Intra- and Inter-national University-Industry Linkage and Innovation in Emerging Economies: Evidence from China

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Abstract

While much prior research has focused upon the role of universities-industry linkage in promotion of industrial innovation, there is little research taking into account the different demand and motivation for university-industry linkage and different capabilities in the industrial and university sectors in emerging economies and distinguishing the different effects of intra- and inter-national university-industry collaboration. To the best of our knowledge, no empirical study based on large survey data exists to date. In this paper we attempt to investigate the different role of intra- and inter-national university-industry collaboration in industrial innovation in emerging economies. Based on a national firm-level survey database from China, it finds that collaboration with domestic universities have played a significant role in the promotion of the diffusion of advanced technology and the creation of new to the country or firm innovation outcomes in China. In contrast to the traditional view that collaboration with universities will lead to greater novel innovation, the contribution of domestic universities to the creation of ground-breaking innovations is limited in China at the catching-up stage of industrialisation. International innovation collaboration with foreign universities, especially those in the Newly Industrialised Economies and the emerging South, appears to be fruitful in enhancing in the creation of ground-breaking innovations in Chinese firms.

Key words: Innovation, Universities, Collaboration, China

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I. Introduction

As an important player in national and regional innovation systems, universities have received increasing attention with respect to their role in innovation, competitiveness and wider social and economic development. Universities are widely regarded as a major contributor to advances in basic scientific research and the creation of innovation of great novelty. Moreover, recent research also suggests that the role of universities is multi-faceted, covering educating, knowledge creation in the form of scholarly publications and patents, problem-solving activities and public space provision (Hughes, 2010). However, most of the received wisdom on the role of universities is based on experiences and evidence from the developed countries. The role of universities in innovation in developing countries, especially the middle-income emerging economies, has received much less attention. Do the universities in emerging economies mainly contribute to basic, cutting-edge research that result in ground-breaking new technology? To what extent are the universities relevant in the diffusion and assimilation of imported frontier technology? Is there any difference between collaborating with domestic and foreign universities? These are important gaps in the literature awaiting for investigation.

This research attempts to examine the role of intra- and inter-national university-industry collaboration in industrial innovations in the emerging economies using firm-level data from China. China provides a good case for this research because of several reasons. First, China is one of the major emerging economies in the world. Second, the industrial and university sectors in China have made impressive progress in innovation since the reforms. In 2010, the total R&D expenditure in China ranked third in the world. Moreover, since 2000, China has experienced a rapid surge in patent applications. The number of patent applications from Chinese researchers to the authorities of the socalled Triadic Patent Families[1] has increased more than seven times over the period from 2000 to 2007 (Fu and Soete, 2010). Thirdly, the Chinese government has made great efforts to encourage university-based research and technology transfer (Wu, 2007; OECD, 2008). All this makes China a good case for the research on the role of universities in industrial innovation in emerging economies.

This research contributes to our understanding of university-industry linkage and innovation in emerging economies in three ways. First, it takes into account the different demand and motivation for university-industry linkage and different capabilities in the industrial and university sectors at different development stage, and examines the role of universities in industrial innovation in the middle-income emerging economies. It finds that in contrast to the traditional view that collaboration with universities will lead to greater novel innovation, the contribution of domestic universities to the creation of ground-breaking innovations is limited in China at the taking-off stage of industrialisation. Second, most of the research on university-industry collaboration focuses on the collaboration between domestic firms and universities or has not distinguished collaboration with foreign and domestic universities. In the globalisation era, firms are increasingly open and internationalised in their R&D activity. It is hence important to understand the effect of such international university-industry collaboration. Finally, it is first study on the role of universities in emerging economies based on large national firm-level innovation survey data. To our knowledge, most of the existing research in this area in the context of emerging and developing countries are based on case study evidence. Findings from the current study should provide useful complementary insights to enhance our understanding of this issue.

The remainder of the paper is organised as follows. Section II discusses the literature and the thoeretical framework. Section III presents a brief background on university-industry linkage in

[1] These are patents applied for/granted in the US, Europe and Japan.

China. Section IV discusses the methodology and data. Section V presents the results. Section VI concludes.

II. The literature and theoretical framework

University-industry linkage and industrial innovation

The literature on national innovation system has highlighted the role of universities in the innovation systems, not only in training and education, but also as an active player in knowledge creation and transfer (Nelson, 1986; Porter and Stern, 1999; OECD, 2008; Fu and Yang, 2009). Universities are also crucial players in the regional innovation system and affect regional innovation capacities to a great extent (Braczyk et al, 1998; Cooke, 2001). Universities may contribute to an economy in a multi-faceted manner through education, knowledge creation in the form of scholarly publications and patents, problem-solving activities and public space provision (Kitson et al., 2009; Hughes, 2010). They disseminate knowledge to the real economy by producing quality students and by interacting with firms through a number of channels such as consulting, licensing, and co-operative research programs (Eom and Lee, 2010). In the era of the knowledge economy, the importance of universities in contributing to economic growth has become an increasing focus of research (Etzkowitz and Leydesdorff, 2000; Sainsbury, 2007). Fast-paced global competition and technological change also link firms to universities not only through the discovery of knowledge but also by aiding industrialisation (Etzkowitz and Leydesdorff, 1997; Hwang et al., 2003). On the other hand, Dasgupta and David (1994) state that 'too' close a relationship between science and industry and short-run policies which move resources into commercial applications of scientific knowledge would jeopardise scientific advancement over the long run. Based on the experience of university-industry linkages in East Asia, Eun et al. (2006) suggested a "contingent or context-specific" perspective on industry-university relationships and suggest that the question as to whether a university should take part in the function of an industry should be answered by considering the internal resources of the university, the absorptive capacity of the industries, and existence of intermediate institutions.

The emergence of open innovation as a new mode of innovation suggests that universities may play an increasingly significant role in industrial innovation (Chesbrough, 2003). Technological convergence, declining transaction costs of acquiring external R&D inputs and the shortening of product development cycle times have accelerated the trend of utilising external sources of knowledge (Grandstrand et al., 1992). Collaboration with various partners, both public and private, are important sources of knowledge that directly strengthen firms' technological competences and may thus increase their capacity to innovate (Freeman and Soete, 1997; Kitson, et al., 2001). Collaboration among organisations facilities the attainment of complementary assets related to innovative labour and allows firms to achieve the goals they cannot pursue alone (Mowery, et al., 1996; Powell and Grodal, 2005). Moreover, collaborations in innovation are found to be complementary to in-house R&D and facilitate inter-organisational, or inter-national, knowledge transfer. Collaboration with customers, suppliers, higher education institutions, even competitors, allows firms to expand their range of expertise, develop specialist products, and achieve various other corporate objectives (Porter and Stern, 1999). With sector and size variations, networking is found to be positively associated with innovation (Goes and Park, 1997; Tsai, 2001). Firms embedded in benefit-rich networks are likely to have greater innovative performance (Powell et al., 1996). By sharing complementary knowledge and skills, firms can break through the bottleneck that constrains their innovation activities and enable the innovation creation process to be more efficient (Fu, 2011). Global engagement in UK firms' innovation is also found to be associated with a higher propensity to innovate (Criscuolo et al., 2005). Yet, as argued by Laursen and Salter (2006), the benefits from openness to external knowledge are subject to decreasing returns as ‘over-searching’ and working with too many partners will have negative consequences for innovation.

Given the widely recognised role of universities in the national innovation system, university-firm collaboration is argued to be crucial for the promotion of technological change (Mansfield and Lee, 1996). A growing number of the developed and developing countries are seeking to use universities as an important driver of knowledge-based economic development and change (Mowery and Sampat, 2005). Through interaction with the science base, firms are able to access a diversified range of knowledge sources in comparison to intra-firm collaboration (Kaufmann and Todtling, 2001), especially those tacit and uncodified knowledge (Yusuf, 2008). University participation in research programmes is also found to have a positive impact on firm patenting and the completion of existing projects in the industrial sector (Cohen et al., 2002; Darby et al., 2003). In sum, contracting out research, entering into university-industry alliances and collaborating with university researchers formally or informally can confer substantial advantage.

Motivations of collaboration and innovation outcomes

However, firms collaborate with universities for different reasons – from paradigm shifting to technical problem-solving – and they do so even in the same country or same university. Universities also interact with firms for diverse reasons and in diverse ways (Walsh and Perkmann, 2008). Therefore, the interaction between firms and universities is heterogenous and include a wide array of activities: joint research, advisory work and contracts, technology commercialization, student placements, among others (Gulbrandsen, Mowery and Feldman, 2011). Each of this wide array of interactions offers different opportunities to generate or disseminate knowledge. The nature of the interactions to a great extent determines their impact on the type of innovation that these interactions will nurture. For example, if university-industry collaboration aims at helping the firm to solve a problem encountered in production or assimilation and adaptation of transferred foreign technology, it would contribute to the diffusion of new to the country or firm innovations but not the creation of ground-breaking innovations. Therefore, the outcomes of the university-industry interaction are diverse and the relationships may be non-linear and contingent (Gulbrandsen et al., 2011).

Capabilities of collaborators and innovation outcome

Moreover, universities are of different type. Some are research oriented and some are teaching and training oriented. Some are capable to produce high quality ground-breaking research and some have strength and enthusiasm in applied research or problem-solving type research activities. At the same time, universities may struggle in terms of reconciling the creation of new knowledge regardless of its commercial value and their role as promoters of technological development (Mowery and Sampat, 2005). Since innovation is path-dependent and skills of researchers are the most important determinant of innovation, with no doubt, the research capabilities of universities will have direct effect on the novelty of the innovation produced from university-industry collaboration.

Motivations, capabilities and impact of intra- and inter-national university-industry collaboration in emerging economies

The stage of development of an economy will influence the motivations of its firms to collaborate with universities and the research capabilities of its universities. As a result, the behavior and innovation impact of university-industry collaboration in emerging economies will be different from the received wisdom which is based on research from developed economies.

First, in the middle-income emerging economies, given the level of economic and technolocial development of these economies, universities are likely to engage more in the diffusion of frontier technology than the creation of such technology. First, ground-breaking innovations are costly and risky. This provides a rationale for developing countries to use foreign technology acquisition as a major source of technological development. Foreign sources of technology account for a large part of productivity growth in most countries. In fact, most innovation activities are largely concentrated in a few developed countries. International technology diffusion will therefore be an important driver in economic growth. Hence, in the emerging economies, since they are at an intermediate stage of development, the assimilation of foreign technology has been a major source of technology upgrading. In China, for example, until 2009, most of the R&D expenditure are spent on development instead of basic and applied research. According to the Second National R&D Resources Survey, about 83% of gross R&D expenditure and 99% of total industrial R&D expenditure in China was spent on development in 2009 (NBS, 2010). As a result, innovations new to the country and firm will be the major type of innovation in these economies.

Moreover, most of the firms in these economies are lacking in absorptive capacity (Eun, et al., 2006). Owing to this constraint in the local industry, there is a need to tap into the expertise of science and engineering experts in the universities to help with the assimilation and adaptation of foreign technology. Collaboration with universities will help to accelerate the adoption of foreign technology. This need of technical assistance in the economy will influence the type of industrial and technology policy the government will adopt to promote economic growth. In other words, government policies will respond to the needs and pull or even push the domestic universities to prioritize the problem-solving tasks raised by the industry. As a result, while research universities are simultaneously centres of learning, the foci of basic and applied research and the source of entrepreneurship in the US, in Asian countries such as China, Korea and Singapore, universities have been geared towards training and only recently began to pay more attention to research, being prompted by government incentives (Hershberg et al, 2007). The Chinese government has been advocating from the start a use-driven science policy, requiring universities to serve the national economy by solving practical problems for industry (Hong, 2006). Universities were encouraged to collaborate closely with industry, for example, in solving production problems for factories (Ministry of Education, 1999; Yuan, 2002).

Second, the extent of development of an economy is often in line with the level of research capabilities of its universities and hence the type of innovation they are to create. The middle-income emerging economies have a higher education sector which is capable to collaborate with the industrial sector to assimilate the transferred foreign technology and make the adaptations necessary for the foreign technology to fit within the local technical, economic and social context. Some of the industry-university alliances are not only capable of shallow assimilation (which facilitates the normal operation of the imported equipments in recipient firms) but also deep assimilation of foreign technology through reverse engineering and R&D to make modifications to the transferred foreign technology. This may lead to the transition from imitation to innovation and the creation of innovations which are ground-breaking at the world level. Moreover, knowledge transfer from universities, which is often embodied in codified forms (e.g., publications, patents, contract R&D projects) and which also often contains tacit knowledge (e.g., collaborative research, informal consultation) becomes in this way an important asset in creating learning organisations.

However, there is a gap in research quality and impact between the universities in the emerging economies and those of the major developed economies. In the case of China, China’s share in science and engineering articles has risen since the mid-1990s, from 9,000 to 119,500 in 2009, accounting for 8.3 per cent of the global research output in that year and was only lower than that of the US. However, the quality of these papers as measured by number of citations per paper was on 5.87 in 2010, which was substantially lower than the world average at 10.57 (CSTII, 2010). The average number of citations per paper published by authors from the US, Netherland and the UK are about three times higher than that by Chinese authors. Other major OECD countries such as Germany, Canada, France, Australia, Italy, Spain and Japan are also much better in this aspect. The average quality of papers published by authors from China is, in general, on a par with that from other emerging economies such as India and Russia (Appendix 1). This gap in quality in published papers between authors from China and world average exist in almost all subject areas although it is small in engineering technology and maths, and substantial in various life science disciplines (CSTII, 2010). The above discussions have led to the following propositions:

H1: In emerging economies, innovation collaboration with universities will help domestic firms to decipher and adapt transferred foreign technology, and facilitate the diffusion of innovations which are new to the country or firm.

H2: The contribution of domestic universities to the diffusion of innovation is likely to be greater than that to the creation of ground-breaking novel innovations in emerging economies.

In an open economy, firms can not only choose various domestic universities but also foreign universities for innovation collaboration. Given the differences in research capabilities between domestic universities and those more innovative foreign universities, firms in emerging economies may also collaborate with foreign universities depending on objectives of the mission (eg., cutting edge, ground-breaking new product or adaptation of imported technology), the research capability of the universities, the communication and financial capabilities of the firm, the cost of the collaboration, as well as the language and culture and geographic distance. In return, the differences in research capabilities and other aspects between domestic and foreign universities will affect the outcome of the collaboration such as the novelty of the innovations. Moreover, communication is crucial for knowledge exchange and integration. Culture and geographic distance between collaborators are likely to hinder frequent and effective communication within collaborative teams. Therefore,

H3: Innovation collaboration between local firms in emerging economies and foreign universities is likely to be associated with innovations of greater novelty.

H4: The innovation effect of innovation collaboration between firms in emerging economies and foreign universities is likely to be greater when the culture and geographic distance between the collaborators is smaller.

III. Universities and industrial innovation in China

Transiting from a centrally-planned to a market economy, universities in China have historically played an important role in its national innovation system, similar to the case of the science and technology system in the former Soviet Union (Liu and White, 2001). In terms of R&D expenditure and patents of inventions, universities and research institutes played a leading role in China (Li, 2009). Reforms started in 1985 rendered the science and innovation system more relevant to the market and signalled a departure from the Soviet model where scientific research and production were completely separated (Xue, 1997; OECD, 2008).

The mid-1980s witnessed several reforms in science policy in China. The most significant change was the cut of government research funding in order to push research organisations into the market (Hong, 2008). From 1986 to 1993, government research funding decreased at an annual rate of 5% (Zhou et al., 2003). Hence universities began to establish their own enterprises at that time, a practice officially approved by the central government in 1991. Another wave of reform of Chinese universities began in December 1994 when a national reform encouraged institutional mergers and decentralization. This reform has had the implication of promoting collaborations between universities and local industries (Hong, 2008). In 1996, the Chinese government set ‘pushing research institutions to be oriented to economic development’ as one of its major tasks in the ninth five-year plan. In 1998, as one of its main policy tools to accelerate technological innovation and the development of high-technology industry, the State Council introduced the ‘985 Program’ which had significant impact on the key research universities in China. In addition, the government announced the Regulation on Higher Education Institution IPR Management, which introduced a Chinese version of the Bayh-Dole Act allowing universities to retain titles to inventions derived from government funding in 1999. This act promoted commercialization of innovation and development of high-tech industry. Since this reform, Chinese universities have become even more enthusiastic about transferring knowledge to industry (Hong, 2008). In 2007, the Chinese government made another important step forward in encouraging innovation and commercialisation. The revised edition of the Law on Science and Technology Progress introduced in 2007 specified that ‘IPR rights of invention patents, copyright of computer software, ownership rights of electronic circuit and new biological variety obtained under S&T funding projects sponsored by fiscal finance or S&T program will be granted to the Investigators of the project according to law, except those related to national security, national interest and major public interest’. This new regulation on IPR ownership gives greater recognition and ownership of IPR to the researchers than the Bayh-Dole Act.

Moreover, the Chinese government has been advocating a use-driven science policy since its establishment, encouraging universities to serve the national economy by solving practical problems for industry (Hong, 2006). On the one hand, university-industry linkages in China are built through licensing, consulting, joint or contract R&D and technology services, closely resembling how universities in the West interact with industry. On the other hand, a second form of use-driven innovation occurs as a result of university-affiliated or university-run enterprises (Ma, 2004; Zhang, 2003). Chinese universities since the market-oriented reforms have had strong incentives to pursue economic gains and strong internal (R&D and other) resources to launch start-ups (Eun et al., 2006). Government-driven spin-off formation has proved an appropriate solution for technology transfer at Chinese universities (Kroll and Liefner, 2008). Economy-wise, the economic reforms have led to a gradual evolution of major players in the national and regional innovation system. The importance of the industrial sector in innovation system has been increasing over the years, which, combined with a varied performance in the enterprises, universities and openness, has led to increased disparities in innovation across Chinese regions (Fu, 2008; Li, 2009). Although universities have become a critical source for the industrial innovations in some regions in China, the fast growth of high-technology industries in other regions are driven mainly by other sources (Chen and Kenney, 2006).

IV. Methodology and data

In order to assess the impact of university collaboration on the innovation performance of industrial firms, we regress a firm's innovation output on their collaboration with universities while controlling for a vector of firm- and industry-specific characteristics. We distinguish firms' innovation with differing degrees of novelty, i.e., innovations which are ground-breaking at world-, country- or firm-levels. In order to explore the effect of the technological and cultural gap on the knowledge transfer through innovation collaboration, we distinguish universities located in a firm's own country, the newly industrialised economies, EU, US and Japan, and other countries.

Measurement of the dependent variable

Here we measure innovation output by the percentage of innovative sales in total turnover. Innovation could be measured in different ways. One way is to use a dummy variable which equals 1 for innovation and 0 for no innovation. This method, however, would omit detailed information with regard to the extent of innovation. A second widely-used measure is R&D expenditure. R&D expenditure itself is, however, in fact one of the *inputs* to innovation. A third widely-used indicator of innovation output is the number of patents (Jaffe, 1989; Acs et al., 2002). Although an indicator based on the number of patents has its advantages, it also suffers from the validity problem that patents might not adequately the commercial success and value of new and adapted products (Acs et al., 2002). There are also studies which use innovation counts (eg., Anselin et al., 1997). These also have limitations, however, in terms of reflecting the depth and breadth of innovation success.

For these reasons, we use the sales of new or improved products as a measure of innovation output as this information is available in the survey dataset. In the survey, firms are asked whether, besides being new to their firm, the innovation was also new to the market. This allows a distinction between innovations of the latter kind - which may be termed 'novel'- and innovations of the former kind - which may be considered as 'diffusionary' innovations. Since we are interested in the different roles of universities in the creation of ground-breaking novel innovation and in translating, deciphering and adapting transferred foreign technology, we use two dependent variables: the proportion of sales accounted for by products which were ground-breaking at the world level, and, secondly, which were new to the country or firm.

Measurement of university-industry collaboration

Research collaboration may take place at different levels and inter-institutional and international collaboration need not necessarily involve inter-individual collaborations (Katz and Martin, 1997). In this paper we consider a number of variables to capture the direct university contribution to firm innovation through innovation collaboration. We use a dummy variable that equals 1 if firms cooperated in any innovation activities with universities and public research institutions and 0 otherwise to proxy the presence of university-industry collaboration. In order to highlight the role of domestic universities in emerging economies, we distinguish universities located in a firm's own country, the newly industrialised economies, EU, US and Japan, and other countries. This also allows us to examine the effects of the technological and cultural gap and hence the appropriateness of foreign knowledge on the strength of benefits from collaborations with universities internationally. Alternatively, we also include an indicator reflecting whether a firm cooperates with any other organizations, such as suppliers, customers, competitors, universities and PRIs, consultants and commercial labs in the course of its innovation activity. This allows for a direct test of the question as to whether collaboration significantly influences firm innovation performance.

The Control Variables

The control variables include a group of variables that focus upon the extent to which the output of product innovations by a firm is a function of the resources committed to innovative activity. These resources are, firstly, intra-mural R&D expenditure and extra-mural R&D expenditure of the firm. Investment in research and development (R&D) is often found to be a significant determinant of innovation. Firms engaged in R&D are more likely to innovate because R&D directly creates new products and processes, and also because these firms are more receptive to new external ideas. However, some economists, e.g. Baldwin (1997), argue that R&D is neither a necessary, nor a sufficient, condition for innovation. Moreover, control of the size of extra-mural R&D is also important as a control over the effects of other type of collaborations, for example, collaboration with suppliers, customers, other firms in the same industry and other firms within the company group. Labour force skills, particularly qualified scientists and engineers, are another widely recognised critical factor that contributes to firm innovation performance (Hoffman et al, 1998; Porter and Stern, 1999). In order to capture this important element and the extent to which the lack of qualified R&D personnel can constrain innovative activity, a dummy variable that equals 1 for firms reporting a lack of qualified personnel as being of medium and high importance and 0 for others is also included as a control variable. These inputs not only directly contribute to innovation but also enhance the firms' capacity to recognize and absorb relevant external resources for innovation (Cohen and Levinthal, 1990).

We also include other variables to capture size and age effects as well as industry sector-specific effects. The extent to which a firm may be able to exploit its innovative activity may depend on its size *per se* and on the degree of competition in its final product markets. Larger firms have a greater range of market opportunities through which to exploit innovative opportunities. The size of the firm can therefore act as a proxy for this enhanced incentive to innovate. From the point of view of smaller firms, the existence of a dominant market position by large firms may inhibit their access to the market and hence their ability to translate innovative activity into a significant proportion of new products in their final sales. On the other hand, large firms face conflicting possibilities that may arise from the presence of dominant positions. Moreover, firm age is likely to be associated with firms' innovation activity: older firms may have accumulated more experience and knowledge and be more capable in innovation. Alternatively, however, older firms may be constrained by organisational rigidity and hence are less active in innovation. Finally, since technological and innovation opportunities may occur unevenly across sectors, we include industry dummy variables to proxy for these effects. The full list of variables is summarised in Table 1.

Two estimation problems arise in this model. The first is that the dependent variable, the percentage of innovative sales, is constrained to a value between 0 and 100 and takes a value of zero in a large proportion of sample. The Ordinary Least Squares (OLS) estimates would thus be biased. Therefore a Tobit model should be introduced to reduce the problem (Tobin, 1958). The second problem is that a number of firms have not undertaken any R&D activity at all and therefore have no sales of new or significantly improved products. So there is a selection effect based on the decision to innovate or not. A Hurdle model which was originally suggested by Cragg (1971) as a generalized form of the Tobit model needs to be employed to allow for the fact that firms decide either to innovate or not, and, with respect to those that are innovative, for the extent to which they are so (Mairesse and Monhen, 2002). The significance of the presence of the selection effects is indicated by Rho statistics, which reflects the correlation between the error terms of the two equations. If there are significant selection effects, the Generalised Tobit model (selection in censored data) is preferred. Otherwise, we utilise the standard Tobit model. However, in this study, since the China dataset is dominated by innovative firms (about 95% firms reported having innovated in terms of their products) and since the UK dataset has similar characteristics, selection bias is not a significant problem[2]. Nevertheless, we also report the results from the Generalised Tobit model as a robustness check.

Data

The research principally uses the 2008 Chinese national innovation survey of 1,408 manufacturing firms in China: this contains data on firms' innovation activities over the 2005 to 2007 period. The survey is carried out by the National Statistical Bureau. It covers 42 cities in China in both the coastal and inland regions of China. A total of 1,408 valid responses were received, with a response rate of 83.6%. The questionnaire in the Chinese innovation survey is designed by Tsinghua University and demonstrates high consistency and comparability with the design of the European Community Innovation Survey (CIS). The large and innovative firms which are responsible for most of the R&D activities which take place in China dominate the survey. After careful data cleansing to exclude observations with missing values of the necessary variables, the final dataset used in the estimation contains 802 firms, of which 95% have innovated in their products. Therefore, the results of this study reflect the role of universities in the innovation of innovative Chinese firms rather than

[2] This is also attested by the estimated rho statistics of the selection model. Results are available from the authors subject to request.

that in Chinese firms generally. This is a limitation of the research that we shall bear in mind when drawing conclusions.

V. Results

Figures 1 and 2 report the extent of utilization of external resources in innovative Chinese firms in terms of the percentage of firms having engaged in innovation collaboration[3] with various types of partners. On average, nearly half of the surveyed Chinese firms report that they collaborated with listed external organisations. Interestingly, universities are the most popular collaborator for Chinese firms, which is not surprising given that, as discussed above, historically universities and public research institutions (PRIs) dominated the innovation system in China and there was a strong government policy of pushing the development of university-industry linkages. Most of the universities collaborate with Chinese universities and around 10% of the firms who collaborate with universities collaborate with foreign universities.

Universities and industrial innovation in China

The estimated results of the role of universities in firm innovation in China using the standard Tobit model are reported in Table 2. Columns 1 to 3 report the regression results using the percentage of sales of products which are ground-breaking innovations in world terms as the dependent variable; and columns 4 to 6 report the results of regressions using innovations which are new to the country or firm and significantly improved products as the dependent variable. The results in columns (1) and (4) suggest that collaboration with other firms or institutions have a positive impact and are significantly associated with the creation of innovations that are new to the world and those which are new to the country/firm. The magnitude of the estimated coefficients is of similar size but those

[3] There is subtle difference in English between collaboration and cooperation, the Chinese wording used in the survey ('he zuo') does not imply this subtle difference. Firms may regard both arms-length close cooperation and collaboration as being 'he zuo'. We therefore translate the wording into 'collaboration' which may include recursive and sustained interactions in addition to arm-length cooperation. This may be a factor in the not small proportion of Chinese firms report having collaborated with external organisations for innovation.

in the diffusionary innovation regression are of higher significance. However, as shown in columns (2) and (5), collaboration with universities does not appear to have contributed significantly to the process in the country on average. This suggests that although there are individual cases of successful university-industry collaboration induced innovation in China, on average, the contribution of universities to firm innovation is not significant nationwide. As Chen and Kenney (2006) argue although universities have formed an effective linkage and become a critical source for the industrial innovations in some regions in China, such as Beijing, the fast growth of high-technology industries in many other regions are driven mainly by other sources.

Breaking down universities according to their country of origin, the estimated results exhibit some interesting findings in columns (3) and (6). Collaboration with domestic universities exhibits a positive but insignificant effect on novel new sales, which can probably be explained by the level of quality and impact of domestic universities in comparison to the world innovation frontier during the sample period (Guan and Ma, 2007). However, the effect regarding diffusion of sales of innovations which are new to the country or firm or significantly improved products is positive and statistically significant. Interestingly, international innovation collaboration between Chinese firms and universities in the newly industrialised economies, namely Hong Kong, Taiwan, Singapore and Korea, appears to have a significant and positive effect on the generation of innovations by Chinese manufacturing firms. Moreover, firms that have collaboration in innovation with universities in countries other than the NIEs and Europe, USA and Japan, such as Russia, Israel, India and Brazil, have a significantly higher proportion of sales on accounted for by products which are new to the world. Surprisingly, linkages with universities in the major industrialised economies, i.e. US, Japan and Europe, although showing a positive effect, involve an estimated coefficient which is not statistically significant. This may be explained by the technology and culture gap between China and these industrialised economies and the appropriateness of the foreign knowledge of the receiving economy. Further research is needed to investigate why collaboration with this group of highly-regarded universities is less fruitful for Chinese industrial enterprises.

Firms' intramural R&D appears to be insignificantly associated with their sales intensity of novel products after controlling for extramural R&D spending but is positive and significantly associated with their diffusion of new sales. This result is consistent with the work of Fu and Gong (2011) which examines the effect of indigenous R&D activities on technology upgrading in China using a large firm-level panel dataset produced by the National Statistical Bureau. In contrast, firms' spending on extramural R&D activities exerts a positive and significant effect on firms' novelty of new sales but not on the diffusion of innovation. This highlights the importance of the utilisation of external innovation resources and extramural R&D activities for the creation of innovation involving products which are ground-breaking in world terms by middle-income emerging economies. Firm size and age do not appear to affect the percentage of innovative sales of firms significantly. Although the estimated coefficient of the constraints in R&D personnel dummy bears the expected negative sign, it is not statistically significant either.

Table 3 reports the results of a robustness check using the Generalised Tobit model to correct for potential selection bias. The estimated results are broadly consistent with the standard Tobit model estimates, especially in respect of the effect of university-industry collaboration. The estimated coefficient of the university collaboration variable remains positive and statistically insignificant, while the pattern of the influence of universities by country of origin remains highly similar to that in Table 2. The effect of collaboration with domestic universities remains significant for the diffusion of new sales but not of novel new sales. International innovation collaboration with foreign universities in the NIEs, major industrialised economies and other countries all demonstrate a positive and significant effect. The level of significance of the estimated coefficients of the NIE and other university collaboration dummies is greater than that of the US/Japan/EU university collaboration dummy, indicating the effectiveness of the former two types of international university linkage. This is, to a certain extent, consistent with the findings from Table 2. As regards the control variables, smaller firms appear to have greater diffusion of new sales, and younger firms appear to create more novel innovations. In sum, the results on the role of universities in firm innovation are robust in the main, having allowed for any possible selection bias.

The collaboration variable is arguably determined simultaneously with the dependent variable of innovation. In other words, there might be a potential endogeneity problem. For example, firms that collaborate with other firms and universities are more likely to have more innovative sales. However, it is also possible that more innovative firms might collaborate to a greater extent with other firms and universities. Moreover, they are also more likely to be invited into any innovation collaboration by other organisations. In order to deal with the potential problem of endogeneity, we employ an instrumental variable regression technique to correct this problem. The instrumental variables used are all the exogenous variables in the model with the addition of four extra exogenous variables including: a firm location dummy which indicates whether a firm is located in the six university concentrated cities; a group dummy that equals 1 for firms belongs to a corporation group; the importance of information from universities for firm innovation; and competition in the industry. Moreover, the use of industry dummies in the regressions is also designed to mitigate part of this potential endogeneity problem. We test whether the assumption of endogeneity is borne out by the data at hand. The Wald tests of exogeneity of the collaboration variables suggest there is no significant endogeneity problem. Therefore, the standard Tobit model estimates are preferred to the instrumental variable model estimates. Nevertheless, we report the estimated results in Table 4 as a robustness check. Consistent with the picture revealed in Tables 2 and 3, the effect of university collaboration remain insignificant for firm innovation, of both novel and diffusionary types.

However, the impact of the general collaboration variable also becomes insignificant using the instrumental variable estimates. Note, however, since the Wald test of exogeneity indicates no significant endogeneity problem, the standard Tobit model estimates should be used as the valid empirical results for the research.

Universities and industrial innovation in university concentrated Chinese cities

Chen and Kenney (2007) found that each Chinese region reacted differently to the government policy of promotion of university-industry linkage. In Beijing, universities and research institutions are a critical source of knowledge. However, in Shenzhen, the rapid growth of high-technology firms did not rely on direct linkages with universities. Moreover, geographical proximity to universities will facilitate greater industry-university collaboration. Since the geographical distribution of research universities in China is uneven, the impact of universities may be greater in these cities but weak in the rest cities and regions. Table 5 reports estimated results of the contribution of universities to firm innovation in selected university-concentrated cities, namely Beijing, Shanghai, Nanjing, Xian, Wuhan and Chongqing. Consistent with the pattern shown in Tables 2 and 3, domestic Chinese universities again appear to have a significant effect on the creation of diffusionary innovations in Chinese firms, while their effect on novel innovation is insignificant. However, the size of the estimated coefficient of the domestic universities variable is almost three times that in Table 2, suggesting a greater innovation effect by universities in these major cities than in the economy as a whole. The effect of international collaboration with universities in other countries also appears to be much larger in these major cities than in the whole economy. However, the impact of collaboration with universities in NIEs loses its statistical significance in the 6-city small sample. This is probably because universities in the NIEs collaborate more with firms in some cities in the coastal medium- or small-sized cities, such as Shenzhen, Guangzhou, Zhejiang and Fujian, rather than those six domestic university concentrated major cities.

In summary, the message from Tables 2 to 4 suggests that the role of universities in the emerging economies is somewhat different from the traditional theory of the role of universities in industrial innovation. Collaboration between domestic universities and industries contributes significantly to diffusionary activities in China but less so to innovation which is ground-breaking in world terms. On the other hand, international innovation collaboration with foreign universities, especially those in the NIEs, contributes significantly to the creation of innovation which is novel at the world level in China.

VI. Conclusions and Discussions

This paper attempts to investigate the role of universities in industrial innovation in emerging economies using a firm-level innovation survey database from China. It then benchmarks the Chinese pattern with that from the UK, a classical industrialised economy from which a significant amount of the received wisdom on the role of universities and their role in innovation has developed. One of the key findings of this study is that collaboration with domestic universities has played a significant role in the promotion of the diffusion of frontier technology and the creation of innovation outcomes which are ground-breaking at country- or firm-levels. In contrast to the traditional view that collaboration with universities will lead to great novel innovation, the contribution of domestic universities to the creation of innovation which is ground-breaking in world terms is limited in China.

International innovation collaboration with foreign universities appears to be fruitful in enhancing Chinese firms' capabilities in the creation of innovation outcomes which are ground-breaking in world terms. In particular, innovation collaboration with universities in the Newly Industrialised

Economies in East Asia, such as Hong Kong, Taiwan, Singapore and Korea, and in countries other than the Western industrialised economies, for example, Russia, Brazil, India and Australia, has proven to be beneficial and effective in promoting novel innovation in Chinese firms. In comparison, collaboration with universities in the Western industrialised economies (the most frequently-used innovation partner among foreign universities) does not appear to be as effective and fruitful as expected. The overall pattern of the effectiveness of international university innovation collaboration attests to the argument regarding the importance of technological and cultural gaps and hence the importance of the appropriateness of technology for effective international technology transfer. This is consistent with the theory of directly technical change (Acemoglu, 2002) and the findings from Fu and Gong (2011) that the transfer of Western technology is not effective in promoting indigenous technological capabilities in many Chinese industrial sectors. In contrast, knowledge from universities in the NIEs and the emerging South appears to be more compatible to the Chinese firms. In summary, international universities from compatible economic and technology backgrounds have played a role as a global source of knowledge, contributing to the creation of innovation which is ground-breaking at the world level in the emerging economies. Future research should investigate in-depth the reasons why international innovation collaboration with universities in the most advanced economies functions ineffectively in nurturing novel industrial innovations.

Findings from this research also indicate that when we focus on innovative firms and control for size and industry, universities appear to be the most popular innovation partner for Chinese firms. Although there is a possible language issue in the definition and interpretation of ‘he zuo’ (‘collaboration’) and the concept in English of ‘cooperation’ which may prevent us from a direct comparison of the levels of collaboration/cooperation between countries, the high percentage of Chinese firms which report having collaborated with universities in innovation activities suggests that the strong government policy push and the marketisation reform of the science and technology system have effectively promoted a strong university-industry linkage in China.

Findings from the current research have important policy and practical implications for firms in both emerging and the wider developing countries with regard to the processes involved in tapping into knowledge and resources from universities to promote innovation. Domestic universities are best positioned to help firms in developing countries to assimilate, grasp, adapt and decipher transferred foreign technology. Given the importance of technology transfer in developing countries, especially in the early stage of industrialisation, policies in the developing countries should greatly promote the university-industry collaboration as a means of enhancing the absorptive capacity of the indigenous economy. Secondly, geographical, technological and cultural proximity have led to a closer relationship between Chinese firms and the NIEs. In these cases, the synergy, compatibility, relatively advanced technology level and adequate technological gap between the two partners form a creative and knowledge-enriching basis from which innovative ideas, products and processes are produced.

Moreover, collaboration with universities from the emerging South also appears to have a robust positive contribution to the production of novel innovations. In recent years, Chinese firms have increasingly established processes of international innovation collaboration with foreign universities following the increasing internationalisation of the Chinese firms. For example, Huawei extended investment on technological alliances to a number of foreign universities such as INATEL University, Brazil (from September 2003) and Shrif University, Iran (from July 2009) (Zhang, 2009). Such efforts also proved to be rewarding. Moreover, China’s technology leadership in the solar PV industry is also obtained through collaboration with an Australian university. Therefore, firms in the developing countries seeking international collaboration should not constrain themselves by considering only universities in the Western countries such as the US, Europe and Japan: universities in the NIEs and the emerging South will provide a more compatible and effective innovation partner in the creation of novel innovation outcomes. Admittedly, the form of interactions between universities and firms are diverse. Each of these activities offers different opportunities to generate or disseminate knowledge. For example, if university-industry collaboration in China has to do mainly with student internships and curriculum alignment, it would not have an impact in terms of generating ground-breaking innovations. Future research should distinguish different forms of university-industry interaction and identifies their different effects and the conditions for each collaboration model to make the most benefits.

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Figure 1

Figure 2

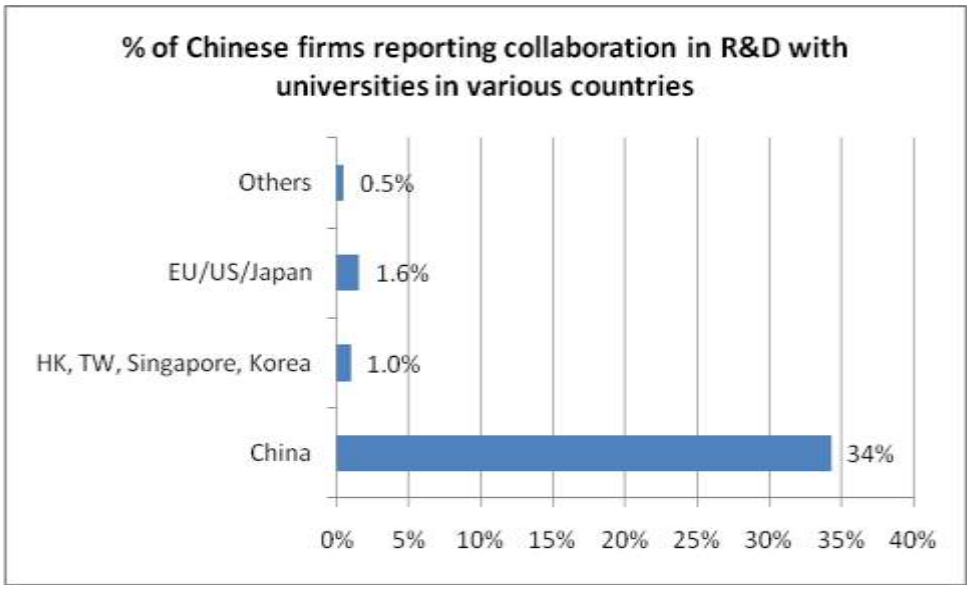

Table 1 Definition of variables

Variable	Definition	Mean
newsal	% of new sales	46.796
newsaln	% of sales of products that are ground-breaking in world terms (‘novel’)	6.798
newsald	% of sales of products that are new to China or the firm or are significantly improved (‘diffusionary’)	40.719
lrdin	Ln(intramural R&D expenditure)	5.105
lrdex	Ln(extramural R&D expenditure)	0.906
size	Firm size dummy equally 1 for large firm and 0 for small firm.	0.714
age	Firm age	16.890
lack_hc1	Human capital constraints dummy variable, 1= the importance of lack of qualified personnel to innovation is medium and high; and 0=low or unimportant	0.797
co	Innovation cooperation dummy variable, 1=yes, 0=no	0.634
cogd	Dummy variable, 1=cooperate with other firms within an enterprise group; 0=no	0.392
cosd	Dummy variable, 1=cooperate with suppliers; 0=no	0.407
cocd	Dummy variable, 1=cooperate with customers; 0=no	0.396
copd	Dummy variable, 1=cooperate with competitors or other firms in the same industry; 0=no	0.291
coprid	Dummy variable, 1=cooperate with private R&D institutions; 0=no	0.243
counid	Dummy variable, 1=cooperate with universities and public research institutions (PRIs); 0=no	0.482
couni1	Dummy variable, 1=cooperate with universities and PRIs in China; 0=no Dummy variable, 1=cooperate with universities and PRIs in the same country; 0=no	0.476
couni2	Dummy variable, 1=cooperate with universities and PRIs in newly industrialised countries in East Asia (Hong Kong, Taiwan, Singapore, Korea); 0=no	0.012
couni3	Dummy variable, 1=cooperate with universities and PRIs in Europe, US and Japan; 0=no	0.019
couni4	Dummy variable, 1=cooperate with universities and PRIs in other countries not listed above; 0=no	0.006

Table 2. Universities and firm innovation in China: Tobit model estimates

	Novel innovation			Diffusion innovation		
	1	2	3	4	5	6
VARIABLES	model	model	model	model	model	model
co with other org.	10.40**			9.828***		
	(5.111)			(3.321)		
co with universities		5.344			4.276	
		(5.205)			(3.513)	
co with domestic uni.			1.345			5.954*
			(5.094)			(3.532)
co with uni in NIEs			35.67***			-5.64
			(11.25)			(17.1)
co with uni in US/EU/Japan			17.29			-13.58
			(10.72)			(11.04)
co with uni in other countries			35.32**			-8.254
			(15.97)			(16.5)
Ln(intramural R&D exp)	2.106**	1.299	1.203	2.949***	3.007***	2.929***
	(0.865)	(0.937)	(0.921)	(0.544)	(0.589)	(0.595)
Ln(extramural R&D exp)		1.623**	1.690***		0.0666	0.0009
		(0.649)	(0.647)		(0.46)	(0.461)
Firm size	5.967	4.837	3.428	-3.446	-5.144	-5.629
	(5.553)	(5.673)	(5.642)	(3.728)	(3.932)	(3.912)
Firm age	-0.257	-0.244	-0.202	-0.0266	-0.024	-0.0467
	(0.159)	(0.168)	(0.161)	(0.0575)	(0.0603)	(0.0622)
constraints in human capital	-1.933	-2.811	-2.645	-2.605	-6.097	-6.154
	(5.134)	(5.171)	(5.067)	(3.63)	(3.874)	(3.869)
Industry dummies	yes	yes	yes	yes	yes	yes
Constant	yes	yes	yes	yes	yes	yes
Observations	928	817	817	910	802	802
F statistics	6.293	5.218	5.73	7.746	5.116	3.445
Log Likelihood	-1454	-1298	-1291	-3741	-3320	-3314

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 3. Robustness check: Generalised Tobit model estimates

	Novel innovation			Diffusion innovation		
	1	2	3	4	5	6
co with other org.	2.3			6.250**		
	(1.442)			(2.824)		
co with universities		2.111			3.967	
		(1.414)			(2.786)	
co with domestic uni.			1.045			5.239*
			(1.402)			(2.779)
co with uni in NIEs			12.09**			-0.693
			(5.914)			(11.99)
co with uni in US/EU/Japan			8.429*			-8.014
			(4.696)			(9.338)
co with uni in other countries			17.08**			-5.956
			(8.088)			(15.87)
Ln(intramural R&D exp)	0.409*	0.357	0.267	2.308***	2.331***	2.329***
	(0.213)	(0.224)	(0.227)	(0.427)	(0.453)	(0.45)
Ln(extramural R&D exp)		0.105	0.119		0.197	0.108
		(0.185)	(0.184)		(0.363)	(0.363)
Firm size	0.729	0.856	0.397	-5.874**	-5.220*	-5.732*
	(1.502)	(1.498)	(1.501)	(2.962)	(2.968)	(2.979)
Firm age	-0.0534*	-0.0563*	-0.0479	-0.0213	-0.0237	-0.0403
	(0.030)	(0.030)	(0.030)	(0.058)	(0.059)	(0.059)
constraints in human capital	-0.205	-0.468	-0.484	-4.728	-5.600*	-6.201**
	(1.613)	(1.573)	(1.557)	(3.171)	(3.104)	(3.112)
Industry dummies	yes	yes	yes	yes	yes	yes
Constant	yes	yes	yes	yes	yes	yes
Observations	817	817	817	802	802	802
Log Likelihood	-3366	-3367	-3354	-3815	-3819	-3813

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 4. Robustness check: Instrumental variable model estimates

	Novel innovation		Diffusion innovation	
	1	2	3	4
co with other org.	18.68		-13.28	
	(16.23)		(12.53)	
co with universities		7.868		-0.775
		(11.86)		(8.565)
Ln(intramural R&D exp)	0.665	0.998	3.637***	3.172***
	(1.085)	(1.012)	(0.744)	(0.66)
Ln(extramural R&D exp)	1.308*	1.523**	0.466	0.164
	(0.763)	(0.751)	(0.545)	(0.518)
Firm size	-0.24	-0.24	-0.00426	-0.0181
	(0.164)	(0.169)	(0.0657)	(0.0661)
Firm age	3.417	4.733	-4.457	-5.526
	(5.762)	(5.675)	(4.129)	(3.923)
constraints in human capital	1.606	-2.302	-10.05*	-6.408
	(6.547)	(5.323)	(5.407)	(4.136)
Industry dummies	yes	yes	yes	yes
Constant	yes	yes	yes	yes
Observations	816	816	801	801
Log Likelihood	-1691	-1679	-3693	-3680
Wald test of exogeneity (p-value)	0.424	0.768	0.077	0.473

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1
Instrumental variables used are all the exogenous variables in the model and four extra exogenous variables including a firm location dummy indicating whether a firm is located in the 6 university concentrated cities; a group dummy that equals 1 for firms belongs to a corporation group; the importance of information from universities for firm innovation; and competition in the industry.

Table 5. Universities and firm innovation in selected university concentrated cities in China

	Novel innovation	Diffusion innovation
	1	2
co with domestic uni.	1.297	15.31*
	(14.14)	(8.044)
co with uni in NIEs	5.047	3.239
	(28.14)	(11.00)
co with uni in US/EU/Japan	26.98	4.418
	(25.52)	(8.481)
co with uni in other countries	50.65***	30.68***
	(12.52)	(6.164)
Ln(intramural R&D exp)	0.429	2.076
	(2.307)	(1.375)
Ln(extramural R&D exp)	0.372	-1.184
	(1.603)	(1.078)
Firm size	-0.673*	0.121
	(0.385)	(0.157)
Firm age	23.57	-38.92***
	(20.84)	(11.02)
Constraints in human capital	13.99	-6.06
	(16.87)	(11.10)
Industry dummies	yes	yes
Constant	yes	yes
Observations	123	117
Log Likelihood	-175.6	-498.8

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1
The six selected university concentrated cities are Beijing, Shanghai, Nanjin, Wuhan, Xian, Chongqing.

Appendix 1. Citations of scientific papers published during 2000-2010: countries with more than 200,000 published papers

	Citations per paper		Number of publications	Citations	
	Frequency	Rank		Number of Citations	Ranking
US	15.77	1	2 967 957	46 796 090	1
Netherland	15.37	2	239 892	3 687 829	9
UK	14.69	3	679 394	9 979 737	2
Germany	13.06	4	762 599	9 960 100	3
Canada	13.04	5	430 856	5 619 293	6
France	12.28	6	542 293	6 660 630	5
Australia	11.82	7	284 250	3 359 748	10
Italy	11.66	8	409 232	4 770 753	7
Spain	10.32	9	315 420	3 256 075	11
Japan	10.23	10	770 252	7 877 699	4
Korea	6.94	11	254 599	1 767 799	14
China	5.87	12	719 971	4 227 779	8
India	5.62	13	266 230	1 497 065	17
Russia	4.65	14	267319	1 243 711	20

Sources: calculated from SCI database (CSTII, 2010)