University of Oxford

ISSN 2045-5119

Department of International Development

TMD Working Paper Series

No. 045

The Dual Role of Universities in Industrial Innovation in Emerging Economies: A Comparative Study of China and the UK

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Abstract

This paper attempts to investigate the role of universities in industrial innovation in emerging economies using a firm-level survey database from China. It also benchmarks the Chinese pattern against that of the UK. It finds that domestic universities have played a significant role in the promotion of the diffusion of frontier technology and the creation of new country- or firm-level innovation outcomes in China. In contrast to the traditional view that collaboration with universities will lead to greater novel innovation (an outcome which is supported by our evidence from the UK), the contribution of domestic universities to the creation of ground-breaking innovations is limited in China. 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
JEL code: O31, O32, O33

Acknowledgements
The authors would like to thank workshop participants at DFID for helpful discussions.

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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.

This research attempts to examine the role of universities in the emerging developing economies using comparative firm-level analysis of the innovation effects of universities in China and the UK. It argues that universities have two roles in industrial innovation in emerging countries in addition to their educational contribution. On the one hand, they serve the traditional role of knowledge creation in the fields of basic and applied scientific research and hence the generation of innovation of great novelty. On the other hand, they decipher and adapt advanced foreign technology which is transferred to the developing countries. Their collaboration with industry facilitates the birth of many forms of innovation which are new to the country and/or particular firms in the emerging economies. The importance of the latter role is likely to be greater than the former in the emerging economies. China provides a good case for research given its quickly improving performance in innovation in recent years and the great effort made by the government in encouraging university-based research and technology transfer (Wu, 2007; Fu & Soete, 2010). The UK provides a classical benchmark for the analysis as one of the major developed economies in the world and a country with an excellent university sector.

The remainder of the paper is organised as follows. Section II discusses the literature and the thoeretical framework. Section III presents a brief overview of the university sector and its role in the national innovation system in China. Section IV discusses the methodology and data. Section V presents the results. Section VI concludes.

II. The literature and theoretical framework

The literature on national and regional 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; Fu & Yang, 2009). 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 (Cosh et al., 2006; Abreu, et al., 2008; 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).

There are two contrasting views regarding the role of a university. The *Triple Helix thesis* argues that universities should form direct links with industry to maximise capitalisation of knowledge and hence serve the need for economic development (Etzkowitz and Leydesdorff, 1997, 2000). In contrast, the so-called *New Economics of Science* states 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 (eg., Dasgupta and David, 1994). Criticising any application of both above theories to developing countries, 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 et al., 2009). UK Community Innovation Survey data suggests that 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 and resources are subject to decreasing returns as 'over-searching' and working with too many partners will have negative consequences for innovation efficiency.

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). University participation in research programmes is also found to have a positive impact on firm patenting (Darby et al., 2003). Public research is also found to have not only initiated new R&D projects but also contribute to the completion of existing projects in the US manufacturing sector (Cohen et al., 2002). In sum, contracting out research, entering into university-industry alliances and collaborating with university researchers formally or informally can confer substantial advantage.

However, the role of universities in innovation is not single- but multi-faceted (Hughes, 2010). Universities may struggle in terms of reconciling the creation of new knowledge regardless of its commercial or innovative value and their role as promoters of technological development (Mowery and Sampat, 2005). The extent of development of an economy will influence the role of its universities in several ways. First, the extent of development of an economy will determine the level of its indigenous technological and innovation capabilities and the major source of technology upgrading. Owing to the lack of sufficient absorptive capacity in the local industry, there is a need to tap into the expertise of science and engineering experts in the universities. 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. Finally the extent of development of an economy determines the type of industrial and technology policy the government will adopt to promote economic growth, which in turn affects the type of demand for university research.

In the middle-income emerging economies, given the level of development and the research capabilities of the economy, universities are likely to have a dual role in the innovation of firms which is in addition to their educational contribution. First, innovation is costly, risky and path-dependent. 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: the US, Japan and a number of European countries. International technology diffusion will therefore be an important driver in economic growth. Hence, in the middle-income emerging economies, since they are at an intermediate stage of development, the assimilation of foreign technology has been a major source of technology upgrading, and innovation which is ground-breaking at the national or firm level 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). Therefore, there is a real demand from the industrial sector for external technological experts to help with the assimilation and adaptation of foreign technology. Linkages with universities will help to accelerate the adoption of foreign technology.

Furthermore, the middle-income emerging economies have a higher education sector which is relatively stronger than the rest of the developing countries. Therefore, universities, and especially elite universities, in the middle-income emerging economies are capable of collaborating 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. Of course, we should not be overly optimistic about the role of universities in this respect in the middle-income emerging economies. Admittedly there is a gap between the universities in these economies and those of the major developed economies, especially in terms of research quality and impact. Even in one of the fields of emergent technologies where the emerging economies might claim a lead based on the number of scientific publications, further analysis of the citation share as well as surrogate indicators shows the need for China to improve its research impact (Guan and Ma, 2007).

Finally, the level of development of an economy determines the type of industrial and technology policy the government will adopt to promote economic growth, which in turn affects the type of demand for university research. For example, in the US, research universities are simultaneously centres of learning, the foci of basic and applied research and the source of entrepreneurship. On the other hand, 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. Elite universities, being prompted by government incentives, have started to contribute to technology deepening (Hershberg et al, 2007). Unlike the many Western countries which have experienced a transition in science policy from one driven by curiosity to one driven by practical needs and uses, 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). The above reflections lead to the following proposition:

Proposition: Universities have two roles in industrial innovation in emerging countries in addition to their educational role. On the one hand, they serve the traditional role of knowledge creation in the field of basic and applied scientific research and hence the generation of innovation of great novelty. On the other hand, they decipher and adapt advanced foreign technology which is transferred to the developing countries. Their collaboration with industries facilitated the diffusion of innovation which can be considered ground-breaking at the country- or firm-level in the emerging economies. The importance of the latter role is likely to be greater than the former in the emerging economies.

III. Universities and industrial innovation in China

The swift rise of the Chinese economy has been accompanied by the rapid development of its technological capabilities. While acquisition of foreign technology has been a major strategy in the first two decades since the reforms of 1978, the past ten years have witnessed rapid growth in domestic R&D investment. The expenditure on research and development (R&D) has increased exponentially. In 2010, the total R&D expenditure in China was greater than that of Germany, UK and France and ranked third in the world, after the US and Japan. In terms of its gross R&D expenditure to GDP ratio, China is now moving close to the EU average and aiming to reach 2.5 percent by 2020. 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 so-called Triadic Patent Families[1] has increased more than seven times over the period from 2000 to 2007. China's share in science and engineering articles has risen sixfold since the mid-1990s, from 9,000 to nearly 57,000 each year, accounting for seven per cent of the global research output in 2007 (Fu et al, 2010; Gilman, 2010).

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 to render the science and innovation system more relevant to the market and signalled a departure from the Soviet model where scientific research at public research institutions and production at state-owned enterprises were completely separated (Xue, 1997).

The mid-1980s witnessed several reforms in science policy in China. The most significant change was the cutting 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

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

practice officially approved by the central government in 1991. Another wave of reform of Chinese universities began in December 1994 when a national forum encouraged institutional mergers and decentralization in jurisdiction for efficiency purposes. This decentralization reform has had the implication of promoting collaborations between universities and local industries (Hong, 2008). In addition, after the introduction of a Chinese version of the Bayh-Dole Act that allowed universities to retain titles to inventions derived from government funding as well as an act promoting commercialization of innovation and development of high-tech industry in 1999, Chinese universities have become even more enthusiastic about transferring knowledge to industry (Hong, 2008).

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), a system which is uniquely Chinese. 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, and thus established their own firms, given the low absorptive capacity of industrial firms and underdeveloped intermediary institutions (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 reform of enterprises and opening up to foreign direct investment, has led to increased disparities in innovation across Chinese regions (Fu, 2008; Li, 2009).

IV. Methodology and data

The empirical test of the proposition is carried out in two stages. First, a statistical test is carried out to examine the impact of the university linkage on firms' innovation with differing degrees of novelty, i.e., innovations which are ground-breaking at world-, country- or firm-levels. Secondly, we compare the pattern observed from Chinese data with that contained in UK data. 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.

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.

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 (Acs et al., 1991; Anselin et al., 1997; and Feldman, 1999). 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 direct university contribution

We consider a number of variables to capture the direct university contribution to firm innovation through innovation collaboration. We include an indicator of the extent to which the firm cooperates with other organizations and institutions in the course of its innovation activity. This is proxied by a cooperation dummy that equals 1 if firms cooperated in any innovation activities with other enterprises or institutions, such as universities and public research institutions, suppliers of equipment/services/software, clients, competitors, consultants, and commercial labs, and 0 otherwise. This allows for a direct test of the question as to whether collaboration significantly influences firm innovation performance. 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.

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. The correlation coefficients of the variables in the China and UK samples are shown in Appendices 1 and 2.

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

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

We then benchmark the innovation effects of universities in China against those in the UK. Our sample of UK firms is drawn from the 2005 *Fourth UK Community Innovation Survey*[3] published by the Office for National Statistics (2006) on behalf of the Department for Innovation, Universities and Skills.[4] The UK survey covered all enterprises with ten or more employees in almost all industries. The survey received valid responses from 13,986 UK enterprises, including 4,296 firms in the manufacturing sector. The response rate of the survey is 58 per cent. It covers 9 regions in England plus Scotland, Wales and Northern Ireland. A postal questionnaire was used and responses were voluntary. The survey provides information on UK innovation over the three years of 2002, 2003 and 2004. Admittedly, there is a three year gap between the UK and the Chinese innovation surveys. However, it is reasonable to assume that the pattern of innovation and the role of universities are unlikely to have experienced big changes in a mature developed economy such as the UK over a short period of three years. Hence the pattern of the role of universities in firms' innovation from the survey is likely to be equivalent to that experienced over the 2005 to 2007 period: this can in fact be proven by detailed comparison of the persistence and changes in UK innovation within UK CIS4 and CIS5 over the 2002 to 2006 period (DTI, 2008).

These two national surveys cover firms in the whole economy. Data covering the whole economy cannot be used to make straightforward comparisons because countries differ in the distribution of activity across industries and the distribution of innovative firms by size and sector. These factors all have an impact on the requirements for, and likelihood of, access to the universities. Therefore, we match the cleansed smaller Chinese survey dataset to the UK survey dataset by size of firm, by industry and by product innovation in the prior three years. The last criterion is important in the current study because the Chinese data is dominated by innovative firms and it is important to make

[3] A copy of the questionnaire can be found at http://www.berr.gov.uk/dius/innovation/innovation-statistics/cis/cis4-qst/page11578.html

[4] Formerly the Department of Trade and Industry or DTI. In 2007, its functions were transferred to the Department for Business, Enterprise and Regulatory Reform (BERR) and the Department for Innovation, Universities and Skills (DIUS).

the dataset comparable in this aspect. By this mechanism, we are able to compare the role of universities in the intensity of producing innovation of different degrees of novelty amongst innovative firms of the same sizes and industry technologies in the UK and China. Due to structural differences between the two surveys, we achieved a comparable UK sample of 793 firms.

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[5] 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. In comparison, about 40% of the British firms in the matched sample reported having cooperated with other organisations in at least some of their innovation activities. Customers and suppliers appeared to be the most frequently used type of collaborator by British firms: around 30% of firms have collaborated with customers or suppliers in innovation activities. Universities and PRIs ranked as the 4th most frequently-used collaborator, ahead of competitors and private R&D institutions. Domestic universities remain the main university collaborator but a higher proportion (18%) of collaborative British firms collaborated with foreign

[5] The wording in the UK survey on this question is ‘cooperation’. Although 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 explain the difference in the China and UK samples where more Chinese firms report having collaborated with external organisations for innovation.

universities. In view of the language and cultural differences between the two economies, direct comparisons of absolute percentages may not produce rigorous results. However, the pattern of collaboration and the relative importance of various collaborators in the two economies still provide plausible insights.

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 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. 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 (Chen and Kenney, 2006).

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 (2010) 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.

Universities and industrial innovation in the UK

Table 6 reports the Tobit model estimates of the UK sample match by size, sector and product innovation status. We also report the estimates of the full UK manufacturing sample to examine any differences between the matched sample and the UK firm population which may be caused by structural differences in industry, size and innovativeness distribution. Cooperation with other firms and institutions in general has a positive and significant effect on novel innovation in the matched sample. Its impact is positive however insignificant for diffusionary innovation. This pattern is somewhat different from that in the matched Chinese sample where the effect of collaboration is stronger for diffusionary innovation. In line with the results in China, the estimated coefficients of the university variable are positive and insignificant. Breaking down the universities by their country of origin, collaboration with domestic British universities shows a significant and positive effect on novel innovations reported in British enterprises whilst its effect is insignificant for diffusionary innovations. This is the opposite of the pattern we observed from the matched Chinese sample. In contrast to the results from China, international collaboration with universities, both in Europe and in other countries, does not appear to have any significant effect on either novel or diffusionary innovation in the British firms. Consistent with the case in China, extramural R&D contributes significantly to novel innovation only. The effects of intramural R&D expenditure also contribute significantly to novel innovation, which is in contrast to the finding that firm-level R&D in Chinese firms is used mainly for assimilation and 'development' and hence contributes less significantly to diffusion innovation. Larger and older firms also appear to have produced less diffusionary innovation. Constraints in R&D personnel do not appear to have any significant effect.

However, in the case of the UK manufacturing sector as a whole, the role of collaboration, especially collaboration with universities generally and with domestic British universities in particular, demonstrates a positive and significant effect on both novel and diffusionary innovations. The contribution of universities is stronger regarding novel innovations than for diffusionary innovations created in British firms. Consistent with the results obtained from the matched UK sample, international innovation collaboration with foreign universities does not show any significant effect for either novel or diffusionary innovations, which raises a very interesting question for future research as to why such international collaborations are set up and why they are not effective.

In summary, the message from Tables 2 to 4 suggests that the role of universities in firm innovation in the UK is consistent with the current received wisdom that they contribute to both novel and diffusionary innovation but their contribution to the creation of innovations which are ground-breaking at world level is greater than that in relation to diffusionary innovation. However, the role of universities in the emerging economies is different. 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

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 constrast to the traditional view that collaboration with universities will lead to greater innovation, a view which is supported by our evidence from the UK, 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 and India, 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 (2010) 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. However, this is not the case in the UK. In the UK, collaborative linkage with domestic university is the only form which contributes significantly to industrial innovations in British firms. Nevertheless, future research should investigate in-depth, in both China and UK, 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. 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.

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Figure 1

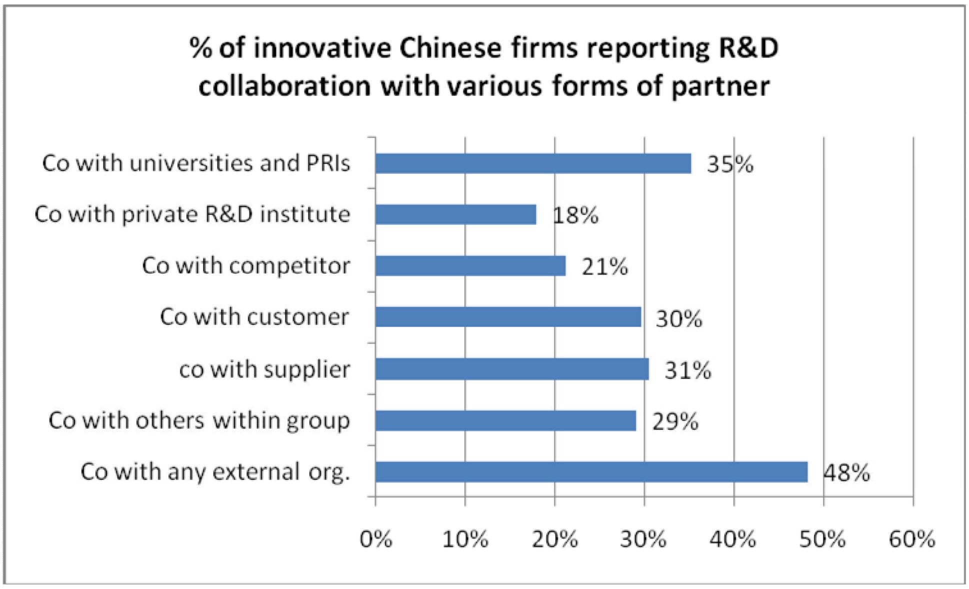


Figure 2

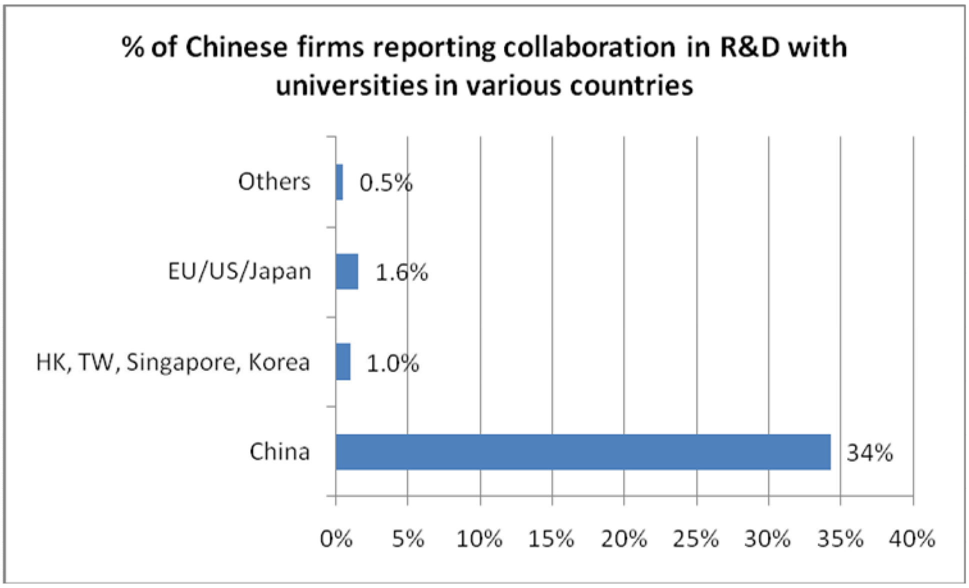
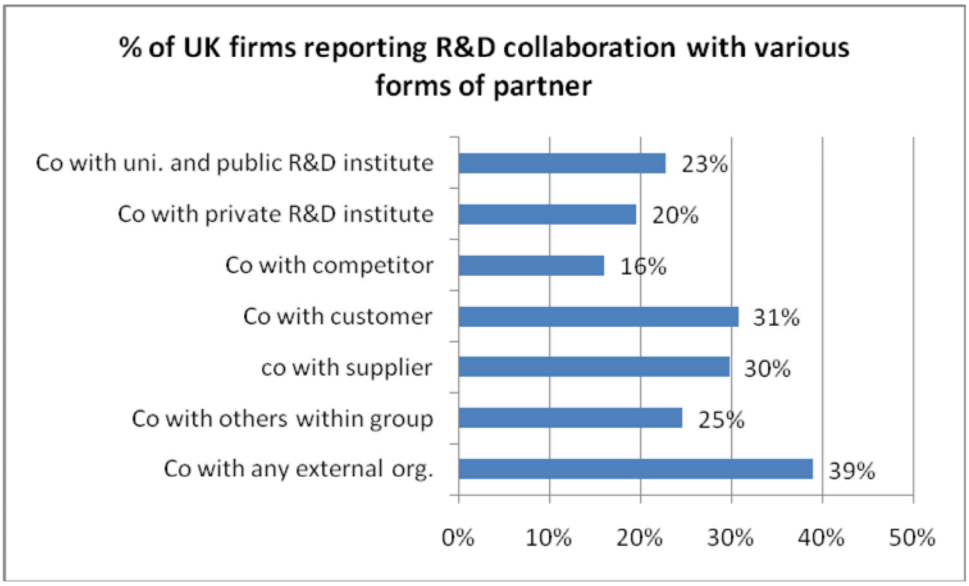
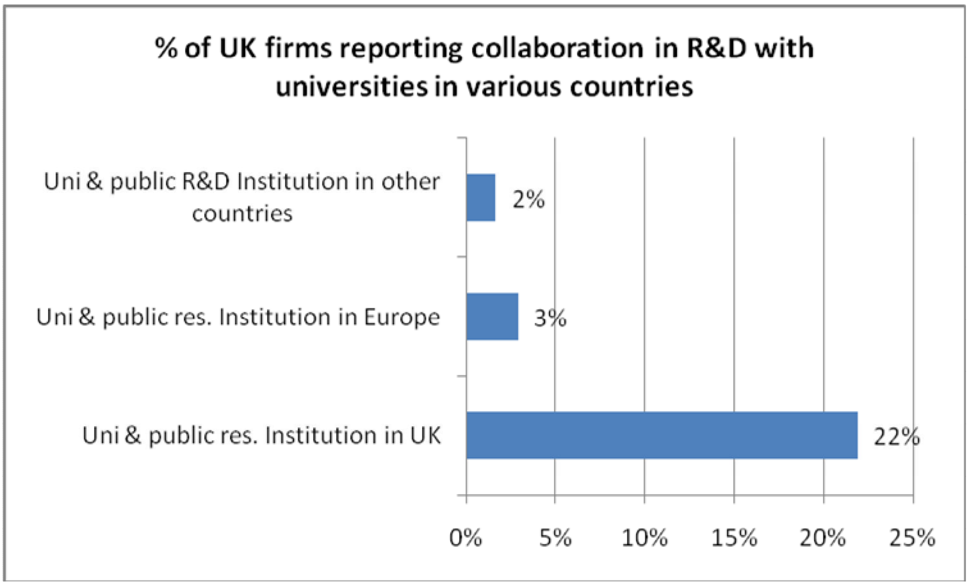


Figure 3



Note: For matched UK sample.

Figure 4



Note: For matched UK sample.

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
age	Firm age	16.890
Size4	Firm size dummy equally 1 for large firm and 0 for small firm.	0.714
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
counid_2	Dummy variable (UK), 1=cooperate with universities and public research institutions (PRIs); 0=no	0.228
couni1_2	Dummy variable (UK), 1=cooperate with universities and PRIs in the UK; 0=no	0.219
couni2_2	Dummy variable (UK), 1=cooperate with universities and PRIs in Europe; 0=no	0.029
couni3_2	Dummy variable (UK), 1=cooperate with universities and PRIs in other countries not listed above; 0=no	0.016

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)
lrdin	2.106**	1.299	1.203	2.949***	3.007***	2.929***
	(0.865)	(0.937)	(0.921)	(0.544)	(0.589)	(0.595)
lrdex		1.623**	1.690***		0.0666	0.0009
		(0.649)	(0.647)		(0.46)	(0.461)
size4	5.967	4.837	3.428	-3.446	-5.144	-5.629
	(5.553)	(5.673)	(5.642)	(3.728)	(3.932)	(3.912)
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)
lack_hc1	-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

VARIABLES	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)
lrdin	0.409*	0.357	0.267	2.308***	2.331***	2.329***
	(0.213)	(0.224)	(0.227)	(0.427)	(0.453)	(0.45)
lrdex		0.105	0.119		0.197	0.108
		(0.185)	(0.184)		(0.363)	(0.363)
size4	0.729	0.856	0.397	-5.874**	-5.220*	-5.732*
	(1.502)	(1.498)	(1.501)	(2.962)	(2.968)	(2.979)
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)
lack_hc1	-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)
lrdin	0.665	0.998	3.637***	3.172***
	(1.085)	(1.012)	(0.744)	(0.66)
lrdex	1.308*	1.523**	0.466	0.164
	(0.763)	(0.751)	(0.545)	(0.518)
age	-0.24	-0.24	-0.00426	-0.0181
	(0.164)	(0.169)	(0.0657)	(0.0661)
size4	3.417	4.733	-4.457	-5.526
	(5.762)	(5.675)	(4.129)	(3.923)
lack_hc1	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)
lrdin	0.429	2.076
	(2.307)	(1.375)
lrdex	0.372	-1.184
	(1.603)	(1.078)
age	-0.673*	0.121
	(0.385)	(0.157)
size4	23.57	-38.92***
	(20.84)	(11.02)
lack_hc1	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.

Table 6. Universities and firm innovation in the UK: standard Tobit model estimates

	Matched sample						Manufacturing full sample					
	Novel innovation			Diffusion innovation			Novel innovation			Diffusion innovation		
	1	2	3	4	5	6	7	8	9	10	11	12
co with other org.	4.514**			1.687			12.92***			13.37***		
	(1.820)			(1.831)			(1.351)			(1.367)		
co with universities		1.641			0.650			9.834***			7.353***	
		(2.128)			(2.392)			(1.685)			(1.803)	
co with domestic uni.			4.754**			1.326			9.613***			6.727***
			(2.222)			(2.337)			(1.733)			(1.850)
co with uni in Europe			-4.584			6.345			0.993			4.638
			(4.061)			(6.681)			(5.001)			(5.559)
co with uni in other countries			-4.08			-3.866			-6.479			-2.601
			(5.586)			(8.057)			(5.432)			(6.643)
lrdin	1.238***	1.060***	1.036***	0.138	0.116	0.13	3.130***	3.121***	3.152***	2.691***	2.814***	2.827***
	(0.275)	(0.284)	(0.281)	(0.261)	(0.275)	(0.2770	(0.214)	(0.222)	(0.222)	(0.202)	(0.207)	(0.207)
lrdex		0.864***	0.873***		0.179	0.13		0.880***	0.904***		0.711***	0.709***
		(0.32)	(0.318)		(0.298)	(0.293)		(0.256)	(0.258)		(0.268)	(0.268)
Size4	-0.511	-0.838	-1.346	-4.283**	-4.272**	-5.184***	-3.525**	-3.807***	-3.804***	-2.550*	-2.419	-2.411
	(1.859)	(1.884)	(1.917)	(1.76)	(1.821)	(1.849)	(1.411)	(1.457)	(1.46)	(1.484)	(1.539)	(1.539)
age	3.535	3.057	2.924	-13.21***	-13.29***	-13.01***	-1.078	-0.893	-1.005	-6.524***	-6.290***	-6.391***
	(3.136)	(3.172)	(3.105)	(4.193)	(4.186)	(4.003)	(1.919)	(1.92)	(1.916)	(2.247)	(2.248)	(2.246)
lack_hc1	0.0986	-0.219	0.19	1.295	1.249	2.222	4.551***	4.298***	4.383***	5.216***	5.143***	5.145***
	(1.737)	(1.734)	(1.725)	(1.685)	(1.689)	(1.676)	(1.139)	(1.14)	(1.143)	(1.175)	(1.18)	(1.185)
Industry dummies	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Constant	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Observations	793	793	793	793	793	793	4,296	4,297	4,297	4,296	4,297	4,297
F	4.665	4.38	2.157	2.242	1.816	1.699	17.35	16.35	15.23	19.03	16.45	15.21
Log Likelihood	(2146	(2144	-2132	-2741	-2741	-2725	-5886	-5907	-5908	-7619	-7652	-7652

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

Appendix 1. Correlation coefficient in the Chinese sample

China	newsal	newsaln	newsald	lrdin	lrdex	co	cogd	cosd	cocd	copd	coprid	counid	couni1	couni2	couni3	couni4
newsal	1															
newsaln	0.2644	1														
newsald	0.877	-0.2169	1													
lrdin	0.2833	0.1081	0.2292	1												
lrdex	0.1475	0.0611	0.1115	0.4035	1											
co	0.1839	0.0558	0.1618	0.3681	0.3194	1										
cogd	0.1504	0.0199	0.1461	0.2651	0.2141	0.5965	1									
cosd	0.1207	0.0409	0.1099	0.2364	0.222	0.6167	0.5988	1								
cocd	0.1444	0.027	0.1409	0.2093	0.1984	0.6033	0.5267	0.6705	1							
copd	0.1089	0.035	0.1041	0.2228	0.2055	0.4852	0.5151	0.635	0.6112	1						
coprid	0.1145	0.0572	0.0834	0.2041	0.2645	0.433	0.4592	0.5493	0.5227	0.557	1					
counid	0.1616	**0.0407**	**0.1352**	0.4018	0.3737	0.7315	0.4151	0.4584	0.4669	0.4329	0.4476	1				
couni1	0.1643	**0.0325**	**0.1421**	0.397	0.3645	0.7224	0.4047	0.4537	0.462	0.4302	0.4319	0.9876	1			
couni2	0.0388	**0.0763**	**-0.0005**	0.0386	0.0817	0.08	0.0855	0.0804	0.0819	0.1389	0.13	0.1094	0.0633	1		
couni3	0.0389	**0.0895**	**-0.0074**	0.0922	0.1019	0.1037	0.1549	0.1292	0.1313	0.1329	0.0904	0.1417	0.0882	0.2474	1	
couni4	0.0655	**0.1267**	**0.0011**	0.0725	-0.0419	0.0595	0.0671	0.0633	0.0645	0.053	0.0641	0.0813	0.0506	0.1419	0.2229	1

Appendix 2. Correlation coefficient in the matched UK sample

UK	newsal	newsaln	newsald	lrdin	lrdex	co	cogd	cosd	cocd	copd	coprid	counid_2	couni1_2	couni2_2	couni3_2
newsal	1														
newsaln	0.4687	1													
newsald	0.5989	-0.0564	1												
lrdin	0.1323	0.1699	0.0552	1											
lrdex	0.1024	0.146	0.0347	0.3939	1										
co	0.0492	0.075	0.014	0.252	0.3145	1									
cogd	0.0573	0.0433	0.0407	0.2423	0.2978	0.7147	1								
cosd	0.0719	0.0772	0.0384	0.2217	0.2766	0.8147	0.6723	1							
cocd	0.054	0.0632	0.0259	0.2066	0.2658	0.8344	0.7233	0.7433	1						
copd	0.0428	0.0277	0.033	0.1275	0.2364	0.5465	0.5731	0.5505	0.5805	1					
coprid	0.0673	0.0155	0.0675	0.2518	0.3782	0.6169	0.5604	0.5973	0.5947	0.5391	1				
counid_2	0.0414	**0.0682**	**0.009**	0.2656	0.3031	0.6806	0.5198	0.5923	0.5879	0.4589	0.6336	1			
couni1_2	0.0518	**0.0774**	**0.0156**	0.2564	0.295	0.6635	0.4968	0.5879	0.5708	0.4581	0.6223	0.9749	1		
couni2_2	0.0109	**-0.0183**	**0.0226**	0.1026	0.1812	0.2163	0.2503	0.2326	0.2267	0.1909	0.2938	0.3178	0.2352	1	
couni3_2	0.0128	**0.01**	**0.0089**	0.158	0.1658	0.1616	0.18	0.1766	0.1721	0.1602	0.2369	0.2374	0.1955	0.4511	1
	UK manufacturing full sample														
counid_2	0.1982	**0.1631**	**0.1585**	0.3204	0.2874	0.675	0.5251	0.5969	0.6049	0.5036	0.634	1			
couni1_2	0.1918	**0.1564**	**0.1541**	0.3119	0.2862	0.6609	0.5079	0.5857	0.5891	0.4943	0.6177	0.9792	1		
couni2_2	0.0755	**0.0575**	**0.0626**	0.1417	0.149	0.2196	0.2215	0.2237	0.2203	0.2142	0.2611	0.3254	0.2367	1	
couni3_2	0.0708	**0.0539**	**0.0588**	0.1436	0.1438	0.1485	0.1599	0.158	0.16	0.153	0.2052	0.22	0.1922	0.3489	1