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# Funding research in universities: do government resources act as a complement or substitute to industry funding?

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## ABSTRACT

The interactions between universities and businesses have become key drivers of today's economic growth and firms' business success. However, a key factor, the existing relationship between government and industry funding, is largely underexplored. This study investigates the relationship between government and industry funding for universities, in the context of developing countries, specifically taking China as a case. We found that there is a substitution effect between the two types of funding and this effect varies from different types of universities. We discuss our findings and draw implications for firms that seek to collaborate with universities.

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## 1. Introduction

There is growing awareness that knowledge is a key driver of economic development, and the institutions associated with fostering knowledge generation and diffusion are regarded as crucial to ensuring sustainable economic success (Hagiú & Yoffie, 2013; Lundvall, 1988). Many studies have demonstrated that high levels of interactions between universities and firms play a vital role in explaining the successful economic performance in the regions where they are located (Cooke, 1992; Gans & Stern, 2010; Saxeninan, 1994). There is a generally accepted belief that universities often undertake longer-term, higher-risk research activities, which constitute an essential contribution to a country's knowledge base and complement the research activities conducted by the private sector (Martin & Salomon, 2003; Mowery & Ziedonis, 2002; Ning et al.,

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2016). In this regard, research on university and business interactions has proliferated in recent decades. Many previous studies have examined the drivers of or barriers to university-industry interactions and business funding for universities (Sharpe, 1991). In terms of the motivations that drive university-industry collaborations and business funding for universities, from the university perspective, the creation of university-industry collaborative interactions may have significant strategic relevance to universities because of their potential as a source of additional funding. From the firm perspective, university-industry interactions may help to reduce high costs of internal research and development (R&D), obtain access to 'state of the art' technology, accelerate new innovations and new product development, and facilitate innovation to meet market demands (Chan & Kanatas, 1985; Chatterji, 1996; Henderson et al., 1998; Leone & Reichstein, 2012; Radnejad et al., 2017; Stiglitz & Weiss, 1981; Tsai & Wang, 2008). Certain firms, especially in the sectors with high knowledge demand, have a considerable interest in continuously cooperating with universities (Lundvall, 2002). On the other hand, researchers have documented many barriers that make industry-university collaborations difficult to achieve (Capwell, 1988; D'Este et al., 2013; Hagi & Yoffie, 2013; Lemley, 1999; Maslach, 2016; Perkmann & Schildt, 2015). Frequently noted barriers include a long geographic distance, cultural and institutional differences, regulatory barriers, and cognitive differences.

However, a key factor, the established relationship between government funding and the funding raised from industry, is largely understudied. It seems that previous studies have mainly assumed that universities are always there and ready to collaborate with firms and to help firms to extract value for their innovation productivity (Giuliani & Arza, 2009; Leydesdorff & Meyer, 2003; Perkmann & Schildt, 2015). This assumption seems questionable. From a theoretical perspective, on the one hand, universities that are funded sufficiently by the government may have a reputation and strengthened capabilities to collaborate with firms to get more funding, meaning that there is a complementary relationship between government and industry funding (Chan & Kanatas, 1985). On the other hand, the incentives of universities that are funded more by the government to collaborate with firms may decrease, illustrating a substitution effect between government and industry funding (Muscio et al., 2012). From a practical perspective, many developed countries have reduced public expenditures for university funding, including the US, the UK, France, Italy and Japan. In contrast, in some developing countries, e.g., China, South Africa and Russia, there is an increase in university funding from the government (Atkinson & Foote, 2019). These controversial theoretical and practical arguments have thus made it necessary to examine the relationship between government and industry funding, particularly in an empirical manner. However, such work is scarce. One exception is the work by Muscio and colleagues (2012), who studied Italian universities, and found that there is a complementary effect between government funding and funding raised through research contracts and consulting activities.

In the light of these arguments, this study intends to contribute to the critical while under-investigated research question of whether government resources act as a complement or substitute for industry funding in universities and how this relationship differs between different types of universities. This study aims to contribute to

the theory and practice. Theoretically, to date, our knowledge about university-business interactions is predominantly limited in developed countries, with little knowledge from developing countries. Theoretical arguments related to these interactions are mainly based on signalling theory and the resource-based view (Chan & Kanatas, 1985; Muscio et al., 2013; Rajan & Winton, 1995). Our work will thus bring novel evidence to this line of inquiry based on the context of a developing country, China, and it will most likely provide new theoretical arguments when taking an institutional view, proven to be the most suitable theory for developing countries, to develop our hypotheses. Practically, our research setting is particularly relevant to firms' innovations and business operations in developing countries. A typical feature of technological innovations is that, compared to their counterparts in developed countries, firms in developing countries often lack internal R&D capabilities and technological accumulation. In many cases, the technological capabilities of firms lag behind those of co-located universities. Thus, firms heavily rely on ideas, knowledge and technology from external sources, particularly local universities (Fu & Gong, 2011; Harzing & Noorderhaven, 2006; Liu, 2005; Mutlu et al., 2015; Ning et al., 2016). Meanwhile, the rapid rise of world-class universities in some developing countries has also attracted many multi-national enterprises (MNEs) to establish R&D facilities for advanced technology in these countries (Ghauri & Rao, 2009; Zhang et al., 2013). Hence, universities, particularly certain newly emerged world-class universities, in some developing countries are important for both domestic and foreign firms, specifically for those performing R &D-oriented activities. Thus, understanding the relationship between industry and government funding to universities has significant implications for firms' collaborative strategy when seeking university knowledge in developing countries. In the empirical analysis, this study takes China, the largest developing country, as a case to investigate the research question.

The remainder of this paper is as follows: [Section 2](#) develops hypotheses and [Section 3](#) describes the data and methods. [Section 4](#) presents the results. The final section summarises and draws implications.

## 2. Theory and hypotheses

We build our hypotheses based on institutional theory. Institutional theory has been widely used, and given that the institutional environment of developing countries are in the process of transition and relatively less stable, it is likely to be more critical to apply it in this context (Li, 2012). The existing research has documented that institutions are the rules of the game, generally shaping actors in these institutional contexts (North, 1990). In reviewing industry-university collaboration, the conclusion is reached that the outcome of different relationships between government and industry funding are largely shaped by specific institutions (Berbegal-Mirabent et al., 2015; Canhoto et al., 2016; Chandrashekhar, 2006; Kerr & Nanda, 2015; Meyer-Krahmer & Schmoch, 1998). The reason is that institutions substantially shape the structure of university awareness, incentives, and capabilities in interaction with firms. As in the case of our study, it may be stated that the stakeholders involved in such interactions often have different motives and behaviours, and operate in different institutional

environments (Han & Chuang, 2015; Mao & Xu, 2014; Taube, 2015; Zhu & Peng, 2012). This situation may lead to distinct relationships pertaining to the industry and government funding in different institutional settings.

Previous studies in this field are mainly limited to Western countries with relatively stable institutional environments. Thus, researchers mainly take the resource-based view as their theoretical background (Grant, 1996; Mowery & Ziedonis, 2015; Muscio et al., 2013; Nelson & Sampat, 2001; Sa & Litwin, 2011; Thune & Gulbrandsen, 2011) and assume that universities will supply knowledge and pools of highly skilled labour to industry and, in turn, industry will offer universities funding to fill the gap left by governments due to increased tightening of expenditures in support of university research. Consequently, they predict that the financial pressure that universities have been subject to will drive universities to seek alternative sources of funding, stimulating university-industry interactions and collaborations. Therefore, these cases mostly take the substitution view of the funding relationship between government and industry funding (i.e., a rise or reduction in government funding will result in a corresponding reduction or rise in industry funding). However, other researchers argue that government and industry funding may act as complement from a signalling and reputational perspective (Avery & Zemsky, 1998; Chan & Kanatas, 1985; Shleifer & Vishny, 1992). Under this assumption, government funding aims to strengthen universities' research capabilities and further produce high-quality research results, which will ultimately become a potential resource for firms, and meanwhile, the funding that universities receive from the government signals the quality of their research to firms, ultimately attracting firms to allocate funding to these universities. Thus, they predict that there is a complementary relationship between government and industry funding.

In this study, we employ a different view, institutional theory, to predict the relationship between government and industry funding. In the context of development countries such as China, we argue that institutional settings may lead us to predict that government funding acts as a substitute for industry funding. We explain this phenomenon based on the following aspects.

First, the funding system for university research in developing universities is usually highly dependent on government fund, and they may show less interest in industry funding due to path dependence, particularly in the case of a rapid increase in government funding to universities. Taking China as a case, since the foundation of the new China in 1949, the Chinese funding system for university research is a typical 'input-orientated' system; resources are first allocated based on the size of the staff or the number of students, particularly, graduate and Ph.D. students. Starting in the mid-1980s, the Chinese funding system began to be reformed and gradually adopted a performance-based system as part of its 'input-orientated' system (Liu & White, 2001). The typical landmark is the establishment of the China National Science Foundation (CNSF) in 1986. Researchers at universities started to compete for research funding on the basis of peer-reviewed project proposals against a set of objectives. In the same year, China issued the '863 Plan', which focussed on a few important high-tech domains by taking advantage of heavy investment by the Chinese central government, with the hope of catching up with developed countries.

The initiative focussed on biotechnology, information technology, new energy, new materials, space technology, laser technology and automatic technology. Similar to NSF projects, scholars from universities, research institutes, and firms can apply for funding for '863 Plan' projects. In 1997, China started its National Key Basic Research and Development Plan (the so-called '973 Plan'). The purpose of this programme was to improve China's basic research capability at the global frontiers of science. Chinese universities have become a dominant player in this plan. In recent years, China has initiated its 'indigenous innovation' strategy and, in parallel, expanded its investment in university funding (Heald, 1993). These actions have led to the prospect of China's government funding to universities; for instance, according to Chinese statistics, the growth rate of government funding for universities between 2001 and 2012 was 20.8%. The funding system becomes competitive but only within the university community, which is still characterised as a central planned system. An unexpected result, possibly due to the path dependent effect, is that it is difficult for universities to change their perceived old model (Liu & White, 2001). Naturally, this is also a response to China's ambitious aim to make China a strong innovative nation (Capwell, 1988; Heald, 1993). This seems logical because, in China, due to the weak innovative capability of firms compared to their counterparts in advanced economies and domestic universities, universities have apparently become the core driver in helping the government realise its strategic goal, i.e., being one of the most innovative countries in the world. Hence, this special institutional environment for university funding makes universities more reliant on government resources.

Second, for developing economies, there is a large gap between the supply of university scientific knowledge and industry demands. Most firms in developing countries often demonstrate weak technological capabilities and mainly focus on traditional, middle- and low-tech industries (Fu et al., 2011). Thus, instead of directly obtaining advanced technology from universities, most firms resort to universities to better understand foreign imported relatively mature technology to help them absorb the technology and to make the use of foreign imported technology more efficiently (Nguyen, 2007). Meanwhile, to save cost, firms in developing countries might reduce the expenditure on research and development with universities, and could not well acknowledge and protect intellectual property and technology. Although the Chinese government has called for indigenous innovations, the overall innovative capability and the level of technology in developing countries remain not as advanced as the developed countries, which lead to the relatively low industrial demand on domestic university technology corporation and transfer. Being confined by the low demand of industry, domestic universities might have less motivations to cooperate with firms and would rather spend more time and financial resources to secure funding from the government than from industry.

Third, the innovation chain, from scientific research, technology development, and industrial applications among universities, research institutes, and firms in developing countries, has been cut. Due to historical reasons and developmental reasons, universities in developing countries may have to learn and depend on the support from the advanced universities in developed countries, and it is usually very hard for universities to develop a comprehensive innovation chain, which is a severe issue in China.



Over a long period of time, China adopted the structure of its innovation system from the former Soviet Union, which divides innovation efforts into research at universities, experiment and technology development at research institutes, and technology application within industry. Close collaborations among universities, research institutions and industry are the precondition for this innovation system. However, due to the institutional reforms since the 1990s, the role of research institutes has been reoriented to make them important market actors, and they were assumed to be able to collect resources from markets instead of obtaining resources via the traditional method of relying on government financing. As a result, except for a few research institutes, most Chinese research institutes were dropped from the government funding system and were transformed into enterprises. Thus, this reform has hurt research institutes' transition capabilities in the Chinese innovation system and consequently leaves a gap between universities and industry. Currently, although the Chinese government has realised this problem and has tried to bridge this gap by strengthening universities' technology transfer capabilities, time is also needed for universities to learn and fill this gap if they are willing.

Fourth, the research assessment system for government funding competition impedes university researchers from collaborating with industry. Research assessment, geared towards article publications, project applications, and patent applications, has become a common problem in Chinese universities and universities in some other developing countries. In particular, in elite Chinese universities, the academic results of researchers have been dramatically highlighted by university administrators for promotion, income, and work evaluation. This mechanism results in less motivation for researchers at universities to collaborate with industry – either to transfer their technology to firms or to conduct joint research. Simultaneously, the emphasis on the publication of scholarly papers and patent applications make the technology developed at universities far removed from commercialisation, which may further prevent industry from collaborating with universities. Combining these factors, we thus predict the following:

**H1:** There is a substitution effect between government funding and industry funding to universities in the context of China.

In order to catch up with the global top universities in advanced countries, the governments in developing countries usually could not fund all the universities, and one strategy is to introduce policy and implement strategy by raising the research standards of selected universities and fund these universities. According to the Matthew effect, after getting more government funding every year, there will be a concentration of resources and talents, and an ongoing cumulative advantage in particular universities, because of the signalling effect of the government funding regarding the innovation competitiveness of the universities (Merton, 1968). Early success in acquiring government funding usually leads to later successes in financing and research as these universities grow, while failing to acquire government funding may be indicative of life-long problems in the development of the universities. In this situation, some universities have intensified the demand and maximised their capability of obtaining governmental funding, which may also lead to a crowding-out effect for industry funding. This Matthew effect also reduces the demand for industry funding,



and exacerbates the education inequality. High level universities have less willingness and demand to collaborate with firms and acquire industrial funding. Whereas, lower level universities may need more industrial support, while they are usually less valued and often neglected by firms, which leads to low level of industrial funding supply (Azoulay et al., 2014).

Without exception, as discussed above, a main feature of the Chinese funding system to universities is that government funding dominates the system, whereas universities are not equally treated in terms of the funding. With this intent, the Chinese government has been choosing approximately 100 universities first, followed by another 30 universities, to invest additional funding in them (Capwell, 1988). In other words, the specific amount of resources that Chinese universities have obtained from the government is mostly decided by their status or ranking among all universities. Thus, there is reason to believe that this main effect of government funding on industry funding has boundary conditions, for example, the types of universities. Here, we focus on the well-known and officially authorised types of universities (such as a ranking system mainly based on universities' strength in science and research), the '211 Project' or '985 Project' ranking system.

The '211 Project' is the Chinese government's primary endeavour aimed at strengthening 100 universities and key disciplinary areas as a national priority for the 21st century. When a university is selected to be part of the '211 Project,' a large amount of money is annually invested by the Chinese government. It is a clear 'input-orientated' system, which is largely dominated by the Chinese government and which simultaneously favours '211 Project' universities while neglects universities that do not belong to the '211 Project' tier. This group of '211 Project' universities accounts for only 5% of Chinese universities, but the total funding for the universities in this group takes more than 70% of Chinese funding resources.

The '985 Project' was launched as a strengthened version of the '211 Project,' focussing on a smaller group and a limited number of first-rate universities of advanced international stature in the '211 Project' group, which made the Chinese university funding system become extremely uneven. This project was divided into two stages. In the initial stage, nine universities were selected from the top 20 Chinese universities. Grants of more than 700 million (RMB), distributed over a three-year period, were given to each of these nine universities. In the second stage, this programme was expanded and now includes 39 universities, most of which receive millions to billions each year.

A serious result of the funding allocation being dominated by the government is the uneven distribution of Chinese research funding for universities. There is a large gap between '211 Project' universities and non-'211 Project' universities. For instance, in 2013, the highest-ranking university (Tsinghua University) in the '985 Project' group received 23 times larger amount of funding than the amount received by the highest-ranking university (Southwest Petroleum University) in the non-'211 Project' group. Within the '211 Project' group, government funding for '985 Project' universities is larger than that for non-'985 project' universities. Therefore, the pyramid structure of China's government funding system, dominated by only a few leading and advanced universities, may generate between-group differences regarding the

**Table 1.** University distributions in annual reports and sample selection.

Year	Number of universities in annual reports	Number of sampled universities
2009	718	619
2010	997	684
2011	969	925
2012	790	771
2013	1,040	777
2014	1,076	1,007
2015	1,152	1,051
2016	1,500	1,123
2017	1,815	1,451
2018	1,942	1,678

industry-government funding relationship. Specifically, universities grouped in the ‘211 Project’, particularly those in the ‘985 Project’, may have sufficient funding from the government and therefore may lose their interest in collecting funding from industry. However, the universities that are not part of the ‘211 Project’ may have to increase their funding through industry. Thus, this situation leads us to predict that the relationship between Chinese government and industry funding may be mediated by university types, which leads us to hypothesise the following:

**H2:** The substitution effect is mediated by the types of universities, i.e., it may be stronger in top-tier universities, but weaker or even inexistent in lower-level universities.

### 3. Data and methods

#### 3.1. Data sources and sample selection

We use a unique dataset compiled by the Chinese Ministry of Education. Since 1994, China has issued an official annual report, the Chinese University Science and Technology (S and T) Development Annual Report (Gaodeng Xuexiao Keji Tongji Ziliao Huibian). This report is the only report currently available regarding university funding. It is a comprehensive statistical report that contains specific research information on Chinese universities. Using this annual report, we can find basic information on many university research activities, such as the number of personnel and staff; the amount of funding from the government, industry and technology transfer; the number of research projects, published papers and books; the number of patent applications; and the number of research institutes at each university.

The number of universities collected in these annual reports varies from year to year (see Table 1). All ‘211 Project’ universities (including ‘985 Project’ universities) and the larger group of government-supported universities are included. Some smaller and privately financed universities are selected for inclusion in the annual reports. This dataset has primarily been used in prior studies (Zhang et al., 2013).

As Chinese universities have experienced a rapid development, to account for the changing situation, we attempt to cover a relatively longer time range. Based on the data availability, this study focuses on universities during the 2009–2018 period as the sample in the study. Due to the merger of universities, university renaming, and university closings during the sample period, we arrange the universities in the sample based on their names in 2018. In the case of mergers, we combine the values of

the indicators. For the renamed universities, we standardise their names based on their names during the study period. For the universities that ceased operations, we keep their records but omit them in the later years. For the universities that were simultaneously merged and renamed, we aggregate the values of the relevant indicators before their merger as one sample university, shown in the dataset by the new name. After the data cleaning, the final distribution of the universities in our study sample is presented in [Table 1](#).

### **3.2. Variable measurements**

To test the relationship between industry and government funding to universities, we operationalise the dependent variable, F-industry, as the total amount of money that a university obtains from collaborations with industry. Similarly, we define our main independent variable, F-government, as an indicator of government funding, that is, the volume of money that a university received from the Chinese government.

Several factors are included as controls. First, using the number of teaching and research staff at a university, we control for university size (e.g. Zhang et al., 2013). Second, following the work of Wang et al. (2016) using the number of published papers and awards in the observed year, we control for a university's research capability. Third, we control for a university's supportiveness of its technology transfer facility by using a dummy variable for whether the university owns a science park. This factor is chosen because science parks are an important institutional innovation for facilitating university-industry collaboration, possibly influencing a university's capacity to collect research funding from the government or industry (Salvador & Rolfo, 2011). Fourth, a university's R&D expenditure in each year is controlled, as in some of the existing literature (Zhang et al., 2013). Fifth, we control for a university's professional type. Chinese universities have been categorised into different types (e.g., international research university, Chinese research university, regional research university, disciplinary research university and specialty university). Five dummy variables are created, and the specialty university is omitted as the reference group. This categorisation is based on the combined research potential and demonstrated capability in support of social development as well as the university's main domain in science. Different types of universities may present different preferences for government or industry funding. This university type is controlled, as in some of the previous literature (e.g. Muscio et al., 2013). Sixth, we control for university location by using three dummy variables: Eastern, Central and Western China. Seventh, due to China's rapid transition, we include year dummies to reflect factors from the Chinese macro level, such as institutional changes. Thus, we include dummy years in our analyses and omit 2009 as the baseline year. Finally, to account for the influence of past experience in obtaining industry funding, we introduce a 1-year lag of the dependent variable. This control also aims to investigate whether evidence of an accumulation advantage emerges along the lines of the Matthew effect argument.

We included a one-year lag of the dependent variable as an additional explanatory variable; thus, our data structure becomes a dynamic panel, indicating that the independent variables are not strictly exogenously correlated with past values and that the

**Table 2.** Descriptive statistics and correlations.

Variable	Mean	S.D.	Min	Max	1	2	3	4	5	6
1. F-industry	27.008	76.824	0.000	463.544	1.000					
2. F-government	60.263	162.749	0.000	1051.202	0.788	1.000				
3. No. staff	796.607	1221.335	14.000	7813.000	0.571	0.703	1.000			
4. No. published paper	724.907	1286.577	0.000	7761.000	0.772	0.860	0.838	1.000		
5. No. award	4.532	9.590	0.000	54.000	0.714	0.731	0.749	0.811	1.000	
6. Science park	0.105	0.307	0.000	1.000	0.635	0.604	0.467	0.615	0.568	1.000
7. R&D expenditure	61.859	166.749	0.000	1041.554	0.909	0.924	0.658	0.859	0.762	0.652

Note: a. The monetary unit is million Yuan (RMB). b. Dummies for university types, university locations and years are not included.

possibility of error exists. Meanwhile, we find that our panel comprises only a few time periods (six) but many individual observations years (hundreds) (Greene, 2003). In this case, the generalised method of moments (GMM) is recommended (Yang & Li, 2011). Compared to a fixed-effect panel, a random-effect panel and pooled OLS regressions, GMM also resolves the problem of university-specific effects, any potential endogeneity of all of the explanatory variables and the problem caused by the lack of good external instruments in the model; thus, the GMM approach provides more robust estimation results. In Stata 13.0, the `xtabond2` command is used (Stadler et al., 2014).

#### 4. Results

Table 2 presents the descriptive statistics and correlations. Except for a few higher correlations, e.g., the correlation between the number of published papers and the number of staff members (0.838), most correlations are moderately low, indicating that the collinearity among the main variables is low. Furthermore, a variance inflation factor (VIF) test indicates that the highest VIF is 6.96, which is lower than the critical threshold value of 10 (Chatterjee & Price, 1991). As the descriptive statistics for the variables indicate, the universities in the sample differ significantly in terms of government funding and industry funding. In addition, F-Government correlates positively with No. staff, No. published papers, No. awards, Science Park and R&D expenditure.

In Table 3, the total sample is divided into two parts according to the number of publications. Universities in the fewer publication group can only acquire about 3.053 million government funding while universities in the more publication group acquire 117.179 million funding. The difference between two groups is statistically significant at the 1% level, illustrating that more publication is associated with larger amount of government funding.

Table 4 reports the estimation results based on GMM estimation, where the F-industry and F-government variables are set as endogenous whereas the others are set as exogenous variables. The AR (2) and Hansen tests show that all p-values are greater than 0.05, which indicates that our modelling choices are appropriate. The F-test statistics for all models are equal to 0, suggesting that our estimated models fit our data very well at the aggregate level.

Model 1 in Table 4 reports the results of a regression that includes only the control variables. Our key explanatory variable, F-government, enters sequentially in

**Table 3.** Government funding between different universities.

Variables	Fewer publications		More publications		MeanDiff
	N	Mean	N	Mean	
F-Government	5,030	3.053	5,056	117.179	-114.126***

Note: \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.1$ .

**Table 4.** Regression results based on GMM estimation (P12).

Variables	Model 1 F-industry	Model 2 F-industry	Model 3 F-industry	Model 4 F-industry	Model 5 F-industry
Constant	-4.692 (-0.215)	-0.647* (-1.719)	-1.554 (-0.787)	0.148 (0.449)	-0.300 (-0.654)
F-industry(-1)	0.334*** (4.788)	0.708*** (50.472)	0.561*** (11.512)	0.709*** (95.706)	0.341*** (3.106)
No. staff	-1.691*** (-3.717)	-0.032* (-1.941)	0.056 (0.373)	0.018 (0.823)	-0.229* (-1.855)
No. published paper	0.346*** (2.768)	0.024 (1.262)	0.274*** (3.156)	0.085*** (10.687)	-0.208** (-2.022)
No. award	0.112* (1.700)	0.035* (1.668)	-0.030 (-0.457)	-0.041*** (-5.339)	-0.010 (-0.108)
Science park	-0.032 (-0.012)	0.993*** (5.861)	-2.526** (-2.203)	0.936*** (6.865)	0.382 (0.935)
R&D expenditure	0.184* (1.790)	0.310*** (17.110)	0.294*** (2.989)	0.208*** (23.298)	1.089*** (5.454)
F-government		-0.112*** (-6.214)	-0.173** (-2.400)	-0.166*** (-19.690)	-0.172 (-1.266)
Observations	10,086	10,086	417	1,025	9,061
AR(1) ( $p$ -value)	0.005	0.000	0.000	0.001	0.000
AR(2) ( $p$ -value)	0.995	0.828	0.804	0.855	0.667
Hansen ( $p$ -value)	0.646	0.0609	1.000	0.529	0.195
F ( $p$ -value)	0.000	0.000	0.000	0.000	0.000

Note: Robust standard errors in parentheses; \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.1$ ; dummy variables are included but are not shown.

Model 2. In Model 2, using the full sample, it is found that the coefficient for government funding is negative and significant. This finding supports Hypothesis 1, indicating that there is a substitutive relationship between government and industry funding. In other words, the finding illustrates that, in China, with the increase in Chinese government investment in university research in recent years, universities have generally become less involved with industry, particularly in activities related to collaborative research and contract research. Government funding thus demonstrates a 'crowding-out effect' on industry funding.

To test the moderating effect of the university grouping status (i.e., Hypothesis 2), we split our sample into three groups: first-tier, second-tier and third-tier universities, namely '985 Project', '211 Project' but non-'985', and non-'211' universities. Sequentially, the regression results are presented in Models 3–5 in Table 2. In Model 3 that is based on the sample of '985 Project' universities, the coefficient of F-government is negative and significant, which is similar to the result in Model 2. This finding is consistent with our expectation that the more advanced a university is, the less likely it is to raise funding from industry. Model 4 is based on the sample of '211 Project' but non-'985' universities. It is found that, although the coefficient of F-government is negative and significant, the coefficient has become -0.166, a smaller negative effect compare with -0.173 in Model 3. This finding illustrates that

the substitutive relationship between government and industry funding seems relatively weaker in the second-tier universities, compared to that in the first-tier universities.

In Model 5, for the group of universities that are non-‘211 Project’, we find that the coefficient of government funding becomes insignificant. This finding shows that, for this group of universities, government funding has no effect on its capability to collect industry funding. It also signifies that the amount of government financial support is not a concern when industry firms decide to undertake research collaborations with universities in this tier. Taken together, we find that Hypothesis 2 is supported, illustrating that the relationship between government and industry funding differs in different types of universities. The less advanced an institution is, the weaker the relationship is. This finding is consistent with the research of Chen and Kenney (2007), who find that universities with less research capabilities demonstrate less reliance on government funding when seeking industry funding.

As expected, there is some path dependence in terms of accessing industry funding. For all models (Models 1–5), the coefficients of the independent variable of the industry funding in the previous year are positive and highly significant. In other words, accessing industry funding increases the volume of funding from industry in the future, which is consistent with the existence of a Matthew effect accumulation. This finding is also consistent with certain previous studies, which state that the institutions that have already collaborated with universities are more likely to be involved in overall technology transfer and other types of collaborations (e.g., Arvanitis et al., 2008).

## 5. Discussion and conclusion

The interactions between universities and businesses have become central in today’s economic development. In relative terms, research has proliferated in recent decades (Bevc & Uršič, 2008; Maresova & Kuca, 2019). Among these studies, a major factor, i.e., the existing relationship between government and industry funding, has been widely overlooked when scholars seek to understand the factors that drive the interactions between universities and businesses. Thus, this study aims to strengthen our understanding of this issue in the context of developing countries. Using a dataset based on Chinese universities, we investigate the relationship between government and industry funding of universities. It is found that there is a substitution effect in Chinese universities, meaning that an increase in government funding makes universities less inclined to pursue industry funding sources, and this relationship differs among different types of universities.

Our finding contradicts the result of Muscio et al. (2013), who support the dominance of the complementarity effect over the substitution effect based on the Italian case (Aulakh et al., 2010; Martin & Salomon, 2003; Thursby & Thursby, 2011; Zhu & Peng, 2012). One main reason for this difference may be due to the difference in the institutional context between developing countries, and developed countries. Developing countries’ funding system for universities may make universities more reliant on funding from the government, and firms in the relatively lower technology

industries show less demand for knowledge from domestic universities than importing technology from abroad. Again, the innovation system in many developing countries, research institutes, traditionally defined as the bridge between the scientific research of universities and the commercialisation of firms, may have weakened their role in technology development and product design due to that. the lacking of industrial demand. Thus, more time is needed for universities to learn and ultimately fill the gap that left behind by research institutes. Moreover, heavily academic-orientated assessment system in some developing countries' universities also makes researchers reluctant to collaborate with firms. All of these arguments, from an institutional perspective, thus complement to the arguments of Western researchers from the resource-based view or signalling theory (Muscio et al., 2013; Rajan & Winton, 1995; Shleifer & Vishny, 1992). Therefore, we state that the resource-based view and signalling theory both somehow reflect the mechanisms in a mature market economy in which a stable institutional environment holds. When the scenario shifts to developing countries with an unstable institutional setting, the relationship between government and industry funding is most likely driven by the country's specific institutions. The nature of the government and industry funding relationship is thus a contextual phenomenon in general.

Thus, our findings offer several implications for firms. First, we suggest that, in general, Chinese universities may not be very interested in collaboration with firms for direct reward, i.e., financial resources. Therefore, firms need to change their collaboration strategies from directly buying or licencing technology and technical services to some relational and long-term activities, for example, joint research. This is particularly true for foreign firms that target the advanced technology of China's elite universities. Second, in some cases in which firms have to choose to collaborate with universities, particularly for short-term or quasi-market activities, all things being equal, firms choose universities with weaker research capabilities, which may increase the success rate because these universities demonstrate preferences for research funding from industry. Collaborating with universities with a relatively weak capability in research and technology may be appropriate for developing Chinese firms because they typically focus on middle- and low-technology fields. Finally, firms need to have a portfolio strategy when seeking to collaborate with universities; for example, they may make plans for specific technological and innovation activities, particularly matching the stage of firm development with the research capabilities of various universities. In short, we suggest that the need for policy makers to change the funding systems and academic assessment system of universities to remove the barriers to knowledge transfer from universities to the business sector is significantly obvious, and thus, firms in turn can be able to deepen and extend their collaboration with universities to purposively benefit from university research.

We acknowledge two limitations and future research directions. First, this study investigate research question, in the context of developing countries by taking the biggest developing country as a case, while future studies may extend the research to the context of other developing countries with commonalities and differences in terms of the funding and academic assessment systems, and thus can further testify the findings in this study and draw implications for firms operating in developing



countries. Second, this study investigates the relationship between government and industry funding from an input perspective, but whether government funding and industry funding result in different university research outputs is unknown because it is possible that government funding substitutes for industry funding and simultaneously makes the university research more productive than industry funding.

### Disclosure statement

No potential conflict of interest was reported by the author(s).

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