Alignment in regional networks:
towards new metrics to assess the effectiveness of technology policy

Alinhamento de redes em uma região em processo de catching-up:
em busca de novas métricas para avaliar a efetividade da política tecnológica

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Abstract: This article addresses how regional level network governance and structure influence the effectiveness of technology policy to improve local firms' innovativeness in a catching-up context. It examines network alignment through an investigation of network governance (i.e., coordination) and structure. Our contribution to the literature relates to the employment of original metrics that allow the understanding of meaning, features and roles of network ties and, therefore, whether network governance and structure have a consistent influence on firms' engagement in network and their innovative performance. The empirical evidence is based on a Brazilian laggard region that has been the focus of technology policy to promote industrial and regional development, the Recife software network of innovation (Porto Digital). We find that implementation of a technology policy and formation of networks to improve firm-level innovation and regional catch-up should involve careful consideration of the intended effects: membership of a network may not be a sufficient condition for improving innovation at firm level.

Keywords: Network alignment; Network governance and structure; Technology Policy; Recife and Porto Digital; Software

Resumo: Este artigo discute como a governança e estrutura de redes em nível regional influenciam a efetividade da política tecnológica para promoção da inovação de firmas locais em contextos de catching-up. Examina-se o alinhamento de redes por meio da investigação de governança (i.e., coordenação) e estrutura de redes. A contribuição para a literatura se refere ao uso de métricas originais que permitem a compreensão dos significados, características e papéis de elos diáticos da rede; e, assim, se sua governança e estrutura apresentam uma influência no engajamento de firmas em redes e em suas performances inovativas. A evidência empírica é baseada em uma região brasileira em processo de catching-up que foi objeto de política tecnológica para promover o desenvolvimento industrial e regional, a rede de inovação de software de Recife (Porto Digital). Os resultados mostram que a implementação de políticas tecnológicas e formação de redes para a promoção de atividades de inovação no nível da firma e de catching-up regional devem considerar os seus efeitos esperados, a participação em redes pode não ser condição suficiente para melhores desempenhos de inovação no nível da firma.

Palavras-Chave: Alinhamento de redes; Governança e estrutura de redes; Política tecnológica; Recife e Porto Digital; Software

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INTRODUCTION

In recent decades, networks have been identified as important assets to support the engagement of localities with innovative activities and the knowledge, production and technological frontiers (OKIMOTO, 1989; FELDMAN, 1993; HERRIGEL, 1993; LAZERSON, 1993; AHUJA, 2000; KENNEY, 2000; BRESNAHAN *et al.*, 2001). Networks supposedly 'breed trustworthy relations' among economic actors (GRANOVETTER, 1973; 1985; GIULIANI, 2010, P. 264), have the potential to reduce transaction costs and favour the creation and diffusion of knowledge and information (BURT, 2010). They encourage learning by interacting (LUNDVALL, 1992), which leads to new knowledge that is essential for innovation (FREEMAN, 1991; POWELL E GRODAL, 2005).

Studies on networks include work on their conceptual role (POWELL, 1990), networks of innovation (FREEMAN, 1991; POWELL e GRODAL, 2005; CANTNER e GRAF, 2010), network dynamics (GIULIANI, 2013), industrial clusters and networks (COOKE, 2001; GIULIANI, 2010), knowledge networks (DANTAS e BELL, 2009), social networks and embeddedness (GRANOVETTER, 1973; 1985), networks and strategic alliances (JORDE e TEECE, 1989), network governance (JONES *et al.*, 1997) and networks in developing countries (see, KIM e VON TUNZELMANN, 1998; DODGSON *et al.*, 2008; GIULIANI, 2010; RAMIREZ e DICKENSON, 2010). These studies have advanced our knowledge about the role of networks in complementing the development and enhancement of innovation capabilities at firm, regional and industry levels. However, the alignment of networks has been scarcely addressed by studies on networks, especially with regards to regions based in developing countries; the same applies to studies on the *multiple functions* of networks (PAMPLONA DA COSTA, 2012). Network alignment means that *heterogeneous* networks presenting different elements that pull in similar directions (VON TUNZELMANN, 2003, p. 46) have different ability to achieve the goals of the systems in which they are embedded (VON TUNZELMANN, 2010, p. 4). The focus so far has been on network structure and the belief that networks can lead to positive outcomes.[1] Networks have *multiple* functions and may not be a sufficient mechanism to foster knowledge exchange among the actors or promote learning by firms without some level of alignment.

This study contributes to the extant literature by focusing on network alignment through an investigation of network governance (understood here as coordination) and structure (JONES *et al.*, 1997, p. 913)[2]. This approach brings to the fore which elements related to governance and structure may influence industry and regional development. Explaining the complexity of network relations in a locality employing this approach supports the identification of important characteristics of the network (such as features, meaning and roles of ties), indicating future steps that may lead to regional network development by government policies. Hence, the study proposes the following research question: *In considering government technology policy to promote firm innovation through networks in a laggard region, do regional level network governance and structure influence policy effectiveness?*

To address this question, this study investigates one software innovation network embedded in the late-industrializing state of Pernambuco (Brazil), in the municipality

1 E.g. Mazzucato (2013) discusses the importance of networks in the evolution of information technology in the USA. Negative experiences related to regional lock-in and sclerosis in networks are discussed in the theoretical economic geography literature, see Boschma (2004) and Martin and Sunley (2006; 2010).

2 Network structure refers to the age and historical evolution of the network (Dodgson, 2011) and the level of formal interactions (Burt, 1992).

of Recife. We analyse network governance and structure by combining qualitative and quantitative methods (YIN, 2003) and using Social Network Analysis (SNA) to visualise the representative network of innovators (DE NOOY *et al.*, 2005). Data were gathered from 47 semi-structured face-to-face interviews with the regional software network of innovators.[3]

3 Another 12 interviews were conducted during the pilot fieldwork.

Our study shows that the effect of government technology policy on firm innovation is partial, because network governance and structure exerts a limited influence on the Recife software network of innovators. On the one hand the promotion of local networks has increased the effectiveness of local innovation performance. On the other hand, local firms have ties largely with only one local Research and Development (R&D) organisation and there is fragmented interaction between local firms, while the skills sub-network misses the presence of crucial actors such as the university.

The manuscript is organised as follows. Section 2 describes the background to the research and Section 3 presents the methods and the analytical framework. Section 4 introduces the case and discusses the results. Section 5 presents the case study analysis and Section 6 concludes and outlines the contributions and policy implications of this study.

TECHNOLOGY POLICY FOR REGIONAL SOFTWARE INNOVATION NETWORKS

Technology policy can encourage the formation and evolution of regional networks if it is directed towards a particular region or the scientific and technical training institutions in a specific geographical area (a characteristic of the case analysed here). It is assumed that the presence of actors with the capabilities to advance the technological development of a particular industry (MALERBA, 2004) or to manage changes to the technological paradigm, will enable spillovers of knowledge to other actors in the region (STORPER, 1995; ASHEIM E GERTLER, 2004; BOSCHMA, 2005; BOSCHMA e MARTIN, 2010; COOKE e DE LAURENTIS, 2010). These spillovers can occur through labour mobility within a delimited geographical area.[4] However, policy should take account of differences in economic and social settings which might influence its implementation and results and also the particularities of the technologies (sector related) and local contexts (region related).

4 Other indirect technology policies may support the formation of networks through actions to improve basic education and training standards, and to promote competition policy and public investment. See Ergas (1987), Mowery (1995) and Steinmueller (2010) for more discussion of these issues.

The software industry, one of the main drivers of the current techno-economic paradigm, is a highly creative sector, involving new learning which 'springs from the non-repeating nature of the task' (BROOKS JR., 1995, p. 7). Each of the activities in a software system and its packaged and customised applications, varies in complexity and may demand different types of scientific, technological and commercial knowledge. This may require 'firms to mix internal competencies, knowledge and experience with external sources of knowledge' (GRIMALDI e TORRISI, 2001, p. 1428) and to *create ties with external actors* (i.e. network) such as universities, suppliers, competitors and users. Although there may be patterns of relationships among software firms, or between software firms and network actors, the role of the network may be different for the individual firms in the industry.

Most software firms innovate by differentiating and customising their products to

particular application contexts, which often involves close relationships with customers (users) (STEINMUELLER, 2001; 2004). Software developments frequently require knowledge that is accessed via networking with, for instance, supplier firms, complementary firms, university researchers and competitors. The creation of formal external ties among software firms may be research-oriented (e.g. via joint R&D agreements) or market-oriented (i.e., designed to access specialised commercial assets, service expertise or new markets) (GRIMALDI e TORRISI, 2001). Although software development is closely related to its employment of well trained and experienced developers, networking activities are also important, which highlights the need for an empirical investigation of networking among software firms embedded in an emerging economy context (ROUSSEVA, 2008). The present research pays particular attention to the case of local Brazilian software firms by investigating networking with both customers and all other relevant actors in the network.

An analysis of network governance and structure enables a deeper investigation of networks than studies that focus on the structure of dyadic ties and consider governance as an emergent or collateral network property. Here we examine the role of networks in supporting firm level innovation activities in emerging economies through an investigation of structural (i.e., the institutional setting) *and* relational (i.e., dyadic ties) embeddedness (JONES *et al.*, 1997). Using consistent indicators to investigate structural embeddedness contributes to our understanding of network alignment while indicators for relational embeddedness explain the relationships among network actors.

Numerous studies of networks draw on SNA (SCOTT, 1991) to explain their role in innovation (e.g., CANTNER e GRAF, 2010; GIULIANI, 2010; 2013), but the role of dyadic ties remains largely unexplored (PAMPLONA DA COSTA, 2012). Tie strength does not always determine ties value because ties can play different roles (GRANOVETTER, 1973; BURT, 1992; 2010) and the structure in which they are embedded is critical (GRANOVETTER, 1985; STORPER, 1996). To understand how and why networks of innovators emerge and evolve within innovation systems in developing countries contexts requires clarification of the relationships underlying dyadic ties combined with evidence on the institutional arrangements in which these ties are embedded. Indicators that 'reflect the quality of relationships such as trust' are required to understand the multi-organisational interactions in developing country contexts (LUNDVALL *ET AL.*, 2009, p. 19). We also need methods that group systems into 'families' based on commonalities, which increases comparability between systems (PADILLA-PÉREZ, 2008), and applies also to innovation networks as a sub-set of Systems of Innovation (SI). These indicators and methods were developed in this study and are one of its major contributions and presented in Section 3.

METHODS

We use a single case study method (Recife software network of innovation, see Section 4) and analyse network in a region with contextual conditions that change over time and, thus, warrant in-depth analysis (YIN, 2003).[5] The data refers to the period 2006-2009.[6] The turnover of the Brazilian software industry was estimated

5 SNA does not capture historical trends or regulatory and institutional issues (Grasenick *et al.*, 2008: 309-310).

6 The data for this study was collected in 2009 and is part of a PhD Thesis, see Pamplona da Costa (2012).

in US$10 billion in 2009 and US$ 19,4 billion in 2016 (products representing approximately 40% and services 60% in both periods). The growth of this industry indicates its relevance as an object of research. The national software industry could benefit from a developed local telecommunications infrastructure, low labour cost (compared to advanced countries) and a consolidated internal market to catch up with the international frontier (MARTINS *et al.*, 2018). Despite the industry growth, its structural characteristics have not changed substantially in the past decade. In 2015 there were 4.408 Brazilian firms in software development and production, in which 95,1% were micro and small firms (ABES, 2018); local firms access predominantly the domestic market and have a low market-share internationally. In addition, local firms struggle to engage in segments of higher technology intensity, which are dominated by foreign firms (MARTINS *et al.*, 2018, p. 20). Therefore, studies on networks remain relevant since the industry is dominated by micro and small firms which may rely on external knowledge to engage in learning by interaction.

We adopt a quantitative approach that uses SNA as a tool for visual representation of the network. The combination of these approaches has been shown to be relevant for explaining collaboration among network actors and network structure (i.e., their age and evolution). Consideration of network age and evolution in our analyses of firms' innovation activities contributes to work on industry development (DODGSON, 2011).

We examine the structure of networks, their controlling mechanisms, features and motivations for dyadic tie formation, and the *multi-functions* and *aims of four sub-networks* within the innovation network: (i) *business sub-network*, including firms, customers, suppliers, supporting agencies and associations; (ii) *skills sub-network*, including research foundations, learning institutes, universities and continued education actors; (iii) *technological sub-network*, including laboratories and research and development (R&D) institutes; and (iv) *financial sub-network*, including local and state government, and the public and private banking system. This is in line with the argument that innovation networks are a sub-set of SI (CANTNER E GRAF, 2006); hence, the network actors related to the same 'group' of components within the innovation system (LUNDVALL, 1992) and with overlapping aims, can be grouped accordingly. This contributes to the operationalisation of the network alignment concept.

Indicators of network governance and structure

Qualitative indicators are needed to examine network governance and structure, there are few qualitative indicators that can be replicated consistently to investigate the governance and structure of networks in different contexts (LUNDVALL *ET AL.*, 2009). We propose four indicators to investigate *direct dyadic ties* to allow examination of network governance: i) consistency among sub-networks; ii) tightness of ties among actors; iii) level of network openness; and iv) network structure.

The consistency of the sub-networks indicator measures structural embeddedness and relates to the *overlap* between the *features* of ties created by firms with other network actors, the *general aims* of the sub-network to which the actor belongs, and the *self-defined*, specific aim of the tied actor. Hence, consistency provides an evaluation of the performance of tied organisations, following a rationale whereby the

higher the *overlap* the higher the *consistency* of the sub-networks. The composition of this indicator follows the Oslo Manual classification for the nature of external relationships among actors (OECD, 2005). The indicator is based on six features of the ties created by each firm with network actors: i) access to open information; ii) acquisition of knowledge; iii) acquisition of technology; iv) access to new sources of finance; v) access to commercial information; and vi) innovation co-operation. The sub-networks consistency provides an evaluation of the performance of tied organisations and evidence of network alignment.

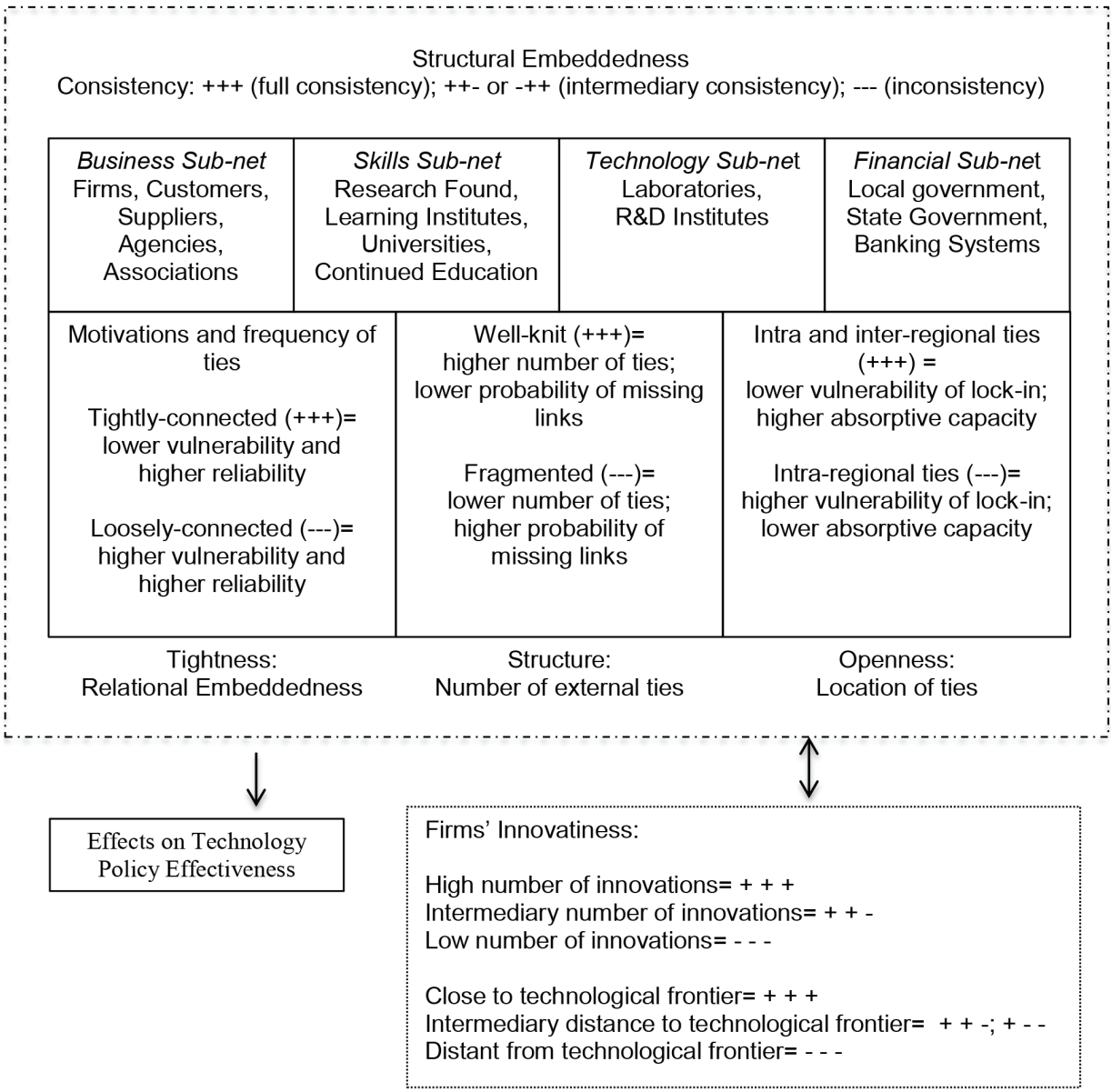
The tightness of ties measures the relational embeddedness of the network and refers to firms' *frequency* (i.e., whether ties are used on a 'one-off' or regular basis) and *motivation* (see below) for creation of each external formal dyadic tie with network actors. In this study we analyse only *direct* ties; we investigate whether the creation of direct ties involves (mainly) the characteristics associated with strong or weak ties as discussed by Granovetter (1973). Ties are tightly-connected if they are direct ties and the *motivations* for their creation are mainly based on trust, affiliation, collective identity and knowledge availability and accessibility; tightly-connected ties are supposedly less vulnerable to breaking under pressure. Loosely-connected ties are also direct ties, however the *motivation* for their creation are mainly based on opportunity or cost and, supposedly, are more vulnerable to breaking under pressure. Firms were asked about motivations for tie creation additional to those listed above.

The structure of the network refers to how the network actors are connected. This could be fragmented or well-knit. This indicator is measured by the number of indirect ties within the network and, instead of reflecting each external tie, relates to the network as a whole. Fragmented networks occur when the number of indirect ties within the core cluster of nodes is small and network actors are mostly isolated. Well-knit networks occur when the number of indirect ties within the core cluster of nodes is high and the network actors have frequent - direct or indirect – connections. Intermediate stages between fragmented and well-knit are possible, and the visualization of the network supports our conclusions on the structure of the network.[7]

The level of network openness refers to the geographical localization of collaborating network actors (they can be located anywhere in the world), and supports conclusions about the regional network's vulnerability to lock-in (GRABHER, 1993; BOSCHMA, 2004). Indicators to measure firm-level innovation follow the Oslo Manual recommendations (OECD, 2005). The data collected for firm-level innovation are for three years period (2006-2009) and referred as 'commercialised innovation', as well as for innovations that were in process of creation, referred here as 'ongoing innovation'. Figure 1 summarizes the analytical framework and the network governance indicators, suggesting the expected *predominant* network outcomes.

7 Well-knit is used in this article to classify the structure of the network; it refers to how ties among the members of the network are connected. The higher the number of connected ties among themselves, the higher is the likelihood of a healthier/stronger network.

Figure 1. Analytical framework and network governance and structure indicators



Source: own elaboration based on Pamplona da Costa (2015).

The main source of empirical information was face-to-face interviews based on semi-structured and open-ended questionnaires, that included different criteria for each type of organisation. The firm questionnaire asked about their innovation processes. The public and private organisation questionnaire collected additional evidence, which was validated by information available from websites, reports and formal studies (enabling data triangulation - YIN, 2003, p. 97); and provided additional historical information on the case study areas. A total of 47 face-to-face interviews was conducted (Table 1). Firms were selected by: size, age, and type of software activity, that is, product or service complexity.[8] The firm sample included 17 Brazilian-owned software firms (16.3% of the total populations of firms), they differ in age and size, and cover a wide range of production activities. Most firms (15) devel-

8 We applied the Brazilian Service of Support for Micro and Small Enterprises (Sebrae) criteria to classify firm size based on number of employees: i) micro firm = 1 to 9; ii) small firms = 10 to 49; iii) medium firms = 50 to 99; and iv) large firms = more than 100 employees. These totals include permanent and seasonal employment based on the argument that the majority of firms are micro or small firms (70%) unable to employ many staff on a permanent basis. The number of seasonal employees is often higher than the number permanent employees.

oped customised software, within which a significant share developed products and/or services of low to medium technology intensity. Examples of firms competing in more sophisticated niches involving higher technology included mobile games, hospital applications, and management systems for large scale agribusiness.

Table 1 - Total number of interviews by type of organisation, Recife

Type of organisation	Number of interviews
Consultants	1
Firms	
Younger than 5 years	1(M), 3(S), 2(M&L)
6 to 10 years	4(S)
11 to 15 years	3(S), 1(M&L)
Older than 16 years	1(S), 2(M&L)
Firms Total	17
Government representatives (local and national)	11
Incubators	2
Research centres	4
Research foundations	2
Supporting organisations	6
University faculties	2
Venture capital fund (national level)	2
Total	47

Source: own elaboration from fieldwork data collection.

Note: (M)=Micro, (S)=Small, (M&L)=Medium and Large

Whenever the network features showed more positive outcomes we concluded that the network governance was more effective, and vice versa. Thus, governance effectiveness is related to the innovation performance of the sampled firms, allowing propositions about whether more effective governance leads to better firm innovation performance.

RECIFE: A CITY TALE

The Recife software IT industry and network of innovation are relatively recent (for instance, when compared to other localities in the Brazilian Southeast, PAMPLONA DA COSTA, 2012) and was intentionally and strategically created by the Brazilian national government in the early 1990s within the framework of the SOFTEX Programme (Afonso *et al.*, 1999). The Programme created a SOFTEX nucleus of software firms in several Brazilian regions to support local firm-level innovation (MIT-SOFTEX, 2002). Only the firms that belonged to the SOFTEX Framework were able to benefit from the incentives offered by the programme, such as: access to National Council for Scientific and Technological Development (CNPq) scholarships for firms developing projects related to exports, provision of legal and marketing consultancy, and updated hardware to support software development. The regional criteria for receipt of a SOFTEX Programme grant included: a local research

university that offered post-graduate degrees in computing science; orientation to software development; a technological park (or a firm proposal for the creation of a park); and matching funding from local government (STEFANUTO, 2004). Thus, it was a technology policy that involved several levels of government, which played a central role in the formation of software innovation networks in different regions of Brazil and facilitated political and institutional interactions within the industry (STEFANUTO, 2004; ROSELINO, 2006). The rationale of the Programme was that geographical proximity among firms and universities would foster networking and improved innovation performance by local software firms. The aim was to support local affiliated software firms' export activity through the provision of technical and managerial support, and international market information. In addition, the Recife's IT industry benefited from indirect support through the creation of the private non-profit research centre, the Recife Center for Advanced Studies and Systems (CESAR), that spun off from the Federal University of Pernambuco in 1996.

In 2000, the state government of Pernambuco implemented various technology policies aimed at developing the local software industry through the creation of Porto Digital, and aimed at supporting economic catch-up by Recife and Pernambuco state generally (SECTMA, 2006). Porto Digital is located on Recife Island and is managed by the Porto Digital Management Unit (NGPD), which hosts software firms and other IT related organisations. The rationale for gathering local network actors in a confined geographic area was to encourage and support networking among software firms and with IT organisations (OLIVEIRA, 2008; QUERETTE, 2016). That is, combining software technology, an industry that is part of the new information technology techno-economic paradigm, and the creation and attraction of new actors to a region that was in need of reconfiguration and renewing (LACERDA E FERNANDES, 2015). Since Porto Digital was established CESAR has located on Recife Island and is a main actor in the local network.

Considering the context wherein the software innovation network is embedded in Recife and the research question addressed in the Introduction, we address below the governance and structure of the Recife software innovation network for commercialised innovation and for ongoing innovation projects for the period 2006-2009.

Innovation, Structural and Relational Embeddedness in Recife

Structural Embeddedness: The consistency of the Recife four sub-networks - commercialised and ongoing innovation projects

The business sub-network is the most frequently accessed by Recife local software firms and shows complete consistency. Customers are the most frequent tie type - most firms develop customized applications. Although access to new sources of financing was mentioned explicitly by only two of the five firms that referred to ties for financing, the interviews showed that their size (all are micro or small firms) is a constraint on investment in innovation projects with no demonstrated demand. However, this applies also to medium-sized and larger and longer-established firms. All these firms stated that customers financed their innovation, which allowed them to survive. An interviewee told us that: 'here we [the firm] only produce what is demanded, the customer dictates what has to be researched for the delivery of what has been demanded' (Recife fieldwork firm interview).

Three firms had ties with locally based firms that develop complementary software, showing the highest frequency of consistent features including acquisition of technology, access to commercial information and innovation cooperation. The development of complementary software provides access to and acquisition (not involving purchase) of technologies that previously were new to the firm. According to the interviewees, innovation cooperation was relevant for both firms involved in the tie. The objective was cooperation to obtain complementary knowledge to support the development of new software, which benefited both firms and resulted in innovation for both.

The creation of ties between Recife firms and local incubators was related mostly to access to new sources of finance. There are two incubators in the region that host software firms and provide subsidized infrastructure and business support. For prospective customers, location in an incubator provides the firm with reputation based on association with an established organisation. According to an interviewee: 'the customers associate your firm with the incubator, thinking that if you have already been accepted by the incubator, your firm must be developing reliable services and is worth of trust' (Recife fieldwork firm interview).

Finally, ties between Recife software firms and private non-profit organisations involved NGPD and SOFTEX Recife, which are based in the region and support the development of the local software industry. The ties created by local firms with both NGPD and SOFTEX Recife are related to these organisations' introduction of two local firms to large and sophisticated local customers. In both cases, the customer was part of the Pernambuco State government, so the referral involved government procurement. NGPD and SOFTEX Recife have excellent reputation in the region and, according to our interviewees, state government relies on their knowledge when choosing local firms to interact with. From the firms' perspectives, these referrals are crucial because they provided access to large customers that previously used providers from other Brazilian regions.

The skills sub-network was the second most frequently accessed sub-network and was partly consistent, with universities and research foundations being the most frequently accessed types of actors. Two findings stand out. First, for the highest frequency of ties created by firms with the national research council (CNPq) and the local research foundation (FACEPE), an aspect associated with the inconsistency found in the sub-network. All the firms with ties to these organisations were motivated by access to new sources of financing. This is as expected since both CNPq and FACEPE provide funding to support firms' research-related activity. However, lack of reference to acquisition of knowledge and acquisition of technology was unexpected because the stated aims of both CNPq and FACEPE include provision of funding for the promotion of firms' scientific and technological development through the performance of in-firm research activity.[9] Hence, local firms do not associate ties with CNPq and FACEPE to fund research, with improved scientific and technological development, which demonstrates inconsistency in the skills sub-network. Second, among the features of the ties created with Cin-UFPE that indicate consistency, innovation cooperation requires further comment. Although departments from UFPE (research university) develop academic-related scientific knowledge, they are open to collaboration with the private sector through the development and employment of applied research.

9 http://www.FACEPE.br/modules.php?name=Content&pa=showpage&pid=1, and http://www.cnpq.br/english/cnpq/index.htm, accessed 19.2.2011.

The technology sub-network is the third most frequently accessed sub-network, and shows a high level of consistency; however, we also found some features related to inconsistency. The results show an absence of ties with CESAR for the acquisition of knowledge and technology. Firm 3 benefits from the subsidized infrastructure offered by the CESAR incubator, legal advice on labour regulations and taxes, and support with business plans. Rather surprisingly, Firm 3 had not engaged with CESAR's software developers or its R&D division. Based on CESAR's mission to 'transfer information technology knowledge between the industry and the academia in a self-sustainable way', we would have expected ties for the acquisition of knowledge or technology.

The financial sub-network was not accessed by Recife software firms during the period analysed for commercialised innovation and scantly accessed for ongoing innovation projects (see Section 4.1.3). Our interviews showed that four Recife firms had ties to the national public agency, FINEP, for innovation projects to be developed only if funding was granted. These results indicate that the financial sub-network is infrequently connected to local firms, which is partly consistent.

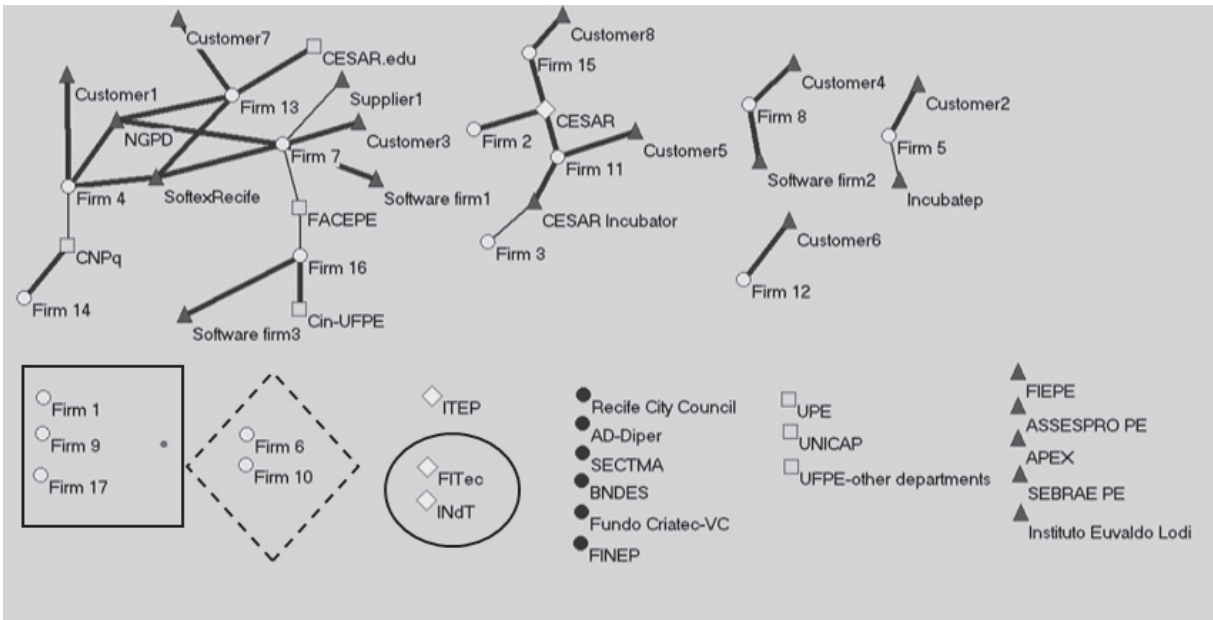
Structure of the Recife Innovation Network and Relational Embeddedness: Commercialised Innovation

The results show that 70% of the sample of interviewed firms had external ties to support their innovation activities (Figure 2). However, the structure of the Recife network of innovators is fragmented rather than well-knit. This suggests diffusion of information within the network, and resulting access to new and valuable information by network actors rather low. However, the majority of the ties are tightly- rather than loosely-connected, indicating that the creation of ties is motivated mainly by issues such as trust, collective identity, personal relationships, and knowledge availability and accessibility. In most cases, geographical proximity supports the creation of tight ties, which corroborates claims that local contexts support trust building and cognitive proximity (as discussed by ASHEIM AND GERTLER, 2004; BOSCHMA, 2005).[10]

There are direct loosely-connected ties, motivated by opportunities and financial issues, but not trust, which is an unexpected finding (GRANOVETTER, 1973). There are six cases of loosely-connected ties related to the business and skills sub-networks. Somewhat surprisingly, ties with incubators were loosely-connected; a tie between the incubated Firm 5 and the incubation programme offered by a local research institute (Incubatep/ITEP) was motivated by costs and opportunity, and based on geographic proximity to Cin-UFPE, where the entrepreneurs were studying: 'the fact that Incubatep is just across the road [from Cin-UFPE] was a major issue for us, because we are still doing our masters at Cin-UFPE, so we can go between venues in a few minutes' (Recife fieldwork firm interview).

10 Although geographic proximity does not always explain tightly-connected ties, for instance, because of labour mobility, as mentioned by Boschma (2005).

Figure 2 - The Recife software network of innovators: commercialized innovations, 2006-2009



Legend:

● Firms; ♦ Technology sub-network; ■ Skills sub-network; ▲Business sub-network

● Financial sub-network;

Tight connections = ━━━━; Loose connections = ————

□= Firms that did not create external ties to support their commercialized innovation during 2006-2009.

○= Autonomous private non-profit R&D organisations originally set up by multinationals that were disengaged from the network of innovators.

◊ = Firms that did not commercialize new software products of services during the period 2006-2009.

Source: own elaboration from fieldwork data collection.

Loosely-connected ties include links with FACEPE (Pernambuco State Research Foundation) and CNPq (national research council), and were motivated by cost and opportunity, and confirm the inconsistency of the skills sub-network discussed above.

Firm level innovations: Recife software network

The empirical findings reveal that most commercialized innovations are software services: 113 new services and 11 new products. Table 2 shows that most firms commercialized one new product in the three years period (2006-2009) and introduced an innovation to the national market. Firms 14 and 16 produced more than one innovation, and Firm14 introduced two new-to-the-world innovations.

The innovations achieved by Firm 16 required external ties with a local firm that develops complementary software, and also has ties with Cin-UFPE (the only example of a firm tie for this organisation), and FACEPE which part-financed the innovation. According to Firm 16, the Cin-UFPE involvement was crucial because it provided access to new knowledge which positioned the firm at the national technology frontier.

Firm14 is the only firm to introduce a new to the world innovation, and to have begun exporting. This firm is one of the most successful software companies in the Recife region, it competes in the international market. In interview we were told that: 'the international market always comes first for us [the firm], we actually develop our products in the English language, and then later assess which products would be interesting to the national market' (Recife fieldwork firm interview). Firm 14 participated in the Cin-UFPE incubation programme 'Recife BEAT', and its first product was the result of Master's level research conducted by one of the firm's founders. Its international innovation relied on a tie with CNPq and it is the only firm in the sample with a tightly-connected tie to this organisation.

Table 2 New software *products* and *services* commercialized by Recife software firms, and *ongoing* innovation projects

Firm #	Total number of innovations		Innovation new to the firm		Innovation new to national market		Innovation new to international market		Ongoing innovation projects
Product/ Service	Prod	Serv	Prod	Serv	Prod	Serv	Prod	Serv	Prod&Serv
Firm 1	0	3	n.a.	3	n.a.	2	n.a.	1	1
Firm 2	-	1	-	1	-	0	-	0	4
Firm 3	-	1	-	1	-	1	-	0	1
Firm 4	-	2	-	1	-	1	-	0	n.d.
Firm 5	0	44	n.a.	44	n.a.	0	n.a.	0	3
Firm 6	-	0	-	n.a.	-	n.a.	-	n.a.	0
Firm 7	2	2	2	2	1	1	0	0	1
Firm 8	-	1	-	1	-	0	-	0	0
Firm 9	1	0	1	n.a.	1	n.a.	0	n.a.	1
Firm 10	-	0	-	n.a.	-	n.a.	-	n.a.	1
Firm 11*	-	18	-	18	-	18	-	15	1
Firm 12*	-	40	-	40	-	0	-	0	1
Firm 13	1	0	1	n.a.	1	n.a.	0	n.a.	0
Firm 14	3	1	3	1	3	0	2	0	n.d.
Firm 15	1	0	1	n.a.	1	n.a.	0	n.a.	0
Firm 16	2	0	2	n.a.	2	n.a.	0	n.a.	1
Firm 17	1	0	1	n.a.	1	n.a.	0	n.a.	1
Sub-total	**11**	**113**	**11**	**112**	**10**	**23**	**2**	**16**	**16**
Total	**124**		**123**		**33**		**18**		**16**

Legend:

n.a.= not answered; n.d.= number of innovations not disclosed.

* = Firm produces both services and products; was unable to state whether the innovation referred to a service or product.

Source: own elaboration from fieldwork data collection.

Of the 10 firms that commercialized *software services*, three account for 90% of total firm level innovation. Table 2 shows that the number of national level innovations is much smaller compared to new software products and especially international innovations, and shows also that four firms stand out for innovative performance.

Firm 5 achieved the highest number of innovations (44), but all were products

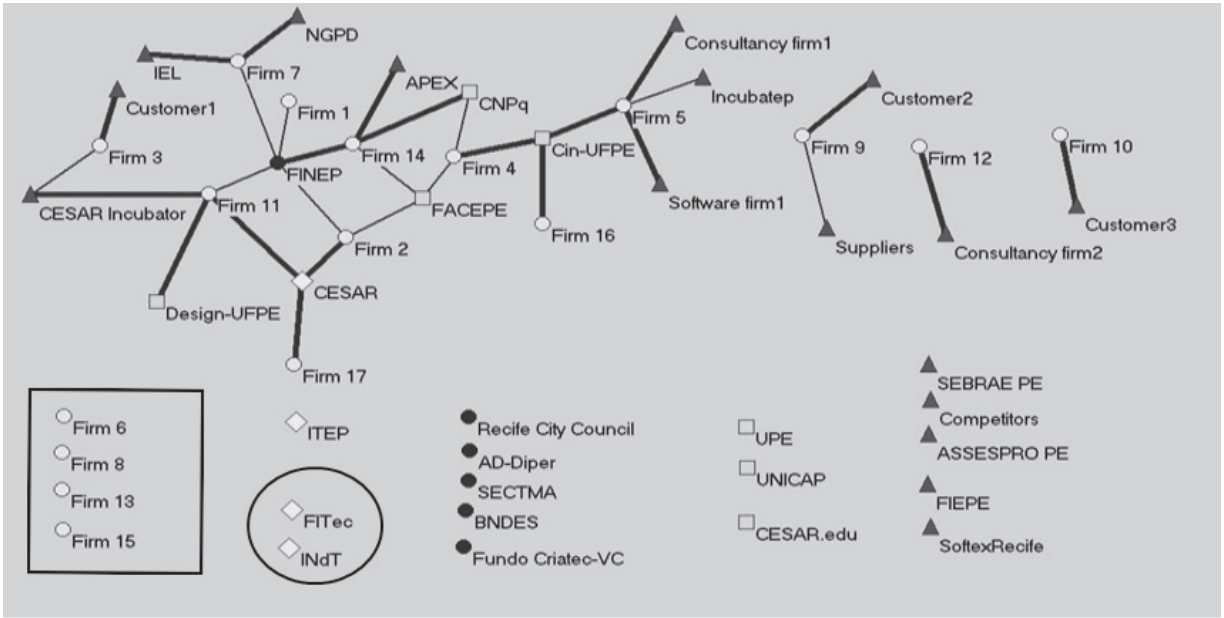
that were new to the firm and resulted from the firm's participation in one-off projects. An interviewee from Firm 5 told us that: 'every project demands a novelty that has to be learnt by us, so the way I see it is that every project is an innovation … but we are aware that the new knowledge employed by us has already been used by others' (Recife fieldwork firm interview). Although Firm 1 has produced fewer innovations than Firms 5, 11 and 12, most are new to the national market and one is new to the world, although at the time of data collection had not been exported. The firm directs its investment mostly to the domestic market and is among the small group of firms with no external ties to support innovation. Firm 11 is involved in all the types of innovation in Table 2, and most are new to the international market, involving new technologies and, in some cases, application of a business model not previously used for the type of software developed.

Table 2 summarised also *ongoing innovation projects* and shows that most (13) Recife software firms were involved in developing new software products or services at the time of the data collection; all the firms had created external ties to support their innovation activities (Figure 3). This was as expected because most firms had developed customised software during the period of investigation, and one would expect local firms to have responded to new customer demands. Also, most firms in the sample are micro or small firms, and it is reasonable to assume they depend on customers to finance financing their innovation. However, close examination shows that not all Recife innovative firms invested in new innovation projects in response to market demands; this includes Firms 1, 2, 7, 14, 16 and 17. Four firms (1, 2, 7 and 14) had created external ties and relied on public funding to invest in software products or services to respond to potential demand. Other firms involved in ongoing innovation projects stated that their new products or services had been financed by their customers (e.g. Firms 3, 5, 9, 10, 11 and 12).

Most ties were with actors in the business sub-network, followed by the skills, finance and technology sub-networks. Some firms, such as Firms 4 and 7, had relinquished ties created in the commercialised innovation stage; however, both these firms had created other ties, indicating that ties may be abandoned and reformed or replaced as to respond to the requirements of different innovation projects. Firms 4 and 7 had abandoned their ties with SoftexRecife, ties that in the commercialised innovation stage had provided referrals to new customers. Neither firm was using SoftexRecife for their ongoing innovation projects. Another finding with regard to the creation of external ties for innovation is the increasing number with funding organisations from both the skills and financial sub-networks. Three firms had set up ties with FACEPE and five firms had ties with FINEP. This suggests that Recife software firms were increasingly more able to access public funding offered by local organisations (e.g. FACEPE) or national funders (e.g. FINEP), although most ties were loosely-connected.

As expected, most of the direct ties created by Recife firms are tightly-connected ties. In addition, although the representation of the network of innovators in Figure 3 shows that the network of innovators is fragmented (as opposed to well-knit), in this innovation stage there was only one main cluster of nodes (rather than 2 as in the commercialised innovation stage), involving 10 innovative firms and the other 14 network actors. Three firms had created isolated ties, Firm 9 created a triad, and Firms 10 and 12 had created binary ties.

Figure 3 - The Recife software network of innovators: ongoing innovation projects



Legend:

● Firms; ♦ Technology sub-network; ■ Skills sub-network; ▲Business sub-network

● Financial sub-network

Tight connections = ━━━━ ; Loose connections = ————

□= Non-innovating firms, April 2009.

○= Autonomous private non-profit R&D organisations originally set up by multinationals disengaged from the network of innovators.

Source: own elaboration based on fieldwork data collection.

Examination of the structure of the network of innovators shows that some of the ties in the commercialised innovation stage had broken down, especially those with business and skills sub-network actors. These were not always loosely-connected ties, as might have been expected. The completion of innovation projects financed by FACEPE explains the break down of ties with that organisation; Firms 7 and 16 were no longer being financed by FACEPE in the ongoing innovation stage. In the case of SoftexRecife and NGPD the discontinued ties had been tightly-connected ties. In the case of Firm 13 there was no involvement in ongoing innovation projects at the time of data collection.

More important than the discontinued ties, were the new ties created by firms. Firstly, Recife software firms accessed funding from FINEP, which engaged in the main network of innovators through the creation of ties by five firms.[11] The majority of the ties created with FINEP were loosely-connected, that is, they were more frequently related to the motivations of 'opportunity' (there was a call where the firm fitted the requirements) and 'costs' (FINEP provides non-reimbursable grants). This confirms the lack of access of the financial sub-network discussed for commercialised innovations. Secondly, the ties with business organisations that were new compared to the commercialised innovation stage, such as the Euvaldo Lodi Institute (IEL) and the Brazilian Trade and Investment Promotion Agency (APEX), were tightly-connected

11 Firm 1 was the only firm in the sample that was awaiting a response to its research funding application.

ties. In the case of the tightly-connected tie between Firm 14 and Apex, this was based on 'trust' and 'knowledge availability and accessibility' (Recife fieldwork firm interview). Thirdly, firms disengaged from the main cluster of nodes in the commercialised stage were engaged in the ongoing innovation stage; for instance, Firm and Firm 11, and CESAR's cluster of nodes being tied to the main cluster represents an improvement in the network.

ANALYSIS

The results show that the level of diffusion of formal interactions is intermediary in the Recife software network of innovators. Although the structure of the network is fragmented, key local actors, keen to support the development and growth of Recife local software firms, are active in the network – at least to some degree. The Recife case shows an interaction between technology policy and network governance and structure in Recife, and a large share of innovative firms engaging in the network to develop their innovation activities. Based on the implementation of state policy to promote networks, and our findings, we can conclude that the promotion of local networks *has* increased the effectiveness of policy directed at improving local innovation performance. We found also that the absolute number of innovations produced by Recife firms was quite large for a laggard region with a relatively new industry. Most of these innovations were new to the firm, suggesting adherence to a strategy of imitation (i.e., recombining existing knowledge) rather than fundamental innovation. This possibly relates to local firms' profile; the majority of firms develop customised software of medium technology intensity and prefer learning from experience aiming to accumulate internal capacities. These will require a level of understanding of localised knowledge that might be accessed in future learning by interacting, when a less fragmented network may emerge.

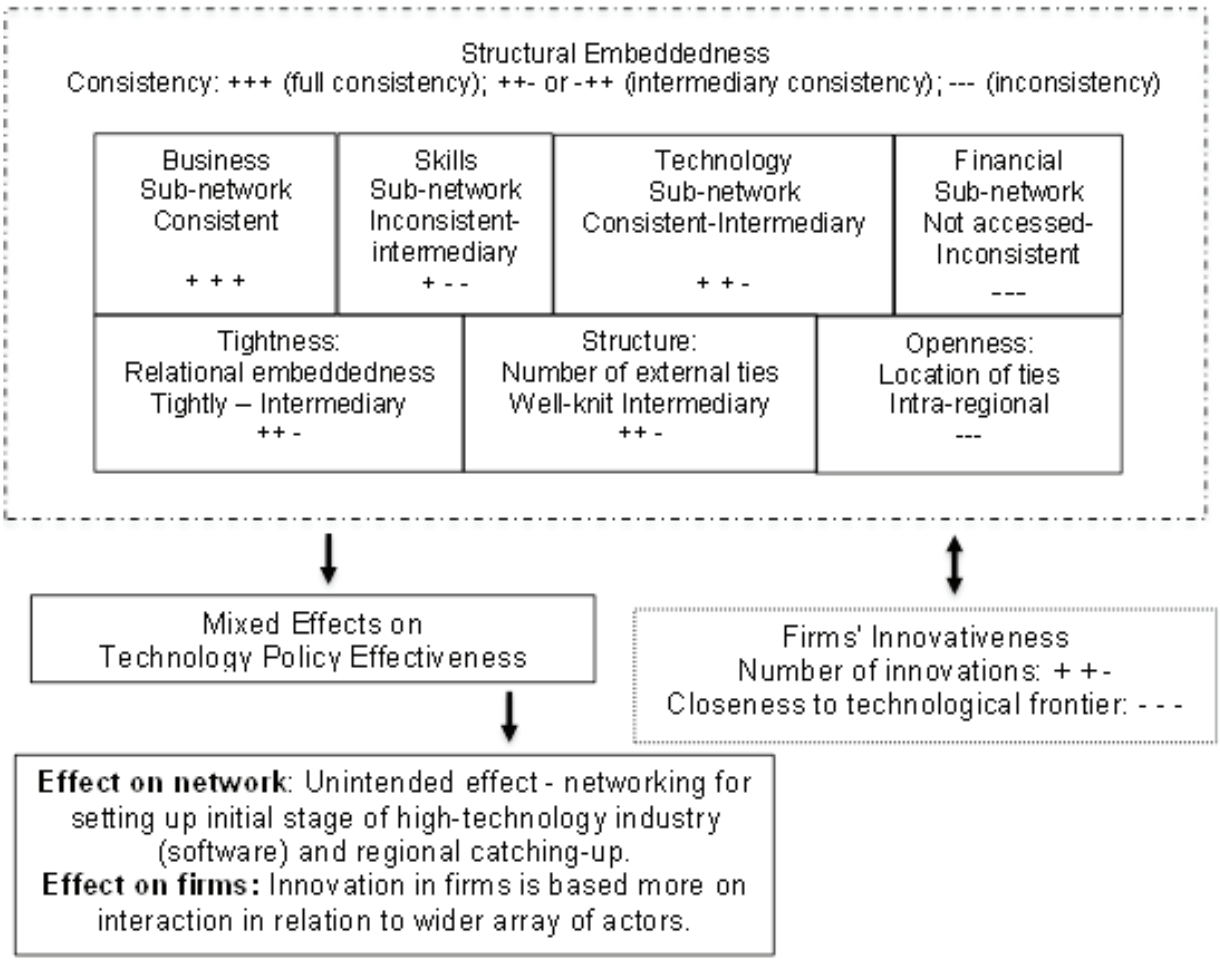
An alternative interpretation is that because many of these innovative firms are small firms, their innovation strategies are largely based on responding to customer demands which do not involve radical innovation. Recife software firms recombine existing knowledge, often directed to local (as opposed to global) and vertical markets. This result was expected; local software firms in laggard regions often adopt such a strategy as a first step towards penetrating local and national markets.

The influence of network governance and structure on the Recife software network of innovators is also mixed in terms of the effect on government technology policy for firm innovation. The results for the network's *structural* and *relational* embeddedness differ. The findings for *structural* embeddedness indicate some level of inconsistency in the skills sub-network (although this primarily is related to funding). They show also low levels of engagement in the network of crucial actors such as university departments. Examination of the ties with local technology sub-network actors shows that local firms have ties with only one local R&D organisation, although this organisation is strongly related to its cluster of nodes. The level of interaction among local firms in Recife is low compared to its full potential.

The results for *relational* embeddedness of network governance and structure show that most direct ties are tightly-connected and, as already discussed, interactions aimed at knowledge exchange and learning among actors require tightly-connected

ties. These findings indicate that the *relational* embeddedness of the Recife network's governance and structure is more constructive than its *structural* embeddedness in terms of influencing technology policy for firm-level innovation through the promotion of networks. Figure 4 summarises the main findings and analysis of the Recife innovation networks, following the indicators developed and summarised in Figure 1.

Figure 4. Recife network governance and structure indicators



Source: own elaboration based on fieldwork (PAMPLONA DA COSTA, 2015).

6. CONCLUSIONS

This study contributes to knowledge in two related areas. It contributes to work on systemic relations and innovation. The method employed in this study advances knowledge about network alignment by operationalising this concept. The analytical framework proposed in this article (Figure 1) allows investigation of the interactions among different networks (described here as sub-networks) with different purposes and membership, and based on different principles. This highlights that a given network may perform according to its stated principles or the principles related to network membership (here, the consistency of networks, i.e., *alignment*), or may depart from performance and/or membership principles (represented here as the inconsistency

of networks, i.e., *misalignment*). Hence, this analysis differentiates sub-networks according to their purpose and provides empirical evidence which questions whether mapping of predominant purposes or use of other conventional techniques to depict networks, is adequate to reveal the influence of networks on innovation effectiveness.

The second contribution of this study is adding to the knowledge on technology policy effectiveness. A general technology policy prescription for the formation of networks as a mechanism to improve firm-level innovation and regional catch-up (such as SOFTEX and Porto Digital), requires careful consideration of the intended effects. The network governance indicators point to the expected *predominant* network outcomes (Figure 1), in which networks presenting more positive outcomes show more effective governance, leading to better innovation performance. Our findings show that high-technology (software) firms, in Brazil (country that is at an intermediate level of development), and which has large regional disparities (Lastres, 2007; Teixeira, 2008), engage in networks in specific ways that bound the innovative performance. We found that those firms engaged in networking show quite high levels of innovative performance in absolute terms, but produce innovations that are more distant to the technology frontier. However, networking seems to be supporting the engagement and development of a particular region – Porto Digital – in a high-technology paradigm to overcome a previous period of socioeconomic and territorial crisis. The Recife Island suffered with the decadence of its key economic activity (maritime shipping and port activities) before the 2000s and public policy for network formation seems to be successful in establishing a new economic activity (software). In 2018 the region still hosts approximately 190 information technology firms and has widened its scope to also host 39 firms in the creative economy (http://www.portodigital.org/home, last accessed in 02 December 2018).[12] Key supporting organisations, such as NGPD, SoftexRecife and CESAR, are present in the region nearly over 20 years. This is remarkable for a laggard region that been addressed by public policy, avoiding discontinuity that has been characteristic of government initiatives in Brazil.

There are some practical implications for policy. Our results suggest that network promotion policies on their own may not be an efficient mechanism for improved innovation performance and economic catch-up. Also, our findings of inconsistency of sub-networks that present different functions (i.e., *misaligned networks*), and poor engagement of organisations expected to play a primary role in fostering development and catch-up or to be relevant for the innovation development process, suggest some reformulation of their organisational missions, and policies aimed at promoting formation of networks should take account of these issues.

The study has some limitations. The choice of the software industry limits generalisation of the findings on network governance and structure. Investigation of network governance and structure in industries that require the creation of different types of external formal ties to those that apply to software development might produce different results from those in this study. Also, the data refers to the period 2006-2009, and an updated study might bring different evidences for the indicators employed in this study. Considering that regional networks embedded in laggard regions take time to develop and stabilise institutionally and in terms of innovation performances, we find that a new study in the region is an opportunity for future research, where issues related to network dynamics and regional resilience can be addressed.

12 A new initiative has been established in the Municipality of Caruaru (Pernambuco State) where one firm is linked to Porto Digital initiative (http://www.portodigital.org/empresas/empresas-embarcadas/empresas-em-caruaru, last accessed in 02 December 2018).

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