

This article was downloaded by: [National Taiwan University]

On: 05 February 2014, At: 23:33

Publisher: Routledge

Informa Ltd Registered in England and Wales Registered Number: 1072954 Registered office: Mortimer House, 37-41 Mortimer Street, London W1T 3JH, UK



European Planning Studies

Publication details, including instructions for authors and subscription information:

<http://www.tandfonline.com/loi/ceps20>

Examining the Role of Geographical Proximity in a Cluster's Transformation Process: The Case of Taiwan's Machine Tool Industry

Liang-Chih Chen^a & Zi-Xin Lin^a

^a Graduate Institute of Building and Planning, National Taiwan University, Taipei, Taiwan

Published online: 12 Oct 2012.

To cite this article: Liang-Chih Chen & Zi-Xin Lin (2014) Examining the Role of Geographical Proximity in a Cluster's Transformation Process: The Case of Taiwan's Machine Tool Industry, *European Planning Studies*, 22:1, 1-19, DOI: [10.1080/09654313.2012.722973](https://doi.org/10.1080/09654313.2012.722973)

To link to this article: <http://dx.doi.org/10.1080/09654313.2012.722973>

PLEASE SCROLL DOWN FOR ARTICLE

Taylor & Francis makes every effort to ensure the accuracy of all the information (the "Content") contained in the publications on our platform. However, Taylor & Francis, our agents, and our licensors make no representations or warranties whatsoever as to the accuracy, completeness, or suitability for any purpose of the Content. Any opinions and views expressed in this publication are the opinions and views of the authors, and are not the views of or endorsed by Taylor & Francis. The accuracy of the Content should not be relied upon and should be independently verified with primary sources of information. Taylor and Francis shall not be liable for any losses, actions, claims, proceedings, demands, costs, expenses, damages, and other liabilities whatsoever or howsoever caused arising directly or indirectly in connection with, in relation to or arising out of the use of the Content.

This article may be used for research, teaching, and private study purposes. Any substantial or systematic reproduction, redistribution, reselling, loan, sub-licensing, systematic supply, or distribution in any form to anyone is expressly forbidden. Terms &

Conditions of access and use can be found at <http://www.tandfonline.com/page/terms-and-conditions>

Examining the Role of Geographical Proximity in a Cluster's Transformation Process: The Case of Taiwan's Machine Tool Industry

LIANG-CHIH CHEN & ZI-XIN LIN

Graduate Institute of Building and Planning, National Taiwan University, Taipei, Taiwan

(Received January 2012; accepted June 2012)

ABSTRACT *This paper examines the relationship between geographical proximity and a cluster's sustained dynamism with a specific focus on the role of geographical proximity in the transformation of cluster firms' production and learning organizations. Using Taiwan's machine tool cluster as an empirical case, this article studies the nature of various intra- and extra-cluster technological networks established by local firms to tackle the cluster's developmental inertia. In contrast to most recent studies that seem to consider geographical proximity less relevant to the sustained prosperity of incumbent clusters, our case study finds that geographical proximity continues to be a critical factor underlying agglomerated firms' capacity to maintain and explore diverse capabilities within and outside the clusters. On the one hand, co-location allows these firms and their coupled actors to experiment with a range of technological networks and organizational forms in the face of the changing competitive conditions. On the other hand, while the spatial boundaries of important technological networks in the cluster are not necessarily confined to the locality, we find that geographical proximity among networked members is the key to the emergence of and better governing over those crucial extra-cluster networks. In addition to responding to the call for empirical work exploring the relationships between geographical proximity and non-geographical proximity in knowledge creation and exchange, this article contributes to the cluster literature by providing evidence on the evolution of clusters and whether the advantages associated with geographical clustering persist over time.*

1. Introduction

The advantages of industrial clusters have been broadly documented (Marshall, 1920; Krugman, 1991; Schmitz, 1995; Porter, 2000). The literature particularly emphasizes that the geographical clustering of firms stimulates interactive learning and innovation,

Correspondence Address: Liang-Chih Chen, Graduate Institute of Building and Planning, National Taiwan University, Taipei, Taiwan. Email: liangchih@ntu.edu.tw

thus engendering sustained competitiveness of the clustered firms and the cluster as a whole (Rallet & Torre, 1999; Maskell, 2001; Pinch *et al.*, 2003; Tallman *et al.*, 2004). Recently, such a localized perspective, however, has been challenged by scholars who argue that as a result of the development of information and communication technologies (ICT) and modern transportation infrastructure, interactive learning and innovation can occur effectively through organizational and relational linkages between spatially distant actors (Howells, 1995; MacKinnon *et al.*, 2002; Lechner & Dowling, 2003; Amin & Cohendet, 2004; Amin & Roberts, 2008). Other scholars have also questioned the dominant character of localized learning processes in clusters, suggesting that local networks of well-established clusters that are too closed and exclusive might cause these clusters lock into a sub-optimal evolutionary trajectory due to “over-embeddedness” (Grabher, 1993; Pouder & St John, 1996; Uzzi, 1997; Martin & Sunley, 2006; Staber, 2009).

According to the above studies, because spatial co-location seems to become less relevant or even disadvantageous for cluster actors’ attempts to maintain or advance their competitiveness, there might be a trend towards de-territorialization of closeness in the evolution of clusters (Torre & Rallet, 2005; Amin & Roberts, 2008; Teixeira *et al.*, 2008; Boschma & Frenken, 2010). Yet, such propositions demand a critical examination of why the phenomenon of clustering remains pervasive and why many incumbent clusters remain vibrant and serve as engines of regional or national economic development. This article aims to address these issues through investigating the relationship between geographical proximity and a cluster’s sustained dynamism, with a specific focus on the role of geographical proximity in the transformation of cluster firms’ production and learning organizations. Using Taiwan’s machine tool (MT) cluster as the case, this article studies the nature of various intra- and extra-cluster technological networks established by Taiwanese MT firms to tackle the cluster’s developmental inertia. Based on our empirical investigation, we find that geographical proximity plays a critical role in facilitating the process of cluster transformation. On the one hand, co-location allows local firms and their coupled actors to experiment with a range of technological networks and organizational forms in the face of changing competitive conditions. On the other hand, while the spatial boundaries of important technological networks in the cluster are not necessarily confined to the locality, geographical proximity among networked members is found to be the key to the emergence of and better governing over those crucial extra-cluster networks. In addition to responding to the call for empirical work exploring the relationships between geographical proximity and non-geographical proximity in knowledge creation and exchange (Boschma, 2005; Torre, 2008), this article contributes to the cluster literature by providing evidence on the evolution of clusters and whether the advantages associated with geographical clustering persist over time (Oinas, 1999; Chapman *et al.*, 2004).

This article begins with a review of the current literature that stresses two main mechanisms: the over-embeddedness and dis-embeddedness of clusters which might result in the decline of clusters. Besides, studies that propose to analyse the dynamics of clustering by disentangling geographical proximity and non-geographical proximity are particularly discussed. Section 3 introduces this study’s research methods and data sources. Section 4 provides a brief description of Taiwan’s MT cluster and discusses some proximity-related issues relevant to the cluster’s ongoing upgrading process. Sections 5 and 6 present our research findings in which we examine the role of geographical proximity in various intra- and extra-cluster technological networks established by Taiwanese MT firms with

the aim of renewing or enhancing their own competitive advantages and that of their situated cluster. The final section summarizes our conclusions.

2. Decreasing Relevance of Geographical Proximity in Clusters' Sustained Development

The territorial agglomeration of firms and economic activities (i.e. industrial clusters or districts) has been the subject of a large body of literature (Brusco, 1982; Scott, 1988, 2002; Sabel, 1989; Harrison, 1992; Humphrey, 1995; Porter, 2000). In addition to the classic advantages of agglomeration, such as easy access to input suppliers and traders, the benefits of a pool of specialized workers and knowledge spillovers (Krugman, 1991), scholars stress that, in contemporary globalized and knowledge-based economies, the geographical proximity of local firms and institutions facilitates the inter-firm learning and innovation as the main source of competitiveness for individual firms and the cluster as a whole (Maskell, 2001; Knobens & Oerlemans, 2006; Maskell & Malmberg, 2007; Carrincazeaux *et al.*, 2008). Nevertheless, this localized perspective has been challenged by scholars who have begun to question the seeming dominance of localized learning and innovation processes. One group of scholars argues that too much proximity in intra-cluster networks might increase the risk of negative lock-in (Grabher, 1993; Pouder & St John, 1996; Uzzi, 1997; Martin & Sunley, 2006; Staber, 2009), while others not only emphasize the importance of extra-cluster networks for learning and innovation among local firms (Lazerson & Lorenzoni, 1999; Oinas, 1999; Bathelt *et al.*, 2004; Owen-Smith & Powell, 2004), but also maintain that, in the era of globalization and advanced ICT development, effective interactive learning need not be confined within a cluster's spatial boundaries, but can also be achieved through networking between economic actors at a distance (Howells, 1995; MacKinnon *et al.*, 2002; Lechner & Dowling, 2003; Amin & Cohendet, 2004; Amin & Roberts, 2008). According to these scholars, there would be two mechanisms causing the decline of clusters, as discussed in the following parts:

2.1 The Over-embeddedness of Local Actors in Clusters

It is acknowledged that spatial clustering can allow industrial actors to gain greater competitiveness through collective efficiency (Schmitz, 1995). Some scholars, however, contend that the same geographical arrangements might also trigger the mechanism of collective negative lock-in (Grabher, 1993; Martin & Sunley, 2003; Staber, 2009). Boschma and Frenken (2010), for instance, use the term proximity paradox to describe the positive and negative impacts of proximity on cluster actors' innovative performance. It is argued that, while geographical proximity potentially promotes the development of local institutions which enable clustered firms to undertake interactive learning, geographical and institutional closeness, however, also act as barriers to novelty or adaptivity. As a result, the local structure might become too narrowly focused on a particular type of economic activity (e.g. technology, organization or market behaviour), locking the cluster into sub-optimal evolutionary trajectories or leaving it unable to react quickly and effectively to exogenous impulses (Grabher, 1993; Malmberg & Maskell, 1997; Visser & Boschma, 2004; Boschma, 2005; Sydow *et al.*, 2010). In addition, other clustering diseconomies are noted. As Carrincazeaux *et al.* (2008) point out, "when co-located firms are too

close cognitively, geographical proximity gives rise to unintended knowledge spillovers and a climate of mistrust as a result of localized competition pressure. ...and clusters may thus come to exhibit instability and fragility” (p. 626). In these situations, cluster firms and clusters themselves would lose their dynamic capability and long-term sustainability.

2.2 The Dis-embeddedness of Local Actors in Clusters

Empirical and theoretical criticism has also been raised against the concept of industrial clusters as a geographical and institutional arrangement conducive to learning and innovation through the localized circulation of knowledge. Many studies have demonstrated that, in general, the knowledge required for clusters to improve their competitiveness not only results from local interaction but also is often obtained through trans-local relationships (Amin & Cohendet, 1999; Bathelt *et al.*, 2004; Owen-Smith & Powell, 2004; Amin & Roberts, 2008; Torre, 2008). Furthermore, thanks to advances in ICT, firms now can use electronic networks to efficiently engage in trans-local knowledge exchanges (Howells, 1995; Amin & Roberts, 2008; Teixeira *et al.*, 2008). This emphasis on non-local and de-territorialized exchanges of knowledge has implications for industrial patterns of spatial clustering. Although it is noted that the development of clusters’ local and non-local relationships might be complementary (Bathelt *et al.*, 2004), studies also suggest that, as the cluster firms’ external interactions grow increasingly distant, the intra-cluster networks that once were crucial for local firms’ production and innovation capabilities might be replaced by distantiated ones (Andersen, 2006; Zucchella, 2006; Menzel & Fornahl, 2010; Ter Wal & Boschma, 2011). In this case, local firms might become dis-embedded from the cluster, thus “hollowing out” the cluster (Bathelt *et al.*, 2004, p. 48). Consequently, the geographic concentration of industrial firms in a cluster would gradually diminish.

2.3 Analysing Clusters’ Dynamics from the Proximity Perspective

The aforementioned studies expose two critical problems incumbent clusters face in sustaining their development. First, such clusters might encounter the issue of over-embeddedness, in which the strong embeddedness of proximate firms and institutions in intra-cluster networks makes the firms and clusters too ossified to adjust themselves in response to external changes. Second, they also face the problem of dis-embeddedness. Because of the improvements in ICT and transport technologies, cluster firms are released from their geographical constraints to work closely with capable extra-cluster actors. Furthermore, along with the growth of extra-cluster linkages as their main sources of innovative knowledge, these firms might thereby reduce their dependence on local networks.

In each of the above situations, the apparent advantages of industrial co-location in terms of facilitating interactive learning and innovation are inadequate to account for a cluster’s dynamism. If this is the case, how can one understand the sustained development of clusters for which the geographical concentration of firms is still so pervasive? To answer this question, some scholars have suggested that we must disentangle geographical proximity from non-geographical proximities (e.g. cognitive, social, organizational and institutional proximities) between actors (Boschma, 2005, Torre & Rallet, 2005), and then analyse the dynamics within and outcomes of the interplay between geographical

and non-geographical proximities in the economic activities of cluster members that result in the cluster's divergent evolutionary processes (Lagendijk & Lorentzen, 2007; Torre, 2008; Boschma & Frenken, 2010; Hall & Jacobs, 2010; Huggins & Johnston, 2010; Ter Wal & Boschma, 2011). For these scholars, the sustained prosperity of clusters is determined by the ability of the cluster actors to maintain an optimal level of proximity, both geographical and non-geographical, with other actors within and outside the cluster (Boschma, 2005; Boschma & Frenken, 2010).

In this line of studies, scholars have placed a particular emphasis on the significance of non-geographical proximity, arguing that geographical proximity *per se* is neither a necessary nor a sufficient condition for effective learning to occur (Boschma, 2005, p. 61), and is relevant only when it influences the development of non-geographical proximities. More specifically, co-location facilitates non-geographical proximities that can induce dynamic interaction among relational actors. Nevertheless, once these actors have found other more efficient means to enhance their non-geographical proximities (e.g. ICT applications), geographical proximity becomes a marginal factor affecting their innovative activities (Boschma, 2005; Torre & Rallet, 2005; Knobens & Oerlemans, 2006; Lagendijk & Lorentzen, 2007; Amin & Roberts, 2008). For instance, although spatial closeness favours knowledge exchange, the need for geographical proximity is rather weak when there is a clear division of precise tasks coordinated by a strong central authority, i.e. improved organizational proximity, and the partners share the same cognitive experience, i.e. improved cognitive proximity (Rallet & Torre, 1999; Teixeira *et al.*, 2008, p. 791; Hervás-Oliver & Albors-Garrigos, 2009). Besides, if the actors share appropriate social and institutional proximities, the effective distanced interaction can be substantiated (Gertler, 2008).

By disentangling proximities, we are able to analyse the interplay between the geographical and non-geographical dimensions of proximity that constitute the interactive dynamism of networked actors and therefore to account for cluster evolution. However, many studies in this realm focus mainly on changes to a cluster's non-geographical arrangements, i.e. the shifting cognitive, social, organizational or institutional proximities between actors within the local or trans-local networks, and how these changes influence this cluster's evolutionary trajectories, but rarely examine the role of geographical proximity in the process. This article would like to fill this gap. Moreover, as discussed in Sections 2.1 and 2.2, recent studies have tended to consider geographical proximity less relevant or even counter-productive to stimulating the transformation of incumbent clusters. We argue such notions not only are derived from theoretical induction that lacks empirical substantiation, but also suffer from a critical flaw in seeing geographical proximity from a biased perspective that fails to account for its possible instrumental role. In our view, to understand the evolution of incumbent clusters, in addition to asking how diseconomies or disadvantages of industrial clustering that result from geographical proximity (or distance) could be overcome by improving other dimensions of proximity, we should simultaneously investigate how geographical proximity can contribute to the alignment of other proximities, thus fostering the renewal or sustained development of clusters. The article will provide empirical evidence for such arguments.

There is a consensus that the long-term growth of clusters is determined by their ability to engender appropriate local and extra-local institutions that allow for the development of diverse and heterogeneous knowledge and organizational forms (Bathelt *et al.*, 2004; Chapman *et al.*, 2004; Caniels & Romijn, 2005; Zucchella, 2006; Menzel & Fornahl,

2010). Following this line of thought, this article considers the establishment of various technological networks by cluster actors to serve as such institutions. Using Taiwan's MT cluster as the case, this article examines the role of geographical proximity in the emergence, structures, internal dynamics and outcomes of various intra- and extra-cluster technological networks crucial to the cluster's vitality. As our findings will show, geographical proximity has been a critical factor underlying local actors' effective governance of important networks within and outside the cluster. Moreover, thanks to industrial co-location, cluster actors are better positioned to seek an optimal level of proximity with other local and non-local partners, thus sustaining the dynamism of local firms and the cluster as a whole.

3. Research Methods and Data

In this article, we selected Taiwan's MT cluster as the study case. To study the role of geographical proximity in the transformation of cluster firms' production and innovation organizations, we relied on qualitative data collected from in-depth interviews with key decision-makers of Taiwanese MT firms and their relevant network partners in the cluster. The strength of using qualitative techniques, particularly the corporate interviews, in studying the spatial phenomena of economic actions is well-recognized (Schoenberger, 1991; Healey & Rawlinson, 1993; Markusen, 1994). Furthermore, since this study aims to capture the dynamics within a cluster's transformation process, and, more specifically, to understand and explore the implicit and subtle elements influencing firms' various intra- and extra-cluster networking activities that might not lend themselves to quantitative measurement, such methods seem most suitable (Oinas, 1999; Agnes, 2000; MacKinnon *et al.*, 2002; Wolfe & Gertler, 2004).

In our previous study from 2005 and 2006, we collected a pool of ethnographic data, involving 63 in-depth interviews with key decision-makers in Taiwanese MT firms and other critical cluster participants, such as suppliers, government agencies, research institutes and industry associations. These data documented the nature and dynamics of various cluster actors' local and non-local networking activities. To address the issues concerned by this study, we conducted another round of interviews. After reviewing secondary data, interviewing some experts and executives from major firms, we drew up a list of interview candidates from Taiwanese MT firms that were notable in driving recent changes in the cluster's technological networks. A second round of fieldwork was conducted from August 2009 to July 2011, in which a total of 28 CEOs or senior managers of Taiwanese MT firms were interviewed. At the same time, we conducted six interviews with other related suppliers and research institutes. Among the interviewees, 22 of them were the same persons that we had interviewed from 2005 to 2006. By comparing their viewpoints and experiences from the two periods, we are allowed to examine the varying strategies employed by these firms and their networking processes in response to the shifting environments.

At the start of the research, temporary hypotheses about the role of geographical proximity to the changes of organization and governance in the cluster's intra- and extra-cluster technological networks were proposed. Using this framework, we developed a semi-structured set of questions that focused on two issues pertinent to this study: First, how do the actors perceive and evaluate the advantages and disadvantages of clustering under different development contexts, and what actions did they take to maximize the

advantages while minimizing the disadvantages. Second, how do the actors evaluate the significance of the extra-cluster networks, and what are the interrelationships between these extra-cluster networks and the local ones. In the interviews, we specifically inquired into the relationship between geographical proximity and a firm's various networking activities and organizations. The respondents were also asked to comment on the relative merit of geographical and non-geographical (i.e. cognitive, social, organizational and institutional) proximities in influencing their governance capabilities over these networks. The interviews typically lasted from 1 to 3 hours, and were fully recorded and transcribed. In addition, other secondary data were used to crosscheck information collected from the interviews. Throughout the research process, we continuously challenged our research findings by triangulating evidence from the interviews and secondary data, and by comparing these findings with different propositions about geographical proximity within the relevant literature on cluster evolution. In the later stages, our findings were also brought to some interviewees, leaders of industrial associations and other researchers that were able to provide a critical evaluation of the industry's transformation process, for rejection or confirmation.

Before presenting our research findings, the following section provides a short description of the development of Taiwan's MT cluster. We then discuss issues of proximity faced by Taiwanese MT manufacturers at the cluster's current evolutionary stage.

4. Proximity Issues in the Transformation of Taiwan's MT Cluster

As the current world's sixth MT producer and third exporter in the global MT industry (Gardner Publications, 2011), Taiwan's MT industry has been known for its competitiveness in terms of efficient and flexible manufacture of low-cost but good-quality MT products (Liu & Brookfield, 2000; Chen, 2009, 2011). The existence of a well-articulated, subcontracting-based production system composed of numerous small- and medium-sized MT firms and specialized suppliers clustered in central Taiwan, including Taichung, Nantou and Changhwa (Figure 1) has been considered the key organizational arrangement supporting the industry's competitiveness (Liu, 1999). Developed since the 1940s, the MT cluster in central Taiwan is now estimated to host more than 60% of Taiwanese MT firms and their suppliers (MOEA, 2007).

The notion of clustering advantages in terms of flexible specialization and interactive learning has been used to explain why this late-developed industry and its actors were able to achieve and maintain its global competitive status (Liu, 1999; Brookfield, 2008). While prior studies have repeatedly stressed the significance of industrial clustering to the success of Taiwan's MT industry, in recent years, some clustering disadvantages have been identified to have obvious negative effects on the firms' as well as the cluster's development. For instance, the heavy dependence of Taiwanese MT makers on the cluster-nurtured subcontracting arrangements has led to criticism that the Taiwan-made MTs lack product differentiation. Besides, given the difficulty of preventing involuntary leakages of their core competencies through the dense production and social networks in the cluster, local firms have been conservative in enhancing their internal technological capabilities, and have been constrained in their cooperation with other local actors. Furthermore, it is also noted that the local industrial system does not encourage the emergence of larger firms that could advance the cluster by commanding greater resources.

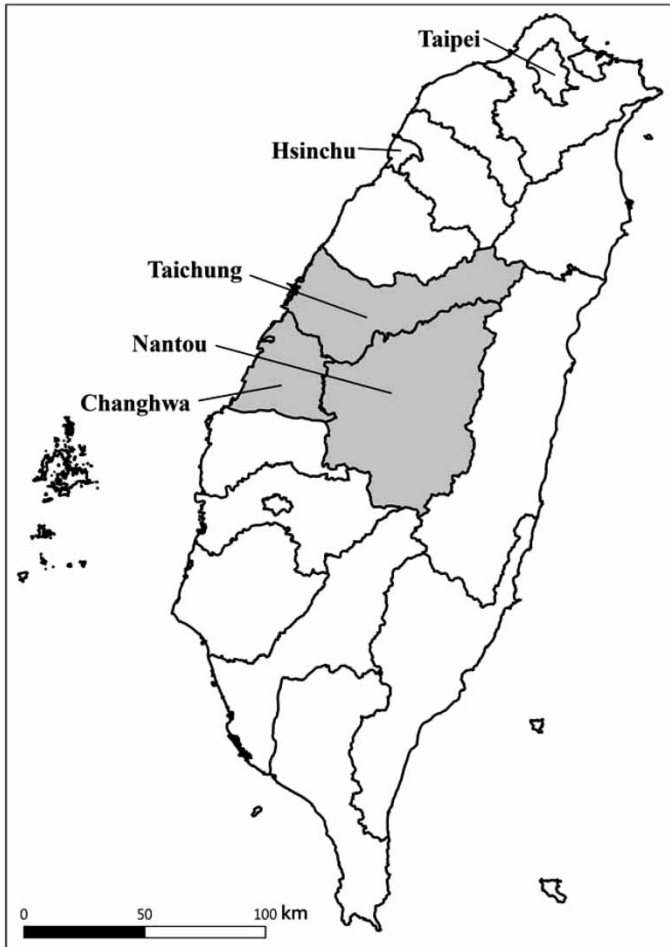


Figure 1. The machine tool cluster in Taiwan.

The above issues encountered by the Taiwan's MT industry might be regarded as typical examples of the proximity paradox (Boschma & Frenken, 2010), as discussed in Section 2.1. To avoid such a situation, scholars have suggested that the clustered actors need to establish optimal levels of geographical and non-geographical proximity through reorganizing their industrial and relational networks (Boschma, 2005; Boschma & Frenken, 2010). In addition to reconfiguring the clusters' industrial and institutional environment, it is argued that the clusters need to build non-local relations to fill their structural holes with extra-cluster knowledge inputs so as to stimulate their revival (Burt, 1992; Bell & Albu, 1999; Bathelt *et al.*, 2004). Yet, for Taiwan's MT cluster, such a proposition leads to further issues concerning the governance of distanced extra-cluster networks. As a catch-up player in the global MT industry, the advanced knowledge that Taiwan's MT industry sought to source would have mainly resided in foreign locations, such as Europe, Japan and the USA. Spatial distance might have initially discouraged these distanced actors from initiating collaboration. In addition to the existence of cognitive distance

between Taiwanese firms and their foreign advanced counterparts, resulted from their technological gaps, these two parties also share little social affinities, including their differences in languages, institutional environments, etc. (Gertler, 2004). All these factors would frustrate effective collaboration and interactions within the extra-cluster networks.

To sustain their competitiveness and catch up with the frontiers, the relatively smaller scale and technologically backward industrial firms in late-industrializing countries, like Taiwan, inevitably require the help of external actors, either within or outside the cluster, to source critical capabilities and knowledge (Schmitz, 1995, Bell & Albu, 1999; Scott, 2002). Nevertheless, as in the situations discussed above, the clustered Taiwanese MT firms face a variety of proximity or distance issues in exploring and exploiting intra- and extra-cluster network relations. On the one hand, their deep embeddedness in the localized networks leads to problems related to excessive proximity with other cluster firms. For instance, a firm's restructuring efforts might receive little support in the cluster's homogenized industrial environment (Boschma & Frenken, 2010). On the other hand, the governance of Taiwanese MT firms over extra-cluster networks raises issues related to excessive distance from their foreign partners, posing significant challenges to the coordination and maintenance of effective distanced interaction (Gertler, 2004, 2008). In the following sections, we will present our findings regarding how Taiwanese MT firms have attempted to deal with these issues through forming various technological networks at the intra- and extra-cluster level.

5. Reconfiguration of Intra-cluster Technological Networks

This section discusses three critical forms of intra-cluster technological networks that have recently emerged in Taiwan's MT cluster, with the aim of dealing with the various disadvantages of clustering. While the first two cases discuss how firms have worked with external local actors (e.g. suppliers, other MT firms and public research institutes (PRIs)) to reconfigure their production or innovation networks, the third case exemplifies a strategy that has been employed mainly by larger MT firms to internalize their inter-firm networks and transform them into more coherent organizations through the establishment of business groups. In our discussion, the role of geographical proximity, and its interplay with other non-geographical proximities in these various networking activities are particularly addressed.

5.1 Intra-cluster Production Networks

Taiwan's MT industry is widely recognized for embedding its adaptive capability in localized subcontracting networks (Liu, 1999; Liu & Brookfield, 2000; Chen, 2009). However, the broad adoption of subcontracting arrangements by the clustered Taiwanese MT makers has raised some serious problems. First, habitual outsourcing to the same pool of suppliers and the resulting involuntary technological spillovers within these networks have led to criticism of Taiwan-made MT products as lacking product differentiation, and have triggered cutthroat competition among Taiwanese MT exporters. Second, local competition for suppliers has become more severe, resulting in the destabilization of established production networks and hesitation among MT firms to deepen their collaborative relationship with local suppliers. Third, the slow technological advancement of local suppliers

vis-à-vis MT firms further constrains the advancement of Taiwan-made products. All these issues represent the multi-faceted non-geographical proximity issues faced by the Taiwanese co-located actors. While the first and the second situations are attributable to the excessive cognitive and organizational proximities between MT firms and their suppliers, the third situation is related to cognitive gaps between these two actors.

To deal with these problems, Taiwanese MT firms have been observed to undergo adopted two major approaches into reconfiguring their production networks. The first is to further diversify local supply sources. While cluster MT firms would traditionally subcontract a given part or activity to less than three suppliers (Brookfield, 2000), recently they have begun to incorporate more local suppliers into their subcontracting arrangements. In so doing, these MT makers protect themselves from the unexpected changes in the supply quality and quantity from their main subcontractors due to the competition for local supplies from other cluster MT firms. The second approach is to increase the ratio of internal manufacturing. By investing in sophisticated equipment to strategically perform a certain proportion of manufacturing in-house, these MT makers are able to retain and capitalize on their core competencies, while simultaneously upgrading their products without being subject to the limitation of local suppliers (Chen, 2011).

In their attempts to rearrange their local production organizations and practices, Taiwanese MT firms face issues such as increasing complexity in business management resulting from more sophisticated external subcontracting arrangements and expanded internal capital investments. However, the geographical proximity of these firms to their suppliers helps them overcome these challenges. For instance, the inevitably increasing logistical costs entailed in the new arrangements are greatly minimized for cluster firms. Geographical proximity also facilitates the intensive interactions required to coordinate intra- and extra-firm production activities as MT firms experiment with new practices. Besides, in our interviews, many respondents emphasized that, given that their firms have little or no prior experience in machining parts internally, the ability to receive prompt assistance from neighbouring firms has been a key to their success in increasing in-house manufacturing.

5.2 Public–Private R&D Networks

In 1977, the Taiwan government established the Mechanical Industry Research Laboratory (MIRL), a PRI intended to assist the technological advancement of Taiwan's MT industry. Equipped with well-educated engineers and high-end facilities, MIRL has worked to acquire advanced technologies from abroad and diffuse them to domestic MT firms. However, in its first two decades of operation, MIRL's role in the industry was marginal (Gau, 1999; Chen, 2010). The lack of three kinds of proximity between MIRL and Taiwan's MT industry could account for such outcomes. First, MIRL's projects mostly focused on the development of high-end machines, and were considered too aggressive or impractical by local MT builders due to low manufacturability and marketability. Thus, cooperation was impeded by a lack of cognitive proximity. Second, there was little social proximity between MIRL engineers and those in the domestic MT industry. The respective engineering groups came from different training and educational backgrounds, hindering the development of social relationships that would have nurtured interaction (Chen, 2010). Third, for Taiwanese MT builders accustomed to working with

nearby partners, the relatively large geographical distance between MIRL's headquarters in northern Taiwan and the cluster in central Taiwan discouraged their regular contact.

Acknowledging this low interaction with industry and determined to tailor its services to industry needs, MIRL relocated its MT division to Taichung in 1995. The establishment of this Taichung branch played an important role in the later development of MIRL's close collaboration with domestic MT firms. In our interviews, respondents from both MIRL and MT firms stressed that the enhanced geographical proximity has greatly facilitated their mutual interaction. Following MIRL's relocation, MT firms have been much more willing to approach this PRI for technological consultation or cooperation, contributing not only to the improvement of their social relationship, but also to their cognitive proximity through interactive learning. Moreover, since the move, both parties have worked together more closely in developing advanced MTs and technologies, and have expanded upon successful collaborative projects to increase the breadth and depth of mutual collaboration. From the early 2000s, such collaboration has led to the emergence of large-scale public-private R&D cooperative initiatives to develop more advanced MTs. For instance, in 2003, MIRL initiated the Linear Motor Machine Tool R&D Alliance, the largest research project in the history of Taiwan's MT industry. Two years later, MT firms in the alliance unveiled eight new linear-motor-based machine tools at the 2005 Taipei International Machine Tool Show, which was regarded as a great achievement for the government-sponsored R&D alliance. On the basis of this success, two additional R&D alliances were established in 2007 and 2009, respectively, to develop high-end MTs (integrated MTs and five-axis MTs).

The findings regarding how MIRL stimulated the emergence of public-private cooperative arrangements in the MT cluster after the organization's relocation have provided further support to the studies that recognize the significance of geographical proximity in enhancing the relational proximity between industries and the PRIs (Anselin *et al.*, 2000; Ponds *et al.*, 2007). More importantly, our empirical case particularly demonstrates that, with the assistance of geographically and relationally proximate PRIs, the rival local firms were able to form collaborative organizations to address an enduring lock-in issue encountered by many incumbent clusters—the lack of horizontal intra-cluster technological cooperation (Staber, 2009).

5.3 Business Group-based Technological Networks

Although the small scale and specialization of Taiwan's MT firms have been among their main competitive strengths, these characteristics also come with some disadvantages. Unlike the large, leading global firms, Taiwan's MT makers are not able to negotiate better import deals for components and accessories or better sales terms with their foreign marketing partners. Specialization in certain MT product segments has also limited these MT makers' capacity to satisfy some larger MT customers that might prefer to purchase various types of MTs from a single manufacturer. In addition, they have been endowed with restricted resources to undertake critical but costly activities such as marketing and R&D. In this context, a strategy to promote the emergence of a few larger firms equipped with greater internal technological and operational capacities could potentially improve the competitive position of Taiwan's MT industry in the global market. In recent years, a handful of major Taiwanese MT makers have actively sought out suitable local firms with complementary resources for incorporation into

their business groups. Meanwhile, some smaller and financially vulnerable local firms have looked for partners to help them sustain their operations. This convergence of interests has led to the development of a few large MT business groups in Taiwan.

In the instance of one Taiwan's current leading MT firm, its CEO pointed out in our interview that his firm has been desiring to expand the scope of its manufacturing capability, especially in large and advanced MTs, to accommodate the demands of global MT customers. In 2004, this firm bought a struggling nearby MT maker specializing in the production of large lathes. In 2005, it took over another local MT firm that required additional resources to support the development of its large new linear-motor-based MTs. Two major MT business groups that have emerged in recent years have adopted similar consolidation strategies through buying out complementary local MT firms. In addition, interviews with the CEOs of these MT business groups revealed that their main goals were to achieve economies of scale and scope of their operations, and, more importantly, to foster inter-firm production and R&D collaboration, especially among locally acquired firms.

From our perspective, industrial consolidation can be considered an important evolutionary trajectory in Taiwan's MT cluster, with local firms forming business groups to overcome the difficulties of horizontal inter-firm collaborations resulting from their cognitive, social, institutional and organizational differences. To effectively pursue such a strategy, one cannot ignore the role of geographical proximity. Co-location can facilitate the matching processes of consolidating firms, as the CEOs interviewed all expressed that they benefited from the rapid circulation and sharing of information among firms within the cluster, enabling them to efficiently learn and screen suitable candidates for acquisition. In addition, since the firms of the business groups are collocated, the governance of inter-firm relations and coordination in this newly emerged arrangement would be greatly eased (Lorenzen, 2002).

6. Formation of Extra-cluster Technological Networks

To break their development inertia, industrial clusters require inflows of critical extra-cluster competences (Bell & Albu, 1999; Bathelt *et al.*, 2004; Owen-Smith & Powell, 2004). In this section, we first demonstrate two forms of extra-cluster technological networks that have been passively or actively built by Taiwanese MT firms recently to source advanced knowledge from overseas. The role of geographical proximity in the governance of these networks will then be discussed in the following part.

6.1 The OEM/ODM-based Technological Networks

The renowned competitiveness of the clustered MT industry in Taiwan for low-cost and efficient manufacturing has sometimes attracted inflows of OEM/ODM (original equipment manufacturing/original design manufacturing) orders from abroad. Being able to build partnerships with leading foreign firms through the OEM/ODM arrangements has been recognized to allow Taiwanese MT firms to obtain financial gains, and, more importantly, to upgrade their technological capabilities (Chen, 2009). Nevertheless, given that the manufacture of MTs in Taiwan depends heavily on subcontracting, success in such arrangements requires not only intensive collaboration between both Taiwanese MT firms and their foreign partners but also the participation of local subcontractors in

Taiwan. In this regard, the proximity of local subcontractors and foreign firms should also be addressed.

In the OEM/ODM arrangements, to ensure the products from their Taiwanese partners meet their specifications and requirements, in addition to providing the blueprints and related technological documents, the foreign firms would dispatch engineers to Taiwan to assist Taiwanese MT makers to tackle issues related to design and manufacturing. At the same time, the foreign firms also help to assess and improve the technological capabilities of relevant local subcontractors. Given the short-term nature of these foreign engineers' residence (sometimes only a few days at a time), dense interaction is necessary to determine how to use limited time to effectively solve existing and potential technological problems. When Taiwanese MT firms take the opportunity to discuss with their foreign partners, some of their key subcontractors might be called to attend these meetings on short notice. The close geographical proximity among cluster actors ensures that such meetings can be easily arranged. When necessary, on-site visits of these foreign engineers to local subcontractors are also common. Moreover, thanks to the efficiency of localized production networks, Taiwanese MT firms and their subcontractors could even manage to produce revised and improved machine parts or products immediately upon receiving the requirements and input, and present them for inspection prior to their foreign partners' departure. Through these various interaction mechanisms, nurtured by the co-presence of these transnational partners in Taiwan's MT cluster, the mutual understanding and efficient collaboration among actors within such extra-cluster technological networks are greatly enhanced.

6.2 Foreign Affiliate-based Technological Networks

A large body of literature has studied how firms penetrate distant markets by establishing foreign affiliates (e.g. branch plants, local offices, etc.) or by acquiring an existing foreign unit to tap into local resources and competencies in distant parts of the world (Maskell *et al.*, 2006, p. 998; Dunning & Lundan, 2008). In the case of Taiwan's MT industry, alongside their global business success, some Taiwanese MT firms have accumulated relatively sufficient technological or organizational competence, enabling them to expand their global reach to non-local technological resources through outward direct investment, i.e. establishing foreign affiliates in countries with more advanced MT technologies.

A typical example is a German investment by a Taiwanese MT component supplier which is currently one of the world's top four ballscrew manufacturers. To break through Japanese barriers to access most of its critical technological and manufacturing supplies, including equipment and materials, this Taiwanese firm acquired a bankrupt German ballscrew maker in 1993. In our interview with the firm's CEO, he expressed that this investment enabled his firm to obtain knowledge transferred from the German source, helping it to fill its technological gap in the development and manufacturing of ballscrews. Since 2006, the firm has further capitalized on cooperation between its Taiwanese and German engineers to produce specialized equipment for its own use, therefore allowing it to reduce its reliance on costly imported manufacturing equipment.

The above experience is hardly unique. According to our data, two other major Taiwanese MT firms that have engaged in outward direct investment since the early 2000s outlined similar processes of exploring and exploiting foreign knowledge based on a division of labour between their foreign branch offices and headquarters in Taiwan. To effectively

benefit from such arrangements, we find that these Taiwanese MT firms have mobilized three main competencies: (1) their internal technological capabilities accumulated through their past experience of manufacturing and developing MT products or components; (2) the embedded manufacturing and technological capability of Taiwan's MT cluster; and (3) knowledge inputs and technical assistance from their foreign branches. While they seem to utilize similar interaction mechanisms as those delineated in the OEM/ODM arrangements to ensure effective transnational cooperation, these Taiwanese global MT firms secure greater autonomy in channelling foreign knowledge inflows by establishing their own foreign affiliates.

In the next part, we turn our discussion to the relationships between geographical proximity and local firms' capacity in governing these extra-cluster technological networks.

6.3 Relationships between Geographical Proximity and the Governance of Extra-cluster Networks

The two forms of extra-cluster technological networks illustrated above have become important channels through which Taiwanese MT firms manage to exploit foreign sources of capabilities that are absent in the cluster. Following the analytical lens of proximity, we can assert that it is through these extra-cluster networks that the clustered Taiwanese MT firms are able to maintain an optimal level of non-geographical proximity with external actors, thus allowing the cluster to constantly absorb new ideas and capabilities. The transnational collaborative arrangements maintain an appropriate mixture of cognitive proximity and distance between Taiwan's MT makers and their foreign partners. While a shared technological background provides the cognitive proximity required to facilitate communication and cooperation, the divergence of the actors' capabilities and interests in the development of MT technologies and products creates a cognitive distance that stimulates learning and innovation. In the meantime, joining foreign firms' OEM/ODM arrangements or establishing their own foreign affiliates allows Taiwanese MT firms to learn more efficiently from extra-cluster technology suppliers through their enhanced organizational, institutional or social proximities. Yet, in these cases, two questions concerned by this study should be answered. First, can problems caused by excessive distance between Taiwanese firms and their remote partners be effectively handled simply through enhancing their non-geographical proximities? Second, what is the interplay between the intra-cluster networks and the extra-local networks? Furthermore, would the development of extra-cluster relationships supplant local ones?

Regarding the first question, this article finds that face-to-face contact between these distantiated partners remains indispensable. To effectively govern such extra-cluster networks, Taiwan's MT firms have devoted special attention to issues resulting from their large geographical separation from remote collaborators, which hampers not only interaction but also the maintenance of organizational, social and institutional proximities. The use of ICT tools, such as telephone, email or fax, is instrumental in connecting the two parties. However, nearly all of our interviewees emphasized that electronic communication tools are used mainly in routine communication related to issues such as business orders and cannot replace the physical contact required to communicate sophisticated information related to MT technologies or business strategies. One thing should also be noted. Given that Taiwanese firms and their foreign partners usually speak different languages and share little cultural and institutional affinity, it is of great importance for

them to meet face-to-face to better understand each other and to build stable collaborative relationships. The MT firms interviewed particularly stated that they sought to deal with such issues through arranging on-site visits for staff or engineers or through participation in international trade fairs (Chen, 2009), etc.

As for the second question, our findings confirm that extra-cluster networks are critical channels for cluster firms to source advanced capabilities. However, in contrast to the literature in Section 2.2 which assumes that cluster firms would become less connected to their intra-cluster networks once they are more dependent on non-local relationships, in Taiwan's case the evidence shows that these two forms of networks are complementary rather than mutually exclusive. The production advantages of clustering have enabled Taiwanese MT firms to initiate and establish various extra-cluster technological networks. Moreover, the ability to flexibly mobilize intra-cluster resources has also been the key factor in Taiwanese MT firms' capacity for adapting to the changing requirements and conditions of their extra-cluster networks. In other words, because Taiwanese MT firms' governance capabilities over their extra-cluster collaborative arrangements rely heavily on their embeddedness in the cluster's environment, the development of extra-cluster linkages not only does not necessarily indicate decreasing significance of intra-cluster ones, but might actually reinforce local firms' inclination to cultivate and exploit their local networks.

7. Conclusion

In studying the evolution of clusters, much of the current literature seems to doubt that geographical proximity is a necessary and sufficient condition for maintaining a cluster's productive and innovative dynamics, and suggests that investigation into the sustained development of clusters should focus on other non-territorial and relational-based proximities (Rallet & Torre, 1999; Boschma, 2005; Torre & Rallet, 2005; Amin & Roberts, 2008). The development of ICT and advanced transport has relaxed the spatial constraints of distanced knowledge exchanges, facilitating extra-local communications and interactions. Thus, the advantages derived from industrial co-location are no longer considered suitable strategies or organizational forms for stimulating the growth of cluster firms. In the meantime, too much geographical proximity might engender excessive (or insufficient) levels of other proximity dimensions, resulting in the emergence of rivalries, cognitive lock-in or other phenomena that could harm the sustained development of the cluster. Furthermore, even if cluster actors could manage to source non-local capabilities through building extra-cluster networks to avoid these negative clustering effects, industrial concentration within the clusters might gradually diminish as the extra-cluster networks develop (Menzel & Fornahl, 2010; Ter Wal & Boschma, 2011).

The above-mentioned studies are dominated by the notion that firms in a mature cluster might incline to become dis-embedded or delocalized from their local environment in the face of current changing business environments. Our empirical study of Taiwan's MT cluster, however, did not find evidence of such a trend. Although local firms have suffered from some cluster diseconomies, rather than dis-embedding themselves from the locality, they have strategically exploited the advantages of co-location to devise new institutional arrangements (i.e. the establishment of various intra- and extra-cluster technological networks) to offset negative effects of clustering or bring new capabilities inflows into

the cluster. In these processes, we find that geographical proximity has been a critical factor facilitating the cluster firms' efforts.

At the intra-cluster level, Taiwanese MT firms have taken advantage of their geographical proximities to other local institutional actors (e.g. firms, suppliers or research institutes) to adjust and experiment with a range of organizational forms, including re-elaborated local subcontracting arrangements, public-private R&D consortia and business groups, and thus to mediate various clustering disadvantages. Industrial co-location provides sufficient redundancy to allow these firms the flexibility to exclude or recruit local actors in their production or innovation networks. Being close to their partners has also nurtured local firms' capacity to strategically use various relational governing instruments to efficiently coordinate complex and uncertain interactions within these newly emerging networks (Chen, 2011).

At the extra-cluster level, one should note that, in the case of Taiwan's MT cluster, many critical non-local technological networks might fail to develop without the production advantages derived from the spatially concentrated industrial networks. These networks are critical for attracting foreign MT firms to collaborate with their Taiwanese counterparts, or for providing Taiwanese firms the capacity to establish technological bases abroad. Moreover, in these extra-cluster networks, geographical proximity is a critical factor underlying the effective interaction among these transnational partners that share weak non-geographical proximities.

Finally, although we are unable to establish the magnitude of the significance of geographical proximity's contribution to the transformation of Taiwan's MT cluster, the evidence implies that geographical proximity still matters and, more specifically, appears to be a necessary condition enabling Taiwanese MT firms to maintain and explore diverse capabilities within and outside the cluster. While one might argue that there are still limitations to the organizational models investigated in this article for the continued upgrading of Taiwan's MT firms, however, we agree with studies of the evolution of some Italian industrial clusters (Cainelli & Zoboli, 2004; Cainelli & Iacobucci, 2007) on that these arrangements should all be considered in evolutionary terms (Bianchi, 2007, p. viii). As many scholars have previously suggested, the evolutionary strength of industrial clusters might result from their diversity or from discrepancies in organizational activities (i.e. new modes of organization), and variety might function as an "antibody" against the hegemony of best-practice organizational solutions (Grabher & Stark, 1997, p. 540; Kirat & Lung, 1999). Our empirical study has shown such an organism of a cluster. While many factors in addition to geography, such as firm capabilities or external shocks, may influence the evolutionary processes and outcomes of clusters, this study suggests that the geographical concentration of actors remains a preferable arrangement to support individual firms and the industry as a whole in coping with volatile business environments.

Acknowledgements

This research is funded by the National Science Council, Taiwan (Grant No. 98-2410-H-002-217-MY2). The authors would like to thank the anonymous reviewers for their constructive comments on the earlier draft.

References

- Agnes, P. (2000) The "end of geography" in financial services? Local embeddedness and territorialization in the interest rate swaps industry, *Economic Geography*, 76(4), pp. 347–366.
- Amin, A. & Cohendet, P. (1999) Learning and adaptation in decentralised business networks, *Environment & Planning D*, 17(1), pp. 87–104.
- Amin, A. & Cohendet, P. (2004) *Architectures of Knowledge: Firms, Capabilities, and Communities* (New York: Oxford University Press).
- Amin, A. & Roberts, J. (2008) *Community, Economic Creativity, and Organization* (New York: Oxford University Press).
- Andersen, P. H. (2006) Regional clusters in a global world: Production relocation, innovation, and industrial decline, *California Management Review*, 49(1), pp. 101–122.
- Anselin, L., Varga, A. & Acs, Z. J. (2000) Geographic and sectoral characteristics of academic knowledge externalities, *Papers in Regional Science*, 79(4), pp. 435–443.
- Bathelt, H., Malmberg, A. & Maskell, P. (2004) Clusters and knowledge: Local buzz, global pipelines and the process of knowledge creation, *Progress in Human Geography*, 28(1), pp. 31–56.
- Bell, M. & Albu, M. (1999) Knowledge systems and technological dynamism in industrial clusters in developing countries, *World Development*, 27(9), pp. 1715–1734.
- Bianchi, P. (2007) Foreword, in: Giulio Cainelli & Donato Iacobucci (Eds) *Agglomeration, Technology and Business Groups*, pp. vii–ix (Northampton, MA: Edward Elgar).
- Boschma, R. (2005) Proximity and innovation: A critical assessment, *Regional Studies*, 39(1), pp. 61–74.
- Boschma, R. & Frenken, K. (2010) The spatial evolution of innovation networks: A proximity perspective, in: Ron A. Boschma & Ron Martin (Eds) *The Handbook of Evolutionary Economic Geography*, pp. 120–135 (Northampton, MA: Edward Elgar).
- Brookfield, J. (2000) Localization, outsourcing, and supplier networks in Taiwan's machine tool industry, Doctoral Dissertation, University of Pennsylvania.
- Brookfield, J. (2008) Firm clustering and specialization: A study of Taiwan's machine tool industry, *Small Business Economics*, 30(4), pp. 405–422.
- Brusco, S. (1982) The Emilian model: Productive decentralization and social integration, *Cambridge Journal of Economics*, 6(2), pp. 167–184.
- Burt, R. (1992) *Structural Holes: The Social Structure of Competition* (Cambridge: Harvard University Press).
- Cainelli, G. & Iacobucci, D. (2007) *Agglomeration, Technology and Business Groups* (Northampton, MA: Edward Elgar).
- Cainelli, G. & Zoboli, R. (2004) *The Evolution of Industrial Districts : Changing Governance, Innovation and Internationalisation of Local Capitalism in Italy* (New York: Physica-Verlag).
- Caniels, M. C. J. & Romijn, H. A. (2005) What drives innovativeness in industrial clusters? Transcending the debate, *Cambridge Journal of Economics*, 29(4), pp. 497–515.
- Carrincazeaux, C., Grossetti, M. & Talbot, D. (2008) Clusters, proximities and networks, *European Planning Studies*, 16(5), pp. 613–616.
- Chapman, K., MacKinnon, D. & Cumbers, A. (2004) Adjustment or renewal in regional clusters? A study of diversification amongst SMEs in the Aberdeen oil complex, *Transactions of the Institute of British Geographers*, 29(3), pp. 382–396.
- Chen, L.-C. (2009) Learning through informal local and global linkages: The case of Taiwan's machine tool industry, *Research Policy*, 38(3), pp. 527–535.
- Chen, L.-C. (2010) How to understand the roles of the state and public research institute in the technological upgrading of industries in newly industrializing countries? The case of Taiwan's machine tool industry, in *DRUID Summer Conference 2010 on Opening Up Innovation*, June 16–18, London, UK.
- Chen, L.-C. (2011) The governance and evolution of local production networks in a cluster: The case of Taiwan's machine tool industry, *GeoJournal*, 76(6), pp. 605–622.
- Dunning, J. H. & Lundan, S. M. (2008) *Multinational Enterprises and the Global Economy* (Northampton: Edward Elgar).
- Gardner Publications (2011) 2011 World machine tool output and consumption survey. Available at <http://www.gardnerweb.com/consump/survey.html> (accessed 10 March 2012).
- Gau, S.-C. (1999) Production network and learning region: The production of machine tools in Taichung, Doctoral Dissertation, Tunghai University.

- Gertler, M. S. (2004) *Manufacturing Culture: The Institutional Geography of Industrial Practice* (New York: Oxford University Press).
- Gertler, M. S. (2008) Buzz without being there? Communities of practice in context, in: Ash Amin & Joanne Roberts (Eds) *Community, Economic Creativity, and Organization*, pp. 203–226 (New York: Oxford University Press).
- Grabher, G. (1993) The weakness of strong ties: The lock-in of regional development in the Ruhr area, in: G. Grabher (Ed.) *The Embedded Firm: The Socio-economics of Industrial Network*, pp. 255–277 (London: Routledge).
- Grabher, G. & Stark, D. (1997) Organizing diversity: Evolutionary theory, network analysis and postsocialism, *Regional Studies*, 31(5), pp. 533–544.
- Hall, P. V. & Jacobs, W. (2010) Shifting proximities: The maritime ports sector in an era of global supply chains, *Regional Studies*, 44(9), pp. 1103–1115.
- Harrison, B. (1992) Industrial districts: Old wine in new bottles? *Regional Studies*, 26(5), pp. 469–483.
- Healey, M. J. & Rawlinson, M. B. (1993) Interviewing business owners and managers: A review of methods and techniques, *Geoforum*, 24(3), pp. 339–355.
- Hervas-Oliver, J. L. & Albers-Garrigos, J. (2009) The role of the firms internal and relational capabilities in clusters: When distance and embeddedness are not enough to explain innovation, *Journal of Economic Geography*, 9(2), pp. 263–283.
- Howells, J. R. (1995) Going global: The use of ICT networks in research and development, *Research Policy*, 24(2), pp. 169–184.
- Huggins, R. & Johnston, A. (2010) Knowledge flow and inter-firm networks: The influence of network resources, spatial proximity and firm size, *Entrepreneurship and Regional Development*, 22(5), pp. 457–484.
- Humphrey, J. (1995) Industrial reorganization in developing countries: From models to trajectories, *World Development*, 23(1), pp. 149–162.
- Kirat, T. & Lung, Y. (1999) Innovation and proximity: Territories as loci of collective learning processes, *European Urban and Regional Studies*, 6(1), pp. 27–38.
- Knoben, J. & Oerlemans, L. A. G. (2006) Proximity and inter-organizational collaboration: A literature review, *International Journal of Management Reviews*, 8(2), pp. 71–89.
- Krugman, P. (1991) *Geography and Trade* (Cambridge: MIT Press).
- Legendijk, A. & Lorentzen, A. (2007) Proximity, knowledge and innovation in peripheral regions. On the intersection between geographical and organizational proximity, *European Planning Studies*, 15(4), pp. 457–466.
- Lazerson, M. & Lorenzoni, G. (1999) Resisting organizational inertia: The evolution of industrial districts, *Journal of Management & Governance*, 3(4), pp. 361–377.
- Lechner, C. & Dowling, M. (2003) Firm networks: External relationships as sources for the growth and competitiveness of entrepreneurial firms, *Entrepreneurship and Regional Development*, 15(1), pp. 1–26.
- Liu, R.-J. (1999) *Networking Division of Labor: Examining the Competitiveness of Taiwan's Machine Tool Industry* (Taipei: Linking).
- Liu, R.-J. & Brookfield, J. (2000) Stars, rings and tiers: Organisational networks and their dynamics in Taiwan's machine tool industry, *Long Range Planning*, 33(3), pp. 322–348.
- Lorenzen, M. (2002) Ties, trust, and trade: Elements of a theory of coordination in industrial clusters, *International Studies of Management & Organization*, 31(4), pp. 14–34.
- MacKinnon, D., Cumbers, A. & Chapman, K. (2002) Learning, innovation and regional development: A critical appraisal of recent debates, *Progress in Human Geography*, 26(3), pp. 293–311.
- Malmberg, A. & Maskell, P. (1997) Towards an explanation of regional specialization and industry agglomeration, *European Planning Studies*, 5(1), pp. 25–41.
- Markusen, A. (1994) Studying regions by studying firms, *Professional Geographer*, 46(4), pp. 477–490.
- Marshall, A. (1920) *Principles of Economics* (New York: Macmillan for the Royal Economic Society).
- Martin, R. & Sunley, P. (2003) Deconstructing clusters: Chaotic concept or policy panacea? *Journal of Economic Geography*, 3(1), pp. 5–35.
- Martin, R. & Sunley, P. (2006) Path dependence and regional economic evolution, *Journal of Economic Geography*, 6(4), pp. 395–437.
- Maskell, P. (2001) Knowledge creation and diffusion in geographic clusters, *International Journal of Innovation Management*, 5(2), pp. 213–237.
- Maskell, P. & Malmberg, A. (2007) Myopia, knowledge development and cluster evolution, *Journal of Economic Geography*, 7(5), pp. 603–618.

- Maskell, P., Bathelt, H. & Malmberg, A. (2006) Building global knowledge pipelines: The role of temporary clusters, *European Planning Studies*, 14(8), pp. 997–1013.
- Menzel, M.-P. & Fornahl, D. (2010) Cluster life cycles-dimensions and rationales of cluster evolution, *Industrial and Corporate Change*, 19(1), pp. 205–238.
- MOEA (2007) *2007 Machinery Industry Yearbook* (Taipei: MOEA).
- Oinas, P. (1999) Activity-specificity in organizational learning: Implications for analysing the role of proximity, *GeoJournal*, 49(4), pp. 363–372.
- Owen-Smith, J. & Powell, W. W. (2004) Knowledge networks as channels and conduits: The effects of spillovers in the Boston biotechnology community, *Organization Science*, 15(1), pp. 5–21.
- Pinch, S., Henry, N., Jenkins, M. & Tallman, S. (2003) From 'industrial districts' to 'knowledge clusters': A model of knowledge dissemination and competitive advantage in industrial agglomerations, *Journal of Economic Geography*, 3(4), pp. 373–388.
- Ponds, R., Oort, F. V. & Frenken, K. (2007) The geographical and institutional proximity of research collaboration, *Papers in Regional Science*, 86(3), pp. 423–443.
- Porter, M. (2000) Location, competition, and economic development: Local cluster in a global economy, *Economic Development Quarterly*, 14(1), pp. 15–34.
- Pouder, R. & St. John, C. H. (1996) Hot spots and blind spots: Geographical clusters of firms and innovation, *The Academy of Management Review*, 21(4), pp. 1192–1225.
- Rallet, A. & Torre, A. (1999) Is geographical proximity necessary in the innovation networks in the era of global economy?, *GeoJournal*, 49(4), pp. 373–380.
- Sabel, C. (1989) Flexible specialization and the re-emergence of regional economies, in: J. Zeitlin & P. Q. Hirst (Eds) *Reversing Industrial Decline? Industrial Structure and Policy in Britain and her Competitors*, pp. 17–70 (New York: St. Martin's Press).
- Schmitz, H. (1995) Collective efficiency: Growth path for small-scale industry, *Journal of Development Studies*, 31(4), pp. 529–566.
- Schoenberger, E. (1991) The corporate interview as a research method in economic geography, *The Professional Geographer*, 43(2), pp. 180–189.
- Scott, A. (1988) *New Industrial Spaces: Flexible Production Organization and Regional Development in North America and Western Europe* (London: Pion).
- Scott, A. (2002) Regional push: Towards a geography of development and growth in low- and middle-income countries, *Third World Quarterly*, 23(1), pp. 137–161.
- Staber, U. (2009) Collective learning in clusters: Mechanisms and biases, *Entrepreneurship and Regional Development*, 21(5–6), pp. 553–573.
- Sydow, J., Lerch, F. & Staber, U. (2010) Planning for path dependence? The case of a network in the Berlin-Brandenburg optics cluster, *Economic Geography*, 86(2), pp. 173–195.
- Tallman, S., Jenkins, M., Henry, N. & Pinch, S. (2004) Knowledge, clusters, and competitive advantage, *Academy of Management Review*, 29(2), pp. 258–271.
- Teixeira, A. A. C., Santos, P. & Oliveira Brochado, A. (2008) International R&D cooperation between low-tech SMEs: The role of cultural and geographical proximity, *European Planning Studies*, 16(6), pp. 785–810.
- Ter Wal, A. L. J. & Boschma, R. (2011) Co-evolution of firms, industries and networks in space, *Regional Studies*, 45(7), pp. 919–933.
- Torre, A. (2008) On the role played by temporary geographical proximity in knowledge transmission, *Regional Studies*, 42(6), pp. 869–889.
- Torre, A. & Rallet, A. (2005) Proximity and localization, *Regional Studies*, 39(1), pp. 47–59.
- Uzzi, B. (1997) Social structure and competition in interfirm networks: The paradox of embeddedness, *Administrative Science Quarterly*, 42(1), pp. 35–67.
- Visser, E. J. & Boschma, R. (2004) Learning in districts: Novelty and lock-in in a regional context, *European Planning Studies*, 12(6), pp. 793–808.
- Wolfe, D. & Gertler, M. (2004) Clusters from the inside and out: Local dynamics and global linkages, *Urban Studies*, 41(5/6), pp. 1071–1093.
- Zucchella, A. (2006) Local cluster dynamics: Trajectories of mature industrial districts between decline and multiple embeddedness, *Journal of Institutional Economics*, 2(1), pp. 21–44.