Working Papers Firms and Region
No. R2/2013

Henning Kroll
Esther Schricke

Patterns of Technology Transfer in Chinese Hotspots of Innovative Development – The Perspective of the Recipient Firms

Fraunhofer ISI

Contact:
Fraunhofer Institute for Systems
and Innovation Research ISI
Competence Center "Policy and Regions"
Breslauer Strasse 48
76139 Karlsruhe, Germany
Telephone: +49 / 721 / 6809-138
Telefax: +49 / 721 / 6809-176
e-mail: christine.schaedel@isi.fraunhofer.de
URL: www.isi.fraunhofer.de

Karlsruhe 2013
ISSN 1438-9843

Contents Page

1 Introduction 1

2 Conceptual Approach and Hypotheses 3

3 Empirical Approach 9

4 Data 10

5 Results 11

6 Summary and Conclusions 21

7 References 23

Tables

Table 1: Number of Employees in 2011 11

Table 2: Sales Volume in 2011 11

Table 3: Stated Relevance of Technology Transfer/External Knowledge 12

Table 4: Stated Relevance of External Knowledge Compared to Own R&D Efforts 12

Table 5: Share of Employees with Higher Education Degree 13

Table 6: Share of Employees Working Full-Time as Dedicated R&D Staff 13

Table 7: Main Competitive Edge as Stated by Company 14

Table 8: Main Purpose of Seeking Technology Transfer as Stated by Company 14

Table 9: Main Type of Knowledge Obtained 16

Table 10: Main Channels Used to Obtain External Knowledge, Main Partners 16

Table 11: Main Market Orientation and Main Orientation of Knowledge Sourcing 17

Table 12: Main Difficulties Encountered with a with to Knowledge Sourcing 18

1 Introduction

As other countries which confronted institutional legacies of a planned economy, China had to substantially reform and adapt its higher education system in the course of the 1980s and the 1990s (OECD 2008; Wu 2010a). Institutions that used to be mere teaching facilities until the late 1970s gradually resumed their scientific activities and in some cases even developed into internationally acknowledged hubs of cutting-edge research (Frietsch et al. 2008; Yang/Welch 2012). In many respects, this process of transformation has set an example of ambitious targets which were successfully achieved, backed up by strong incentive systems (Wu 2010b). It has, however, not remained limited to the realm of scientific merit alone. One further consequence is that, unlike in other developing nations (Intarakumnerd et al. 2002; Liefner/Schiller 2008), Chinese universities have become potentially more relevant sources of knowledge for local firms.

Furthermore, China's rapid development did not only come with a renewed push for scientific excellence but also with quickly developing ambitions with regard to technological upgrading in the domestic industrial sector (Jin et al. 2008; Lee et al. 2011). The pre-reform system's approach of relying on freely available research results of public research institutes (Segal 2003) predictably failed (Chen/Kenney 2007). During the process of institutional transformation, therefore, many of these institutes were either privatised straight away or substantially reformed (OECD 2008). These reforms, however, did progress fast enough to satisfy the rapidly emerging demands of the national industry (Kroll/Schiller 2010). As a result and in part expedited by a parallel decrease in their basic funding for research (Chen/Kenney 2007), Chinese universities were confronted with substantial opportunities in different areas of what the academic discussion has come to label the 'third role' (Kroll/Liefner 2008; Wu 2010a). Already involved in a process of transformation since the 1980s, they were arguably able to adapt to this novel role in the field of applied R&D faster than public research organisations, even if they, too, had to overcome notable internal challenges before all internal stakeholders were ready to accept university-industry relations as part of their mission (Kroll/Liefner 2008; Wu 2010a). In any case, the industrial share of funding for university R&D has been and remains higher than that of funding for public research activities at many of those other public research institutions which, with a view to their mission, should deliver more applied results (Kroll/Schiller 2010). In addition , the intensity of those co-operations with the private sector that can be evidenced by co-patents has visibly increased (Motohashi 2008).

That notwithstanding, much of the literature underlines that the Chinese system of technology transfer has developed quite particular, and not always beneficial, features

during the nation's gradual process of institutional reform. In particular, Chinese universities have focused on very entrepreneurial approaches to commercialisation and technology transfer, while market-oriented co-operative relations have taken longer to become effective (Gu 1999; Kroll/Liefner 2008)One prominent element of this entrepreneurial approach are the 'academy-run' or 'spin-around' firms (Eun et al. 2006; Kondo 2003), institutionally invested and dependent firms that have emerged side by side with actual spin-offs in China (Eun/Lee 2010; Kroll/Liefner 2008). While some studies underline that these structural tendencies persist until today (Wu/Zhou 2012), others (Guan et al. 2005; Motohashi/Yun 2007; Tagscherer et al. 2012) point out that there is no evidence suggesting that university-industry co-operations in China are limited to, or even very focused on, co-operations with such newly set-up firms. Among other studies, a 2009 survey of 21 universities and 31 companies in Beijing, Tianjin and Hebei unambiguously demonstrated that partners from science and industry maintained quite different forms of co-operations from small-scale project-oriented contract research, the strategic set-up of joint science-industry research centres in high-tech industries, to the formation of long-term national alliances for pre-competitive R&D in defence-related or heavy industry (Tagscherer et al. 2012: 35). In fact, Chinese universities seem to engage in a much larger part of the broad array of possible university-industry relations (D'Este/Patel 2007; Kodama/Branscomb 1999) and fulfil a much broader set of functions in their region (Uyarra 2010) than commonly acknowledged (Chen/Kenney 2007; Motohashi/Yun 2007; Quan 2010; Wu 2010a).

Nonetheless, different studies have continued to express scepticism as to how meaningful and effective these still specifically Chinese types of science-industry co-operation really are (e.g. Cao 2004). Even very recently, some went so far as to claim that “the role of [university-industry linkages in China] is largely stalled or out of sync with industry progress” (Wu/Zhou 2012: 823) highlighting in particular that many universities in China are not yet able to assist the country's technologically most advanced firms. On the other hand, however, these studies acknowledge that 'many smaller and medium sized firms [remain] in great need of R&D support' (Wu/Zhou 2012: 825) – and could thus indeed profit from public technology transfer. Other studies, moreover, underline that some of the leading institutions have indeed become able to do so (Yang/Welch 2012). In a sense, therefore, these critical accounts reiterate the key findings of previous studies highlighting that well-functioning science-industry linkages in China thrive on 'islands' that are only to a limited extent connected to the rest of the economy (Kroll/Schiller 2010). In addition, they are in line with a plethora of papers which underline the substantial degree of variety between regional innovation systems in China – from different types of well-connected urban hotspots to a large, technologi-

cally lagging periphery (Chen/Kenney 2007; Guan/Chen 2010; Kroll/Tagscherer 2009; Zhang et al. 2012).

What remains unanswered, however, is to what extent the potential recipients of technology transfers in China's hot-spot of innovation are still facing the specifically Chinese obstacles mentioned in earlier studies (Cao 2004). Even though arguably disconnected from other parts of the broader industrial system, these hot-spots of development still undisputedly constitute one of the dynamic cores of the Chinese national innovation system, remain central to building China's domestic technological capabilities and, in the long term, may well generate more relevant spill over effects than today (Kroll/Schiller 2010; Lee et al. 2011; Zhao/Richards 2012). For the moment, however, the situation on the 'islands of innovation' remains too specific to draw on general studies on technology transfer in the Chinese economy to improve our understanding of these particular environments.

Consequently, the authors see merit in a study that is aimed at illustrating how the network of knowledge exchange in China has evolved in one of the core locations that served as the drivers of the national innovation system in the last decade. In particular, it seeks to establish whether some of the 'classic' intrinsic problems of the Chinese technology transfer system that were lamented in the 1990s (Gu 1999) and the early 2000s (Cao 2004) still prevail, or if the system of knowledge exchange in some of the leading innovation locations has in the meantime been substantially transformed and in some respect become more similar to international set-ups as has been suggested by newer studies (Liu et al. 2011; Zhao/Richards 2012).

2 Conceptual Approach and Hypotheses

For at least two decades, Chinese policy making has sought to develop the national business sector's techno-economic capabilities beyond imitation and adaptation (Chen/Kenney 2007; Frietsch/Schüller 2010; OECD 2008). Beyond prestige related considerations, one key political rationale behind this certainly is that business models based on innovation instead of labour cost competition enable Chinese firms to pay higher wages and thus, indirectly, safeguard societal well-being. Accordingly, pre-competitive research and technology transfer have been high on the central government's agenda since at least the 1980s (Cao et al. 2006; Chen/Kenney 2007). On the contrary, from an individual firm's perspective investment in technological upgrading only becomes relevant when it promises to yield tangible additional opportunities in terms of profit or growth (Dosi 1988). In the 1990s and early 2000s, the market mechanism as such did not provide incentives such as that Chinese firms could compete

based on low labour cost or regulatory arbitrage with regard to for example pollution, and rely on technological imports from abroad (Chen 2007; Lee et al. 2011) – as could be theoretically expected (Nelson 2008) and which has many times been observed in emerging economies (Ernst/Kim 2002; Kogut 2004; Revilla Diez/Berger 2005). To some extent, undoubtedly, some of these incentive frameworks continue to persist until today, in particular in manufacturing regions like the Pearl River Delta (Kroll/Schiller 2012; Schiller 2011).

In recent years, however, this established situation has come under pressure by rising wages, tightening regulations, as well as an increasingly discerning and affluent customer base (Asian Development Bank (ADB) 2010; Lee et al. 2011). As a result, companies favouring old-style business models move further inland while more and more companies in the affluent urban centres, characterised by a dynamic public research landscape, have successfully demonstrated that money can just as well be made by producing technologically more advanced and higher-quality products even if this requires drawing on a well-educated, more expensive workforce (Altenburg et al. 2008; Wang/Zhou 2013). In parallel, more and more Chinese universities have developed to a point where they have become relevant sources of forward engineering (Frietsch et al. 2008; Lee et al. 2011). Evidently, Chinese firms have been making active use of these opportunities (Motohashi 2008; Motohashi/Yun 2007) which in turn helped them to improve their own technological capacity and their ability to innovate (Brehm/Lundin 2012; Fu et al. 2012; Guan et al. 2005; Tagscherer et al. 2012). In the late 2000s and early 2010s, therefore, the formerly poor match of technology supply and demand (Kroll/Schiller 2010) improved while, in parallel, the national government reinforced its investments in science, technology and innovation (Cao et al. 2006; Lee et al. 2011; OECD 2008). Certainly, there are still a number of Chinese regions where either the sheer absence of public research capabilities or the prevalence of traditional business models will keep the potential for the development of a dynamic local network of knowledge exchange rather limited (Schiller 2011; Zhang et al. 2012). In other locations, like Beijing, in contrast, university-industry relations have been the backbone of the regional technology sector from its outset, even during the planned economy era (Chen/Kenney 2007; Segal 2003; Zhao/Richards 2012). As a result, these locations are a priori endowed with a much denser local network of relations between the university and the industrial sector (Guan et al. 2005; Tagscherer et al. 2012). As Fu et al. (2012) rightly point out, however, these networks have to be understood in Chinese terms as guanxi – long-standing personal relations between people who know each other from working in a similar field or having studied at the same university. While this network of inter-personal relations may create an environment of trust, it does not necessarily en-

sure an effective, dynamic and viable network of inter-business relations. Even though people know each other well, they may not necessarily be knowledgeable about the implementation of technology transfer or free to act as they see fit. In the past decade, for example, the effectiveness of the network, which existed even then, remained severely hampered by other deficiencies such as low absorptive capabilities in local firms, unclear ownership rights, lack of venture capital, and the government's strongly interventionist approach to technology policy (Cao 2004). In more general terms, it has been argued that the existing networks cannot become effective without the right incentive systems and framework conditions (Wu/Zhou 2012).

It is also important to note that the dynamic of the local system of technology transfer does not depend on the technology providers alone, but at least to the same extent on the characteristics of the potential recipients of technology transfers (Bozeman 2000). This was empirically confirmed for the case of China years ago/a few years ago (Cao 2004). Against this background, it has to be regarded as a deficit that the majority of recent studies aimed at analysing the system of technology transfer in China's hotspots of innovation have tended to focus on the perspective of the technology providers. With comparatively new reviews of the public research perspective now available (Wu/Zhou 2012; Wu 2010b), it is this perspective of the firm that remains missing from the overall picture. Unambiguously, more general studies (e.g. Brehm/Lundin 2012; Motohashi/Yun 2007) have demonstrated the great potential of company-level studies to assess how useful and effective the technological offers made by domestic universities really are, a potential that remains to be leveraged through more focused studies.

In order to evaluate the current state of development of knowledge exchange and technology transfer in China's hotspots of innovative development, our analysis will have to focus on a sample of enterprises in Beijing that are part of the established local network and thus preferred recipients of technology transfers. To determine which limitations and particularities prevail in the local system of knowledge exchange, we will analyse the firms' views on the local situation and benchmark their assessment against that of companies in a potentially more favourable – and less specifically Chinese environment. To the authors' knowledge, no study has so far been conducted from this particular perspective.

More specifically, the empirical analysis will focus on a sub-group of firms which can be assumed to be part of Beijing's existing local network of technology-related interpersonal relations. To that end, the study focuses on firms which have either tried to register as 'technology-firms' or applied for funding for 'technology activities'. To determine whether the technology transfer system in Beijing still displays 'Chinese particu-

larities' and 'typically Chinese obstacles' the Beijing firms' assessment of their own situation and the local framework conditions were benchmarked against a representative sample of German firms which claim to be 'innovative'. Germany was selected as a country of reference as, firstly, it is an economy within which the notion of technological innovation can be expected to be a concept fully understood by most entrepreneurs and, secondly, it is an economy in which a co-operative approach to technological development and R&D is fairly widespread (Schmoch 2000). Thus, the Chinese firm's assessments of a number of technology-transfer related issues in their specific environment will be compared against those of a sample of innovating firms from a stable environment in which knowledge, technology and innovation have undisputedly become central to economic success and where co-operation and knowledge transfer constitute relevant sources of international competitiveness.

In the following we specify this paper's objectives by means of five distinct hypotheses.

As a first hypothesis, we suggest that the overall level of technological capability in the Chinese industrial sector is more limited than that of innovating firms in Germany, even among those companies registered as 'technology firms' (Lee et al. 2011; OECD 2008). In particular, the literature suggests that not many firms have moved into a position from which they can develop and patent global novelties (Kroll 2011). Instead, they are more likely to focus their technological activities on the domestic market (Schiller/Kroll 2013) which, for the time being, offers sufficient volume and business opportunities based on the adaptation of solutions that are available elsewhere. Consequently, most of the firms surveyed in China have only recently begun to feel a need to invest substantially in own, internal R&D capabilities, if at all. Instead, they are likely to be used to rely on external inputs and inspiration which they then transfer into actual products (Lee et al. 2011; Zhu/Chen 2006).

Hypothesis 1: Chinese firms looking to register as technology firms display lower technological capabilities than innovating firms in Germany – illustrated by their more limited tendency to develop global novelties; in line with this, they tend to be more dependent on external knowledge transfer and likely to place less confidence into their own, internal R&D capacities.

As a second hypothesis, we suggest that, due to the way in which the sample was drawn, many of the surveyed firms are likely to orient their internal structure towards the requirements put forward by the government for the funding or registration that they sought to obtain. According to local experts, these include stipulations regarding the formal qualification of the staff, the number of dedicated R&D personnel and the stated

business model. On the other hand, much of the literature on technology transfer in China suggests that many employees in firms do not have the necessary qualifications needed to process external technological knowledge (Cao 2004; Tagscherer et al. 2012). In addition, many firms are said to lack market related knowledge, which leads to difficulties in selling their products (Kroll/Schiller 2010). Consequently, we can expect that their declared motivations for absorbing knowledge will suggest that a number of internal capabilities leave room for improvement, in particular those related to employees' qualification and to the applicability and customer orientation of their products.

Hypothesis 2: Most Chinese firms looking to register as technology firms will fulfil official 'high-tech' criteria with a view to workforce qualification, R&D employment and their declared competitive edge to a stronger extent than German firms; nonetheless, some of their motivations for accessing external knowledge will indicate that their workforce's task-related qualification and customer orientation remain to be improved.

As a third hypothesis, we put forward that while many Chinese technology firms may be quite experienced with regard to the adoption and adaptation of external knowledge, a not uncommon narrative suggests that much of this absorption of knowledge is based on the re-engineering of existing hardware, rather than on an actual capability to either process more abstract, codified knowledge or to collaborate with partners from academia (Tagscherer et al. 2012; Wu/Zhou 2012). While the trade of embedded technological content has been established for more than a decade and seems to function rather well (Gu 1999; Kroll/Liefner 2008), recent studies have confirmed that the actual impact of university-industry relations depends on the firms' actual investment in their own absorptive capacity (Brehm/Lundin 2012). Furthermore, less positive assessments have been published of Chinese universities' ability to license patents (Wu, 2010b) and of Chinese firms' general ability to absorb external knowledge (Liu/Zheng 2011) which in the past has prompted the emergence of an overly entrepreneurial technology transfer system (Eun et al. 2006; Kondo 2003) that seems different from the personal-interaction-based German system (Schmoch 2000). With a view to potential partners, the still limited technological capabilities in the domestic industrial sector suggest that for many firms there is little alternative to collaborating with public research organisations if they want to learn something substantially new (Lee et al. 2011; Motohashi/Yun 2007). In addition, the high intensity of competition-oriented thinking in the Chinese business sector can be expected to limit any collaboration between those firms who fear that sharing knowledge might expose their business secrets.

Hypothesis 3: The firms surveyed in China have a lower absorptive capacity than those in the German sample; hence, many of them will seek to obtain ready-made products

and prototypes; co-operative R&D, in contrast, will remain less common. Since the technological capabilities in the industrial sector remain low, more firms will focus on transfer from public research.

As a fourth hypothesis, we suggest that many Chinese firms are still 'national champions' neither able nor willing to compete on the global marketplace (Lee 2005; Liu/Zheng 2011). For the time being, the domestic market offers sufficient volume and opportunity as well as a slightly less discerning customer base that matches the firms' own technological capabilities well (Schiller/Kroll 2013). While capabilities relevant for global competiveness can only be learned abroad (Zhu/Chen 2006), this domestic market could for a transitory period be served without intensive localised R&D co-operation. Increasingly, however, the development of novel products for a more and more challenging customer base requires an interaction with partners knowledgeable about technology but arguably also about local specifics and customer requirements (Fu et al. 2012; Schiller/Kroll 2013). As a result, it would seem logical if Chinese technology firms have a stronger tendency to co-operate with domestic partners than their much more internationally oriented German counterparts.

Hypothesis 4: The activities of Chinese firms looking to register as technology firms are mostly focused on the domestic market; due to this focus, the degree of R&D collaboration with local partners will also be higher.

Finally, much of the literature suggests that different – i.e. by and large more obstructive – framework conditions for technology transfer and knowledge exchange continue to persist in the Chinese innovation system. Beyond cultural particularities (Fu et al. 2012), examples of those framework conditions are a fragmentation of and lack of co-operative culture in the industrial sector, a general lack of awareness regarding IPR issues, a limited impartiality of some courts which leads to a limited implementation of IPR regulations, as well as a lack of managerial competences related to innovation within Chinese firms themselves (Cao 2004; Zhu/Chen 2006). If all those claims hold true, it can be expected that Chinese companies encounter remarkably different obstacles in their attempts to obtain external knowledge as much as they can be expected to express different demands with a view to policy makers in charge of amending the situation.

Hypothesis 5: Due to different framework conditions, the difficulties encountered by Chinese technology firms in obtaining external knowledge differ substantially from those encountered by innovating firms in Germany; as a result, their expressed demands with a view to desirable policy support will be different.

In the following, these five main hypotheses will be tested through the empirical collection of relevant datasets in both China and Germany. The precise empirical will be described in more detail in the next section.

3 Empirical Approach

To obtain the companies assessment of technology related issues, two surveys were conducted in Germany and Beijing with identical questionnaires in the respective national languages. The questionnaires comprised four main sections related to basic company information, the firms' current innovative efforts, actual and desired technology transfer activities in the firm, opinions and expectations regarding external knowledge sourcing, as well as the respondents' expectations with a view to policy. Overall, the questionnaire contained seventeen different questions. With a view to the delineation of the potential survey population and the criteria relevant for the inclusion of firms into the sample, different approaches had to be chosen, due to the different framework conditions in Germany and China. Both surveys were conducted in mid-2011.

In China, the survey was conducted on paper and, in part, in person. In line with the conceptual approach, the sample was stochastically drawn from the management databases of government management departments dealing with the certification of company-based R&D agencies and the allocation of public R&D funding for enterprises. Naturally, most of the firms listed in their databases have acquired or are attempting to acquire either a certification for internal R&D agencies by the Beijing Municipal S&T Commission or public funding for innovation activities. As intended, the firms surveyed in Beijing thus reflect a subset of the firm population which is comparatively active in innovation and likely to be part of the established network. Arguably, they thus constitute a (fairly) representative element of the 'islands of innovation' in large urban centres that have been referred to in earlier literature. As most interviews were conducted in person and the survey had the support of the authorities in Beijing, a high response rate could be achieved, resulting in an overall sample size of 178 questionnaires.

In Germany, the survey was run as an online survey based on electronic questionnaires and email, using the EFS survey software. The overall population of addressees was drawn from the Amadeus/Markus firm database. While this database does not provide complete coverage of all firms, it is not known to have any particular bias. Firms listed with less than 25 employees were excluded as information on them is often known to be less reliable or dated. Beyond that, no further stipulations were laid down, so that the potential survey population covered about 39,000 firms across Germany. Of those, 450 started to fill out the questionnaire and 265 completed it, leading to an over-

all response rate of 1.5%. Despite this comparatively low turnout, the general representativeness of the sample could be confirmed across regions, firm sizes and industrial sectors. Later on, the sample was filtered so that only those firms which indicated to be innovative remained, limiting the sample to 120 to 140 answers, depending on the question.

In the following, the significance of the differences between findings will be determined by standard t-tests of the difference of the two independent samples' means. While the nature of the survey does not necessarily suggest that all variable meet all criteria for a t-test in finite samples of limited size, the probability of a positive answer to many of the questions (arguably about 0.5) suggests that their overall probability distribution will converge against normality with a rate that makes the t-test a suitable choice at sample sizes around n=130.

4 Data

Before a more detailed analysis of the data can be undertaken, it has to be established whether the two samples differ substantially in structure, i.e. whether the broader German sample really constitutes an appropriate point of reference for the more selective sample of technology firms in Beijing. Naturally, this analysis of general structural criteria cannot replace the need for awareness that we are benchmarking a regionalised 'island of innovation' with the situation in a broader national economy – including the natural implication that the sectoral structure of the two samples will not be alike. These more general implications, however, have been dealt with in the introduction and will be taken up in the discussion and conclusion. Furthermore, it can be stated that the Chinese sample covers a broad range of sectors so that no specific technology-related bias can be expected to come into play (biotech/pharmaceuticals, agricultural technology, ICT, traffic/transportation, energy technology, environmental technology). Beyond that, Table 1 illustrates that there is no particular size-related bias in either one of the samples. On average, firms in the samples employ between 50 and 250 staff, while both smaller and larger numbers of employees are common. With a view to Table 2, however, we observe that the sales volume of German firms is notably higher. On average, their turnover reaches 5-50 million euros whereas it ranges between 1-10 million euros in China. Against the background of similar employment figures, it thus seems that German are somewhat better established t in their potential markets, or that, quite simply, their staff realises greater efficiency.

Table 1: Number of Employees in 2011

	less than 10	10 - 49	50 - 99	100 - 249	250 - 499	more than 500
China (Beijing), n=129	0.8%	20.9%	42.6%	13.2%	22.5%	-
Germany, n=120	-	32.5%	24.2%	24.2%	9.2%	10.0%
difference of mean significant	No (CN: 3.36, DE: 3.40)					

Source: Research and calculations by Fraunhofer ISI.

Table 2: Sales Volume in 2011

	below 250.000	250.000 - 1 million	1 - 5 million	5 - 10 million	10 - 50 million	more than 50 million
China (Beijing), n=129	1.6%	9.4%	28.3%	43.3%	17.3%	-
Germany, n=120	1.7%	-	24.2%	23.3%	28.3%	22.5%
difference of mean significant	yes, at 99.9% level (CN: 3.65, DE: 4.44)					

Source: Research and calculations by Fraunhofer ISI.

5 Results

Hypothesis 1: *Lower Innovative Capacity, Higher Dependence on External Technology*

With a view to Hypothesis 1, our analysis finds that 81% of the firms surveyed in Germany sell products or services that can be regarded as international novelties, while two thirds of the firms surveyed in Beijing offer products or services that are new to the domestic market, but exist in similar form elsewhere. In line with this proof of more modest ambitions and/or capabilities, the findings presented in Table 1 confirm that most Chinese firms express a notably higher need for external knowledge sourcing than their German counterparts. On average, Chinese enterprises state that technology transfer was of high to very high importance for their business, while German firms merely tended to express a somewhat less than 'high' importance. Moreover, the results presented in Table 2 underline that these statements do not only hold in general terms but also in relation to the firms' assessment of their own internal R&D effort. Whilst in Germany external knowledge tends to be assigned an only somewhat more than 'medium' importance in relation to their own capabilities, Chinese companies al-

most unanimously regard technology transfer as 'highly', i.e. more, important than their own internal R&D efforts.

Table 3: Stated Relevance of Technology Transfer/External Knowledge

	very high	high	medium	low	very low
China (Beijing), n=128	46.9%	50.8%	2.3%	0.0%	0.0%
Germany, n=133	9.0%	39.1%	39.1%	12.0%	0.8%
difference significant	yes, at 99.9% level (CN: 1.55, DE: 2.56)				

Source: Research and calculations by Fraunhofer ISI.

Table 4: Stated Relevance of External Knowledge Compared to Own R&D Efforts

	very high	high	medium	low	very low
China (Beijing), n=128	38.3%	52.3%	9.4%	0.0%	0.0%
Germany, n=133	8.3%	31.6%	46.6%	12.8%	0.8%
difference significant	yes, at 99.9% level (CN: 1.71, DE: 2.66)				

Source: Research and calculations by Fraunhofer ISI.

Hypothesis 2: *Fulfilling High-tech-Criteria while Stating Need for Improvement*

With regard to Hypothesis 2, Table 5 illustrates that more than two thirds of the surveyed firms in China employ more than 50% of staff with a higher education degree while the average in Germany remains in the area of 5-24%. Furthermore, Table 6 highlights that Chinese firms have a significantly higher tendency to employ staff as dedicated R&D personnel. In China, one half of the surveyed firms employs more than 25% of their personnel in this way while in Germany, the average firm assigns less than 10% of its workforce to full-time R&D related tasks. Accordingly, Chinese firms are found to mention technological lead and qualification of personnel significantly more often as factors that set them apart from competitors (Table 7) while the quality of products and services and their adaptation to customer requirements are issues considered to be of similar importance in both countries. On the contrary, most of the surveyed Chinese firms do not yet see their strength in more market-related qualities such as flexibility.

Finally, however, Table 8 highlights that the differences in the factors that motivate companies in China and Germany to seek technology transfers are in fact not very pronounced. While the above focus on a technology-related edge is mirrored in the finding that a focus on 'increasing the degree of novelty of products and services' as well as on 'increasing own R&D competences through learning' is somewhat more common than in Germany, these differences are not very significant. On the other

hand, there are indeed notable differences with a view to a focus on 'increasing the qualification of own personnel' – suggesting that the existing qualifications of the firms' many R&D employees (Table 5 and Table 6) are of limited value to the companies' actual business. Furthermore, a wish to 'improve marketing and advertisement strategies' suggests that these market-related competences are not available within the firms themselves.

Table 5: Share of Employees with Higher Education Degree

	1-4%	**5-24%**	**25-49%**	**above 50%**
China (Beijing), n=128	0.0%	14.1%	18.0%	68.0%
Germany, n=120	22.5%	54.2%	15.0%	8.3%
difference significant	yes, at 99.9% level (CN: 3.54, DE: 2.09)			

Source: Research and calculations by Fraunhofer ISI.

Table 6: Share of Employees Working Full-Time as Dedicated R&D Staff

	none	**below 10%**	**10-24%**	**25-49%**	**above 50%**
China (Beijing), n=127	0.8%	9.4%	33.9%	22.8%	33.1%
Germany, n=136	28.7%	38.2%	25.0%	5.1%	2.9%
difference significant	yes, at 99.9% level (CN: 3.78, DE: 2.15)				

Source: Research and calculations by Fraunhofer ISI.

Table 7: Main Competitive Edge as Stated by Company

	China (Beijing) (n=129)	Germany (n=136)	*significant difference*
Technological lead (ongoing R&D)	**89.1%**	47.8%	***
Degree of adaptation to customer requirements	54.3%	55.1%	-
Quality of company's products/services	49.6%	58.8%	-
Qualification of personnel	**43.4%**	15.4%	***
Degree of novelty of current products/services	40.3%	39.7%	-
Ability to respond in a flexible way to customer requirements	16.3%	**61.8%**	***
Spatial proximity to / close co-operation with customers	14.0%	8.8%	-
Branding, marketing and advertising	8.5%	4.4%	-
Low production cost	7.8%	4.4%	-

° (significant) at 90% level, * significant at 95% level, ** significant at 99% level, *** significant at 99, 9% level

Note: A maximum of three different types of competitive edge could be stated.

Source: Research and calculations by Fraunhofer ISI.

Table 8: Main Purpose of Seeking Technology Transfer as Stated by Company

	China (Beijing) (n=124)	Germany (n=126)	*significant difference*
Increase degree of novelty of products/services	75.8%	65.9%	°
Increase of own R&D competence through learning effects	75.0%	65.9%	-
Increase qualification of own personnel	**54.0%**	31.7%	***
Improve adaptation to customer requirements	51.6%	42.9%	-
Improve quality of existing products/services	39.5%	38.9%	-
Improve marketing and advertisement strategies	**29.8%**	13.5%	***
Increase ability to flexibly respond to customer requirements	20.2%	26.2%	-
Lower production cost	1.6%	**29.4%**	***

° (significant) at 90% level, * significant at 95% level, ** significant at 99% level, *** significant at 99, 9% level

Note: A maximum of three different types of competitive edge could be stated.

Source: Research and calculations by Fraunhofer ISI.

Hypothesis 3: *Low Absorptive Capacity, Limited Transfer Channels, Focus on Public Partners*

Concerning Hypothesis 3, Table 9 corroborates that it is significantly more common among the surveyed technology firms in China to obtain either prototypes or readily developed products from external sources than it is among innovating firms in Germany. On the other hand, this does not imply that a significantly lower number of them focus on obtaining patents or drawing information from relevant scientific publications. As it seems, many Chinese firms tend to add a complementary aspect to their activities rather than opting for a completely different profile.

In line with this, Table 10 illustrates that the patterns of technology transfer channels used by Chinese and German firms are in fact surprisingly similar. In both cases, the 'joint development of solutions in R&D co-operations', 'consultancy of internal developers', and the 'training of own personnel' are the three most commonly used approaches to obtaining external knowledge. Thus, we find those approaches based on personal contacts and collaboration dominant in both countries. If anything, R&D co-operations are slightly more common in China than in Germany. Nonetheless, Chinese firms do indeed display a higher propensity to license patents as well as they focus more often on the hiring of additional R&D staff and the outsourcing of R&D projects as channels of transfer.

What is correct, moreover, is that the surveyed Chinese technology firms are significantly more inclined to collaborate with public research organisations and universities than innovating firms in Germany. On the other hand, this does not seem to negatively affect their tendency to actively collaborate in R&D with customers, suppliers and consultants to a notable degree. In fact, the prevalence of R&D collaborations among competitors seems to be significantly higher among the surveyed firms in China than in Germany.

Table 9: Main Type of Knowledge Obtained

	China (Beijing) (n=125)	**Germany (n=131)**	***significant difference***
Basic scientific knowledge (Publications)	44.8%	49.6%	-
Basic technological knowledge (Patents)	68.8%	58.8%	°
Prototypes	**48.8%**	22.9%	***
Readily developed products	**59.2%**	26.0%	***

° (significant) at 90% level, * significant at 95% level, ** significant at 99% level, *** significant at 99, 9% level

Note: A maximum of three different types of competitive edge could be stated.

Source: Research and calculations by Fraunhofer ISI.

Table 10: Main Channels Used to Obtain External Knowledge, Main Partners

	China (Beijing) (n=128)	**Germany (n=131)**	***significant difference***
Joint development of solutions in R&D co-operations	76.6%	66.4%	°
Consultancy of internal developers by external experts	58.6%	43.5%	*
Training of own personnel with a view to R&D competences	49.2%	52.7%	-
Permanent hiring of new personnel with R&D capabilities	36.7%	30.5%	-
Temporary hiring of ext. personnel with R&D capabilities	**36.7%**	6.9%	***
Licensing of existing (invention) patents	**35.9%**	11.5%	***
Provision of results developed in the course of past projects	26.6%	27.5%	-
Outsourcing of R&D projects	**19.5%**	9.9%	*
Licensing of existing utility models	**9.4%**	0.0%	***
	(n=129)	(n=136)	
Public Research Organisations and Universities	**86.0%**	62.5%	***
Customers	59.7%	51.5%	-
Competitors	**45.7%**	15.4%	***
Suppliers	43.4%	54.4%	°
Consultants	27.9%	30.9%	-

° (significant) at 90% level, * significant at 95% level, ** significant at 99% level, *** significant at 99, 9% level

Note: A maximum of three different types of competitive edge could be stated.

Source: Research and calculations by Fraunhofer ISI.

Hypothesis 4: *Orientation of Knowledge Sourcing towards Domestic Source*

As for Hypothesis 4, Table 11 unsurprisingly confirms that a substantially higher share of the, on average, technologically more advanced firms in Germany sells on the global market, while a dominant share of the Chinese technology firms focuses their activities on the domestic market. This, however, is not necessarily reflected in their selection of R&D co-operation partners as the percentage of firms maintaining contacts with firms, universities or public research institutes abroad does not differ significantly from that of German firms. With a view to their choice of domestic partners, however, we indeed find a significantly higher propensity to collaborate with public research organisations or universities as well as a significantly lower prevalence of co-operations with business partners, even including competitors.

Table 11: Main Market Orientation and Main Orientation of Knowledge Sourcing

	China (Beijing) (n=129)	**Germany (n=136)**	***significant difference***
National Market	**92.2%**	44.1%	***
International Market (technologically leading economies)	12.4%	**75.7%**	***
International Market (developing and emerging economies)	13.2%	16.9%	-
Domestic Public Research/University Partner	**86.0%**	60.3%	***
International Public Research/University Partner	20.9%	12.5%	°
Domestic Business Partner (excl. consultants)	55.9%	**70.5%**	***
International Business Partner (excl. consultants)	46.3%	36.4%	-

° (significant) at 90% level, * significant at 95% level, ** significant at 99% level, *** significant at 99, 9% level

Note: A maximum of three different types of competitive edge could be stated.

Source: Research and calculations by Fraunhofer ISI.

Hypothesis 5: *Different Obstacles Resulting from Different Framework Conditions*

Hypothesis 5, finally, can surprisingly not be confirmed in the manner suggested. In fact, very few significant differences can be identified, even with regard to those issues that were covered with specific regard to the assumed Chinese situation such as 'organisational problems during the process of realisation', 'lack of sufficiently qualified personnel', 'inadequate legislation, regulations', and 'reservations regarding reliability of partners in the IPR-field'. Instead, the most notable difference identified by the surveys was that it was substantially more common among Chinese firms to perceive a 'lack of

internal sources of finance' and to consequently lament a 'lack of public support with a view to subsidy programmes'. Apparently, many of the surveyed technology firms in China are more worried about their ability to finance future R&D co-operations than about their own internal capabilities to absorb and process external knowledge and the external framework conditions that enable them to do so.

Table 12: Main Difficulties Encountered with a with to Knowledge Sourcing

	China (Beijing) (n=126)	**Germany (n=127)**	***significant difference***
Lack of public support with a view to subsidy programmes	**63.5%**	14.2%	***
Lack of internal sources of finance	**39.7%**	15.7%	***
Excessive cost (unfavourable cost-benefit analysis)	34.9%	37.8%	-
Organisational problems during the process of realisation	22.2%	28.3%	-
Lack of information on suitable co-operation partners	22.2%	20.5%	-
Inadequate legislation, regulations, administrative procedures	19.0%	12.6%	-
Lack of sufficiently qualified personnel	15.9%	23.6%	-
Reservations regarding reliability of partners in the IPR-field	15.9%	19.7%	-
Lack of suitable external sources of finance	11.1%	11.8%	-
Lack of suitable co-operation partners	11.1%	19.7%	°
Lack of interest on the side of potential co-operation partners	4.0%	4.7%	-
Internal resistance to/reservations against R&D-cooperation	1.6%	6.3%	°

° (significant) at 90% level, * significant at 95% level, ** significant at 99% level, *** significant at 99, 9% level

Note: A maximum of three different types of competitive edge could be stated.

Source: Research and calculations by Fraunhofer ISI.

Discussion

Evidently, most of our findings have been found to be in line with our general assumptions while some of our assumptions could be proved to be wrong. What has been confirmed for the surveyed sample in the Beijing area is the overall picture of a set of technologically-learning, domestically-oriented firms that are still less established in their potential markets than the average firm in a technologically well-developed nation. Undisputedly, some of them have reached international standards but the large majority rightly follows a different path – apparently due to lacking financial resources to change the prevailing business model of external sourcing and adaptation. Arguably, much of

the external knowledge still feeds into a routine of re-engineering and adaptation rather than inspiring a genuine process of new product development – which remains absent in many firms.

Likewise, we find evidence of a state-driven model of technological upgrading, documented by the high extent of fulfilling formal criteria and an apparent lack of ability or interest to shift the main business model by own initiative. Instead, many of the surveyed firms deplore their lack of internal resources to launch R&D activities and call for the government to provide these. Given that their typical relation/ratio of personnel to sales remains significantly lower than that common among economically well-established German firms, this appears to a degree conclusive. On the other hand, it reveals that R&D driven activities do not necessarily constitute the natural basis of all the surveyed firms' business model to the extent that they would be willing to prioritize investing into it – despite their prevalent claim that 'technological lead' constitutes their prime competitive advantage.

Interestingly, however, this combination of limited technological capacities as well as limited internal resources of various kinds seems to have added momentum to, rather than obstructed, the development of a dense network of R&D co-operation and technology transfer. Beyond certain Chinese particularities, most of the technology firms surveyed in Beijing are driven by quite similar motivations, use the same channels of transfer, and work with a comparable set-up of partners, as their German counterparts. In many cases, the findings do not reflect the originally expected “either/or” between a 'transformation economy model' and a 'developed economy model' but a mix of both. Apparently, both rely intensively on per-existing networks of personal contacts even if those may at times be of a quite different nature. While it is true that Chinese firms focus more strongly on embedded knowledge (prototypes/products) than firms in Germany, that is not to say that they focus less on licensing patents or considering publications, that they engage less in R&D co-operations, or that they are less interested in external consultancy or the training of their staff. While it is true that more Chinese than German firms focus on co-operations with public research organisations or universities, it does not in general terms imply that they collaborate less with their partners along the value chain. On the contrary, the assumption that Chinese firms collaborate less with their competitors could be directly refuted.

In general terms, the majority of the surveyed firms were implicitly very optimistic with regard to their ability, if necessary, to obtain relevant external knowledge. Contrary to commonly accepted wisdom, neither the institutional framework conditions nor the characteristics of their potential partners were seen as major obstacles. Instead, many

firms claimed that they had problems with establishing internal R&D capacities and did not consider technology transfer as such as an appropriate means to that end. Instead, they expressed a strong focus on funding.

If these findings are taken at face value they seem to question many of the established findings on a 'stalled' or at least heavy going process of technology transfer from Chinese universities to the surrounding enterprise sector. Before rushing to conclusions, however, the findings should be put into perspective from two different angles.

Firstly, we have to take into account which subsample of the overall population of enterprises has been surveyed. Evidently, we are talking about a sub-group of even those firms that have the advantage to operate on the 'Beijing island of innovation'. As outlined in the conceptual section, many of them are likely to have had long-standing interpersonal relations with many of their current R&D co-operation partners long before the challenge of launching more innovation-oriented projects had become an issue. Possibly, a number of them even are former public R&D institutes which have been privatised and turned into private R&D service providers in the late 1990s. Among many of those players, issues of mutual trust or distrust will have been resolved years ago – and help to circumvent many of the limitations related to framework conditions that may in general terms still be present. Hence, our findings do not suggest that the documented, well-functioning transfer network can easily be extended to any desirable number of additional firms. Potentially, entering the network may actually be quite difficult for newcomers from outside the established circle.

Secondly, it has to be acknowledged that while many firms stated that their situation with regard to networkedness and access to external knowledge was not bad, they still stated an internal level of technological competence that must appear dissatisfactory to many of them – and in any case to a Chinese government aiming at more 'indigenous innovation'. What we find lacking, therefore, is the combination of internal R&D capacity, relevant task-related qualification and good access to external knowledge that was found to be characteristic for German firms. As long as many of the Chinese firms have not launched substantial internal R&D activities, external knowledge will merely be fed into the well-established process of adapting existing products instead of inspiring genuinely novel, globally relevant developments. While most firms fulfil the government-set formal criteria for technology-orientation and even realise some sales, their efforts to employ additional personnel and to commission external consultancy suggest that much remains to be done. Hence, our findings do not refute the statement that the current system of technology transfer continues to display a fairly limited capability to

support industrial upgrading in China. What they suggest, in contrast, is that the degree of connectedness to external partners is not the main issue.

From an outsiders' perspective, therefore, it remains questionable whether the firms are right in stating that additional public funding would solve most of the problem. On the one hand, it may well be a necessary condition and a suitable priority request vis-à-vis policy makers. On the other hand, many firms appear financially viable in that they already sell products so that at least the notion that the funding for R&D efforts has to come from public sources should be critically considered. Lest all surveyed firms remain completely unprofitable it seems surprising that they should lack internal finance to the stated degree. If that really is the case, however, it would in more general terms question the viability – and sensibility – of technological upgrading in Beijing. In practice, however, we have found that many of the companies are making adjustments aimed at improving their internal capabilities by training personnel as much as by hiring new staff (both temporarily and permanently), by inviting external consultants as much as by joining in R&D co-operations. Possibly, some of the firms have thus not failed to indicate the issue of internal managerial or technological capability because they were not aware of the problem, but because they felt that it was already being dealt with successfully.

6 Summary and Conclusions

In summary, our study has highlighted that technology transfer systems in China may involve more channels, involve more partners, and in global terms be more dynamic than commonly assumed – at least in the case of well-developed urban innovation systems such as Beijing. With certainty, the times where spin-offs had to be set up for a lack of other options are over. Instead, our survey documents a vibrant set of interactions between not only science and industry but also up and down the value chain within industry itself. In terms of quantities, at least, this system does no longer appear inferior or very differently structured than those of technologically more advanced nations. Moreover, most of the surveyed companies could not find fault with many of the commonly assumed obstructions of knowledge exchange in China – such as lack of trust or unfavourable and poorly implemented regulations

Despite these surprising findings, however, other results of the survey still underline that most of the firms that the government registers as 'technology-enterprises', continue to predominantly sell on and develop for the domestic market. Despite an impressive share of R&D staff in their workforce, many of them still lack a well-established internal R&D process and are only starting to develop sufficient absorptive capacity to

become able to integrate more complex and abstract forms of external knowledge. In brief, technology transfer in China fails to achieve the complementary, inspiring function that it fulfils in many technologically more developed economies. Instead, it is used to substitute a lack of in-house developments and to feed the established process of re-engineering and adaptation. Arguably, this remains sufficient to realise sales on the domestic markets but at least the firms themselves claim that it does not generate sufficient internal funds to finally start off the needed internal R&D processes.

In conclusion, more has been achieved with regard to technology transfer in China than is commonly acknowledged, even though it is correct that the results remain less than convincing. Certainly, one has to remain sceptical with regard to the firms' own claim that money alone will solve much of the remaining problem of limited internal capacities. On the other hand, we find tentative evidence that a good number of them are silently working in parallel on the less monetary issues such as qualification and market orientation. Furthermore, the government is likely to eventually heed the call for additional funding to build internal capabilities.

Undoubtedly, many of China's 'technology companies' have a long way to go before they can develop the technological capacity needed to compete on the global markets – should they at all aim to do so. That notwithstanding, this article has collected tangible evidence that cautions against underestimating the inherent potential of science-industry relations in China. In fact, it would even today be more appropriate to speak of a potential to expand current practices rather than a dormant potential. In a few years' time, a quite substantial number of Chinese firms will be likely to have developed much stronger internal capacities while the interpersonal network of knowledge exchange will certainly be no weaker than today.

Acknowledgement

We acknowledge the contribution of the Beijing Research Center for Science of Science as part of the Beijing Academy of Science and Technology which has not only financed part of this research but also implemented the empirical study in China. In particular, we acknowledge the support of Director Zhang Shiyun and the contributions of Ms Chang Jing who had a substantial part in compiling the Chinese dataset. Furthermore, we thank an anonymous internal reviewer for critical yet constructive comments on a first draft of this paper.

7 References

Altenburg, T./Schmitz, H./Stamm, A. (2008): Breakthrough? China's and India's Transition from Production to Innovation, *World Development,* 36, 325-344.

Asian Development Bank (ADB) (2010): *Asia 2050: Realizing the Asian Century*. Metro Manila: Asian Development Bank (ADB).

Bozeman, B. (2000): Technology transfer and public policy: a review of research and theory, *Research Policy,* 29, 627-655.

Brehm, S./Lundin, N. (2012): University-industry linkages and absorptive capacity: An empirical analysis of China's manufacturing industry, *Economics of Innovation and New Technology,* 21, 837-852.

Cao, C./Suttmeier, R.P./Simon, D.F. (2006): China's 15-year science and technology plan, *Physics Today,* 54, 38.

Cao, C. (2004): Zhongguancun and China's High-Tech Parks in Transition: "Growing Pains" or "Premature Senility"?, *Asian Survey,* 44, 647-668.

Chen, K./Kenney, M. (2007): Universities/Research Institutes and Regional Innovation Systems: The Cases of Beijing and Shenzhen, *World Development,* 35, 1056-1074.

Chen, Y.-C. (2007): The Upgrading of Multinational Regional Innovation Networks in China, *Asia Pacific Business Review,* 13, 373-403.

D'Este, P./Patel, P. (2007): University-industry linkages in the UK: What are the factors underlying the variety of interactions with industry?, *Research Policy,* 36, 1295-1313.

Dosi, G. (1988): The nature of the innovation process. In: Dosi, G./Freeman, C./Nelson, R./Silverberg, G./Soete, L. (eds.): *Technical change and economic theory*. London: Pinter, 221-238.

Ernst, D./Kim, L. (2002): Global production networks, knowledge diffusion, and local capability formation, *Research Policy,* 31, 1417-1429.

Eun, J.-H./Lee, K. (2010): An empirical inquiry into 'academy-run enterprises' in China: Unique characteristics and evolutionary changes, *International Journal of Innovation Management,* 14, 123-150.

Eun, J.-H./Lee, K./Wu, G. (2006): Explaining the 'University-run enterprises' in China: A theoretical framework for university-industry relationship in developing countries and its application to China, *Research Policy,* 35, 1329-1346.

Frietsch, R./Hinze, S./Tang, L. (2008): *Bibliometric data study: Assessing the current ranking of the People's Republic of China in a set of research fields* (= Discussion Papers Innovation System and Policy Analysis No. 15). Karlsruhe: Fraunhofer ISI.

Frietsch, R./Schüller, M. (2010): *Competing for Global Innovation Leadership: Innovation Systems and Policies in the USA, Europe and Asia*. Stuttgart: Fraunhofer Verlag.

Fu, W./Schiller, D./Revilla Diez, J. (2012): Strategies of using social proximity and organizational proximity in product innovation: empirical insight from the Pearl River Delta, China, *Zeitschrift für Wirtschaftsgeographie,* 56, 80-96.

Gu, S. (1999): *Implications of National Innovation Systems for Developing Countries: Managing Change and Complexity in Economic Development* (= UNU/INTECH Discussion Paper 9903). Maastricht: UNU/INTECH.

Guan, J./Chen, K. (2010): Measuring the innovation production process: A cross-region empirical study of China's high-tech innovations, *Technovation,* 30, 348-358.

Guan, J.C./Yam, R.C.M./Mok, C.K. (2005): Collaboration between industry and research institutes/universities on industrial innovation in Beijing, China, *Technology Analysis and Strategic Management,* 17, 339-353.

Intarakumnerd, P./Chairatana, P./Tangchitpiboon, T. (2002): National innovation system in less successful developing countries: The case of Thailand, *Research Policy,* 31, 1445-1457.

Jin, F./Lee, K./Kim, Y.-K. (2008): Changing engines of growth in China: From exports, FDI and marketization to innovation and exports, *China and World Economy,* 16, 31-49.

Kodama, F./Branscomb, L.M. (1999): University research as an engine for growth: how realistic is the vision? In: Branscomb, L.M./Kodama, F./Florida, R. (eds.): *Industrializing Knowledge: University-Industry Linkages in Japan and the United States*. London: MIT Press, 3-19.

Kogut, B. (2004): From Regions and Firms to Multinational Highways: Knowledge and Its Diffusion as a Factor in the Globalization of Industries. In: Kenney, M./Florida, R. (eds.): *Locating Global Advantage: Industry Dynamics in a Globalizing Economy*. Stanford: Stanford University Press, 261-284.

Kondo, M. (2003): The Chinese Model to Create High-Tech Start-Ups from Universities and Research Institutes. In: von Zedtwitz, M./Haour, G./Khalil, T.M./Lefebvre, L.A. (eds.): *Management of Technology: Growth through Business Innovation and Entrepreneurship - The Tenth International Conference on Management of Technology*. Oxford: Pergamon.

Kroll, H. (2011): Exploring the validity of patent applications as an indicator of Chinese competitiveness and market structure, *World Patent Information,* 33, 23-33.

Kroll, H./Liefner, I. (2008): Spin-off enterprises as a means of technology commercialisation in a transforming economy – Evidence from three universities in China, *Technovation,* 28, 298-313.

Kroll, H./Schiller, D. (2010): Establishing an interface between public sector applied research and the Chinese enterprise sector: Preparing for 2020, *Technovation,* 30, 117-129.

Kroll, H./Schiller, D. (2012): Upgrading strategies of electronics firms within the Regional Innovation System of the Pearl River Delta, illustrated by the example of two Hong Kong Firms. In: Petti, C. (ed.): *Technological Entrepreneurship in China*. Cheltenham: Edward Elgar, 41-65.

Kroll, H./Tagscherer, U. (2009): *Chinese Regional Innovation Systems in Times of Crisis – The Case of Guangdong* (= Fraunhofer ISI Discussion Papers Innovation Systems and Policy Analysis No. 19). Karlsruhe: Fraunhofer ISI.

Lee, K. (2005): Making a Technological Catch-up: Barriers and opportunities, *Asian Journal of Technology Innovation,* 13, 97-131.

Lee, K./Jee, M./Eun, J.-H. (2011): Assessing China's Economic Catch-Up at the Firm Level and Beyond: Washington Consensus, East Asian Consensus and the Beijing Model, *Industry and Innovation,* 18, 487-507.

Liefner, I./Schiller, D. (2008): Academic capabilities in developing countries – a conceptual framework with empirical illustration from Thailand, *Research Policy,* 37, 276-293.

Liu, F./Zheng, G. (2011): Open innovation in Chinese high-tech enterprises: An empirical research based on Zhejiang province, art. no. 6118195, 1643-1647. Singapore: IEEE International Conference on Industrial Engineering and Engineering Management.

Liu, F.C./Simon, D.F./Sun, Y.T./Cao, C. (2011): China's innovation policies: Evolution, institutional structure, and trajectory, *Research Policy,* 40, 914-931.

Motohashi, K. (2008): Assessment of technological capability in science industry linkage in China by patent database, *World Patent Information,* 30, 225-232.

Motohashi, K./Yun, X. (2007): China's innovation system reform and growing industry and science linkages, *Research Policy,* 36, 1251-1260.

Nelson, R. (2008): Economic Development from the Perspective of Evolutionary Economic Theory, *Oxford Development Studies,* 36, 9-21.

OECD (ed.) (2008): *Reviews of innovation policy: China* OECD Publ., Paris.

Quan, X. (2010): Knowledge diffusion from MNC R&D labs in developing countries: evidence from interaction between MNC R&D labs and local universities in Beijing, *International Journal of Technology Management,* 51, 364-386.

Revilla Diez, J./Berger, M. (2005): The role of multinational corporations in metropolitan innovation systems. Empirical evidence from Europe and Southeast Asia, *Environment and Planning A,* 37, 1813-1836.

Schiller, D. (2011): The Role of Foreign and Domestic Firms in Regional Innovation Systems of Latecomer Countries: Empirical Evidence From the Electronics Industry in the Pearl River Delta, *Erdkunde,* 65, 23-40.

Schiller, D./Kroll, H. (2013): The global economic crisis as leverage for emerging regional growth paths? Differentiated evidence from China – three years onwards. In: Eriksson, S. (ed.): *Clusters and Economic Growth in Asia*. Cheltenham: Edward Elgar.

Schmoch, U. (2000): Konzepte des Technologietransfers. In: Schmoch, U./Licht, G./Reinhard, M. (eds.): *Wissens- und Technologietransfer in Deutschland*. Stuttgart: Fraunhofer IRB Verlag, 3-13.

Segal, A. (2003): *Digital Dragon. High-Technology Enterprises in China*. Ithaca, London: Cornell University Press.

Tagscherer, U./Kroll, H./Luo, X. (2012): Regional Innovation Systems in China - An Analysis of Industry-Science Linkages in Bohai Bay Area. In: Petti, C. (ed.): *Technological Entrepreneurship in China*. Cheltenham: Edward Elgar, 16-40.

Uyarra, E. (2010): Conceptualizing the Regional Roles of Universities, Implications and Contradictions, *European Planning Studies,* 18, 1227-1246.

Wang, Y./Zhou, Z. (2013): The dual role of local sites in assisting firms with developing technological capabilities: Evidence from China, *International Business Review,* 22, 63-76.

Wu, W./Zhou, Y. (2012): The Third Mission Stalled? Universities in China's Technological Progress, *The Journal of Technology Transfer,* 37, 812-827.

Wu, W. (2010a): Higher Education Innovation in China. Washington D.C.: The World Bank, East Asia and Pacific Region Human Development Department. Online: http://siteresources.worldbank.org/INTEASTASIAPACIFIC/Resources/China-HigherEducationInnovation.pdf (accessed: 23.01.2013a).

Wu, W. (2010b): Managing and Incentivizing Research Commercialization in Chinese Universities, *The Journal of Technology Transfer,* 35, 203-224.

Yang, R./Welch, A. (2012): A world-class university in China? The case of Tsinghua, *Higher education,* 63, 645-666.

Zhang, R./Sun, K./Delgado, M.S./Kumbhakar, S.C. (2012): Productivity in China's high technology industry: Regional heterogeneity and R & D, *Technological Forecasting and Social Change,* 79, 127-141.

Zhao, J./Richards, J. (2012): Beijing innovation system: The perspective of organisational structure and spatial distribution, *International Journal of Learning and Intellectual Capital,* 9, 413-428.

Zhu, Z./Chen, J. (2006): Open Innovation and Technological Learning in China, 10.1109/IEMC.2006.4279914, 483-487. Salvador, Bahia, Brazil: Engineering Management Conference, 2006 IEEE International, 483-487.

The series "Working Papers Firms and Region" presents research work of the Competence Center "Policy and Regions" of Fraunhofer Institute for Systems and Innovation Research ISI, Karlsruhe, Germany.

No.	Authors	Title
R2/2013	Henning Kroll	Patterns of Technology Transfer in Chinese Hotspots of Innovative Development – The Perspective of the Recipient Firms
R1/2013	Esther Schricke	Occurrence of cluster structures in knowledge-intensive services
R6/2012	Friedrich Dornbusch, Henning Kroll, Esther Schricke	Multiple Dimensions of Regionally-Oriented University Involvement – How Motivation and Opportunity Prompt German Researchers to Engage in Different Ways
R5/2012	Natalia Irena Gust-Bardon	Regional Development in the Context of an Innovation Process
R4/2012	Natalia Irena Gust-Bardon	The Role of Geographical Proximity in Innovation: Do Regional and Local Levels Really Matter?
R3/2012	Thomas Stahlecker Henning Kroll	The cluster concept as a multi-dimensional thematic field: Methodological and substantive perspectives
R2/2012	Henning Kroll Esther Schricke Thomas Stahlecker	Developing new roles for higher education institutions in structurally-fragmented regional innovation systems
R1/2012	Knut Koschatzky	Cluster quo vadis? The future of the cluster concept

No.	Authors	Title
R3/2011	Knut Koschatzky Miriam Hufnagl Henning Kroll Stephanie Daimer Nicole Schulze	Relevanz regionaler Aktivitäten für Hochschulen und das Wissenschaftssystem
R2/2011	Joachim Hemer	A Snapshot on Crowdfunding
R1/2011	Emmanuel Muller Jean-Alain Héraud Nina Menz Mickael Benaim Andrea Zenker	La mesure de l'impact des clusters – quelques éléments de réflexion et de bibliographie
R2/2010	Knut Koschatzky Thomas Stahlecker	The changing role of universities in the German research system: engagement in regional networks, clusters and beyond
R1/2010	Thomas Stahlecker Knut Koschatzky	Cohesion policy in the light of place-based innovation support: New approaches in multi-actors, decentralised regional settings with bottom-up strategies?
R8/2009	Martin Fischer Björn Wolf	Entstehungsbedingungen und Gestaltungsformen von Public-Private-Partnerships als Ausgestaltungsform strategischer Forschungskooperationen zwischen Wissenschaftseinrichtungen und Unternehmen in Deutschland
R7/2009	Emmanuel Muller Andrea Zenker Jean-Alain Héraud	Entering the KIBS' black box: There must be an angel! (or is there something like a knowledge angel?)
R6/2009	Knut Koschatzky	The uncertainty in regional innovation policy: some rationales and tools for learning in policy making
R5/2009	Bärbel Hüsing Thomas Stahlecker	Impact of regionalised RTDI policy measures in Germany: The "Network RNA Technologies Berlin (RiNA)" as an example

No.	Authors	Title
R4/2009	Knut Koschatzky Elisabeth Baier Henning Kroll Thomas Stahlecker	The spatial multidimensionality of sectoral innovation – the case of information and communication technologies
R3/2009	Knut Koschatzky Thomas Stahlecker	Cohesion policy at the interface between regional development and the promotion of innovation
R2/2009	Henning Kroll	Spillovers and Proximity in Perspective A Network Approach to Improving the Operationalisation of Proximity
R1/2009	Henning Kroll	The Regional Development of Science and Innovation in China – A Brief Review of Current Evidence on Matches and Mismatches –
R3/2008	Arlette Jappe-Heinze Elisabeth Baier Henning Kroll	Clusterpolitik: Kriterien für die Evaluation von regionalen Clusterinitiativen
R2/2008	Arlette Jappe-Heinze Knut Koschatzky	The spatial embeddedness of multinational enterprises' research activity A bibliometric analysis
R1/2008	David Doloreux Andrea Zenker Emmanuel Muller	Services à forte intensité de connaissances, contexte régional et comportements d'innovation: une comparaison internationale
U1/2007	Emmanuel Muller David Doloreux	The key dimensions of knowledge-intensive business services (KIBS) analysis: a decade of evolution
R1/2007	Knut Koschatzky Vivien Lo	Methodological framework for cluster analyses
U2/2006	Björn Wolf	Das Finanzierungsumfeld junger Unternehmen in Deutschland

No.	Authors	Title
U1/2006	Björn Wolf	Empirische Untersuchung zu den Einflussfaktoren der Finanzierungsprobleme junger Unternehmen in Deutschland und deren Auswirkungen auf die Wirtschaftpolitik
R1/2006	Emmanuel Muller Arlette Jappe Jean-Alain Héraud Andrea Zenker	A regional typology of innovation capacities in New Member States & Candidate Countries
U1/2005	Björn Wolf Birgit Ossenkopf	Kapitalschonende Entwicklungswege – Ansätze zur Lösung der Finanzierungsprobleme junger innovativer Unternehmen
R2/2004	Thomas Stahlecker Knut Koschatzky	On the significance of geographical proximity for the structure and development of newly founded knowledge-intensive business service firms
R1/2004	Thomas Stahlecker Andreas Koch	On the Significance of Economic Structure and Regional Innovation Systems for the Foundation of Knowledge-Intensive Business Services A Comparative Study in Bremen, Munich, and Stuttgart, Germany
R1/2003	Bodo Kubartz	Wirtschaftliche, soziale und geographische Aspekte in Innovationsnetzwerken – Eine Untersuchung des Nähekonzeptes am Beispiel von Forschungs- und Entwicklungsdienstleistern
R2/2002	Knut Koschatzky	Innovationsorientierte Regionalentwicklungsstrategien: Konzepte zur regionalen Technik- und Innovationsförderung
R1/2002	Ralph W. Bruns Jens Görisch	Unternehmensgründungen aus Hochschulen im regionalen Kontext – Gründungsneigung und Mobilitätsbereitschaft von Studierenden

No.	Authors	Title
U1/2001	Rana Adib Frank Gagelmann Knut Koschatzky Klaus Preiser Günter Hans Walter	An Integrated Microfinancing Concept for Rural Electrification by Photovoltaics in Developing Countries
R3/2001	Knut Koschatzky	The role of higher education institutions for entrepreneurship stimulation in regional innovation systems – Evidence from the network-oriented "EXIST: Promotion of university-based start-ups" programme in Germany
R2/2001	Emmanuel Muller Andrea Zenker	Business services as actors of knowledge transformation and diffusion: some empirical findings on the role of KIBS in regional and national innovation systems
R1/2001	Knut Koschatzky Casper Merkle Martin Berger Volker Meyer	Innovation und Kooperation bei unternehmensnahen Dienstleistern in Baden, Gironde und Südholland – Ein Vergleich zwischen jungen und alten Betrieben
R2/2000	Ulrike Broß Günter H. Walter	Socio-economic Analysis of North Rhine-Westphalia Joint Research Project INCO-COPERNICUS
R1/2000	Knut Koschatzky	The regionalisation of innovation policy in Germany – Theoretical foundations and recent experience
R4/1999	Knut Koschatzky Ulrike Broß	Struktur und Dynamik von regionalen Innovationsnetzwerken unter Transformationsbedingungen – das Beispiel Slowenien
R3/1999	Emmanuel Muller	There is no territorial fatality! (or how innovation interactions between KIBS and SMEs may modify the development patterns of peripheral regions)

No.	Authors	Title
R2/1999	Knut Koschatzky Andrea Zenker	The Regional Embeddedness of Small Manufacturing and Service Firms: Regional Networking as Knowledge Source for Innovation?
R1/1999	Ulrike Broß Knut Koschatzky Peter Stanovnik	Development and Innovation Potential in the Slovene Manufacturing Industry First analysis of an industrial innovation survey

Address to order (print version):
Fraunhofer Institute for Systems
and Innovation Research ISI
Library
Breslauer Strasse 48
76139 Karlsruhe
Germany
Phone +49 / 721 / 6809-217 / -219
Fax: +49 / 721 / 689152
E-Mail: bibl@isi.fraunhofer.de