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Network (Mis)Alignment, Technology Policy and Innovation: The Tale of Two Brazilian Cities

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Network (mis)alignment, technology policy and innovation: the tale of two Brazilian cities

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Abstract:

This article addresses network alignment through an investigation of network governance (coordination) and structure, and examines how regional level network governance and structure influence the effectiveness of technology policy to improve local firms' innovativeness in a developing country context. It examines whether network governance and structure have a consistent influence on firms' innovative performance in developing country regions with different levels of socio-economic development. The empirical evidence is based on case studies of the Campinas and Recife regional software networks in Brazil and the innovative performance of the participating local firms. We find that adoption of a general technology policy prescription 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 necessary condition for improved innovation at firm level.

Key words: network alignment; network governance; Brazilian software industry; innovation networks; technology policy effectiveness; regional development

JEL Classification: O1; O29; O38; O54

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1. Introduction

The concept of network alignment was introduced by von Tunzelmann (2003), in the context of the relation between networks and innovation. Network alignment is a systemic approach and assumes that *heterogeneous* networks involve different elements that pull in similar directions (von Tunzelmann, 2003: 46) and have different ability to achieve the goals of the systems in which the networks are embedded (von Tunzelmann, 2010: 4). Government policies to encourage formation of networks to promote technological development need to take account of network alignment (Kim and von Tunzelmann, 1998). Networks have *multiple* functions (and different levels of effectiveness) and may not be a sufficient mechanism to foster knowledge exchange among the actors or promote learning by firms without some level of alignment.[1]

This paper focuses on network alignment through an investigation of *network governance and structure*. Network governance is defined here as inter-organisational coordination (Bevir, 2009: 57) which is exerted in the particular institutional setting (Jones et al., 1997: 913) in which the innovation network actors are embedded. Network structure refers to the age and historical evolution of the network (Dodgson, 2011) and the level of formal interactions (Burt, 1992).

Technology policy in developing countries is being aimed at network formation as a mechanism to foster firm-level innovation (see Dodgson et al., 2008), mirroring successful innovation performance in the advanced countries (Ahuja, 2000; Bresnahan et al., 2001; Herrigel, 1993; Kenney, 2000; Lazerson, 1993; Okimoto, 1989). However, the effectiveness of these developing country policies needs more research. Networks are characterized by sets of elements that supposedly are conducive to innovation. They 'breed trustworthy relations' among economic actors (Giuliani, 2010: 264; Granovetter, 1973, 1985), 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 and Grodal, 2005).

Previous studies include work on the conceptual role of networks (Powell, 1990), networks of innovation (Cantner and Graf, 2010; Freeman, 1991; Powell and Grodal, 2005), network dynamics (Giuliani, 2013), industrial clusters and networks (Cooke, 2001; Giuliani, 2010),

[1] See Bodas Freitas and von Tunzelamnn (2008) for a discussion of policy alignment.

knowledge networks (Dantas and Bell, 2009), social networks and embeddedness (Granovetter, 1973, 1985), networks and strategic alliances (Jorde and Teece, 1989), network governance (Jones et al., 1997) and networks in developing countries (see, Dodgson et al., 2008; Giuliani, 2010; Kim and von Tunzelmann, 1998; Perini, 2009; Ramirez and Dickenson, 2010). All 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. Networks encourage shared complementary knowledge and problem solving. However, the focus so far has been on network structure and the belief that networks can lead to positive outcomes.[2] Their structure is often measured using static indicators (see Giuliani, 2013 for a discussion on network dynamics).[3] There are no studies that address the *multiple functions* of networks explicitly. The present paper investigates the following research question: *In developing country contexts, how do the network governance and structure influence the effectiveness of technology policies that promote innovation based on the formation and evolution of networks?*

We address this question through an analysis of the software innovation networks embedded in two Brazilian regions. Evidence from developing countries, such as Brazil, is particularly relevant and challenges the view that support for networks that is based on prescriptions for the advanced economies, is sufficient to foster firm-level innovation. Systems of innovation (SI) in emerging economies, and innovation networks as a sub-set of these systems, often have 'missing' links (Bell and Albu, 1999; Chaminade and Vang, 2008; Cimoli, 2002), and/or 'dysfunctional' links (Bell and Pavitt, 1993; Cassiolato et al., 2003).

The regional Brazilian software innovation networks we investigate were created within a federal government programme, SOFTEX, in the early 1990s. 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 91 semi-structured (mostly face-to-face)

[2] E.g. Mazzucato (2013) discusses the importance of networks in the evolution of information technology in the USA.

[3] 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); and empirically, see Grabher (1993).

interviews with the regional software networks of innovators.[4] The innovation networks were split into four sub-networks with different functions and aims.

Section 2 describes the background to the research and Section 3 presents the methods and the analytical framework. Section 4 introduces the cases and discusses the results for the Campinas and Recife cases respectively. Section 5 presents the case study analysis and Section 6 concludes and outlines the contributions and policy implications of this study.

2. Background

Technology policy and networks

The roles of the state and government intervention (Block, 1994; Mazzucato, 2013; Stiglitz, 2002) in the form of technology policy for industrial development (Ergas, 1987; Pavitt, 1987), for promoting social welfare, are related to the formation and evolution of networks. The issues involved include whether the economic actors will be responsive to policy interventions in light of their history and experience of a particular economic setting, and whether the state is capable of assessing whether strategic alliances among economic actors should be fostered or left to emerge as a consequence of self-interest. There is a second issue which is related to the definition of technology as a partly public good (Mowery, 1995; Storper, 1995), as inherently risky, with possible negative externalities such as free-riding and incomplete appropriability of private profits (Dasgupta, 1987). This could result in under-compensation for the costs of investment (Steinmueller, 2010). In relation to the issues of appropriability and risk, government intervention might be both necessary and, from a social welfare perspective, justified.[5]

Government can facilitate the formation and maintenance of networks by funding institutions that develop new scientific or technological activities, and supporting the training of skilled labour (Mowery, 1995). This fosters the formation of informal networks among actors with a common professional background and provides the opportunity for individuals and organisations to engage in scientific and technological development communities (Salter and Martin, 2001). This type of policy has proved important for public-private sector

[4] Another 12 interviews were conducted during the pilot fieldwork.
[5] In contrast to the approach in this paper, Fuchs (2010) examines the case of the US Defense Advanced Research Projects Agency in the period 1992-2008 and shows that the role played by its programme managers' networks were crucial for supporting identification and development of new technologies for the US defence industry.

collaboration (Faulkner and Senker, 1995) and the establishment of ongoing networks of participants.

New regulation to improve relations among the actors and agents involved in technological activities and innovation can also influence the formation and maintenance of networks.[6] More fundamental science and technology policies promote the formation of networks and include, among other things, actions related to basic research, higher education, public procurement, subsidies and tax reductions (Lundvall and Borrás, 2005; Mowery, 1995).

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. 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 (Asheim and Gertler, 2004; Boschma, 2005; Boschma and Martin, 2010; Cooke and de Laurentis, 2010; Storper, 1995). These spillovers can occur through labour mobility within a delimited geographical area.[7] However, policy should take account of differences in economic and social settings which might influence its implementation and results (Dasgupta, 1987) and also the particularities of the technologies (sector related) and local contexts (region related).

Networking in the software industry

The software industry is a highly creative sector, involving new learning which 'springs from the non-repeating nature of the task' (Brooks Jr., 1995: 7). Software development involves systematic planning of the division of labour (Brooks Jr., 1995), systematic documentation and training (Cusumano and Selby, 1995), and well established communication and coordination among software programmers (Heeks et al., 2001). 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 and Torrisi, 2001: 1428) and to create ties with external actors such as universities, suppliers, competitors and users. Although there may be patterns of

[6] Steinmueller (2010: 1192) refers to this as policy as 'thematic funding' whose requirements may include project teams with industry and academic membership.
[7] 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. The relevance of indirect technology policies is beyond the scope of this article. See Ergas (1987), Mowery (1995) and Steinmueller (2010) for more discussion of these issues.

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.

The international software industry is highly concentrated, especially in the development of packaged and platform applications, which mainly is dominated by US software suppliers (Steinmueller, 2004). Most software firms innovate by differentiating and customising their products to particular application contexts, which often involves close relationships with customers (users). Software developments frequently require knowledge that is accessed via networking with, for instance, supplier firms, complementary firms, university researchers and competitors. In some cases, 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 and Torrisi, 2001).

Market-oriented ties may include the use of established systems or platforms that benefit from the network externalities derived from well-diffused technologies developed by the platform providers, which can be customised (often as a value-adding computer service activity) to particular users (Shapiro and Varian, 1999). 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), in a study of Bulgarian software firms argues that a high level of absorptive capacity (Cohen and Levinthal, 1990) is one of the requirements for technological catch-up at firm-level, and that customers often play a crucial role especially in relation to customised software. Rousseva does not investigate the role of networks in the Bulgarian software industry, but her results show that networking with customers is relevant for the development of local software firms in emerging economies contexts. 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.

Network governance and structure in developing countries

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), within a single analytical framework (see Figure 1). 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 and Graf, 2010; Giuliani, 2010), but the role of dyadic ties remains largely unexplored. Tie strength does not always determine tie value because ties can play different roles (Burt, 1992, 2010; Granovetter, 1973) 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: 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 SI. Section 3 presents the conceptual tools and methodology employed for this study.

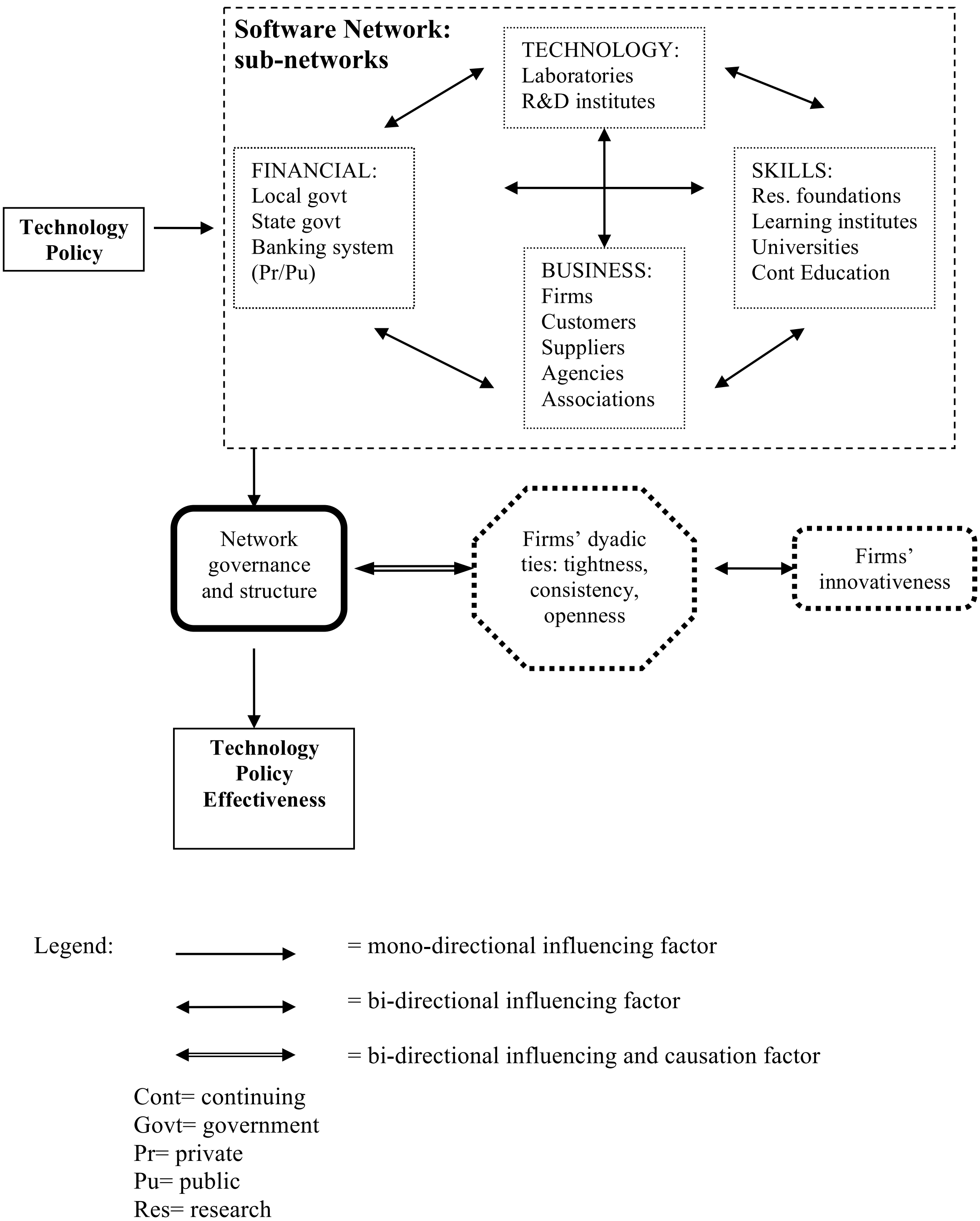
3. Methods and analytical framework

Multiple case study

We use a multiple case study method to address our exploratory research question and analyse networks in regions with contextual conditions that change over time and, thus, warrant in-depth analysis (Yin, 2003). SNA does not capture historical trends or regulatory and institutional issues (Grasenick et al., 2008 :309-310). 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).

We examine the structure of networks, their controlling mechanisms, features and motivations for dyadic tie formation, and the *multi-functions of the sub-networks* within the innovation network. This contributes to the operationalisation of the network alignment concept developed by von Tunzelmann (2003, 2010), as summarised in Figure 1. Network structure refers to whether the network is emergent (based on incidental interactions) or purposive (intentionally and strategically created) and which actors participate in the network. Here, we investigate purposive networks. Consideration of network age and evolution in our analyses of firms' innovation activities contributes to work on industry development (Dodgson, 2011).

Figure 1 Analytical Framework



Source: Pamplona da Costa (2012), adapted from von Tunzelmann (2010: 16).

Some of the actors were identified by consulting publicly available reports, academic studies and specialist press, on technology policy in Brazil. In order to examine governance and multi-functional roles, we split the innovation network into *four sub-networks with different functions and aims*: business, skills, technological and financial. This is in line with the argument that innovation networks are a sub-set of SI (Cantner and Graf, 2006; Cimoli, 2002); 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.

The case studies: technology policy aimed at the creation and evolution of networks

We selected two purposively created software innovation networks, Campinas and Recife. They were created by the Brazilian national government in the early 1990s within the framework of the SOFTEX Programme (Afonso et al., 1999). The SOFTEX Programme created a SOFTEX nucleus of firms in several Brazilian regions, to support firm-level innovation. Only the firms that belonged to these were able to benefit from the incentives offered by the programme. The rationale 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. The regional criteria for receipt of a SOFTEX grant included: a 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.

The SOFTEX programme granted US$1m (an approximate nominal value for the year of 1993) to the Nucleus in the form of National Council for Scientific and Technological Development (CNPq) scholarships for firms developing projects related to exports, and provided legal and marketing consultancy, and updated hardware to support software development. The SOFTEX Programme failed in its original aim of a 1% global share of the software industry by 2000 or an estimated US$2bn. In 2000 it had 0.03% of the global software market (MIT-Softex, 2002). However, it 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 (Roselino, 2006; Stefanuto, 2004).

Indicators of network governance and structure

Qualitative indicators are needed to examine network governance and structure. Despite increased interest in methods aimed at capturing the meaning of network ties (see Ceci and Iubatti, 2012), there are few qualitative indicators that can be replicated consistently to investigate the governance and structure of networks in different contexts (i.e., regions with different socio-economic indicators and different industries) (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.[8]

The consistency of the sub-networks indicator measures structural embeddedness and the 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 (see Table A1 for a summary on the consistency of each of the four sub-networks investigated). 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.

[8] These indicators have some overlaps with SNA measures; however, these latter derive from a static approach and are not adequate for the detailed examination of network governance, structure and alignment proposed here.

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.[9]

The level of network openness refers to the geographical localization of collaborating network actors, and supports conclusions about the regional network's vulnerability to lock-in (Boschma, 2004; Grabher, 1993). Indicators to measure firm-level innovation follow the Oslo Manual recommendations (OECD, 2005); the data we collected for firm-level innovation are for the period 2006-2009. Table 1 summarizes the network governance indicators, suggesting the expected *predominant* network outcomes.

[9] 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. This follows the system of innovation and network of innovator approaches, where connections are crucial for learning by interacting. Well-knit derives from medical terminology to describe the healing process of broken bones: those that join firmly are described as well-knit.

Table 1 - Summary of network governance indicators and variables for analysis

Indicators	Variable	Potential network features and intensities*	Possible outcomes
Consistency	Feature of external tie created by each firm:	Consistent sub-network = (+ + +) Full/Large overlap between features of external ties created by each firm, and aims of each network actor	i) High occurrence of overlapping aims ii) Higher chance of policy effective results
		Inconsistent sub-network = (- - -) None/Small overlap between features of external ties created by each firm, and aims of each network actor	i) Low occurrence of overlapping aims ii) Lower chance of policy effective results
Tightness	Motivation for external tie creation by each firm and frequency of ties occurrence.	Tightly-connected ties = (+ + +) Higher number and frequency of strong ties	i) Lower vulnerability to break when put under pressure ii) More reliability in the transmission of information within the network
		Loosely-connected ties = (- - -) Lower number and frequency of strong ties	i) Higher vulnerability to break when put under pressure ii) Less reliability in the transmission of information within the network
Structure	Number of external ties created by each firm	Well-knit network = (+ + +) Higher number of ties among local firms and network actors	i) Lower probability of missing links among actors
		Fragmented network = (- - -) Lower number of ties among local firms and network actors	ii) Higher probability of missing links among actors

*Intermediary stages for each indicator are represented as follows: intensity closer to full network features equals to (+ + -), and intensity closer to absence of network features equals to (+ - -). Figure 5 in section 5 summarises the results for the two investigated networks. Source: own elaboration based on Pamplona da Costa (2012).

Data collection and analysis

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: 97); and provided additional historical information on the case study areas. A total of 91 interviews was conducted, 84 face-to-face and 7 by telephone (see summary in Table 2).

Table 2 - Total number of interviews by type of organisation

Type of organisation	Number of interviews Campinas	Number of interviews Recife	Total number of interviews
Consultants	2	1	3
Firms	21	17	38
Government representatives	2	2	13*
Incubators	3	2	5
Research centres	4	4	8
Research foundations	1	2	3
Supporting organisations	7	6	13
University faculties	4	2	6
Venture capital fund	2	0	2**
Total	46	36	91

Legend: *= total number of representative including national government. Number of government representatives interviewed in Campinas=4, Recife=2 and national government= 9.

**= venture capital fund representatives were based in Campinas city, but their activities related to the Brazilian national territory.

Source: own elaboration from fieldwork data collection.

The criteria for selecting firms included: size, age, and type of software activity, that is, product or service complexity.[10] The firm sample included 21 firms in Campinas and 17 in Recife (respectively 19.6% and 16.3% of the total populations of firms). The firms differ in age and size (Table 3), and cover a wide range of production activities.

[10] 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 employees; ii) small firms = 10 to 49 employees; iii) medium firms = 50 to 99 employees; 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 (80% in Campinas and 70% in Recife) unable to emply many staff on a permanent basis. The number of seasonal employees is often higher than the number permanent employees.

Table 3 - Campinas and Recife software firms' profile (age and size)

	Age/Size	Micro	Small	Medium and Large
Campinas	Younger than 5 years	7 Firms	2 Firms	-
	6 to 10 years	2 Firms	3 Firms	2 Firms
	11 to 15 years	-	3 Firms	1 Firm
	Older than 16 years	-	-	1 Firm
Recife	Younger than 5 years	1 Firm	3 Firms	2 Firms
	6 to 10 years	-	4 Firms	-
	11 to 15 years	-	3 Firms	1 Firm
	Older than 16 years	-	1 Firm	2 Firms

Source: own elaboration from fieldwork data collection

Data analysis was conducted in three stages: i) interview transcription; ii) construction of network governance indicators; and iii) analysis of the variables and application of quantitative research methods and SNA software Pajek (2-mode matrix) (de Nooy et al., 2005) to support individual visual representations of the two networks. If 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.

4. The Tale of Two Cities: Campinas and Recife

The cases identified are two regional software innovation networks that participated in the SOFTEX Programme - Campinas and Recife. These innovation networks are based in regions at different stages of industrial development and different levels of socio-economic development. We are interested in whether the historical institutional development has a persistent influence on the evolution of the related innovation networks.

4.1 - The Tale of City 1: Campinas software innovation network

Campinas is in the most economically developed region of Brazil, São Paulo State in the Southeast.[11] In 2010, the Campinas share of Brazil's population was 42.1% and the São Paulo State share was 21.6% (IBGE, 2010a). Respective GDP in 2008 was 56.0% and 33.1% (IBGE, 2008). These indicators are evidence of the economic potential of São Paulo state. In 2008, per capita GDP in Campinas was US$11.9K compared to the national average of

[11] The country is comprised of 27 states (Brazilian Institute of Geography and Statistics-IBGE).

US$6.8K.[12] In 2010, the population of the Campinas City was 2.6% of total São Paulo State population and 0.6% of the total population of Brazil (IBGE, 2010b).

Campinas has benefited from national and state level policies to support regional industry development since the late 1960s, mainly through the establishment of both private and public organisations engaged in research and scientific activities in information technologies (IT). The strong economic and industrial dynamics of São Paulo State and Campinas city are paralleled by a strong and well-established regional scientific system. The São Paulo State Research Foundation (FAPESP, created in 1962) is one of the most important public research funding organisations in Brazil, with an estimated budget of US$402m in 2009.[13] Campinas is geographically close (100km distant) to São Paulo, the capital city of São Paulo State, which is one of the most economically dynamic cities in Brazil. Campinas city is host to one of the best-reputed public research universities in Brazil, the State University of Campinas (Unicamp),[14] which conducts research in several disciplines, and the region includes several private teaching universities. There are six IT related R&D centres (2 public – founded in the 1970s and 1980s, and 4 private – founded in the 1990s) and three publicly supported incubators which support software start-ups in Campinas city and its surroundings, which contribute to the development of the regional benefit the software industry (Table A2 presents the main organisations established in the region).

4.1.1 Structural Embeddedness: The consistency of the Campinas four sub-networks

The features of the dyadic ties created by Campinas firms indicate the consistency of the four sub-networks examined.[15] The business sub-network was the most frequently accessed by Campinas software firms and presented the highest consistency among the investigated sub-networks. This indicates a high level of overlap among the reasons that firms create ties and the aims of the business organisations they tie to. The business actors with the highest number of ties are incubators, customers and other software firms. In contrast to expectations, reasons such as ‘acquisition of knowledge and technology’, were rare; the firms develop customised software applications that require close user-producer relationships and a good understanding

[12] Exchange rate based on Brazilian Central Bank conversion rate of R$1 = US$2.337 at 31.12.2008. Available at http://www4.bcb.gov.br/pec/conversao/conversao.asp, accessed 16.6.2011.
[13] Fieldwork interview in Campinas.
[14] According to the QS Ranking, Unicamp is 9th in the 2014 BRICS ranking (http://www.topuniversities.com/node/2250/ranking-details/brics-rankings/2014); 3rd in the 2014 Latin America ranking (http://www.topuniversities.com/node/2250/ranking-details/latin-american-university-rankings/2014), and 215th in the 2013 world ranking (http://www.topuniversities.com/node/2250/ranking-details/world-university-rankings/2013), accessed 28.7.2014.
[15] Table A2 shows the main activities of some of the Campinas software network actors.

of the customer's business and technologies, which are expected to enable acquisition of knowledge (Brooks Jr., 1995). There was an inconsistency demonstrated by the case of a tie between two software firms that developed complementary software. It was for financial reasons, and not as although be expected related to 'access to new knowledge' and 'innovation cooperation'. This tie was driven by compliance with a of the funding agency financing the development of the new software.

The skills sub-network was the second most frequently accessed sub-network, with universities being the most frequently accessed type of actor. Technical colleges, continuing education organisations, research councils and research foundations were rarely accessed. The inconsistency within this sub-network is that the ties formed by local firms with eight university departments were not aimed at acquisition of knowledge. This is an unexpected result since educational organisations and, especially universities, produce new knowledge that potentially could be used in the private sector.

Similarly, acquisition of technology was expected to be relevant for ties with skills sub-network actors, but was rarely mentioned: it was cited as relevant by (only) one firm in the network, and referred to a tie with a university department and related to the type of knowledge required specifically by that firm and its availability in the university:

> Their [university department] technology is complementary to what we do, and collaborating with them gives us access to the technology we need at a much cheaper price than offered by the private sector, this is one of the main reasons why we created ties with these two [not disclosed to avoid their identification] university departments (Campinas fieldwork firm interview).

Innovation co-operation and access to open information sources were also not cited, confirming the inconsistency of this sub-network. Dyadic tie creation with research councils and research foundations was also not based on either acquisition of knowledge or acquisition of technology. Research councils provide funding for the performance in firms of basic and applied research and development (R&D) activities that are directly related to the creation of new knowledge and technology. In this sub-network, *only* access to new sources of financing was cited as relevant for tie creation, demonstrating another inconsistency in this sub-network, and suggesting that Campinas firms might be replacing private finance with public funding for their R&D activities.

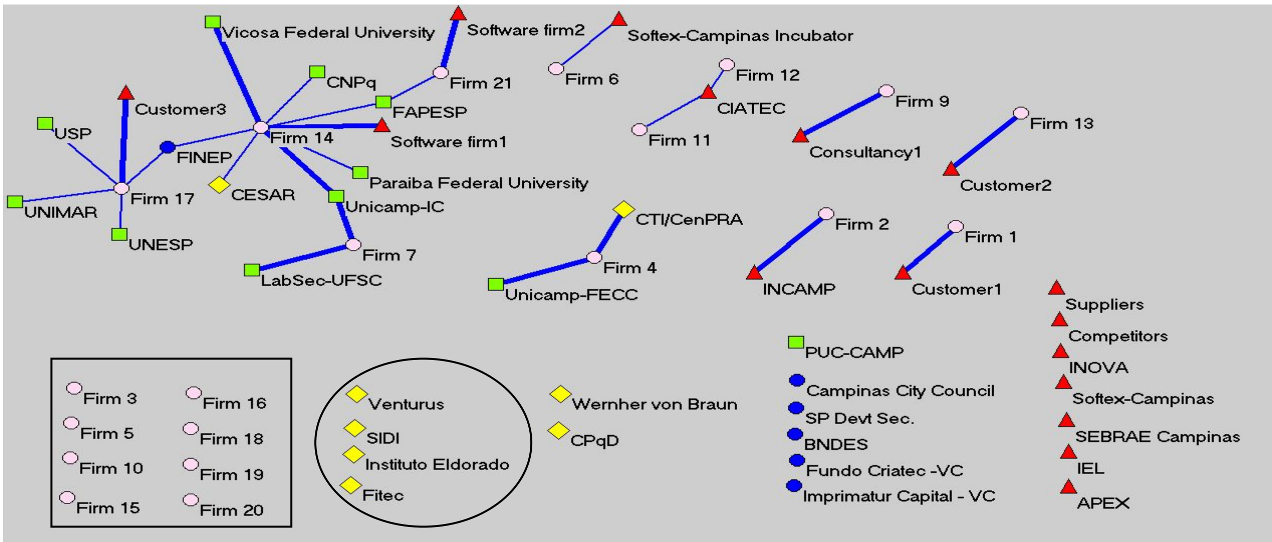
The technology sub-network was the third most frequently accessed sub-network by the local Campinas software firms. The drivers of tie creation include innovation cooperation, which suggests that the sub-network is consistent. However, the absence of acquisition of knowledge and technology was an unexpected result and is an indication of inconsistency in this sub-network. The number and frequency of firm ties with the financial sub-network are the lowest among the four sub-networks investigated. Ties motivated by access to new sources of financing show the consistency of the sub-network. However, there is evidence of some level of inconsistency in that only one firm referred to innovation cooperation and acquisition of knowledge and technology as reasons for creating ties with a funding agency to obtain funding for firm-level innovation. All three of these features are crucial for innovation.

4.1.2 Structure of the Campinas Network and Relational Embeddedness

The number of firms that innovated, and whether they created external ties to support their innovation, shows that almost all Campinas firms innovated during the period 2006-2009.[16] This was expected because innovation is intrinsic to software industry developments (Brooks Jr., 1995; Grimaldi and Torrisi, 2001; Steinmueller, 1996). Forty per cent of interviewed firms had no external ties to support their innovation activities, and innovated alone (Figure 2). This suggests that the Campinas network of innovators is fragmented rather than well-knit and that there is a low level diffusion of information in the network of innovators, which might have implications for network effectiveness.

[16] The exception is one firm that, at the time of data collection, was being incubated and had yet to commercialized the innovation.

Figure 2 - The Campinas software network of innovators: commercialized innovations during 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 commercialised innovation.
○= Autonomous private non-profit R&D organisations originally set up by multinationals that are disengaged from the network of innovators.
Note: Firm 8 did not commercialise innovations during the period under analysis.
Source: own elaboration based on fieldwork data collection.

Although the structure of the network is not well-knit, the majority of ties are tightly-connected. Loosely-connected ties are more frequent among network actors in the skills and technology sub-networks and generally involved firms in the main cluster of nodes (Figure 2). The existence of loosely-connected ties was more frequent than expected and an unexpected result, because ties created with organisations involved in the creation of new knowledge or technology presumably are motivated by trust, collective identity, knowledge availability and accessibility while loosely-connected ties are related to cost and opportunity motivations, financial issues and requirements for ties. The reasons for the loosely connected ties related to opportunity and cost. Cost relates to ties created with funding organisations. Opportunity applies to ties with university departments and R&D organisations, both outside the region. These motivations are related to the inconsistencies of the skills and technology sub-networks (discussed in Section 4.1.1). The motives for these loosely-connected ties with three university departments are customer requirements and contract terms. According to an interviewee: ‘the main reason why we got involved with these universities is because they were included in the project by the client' Campinas firm interview). Therefore, we can assume that in the absence of such a requirement they may not have been formed, which makes them somewhat 'ephemeral'. Although inter-regional ties are loosely-connected, actors engaged in the Campinas network of innovators are able to and do access other network actors outside their region. This might be relevant for avoiding the network lock-in and sclerosis.

4.1.3 Firm level commercialized innovations at the firm-level: Campinas software network (2006-2009)

The results show that there are more commercialized innovations relating to software services (17 firms) than to software products (6 firms). Among software products, two firms (Firms 2 and 7) stand out for number of innovations. Table 4 summarizes the innovation performance of local firms that commercialized software products and services.

Firm 2 has commercialized product innovations new to the firm, and has external ties with the Incamp incubator. Firm 7 has commercialized the most product innovations, all new to the national market, and three new to the world market. However, none had been exported at the time of data collection. This firm has external ties with two skills sub-network actors (university departments) that supported two of their commercialized innovations. There are various reasons for this firm's outstanding performance compared to other local firms that have commercialized software products. Firstly, this firm is an informal 'spin-off' from IC-Unicamp. Second, Firm 7 has a strong ongoing connection with the IC research group through formal training of its employees (Masters and Doctoral training), and a relationship based on trust. Relationships based on human resources training are not captured by the representation of the networks of innovators in Figure 2, which highlights the need for detailed investigation to explain the functioning of networks of innovators, and firms' innovativeness. In 2006-2009, Firm 7 had the highest number of commercialized new software services, both new to the firm and new to the national and international markets. However, it had yet to start exporting at the time of data collection.

Most firms had introduced a maximum of four new services to the market during the period 2006-2009, mostly innovations new to both the firm and the national market. Firms with new to the world innovations were in the minority, and eight firms had produced more than four software services innovations.

Table 4 New software *products* and *services* commercialized by Campinas software firms - June 2006 to 2009: outliers and total

Firm number	Total number of innovations	Innovation new to firm	Innovation new to national market	Innovation new to international market
Firm7	10+	10+	10+	3
Sub-total: products	**26**	**26**	**15**	**3**
Firm1	7	7	1	1
Firm3	99	99	9	1
Firm7	3	3	3	3
Firm12	35	35	0	0
Firm15	30	10	15	5
Firm19	6	6	6	0
Firm20	3	3	2	1
Firm21	3	3	2	1
Sub-total: services	**207**	**185**	**46**	**12**
Total	**233**	**211**	**61**	**15**

Source: own elaboration from fieldwork data collection

Firms 14 and 15 had adapted software services developed in the firm before 2006-2009, to provide new services for the national market. Firms 3 and 15 stand out for the number of commercialized software services at both firm and national market levels, and both had innovated at world level; in the case of Firm 3, the new service had been exported. These firms had several common characteristics: they had been established for between 6 and 10 years; their innovation was not supported by external ties; they had been developed in the same incubator; they had grown through mergers with other Brazilian software firms; and they had developed complementary software related to mobility.

Firm 12 shows outstanding innovation performance at firm level and was developed in the same incubator as Firms 3 and 15. It works on software services related to mobility. These findings suggest that the relative youth of the mobility software industry, which is related to the development of customized software (e.g. mobile games), there might be more market opportunities for Brazilian software firms to perform and innovate in this industry than in more mature and consolidated software market niches (e.g., development of ERP platforms, historically an oligopolistic market).

Firms 1, 20 and 21 had not developed from an incubator and all have commercialized new to the world innovations. Firm 1 is one of the most successful software firms in the region, has international CMMI[17] (SEI, 2007) level 5 certification, exports outsourcing services and has external ties confined to customers. Firm 20 is an informal 'spin-off' from IBM Brasil, which guaranteed procurement for the first years of the firm's operation. Firm 21 is one of the oldest and largest local firms in the region and is involved in automated banking, an industry where Brazil has good international reputation, although mostly supplies the domestic market (Softex, 2005).

The new software services commercialized during 2006-2009 include innovations produced by Firm 14. Table 4 shows that this firm does not show outstanding levels of innovations that are new to the world. Figure 2 shows that this firm has the highest number of external ties to support its innovation activities. Two of its innovations were new to the national market.[18] This firm spun-off from one the most successful software firms in the region, was incubated for two years, and received some private venture capital investment. The venture capitalist was introduced to the firm by one of the incubator's consultants, who acted as a bridge between them. The firm has received grants from FINEP and CNPq. It did not cite the incubator or the venture capitalist as external collaborators in its innovation activities. However, the interviews demonstrated the relevance of these actors for the firm's growth. This firm is among the youngest examined (around 5 years) and has grown from a micro to a small firm during the five-year period. It belongs to a local export consortium (ActMinds) and has an office in the USA to investigate the prospects for new markets in that country. It can be said that: i) Firm 14 is part of an effective network, as discussed by Burt (1992), evidenced by its direct and tightly-connected ties based on trust, and collaborates to gain access to reliable and relevant information; and ii) firms with links to successful organisations (e.g. Firms 7 and 14) that participate in the network of innovators, are capable of continuous successful performance. However, since Firms 7 and 14 are exceptions in the sample, we cannot draw firm conclusions.

4.2 The Tale of City 2: Recife software innovation network

Recife provides a contrast; it is in the economically lagging Northeast state of Pernambuco, in a region that accounts for a much lower share of national GDP compared to the Southeast - 13.1% in 2008 (IBGE, 2008) and 27.8% of the Brazilian population in 2010 (IBGE, 2010a).

[17] CMMI certification is recognized worldwide and classifies software processes into 5 levels (level 1 lowest level of maturity to 5 the highest level). Brazilian software firms awarded CMMI certification (above level 3) benefit from access to public calls.

[18] Only 2 other firms (16 and 9) of the same longevity as Firm 14 have managed to commercialize innovations new to the firm and to the national market.

Pernambuco State's share of Brazil's population was 4.6% in 2010 (IBGE, 2010a), and its share of the GDP was 2.3% in 2008 (IBGE, 2008), which shows that economically it is lagging behind the Southeast region and São Paulo State. Recife's per capita GDP was US$6.2K in 2007 compared to the national average of US$6.8K, and is considerably lower (52%) than Campinas city. In 2010, Recife city's population accounted for 17.4% of the population of Pernambuco State and 0.8% of the total Brazilian population (IBGE, 2010b).

Recife is geographically distant from the most economically dynamic region (about 2,600km distant from São Paulo City) and receives less support from national policies for software industry development. Recife's IT industry is relatively recent and its software industry benefited from direct public support only in the 1990s with the establishment of the SOFTEX Nucleus in 1992, and 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.[19] 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 (SECTMA, 2006) generally. 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). Since Porto Digital was established CESAR has located on Recife Island and is a main actor in the local network (Table A3 presents the main organisations established in the region).

The scientific system in Recife is very poor compared to Campinas, due to less good performance by the public research university and engagement in fewer scientific fields than the research university in Campinas, and because the budget of Pernambuco State Research Foundation (FACEPE, established in 1989) in 2009 was estimated at US$17.2m (i.e. more than 20 times less than the FAPESP budget) (FACEPE, 2006). In 2007, the percentage of university graduated students from the São Paulo State, 29.6% (INEP, 2009), was more than

[19] For comparison, according to the QS Ranking, the Federal University of Pernambuco is 79th in the 2014 BRICS ranking (http://www.topuniversities.com/node/9543/ranking-details/brics-rankings/2014); 43rd in the 2014 Latin America ranking (http://www.topuniversities.com/node/9543/ranking-details/latin-american-university-rankings/2014), and 701+ (i.e., below 700) in the 2013 world ranking (http://www.topuniversities.com/node/9543/ranking-details/world-university-rankings/2013). All accessed 28.7.2014.

proportionate to its share of the Brazilian population, that is, 21.6%, compared to 2.6% in Pernambuco State (INEP, 2009), less than proportionate to its share of the Brazilian population, that is, 4.6%.

4.2.1 Structural Embeddedness: The consistency of the Recife four sub-networks

The business sub-network is the most frequently accessed by Recife local software firms and shows complete consistency.[20] 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. An interviewee told us that: '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

[20] Appendix Table A3 shows the aims of some of Recife's software network actors.

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.[21] 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.

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 help with business plans. Rather surprisingly, Firm 3 had not engaged with CESAR's software developers or its R&D division. Based on

[21] 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.

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.[22]

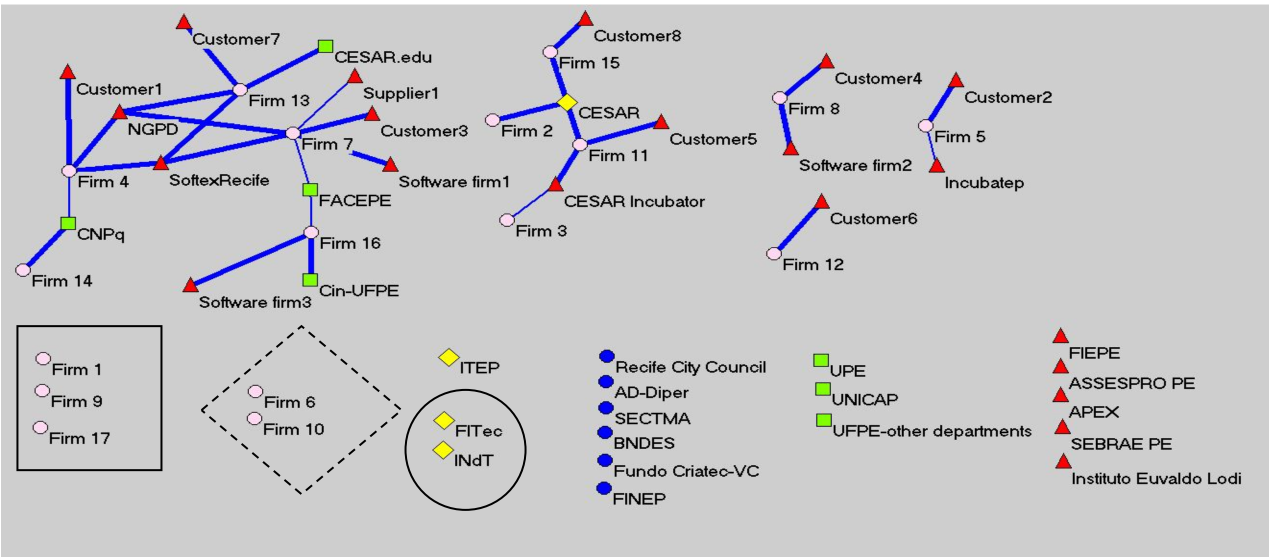
The financial sub-network was not accessed by Recife software firms during the period analysed. Our interviews showed that four Recife firms had ties to the national public agency, FINEP, for innovation projects to be developed only if funding was granted. These results indicate that the financial sub-network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

4.2.2 Structure of the Recife Network and Relational Embeddedness

The results show that 70% of the sample of interviewed firms had external ties to support their innovation activities (Figure 3). 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).[23]

[22] www.cesar.org.br, accessed 08 November 2008.
[23] Although geographic proximity does not always explain tightly-connected ties, for instance, because of labour mobility, as mentioned by Boschma (2005).

Figure 3 - The Recife software network of innovators: commercialized innovations during 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

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).

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 in Section 4.1.

4.2.3 Firm level commercialized innovations: Recife software network (2006-2009)

The empirical findings reveal that most commercialized innovations are software services: 113 new services and 11 new products.

Table 5 New software *products* and *services* commercialized by Recife software firms - April 2006 to 2009: outliers and total

Firm #	Total number of innovations	Innovation new to the firm	Innovation new to national market	Innovation new to international market
Firm 14	3	3	3	2
Firm 15	1	1	1	0
Firm 16	2	2	2	0
Firm 17	1	1	1	0
Sub-total: products	**11**	**11**	**10**	**2**
Firm1	3	3	2	1
Firm5	44	44	0	0
Firm11*	18	18	18	15
Firm12*	40	40	n.a.	n.a.
Sub-total: services	**113**	**113**	**23**	**16**
Total	**124**	**124**	**33**	**18**

Legend:
n.a.= not answered
* = 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

Table 5 shows that most firms commercialized one new product in the 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.

Of the 10 firms that commercialized *software services*, three account for 90% of total firm level innovation. Table 5 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. Firm 1 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 5, 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.

5. Analysis

The results for the Campinas case show that the structure of the network of innovators is fragmented, which suggests low level diffusion of formal interactions within the network. This finding suggests also that Campinas software firms’ response to government policies promoting network formation, is low compared to its firms’ interactions with other firms and other organisations. The Campinas case show that the interactions between technology policy and network governance and structure are limited, and the high levels of innovative performance are due to the large share of innovative firms that rely on internal resources for their innovation activities. Campinas firms prefer learning from experience to learning by interacting. Most of the innovations produced are new to the firm and are imitative rather than radical inventions. This suggests that many Brazilian software firms recombine existing knowledge which is applied in local (as opposed to global) and vertical markets. Software applications innovations generally require a level of understanding and localised knowledge. This result was expected and is a common feature of local software firms in developing countries. The low level of diffusion of interactions within the network of innovators was also expected, and is related to the imitative innovation strategies of local firms. Imitative software firms often rely on experience-based learning and do not find external ties necessary.

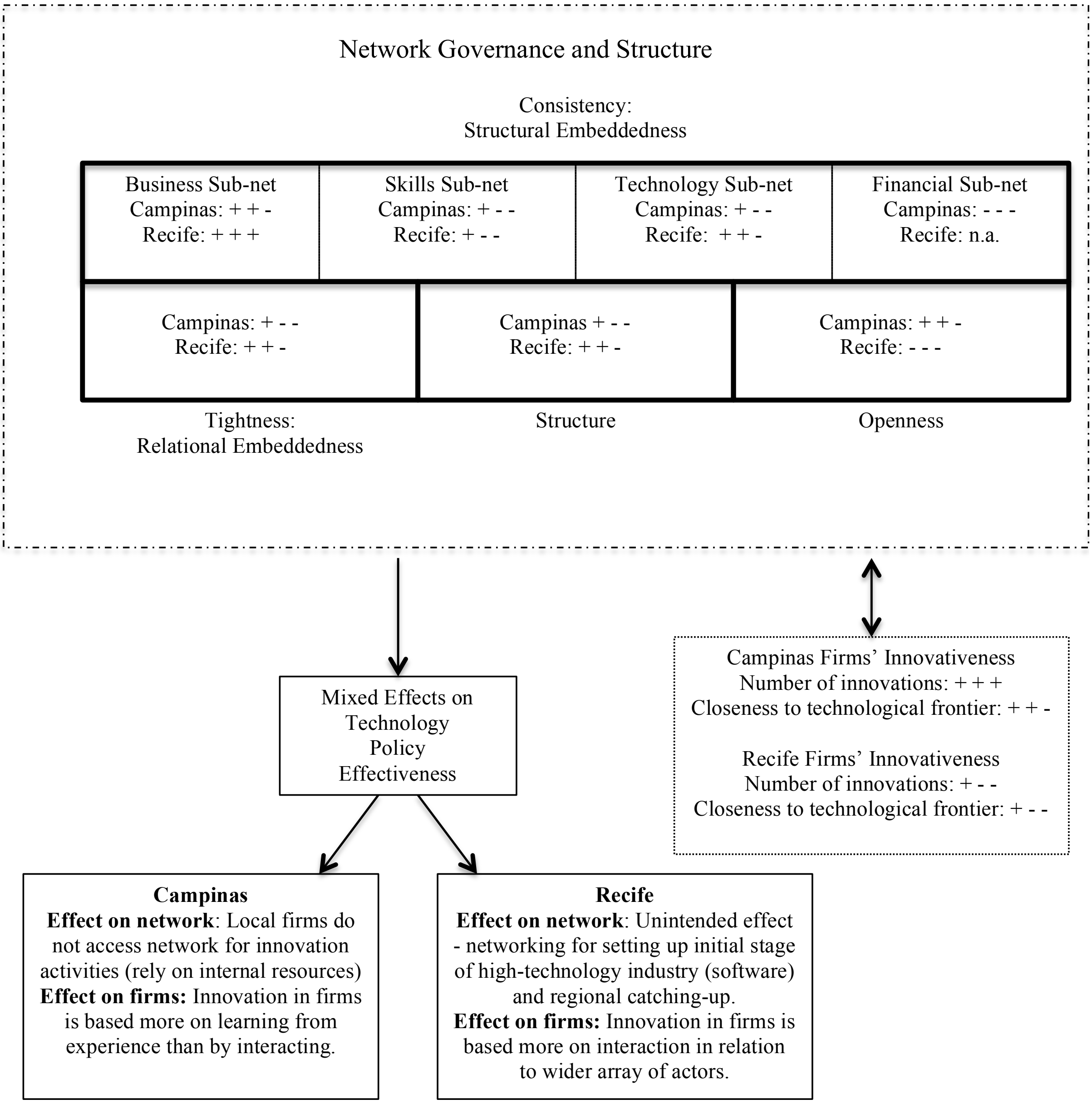
Our results show that the network governance and structure of the Campinas software network of innovators has a *mixed influence* on the effectiveness of government technology policy to encourage firm innovation. This is demonstrated in the different results for network *structural* embeddedness compared to *relational* embeddedness. The results for *structural* embeddedness indicate inconsistencies in the crucial skills sub-network, low engagement of technology sub-network actors, and low levels of interaction among local firms for innovation related activities. The results for *relational* embeddedness reveal that most Campinas firms' direct ties are tightly-connected ties, for interactions aimed at knowledge exchange and learning among actors. This shows that the *relational* embeddedness of the Campinas network's governance and structure has a more positive influence than its *structural* embeddedness, on the effectiveness of technology policy in relation to the promotion of firm-level innovation through network formation.

The results for the Recife case show that the level of diffusion of formal interactions is slightly higher 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 broader interaction between technology policy and network governance and structure in Recife (compared to Campinas), 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 rather than fundamental innovation. 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. In Recife also, 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. The results for *relational* embeddedness of network governance and structure are similar to the Campinas results for tightness of ties; 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 below summarises the main findings and analysis of the Campinas and Recife innovation networks. According to the indicators displayed in Table 1, more positive outcomes for network feature result in more effective governance, supposedly leading to better innovation performance. However, the sampled firms of this study have showed that such proposition has not been fulfilled.

Figure 4 - Campinas and Recife innovation networks: main findings



Legend:
Intensity of indicators (as proposed in Table 1):
- Consistency: Full consistency= + + +; Intermediary consistency= + + - ; + - - ; Inconsistency= - - -
- Tightness: Tightened ties= + + +; Intermediary tightness= + + - ; + - - ; Loosely ties= - - -
- Structure: Well-knit= + + +; Intermediary structure= + + - ; + - - ; Fragmented= - - -
- Openness: Access to external actors to the region= + + +; Intermediary access= + + - ; + - - ; No access to external actors to the region: - - -
- n.a.: not accessed

Firms' Innovatiness:
- High number of innovations= + + +; Intermediary number of innovations= + + -; Low number of innovations= - - -
- Close to technological frontier= + + +; Intermediary distance to technological frontier= + + -; + - - ; Distant from technological frontier= - - -

Source: own elaboration based on fieldwork.

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. It can be concluded that networks are more than the collection of dyadic relations among the actors which is common to many empirical studies and the System of Innovation literature.

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, requires careful consideration of the intended effects. Firms' engagement in networks may not be a necessary condition for firm-level improvements related to innovation. The network governance indicators point to the expected *predominant* network outcomes (Table 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 a country (Brazil) that is at an intermediate level of development, and which has large regional disparities (Lastres, 2007; Teixeira, 2008), engage in networks differently and present different innovative performance (as showed by the Campinas case). Brazilian software firms embedded in regions with different socio-economic and industrial development, show diverse engagement in networks (by the number of firms that rely on external sources and the type of accessed actor) and contrasting innovative performance. We found that those firms less engaged in networking, that is, the Campinas software firms, show higher levels of innovative performance in absolute terms, and produce innovations that are closer to the technology frontier compared to regions, such as Recife, where software firms focus more on networking.

However, although Recife shows comparatively lower innovation performance, networking in this region seems to be supporting regional catch-up.

There are some practical implications for policy; our results suggest that there is no one-size-fits-all network governance and structure, which is consistent with the findings from other studies of networks (e.g. Ahuja, 2000; Grasenick et al., 2008). The institutional, cultural and economic settings can differ among regions, and policy makers formulating policy to promote network formation to improve firms' innovation performance should be aware that reproducing the network governance and structure from successful regions may not be appropriate for (all) other regions. Network promotion policies on their own may not be an efficient mechanism for improved innovation performance and economic catch-up. Finally, the finding of inconsistency of sub-networks that present different functions, that is, *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. The technological activities performed by software firms may require the creation of external formal ties with specific types of actors and the nature of those ties might involve less mutual dependence (and loosely-connected ties) than in cases of more closely linked economic performance among collaborators. 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. This is an opportunity for future research.

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Appendix

Table A1 Indicators for consistency of sub-networks[24]

Sub-network	Type of sub-network actor	General aims by sub-network	Features indicating consistency
Business	a) industrial associations b) competitors c) customers d) suppliers e) consultancy firms f) incubators g) private non-profit organisations acting on behalf of the public interests	i) foster and support interactions among firms and between firms and customers ii) support for research funding applications iii) access to information on national and international markets iv) provision of facilities or knowledge for software development, training and workshops v) support the design of business plans and training on organisational matters vi) support software process improvement vii) incubation programmes	1. Access to open information source 2. Acquisition of knowledge 3. Acquisition of technology 4. Access to new sources of financing 5. Access to commercial information 6. Innovation co-operation
Skills	a) universities b) technical colleges c) continued education organisations d) research council e) research foundation	i) IT training in different levels, such as undergraduate, Masters, Doctorate and Post-Doctorate and continued education; ii) support new knowledge creation through basic or applied research funding programmes; iii) support new knowledge creation through funding programmes for development activities.	1. Access to open information source 2. Acquisition of knowledge 3. Acquisition of technology 4. Innovation co-operation
Technology	a) research organisations b) development organisations	i) perform basic or applied research for, among others, the commercialization by the private sector ii) development activities for, among others, the commercialization by the private sector.	1. Acquisition of knowledge 2. Acquisition of technology 3. Innovation co-operation
Financial	a) private and public banking organisations b) public funding organisations c) venture capitalists d) government authorities	i) grants or loans for firm-level basic or applied R&D activities ii) venture capital for start-ups iii) tax incentives for firm-level innovation activities iv) creation of technological parks or incubation programmes	1. Acquisition of knowledge 2. Acquisition of technology 3. Access to new sources of financing

Source: Pamplona da Costa (2012).

[24] Consistency here is understood as what von Tunzelmann (2003) calls alignment.

Table A2 Campinas network actors

Actor	Year of Foundation	Main activities
APEX-Brasil	1997	Promotion of Brazilian exports
Campinas City Council	n.a.	Fiscal policies
Ciatec	1991	Manage the two Campinas High-Technology Parks
Ciatec Incubator	1996	Incubation programme
CNPq	1951	Brazilian Research Council
CPqD	1976	R&D centre
Criatec-Fund	2007	Venture capital fund/ BNDES and private sector
CTI/CenPRA	1982	R&D centre
FAPESP	1962	State level research foundation
FINEP	1967	Brazilian Innovation Agency
FITec-Campinas	2002	R&D centre (founded by MNC)
Incamp	2001	Incubation programme
Inova Soft	2003	Inova Centre for Information Technology
Inova Unicamp	2003	Unicamp Innovation Agency
Instituto Eldorado	1997	R&D centre (founded by MNC)
Prosoft-BNDES	1999	BNDES programme for software
PUC-CAMP	n.a.	Training in IT undergraduate.
Sebrae-SP	1972	Support for micro and small entrepreneurships
Secretary for Development/SP	1965	Promote sustainable economic growth and technological innovation in the São Paulo State.
SIDI		R&D centre (founded by MNC)
SOFTEX Campinas	1993	Fostering and support local software industry.
SOFTEX Campinas Incubator	1995	Incubator programme: software only
Unicamp-FEEC	1967	Training in IT undergraduate, Master's, professional Master's, Doctorate and Post-Doctorate
Unicamp-IC	1969	Training in IT undergraduate, Master's, professional Master's, Doctorate and Post-Doctorate
Venturus	1995	R&D centre (founded by MNC)

Legend: n.a. = not available.
Source: Pamplona da Costa (2012).

Table A3 Recife network actors

Actor	Year of Foundation	Main activity
APEX-Brasil	1997	Promotion of Brazilian exports
Assespro-PE	1976	Industry association
CESAR	1996	Local R&D centre
CESAR Incubator		Incubator programme
CESAR.edu	2006	Training in IT- Master's and continued education
Cin-UFPE	1974	Training in IT undergraduate, Master's, professional Master's, Doctorate and Post-Doctorate
CNPq	1951	National research council
Criatec-Fund	2007	Venture capital fund/ BNDES and private sector
DEINFO-UFRPE	2005	Training in IT undergraduate
DSC-UPE	2004	Training in IT undergraduate
FACEPE	1989	State level research foundation
FIEPE	1939	Pernambuco Industrial Association
FINEP	1967	Brazilian Innovation Agency
FITec-Recife	2002	R&D centre (founded by MNC)
IEL-PE	1969	Support the improvement of firms' management skills and their entrepreneurial capabilities.
Incubanet	2005	Incubator Association
Incubatep	1990	Incubator programme
INdT-Recife	2006	R&D centre (founded by MNC)
ITEP	1945	Pernambuco Technological Institute/ State level
NGPD	2000	Porto Digital Management Unit
Recife City Council	n.a.	Fiscal incentives to software firms based in Porto Digital
Recife-BEAT	1997	Pre-incubation programme/ Cin-UFPE
Sebrae-PE	1972	Support for micro and small entrepreneurships
SECTMA	1993	Foster scientific, technological and innovation development of Pernambuco
SOFTEX-Recife	1993	Fostering and support local software industry.
UNICAP	n.a.	Training in IT undergraduate

Legend: n.a. = not available
Source: Pamplona da Costa (2012).

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