is concerned (*cf.*, Figure 11), we must emphasise the growth in terms of scientific contribution of Austria, which enters the network of UTM in 2000-2003 with 5.7%, and accounts in the last period for 8.4% of co-authorships, and the case of Germany, which also enters the international network in the second period, representing 11.4%, but grows to 15% between 2004-2007.

With not such a good performance is the case of Brazil, for instance, strong in the first period of analysis, accounting then for a percentage of 14.3%, but declining drastically in the following periods. The same is true of Denmark, which also had a share of contribution of 14.3% between 1996-1999, but finished the time frame of analysis with just 2.8%. In the case of France, it had strong collaborative behaviour in the second four-year period, with 20% of co-authorships, but then declined in the last period to 5.6%. Italy also represented 20% of co-authorships between 2000-2003, but ended the time frame of study accounting for just 4.7%. Much worse are the cases of the UK and the USA, gradually decreasing their share of R&D collaboration with UTM over the years. The UK represented 28.6 % of international co-authorships for UTM between 1996-1999, and then declined in the following period to 20%, ending with an average figure of 16.8%. The USA had a stronger contribution in the first period, representing 42.9% of international co-authorships, but then fell drastically to 5.7% and 3.7% in the subsequent periods. Just a brief note also for the case of Spain, which entered UTM's international scientific network in the second four-year period, with a share of 5.7%, maintaining it around 5.6% in the last period, and finally Finland, which only becomes a strong international partner in the last four-year period, representing 10.3% of international co-authorships.

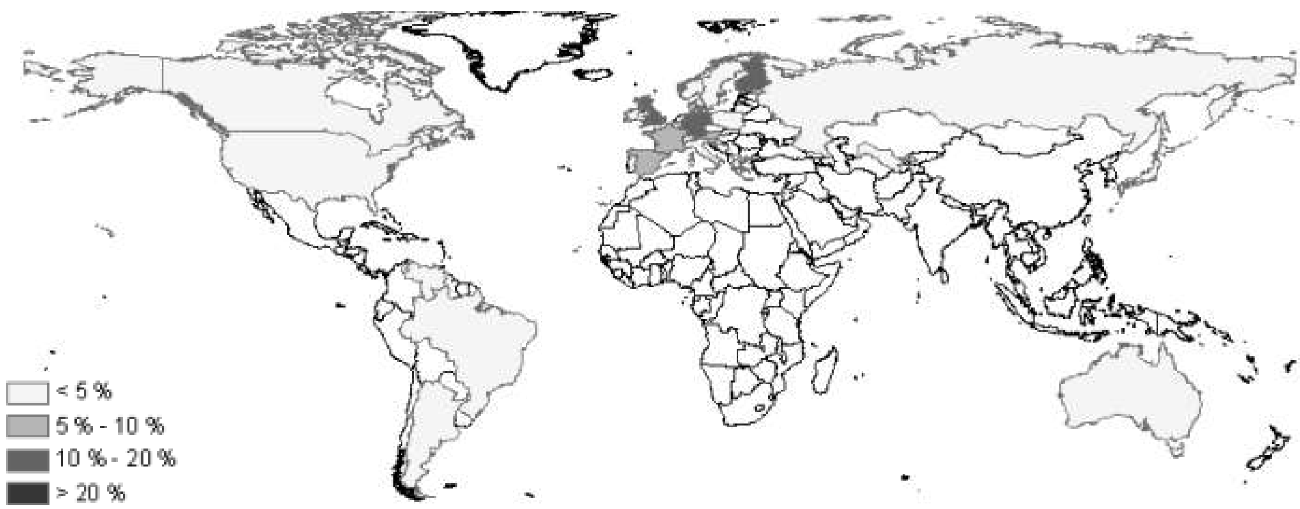
UTM



1996-1999



2000-2003



2004-2007

Figure 11: Country's affiliation of foreign co-authors (in % of total), for UTM, per four-year periods
Source: Authors' computations - see Table A4 in Appendix

4.2. The citation networks

By analysing citation data it is possible to evaluate the degree of diffusion of the knowledge produced by INESC Porto and recognise the expansion of its international scientific influence network by also comparing it to each international citation network of its most prolific expertise areas. As a matter of fact, when looking at Figure 12, it becomes clear how INESC Porto's network is very different from those specific to each area of expertise of its most productive units. About 32.6% of INESC Porto's authors overall citations come from authors affiliated in Portuguese R&D institutions, including here also self-citations, within the time frame period of analysis.

This means that the majority of citations come from abroad, which reveals, at least, a recognition of INESC Porto's scientific production from its international peer communities. Obviously, at this point, and taking into consideration the information at our disposal, we cannot distinguish between the relevant or irrelevant citations, positive or negative ones, as suggested above, in Table 2. Such information would certainly better our analysis and contribute to a more exact inference over the importance of INESC Porto's scientific output for the international scientific community. Nevertheless, our review of the data concerning the affiliations of authors citing the scientific work of INESC Porto is instructive, to say the least, and revealing of the diffusion of its scientific knowledge.

Citations reveal, therefore, that authors citing INESC Porto output are affiliated in a total of 51 foreign countries, as distinctive as Argentina, Australia, Bulgaria, Colombia, Egypt, India, Iran, Israel, Malaysia, New Zealand, the People's Republic of China, Saudi Arabia, South Africa, Thailand, Tunisia, Uruguay, and Vietnam, to name just a few.

To be exact, the largest number of foreign authors citing INESC Porto are affiliated in the People's Republic of China, which have a share of 12.8% of the total. China is followed by the UK, whose authors affiliated in its institutions account for 5.6% of the total authors citing INESC Porto's scientific output. In the third place of foreign citing countries is the USA, with 5.1%. Then Spain follows, with a share of 3.8%, Canada amounts to 3.5% of citations, and Germany represents 3.4%. Italy has a share of 2.8%, South Korea comes next with 2.6%, and Switzerland has a percentage of 2.5%. We conclude for this on the wide diffusion of the knowledge produced by INESC Porto, and its influence in the scientific work developed in the five continents, with a higher emphasis on the knowledge hubs located in South-east Asia, North America and Europe. But looking carefully at Figure 12, it also shows us the great difference between the knowledge-diffusion network of each R&D working unit of INESC Porto. UOSE, for instance, has, similarly to INESC Porto as a whole, 34.3% of its citations concentrated in Portugal, with the large majority still coming from abroad. More specifically, 13.5% of the citing authors are affiliated in organisations from the People's Republic of China, which leads by large margin, followed by the UK and the USA, whose authors' affiliations account for 5.8% and 4.2%, respectively. Spain comes next, with 3.8% of the total citations, Canada has 3.5% and Germany 3.1%.

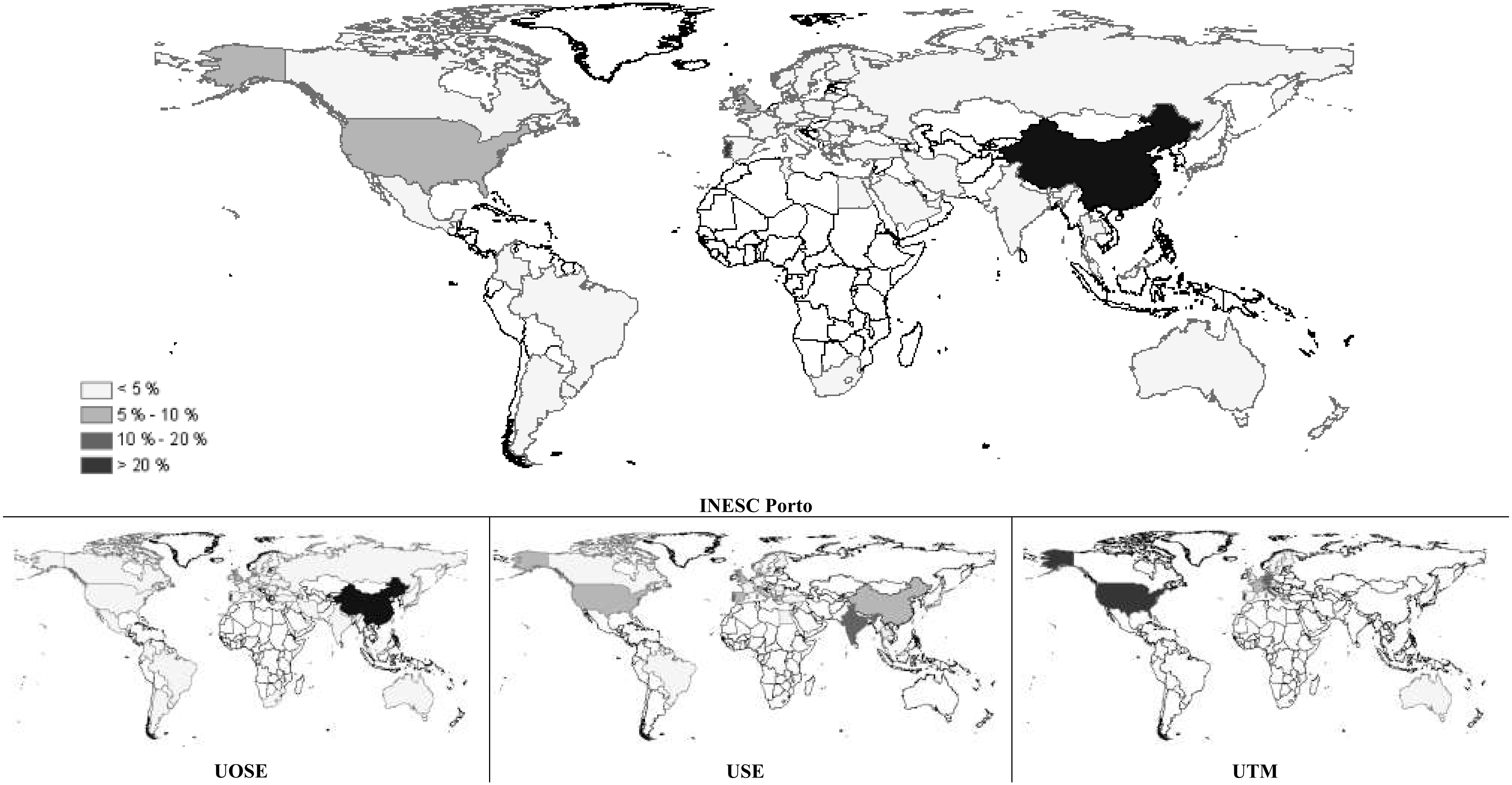


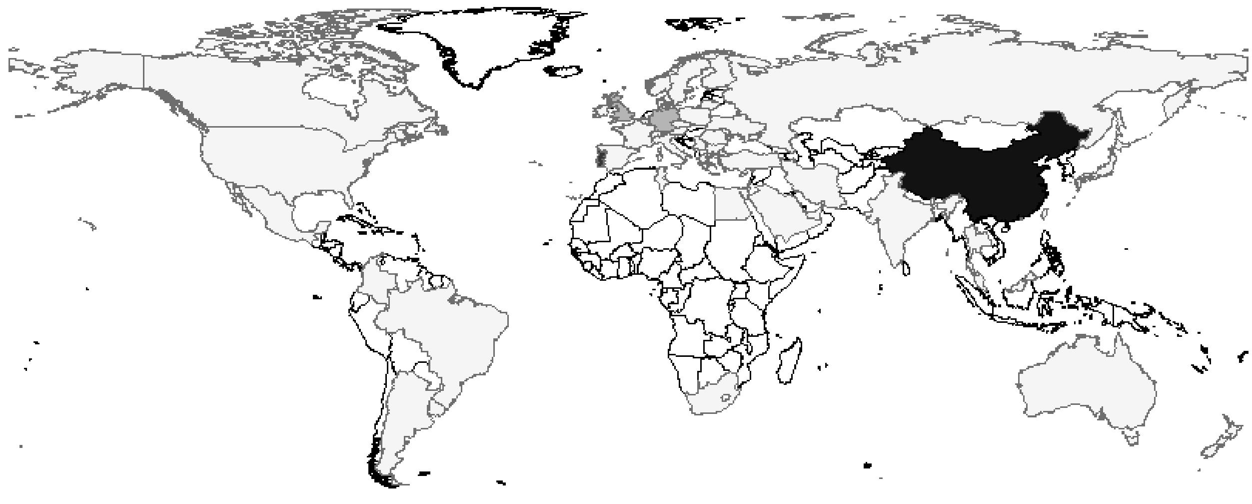
Figure 12: Country's affiliation of authors citing INESC Porto's scientific production (in % of total), 1996-2007
Source: Authors' computations - see Tables A5-A8 in Appendix

USE is the only case in which Portugal is not in the first place citing its scientific output, which is India instead, accounting for 15.3% of the overall citations, while the Portuguese affiliated authors citing its works account for 10.6%. Spain has an average of 8.5%, as well as China, while Greece is also strongly influenced by USE's knowledge, accounting for 8% of the total citations. The UK has about 6.1% of USE's citations, and the USA comes next, with 5.7%. For UTM, Portuguese affiliated authors account for 28.6% of its total citations, and the USA comes in second place, with 21.1%. The ranking is completed with the significant contribution of citations coming from Germany (12.9%), Italy (10.4%), and France.

The previous static analysis produced by looking at the data covering the time frame 1996-2007 can now be complemented by a dynamic one that considers each four-year period within that time interval, in order to visualise how the network of international influence of INESC Porto has evolved, as well as its areas of expertise. Starting with the broad impact network of INESC Porto (*cf.*, Figure 13), and already bearing in mind that around 32.6%, as stated previously, are citations that are originated from Portuguese affiliated authors, we realise the huge importance of the People's Republic of China as the most important international receiver of INESC Porto's scientific contributions. During the time period 1996-1999, it already accounted for 11.7% of total citations, improving in the following four-year period to 19.7%, but decreasing in the latest period, to an amount of 7.9%.

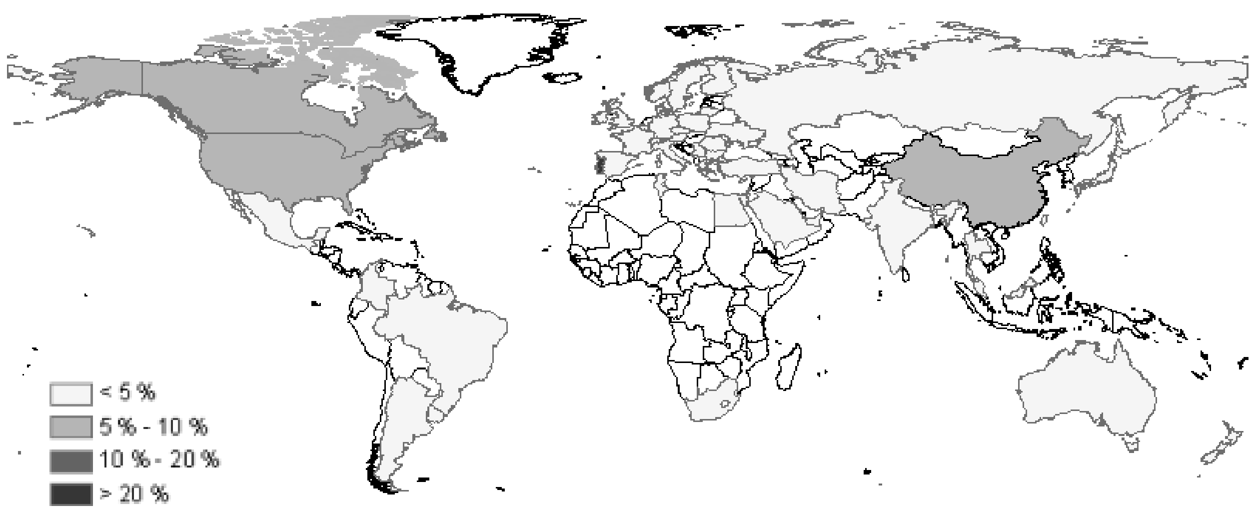
Also having a negative outlook, as far as citations are concerned, are countries like the UK, Russia and Switzerland. In the particular case of UK, it has steadily decreased its citations of INESC Porto's scientific output from 7.2%, in the first period, to reach only 3.4% in the latest. Russia drops from a share of citations of 4.4% in the first period, to reach only 0.4% in 2004-2007, while Switzerland had a percentage of 3.6% in the first time interval, but ends the latest with 1.5%. With a much fluctuating performance, concerning the citations of the scientific production of INESC Porto, are countries like the USA, Spain, South Korea, Germany, and France. As far as the USA is concerned, it starts the first period of analysis with a citation share of 4.4%, which then declines to 2.3%, and recovers in the latest time interval to 8.2%. Spain also starts with a citation share that accounts for 4.5%, diminishes to 3.2% in the following period, and recovers slightly in 2004-2007 to 3.7%. Germany gets 5.2% of the total citations within 1996-1999, but falls to 1.2% in the next period, to recover in the latest one to 3.5%. France has similar behaviour, starting with 4.3%, but then citing poorly in the second four-year period, to recover to 2% in 2004-2007. South Korea, on the contrary, starts poorly, with 2.7% of the overall citations of INESC Porto scientific output, but amounts to 3.6% in the second time interval, to fall back to 1.7% in the latest.

INESC Porto



1996-1999

2000-2003



2004-2007

Figure 13: Country's affiliation of authors citing INESC Porto's scientific production (in % of total), per four-year periods

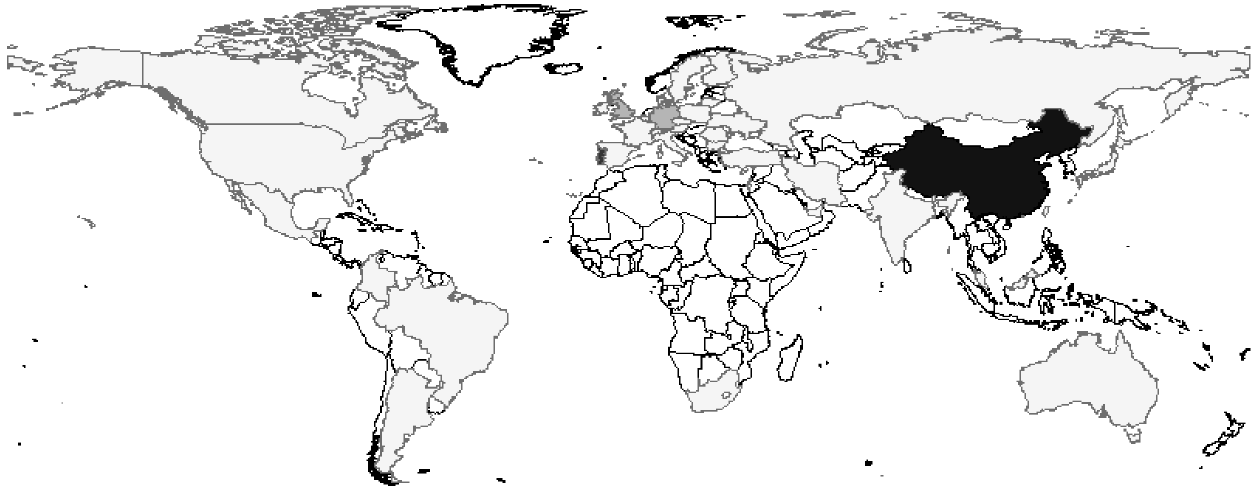
Source: Authors' computations - see Table A5 in Appendix

With a much better performance, as far as foreign citations of INESC Porto scientific production is concerned, are the cases of Italy and Canada, countries that increase their share of international citations. Italy starts with 0.9% in the first four-year period and gets up to 2004-2007 with a share of 4.2%, while Canada has a more promising performance, since it starts with 2.1% and ends by placing itself in fourth place of the overall citations of INESC Porto output, with a share of 5.9%.

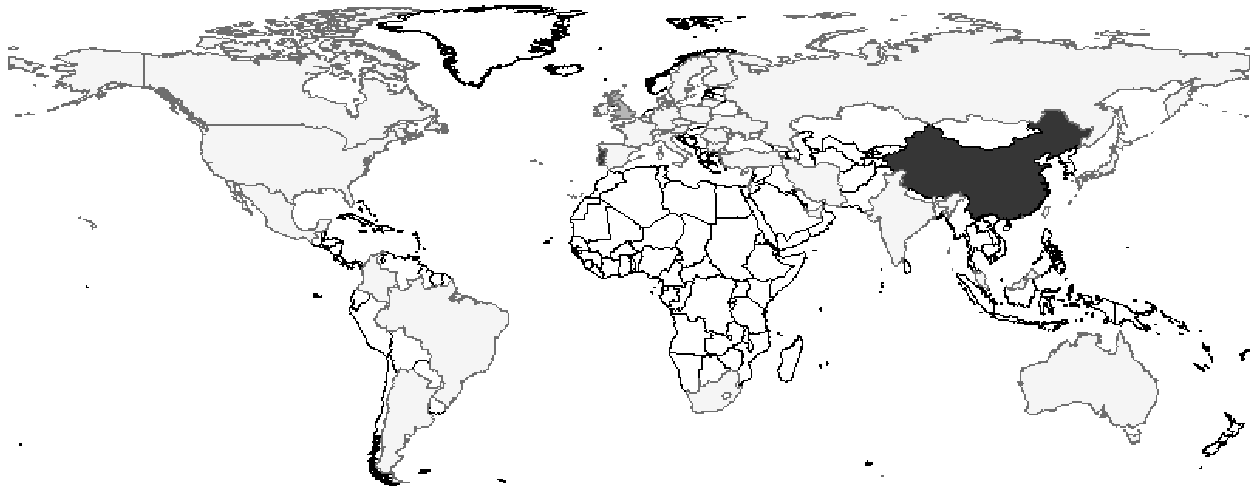
Focusing now on the broad international network of the optoelectronics unit (UOSE), as shown in Figure 14, we can see how it has changed over the years and how it is significantly different from the average picture given by INESC Porto, as presented previously. Countries like the USA, Germany, Australia, Poland and Finland, when taking a closer look, have fluctuated inside the network of citations between 1996 and 2007.

As far as the USA is concerned, it had a share of 4.4% in the first four-year time interval, but it diminished by 2000-2003, recovering in the last period to 6.6%. Germany also had a better share of citations in the first time period, amounting to 5.3%, but then fell in the second period to 1.2%, and recovered slightly to 2.4% in the latest. A similar pattern happens in the case of Australia, which starts with a share of 2.5%, and diminishes to 0.7% in the second four-year period, recovering, nevertheless, to 2.8% in 2004-2007. Evidencing a counter tendency are countries like China and South Korea, which start with shares of 11.9% and 2.8%, respectively, in the time period of 1996-1999, improving in the next period to, respectively, 20.7% and 3.3%, but then falling back to 8.5% and 2.1%, respectively in the latest time interval. With much worse figures are countries like Russia, Spain, Switzerland, and the UK, which have decreased their shares in the total UOSE citations over the years, namely, the UK, which starts by accounting for 6.9% and ends with 3.9%. On the other hand, Canada, for instance, has a more positive presence in the network of influence of UOSE, since it starts 1996-1999 with 2.1% and it arrives at 2004-2007 with a representation in terms of citations of 6%.

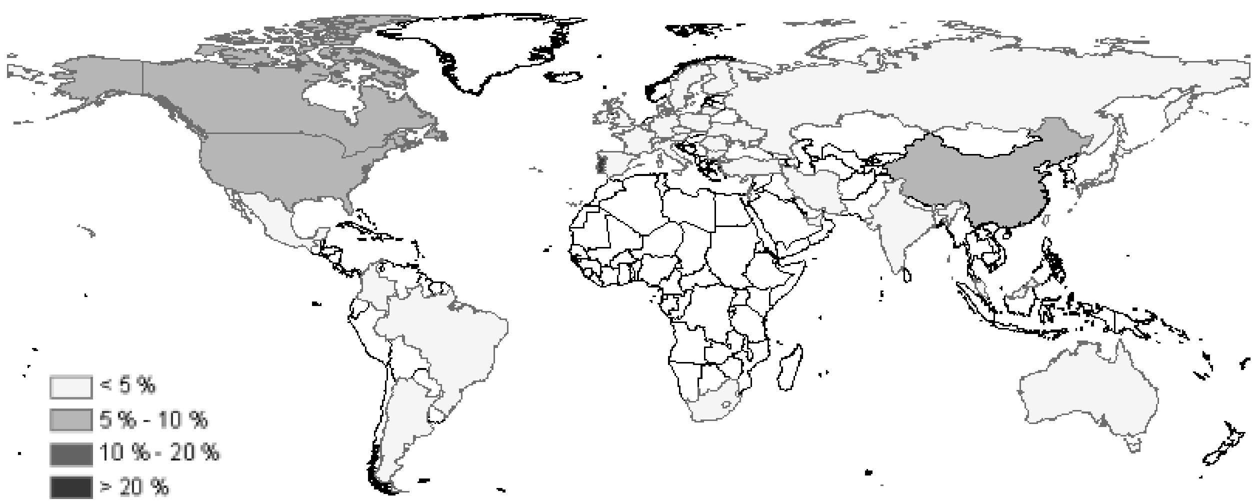
UOSE



1996-1999



2000-2003



2004-2007

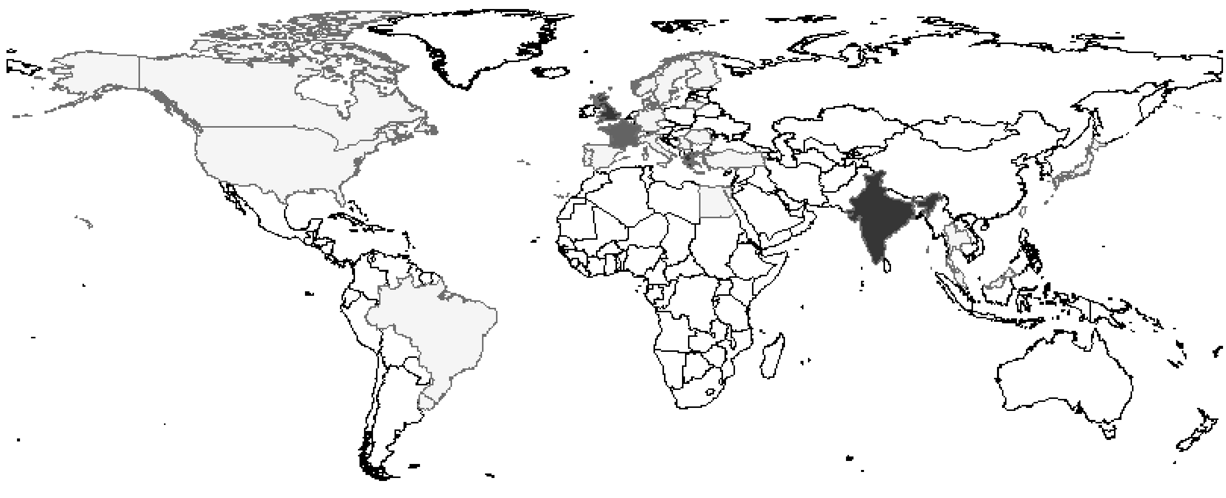
Figure 14: Country's affiliation of authors citing UOSE scientific production (in % of total), per four-year periods

Source: Authors' computations - see Table A6 in Appendix

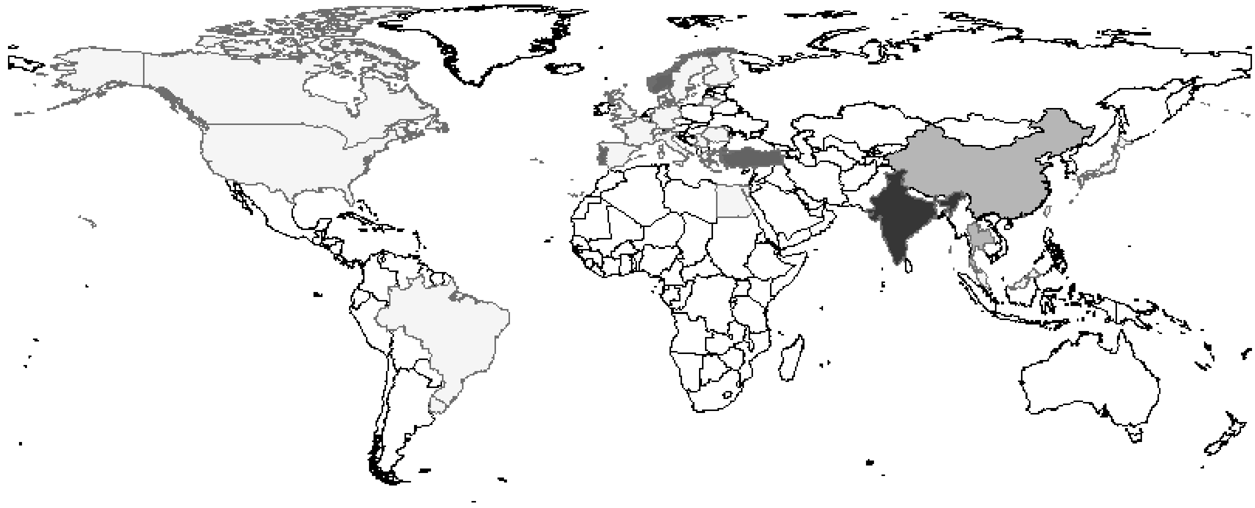
As far as USE is concerned, its international knowledge diffusion is larger than for the other scientific units of INESC Porto, since citations coming from Portuguese affiliated authors account for only 10.6% (*cf.*, Figure 15). Within 28 countries, the negative evolution within its network of countries like the UK, Greece, and France must be highlighted. The UK, as well as Greece, accounted in the first four-year period for a share of 24.3% each, but both decline this representation in citations drastically in the following periods, since the UK shrinks its share to 2.2% and 2.3% in the most recent periods, and Greece produces no citation in 2000-2003, but recovers its share to 6.2% in 2004-2007. France also had a significant share of citations of USE's knowledge production in the first period of analysis, namely of 16.2%, but vanishes from records in terms of citations in the following period, and gets 2.3% in the latest time interval.

Also with a negative fluctuation of citations inside the network of knowledge diffusion of USE are countries like India, Thailand, Turkey, and Norway, since India, for instance, had ranked at the top of citations in the first two periods, with shares of 27% and 29.7%, respectively, but accounts for only 6.9% in the last period of analysis. Thailand, Turkey and Norway only appear within the 2000-2003 time interval with shares of citations of 6.6% for the first country mentioned, and 11% for the other two. Countries that are steadily increasing their citations of USE output are the USA and the People's Republic of China, which enter this network only in the second time period, accounting then for a share of 2.2% and 6.6%, respectively, but reach 2004-2007 with an amount of 8.5% and 11.6%. Entering the network late are countries like Spain and Taiwan, which gave citations to USE's scientific publications in a proportion of 13.9% and 7.7%, respectively, in the time period of 2004-2007.

USE



1996-1999



2000-2003

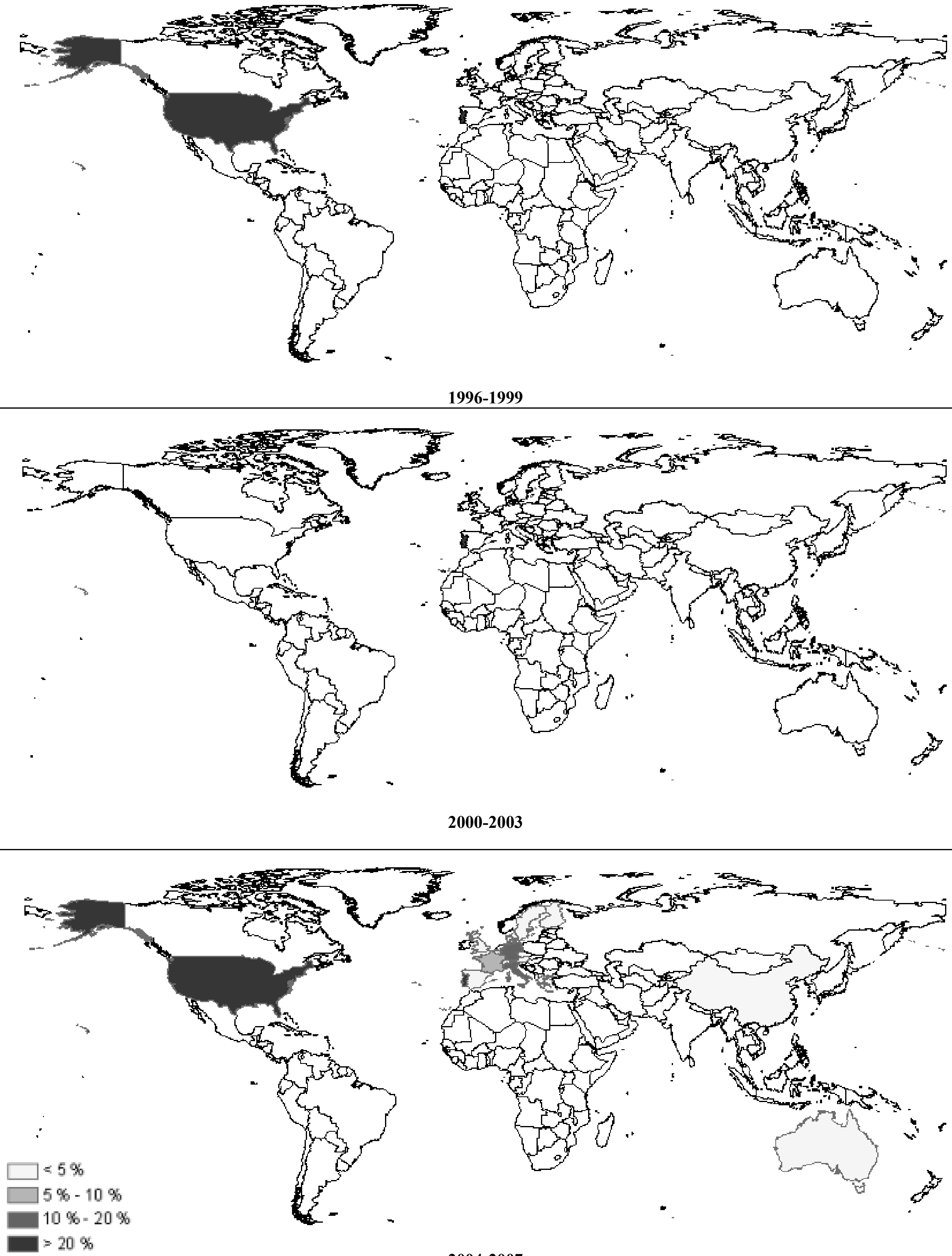
2004-2007

Figure 15: Country's affiliation of authors citing USE scientific production (in % of total), per four-year periods

Source: Authors' computations - see Table A7 in Appendix

Again, the case of UTM, the telecommunications and multimedia unit, is very different, since it has only Portugal and the USA citing its scientific production in the first time interval, with about 25% and 75%, respectively, and still maintains two countries citing its scientific accomplishments between 2000 and 2003, namely Portugal (with a share of 42.9%) and Hong Kong (57.1%). It then widens its international knowledge-diffusing network, in the latest period of analysis, up to 17 countries (*cf.*, Figure 16). Between 2004 and 2007, Portugal still represents 27.6% of citations of this INESC Porto's unit, but the USA has a share of 22.1%, Germany takes a share of 13.8%, Italy gets 11.1% and France has 6.7% of total citations. This dynamic analysis of the diffusion of knowledge of INESC Porto and its areas of scientific expertise shows us the widening and dynamics of INESC Porto's geographical influence network, with different countries entering and exiting this network over the years. There is an impressive influence and impact of INESC Porto's scientific production reflected in the range of countries associated with high technological and scientific accomplishments which have cited and integrated INESC Porto's knowledge into their own R&D efforts.

UTM



2004-2007

Figure 16: Country's affiliation of authors citing UTM scientific production (in % of total), per four-year periods

Source: Authors' computations - see Table A8 in Appendix

5. Conclusion

In the present study, we addressed the topic of assessment of 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.

We gathered illuminating statistical evidence on how the geographical boundaries and dynamics of INESC Porto's networks, as a whole, and its scientific working units, in particular, have evolved in terms of co-authorships and citations. We demonstrate that the influence and impact of R&D organisations go beyond local boundaries and evidence a significant heterogeneity within the organisation and dynamics over time.

In terms of co-authorship, the network of INESC Porto more than duplicated (13 countries in the beginning of the period to 27 in 2004-07). In terms of citations, although it encompassed a large number of countries (almost 40 countries) it remained stable between 1996 and 2007 (Table 7).

Table 7: Size of the scientific networks of INESC Porto and some of its units, 1996-2007

		1996-1999	2000-2003	2004-2007	1996-2007	Δ (2007/1996)-1
Co-authorships	INESC Porto	13	17	27	**31**	**1,1**
	UOSE	7	9	13	**14**	**0,9**
	USE	6	9	8	**15**	**0,3**
	UTM	4	10	21	**22**	**4,3**
Citations	INESC Porto	36	43	38	**52**	**5,6**
	UOSE	35	34	28	**43**	**-0,2**
	USE	6	12	21	**28**	**2,5**
	UTM	1	1	16	**16**	**15,0**

Its more prolific units present rather distinct patterns, both in terms of size and evolution of its boundaries. The network size of foreign co-authorships was not much different between the three units at the beginning of the 2000s (around 10 countries) but it presented quite distinct evolutions in the last period (2004-07). The most remarkable increase was registered by the multimedia (UTM) unit, whose network size rose exponentially to 21 countries in 2004-07. This contrasted with the decline (down to 8 countries) of the energy (USE) unit. The citation network of the optoelectronic unit (UOSE) was by far the largest, until 2003, involving 34 different countries, which contrasted with the size (12 countries) of USE and UTM (1). But again, after 2003, the size of the citation network of UTM and USE converged spectacularly to that of UOSE's, reaching the last period with 16 (UTM) and 21 (USE).

The composition of the co-authorship and citation networks (Table 8) also differs considerably between units. Globally, the UK, Spain, the USA, Brazil and Germany are the core partners of INESC Porto's international co-authorship network. Brazil is not just a core player, as far as the overall scientific production of INESC Porto is regarded, but it is also a stable partner within its international scientific relationships, between 1996 and 2007. Greece, the UK and the USA decrease their share of collaborative presence during the period of analysis. Germany, Finland and Spain have been moving positively inside INESC Porto's international co-authorship network.

Table 8: Composition of the scientific networks of INESC Porto and some of its units, 1996-2007

		1996-1999	2000-2003	2004-2007	1996-2007
Co-authorships	INESC Porto	US; UK; Macau	Spain; UK; France	UK; Spain; US	**UK; Spain; US**
	UOSE	US; UK; Russia; Switzerland	Spain; US; Finland	US; Brazil; UK	**US; UK; Brazil; Spain**
	USE	Macau; Brazil; Greece	Greece; Spain; Bosnia	Spain; Venezuela; Brazil	**Spain; Brazil; Greece**
	UTM	US; UK; Brazil; Denmark	UK; France; Italy	UK; Germany; Finland	**UK; Germany; France**
Citations	INESC Porto	China; UK; Germany	China; UK; Taiwan	China; US; Canada	**China; UK; US**
	UOSE	China; UK; Spain	China; UK; Taiwan	China; US; Canada	**China; UK; US**
	USE	India; Greece; UK	India; Norway; Turkey	Spain; China; India	**India; China; Spain**
	UTM	US	Hong Kong	US; Germany; Italy	**US; Germany; Italy**

When considering the international co-authorship behaviour of INESC Porto's most prolific units – UOSE, USE and UTM -, it is evident how they all have specific evolution patterns of their own international network, strongly differentiated from that identified for INESC Porto. The USA and the UK are the most important partner countries in UOSE's specific scientific network, though with declining shares. Brazil, Finland and Canada increased their contribution to UOSE's co-authorship network. Countries that have been gaining weight, as far as USE's international co-authorships are concerned, are Spain, Venezuela and the USA. Partners that have lost collaborative share include Greece, Macau, Bosnia and Herzegovina, and the UK. Regarding the telecommunications and multimedia (UTM) unit, the growth in terms of the scientific contribution of Germany, Austria, Finland, Spain and Netherlands is clear. In contrast, the UK and the USA gradually decreased their share of R&D collaboration with UTM, although the UK represents the highest average share of UTM foreign co-authorships.

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Appendix

Table A1: Mapping the geographic distribution of INESC Porto's co-authorships

	1996-1999	2000-2003	2004-2007	1996-2007	
United Kingdom	18,6	14,4	12,9	**14,1**	↓
Spain	2,3	16,7	10,9	**11,4**	↑
United States	23,3	8,9	9,5	**11,1**	↓
Brazil	9,3	7,8	8,5	**8,4**	↓
Germany	2,3	5,6	9,0	**7,2**	↑
France	4,7	11,1	4,0	**6,0**	→
Finland	0,0	5,6	6,0	**5,1**	↑
Greece	7,0	5,6	4,0	**4,8**	↓
Italy	0,0	8,9	3,0	**4,2**	↑
Austria	0,0	2,2	4,5	**3,3**	↑
Canada	0,0	1,1	4,0	**2,7**	
Venezuela	0,0	0,0	4,5	**2,7**	
Russia	4,7	2,2	2,0	**2,4**	
Macau	16,3	0,0	0,0	**2,1**	
Switzerland	4,7	0,0	2,0	**1,8**	
Bosnia and Herzegovina	0,0	3,3	1,0	**1,5**	
Poland	0,0	0,0	2,5	**1,5**	
The Netherlands	0,0	0,0	2,5	**1,5**	
Denmark	2,3	0,0	1,5	**1,2**	
Ireland	0,0	3,3	0,5	**1,2**	
Sweden	0,0	0,0	2,0	**1,2**	
Australia	0,0	0,0	1,5	**0,9**	
Belgium	2,3	0,0	0,5	**0,6**	
Israel	0,0	0,0	1,0	**0,6**	
Norway	0,0	1,1	0,5	**0,6**	
Slovenia	0,0	0,0	1,0	**0,6**	
Argentina	0,0	1,1	0,0	**0,3**	
Cape Verde	2,3	0,0	0,0	**0,3**	
Japan	0,0	0,0	0,5	**0,3**	
Macedonia	0,0	1,1	0,0	**0,3**	
Uzbekistan	0,0	0,0	0,5	**0,3**	

Table A2: Mapping the geographic distribution of UOSE's co-authorships

	1996-1999	2000-2003	2004-2007	1996-2007	
United States	36,8	15,6	23,3	**23,4**	↓
United Kingdom	26,3	12,5	11,6	**14,9**	↓
Brazil	0,0	12,5	18,6	**12,8**	↑
Spain	5,3	28,1	4,7	**12,8**	→
Russia	10,5	6,3	9,3	**8,5**	↓
Finland	0,0	15,6	2,3	**6,4**	↑
Switzerland	10,5	0,0	7,0	**5,3**	→
Canada	0,0	3,1	7,0	**4,3**	↑
France	5,3	3,1	4,7	**4,3**	→
Belgium	5,3	0,0	2,3	**2,1**	↓
Poland	0,0	0,0	4,7	**2,1**	
Germany	0,0	0,0	2,3	**1,1**	
Italy	0,0	3,1	0,0	**1,1**	
Uzbekistan	0,0	0,0	2,3	**1,1**	
Argentina	0,0	0,0	0,0	**0,0**	
Australia	0,0	0,0	0,0	**0,0**	
Austria	0,0	0,0	0,0	**0,0**	
Bosnia and Herzegovina	0,0	0,0	0,0	**0,0**	
Cape Verde	0,0	0,0	0,0	**0,0**	
Denmark	0,0	0,0	0,0	**0,0**	
Greece	0,0	0,0	0,0	**0,0**	
Ireland	0,0	0,0	0,0	**0,0**	
Israel	0,0	0,0	0,0	**0,0**	
Japan	0,0	0,0	0,0	**0,0**	
Macau	0,0	0,0	0,0	**0,0**	
Norway	0,0	0,0	0,0	**0,0**	
Macedonia	0,0	0,0	0,0	**0,0**	
Slovenia	0,0	0,0	0,0	**0,0**	
Sweden	0,0	0,0	0,0	**0,0**	
The Netherlands	0,0	0,0	0,0	**0,0**	
Venezuela	0,0	0,0	0,0	**0,0**	

Table A3: Mapping the geographic distribution of USE's co-authorships

	1996-1999	2000-2003	2004-2007	1996-2007			
Spain	0,0	18,2	26,8	**19,0**			↑
Brazil	20,0	4,5	19,5	**15,2**		→	
Greece	13,3	22,7	9,8	**15,2**	↓		
Venezuela	0,0	0,0	22,0	**11,4**			↑
Macau	46,7	0,0	0,0	**8,9**	↓		
Bosnia and Herzegovina	0,0	13,6	4,9	**6,3**	↓		
United Kingdom	6,7	9,1	4,9	**6,3**	↓		
United States	0,0	4,5	7,3	**5,1**			↑
France	6,7	9,1	0,0	**3,8**	↓		
Ireland	0,0	9,1	0,0	**2,5**	↓		
Argentina	0,0	4,5	0,0	**1,3**			
Cape Verde	6,7	0,0	0,0	**1,3**			
Canada	0,0	0,0	2,4	**1,3**			
Macedonia	0,0	4,5	0,0	**1,3**			
Sweden	0,0	0,0	2,4	**1,3**			
Australia	0,0	0,0	0,0	**0,0**			
Austria	0,0	0,0	0,0	**0,0**			
Belgium	0,0	0,0	0,0	**0,0**			
Denmark	0,0	0,0	0,0	**0,0**			
Finland	0,0	0,0	0,0	**0,0**			
Germany	0,0	0,0	0,0	**0,0**			
Israel	0,0	0,0	0,0	**0,0**			
Italy	0,0	0,0	0,0	**0,0**			
Japan	0,0	0,0	0,0	**0,0**			
Norway	0,0	0,0	0,0	**0,0**			
Poland	0,0	0,0	0,0	**0,0**			
Russia	0,0	0,0	0,0	**0,0**			
Slovenia	0,0	0,0	0,0	**0,0**			
Switzerland	0,0	0,0	0,0	**0,0**			
The Netherlands	0,0	0,0	0,0	**0,0**			
Uzbekistan	0,0	0,0	0,0	**0,0**			

Table A4: Mapping the geographic distribution of UTM's co-authorships

	1996-1999	2000-2003	2004-2007	1996-2007		
United Kingdom	28,6	20,0	16,8	**18,1**	↓	
Germany	0,0	11,4	15,0	**13,4**		↑
France	0,0	20,0	5,6	**8,7**		↑–
Italy	0,0	20,0	4,7	**8,1**		↑–
Austria	0,0	5,7	8,4	**7,4**		↑
Finland	0,0	0,0	10,3	**7,4**		↑
United States	42,9	5,7	3,7	**6,0**	↓	
Spain	0,0	5,7	5,6	**5,4**		↑
The Netherlands	0,0	0,0	4,7	**3,4**		↑
Brazil	14,3	0,0	0,9	**2,7**	↓	
Canada	0,0	0,0	3,7	**2,7**		
Denmark	14,3	0,0	2,8	**2,7**		
Greece	0,0	0,0	3,7	**2,7**		
Australia	0,0	0,0	2,8	**2,0**		
Poland	0,0	0,0	2,8	**2,0**		
Sweden	0,0	0,0	2,8	**2,0**		
Israel	0,0	0,0	1,9	**1,3**		
Norway	0,0	2,9	0,9	**1,3**		
Ireland	0,0	2,9	0,0	**0,7**		
Japan	0,0	0,0	0,9	**0,7**		
Slovenia	0,0	0,0	0,9	**0,7**		
Switzerland	0,0	0,0	0,9	**0,7**		
Argentina	0,0	0,0	0,0	**0,0**		
Belgium	0,0	0,0	0,0	**0,0**		
Bosnia and Herzegovina	0,0	0,0	0,0	**0,0**		
Cape Verde	0,0	5,7	0,0	**0,0**		
Macau	0,0	0,0	0,0	**0,0**		
Macedonia	0,0	0,0	0,0	**0,0**		
Russia	0,0	0,0	0,0	**0,0**		
Uzbekistan	0,0	0,0	0,0	**0,0**		
Venezuela	0,0	0,0	0,0	**0,0**		

Table A5: Mapping the geographic distribution of citations to INESC Porto's works

	1996-1999	2000-2003	2004-2007	1996-2007		
Portugal	29,7	30,3	37,1	**32,6**		↑
People's Republic of China	11,7	19,7	7,9	**12,8**	↓	
United Kingdom	7,2	6,7	3,4	**5,6**	↓	
United States	4,4	2,3	8,2	**5,1**		↑
Spain	4,5	3,2	3,7	**3,8**	↓	
Canada	2,1	2,3	5,9	**3,5**		↑
Germany	5,2	1,2	3,5	**3,4**	↓	
Italy	0,9	2,9	4,2	**2,8**		↑
South Korea	2,7	3,6	1,7	**2,6**	↓	
France	4,3	1,3	2,0	**2,5**	↓	
Switzerland	3,6	2,5	1,5	**2,5**		
Australia	2,5	0,7	2,5	**1,9**		
Poland	2,0	1,0	2,6	**1,9**		
Russia	4,4	1,0	0,4	**1,9**		
Brazil	0,5	0,6	3,3	**1,6**		
India	1,2	2,9	0,9	**1,6**		
Taiwan	0,6	3,8	0,6	**1,6**		
Belgium	2,2	0,2	2,2	**1,6**		
Japan	1,3	0,3	2,0	**1,2**		
Finland	0,2	3,4	0,1	**1,1**		
Ireland	0,8	1,6	1,0	**1,1**		
Hong Kong	0,9	0,9	0,6	**0,8**		
Malaysia	0,0	2,3	0,1	**0,7**		
Singapore	1,0	0,7	0,3	**0,6**		
Lithuania	1,3	0,0	0,1	**0,5**		
Iran	0,0	0,5	0,7	**0,4**		
The Netherlands	0,9	0,1	0,2	**0,4**		
Israel	1,1	0,0	0,0	**0,3**		
Greece	0,4	0,0	0,5	**0,3**		
Bulgaria	0,0	0,9	0,1	**0,3**		
Mexico	0,6	0,3	0,0	**0,3**		
Czech Republic	0,9	0,0	0,0	**0,3**		
Turkey	0,1	0,8	0,0	**0,3**		
Denmark	0,2	0,2	0,4	**0,3**		
Romania	0,2	0,0	0,5	**0,3**		
Sweden	0,0	0,0	0,6	**0,2**		
Viet Nam	0,0	0,0	0,6	**0,2**		
Cyprus	0,2	0,2	0,2	**0,2**		
Ukraine	0,1	0,4	0,0	**0,2**		
Colombia	0,0	0,4	0,0	**0,1**		
United Arab Emirates	0,1	0,0	0,2	**0,1**		
Austria	0,0	0,2	0,1	**0,1**		
Egypt	0,0	0,1	0,2	**0,1**		
Argentina	0,1	0,1	0,0	**0,1**		
Norway	0,0	0,3	0,0	**0,1**		
South Africa	0,0	0,2	0,0	**0,0**		
Thailand	0,0	0,2	0,0	**0,0**		
New Zealand	0,0	0,1	0,0	**0,0**		
Yugoslavia	0,0	0,1	0,0	**0,0**		
Saudi Arabia	0,0	0,1	0,0	**0,0**		
Tunisia	0,0	0,1	0,0	**0,0**		
Uruguay	0,0	0,0	0,0	**0,0**		

Table A6: Mapping the geographic distribution of citations to UOSE's works

	1996-1999	2000-2003	2004-2007	1996-2007	
Portugal	30,0	31,7	41,2	**34,3**	↑
People's Republic of China	11,9	20,7	8,5	**13,5**	↓
United Kingdom	6,9	6,7	3,9	**5,8**	↓
United States	4,4	1,5	6,6	**4,2**	↑
Spain	4,6	3,4	3,4	**3,8**	↓
Canada	2,1	2,5	6,0	**3,5**	↑
Germany	5,3	1,2	2,4	**3,1**	↓
Switzerland	3,7	2,7	1,8	**2,8**	↓
South Korea	2,8	3,3	2,1	**2,7**	→
France	4,1	1,3	1,4	**2,3**	↓
Italy	0,9	3,0	2,8	**2,2**	
Poland	2,1	0,9	3,2	**2,1**	
Russia	4,5	1,1	0,5	**2,1**	
Australia	2,5	0,7	2,8	**2,0**	
Brazil	0,5	0,6	3,6	**1,6**	
Belgium	2,2	0,2	2,2	**1,6**	
Taiwan	0,6	3,9	0,0	**1,4**	
Ireland	0,8	1,7	1,2	**1,2**	
India	0,7	2,4	0,6	**1,2**	
Finland	0,2	3,6	0,0	**1,2**	
Japan	1,3	0,0	2,0	**1,1**	
Malaysia	0,0	2,5	0,0	**0,8**	
Singapore	1,0	0,4	0,3	**0,6**	
Hong Kong	0,9	0,3	0,4	**0,5**	
Lithuania	1,3	0,0	0,0	**0,5**	
Iran	0,0	0,4	0,9	**0,4**	
Israel	1,1	0,0	0,0	**0,4**	
Bulgaria	0,0	1,0	0,1	**0,3**	
Czech Republic	0,9	0,0	0,0	**0,3**	
Mexico	0,6	0,3	0,0	**0,3**	
The Netherlands	0,9	0,0	0,0	**0,3**	
Viet Nam	0,0	0,0	0,8	**0,3**	
Cyprus	0,2	0,2	0,3	**0,2**	
Romania	0,2	0,0	0,5	**0,2**	
Ukraine	0,1	0,4	0,0	**0,2**	
Denmark	0,2	0,2	0,0	**0,1**	
Colombia	0,0	0,4	0,0	**0,1**	
Sweden	0,0	0,0	0,4	**0,1**	
Turkey	0,1	0,3	0,0	**0,1**	
United Arab Emirates	0,1	0,0	0,2	**0,1**	
Argentina	0,1	0,1	0,0	**0,1**	
South Africa	0,0	0,2	0,0	**0,1**	
Austria	0,0	0,1	0,0	**0,0**	

Table A7: Mapping the geographic distribution of citations to USE's works

	1996-1999	2000-2003	2004-2007	1996-2007		
India	27,0	29,7	6,9	**15,3**	↓	
Portugal	4,1	16,5	10,4	**10,6**		↑
People's Republic of China	0,0	6,6	11,6	**8,5**		↑
Spain	0,0	0,0	13,9	**8,5**		↑
Greece	24,3	0,0	6,2	**8,0**	↓	
United Kingdom	24,3	2,2	2,3	**6,1**	↓	
United States	0,0	2,2	8,5	**5,7**		↑
Italy	0,0	0,0	8,9	**5,4**		↑
Taiwan	0,0	0,0	7,7	**4,7**		↑
France	16,2	0,0	2,3	**4,2**	↓	
Egypt	0,0	3,3	3,5	**2,8**		
Denmark	0,0	0,0	3,9	**2,4**		
Norway	0,0	11,0	0,0	**2,4**		
Turkey	0,0	11,0	0,0	**2,4**		
Lithuania	0,0	0,0	2,3	**1,4**		
Malaysia	0,0	0,0	2,3	**1,4**		
Romania	0,0	0,0	2,3	**1,4**		
Thailand	0,0	6,6	0,0	**1,4**		
Brazil	0,0	0,0	1,5	**0,9**		
Sweden	0,0	0,0	1,5	**0,9**		
Yugoslavia	0,0	4,4	0,0	**0,9**		
Canada	0,0	0,0	1,2	**0,7**		
Finland	0,0	3,3	0,0	**0,7**		
Hong Kong	0,0	0,0	1,2	**0,7**		
Japan	0,0	3,3	0,0	**0,7**		
Singapore	4,1	0,0	0,0	**0,7**		
Germany	0,0	0,0	0,8	**0,5**		
Uruguay	0,0	0,0	0,8	**0,5**		

Table A8: Mapping the geographic distribution of citations to UTM's works

	1996-1999	2000-2003	2004-2007	**1996-2007**		
Portugal	25,0	42,9	27,6	**28,6**	→	
United States	75,0	0,0	22,1	**21,1**	↓	
Germany	0,0	0,0	13,8	**12,9**		↑
Italy	0,0	0,0	11,1	**10,4**		↑
France	0,0	0,0	6,7	**6,3**		↑
Hong Kong	0,0	57,1	2,3	**5,7**	↓	
Sweden	0,0	0,0	2,3	**2,1**		↑
Belgium	0,0	0,0	1,7	**1,6**		↑
Greece	0,0	0,0	1,7	**1,6**		↑
People's Republic of China	0,0	0,0	1,7	**1,6**		↑
Spain	0,0	0,0	1,7	**1,6**		
Australia	0,0	0,0	1,5	**1,4**		
Denmark	0,0	0,0	1,5	**1,4**		
The Netherlands	0,0	0,0	1,5	**1,4**		
Austria	0,0	0,0	1,0	**0,9**		
United Kingdom	0,0	0,0	1,0	**0,9**		
Finland	0,0	0,0	0,6	**0,5**		

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