Technological Learning and Innovation in China in the Context of Globalization

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Abstract: A team of China- and U.S.-based geographers develops the theoretical concept of "learning field" to advance the study of technological innovation through networking under conditions of ongoing globalization. The concept is applied in a survey of ca. 100 firms in the Zhengzhou Economic and Technological Development Zone, located in a relatively underdeveloped region of China. The findings emphasize the different patterns and challenges confronting companies of differing size, property rights, and R&D capacities, as well as the variable extent to which technological learning is based on local versus global linkages and networking. Key elements involved in successful technological upgrading (in addition to networking) are identified, including market structure, competitive strategies, and capital. Also examined are the roles played by geographic, relational, and institutional factors in providing opportunities for learning and cooperation among firms in an industrial district. *Journal of Economic Literature*, Classification Numbers: D21, D83, O31, P20. 8 figures, 3 tables, 67 references. Key words: technological learning, learning field, networking, economic and technological development zone, China.

INTRODUCTION

In the context of globalization and transition to a knowledge economy, innovation and technological change have become increasingly important to competitiveness and economic growth. The capacity of regions to support learning and innovation has been identified as a key source of technological change and ability to compete in the global market. A number of overlapping concepts (e.g., untraded interdependence, relational assets, institutional thickness, innovative milieus, regional innovation systems, learning regions, and creative fields) have been promoted to explain the mechanisms of technological learning and knowledge creation in the process of globalization and spatial restructuring (Camagni, 1991; Putnam, 1993; Amin and Thrift, 1994; Florida, 1995; Asheim, 1996; Storper, 1997; Cooke and Morgan, 1998; Scott, 2006).

Recent research on technological learning and innovation has explored the forces driving economic success mainly in mature capitalist economies, such as the Third Italy, Silicon Valley, and Baden Württemberg. However, this literature underemphasizes the importance of

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wider networks and structures, and inadequately grounds its arguments in empirical enquiry (Mackinnon et al., 2002). Recently, scholars have begun to draw attention to extra-local connections and global production networks and suggest that network-based approaches may offer a better avenue for analyzing how key actors such as firms and institutions operate through and across spatial scales (Bunnell and Coe, 2001; Dicken and Malmberg, 2001; Henderson et al., 2002; Coe et al., 2004; Hess and Yeung, 2006). They argue that co-existence of high levels of "local buzz"[2] and global information pipelines may provide firms located in outward-looking and dynamic clusters with a string of particular advantages unavailable to outsiders (Bathelt et al., 2004). Consequently, there is a need for two research themes (local learning and agglomeration, and global integration and production networks) to converge around the notion of the local and the global as two interrelated scales of analysis within the processes of economic and political rescaling (Swyngedouw, 1997; Scott, 2004).

Moreover, the nature and patterns of learning and networking in developing countries remain under-researched. Processes of technological change in developed countries, where firms are innovating by pushing the knowledge frontier, are fundamentally different from such processes in developing countries, where innovation primarily takes place through enterprises learning to master, adapt, and improve technologies that already exist in more technologically advanced countries (UNCTAD, 2007). In addition, great heterogeneity and different models of national technological learning exist among developing countries (Mani and Romijn, 2003; Soubbotina, 2006). Theories emerging from geographic studies of Silicon Valley or the City of London are inadequate for development of general theories (Yeung and Lin, 2003; Wei, 2007).

The limited studies on technological learning in China deal mainly with a few science and technology parks and development zones in its leading city regions, such as Beijing, Shanghai, Suzhou, Shenzhen, and Xi'an (Wang and Wang, 1998; Lu, 2001; Walcott, 2002, 2003; Zhou and Tong, 2003; Liefner et al., 2005; Wei and Leung, 2005; Zhou, 2005; Liu and Dicken, 2006), and to a lesser extent, the characteristics of the national system (Liu and White, 2001; Lu and William, 2001; Sun, 2002a, 2002b; Sigurdson et al., 2005). China's extraordinary size and diversity mean that technological innovation in different regions forms local innovation systems, which are playing an increasingly vital role in the development of China's national system. Moreover, compared to high-tech zones serving as bases for the development of the high-tech industry, the economic and technological development zones (ETDZ), launched to absorb FDI and develop modern industries, are also important components of China's spatial innovation systems. In 2005, the cumulative FDI of the 54 national ETDZs was $99.93 billion, and in 2006, their FDI, foreign trade, and GDP were $13.02 billion, $225.24 billion, and 819.5 billion yuan, which accounted for 22, 15, and 4.5 percent of the national totals, respectively. Clearly, there is a need to devote more scholarly attention to ETDZs, and particularly the ones in China's less developed interior region.

How do firms located in China's ETDZs conduct technological learning and innovation? Is geographical proximity the main mechanism that facilitates innovation-promoting learning? What are the roles of relational and institutional proximities? Are the national ETDZs becoming innovation regions or learning regions? In this paper, we seek to investigate these questions based on questionnaire surveys and field interviews of ca. 100 companies to capture the network relations of firms in the Zhengzhou ETDZ, located in the interior of China. We devote particular attention to the structures and limitations of companies in their efforts

[2]I.e., internal communication flows among individuals and firms within the cluster.

to achieve technological upgrading and innovation through networking. In the following section, we briefly discuss the theoretical debates relating to our approach and construct a theoretical framework to analyze spatial technological learning in China. We then describe our methodology and examine the development and structure of the Zhengzhou ETDZ. We analyze the different learning patterns of firms in a fifth section of the paper, and finally summarize our findings in the conclusion.

THEORETICAL DEBATES AND CONCEPTUAL FRAMEWORK

Theoretical Debates

Recently, interest in the spatial characteristics of technological learning has increased substantially, and includes research under a multitude of headings (e.g., industrial districts, innovative milieus, local or regional innovation systems, learning regions, clusters, regional and global production networks, and the creative field).[3] As information and communication technologies have developed and expanded, information (i.e., codified knowledge) has increasingly become ubiquitous, so technological innovation has come to depend more and more on what is known as "tacit knowledge" (Gertler, 2003; Morgan, 2004), deeply personalized knowledge possessed by individuals that is virtually impossible to make explicit and to communicate to others through formal mechanisms (Dicken, 2003, p. 116). Rather heated debates among economic geographers and regional economists have arisen over such questions as: (1) Can tacit knowledge only be communicated by close contact made possible through geographic proximity, or can it be transferred over long distances? (2) Are geographical proximity and non-spatial linkages between firms and organizations (the so-called "relational or organizational proximity") prerequisites for institutional proximity (an environment of shared political and economic institutions and culture)? Does the basic character of acquiring technological knowledge vary over space (i.e., is place-specific)?

Although much of the literature focuses on geographic proximity and emphasizes the role of face-to-face contact or local initiative in transferring and diffusing tacit knowledge (Morgan, 2004; Storper, 2004), scholars have devoted increasing attention to relational or organizational proximity, emphasizing the role of extra-local linkages and sometimes physically separated communities of practicioners connected by digital and wireless technologies (Saxenian and Hsu, 2001; Amin and Cohendet, 2004; Perkmann, 2006; Poon et al., 2006). Tacit knowledge is believed to play a decisive role in determining where innovation takes place, because of the difficulty of disseminating this type of knowledge over long distances, its context-specific nature, and dependency on socially organized learning processes (Gertler, 2003). However, given the fact that technological learning and innovation are derived from a combination of tacit and codified knowledge, it may be more helpful to view tacit and codified knowledge as complementing (rather than replacing or competing with) one another. Therefore, to better understand the geography of innovation, we need an integrated framework within which to integrate geographical, relational, and institutional proximities.

The concept of embeddedness (Polanyi, 1944), which has gained much prominence in economic geography over the past decade, yields the central insight that markets and the behavior of economic actors within them are socially constructed and embedded. However,

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[3]For example, see Bathelt (2003, 2005), Moulaert and Sekia (2003), Oinas and Malecki (2002), Scott (2006), and Storper (1997).

many economic geographers, differing from Polanyi's original conceptualization and the work of economic sociologist Mark Grannovetter (1985), have tended to view embeddedness as a spatial concept operating only at the local and regional levels of analysis. Nonetheless, the recent literature on innovation employs a range of scales, including the global, the national, and the regional/local (Dicken and Malmberg, 2001; Yeung, 2005), even focusing on relationships operating between and across different scales (Bunnell and Coe, 2001). Therefore, an integrated theoretical framework for investigating the geography of technological learning and innovation must take into account the multiscalar character of embeddedness, as well as changes in its character over time (e.g., Hess, 2004).[4] Technological learning embedded in global production networks and national innovation systems in a globalized economy therefore is not only place dependent, but also nationally and globally dependent (Nelson, 1993; Bunnell and Coe, 2001).

An Integrated Conceptual Framework: The Learning Field

Based on the above, we now briefly demonstrate how we have arrived at the concept of the "learning field," the basic theoretical concept underlying the integrated framework for our study of technological learning in China. Storper (1997) attempted to reformulate the foundations of economic geography according to relational and evolutionary perspectives, referring to technology, organization, and territory as the "holy trinity" (overlapping constituent pillars of the economy).[5] Building upon this model, we extend his conceptualization of technological learning to the intertwined and complementary geographical, relational, and institutional proximities, and extend his concept of territory to space more broadly (including not only territorial innovation systems but national and transnational/global innovation systems as well). There has been growing recognition that mobile, "knowledgeable," or "learning" individuals contribute to knowledge creation and transfer (Williams, 2006); we think that individuals (as well as firms) are an important actor in the technological innovation process, and that the learning activities of organizations/individuals occur not only within and among industrial districts or clusters formed by small and medium-sized enterprises, but in large firms and transnational corporations as well. Furthermore, we integrate Storper's ideas into a general integrated framework of spatial technological learning by adding an additional three "pillars" to his trinity—scale, embeddedness, and evolution.

Our new approach to the geographical study of technological learning necessarily entails investigating the relationships between these pillars. One helpful and effective methodology is actor-network theory (ANT), which highlights the importance of linking time and space within heterogeneous networks (Murdoch, 1998), and facilitates the study of networks by acknowledging their three critical dimensions: (1) the autonomous power of actors; (2) the role of intermediaries; and (3) the interconnections of nodes (Yeung, 2003). Just as ANT uses the term "agent" for both human and non-human actors alike, we can view relationships

[4]Similar to the case with embeddedness, the evolutionary (or time-based) concepts of path dependence and path creating (Boschma and Lamboy, 1999; Boschma and Frenken, 2006; Martin and Sunley, 2006) may take place across different geographical scales. It is thus more useful to conceptualize these notions as dependent on space more broadly, rather than on place alone.

[5]Storper's work, in turn, was the point of departure for the construction of a relational economic geography by Bathelt and Glücher (2003), who although sharing Storper's view of the importance of context-specific institutions, devote more attention to evolution and interaction.

between organizations/individuals, technology, and space as actor networks by using the notions of multiscalarity, embeddedness, and path-dependence.

Borrowing the concept of the "creative field" from Scott (2006), we refer to our integrated framework as a "learning field" and posit that the central issue in developing countries such as China is acquiring the capacity to catch up with more advanced countries technologically ("learning") rather than advancing the frontiers of knowledge via technological breakthroughs ("innovation").[6] Our framework of the learning field not only is based on interaction among sets of existing social relations, but also: (1) illustrates some important attributes of actor networks (e.g., heterogeneity, contingency, and path-dependence); and (2) integrates the typology of spaces (namely regions, networks, and fluid spaces) within a simultaneous and hybrid learning field (Mol and Law, 1994).[7] It thus represents a theoretical perspective in which actors, dynamic processes, and the development resulting from their relations are central units of analysis, expanding Scott's concept into a systemic theoretical model and providing a useful paradigm for analyzing the geography of learning and innovation in advanced, developing, and transitional economies.

In the following investigation of technological learning in the Zhengzhou ETDZ, we seek to verify the heterogeneity, path dependence, and contingency of networking by different firms located in this region and its effect on technological learning. In so doing, we explore the extent to which, in a less developed region of China, technological learning depends not only on geographical but also relational and institutional proximity, not only on territorial embeddedness but also on societal and network embeddedness, and not only on path dependence but also on path creation.

RESEARCH SETTING AND METHODOLOGY

The Zhengzhou ETDZ, launched by the Zhengzhou municipal government in 1993 and designated a national ETDZ in 2000, is one of the most important new industrial spaces in Zhengzhou (Fig. 1), the capital of Henan Province in central China. Henan, the main cradle of Chinese civilization, is China's most populous province, with a population of nearly 100 million. Its GDP ranks fifth among China's provinces, and although its economy grew at more than 10 percent annually between 1992 and 2006, its per capita GDP was only 11,346 yuan in 2005.[8] Zhengzhou, the political, economic, and cultural center of Henan Province and its primary city, has more than 2.5 million urban residents. Its regional total population and GDP (including counties under the jurisdiction of the city) were 6.80 million and 16.6

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[6]Scott (2006, p. 52, p. 54) defines the creative field as a ". . . field of creative forces [that] can be used to describe any system of social relationships that shapes or influences human ingenuity and inventiveness," which ". . . comprises all those instances of human effort and organization whose spatial and locational attributes, at what[ever] scale they may occur, promote development- and growth-inducing economic change." We agree with Scott that an intrinsic element of the creative field is that both it and its effects on entrepreneurship and innovation are reflexively intertwined.

[7]Scott has attempted to broaden the concept of the creative field to include the entrepreneur in a spatial context, the space-time dynamics of innovative activity, and cultural economy at a variety of geographical scales. However, his focus is on agglomerated economic structures (e.g., industrial districts, regional productive complexes, urban economic systems) and his framework lacks a comprehensive theoretical enquiry into the creative field as "a nexus of multiscalar interdependencies running differentially throughout the domains of production, work, and territory" (Scott, 2006, p. 83).

[8]Henan ranks 17th among the provinces in terms of this indicator, which falls below the national average of 14,040 yuan.

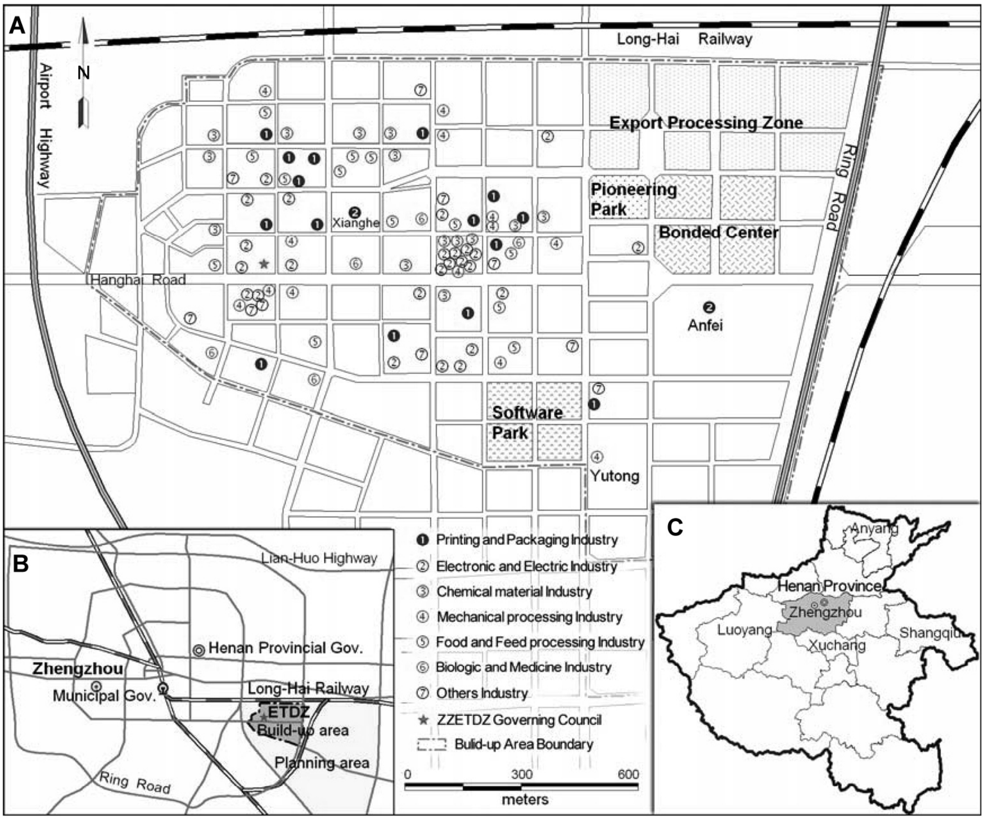

Fig. 1. The location of the Zhengzhou ETDZ (A) within Zhengzhou municipality (B) and Henan Province (C).

million yuan, respectively, in 2005. Zhengzhou is one of the most advanced regions among the provincial capitals in the interior.[9]

Although the economy of the Zhengzhou ETDZ has grown quite rapidly in recent years (Table 1), its development levels are not particularly impressive when compared with China's 54 ETDZs nationally, or the 9 and 13 ETDZs of Central and Western China, respectively (Figs. 2 and 3). For example, in 2006, the Zhengzhou ETDZ's GDP, tax revenues, imports and exports, and FDI were only on a par with the average for the 13 western ETDZs, and much lower than the averages for China and the Central region. Its GDP was only 6 percent of Guangzhou's (the largest of the 54 national ETDZs), and one-third and one-fourth, respectively, of the ETDZs of Xi'an and Wuhan in the neighboring provinces of Shaanxi and Hubei (Fig. 3). Wuhan and Xi'an were designated by the state as key industrial and education centers in the interior, and their large state-owned enterprises (SOEs) received massive

[9]To gain some perspective on the difference between central China's provincial capitals and those of the eastern coastal region, a comparison between Zhengzhou and a comparably sized eastern provincial capital is instructive. Although Zhengzhou's total population was 0.29 million more than Hangzhou's (the capital of Zhejiang Province), its GDP was 12.8 million yuan less, and its per capita GDP only 55 percent of Hangzhou's in 2005.

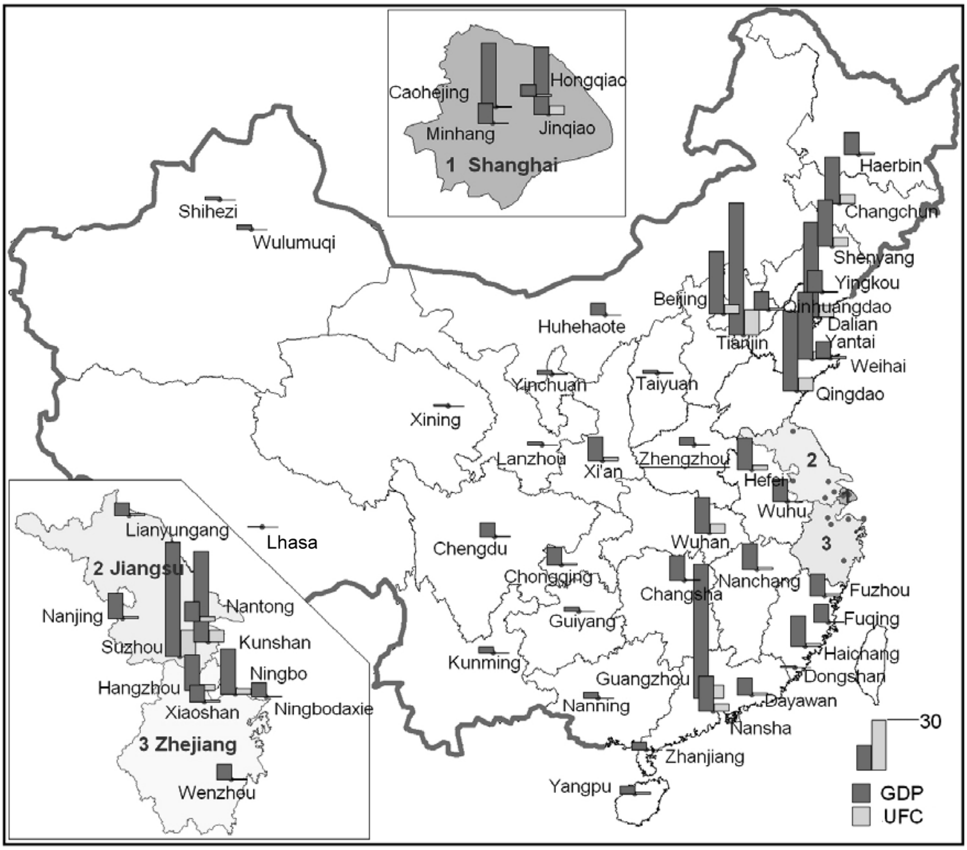

Fig. 2. GDP and utilized foreign capital (UFC) in China's 54 ETDZs in 2006. GDP is denominated in billions of yuan, UFC in millions of dollars.

Table 1. Development of the Zhengzhou ETDZ, 2000–2006

Year	GDP[a]	Industrial value added[b]	Tax revenue[b]	Exports[c]	UFC[d]	*N* of enterprises
2000	0.70	–	0.08	9.00	8.00	358
2002	1.61	0.72	0.20	6.00	19.00	620
2004	3.11	1.48	0.40	22.97	45.04	1147
2005	3.76	1.68	0.48	39.58	35.07	1500
2006	4.91	2.08	0.70	56.46	81.27	–

[a]Million yuan.
[b]Billion yuan.
[c]Million dollars.
[d]UFC = utilized foreign capital, million dollars.

investments during Mao's era. Conversely, Zhengzhou was developed as a transportation node. Sandwiched between Wuhan and Xi'an, its urban industries were dominated by light manufacturing (e.g., textiles and food processing), rather than on the resource industries

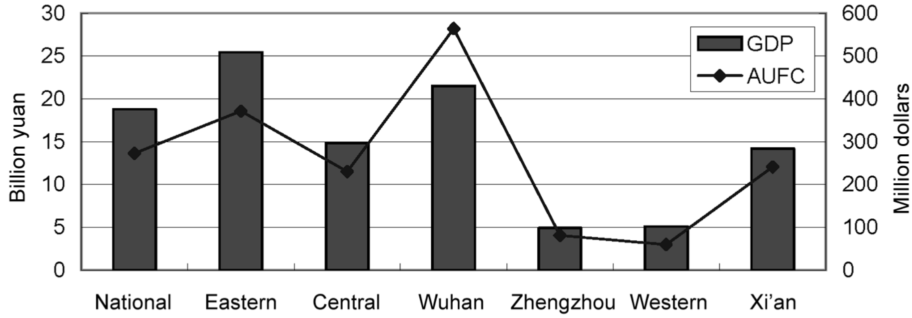

Fig. 3. Zhengzhou ETDZ in comparison with selected national ETDZs in terms of GDP (bill. yuan) and utilized foreign capital (UFC; mill. dollars).

(coal, aluminum, construction materials, and electricity) upon which regional industrial development during that period was based. Given a lack of state investment and foreign capital, Zhengzhou has been at a competitive disadvantage relative to China’s coastal and key interior cities. Thus the experience of the Zhengzhou ETDZ illustrates well the challenges confronting ETDZs in less developed interior cities, as well as the necessity and importance of technological learning by networking.

Application of the new economic geography to the study of technological learning requires a process-based methodological framework that goes beyond stylized facts and close dialogue (Yeung, 2003). In order to trace actor networks for technological learning and investigate them *in situ* from the multiscalar dimensions of economic action, we utilized questionnaires and firm interviews to gather empirical data and information. All told, as of 2005, 155 industrial firms had rented land or built production facilities in the Zhengzhou ETDZ, among which roughly 110 firms then were in operation, with annual sales of more than 5 million yuan. Our survey was conducted from June to August 2006, during which we hand-delivered questionnaires to the general managers of these 110 firms. In response, we received 103 returns; of these 97 were useable, representing an effective return rate of 88.2 percent. We also visited a dozen firms, and obtained very detailed interviews with five large firms.

MAIN CHARACTERISTICS OF TECHNOLOGICAL LEARNING

Profiles of Surveyed Firms

Among the 97 surveyed firms, 6 were SOEs, 71 were privately owned (POEs), 13 were foreign joint ventures (JVs), and 7 wholly foreign owned enterprises (WFOEs). In terms of firm size, two firms had a registered capital exceeding \$15 million (both JVs). The largest was Henan Anfei Electronic Glass Co. Ltd., a JV among Henan Ancai Group (headquartered in Anyang), LG-Philips Displays, and Nanjing Huafei Color Display Systems Co. Ltd., with a registered capital of \$55 million. The other was Lions Bus, a JV between Zhengzhou Yutong Bus Co. Ltd. and the German MAN Nutzfahrzeuge AG; each partner invested \$7.5 million in the venture. Only one firm reported a registered capital between \$10 million and \$15 million, a shareholding company transformed from a SOE. Two firms had registered capital between \$5 million and \$10 million—one was a private enterprise and another was a

Table 2. Profiles of Surveyed Firms in the Zhengzhou ETDZ

Sectors	Total firms	State-owned	Privately owned	Foreign joint ventures	Wholly foreign owned
Electronics and electric	29	3	20	3	3
Printing and packaging	15	1	12	2	
Chemical material	14		12	2	
Mechanical processing	14		9	4	1
Food and feed processing	12		9	1	2
Biological and medical	5		5		
Others	8	2	4	1	1
Total	97	6	71	13	7

JV formed by local tobacco firms and foreign companies from Hong Kong and Singapore. Among the 13 JVs, five firms received investment from Hong Kong and three from the United States; foreign partners in the others were from Taiwan, South Korea, Germany, the Netherlands, Australia, and Singapore. The seven WFOEs were all small in size, owned by individuals from Hong Kong (two firms), Japan (two firms), and Taiwan, Singapore, and the United States.

In addition to local and foreign investments, 11 firms received investments from other regions in China. These were generally dominated by companies from the major coastal provinces, including Shanghai (three firms), Beijing (two firms), Guangdong, and Jiangsu. The only source of investment from an interior province was Shanxi, a province that capitalizes on its coal industry.

The 97 firms were mainly in seven industrial sectors: electronics and electrical products, printing and packaging, chemical materials, mechanical processing, food and feed processing, biology and medicine, and "other" (Table 2). More than half of the firms were established after 2000, and only 5 percent before 1990, which shows the relatively brief history of firm development.

Networks and Linkages across Geographical Scales

We have distinguished five types of geographical scale in this study: within the Zhengzhou ETDZ; Zhengzhou city; Henan Province; China; and transnational. The first two types may be considered as local in scale (intra-region), the middle two as extra-local (inter-region), and the last as global. Within the Zhengzhou ETDZ, the importance of intra-regional trade and other forms of firm interdependence was clearly secondary to that of inter-regional linkages. The majority of connections between suppliers and clients was extra-local; only 30 of the 97 surveyed firms reported local cooperation with other rival firms in the same industry, whereas 55 firms reported extra-local cooperation with rival firms (Table 3).

Compared to the cooperative linkages occurring within the ETDZ, intra-urban linkages contributed somewhat more to the start-up and development of firms in the ETDZ, because the ETDZ alone could not provide the necessary technology and service support for its firms. Interestingly, (transnational) linkages with foreign suppliers and clients were clearly stronger

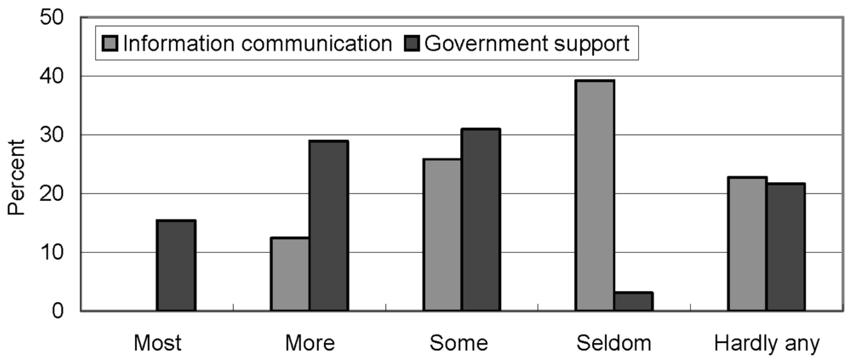

Fig. 4. Communication between employees of different firms ("personal information") and support from local government.

Table 3. Linkage Frequencies of Firms in Zhengzhou ETDZ at Different Scales

Types of cooperation	In ETDZ	Outer ETDZ in Zhengzhou	Outer Zhengzhou in Henan	Outer Henan in China	Transnational
Suppliers	6	49	67	73	21
Clients	16	71	82	80	21
Rivals	13	17	22	30	5
Universities/research institutions	0	18	9	21	0
Service institutions	1	36	3	19	0
Total	36	191	183	223	47

than intra-ETDZ linkages; more than 20 percent of firms in the ETDZ had developed cooperative linkages with foreign suppliers and clients (Table 3).

In territorial innovation models such as industrial districts and learning regions, the communication of information between individuals was one of the most important means of learning and innovation. However, in the Zhengzhou ETDZ, personal information communication among firms seldom occurred. Officials in more than half of the firms surveyed believed that communication of technological knowledge between their employees and those in other firms occurred rarely or not at all; respondents in only 12.4 percent of the firms surveyed thought that such communications occurred more frequently (Fig. 4).

Original Sources of Technology and Acquired Learning

The technological capability of a firm depends on two key aspects: its original source and acquired learning. Production equipment is an important original source of "hard technology." Of the 97 firms surveyed, 31 purchased complete sets of equipment from overseas suppliers. These equipment suppliers mainly were from Germany (13 firms), Japan (9 firms), the United States (6 firms), Taiwan (6 firms), South Korea (2 firms), the UK (2 firms), Italy (2 firms), and Switzerland (2 firms). Eighty-two (82) firms bought complete sets of equipment from domestic suppliers, mainly located in the coastal provinces, including Shanghai,

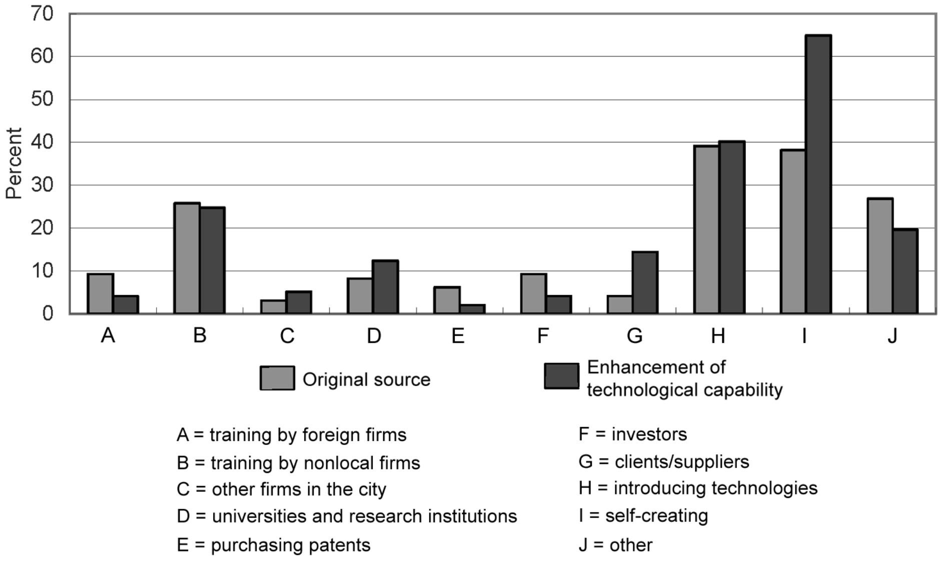

Fig. 5. Sources of technology for firms in the Zhengzhou ETDZ.

Guangdong, Jiangsu, Beijing, Zhejiang, Shandong, Liaoning, and Hubei.[10] Meanwhile, 10 firms only had to acquire components for their equipment (rather than complete systems) and five firms produced their own equipment.

Regarding sources of "soft technology," both the original source and acquired learning came largely from the firm's own technicians. Nearly 40 percent of firms obtained their technologies by hiring technicians and nearly 65 percent of firms improved such technologies by internal innovations. More than 10 percent of firms obtained their technologies by receiving training from foreign technicians, and more than 25 percent from technicians elsewhere in China (Fig. 5). Only a minority of firms established technological linkages with universities and institutions, other local firms, foreign firms, and clients/suppliers, although they viewed those external actors as important technological sources. Relative to the original sources of technology, some modes of acquired learning (e.g., self-creating, linkages with clients/suppliers, and with universities/institutions) assumed a more important role in enhancing the technological capability of a firm.

Technology transfer is vital for firms to improve their technological capabilities. Among the 97 surveyed firms, 33 benefited from technology transfer, believing that they had acquired technologies at least at the level of the 1990s. Production, processing, quality control, management, and marketing are the main components of technology transfer. In the context of China's drive to embrace economic globalization and develop indigenous innovation capacities, firms in the Zhengzhou ETDZ also view their R&D capabilities as increasingly important. More than 70 percent of firms regarded self-creating/internal innovation as the most important component of acquired learning, whereas more than 20 percent of firms viewed importing and imitating technology as their main patterns of technological learning.

[10]Henan also represented an important source of technology. Eight firms purchased complete sets of equipment from the province (five purchased from Zhengzhou municipality).

However, a majority of firms still lack independent R&D capabilities: 30 firms had no R&D personnel; only one-third could develop some technologies at the more advanced domestic level; and only one-fifth at the most advanced domestic level. In addition, only 21 firms had patents.[11]

Support from Local Government

In China, there are strong incentives for local governments to develop local economies by establishing various development zones such as ETDZs, science and technology parks, and industrial districts in order to attract investment. The role of local governments is particularly important in the investment decisions of individual companies. Our survey found that about half of the firms selected their locations in the ETDZ on the basis of the investment environment and infrastructure. More specifically, 40 percent cited government support, 20 percent strategic reasons involving market penetration, and 15 percent supply chains, skilled labor, and technology and management levels. In terms of the role exercised by the local government during the construction process, 15.4 percent and 28.9 percent of the firms surveyed, respectively, thought they received the highest level or frequent support from the administrative committee of the ETDZ, although 21.6 percent indicated that they received hardly any local government support.

In response to the question about the roles of local government in the operation and development of the firm, 43.23 percent and 41.24 percent of firms believed that the role of the local government lies in the development of hard infrastructure and improvement of the business environment, respectively. Only 22.68 percent, 8.25 percent, and 6.19 percent thought the role of the local government was to provide financial support, education and training, and export assistance, respectively. And 37.11 percent of the firms surveyed thought the local government hardly provided any help.

The Nature of the ETDZ

While the early Italian industrial districts emphasized small firm clustering and flexible production, scholars are increasingly adopting a broader concept of the industrial district. Park and Markusen (1995) defined an industrial district as a sizeable and spatially delimited area of new, trade-oriented economic activity that has a distinctive economic specialization (be it resource related, manufacturing, or services oriented). Markusen (1996) identified four distinctive types: Marshallian, hub-and-spoke, satellite platform, and state-centered. The Zhengzhou ETDZ is a new industrial space formed to develop the manufacturing industry, improve trade, and attract foreign and domestic investment. Among the 97 surveyed firms, one-third exported their products abroad, and the state granted 22 the right of self-export.

Obviously, the Zhengzhou ETDZ is a new industrial district but can hardly be delineated as a particular representative type. The learning characteristics of Zhengzhou ETDZ indicate that this young ETDZ is neither a learning region nor a Marshallian industrial district emphasized by territorial innovation models. It is neither a transnational satellite platform nor a local innovation district identified by Walcott (2002, 2003) for Chinese science and technological industrial parks. To better understand technological learning in the Zhengzhou ETDZ, we need to further investigate the networking of representative firms.

[11]The total number of patents was less than 100.

STRUCTURE OF TECHNOLOGICAL LEARNING BY NETWORKING

Each enterprise may have its own specific network of technological learning. Transnational corporations, large firms, and small firms may have different technological capabilities and technological learning patterns. In the Zhengzhou ETDZ, we found three dominant patterns of technological learning networks, each with its different learning field and unique characteristics of embeddedness, spatial scale, and evolution of technological learning.

Focal Firms and Extra-local Learning

Anfei Electronic Glass Co. Ltd., the largest corporation in the Zhengzhou ETDZ, is a typical focal firm. It was founded in 2001 as a joint venture among Henan Ancai Group, the largest cathode ray tube (CRT) glass producer both in China and the world, Nanjing Huafei Color Display Systems Co. Ltd., the largest joint venture project of CRT manufacturing in China between Nanjing Huadong Electronics Group and Royal Phillips Electronics, and LG-Phillips Displays (LP Displays), one of the world's leading global suppliers of picture tubes used for television sets and computer monitors, jointly found by LG Electronics and Royal Philips Electronics. Since 2003, Anfei has developed more than 40 new products of the SuperSlim and UltraSlim CRT glass series, as well as many new processing techniques. While intra-firm learning among different divisions and local linkages with clients/suppliers and related supportive institutions such as local governments, research institutions, and financial institutions are very important for technological innovation, the extra-local learning from Ancai, Huafei, and LG Phillips is also very important (Fig. 6). While Anfei's technicians and administrators mainly come from Ancai (which holds 66 percent of the stock of Anfei), Huafei and LG Phillips, which hold 20 percent and 14 percent, respectively, are not only the main clients, but also important management and technology knowledge sources. However, transnational corporations like LG Phillips can only transfer certain management techniques and mature technologies. Important product and process innovations mainly depend on Ancai and Anfei's independent innovation capabilities.

Although the global demand for CRTs is expected to remain strong, the transformation of the demand from CRTs to TFT-LCDs (thin film transistor–liquid crystal displays) has become an inescapable trend. The TFT monitors are rapidly displacing competing CRT technology. When Ancai bought nine production lines of CRTs from Corning, Inc., a world leader in specialty glass and ceramics in the United States, at the price of $49.9 million in 2003, it had a strong desire to import the technology for manufacturing LCD glass substrates, but Corning, Inc. refused to transfer the technology to Ancai and only made a promise to provide some technical help. Therefore, in order to promote the transformation of products and technologies as rapidly as possible, Ancai decided to develop the technology of manufacturing LCD glass substrates independently and prepared to invest 2.2 billion yuan to set up a factory to produce LCD glass substrates in the Zhengzhou ETDZ in 2005. Unfortunately, limited by capital, technology, location, and linkages with backward clients, the project, on which both the local government and Ancai placed high expectations, could not be implemented.

The experience of Anfei shows that although learning through local and extra-local networking is very important, learning through cooperation with foreign companies is a

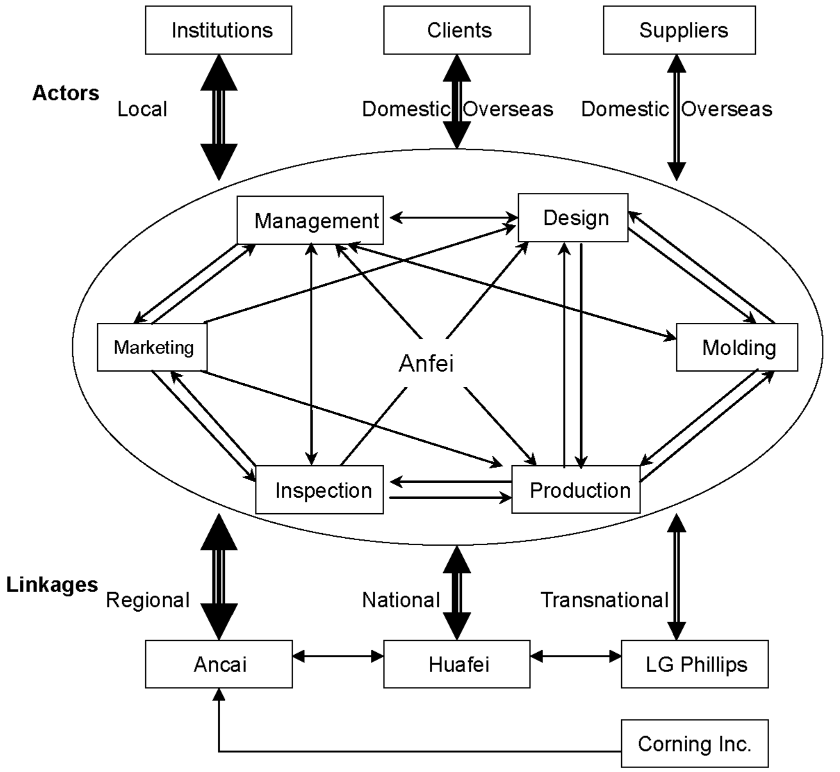

Fig. 6. Learning field of Anfei Electronic Glass Ltd.

complex bargaining process (Yeung and Li, 1999). Successful technological upgrading and innovation depend on a set of requirements such as independent capital and technological capabilities of a firm, competitors' strategies, and market opportunities, rather than networking alone.

Firm Recombination and Interactive Learning

Xianghe Group Electric Equipment Ltd. is the result of a merger of Switchgear Manufacturing Corporation, Transformer Manufacturing Corporation, and Insulated Equipment Ltd., all relocated from downtown Zhengzhou to the ETDZ in the late 1990s and belonging to Zhengzhou Xianghe Group Ltd., a state-owned firm group invested and administered by the Zhengzhou Electric Office. However, prior to the merger in 2001, and despite the fact that the three companies belonged to the same firm group and were located in the same neighborhood of Zhengzhou ETDZ, there were few direct linkages among them.

The establishment of the new firm from the merger has greatly enhanced technological capabilities and opportunities for intra- and inter-firm technological learning. On one hand, the combination greatly facilitates the sharing of tacit and codified knowledge as well as learning experiences through intra-firm network exchanges and communications. On the other hand, the merger also helps promote linkages and cooperation with other firms and the

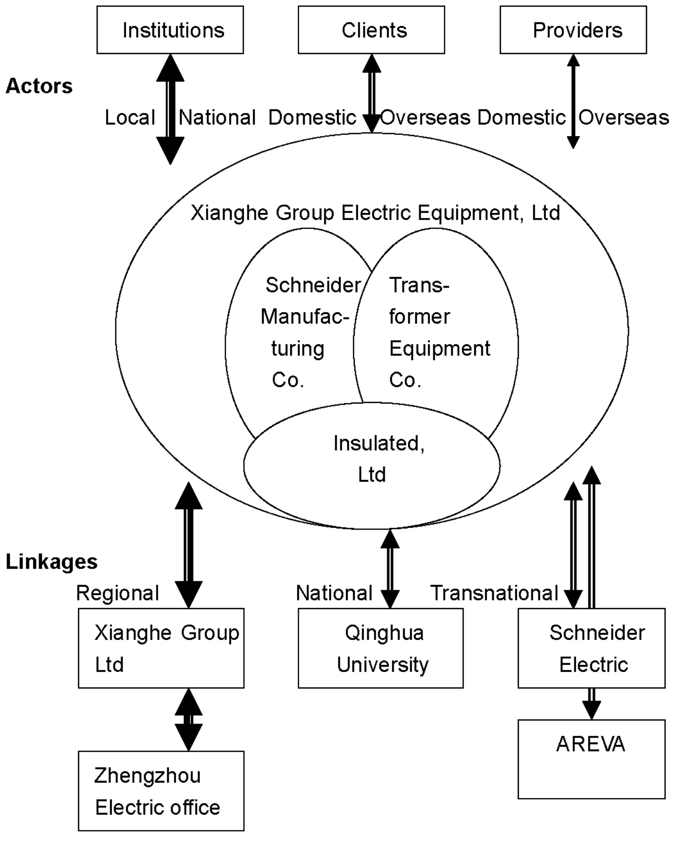

Fig. 7. Learning field of Xianghe Group Electric Equipment Ltd.

establishment of more effective learning pipelines. In 2002, Xianghe gained technological authorization to produce RM6 and SM6 network switchgear locally from Schneider Electric, a world leader in electricity and automation management. In 2006, Xianghe also gained the technological support needed to produce breaker series from AREVA, a France-based multinational industrial conglomerate that deals with energy. In the field of insulated equipment manufacturing, Xianghe has been maintaining technological cooperation with Qinghua University; Xianghe Insulated Equipment Ltd. was established using organic composite insulator technology from Qinghua University (Fig. 7).

Xianghe is one of the best-performing firms in the Zhengzhou ETDZ. Its sales revenue increased from only 61.26 million yuan in 2003 to 114.52 million yuan in 2005, and its R&D and technological upgrading expenditures were 2.92 and 0.56 million yuan, respectively. Xianghe has been devoting more attention to developing new products and has been developing its own technological capabilities through the interaction of intra-firm and extra-local learning networks. In 2005, it developed three new products and the cumulative number of its new products developed reached 33 (with a value of 20 million yuan). In 2006, although its target market remained limited to Henan Province and its environs, it exported its first products to Vietnam and India.

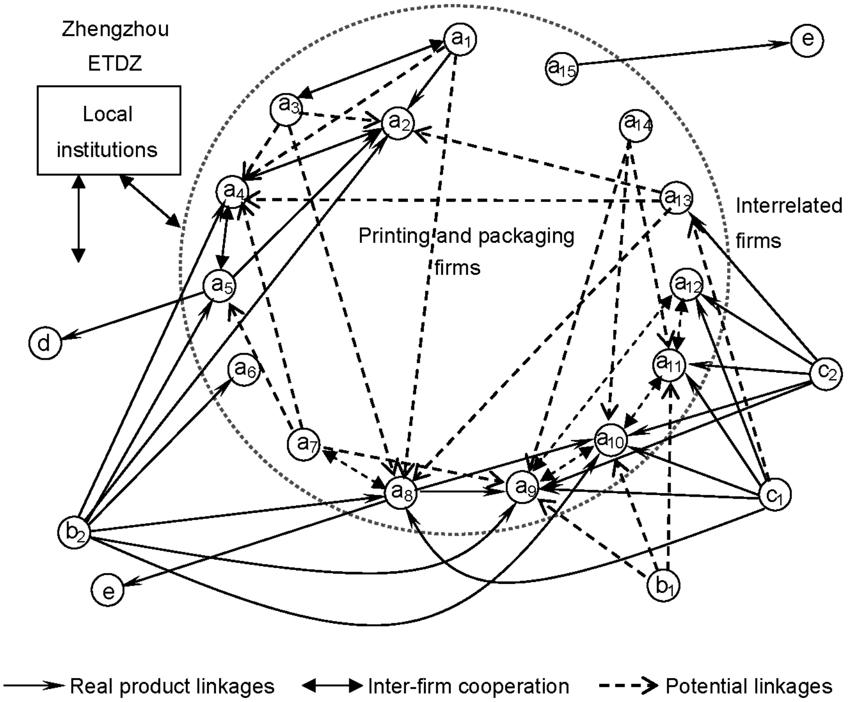

Fig. 8. Learning field of printing and packaging firms. The letter "a" represents a printing and packaging firm; letters "b–e" represent related firms.

Industrial Clusters and Local Learning

The printing and packaging industry is another important sector in the Zhengzhou ETDZ. There were 15 firms in this sector among the 97 surveyed firms, although each was small in size. Except for a single firm with registered capital of 60 million yuan, the registered capital of any of the other 14 firms was below 20 million yuan. This industry may be regarded as an embryonic industrial cluster, if we define cluster as a geographically proximate group of interconnected companies and associated institutions in a particular field (Porter, 1998). But linkages and cooperation seldom occurred among the 15 firms, which were evidently weaker than with interrelated firms (Fig. 8). Both trade and non-trade interdependencies of firms in this sector are rarely embedded in the ETDZ, but rather mostly in Zhengzhou and other cities in Henan.

The printing and packaging industry is a ubiquitous sector, characterized by intense competition, mature technologies, and similar local markets. However, the firms of this sector in the ETDZ believed they would have the potential to collaborate and learn from one another if they could establish mutual trust and enhance personal communication. In the development of this sector, inter-firm connection is largely a result of history. A culture of trust and personal communication has evolved over time, which makes it a prerequisite for firms to collaborate and learn from each other, although geographical proximity may provide opportunities for personal communication.

DISCUSSION AND CONCLUSION

Technological learning and innovation are some of the most important sources of competitiveness and growth of firms, regions, and nations, not only in advanced economies but in developing economies as well. They must take place in specific economic, social, and geographic spaces, which we define as learning fields. Because innovation is a process of interactive learning among many heterogeneous actors, a learning field must exist that is composed of the factors of Storper's holy trinity. We extend the concept to include organizations/individuals, technology, and space, and highlight characteristics of scale, embeddedness, and evolution. Based on actor-network theory and the creative field concept, a learning field can be defined as an integrated conceptual framework for investigating technological learning and innovation. It may bridge the debates on territorial, national, and transnational innovation systems; on local, national, and global production networks; and on geographical, relational, and institutional proximities.

Different learning fields exist for different firms, regions, and nations. It is obvious that wide gaps exist in the extents and strengths of learning fields between advanced and developing economies. Whereas geographical proximity, territorial innovation systems, and local production networks are dominant in the patterns of technological learning and innovation in advanced economies, relational proximity, national and transnational innovation systems, and national and global production networks may be more important for developing economies. While non-local and global linkages of industrial districts and clusters in advanced economies are the most important tools for breaking path dependence of economic development and technological evolution, such linkages in developing economies are the most important prerequisites for learning and upgrading technology and industries.

ETDZs and science and industry parks are the two types of new industrial districts that have flourished in China since the early 1990s. Zhengzhou ETDZ, as a representative of the former type in interior China, shows that learning fields in less favored regions are mainly centered on non-local linkages, and local trade and non-trade interdependencies are not the main sources of technological learning. Whereas both local and non-local networking with other companies, universities, and public research organizations are vital for companies in the Zhengzhou ETDZ to obtain new ideas and design new products, different patterns and limitations of networking exist for firms of different sizes, property rights, and R&D capacities. The experience of Anfei has shown that learning through cooperation with foreign companies is a complex bargaining process. Successful technological upgrading and innovation of a firm or a region depends on a set of diverse requirements above and beyond networking proper.

Although geographical, relational, and institutional proximities are all vital to technological learning and knowledge creation, they play different roles in the transfer of tacit and codified knowledge. Our study of Zhengzhou ETDZ shows that while geographical proximity may provide physical opportunities to learn and cooperate among different actors in a new industrial district, there is no guarantee that learning and cooperation will take place. Relational proximity is also not easy to establish; it is embedded in the history of a firm's development, and special investment is needed to nurture the relationship. Trust and formal institutional arrangements are necessary preconditions for relational proximity, which is why institutional proximity is of critical importance. The building of trust and formal institutions in local societies requires that different actors (e.g., local governments, firms, financial institutions, and research institutions) support and enhance their daily communications at both an organizational and personal level.

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