Channels for the Diffusion of Innovations in Industrial Clusters: The Role of Networks between Local Firms

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Abstract
This paper investigates the overall impact of new-to-the-cluster firms on the transfer of technologies through diverse channels of diffusion. It analyses the diffusion of two successful innovations that spread after the arrival of advanced firms in a footwear cluster in Brazil, particularly through social network relationships among local firms. The specific research questions are: What are the channels behind the transfer of innovations? How important are they, and for which type of firms? Relevant information was collected from the entire cluster. It emerged from the findings that relocated firms were important in supplying the region with trained labour; and local firms were important in disseminating the innovations through their network and labour turnover, magnifying the diffusion of innovations and the impact of relocated firms. This evidence brings into focus the benefits of networks in industrial clusters, especially with the arrival of relocating firms. New technologies are not readily understandable to all local firms and some local firms can use local partnerships to help them in this.

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This paper investigates the overall impact of new-to-the-cluster firms on the transfer of technologies through diverse channels of diffusion. It analyses the diffusion of two successful innovations that spread after the arrival of advanced firms in a footwear cluster in Brazil, particularly through social network relationships among local firms. The specific research questions are: *What are the channels behind the transfer of innovations? How important are they, and for which type of firms?* Relevant information was collected from the entire cluster. It emerged from the findings that relocated firms were important in supplying the region with trained labour; and local firms were important in disseminating the innovations through their network and labour turnover, magnifying the diffusion of innovations and the impact of relocated firms. This evidence brings into focus the benefits of networks in industrial clusters, especially with the arrival of relocating firms. New technologies are not readily understandable to all local firms and some local firms can use local partnerships to help them in this.

I. Introduction

Although it is commonly agreed that the arrival of more developed firms in new regions generates positive externalities through knowledge spillovers (Griliches, 1992, Mohnen, 1996), little is known about the channels of transmission through which they operate, and only a few empirical studies (Javorcik, 2004, Ben Hamida, 2013) have been able to trace how spillover knowledge actually makes its way from one firm to another.

The diffusion of knowledge may not always take place directly between the newly relocated firm and all local firms. It may be mediated through leading local firms, i.e., the knowledge may go from relocated firms to leader local firms and then be diffused to other local firms. Although the literature has suggested this possibility (Cameron et al., 2005, Li et al., 2011b, Branstetter, 1996), the channels of diffusion have not been systematically analysed and empirical evidence is lacking. For instance, Li et al. (2011b) suggest that new technologies can be transferred from

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1 This paper is an adaptation of one of the core chapter of my DPhil thesis.

2 Implementation and confirmation are the last two stages in the diffusion of innovations. According to Rogers (2003) the diffusion occurs in five stages: (1) knowledge: in which potential adopters find out about an innovation;
advanced domestic regions to less advanced ones more through competition, associations, flows of human resources and imitation than through foreign direct investments (FDI).

This paper aims to fill this hole in the literature by exploring the way knowledge has been spread in a footwear cluster in the northeast of Brazil. The research questions are: what are the channels behind the transfer of innovations? How important are they, and for which type of local firms?

To answer these questions I focus on two specific innovations in the thermoplastic shoe industry in the Cariri region. The analysis explores which sources drive the diffusion of innovation: local or relocated firms, and which channels are more likely to operate during the implementation and confirmation stages of innovation diffusion. Implementation (when the innovation is actually used) and confirmation (when the adopter reviews the innovation and decides to continue using it) stages were chosen as interviewees easily recognised them, ensuring a more knowledgeable answer.\(^2\)

The research proposed in this study contributes to the literature with new theoretical and empirical evidence. It is novel in three ways: (1) the direct importance of the network is examined throughout the diffusion process, (2) the role of local firms in the dissemination of innovations (after obtaining knowledge about them from relocated firms) receives special attention, and (3) the channels are empirically disentangled.

Surprisingly, the role of networks has been neglected in the FDI literature despite its importance in the transfer of technologies. Studies analysing the arrival of more developed firms have not considered the interpersonal relationships between employees and directors of different companies and the potential magnification of technological spillovers. However, we already know that the position of firms in inter-organisation networks influences the diffusion of innovations (Powell et al., 1996, Walker et al., 1997), and densely embedded networks are advantageous to the diffusion of innovations (Coleman, 1988).

Networks have not been extensively or systematically analysed in the cluster literature either, although empirical studies have found that firms which are members of local networks accelerate the diffusion of knowledge and improve learning in industrial clusters (Maskell and Malmberg, 1999, Gebreeyesus and Mohnen, 2011, Capello and Faggian, 2005). Giuliani (2007)

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\(^2\) Implementation and confirmation are the last two stages in the diffusion of innovations. According to Rogers (2003) the diffusion occurs in five stages: (1) knowledge: in which potential adopters find out about an innovation; (2) persuasion: in which potential adopters form a positive or negative impression of the innovation; (3) decision: in which the innovation is actually adopted or rejected; and finally (4) implementation and (5) confirmation.
and Boschma and ter Wal (2006) investigate network effectiveness in industrial clusters but, as analysed in the next section, these studies do not focus on the arrival of more advanced firms in the cluster.

In this study, inter-firm linkages were analysed by the construction of graphs, socio-metric measures and qualitative information collected during interviews. Through these linkages, the network was explored to comprehend how family relations and business partnerships affect the implementation and confirmation stages of diffusion and, consequently, the cluster’s performance after the arrival of more advanced firms.

It emerges from the findings that relocated firms were important in supplying the region with trained labour, and local firms were important in disseminating the innovations through their network and through labour turnover, increasing the diffusion of innovations and the impact of relocated firms. This evidence highlights the benefits of networks in industrial clusters, especially when firms relocate to the cluster. New technologies are not readily understandable to all local firms and some local firms (those that are not able to understand information from a given external source) can access them by means of local partnerships. Therefore, a connected cluster ensures that information introduced into the cluster by a relocating firm reaches firms with lower absorptive capacity by using local leader firms as mediators.

The paper is organised as follows. In the second section, the available literature is discussed. In section three, a brief description of the research setting is given, followed by the collection of network data and the selection of two specific innovations in section four. Section five presents the diffusion of innovations and the network of the cluster, while the conclusion is presented in the last section.

II. Literature Review: how does the transfer of technology really take place in clusters?

In this section, I will be analysing the related literature on FDI, clusters and diffusion of innovations. Although the FDI literature considers vertical and horizontal FDI\(^3\), I will be

\(^3\) Vertical FDI is related to the idea of product relocation, i.e., the transfer of unskilled-labour intensive production activities to locations where unskilled labour is abundant, while horizontal is based on the idea of placing production close to customers (BEUGELSIDIJK, S., SMEETS, R. & ZWINKELS, R. 2008. The impact of horizontal and vertical FDI on host’s country economic growth. International Business Review, 17, 452-472.) In the horizontal case, the FDI could happen given the relocation of a firm or the arrival of subsidiaries. It is suggested that horizontal FDI (ibid.) and
analysing both without distinguishing them, as I consider that if the new firm is more advanced than local firms, there is a possibility for technology transfer, regardless of the type of FDI.

Relocating firms are frequently more advanced than local firms (Blomstrom and Sjoholm, 1999, Bellak, 2004, Sabirianova et al., 2005) and their knowledge may spill over to local firms (Rugraff et al., 2008). The channels through which innovation diffuses are generally identified in the literature as: (1) competitive and demonstrative effects, when local firms imitate or reverse engineer technologies brought in by more advanced firms (Glass and Saggi, 1998, Wang and Blomstrom, 1992, Rodriguez-Clare, 1996), (2) labour mobility, when workers trained by or working in more developed firms decide to leave and join an existing firm or open up a new local firm, taking with them some or all of the firm-specific knowledge from the relocated firm or subsidiary (Buyinza, 2009), and (3) vertical linkages, when local firms provide better quality goods and services to relocated clients or are provided with them by relocated suppliers (Javorcik, 2004, Javorcik, 2008, Gorg and Greenaway, 2004).

As investigated in Ben Hamida and Gugler (2008), many empirical studies have measured productivity spillovers by analysing the relationship between production and the presence of foreign firms, treating the mechanism by which spillovers occur as a black box. Das (1987) determines spillovers by the degree of foreign presence, measured by the ratio of the value of capital stock of foreign-owned firms to the value of capital stock of the locally owned firms. In Wang and Blomstrom (1992) spillovers are endogenously generated by the technological competition between foreign affiliates and local firms. In Javorcik (2004), forward spillovers are defined as the weighted share of output in upstream sectors produced by firms with foreign capital participation, while backward spillovers are defined as the foreign presence in industries that are being supplied by the sector.

Unavailability of detailed micro-level data is the most important reason for the lack of empirical studies disentangling the channels through which spillovers work (Saggi, 2002). Ideally, an assessment of the overall spillover outcome should separate out the effects of different channels, but the influence of labour mobility on the efficiency of local firms, for example, is difficult to evaluate, as it might involve shadowing the workers in order to investigate their impact on the productivity of other workers, as mentioned by Saggi (2002). Consequently, it is not surprising that there is a shortage of detailed studies analysing the channels using this relocation of headquarters (MARIN, A. & BELL, M. 2006. Technology spillovers from foreign direct investment (FDI): The active role of MNC subsidiaries in Argentina in the 1990s. *Journal of Development Studies, 42*, 678-697.) have a higher impact on technology transfer than vertical FDI and the relocation of subsidiaries.
method.

As analysed in Gorg and Strobl (2004), there is evidence, though, that labour mobility is one of the most important channels for diffusion. In developing countries, subsidiaries are important providers of training for workers who later move to other companies. Djankov and Hoekman (2000) show that multinationals are more likely to provide training than domestic firms. Using a matched firm and worker level dataset for Ghanaian manufacturing firms, Gorg et al. (2007) found that workers who received training in foreign firms experienced more rapid wage growth than workers who were trained in domestic firms, which is consistent with the idea that training provided by foreign firms is more productive than that provided by domestic firms.

More directly, Gershenberg (1987) and Almeida and Kogut (1999) followed the mobility of managers and technical experts and studied the transfer of knowledge. Gershenberg (1987) shows the importance of managers’ mobility from multinationals to domestic firms using a survey of 72 managers in manufacturing firms in Kenya, although he does not quantify the importance of these movements. Almeida and Kogut (1999) studied inter-firm mobility of major patent holders, and found that the mobility of scientists does indeed influence local transfer of knowledge.

FIAS (2003) presents evidence for vertical rather than horizontal spillovers in Latvia. The survey demonstrated that the majority of multinationals are engaged in local sourcing. Thirty-three per cent of Latvian firms supplying multinationals received assistance from their customers, and one third of Latvian firms benefited from the presence of foreign firms in their sector (Javorcik, 2004).

Similar to this paper, but using different methodology, Ben Hamida (2013) attempts to measure several channels of diffusion using firm-level manufacturing data from Switzerland. To assess the overall spillover effects of foreign firms on their local counterparts, he employs three different proxy variables with respect to three possible intra-industry spillover channels. Firstly, the share of foreign presence reflects spillovers from demonstration effects, resulting from the technology transfer that occurs due to direct contact between local agents and foreign affiliates operating at different levels of technology. Secondly, interaction between the foreign presence and human capital is assumed to determine the effect on worker mobility of the presence of foreign firms in the local market. Thirdly, the price mark-up is used as the proxy for competition effects. Although the author uses proxies that might not exactly represent the related channel, it is one of the few papers measuring the importance of more than one channel.
Given the heterogeneity of local firms, there is a need to consider different channels of diffusion. For instance, Mody (1989) and Ben Hamida (2013) argue that firms differ in their technological competence and in turn differ in their choice of how to benefit from the presence of foreign firms. Mody (1989) suggests that low technology firms gain more from spillovers such as worker mobility, since this channel provides personnel assistance which help domestic firms better understand and implement foreign technology (Ben Hamida, 2013). Ben Hamida (2013) argues that, “worker-mobility-related spillovers are fully absorbed by low technology firms; while demonstration-related spillovers are absorbed by all groups of firms with mid technology firms experiencing the larger benefit” (page 754). This study indicates that relatively highly technological local firms are more able to benefit from spillovers through demonstration effects, which require higher absorptive capacity to learn about new technologies.

The role of local firms in the transfer of technologies has already been suggested in the literature, but not systematically measured. Branstetter (1996) estimates the impact of international and intra-national knowledge spillovers on innovation and technological change at the firm level, using data from the U.S. and Japan. He finds robust evidence that knowledge spillovers are primarily an intra-national phenomenon. Similarly, Li et al. (2011b) find that interregional technology transfer has a more significant impact on regional technology development than foreign investments. They suggest that a transit region, which is close to the technology frontier, is the crucial link for transferring knowledge from technology peaks to technology valley regions.

The role of networks is well known in the diffusion of innovations literature.4 “Inter-organisation networks can provide access to knowledge spillovers, serving as information conduits through which news of technical breakthroughs, new insights in problems, or failed approaches travels from one firm to another” (Ahuja, G, 2000, page 427). As mentioned by Cowan et al. (2003), knowledge is passed informally through face-to-face contact because much of the relevant knowledge is tacit and can only be transmitted through direct interactions. In this sense, “space matters for knowledge diffusion, and social space may matter as much as or more than geographic space” (page 3).5 Three aspects of a firm’s network structure are relevant: (1)

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4 The empirical literature using social network analyses diffusion in Silicon Valley, Japanese business groups, the biotech industry, Italian industrial districts, the automobile industry and the fashion industry (COWAN, R., JONARD, N. & ÖZMAN, M. 2003. Knowledge Dynamics in a Network Industry. Maastricht : MERIT, Maastricht Economic Research Institute on Innovation and Technology.)

5 According to the authors there are three types of models for diffusion: (1) nearest-neighbour model where agents are directly connected to nearest neighbours in the physical space. The networks are locally very dense but with relatively long average paths between pairs of agents. (2) Random graphs where agents are connected with some probability to other agents regardless of location. The networks have short average paths between pairs of agents but
the number of direct ties maintained by a firm, (2) the number of indirect ties maintained by the firm, i.e., the firms it can reach in the network through its partners and their partners, and (3) the degree to which a firm’s partners are linked to each other (Ahuja, G, 2000, page 428).

Only a few studies have attempted, though, to consider the entire local network of an industrial cluster to analyse the role of local firms and, even though neither of these studies focuses its analysis on the impact of relocated firms, they provide an overview of the findings in the literature. The first paper analyses the Chilean wine cluster in Colchagua (Giuliani and Bell, 2005). The authors test the hypothesis that knowledge does not flow freely in the air by virtue of geographical proximity but flows within linked firms with high absorptive capacity. They interviewed 28 fine wine producers and four other producers, analysing technical support, technical advice and joint experimentation. The second paper analyses the Italian footwear cluster in Barletta (Boschma and ter Wal, 2006). The authors examine which factors were responsible for individual firms’ position within the network and for their innovative performance. The hypotheses were based on firm-specific features (such as size and absorptive capacity), network positions and location (local versus non-local relationships). The authors interviewed 33 out of 58 firms and showed that absorptive capacity affects economic performance.

The current study differs from the previous two studies in the following ways. First, neither of these studies focuses its analysis on the impact of new-to-the-cluster firms. Second, they use data from well-established clusters mostly in developed countries, while this study relies on data from an evolving cluster in a developing country. Third, the main focus of previous studies was on knowledge networks while this study explores the role of social and business networks on the diffusion of innovations. As mentioned in Gebreeyesus and Mohnen (2011), evolving clusters in developing countries have limited or no external linkages with knowledge institutions or international technology leaders. They mainly rely on relations with family and business partners for gaining information and knowledge about innovations.

In fact, Gebreeyesus and Mohnen (2011) present evidence of the diffusion of innovations in an Ethiopian footwear cluster, which is more comparable to the Cariri footwear cluster. Using firm-level data from a cluster of informal footwear firms in Ethiopia, the study provides empirical evidence on the impact of firm heterogeneity on embeddedness in networks, and of absorptive
capacity on the innovation performance of firms. The authors find that business interactions with buyers, suppliers and other producers are the major channels through which knowledge flows in the cluster. Similar to this study, the authors find a strong family network within the cluster as “second-generation entrepreneurs (parents with shoe making experience) account for about 21 per cent of the entrepreneurs. Above half (55%) have also reported that they have siblings in the shoe making business in the cluster that includes producers, suppliers, buyers or other related activities” (page 11). Contrary to this study, the authors find no significant evidence that family ties favour innovation. This disparity could be explained by the use of different methodologies and a more generic measure of innovation in the Ethiopian study.

Briefly, many empirical studies have measured productivity spillovers but treat the mechanism by which spillovers occur as a black box. Unavailability of detailed micro-level data is the most important reason for the lack of empirical studies disentangling the channels. The present paper is able to contribute to the literature that separates out the individual channels thanks to a rich body of primary data collected in the Cariri Region. The analysis is centered on the role of networks, which has been neglected in the FDI literature and not systematically measured in the technology transfer literature. In fact, only a few studies have considered the entire local network of an industrial cluster to analyse the role of local firms, but none of these studies focuses its analysis on the impact of relocated firms, or on the diffusion of specific innovations in order to measure the actual diffusion.

III. Research Setting – brief background

From the mid-1980s onwards, a large number of footwear firms from the Vale dos Sinos (in the south of Brazil) set up business in the northeast of the country. The relocation process continued over the next 30 years. The investments in the state of Ceará were located in two areas: the Cariri (the cities of Barbalha, Crato and Juazeiro do Norte) in which most of the micro and small footwear firms in the northeast are concentrated, and the metropolitan region of Fortaleza (the cities of Fortaleza, Caucaia, Horizonte, Marangaupe and Cascavel).

After the establishment of the firm I will refer to as R-44 (R- meaning relocated) in the northeast in 1996 with over 3,000 employees, the region attained national visibility. R-44 is a

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6 This evidence is also shown in LI, E., LI, X. & LIU, Z. 2011a. Relationships and evolving networks of rural manufacturing clusters: A case study in Yucheng County, Henan Province of China. Chinese Geographical Science, 21, 364-376. They suggest that family numbers in rural communities and the associated culture largely influence rural clusters while high-tech clusters are influenced by technology-based linkages.
subsidiary of the largest injected footwear manufacturer in the world, with over 26,000 employees nationwide and a production capacity of 200 million pairs of shoes per year. This visibility attracted the attention of other southern firms, suppliers, skilled labour and other institutions (da Costa, 2007) which were scarce in the region.

After the relocation of southern firms to Cariri, two phenomena occurred: (1) the region focused its production on the use of synthetic materials derived from petroleum, such as Polyvinyl Chloride (PVC), Polyurethane (PU) and Ethylene Vinyl Acetate (EVA), decreasing the use of leather in the local industry; and (2) the region gained dynamism, with production output attaining national and international levels.

Almost 30 years after the migration of the first southern firms, the northeast is now responsible for 30% of national employment in the sector, 40% of the number of shoes produced nationally, and 30% of national exports. Those firms that migrated from the south, representing 10% of all enterprises, account for 80% of the jobs (BNDES, 2006, da Costa, 2010, Santos et al., 2002). Ceará attracted most of the firms that relocated to the northeast. The share of total Brazilian footwear employment per northeastern state shows the relevance of such investments. The numbers employed in Ceará in the footwear industry rose from less than 2% in 1994 to more than 17% in 2010.7

The Cariri region is already producing over 100 million shoes per year, eleven per cent of the total number of shoes produced in the country (Abicalçados, 2011). There are 170 formal firms in the Cariri cluster and approximately the same number of informal firms. Twenty firms have relocated from the south, and these account for over 80% of the total production of the cluster. There are 74 firms producing PVC injected shoes, 40 producing EVA shoes, and 56 producing other types of shoes or components. The region has 130 firms in the footwear industry with up to nineteen employees, 35 between 19 and 100, fifteen between 101 and 499 and five with more than 499 employees (SEBRAE).

IV. Data and Methodology

Comprehensive data collection was required in order to perform a social network analysis. The path of innovations in the Cariri cluster can only be fully understood if all the firm’s owners in

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the sector are asked face-to-face about their adoption decision.\(^8\) In addition, family and business networks will only be fully representative of the cluster if the entire cluster is interviewed.\(^9\)

Previous literature has commonly used ego, sampling or snowball sampling networks, but limitations are stressed, such as small numbers of participants, sampling bias and over-impact of first participants (Knoke and Yang, 2008). These limitations were avoided in this study, as the entire network was interviewed (innovative and non-innovative footwear-related firms). The eight months spent in the region, the concentration of the cluster in three cities only ten kilometres apart, and my previous experience in the footwear sector\(^10\) helped in obtaining the required data.

The data was collected in three stages. Firstly, institutions, suppliers and producers were interviewed to learn about the industry, to identify relevant innovations in the industry during the last 30 years and to test the questionnaire. This phase was performed between November and December 2011. Secondly, the main fieldwork was developed between March and August 2012. During this period nearly all producers were interviewed\(^11\) in order to gather all relevant data. Thirdly, conflicting information was clarified by conducting additional interviews, and the results were discussed with experts in the cluster during July 2013.

During the first phase of the fieldwork, eight innovations were identified: four were analysed in depth and two are presented in this paper.\(^12\) The two innovations were selected based on the year of their first implementation and on their current diffusion; in other words, innovations widely diffused throughout several years were favoured over others. They were implemented in the thermoplastic footwear industry. Thermoplastic sandals are the current specialisation of the cluster and the area of expertise of the relocated firms. The innovations comprise the arrival of two types of machines:\(^13\)

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\(^8\) Face-to-face interviews were essential to explain the concepts. For example, during the pilot phase one of the first questions was related to general innovation adoption, similarly to the Community Innovation Survey (CIS) question: “During the three years, did your enterprise introduce new or significantly improved goods/methods of manufacturing?” More the half of the interviewees answered that they didn’t innovate, when in fact more than 80 percent introduced new or significantly improved goods/methods of manufacturing, which was discovered when more detailed information was gathered from face-to-face discussion with interviewees.

\(^9\) Interviewing the entire cluster allows the analysis of actors’ network positions as well as of the structural properties of the network (ibid.)

\(^10\) I worked full-time in a footwear export firm for five years.

\(^11\) Only five firms declined to be surveyed. Secondary information about these firms was gathered so as not to lose data about their participation in the industry from the study.

\(^12\) Six innovations were identified but not studied in this paper.

\(^13\) As stated in GEBREETYESUS, M. & MOHLEN, P. 2011. Innovation performance and embeddedness in networks: evidence from the Ethiopian footwear cluster. United Nations University, Maastricht Economic and Social Research and training centre on Innovation and Technology, innovation in a small enterprise in the developing countries context is largely an adoption of a product, process or method that has already been developed elsewhere.
1. **Conventional PVC Injection Moulding Machine**: With this machine firms produce PVC strips, soles and outsoles. It is particularly relevant to rubber plate producers as PVC strips and outsoles are complementary goods. The machine typically costs GBP 20,000 as at July 2013. It was first implemented in 1983, so it has 30 years of development and has been implemented by 74 out of 170 firms in the cluster.

2. **Expanded PVC Injection Moulding Machine**: With this machine firms produce complete PVC shoes, replacing rubber components. It is particularly relevant to firms that do not produce rubber plates or want to increase the added value of their products. The machine typically costs GBP 50,000 as at July 2013. It was first implemented in 1995, so it has had 18 years of development and has been adopted by 51 out of 170 firms in the cluster.

The diffusion of these two innovations is comparable as both have more than eighteen years of diffusion and were widely implemented by the local firms. Although the innovations arrived in the region twelve years apart, the first in 1983 and the second in 1995, the innovations only started to be diffused in the beginning and middle of the 1990s, when the cluster had already a certain degree of absorptive capacity. This is why the diffusion is fairly similar and the findings of one correlate with the other, though, for the diffusion of the second innovation more foreign (typically from the south of the country) and local labour was available in the cluster and, consequently, these channels were slightly more important than for the diffusion of the first.

Methodologically, the analysis of these two innovations resembles the case of multiple experiments. In other words, the generalisation is analytic, as the first diffusion is used as a template with which to compare the empirical results of the second. If two or more cases support the same theory, which is the case here, the empirical results are considered more potent (Yin, 2013).

The year of adoption of these specific innovations and further information about the technical advice required for their adoption was gathered. The data was based on respondents’ recall of retrospective data, which might be subject to error (Valente, 1996). Nevertheless, the implementation and confirmation of important innovations is a radical event, fundamentally changing their production methods, thus increasing the likelihood of accurate recall (Valente, 1996).

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(PELLENBARG, P. H., WISSEN, L. J. G. V. & DIJK, J. V. 2002. Firm relocation: state of the art and research prospects. University of Groningen, Research Institute SOM (Systems, Organisations and Management). Hence, the traditional measures of innovation in large firms in the developed world, such as R&D expenditure or patented innovation, are not relevant.)
During the second period of fieldwork, structural interviews were performed with the shoe producers in the Cariri cluster (i.e., 170 firms) and information was gathered to record their networks. The interviews lasted on average 45 minutes\textsuperscript{14}, and three main networks were investigated: family, formal and informal business partners\textsuperscript{15}, plus details about the adoption of the four selected innovations. An informal business partner is defined as a firm that has an informal degree of involvement with other firms with the intention of creating a profit. A formal business partner is defined as a firm that plays a significant role in owning, managing or creating another firm. The survey also covered other variables related to enterprise history, owner’s profile, innovation experience, production, sales and costs.

Information concerning horizontal and vertical knowledge linkages were collected by the roster free-recall method (Wasserman and Faust, 1994). The questionnaire required respondents to recall actors with which they have business and personal relations and add them to the list (Marsden, 1990, Giuliani and Bell, 2005). Assistance was provided by classifying actors, such as suppliers, clients, competitors, consultants, universities and public institutions. This ensures that the complete network was identified and made it possible for respondents to add external linkages (Ter Wal and Boschma, 2008).

Information about respondents’ perceptions of the relocated firms was also collected. Respondents were asked for their personal opinions regarding the importance of labour mobility, the arrival of suppliers and the connections that the relocated firms generated. Subsequently, respondents were requested to answer specific questions about their employees. They were asked whether they had hired employees from traditional clusters in Brazil directly, e.g., recruiting in the south; or indirectly, i.e., if the employee was already in the region as a past employee of a relocated firm. Knowing about the network and the incidence of relocated labour in each firm was helpful to understand the connections of local and relocated firms, and to magnify the importance of labour mobility in the region. Also, and most importantly, it helped to double check information regarding the adoption of innovations, as networks and labour mobility were important channels for the diffusion.

Social Network analysis (SNA) was used in this research to systematically analyse the diffusion of innovations. Social networks are an appropriate conceptualisation of firm interaction and

\textsuperscript{14} The interviews last a minimum of 15 minutes and a maximum of 4.5 hours.

\textsuperscript{15} Other networks were gathered such as technical advice networks, providers’ networks and institutional networks (memberships in institutions and participation in national and international fairs). Based on arguments presented in Section I, family and business partnerships were used in this paper.
knowledge flows (Ter Wal and Boschma, 2008, Borgatti et al., 2009). Firm interaction has played a crucial role in foreign direct investment and the cluster literature, but network theory has only recently been applied to examine the appearance of the structure of interaction in regions and geographical clusters (Ter Wal and Boschma, 2008). Mapping the relations of relocated and host firms through networks can disentangle the concept of horizontal and vertical linkages more systematically.

The diffusion of these two innovations was reconstructed in order to analyse the influence of relocated firms. First, the person that helped in the implementation was identified, then the firm that was associated with that person, and lastly, the source of the innovation was classified in channels and analysed. The channels were divided into five categories:

- **Demonstrative effects:** the owner or production manager mentioned that the firm was inspired to implement the innovation by the fact that another firm had implemented it. They learned the innovations through imitation or reverse engineering, and the source firm did not help directly in the process of implementation.

- **Labour mobility:** the owner or production manager mentioned that the firm implemented the innovation after hiring an employee that was already working with the innovation in a previous firm. Information about the employee was gathered to trace his former employer.

- **Network:** the owner or the production manager mentioned that the firm implemented the innovation after receiving assistance from family or business partners. Frequently, the owner of a business or one of his employees would come to his relative's firm to help the implementation of the innovation. This process took normally 3-7 days and further support was given to solve problems after the implementation.

- **Supplier:** the owner or the production manager mentioned that a formal or informal supplier helped in the implementation of the innovation. An informal supplier is a competitor that produces shoes as its main activity but also sells new or second hand machines to other firms, giving technical advice to the buyer.

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• **Training Centres:** the owner or the production manager mentioned that the firm received assistance from public institutions during the implementation. These are nationwide institutions and the subsidiary usually brought technical advice from subsidiaries located where the industry is more advanced.

The role of customers was also investigated, but given the characteristics of the industry, they did not play an important role during the implementation or confirmation stages of the diffusion. Customers could have an influence in the early stages of diffusion such as the persuasion (when potential adopters form a positive or negative impression of the innovation) and decision (when the innovation is actually adopted or rejected) stages, but not in the implementation and confirmation stages. For instance, a shoe buyer might inform the producer that he would like to buy a certain type of shoe but would not help in the implementation of the required machinery to produce it.

The software package Gephi was used to represent the network and the diffusions. The software allowed the creation of network graphs through the use of nodes representing the firms; undirected links representing the family and business relations; and different colour and sizes representing other attributes. It also enabled the creation of the diffusion paths through the use of nodes representing the firms; directed links or arrows representing the implementation of the innovation from the source to the target; and the representation of several attributes through different colours and sizes.

V. **Evaluating the Role of Networks**

In this section, I will be presenting the diffusion of two specific innovations. I will be dividing this section into four subsections: diffusion through labour mobility, networks, suppliers and other channels. The most important subsection relates to diffusion through networks, where the network of innovative and non-innovative firms is presented and its effectiveness is tested considering the diffusion of conventional and expanded PVC injection machines.

Figure 1 presents the diffusion of the two types of injection machines. Figure 1-A shows the firms that became the source or target of the implementation of conventional PVC injection machines in the path of diffusion (firms connected by arrows), while Figure 1-B shows the 53 organizations that became the source or target of the implementation of expanded PVC injection machines in the path of the diffusion.
The colour of the nodes represents the origin of the firm:

- Black represents relocated firms
- Grey represents local firms
- Green represents firms outside the cluster, located in traditional clusters in Brazil\textsuperscript{17}
- Red represents firms outside the cluster, located in traditional clusters outside Brazil\textsuperscript{18}

The colour of the arrows represents the channels for the implementation as discussed in Section IV:

- Red represents diffusion through demonstrative effects
- Ultramarine represents diffusion through networks
- Orange represents diffusion through labour mobility from the south, which could come from a relocated firm (black node) or a firm located somewhere else (coloured node)
- Yellow means that the diffusion happened through labour mobility within the region
- Green means that the diffusion happened through suppliers
- Light blue means that the diffusion happened through public institutions

\textsuperscript{17} These firms are included in Figure 1 because they are sources for the innovations but they are not included in Figure 2, 3 or 4 as they are not part of the cluster.

\textsuperscript{18} These firms are included in Figure 2 because they are sources for the innovations but they are not included in Figure 2, 3 or 4 as they are not part of the cluster.
The size of the node represents the out-degree of the firm. Out-degree measures the number of times the firm was the source of the diffusion. In other words, it shows how many arrows leave the node or how many times the firm passed the innovation on to other firms. In brief, firms with higher out-degree centrality had the role of spreading the innovation across the network through demonstration, networking, labour mobility or other channels.

The most important channels for the diffusion of innovations were networks and - as expected - labour mobility, which together represented over the 70% of the diffusion for both innovations. For the first innovation, representing 38% of the diffusion, networks were even more important because fewer expert local and foreign workers were available in the labour market in the 1980’s and 1990’s. This evidence is in line with the literature suggesting that interpersonal relationships play a pivotal role when certain markets are weak or absent in the cluster (Gebreeyesus and Mohnen, 2011).
Local and relocated firms had high out-degree centrality as it is seen from the size and colour of the nodes in Figure 1. This indicates that both types of firms were important as sources in the diffusion of innovations. Relocated firms were more important through foreign labour mobility (represented by orange arrows) while local firms through networks and local labour mobility (represented by ultramarine and yellow arrows respectively).

a. Diffusion through Labour Mobility

Aggregating local and foreign workers, labour mobility was the main channel for the diffusion of both innovations. This channel was involved in 43% of the diffusion of conventional PVC injection machines and 66% of the diffusion of expanded PVC injection machines. These percentages were equally distributed among local and foreign labour mobility, representing respectively 22% and 21% for the first diffusion, and 33% each for the second diffusion (see Figure 1). Labour mobility was more important for the diffusion of expanded PVC injection machines, representing 66% of the diffusion, as more local and foreign workers were available in the labour market.

Relocated firms transferred important information to local firms by releasing foreign workers who ended up working for local firms or starting their own businesses. At first, relocated firms paid higher wages and signed labour contracts to avoid labour turnover, particularly amongst the relocated workers with extensive tacit knowledge. Eventually, labour contracts expired and relocated employees faced the decision to either return to their original location, or to become part of the local market and to create their own enterprises.

b. Diffusion through Networks

In order to analyse the role of networks as a diffusion channel, Figure 2 presents the family, formal and informal business partners of the entire cluster. The effectiveness of the network is tested using the diffusion of conventional and expanded PVC injection machines (Figure 1) as an outcome of the network (Figure 2). It is to be expected that more connected firms have a higher probability of implementing innovations, and that a significant number of these connections

19 In other words, some local (grey nodes) and relocated (black nodes) firms had high out-degree centrality represented by bigger nodes.
were used to actually diffuse these two specific innovations.

In the diagram of the network of the Cariri cluster (Figure 2), the colour of the node represents the origin of the firm,\textsuperscript{20} i.e.:

- Black represents relocated firms
- Grey represents local firms

The colour of the links represents the relationship between firms, where:

- Dark Blue symbolizes that the firms are family partners
- Mid Blue symbolizes that the firms are formal business partners
- Light Blue symbolizes that the firms are informal business partners

The size of the node represents the degree centrality. Degree centrality measures the number of social connections the firm has in the network. The bigger the node, the more central is the firm to its network.

In total, out of the 170 firms, 86 had at least one family or business partner and 35 had three or more partners (calculations from Figure 2-A)\textsuperscript{21}. Most of the firms reported having direct family members in the industry, representing 66\% of the network relations\textsuperscript{22}, while 20\% and 14\% reported having informal and formal business partners, respectively.

\textsuperscript{20} Only internal linkages were considered in this section as very few relocated firms had external linkages and none local firms had family or business partners outside the cluster.

\textsuperscript{21} In this part only relocated and local firms were considered, excluding institutions that support the industry.

\textsuperscript{22} In fact, one third of the firms started a business because a family member was already in the business.
The density of the network, defined as the sum of all actual connections divided by the number of all possible connections\textsuperscript{23}, is 1.3\%. It is difficult to compare this number with other densities in the literature as (1) there is a limited number of studies that analysed the entire network in order to calculate network density, and (2) the definition of networks is not always alike, mainly because the literature so far has analysed high-tech or well-established clusters in developed countries where other types of networks are relevant.\textsuperscript{24} For instance, Gilsing et al. (2008) shows that the density of networks defined as cooperative technology agreements in pharmaceutical, chemical and automotive industries ranges from 0.5\% to 2.9\% with an average of 1.3\%. Giuliani (2007) shows that business networks, extensively defined as firms with which a firm interacts for business reasons\textsuperscript{25}, presents a density between 20\% and 35\% in the wine sectors in Chile and Italy; while knowledge networks, defined as firms that are a source of technical advice\textsuperscript{26}, presents a density between 4\% and 9\%. Finally, Boschma and ter Wal (2006) show that the market knowledge of a footwear cluster in Italy presents a density of 3.7\% while the technical knowledge presents a density of 1.6\%.\textsuperscript{27} Compared to the last two papers, the network definition used in this study is limited to stronger ties between firms\textsuperscript{28}, and this could explain, on one hand, the reduced number of links but, on the other hand, the high effectiveness of these

\textsuperscript{23} All possible connections are estimated as $n \ast (n - 1)/2$, where “$n$” is equal to the number of nodes in the network.

\textsuperscript{24} As explained in Section 1

\textsuperscript{25} She exemplifies that “business networks are the trade of inputs or services, membership of the same local consortium, or meeting at local industry events, which imply a personal direct interaction about, for example, their productive activities, the local labour market, and/or international markets. A business interaction occurs also when two firms borrow each other's machinery or tools for production, or their technical employees meet and discuss their appropriate use, when firms buy each other's grapes or bulk wine or, finally, when entrepreneurs gather together to fund a new oenotourism initiative in the area.” (page 150). She asked, “With which of the cluster firms mentioned in the roster do you interact for business matters?” (Page 151) (GIULIANI, E. 2007. The selective nature of knowledge networks in clusters: evidence from the wine industry. \textit{Journal of Economic Geography}, 7, 139-168.)

\textsuperscript{26} She asked, “If you are in a critical situation and need technical advice, to which of the local firms mentioned in the roster do you turn?” and “Which of the following firms do you think have benefited from technical support from this firm?” (ibid.)

\textsuperscript{27} The firm indicated from which enterprises technical support and market knowledge were received, which organisations benefited from technical support and market knowledge provided by the firm, and with whom the firm was involved in research collaboration (BOSCHMA, R. & TER WAL, A. 2006. Knowledge networks and innovative performance in an industrial district. The case of a footwear district in the South of Italy. Utrecht University, Section of Economic Geography.)

ties in the diffusion of innovations.29

Network was especially important for the diffusion of innovations in the Cariri region, because the firms are well connected by strong (family) ties. In fact, network was the second most important channel for diffusion of both innovations, responsible for the diffusion of 38% of conventional PVC injection machines and 22% of expanded PVC injection machines. The decrease in importance from the first diffusion to the second happened as more labour was available and fewer firms needed to rely on networks to learn to implement new technologies.

In order to contrast the diffusion of innovations with the actual network of family and business partnerships, three types of information were gathered: (1) the degree centrality of innovative and non-innovative firms to demonstrate that innovative firms had on average more family relations or business partners than non-innovative firms, (2) the network density of innovative and non-innovative firms to reinforce the higher connectivity of innovative firms, and (3) the percentage of the overall links used in the diffusion of the innovations, to display the effectiveness of the network.

Figure 3-A shows the family relations and business partnerships of the entire cluster30, while Figure 3-B shows the network of the 74 firms that implemented the innovation. The comparison of these two graphs through the use of Gephi tools shows that on average firms that implemented the innovation were 43% more connected to other firms than firms that did not innovate.31 In fact, the density of the network among firms that innovated was 2.8% while the density of the network among firms that did not was 0.4%. In other words, firms that implemented conventional PVC injection machines were significantly more connected than firms that did not.

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30 As in Figure 2-A

31 In fact, firms that innovated had on average 3.2 connections with other firms, while firms that did not innovate had 2.2 connections.
Regarding the actual effectiveness of the network, 30% of the network was used to implement conventional PVC injection machines (see Figure 3-B and 3-C). While Figure 3-B shows the network of the 74 firms that implemented the innovations (76 connections), Figure 3-C shows the 23 family relations and business partnerships that were actually used to implement the innovation, representing the 30% of the network. This percentage indicates that some connected firms either decided on innovation through other channels than their networks, or were the first firms to innovate and searched for the information elsewhere as none of their network had yet implemented the innovation. Excluding the latter option, i.e., excluding the first among related firms to adopt the innovation, and calculating the percentage of the relevant network used (see Table 1), the effectiveness of the networks increases from 30% to 51%. In other words, 51% of the firms that were able to learn the innovation from the network decided to do so.

To see what type of local firms diffused the innovation, the size and experience of local firms that diffused the innovations were compared to those that innovated but did not diffuse. According to Mitchell (1994), Audia and Greve (2006) and Gebreeyesus and Mohnen (2011), size and level of experience could be considered proxies for a firm’s absorptive capacity resulting in innovation leadership. Larger firms are likely to develop routines and processes that facilitate assimilation and innovation, while skills in similar contexts are usually developed through training whilst actually working, and practical experience: the majority of workers have no formal technical training, but acquire their skills on the job.32

<table>
<thead>
<tr>
<th>Use of the Network</th>
<th>Definition</th>
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<tbody>
<tr>
<td>Conventional</td>
<td>Expanded</td>
</tr>
<tr>
<td>30.26%</td>
<td>28.89%</td>
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Percentage of links used in the diffusion of innovations among firms that innovated

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32 In-house R&D activities and highly educated personnel are often used as a measure of absorptive capacity. However, firms in developing countries have neither separate R&D departments nor formally trained technicians or scientists [GEBREEYESUS, M. & MOHNEN, P. 2011. Innovation performance and embeddedness in networks: evidence from the Ethiopian footwear cluster. United Nations University, Maastricht Economic and social Research and training centre on Innovation and Technology.]
Local firms that diffused conventional PVC injection machines were larger and more experienced than other local firms. They had 1.3 times more employees and had been in the business 5.7 years longer on average (calculations from the survey). In fact, these local firms had 198 employees on average and had 14 years of experience on average, compared with 87 employees and 9 years’ experience in the case of the remaining firms. In other words, larger and more experienced local firms were responsible for diffusing the innovation to less developed local firms.

Similarly to the analysis of conventional PVC injection machines, Figure 4-B shows the network of the 51 firms that implemented expanded PVC injection machines compared to Figure 4-A, which presents the family relations and business partnerships of the entire cluster\(^{33}\). The comparison of these two graphs through the use of Gephi tools shows that, on average, firms that implemented the innovation were 36% more connected to other firms than firms that did not innovate.\(^{34}\) In fact, the density of the network among firms that innovated was 3.5%, while the density of the network among firms that did not innovate was 0.8%. In other words, firms that implemented expanded PVC injection machines were significantly more connected than firms that did not implement the innovation.

Regarding the actual effectiveness of the network, 29% of the network was used to implement expanded PVC injection (see Figure 4-C). While Figure 4-B shows the network of the 51 firms that implemented the innovations (45 connections), Figure 4-C shows the 13 family relations and business partnerships that were actually used to implement the innovation, representing 29% of the network. When the irrelevant links are excluded as explained before (see again Table 1), the effectiveness of the network increases from 29% to 53%. In other words, 53% of the firms that were able to learn about the innovation from the network decided to do so.

Local firms that diffused expanded PVC injection machines were larger and more experienced than other local firms. They had 1.7 times more employees and had been in the business 8.2

\(^{33}\) As in Figure 2-A and 3-A.

\(^{34}\) On average, firms that did not innovate had 2.4 connections and firms that innovated had 3.3 connections.
years longer on average (calculations from the survey). In fact, these local firms had 253 employees on average instead of 87 and had 17 years’ experience on average instead of 9 of following firms. In other words, larger and more experienced local firms were responsible for diffusing the innovation to less developed local firms.

Network was an important channel, as adopting firms had the possibility of constantly contacting their network to overcome difficulties during the implementation. This link was seen to be more popular among local firms, as relocated firms have not created enough links with local firms to pass innovations through this channel. After a few years, new adopters did not need to rely on demonstration channels or labour mobility as by the time they decide to adopt they already had within their networks one or more firms that had already adopted the innovation. At the beginning, the more developed local firms implemented the innovation, diffusing it later to less develop firms.

c. Diffusion through Suppliers

Suppliers were not as important as labour mobility and the network as only 15% of the firms learned to implement conventional PVC injection machines from suppliers and even fewer, 4%, learned to implement expanded PVC injection machines from suppliers (see Figure 1). The reason for this is that, although representatives arrived in the region in the 2000’s, only a few
suppliers located subsidiaries in the region, which reduced the chances of vertical linkages between local and relocated firms\(^{35}\).

The difference between 15% in the case of the first diffusion and 4% in the case of the second can be explained by the fact that conventional PVC injection machines are provided by national suppliers, while expanded PVC injection machines are provided by international suppliers (mainly from China and Taiwan). Although neither type of supplier was present in the region, the Brazilian suppliers were more accessible, while the international ones were more expensive to access as it required participation in international fairs or the arrangement of international training courses. Also, for the second diffusion, other channels were available such as local and foreign labour mobility.

National suppliers helped local firms to implement conventional PVC injection machines more homogenously. Firms that did not have the network to access the innovation, the capacity to hire local or foreign expert workers or the absorptive capacity to learn though demonstration effects, bought and accessed the technology through suppliers.

d. Diffusion through Other Channels

Other channels were of minor importance in the diffusion of innovations. They represented four and eight per cent of the diffusion of conventional and expanded PVC injection machines, respectively. These channels are certainly more relevant in the early stages of diffusion - knowledge, persuasion and decision stages - but not in the implementation and confirmation stages.

Demonstrative effect was not relevant because diffusion through imitation and reverse engineering receives little technical support from the source (Ben Hamida, 2007, Mody, 1989).\(^ {36}\) It requires from the adopting firm the use of extra inputs and time for successfully implementation, and the relevant absorptive capacity to learn about the innovation.\(^ {37}\) Training was not as important because teaching centres such as SEBRAE and SENAI did not offer related courses at the beginning of the diffusion. National and international fairs were only important to

\(^{35}\) The first national provider to open a machine subsidiary did so in 2012.

\(^ {36}\) “When the foreign firms enter the market, they demonstrate advanced technologies, and local entrepreneurs after observing an innovative product adapted to local conditions may recognize its feasibility and thus strive to imitate it” (page 756) (BEN HAMIDA, L. 2013. Are there regional spillovers from FDI in the Swiss manufacturing industry? *International Business Review*, 22, 754-769.)

\(^ {37}\) Thus, only relatively advanced local firms are likely to benefit from these effects, while less advanced firms are not in a position to compete with relocated firms, and gain more from other spillovers channels such as worker mobility.
a few local firms that were wealthier and earlier innovators than most of the local firms; this channel required greater effort from the implementing firm as they received reduced support from the source.

VI. Conclusions

This paper has unveiled the mechanisms by which spillovers take place, by using a rich body of primary data collected in the Cariri Region. Although all the possible channels regarding the implementation and confirmation stages of two innovation diffusions were disentangled, the analysis was centered on the role of networks. Such a role has been neglected in the FDI literature and not systematically measured in the technology transfer literature.

The study provided various pieces of evidence. Firstly, the level of connectivity of local firms influenced the magnification of the use of innovations in the cluster. Secondly, the relocated firms were important in supplying the region with trained labour which was accessed by more developed local firms. Thirdly, leader local firms (larger and more experienced firms) were important in disseminating the innovation to other local firms through local labour turnover.

The level of connectivity of firms has been mostly neglected in the cluster and FDI literature even though it is important in the literature of the diffusion of innovations. It pays especial attention to local firms as not only is their absorptive capacity important when analysing the impact of relocated firms but also how connected they are. Precisely, the impact of relocated firms in clusters can be magnified if the cluster shows high levels of connectivity among local firms. And such magnification occurs even if relocated firms are not connected to local firms, as might be the case on most occasions.

This evidence focuses on the benefits of networks in industrial clusters, especially with the arrival of relocating firms. New technologies are not readily understandable to all local firms, and those with low absorptive capacity can use local partnerships to understand them. Therefore, a connected cluster ensures that information introduced into the cluster by a relocated firm reaches even firms with lower absorptive capacity by using local leader firms as mediators.

Relocated firms are important, supplying local firms with foreign employees even if they do not supply the labour market with trained local labour. Almost all the labour mobility from relocated to local firms was that of foreign workers. Relocated firms did train local labour to
replace its foreign labour, but it was the foreign labour that was desired and absorbed by local firms. These foreign employees were trained in both innovations, which increased the innovative capacity of firms in that they could hire only one employee and yet implement more than one innovation.

Leader local firms supplied trained local labour to the market, which helped other firms to implement the innovations. More advanced local firms had the capacity to hire foreign workers directly from relocated firms or use other expensive channels to train their local workers. These local workers ended up in the local labour market and were absorbed by other local firms. The local firms that benefited from local trained labour were less developed firms that could not afford to hire foreign workers.

References


BOSCHMA, R. & TER WAL, A. 2006. Knowledge networks and innovative performance in an industrial district. The case of a footwear district in the South of Italy. Utrecht University, Section of Economic Geography.


