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"Porque en realidad nuestro norte es el Sur" Joaquín Torres García

Network governance and government technology policy in Brazil: A new methodological approach based on lessons from the software industry

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Abstract:

This article aims to provide evidence on how the network (i.e. coordination) and structure may respond to government technology policy directed at local firms' innovativeness in a developing country context. The research investigated two regional software innovation networks in Brazil (Campinas and Recife), which were formally created by the Brazilian national government in the early 1990s. It developed qualitative and quantitative indicators to address network governance and structure bringing evidence on the consistency of sub-networks, tightness of dyadic ties, and structure and openness level of the network. Empirical data was gathered by 103 in depth interviews. The main findings reveal that network governance and structure had different levels of responsiveness to government technology policy directed at firm-level innovation, showing different degrees in each regional network. The main implications for policies are that there is no one-size-fits-all network governance and structure. The institutional, cultural and economic settings may differ among regions, and policies aimed at promoting network formation to improve firms innovative performance should take into account that reproducing the network governance and structure of regions that have been successful may not be appropriate to other regions.

Tema 7: Sistema Nacional de Inovação e a Dimensão Territorial

Key words:

Government technology policy, regional innovation networks, network governance and structure, firm-level innovation, developing countries

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1. Introduction and background

Networks are a structure of interactions and an intermediate form between market and hierarchy (Powell, 1990), in which the actors do not act in an isolated fashion (Callon, 1999). Networks, it is supposed, 'breed trustworthy relations' among economic actors (Giuliani, 2010: 264, Granovetter, 1973, 1985), potentially reducing transaction costs and favouring the creation and diffusion of knowledge and information (Burt, 2010). The literature on networks and innovation emphasizes their conceptual relevance for supporting firm-level innovation. Firms learn through interaction (Lundvall, 1992a), and this learning includes new knowledge that is essential for innovation (Cimoli, 2002, Freeman, 1991, Powell and Grodal, 2005). Innovation networks are a sub-set of interactions in innovation systems (Cantner and Graf, 2006, Cimoli, 2002).

The relevance of network arrangements to support firm-level innovation has been addressed extensively (Cimoli, 2002, Freeman, 1987, 1991, Lundvall, 1992b, Nelson, 1993, Powell and Grodal, 2005). Evidence on the significance of network arrangements (especially for developed countries), including networks of individuals and informal networks, for innovation is often interpreted as meaning that firms that are embedded in network arrangements are likely to be more innovative (Castilla *et al.*, 2000, Grasenick *et al.*, 2008, Herrigel, 1993, Lazerson, 1993, Saxenian, 1990, Uzzi, 1997). Network studies take account of the fact that firms are not isolated actors and will be influenced by dyadic ties formed with other network actors. In addition, and significantly, it is not necessarily the strength of a tie that determines its value because ties can play different roles (Granovetter, 1973) and the structure in which they are embedded is also critical (Storper, 1996).

Networks can be seen as emerging entirely from a process of dyadic tie formation, arising through happenstance or chance, and that the strength of inter-organisational ties is the result of personal interactions that reflect personalities and various experience. Alternatively, the processes of network tie formation and the evolving strength of ties can be seen as reflecting the purposive aims of organisations that take account of some parts or all of the structure of the network. This latter view suggests the presence of agency in the formation and evolution of networks.

An understanding of both paths to the formation of networks is relevant to an investigation of network development, which includes governance issues (where governance meaning coordination), and calls for a definition of network governance and structure.

Network governance and structure is defined *as inter-organisational coordination exerted in a particular institutional setting*[2] and understand coordination as occurring when two (or more) network actors pursue a common outcome and establish a tie in order to pursue it (Bevir, 2009: 57). This article investigates firm-level innovation, where the innovation is an outcome pursued by network actors, and examine dyadic ties taking account of the possible influence of these ties and their coordination. The institutional setting influences the agency exercised in the formation of ties and the exertion of control in the effort to shape the overall structure of the network. The institutional setting also may involve different levels of investigation, such as local, regional, national or global, which aligns with the systems of innovation approach introduced by Freeman (1987).

The possibility of governance, and the corollary that some acts of governance may be superior to others, suggests that governments might want to implement technology policies to support the creation of networks, the expected by-product being networks effective governance as a means to improve firm-level innovation (Herrigel, 1993, Lazerson, 1993, Saxenian, 1994 illustrate successful government intervention to support regional network development).

The confluence of successful experience in developed economies and growing awareness of the systems of innovation approach since the late 1980s (Freeman, 1987, Lundvall, 1992b, Nelson, 1993) has inspired developing country governments to make network formation an element of their technology policies and to invest in the creation of local and regional networks. However, *it is still debateable whether and to what extent government policies to induce network formation and development are effective*. Based on perceptions of experience such as that mentioned above, governments in developing countries have assumed that regional networks can be engineered or arranged to become efficient mechanisms to support both economic catch-up with the developed countries and laggard regions in the national economy catching up more generally. This was the aim of policies formulated for the Brazilian software industry (Afonso *et al.*, 1999, MIT-Softex, 2002, Roselino, 2006).[3]

There are three aspects of government intervention related to individual and collective gain. Firstly, from the social welfare perspective, government intervention should be social welfare improving. Since any intervention will involve a re-allocation of resources (government's or those of other actors') and possible negative effects on social welfare, it is

important to establish *whether government intervention is necessary*. That is, whether the absence of government intervention lead to inferior social welfare outcomes. For example, if networks would be beneficial, but their formation unlikely, would government intervention catalyse or stimulate the engagement of actors sufficient to lead to the development or exchange of relevant knowledge? A positive answer to this question is needed to support government intervention. Advocates of government intervention identify market shortcomings that could lead to market failure, some of which might be overcome or mitigated through government intervention (Boyer, 1997, Evans, 1995).[4] Technology is endowed with some non-rival and non-excludable goods characteristics (Pavitt, 1987, Storper, 1995). The market imperfections related to technology require government intervention by means of technology policy, a necessary condition for economic development (Pavitt, 1987).

Secondly, we need some clarification about *whether network actors and agents are likely to respond to government policy intervention*. This requires some assessment of the 'feasibility' of intervention. Since the desirable features of networks flow from the voluntary actions of their participants it is possible that little or nothing might result from government incentivised or directed efforts to create 'networks'. Network actors may act opportunistically to fulfil the requirements of the intervention in order to receive the incentive, or comply with the formalities without expending the additional effort required to derive value from network membership. The history of the actors matters here since it may influence their responsiveness to government intervention or their willingness to explore with their new 'partners' whether there are any gains to be derived from a relationship that has been foisted upon them. Networks can be emergent (i.e. based on incidental interactions) or purpose-built (i.e. strategically created), and technology policy formulation and implementation must take account of the history (if any) of the relations between the actors that might be involved in the network.

In addition to network creation issues (emergent or purpose-built networks), there are the issues of actors' responsiveness to government policy implementation, such as the motivation for actor-to-actor tie formation, including among others: i) past personal relationships, ii) common professional background, iii) cost savings, and iv) geographic or social proximity. Tie formation may vary, its formation is likely to be related to the stage of network emergence or the response of the actor to government intervention. Thirdly, there is a need to investigate *whether the governance process established by the government*

intervention will be more effective than would have followed from autonomous governance by network participants. This implies that governments intervene not just in network formation, but also in the governance of ongoing networks, not least to establish some accountability for their investment. How this accountability should be demonstrated then becomes an important regulatory issue – can governments distinguish networks that have 'gone wrong', for example collusive and anti-competitive networks (including those dominated by single actors), which will be more likely to suppress than to foster innovation, and to engage in other actions that may be social welfare reducing (e.g. collusive pricing).

In developing country contexts the lack of engagement of actors in innovation networks ('missing' links) seems to be frequent (Bell and Albu, 1999, Chaminade and Vang, 2008, Cimoli, 2002), and there is a low level performance of the components of innovation systems compared to what might be expected ('dysfunctional' links) (Bell and Pavitt, 1993, Cassiolato et al., 2003, Lastres and Cassiolato, 2001). Indicators that 'reflect the quality of relationships' are required for an understanding of multi-organizational interactions in developing country contexts (Lundvall et al., 2009: 19). The lack of systemic interactions in developing countries' systems of innovation is identified in empirical studies of innovation in Brazil (Cassiolato and Lastres, 1999, 2003), and has lead Brazilian scholars to develop an approach considered more appropriate to investigate innovation in Brazil, the Local Productive Arrangements and Innovation Systems (LPAIS) (Lastres, 2007).5 The LPAIS uses empirical evidence gathered at the local and regional level in Brazil, to account for the presence of strong socio-economic and cultural differences, and investigates three main issues: i) which markets are targeted by the 'arrangement'; ii) which governance mode is present in the 'arrangement' – that is, whether the decision power follows a hierarchical or network type structure; and iii) the relevance of the territory with regard to the presence of local capabilities. The main aim of LPAIS studies is to understand local industry performance and how territories can improve their competitiveness in a globalised economy (Lastres, 2007). The approach has been applied to investigate innovation in Brazilian regions (for instance by Britto and Stallivieri, 2010, Campos et al., 1998, Cassiolato et al., 2008, da Silva, 2008, Garcia and Souza, 1999, IPARDES, 2006, Machado, 2003, Teixeira, 2008).

Although the LPAIS approach deals with governance issues related to the presence of networks in clusters or industrial regions (Redesist, 2005),[7] it does not examine the extensions to, features of or motivations for tie creation by firms within the investigated 'local

arrangements'. Further research on the formation of regional networks of innovators in Brazil that investigates the creation of inter-organisational dyadic ties by firms is needed. This study focus on network governance and structure to investigate the dyadic ties formed by firms with regard to their innovation activities. This study differs from the LPAIS approach mainly with regard to the level of analysis and methodology applied. The level of analysis investigated here refers to the nature of and motivation for each tie in order to achieve a better representation of the network, which allows an interpretation of the network structure (including the institutional setting) and how government policy effectiveness relates to network governance and structure. Firms are at the core of the innovation system, because technological accumulation is localized mainly in firms and they are supposedly the network actors that most benefit from innovation (Bell and Pavitt, 1992, Malerba, 2004: 24). This assumption leads to a focus on network governance and structure related to firm-level innovations in developing country contexts and, in the case of this article, especially Brazil.

Considering the discussion above, this article suggests the following research question: 1) *What is the responsiveness of network governance and structure to technology policy aimed at the promotion of networks in a developing country context, especially in the case of Brazil?*

2. Research Methods

Network governance studies tend to analyse either the dyadic ties within networks *or* the structure of the networks. In this article we integrate the elements of dyadic ties *and* network structure as well as government technology policy, within a single analytical framework. The research follows a qualitative case study approach based on the following: governance, defined as coordination (Bevir, 2009); the introduction of exploratory research questions; and an analysis of network features referring to contextual conditions and changes over time (Yin, 2003). The employment of a quantitative approach is used to complement these methods, using Social Network Analysis (SNA), an important tool especially with regard to visual representation of the network, which provides insights into bridges within networks and its structure.

We employ original indicators, developed elsewhere (Pamplona da Costa, 2012), to examine network governance and structure. To our knowledge, although there has been increasing interest in methods aimed at capturing the meaning behind network ties (see Ceci

and Iubatti, 2012), the literature lacks indicators that can be replicated consistently to investigate governance and structure of networks. Network actors were identified partly *a priori* from publicly available reports, academic studies and specialized press on technology policies implemented in Brazil. We group actors into categories, allowing investigation of the consistency of the network. We use four subnetwork categories: business; skills; technological; and financial sub-networks.

The investigation of *dyadic ties* supported an examination of network governance by providing evidence on: i) number and type of actors tied to each firm; ii) frequency of collaboration; tightness of ties among actors; iii) consistency among sub-networks; iv) level of network openness; and v) network structure. The tightness of ties relates to the motivation for firms to create external formal ties with network actors, and tie frequency. In this study we analyse only *direct* ties to 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 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, based on opportunity or cost, and supposedly are more vulnerable to breaking under pressure.

The consistency of the sub-networks indicator relates to overlaps between the features of ties created by firms with other network actors (based on OECD, 2005), the general aims of the subnetwork to which the actor belongs, and the self-defined, the specific aims of the tied actor. Hence, consistency provides an evaluation of the performance of tied organizations. The level of openness of the network relates to the geographical localization of collaborating network actors, and supports conclusions about the regional network's vulnerability to lock-in (Grabher, 1993, Grasenick *et al.*, 2008, Semlinger, 2008).

The structure of the network refers to how the network actors are connected - fragmented or well-knit. Fragmented networks occur when the number of indirect ties is small and network actors are generally isolated. Conversely, well-knit networks occur when the number of indirect ties is high, and 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). Table 1 summarizes the network governance indicators, suggesting the expected *predominant* network outcomes as derived from the literature.

Selection of case study, data collection and data analysis

The Brazilian federal government Softex Programme implemented in 1993, was aimed at promoting the local Brazilian software industry through the creation of regional networks, that is, purposive networks. The study selected two software networks that were created at the same time,

under similar incentives and regulations, based in two Brazilian regions that present different stages of socioeconomic and industrial development: i) Campinas, a city based in the Southeast region and considered Brazil's leader region for the software industry;[9] and ii) Recife, a city based in the Northeast region that has been trying to catch up to Brazil's leading software region.[10]

Campinas is in the most economically developed Brazilian region and has benefited from national and state level policies to support regional industry development since the late 1960s, mainly through the establishment of organisations that are directly related to research and scientific activities. Government policy has played a role in this leadership position. The strong economic and industrial dynamics of São Paulo State and Campinas city are combined with 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.[11]

Recife, in contrast, is in an economically lagging Brazilian region, which is geographically distant from the most economically dynamic region, and has received less support from national policies directed to the development of the software industry.[12] The software industry is relatively recent in the Recife region. It began in the 1980s, benefited from the establishment of the Softex Agent in 1992 and the creation of the private non-profit Recife Center for Advanced Studies and Systems (CESAR) in 1996. The lower level of national support has triggered the implementation by the government of Pernambuco state, where Recife is located, of technology policies directed towards the development of the local software industry and aimed at supporting economic catch-up by Recife and Pernambuco state (SECTMA, 2006). The result of the Pernambuco state government intervention was the creation of Porto Digital in 2000 (Oliveira, 2008).

The main source of empirical information was face-to-face interviews using semi-structured (majority), and open-ended questionnaires. The questionnaires used different

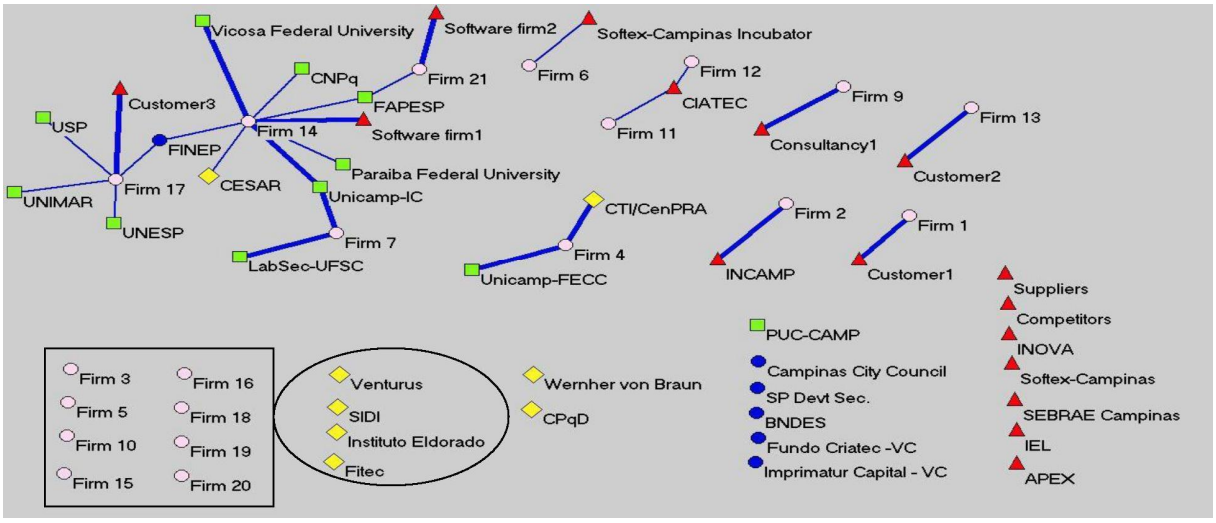
criteria for each type of organization. The firm questionnaire collected data on their innovation processes. The public and private organization questionnaires collected additional evidence, which was validated by information available on websites, in reports and from formal studies (data triangulation discussed by Yin, 2003: 97). A total of 103 interviews was conducted, 94 face-to-face and 9 by telephone (see summary in Table 2). The other information sources allowed the evidence provided by interviewees to be corroborated (Yin, 2003) and provided additional knowledge about the history of the case studies.

Data analysis occurred in three stages. The *first* comprised transcription of interviews and elaboration of notes to produce comprehensive and accessible data and to create comparable data among the units of analysis. The *second* stage involved the compilation of tables classifying the information collected to construct indicators of network governance (network tie tightness, structure, consistency and openness). The *third* stage comprised analysis of the variables in Table 1, using the network governance indicators to understand and explain possible relationships among them. In this third stage, quantitative research methods and SNA software Pajek (2-mode matrix) (de Nooy *et al.*, 2005) were used to support individual visual representation of the two networks, supporting the identification of patterns within the network as well as its structure.

3. Results I - The Campinas software innovation network

This section presents the results for how many and which firms perform innovation, and exploits the indicators developed above. The representation of the network of innovators supports the empirical evidence represented in Figure 1, which in turn supports the visualization of the network of innovators that produced commercialized innovations during the period April 2006-April 2009. Figure 1 depicts the actors engaged in the network of innovators, and the clusters of nodes to which they belong, and also which actors function as bridges within the network of innovators. It shows whether ties are tightly or loosely-connected. Table 3 summarises the main findings for the network governance and structure of the Campinas software network of innovators and the implications of the results will be discussed in the following section.

Figure 1 - The Campinas software network of innovators: commercialized innovations during 2006-2009



Legend:

- Firms
- Technology sub-network ■ Skills sub-network
ABusiness sub-network
- Financial sub-network Tight connections =
Loose connections = --------

□= Firms that did not create external ties to support their commercialized innovation.

o= Autonomous private non-profit R&D organizations originally set up by multinationals that are disengaged from the

network of innovators.

Note: Firm 8 did not commercialize innovations during the period under analysis.

Source: own elaboration based on fieldwork data collection.

Bridging

The first consideration in Figure 1 is that there are a few bridging organizations (as opposed to firms) in the main cluster of nodes, and they are part of the skills (FAPESP and IC-Unicamp) and financial (FINEP) sub-networks. The second consideration is that close investigation of the aims of FAPESP and FINEP combined with empirical evidence from local firms, indicates a small likelihood of these two organizations fostering the creation of ties among firms indirectly connected to them. This is mainly because proposals for grants are subjected to 'blind' assessment, with no personal contact between firms and grant application reviewers. Nevertheless, both organizations act as bridges by providing funds through special calls or programmes that require the creation of ties among firms, or between firms and actors which may belong to the skills and technology subnetworks (this conforms to the 'thematic funding' technology policy channel discussed by Steinmueller, 2010).

IC-Unicamp (Computing Science Institute) also plays a bridging role. Empirical evidence shows that IC-Unicamp can and is likely to function as a bridge between two tied firms and other firms within the network of innovators. However, according to our interviewees, this role is unlikely to be at the organizational level, and relates to faculty member's individual initiatives and relationships. Over its history, IC-Unicamp has created a community of former students (alumni). These individuals are part of an informal network in which 'collective identity' is relevant for the sharing of information on new market opportunities and firm strategies (see Pavitt, 1987, on communities of common knowledge). A final comment on bridging organizations not depicted in Figure 1 relates to the role of local incubators. Although none of the three local incubators is tied to the main cluster of nodes, they function as bridges for creation of ties between incubated and 'graduate' firms. This is because the managers of incubators are knowledgeable about both groups of firms, and are likely to suggest contacts for collaboration (either formal or informal).

Commercialized innovation: Campinas software network (2006-2009)

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

Table 4 New software *products* commercialized by Campinas software firms - June 2006 to June 2009

Firm number	Total number of innovations	Innovation new to firm	Innovation new to national market	Innovation new to international market
Firm2	6	6	**0**	**0**
Firm5	2	2	1	**0**
Firm7	10+	10+	10+	3
Firm 13	3	3	1	**0**
Firm 14	3	3	2	**0**
Firm 16	2	2	1	**0**
Total	26	26	15	3

Source: own elaboration based on fieldwork data collection.

Firm2 commercialized innovations that were new to the firm, and has external ties with the Incamp incubator. Firm7 commercialized the most product innovations, all of which were new to the national market, and three of which were new to the world. However, none of these innovations had been exported at the time of data collection. This firm has external ties with two skill sub-network actors (university departments) that supported two of their commercialized innovations.

We found that most firms 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 that had innovated at world level were in the minority. Table 5 summarizes the software services innovations commercialized during the period 2006-2009; eight firms produced more than four software services innovations.

Table 5 New software *services* commercialized by Campinas software firms - June 2006 to June 2009

Firm number	Total number of innovations	Innovation new to the firm	Innovation new to national market	Innovation new to international	External collaborator
Firm1	7	7	1	1	Yes
Firm2	3	3	0	0	Yes
Firm3	99	99	9	1	No
Firm4	1	1	1	0	Yes
Firm6	3	3	0	0	Yes
Firm7	3	3	3	3	Yes
Firm9	4	4	4	0	Yes
Firm 10	1	1	0	0	No
Firm11	1	1	0	0	Yes
Firm 12	35	35	0	0	Yes
Firm 14	4	2	2	0	Yes
Firm 15	30	10	15	5	No
Firm 17	3	3	0	0	Yes
Firm 18	1	1	1	0	No
Firm 19	6	6	6	0	No
Firm20	3	3	2	1	No
Firm21	3	3	2	1	Yes
Total	207	185	46	12	Yes

Source: own elaboration based on fieldwork data collection.

Firms 14 and 15 re-employed software services developed in the firm before the period 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. Both these firms also innovated at the international level and, in the case of Firm 3, the new service had been exported. These firms had common characteristics: they were between 6 and 10 years old; they had not established external ties to support their innovation; they had graduated from the same incubator; they had grown through mergers with other Brazilian software firms; and they had developed complementary software related to mobility.

Firm 12 showed outstanding innovation performance at firm level, had been a member of the same incubator as Firms 3 and 15, and had developed software services related to mobility.

These findings may indicate that, due to the relatively youth of the mobility software industry, which is related also 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).

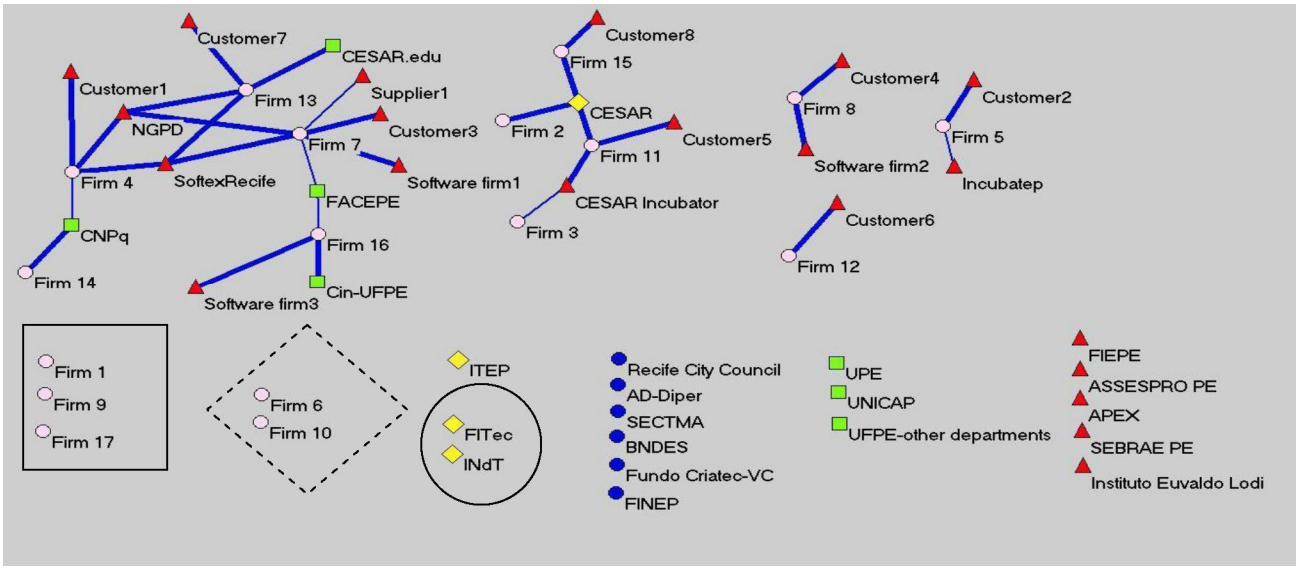
Firms 1, 20 and 21 had commercialized new to the world innovations. None of them had been incubated. Firm 1 is one of the most successful software firms in the region, has international CMMI[13] (SEI, 2007) certification level 5, exports outsourcing services and has external ties only to customers. Firm 20 is a case of 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 a good international reputation, although this industry mostly supplies the domestic market (Softex, 2005).

Among new software services commercialized during 2006-2009 are the innovations produced by Firm 14. According to Table 5, this firm's innovation level is not outstanding in terms of inventions new to the world, Figure 2 shows that this firm had the highest number of external ties to support its innovation activities. Two of its innovations were new to the national market, which means that they had no competitors in this market when their services were commercialized.[14] Firm 14 was a spin-off of one the most successful software firms in the region, had been incubated for two years, and had received some private venture capital investment as well as funding from FINEP and CNPq.

4. Results II - The Recife software innovation network

This section exploits the indicators developed in Section 2. Figure 2 is a visualization of the Recife software network of innovators in the period April 2006-April 2009. Table 6 summarises the main findings for the network governance and structure of the Campinas software network of innovators and the implications of the results will be discussed in the following section.

Figure 2 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 organizations 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 based on fieldwork data collection.

Table 6 - Summary of network governance in Recife innovation network

Indicators		Network features
Consistency	Business Sub-net	- Mostly frequently accessed sub-net - Full consistency - Actors with highest number of ties: customers, other locally based software firms, non-profit organisations
	Skills Sub-net	- Second mostly frequently accessed sub-net - Intermediary consistency - Actors with highest number of ties: universities and research foundation/council - Unexpected results: absence of acquisition of knowledge and technology in dyadic ties with research foundation/council.
	Technology Sub-net	- Third mostly frequently accessed subnet - High consistency - Actors with highest number of ties: universities and research foundation/council - Unexpected results: absence of acquisition of knowledge and technology in dyadic ties with research centre
	Financial Sub-net	- Financial sub-net actors were not engaged in the network
Tightness	Tightly-connected x Loosely-connected	- Mostly tightly-connected. Existence of loosely-connected ties with business and skills sub-network actors was an unexpected result; such type of ties involves the creation of new knowledge or technology, which supposedly is motivated by trust and collective identity
Structure	Well-knit x Fragmented	- Intermediary fragmentation: seventy percent of interviewed firms created external ties to support their innovation activities
Openness	Intra-regional and Inter-regional	- Inter-regional: most connections are with actors based in the region.

Source: own elaboration based on fieldwork.

Bridging

Figure 2 shows that four organizations could function as bridges in the Recife network of innovators; two are part of the skills sub-network – CNPq and FACEPE, and two are part of the business sub-network - NGPD and SoftexRecife. However, CNPq and FACEPE are unlikely to act as bridges because it is not part of their remit. Funding programmes are based on open calls and blind assessment of applications. However, some of FACEPE's funding programmes require participation of academic researchers in the firms' projects and the funding application, which would mean that FACEPE would be functioning indirectly as a bridge. Which researchers and which organizations are invited to participate in the firm's application project is the firm's not FACEPE's decision. The same could apply to CNPq; however, the research council more often supports research in firms by funding the secondment of university students through bursaries and scholarships rather than research grants.

With regard to the main cluster of nodes, NGPD and SoftexRecife may function as bridges because of their position within the network of innovators, and closer examination shows that firms are tied to customers, other local software firms and local organizations through NGPD and SoftexRecife (e.g., the case of Firm 13). Although Figure 2 shows that the firms connected to NGPD overlap with the firms that are connected to SoftexRecife, our results show that the number of firms benefiting from these organizations' support is not limited to those represented in Figure 2. For instance, Firm 1 has used SoftexRecife facilities (testing laboratory), and Firm 10 received support from NGPD for writing a grant application to FINEP.

Investigation of the secondary cluster of nodes in Figure 2 shows that CESAR is the main bridging organization, and links local firms indirectly. All the ties between firms and CESAR are tightly-connected, suggesting that firms are likely to regard referrals from CESAR as reliable, possibly increasing the chances of CESAR's bridging activities being successful. However, Figure 2 shows CESAR's disengagement from the main cluster of nodes within the network, and its own cluster of nodes. This was an unexpected result because CESAR is the main information technology R&D organizations in the region (and one of the most important in the country), and was identified by nine firms as being an important asset for the region.

Commercialized innovation: Recife software network (2006-2009)

The empirical findings reveal that most commercialized innovations are software services: 113 new services and 11 new products. The former involved 10 firms and the latter 7 firms.

Table 7 New software *products* commercialized by Recife software firms - April 2006 to 2009

Firm #	Total number of innovations	Innovation new to the firm	Innovation new to national market	Innovation new to international market
Firm 1	0	n.a.	n.a.	n.a.
Firm 5	0	n.a.	n.a.	n.a.
Firm 7	2	2	1	0
Firm 9	1	1	1	0
Firm 13	1	1	1	0
Firm 14	3	3	3	2
Firm 15	1	1	1	0
Firm 16	2	2	2	0
Firm 17	1	1	1	0
Total	11	11	10	2

Legend: n.a.= not applicable

Source: own elaboration from fieldwork, April 2009.

Table 7 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 actors in the business and skills sub-networks. Firm 16 created one tie with a local firm that develops complementary software, and also ties with Cin-UFPE (the only example of a firm tie for this organization) and FACEPE, which part-financed the innovation. According to Firm 16, Cin-UFPE involvement was crucial because it supported the firm's access to new knowledge, which put it at the national technological frontier.

Firm14 stands out as the only firm that introduced an innovation at the international level, and was exporting. This firm is one of the most successful software companies in the Recife region, it competes in the international market, it participated in the Cin-UFPE incubation programme 'Recife BEAT', and its first product resulted from Master's level research conducted by one of the firm's founder. It forged a tie with CNPq for its international level innovation and is the only firm in the sample with a tightly-connected tie to this organization.

Of the 10 firms that commercialized software services, 3 account for 90% of total firm level innovation. Table 8 shows that there were much smaller numbers of national level innovations (compared to new software products) and especially international (new to the world) innovations, and shows that four firms stand out for innovative performance.

Firm 5 achieved the highest number of innovations (44), but all were firm level innovations resulting from the firm's participation in one-off projects.

Table 8 New software *services* commercialized by Recife software firms - April 2006 to 2009

Firm #	Total number of innovations	Innovation new to the firm	Innovation new to national market	Innovation new to international market
Firm1	3	3	2	1
Firm2	1	1	0	0
Firm3	1	1	1	0
Firm4	2	1	1	0
Firm5	44	44	0	0
Firm6	0	n.a.	n.a.	n.a.
Firm7	2	2	1	0
Firm8	1	1	0	0
Firm9	0	n.a.	n.a.	n.a.
Firm10	0	n.a.	n.a.	n.a.
Firm11*	18	18	18	15
Firm12*	40	40	Not answered	Not answered
Firm13	0	n.a.	n.a.	n.a.
Firm14	1	1	0	0
Firm15	0	n.a.	n.a.	n.a.
Firm16	0	n.a.	n.a.	n.a.
Firm17	0	n.a.	n.a.	n.a.
Total	113	113	23	16

Legend:

n.a.=not applicable

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

service or product.

Source: own elaboration from fieldwork, April 2009.

Firm 1 produced fewer innovations compared to Firms 5, 11 and 12. However, most of Firm 1's innovations were new to the national market and one was new to the world, although at the time of data collection had not entered the export market. The firm directs its investments mostly to the domestic market. Firm 1 is among the group of a few firms with no external ties to support innovation.

Firm 11 had involvement in all the types of innovations in Table 8, most of them new to the international market, which involved new technologies and, in some cases, involved the application of a business model not previously used for the type of software developed.

5. Analysis and conclusions

Studies of innovation highlight the promotion of networks through different technology policy channels, including networks that enable firms to increase the possibilities of learning-by-interaction, and of acquiring new knowledge crucial for innovation (Lundvall, 1992a). Brazilian government introduced policies in the early 1990s to foster the formation of regional software networks in different regions of the country. The two networks analysed, Campinas and Recife, have different histories in the ICT industry (Pamplona da Costa, 2012: Chapter 4).

Aiming to answer the research question proposed in this article, we find that 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 that the rate of response of Campinas software firms to government policies to promote network formation is low compared to the potential for interactions among firms, and between firms and other organizations. Hence, there are *limited* interactions between technology policy, and network governance and structure in Campinas, where firms achieve high levels of innovative performance and where a large share of innovative firms relies on internal resources for developing their innovation activities. Firms prefer learning from experience rather than by interacting.

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, although not always hugely. The results for the Recife case show broader interaction between technology policy and network governance and structure in Recife (compared to Campinas), and a large share of innovative firms engaged 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.

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 differently in networks and present different innovative performance. Brazilian software firms embedded in regions with different structures (i.e. socio-economic and industrial development), show different engagement in networks and contrasting innovative performance. We found that 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 showed comparatively lower innovation performance, networking in this region seems to have supported regional catching up. This study contributes to the knowledge on technology policy effectiveness; adoption of a general technology policy prescription for the formation of networks as a mechanism to improve firm-level innovation and regional catching-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. Regional path-rigidity and contextual as well as network specific influences in new networks and during their evolution must also be considered in technology policy formulation.

Another contribution of this paper is the combining of qualitative methods with SNA. For instance, the representation in Figure 2 of the network of innovators does not do full justice to the role played by CESAR within the Recife network of innovators. From this representation it might be assumed that CESAR's disengagement from the network would cause little disruption to network evolution. However, the empirical evidence shows that, CESAR has become the network's anchor, and its reputation has spilled over to all the

organizations in the network. Its withdrawal from the network (were its headquarters to be relocated for instance) would cause huge disruption to the evolution of the network.

In relation to 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 on networks (e.g. Ahuja, 2000, Grasenick *et al.*, 2008). The institutional, cultural and economic settings may differ among regions, and policies aimed at promoting network formation to improve firms' innovation performance should take into account that reproducing the network governance and structure of 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 findings of inconsistency of sub-networks, and poor engagement of organizations expected to play a primary role in fostering development and catch-up or to be relevant throughout the innovation development process, suggest some reformulation of their organizational missions, and policies aimed at promoting formation of networks should take account of these issues.

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