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Does Higher Education Promote Firm Innovation in China?

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Received: 8 August 2020; Accepted: 27 August 2020; Published: 7 September 2020

Abstract: Endogenous growth theories have underpinned the pivotal role of education in innovation. However, our empirical study uncovers a mixed effect of higher education on firm innovation in China. Using Chinese Patent Census Data, a unique dataset, this paper is able to quantify innovation in China by incorporating a quality dimension for the first time. By merging the patent data with the Chinese Industrial Enterprise Database and province-level data on education, we find that the number of higher education institutions has a negative impact on firm-level innovation. However, the quantity of elite higher education institutions at the provincial level exerts a positive impact on firm innovation. In addition, heterogeneity analyses show that the effect of elite higher education on firm innovation is significantly positive for privately owned enterprises, but insignificant for state- and foreign-owned enterprises. Furthermore, the positive effect of elite higher education on innovation in high-tech industries is larger than in other industries.

Keywords: higher education; elite higher education; innovation; state-owned enterprises; high-tech industry

1. Introduction

In the competitive global marketplace, innovation is viewed as a key driver of competitiveness, both at micro and macro levels [1]. As an important source of innovation, education provides a significant contribution toward improving the knowledge base and creativity of the workforce [2–4], as well as being necessary for inspiring new technologies [5].

Endogenous growth theories have underpinned the pivotal role of education in promoting innovation [6–8]. However, previous empirical studies have mainly focused on the relationship between the education levels of employees and firm innovation [9–11], while studies on the impact of higher education (post-secondary education) at the macro level are scarce [12].

Firm-level innovation is not only affected by the education of employees, but also by external factors such as the number of colleges and universities. Firm innovation is often based on concepts and applications originating from basic research conducted in universities [13]. Therefore, it is also important to examine the impact of education at an aggregated level.

Since the beginning of the 21st century, both higher education and innovation in China have undergone rapid expansion. The average annual growth rate of the number of regular higher education
The number of new student enrollments at regular higher education institutions also saw an upsurge since 1998 [14]. The annual growth rate of patent counts was 12.77% during the period of 1985–2000 and 20.73% during 2000–2018 [15].

The development of education in China has benefited from a series of government policies. In 1995, in the Decision on Accelerating the Advancement of Science and Technology, the Chinese government first proposed the implementation of the Strategy of Developing the Country through Science and Education, emphasizing the fundamental role of education in stimulating innovation. In the same year, as one of the key measures of the strategy, the Chinese government launched the “211 Project”, focused on the development of around 100 colleges and universities and a number of key disciplines. In 1999, with the aim of building a number of world-class universities, the Chinese government commenced the “985 Project”, focused on developing 39 top universities in China. Meanwhile, the Ministry of Education of China issued the Action Plan for Education Promotion for the 21st Century, which proposed higher education reform with “university expansion” at its core, resulting in an acceleration in the growth of the number of regular institutions of higher education. Based on data from the National Bureau of Statistics (NBS) of China and the U.S. Census Bureau, the ratio of the number of people with higher education in China to that in the United States has increased sharply, from 44.92% in 2000 to 94.48% in 2010. On the other hand, data from the World Intellectual Property Organization [15] have shown that China rose to the top of the world rankings in terms of the number of patent applications in 2011.

The aim of this study is to examine the role of higher education, especially elite higher education, in improving firm-level innovation in China. Elite higher education is measured by the number of universities under the direct administration of the central government or in the “211 Project”. This study makes four important contributions to the literature: First, it represents the first empirical analysis of the impact of macro-level higher education on firm innovation and is the first paper using the Chinese Patent Census Database to identify innovation quality, which is measured through the number of patent claims. Second, we find that the quantity of higher education institutions plays a negative role in promoting firm innovation, in contradiction with the predictions of endogenous growth theories. Third, we find that this negative impact mainly comes from non-elite institutions, while elite higher education has a positive effect on firm innovation. Fourth, we find that elite higher education promotes innovation in privately owned enterprises (POEs), but not in state-owned enterprises (SOEs) or foreign-owned enterprises (FOEs).

The rest of the paper is organized as follows: Section 2 reviews the relevant literature. Section 3 introduces the data (including our unique patent data) and the empirical methodology. Section 4 analyzes the empirical results. Section 5 conducts a series of heterogeneity analyses and discusses several new findings. The implications for theories and managerial practices are presented in the concluding Section 6.

2. Literature Review

The relevant literature on education mainly focuses on the impact of education on income or economic growth [16–20].

There have also been some empirical studies examining the impact of micro-level education on firm innovation, such as the education of CEOs or other employees. Using data from the Study of Competitiveness, Technology, & Firm Linkage and the Investment Climate Survey conducted by the World Bank from 2002 and 2003, respectively, Sun et al. [11] pointed out that, in China, the education level of the management team significantly improved the number of patents of a firm. Schneider et al. [9] found that product innovation activities were above average in departments with employees with higher academic qualifications.

However, Koroglu and Eceral [21] found that the proportion of employees with university degrees had no significant effect on the number of patents of firms in Ankara’s defense and aviation industries. Benhabib and Spiegel [22] pointed out that the growth-enhancing margin was derived only from
human capital with higher educational qualifications, rather than from total human capital. Some scholars have found evidence of the promotion effect of human capital with higher education on total factor productivity in high-income countries, but not in low-income countries [23].

In short, the methodology used in the above literature was multiple linear regression, where the explanatory variable was micro-level education. To date, evidence regarding the impact of education on innovation has been mixed [24]. One reason for this may be that studies based on micro-level education cannot cover the impact of education outside the firm, which is very important, considering the prevalence of research and development (R&D) outsourcing, co-operation with universities and scientific research institutions, and other types of knowledge communication and spillovers. Therefore, it is necessary to investigate the impact of education at the macro level. To the best of our knowledge, there have been no previous studies analyzing the impact of macro-level higher education on firm innovation.

Macro-level higher education is one of the important factors affecting firm innovation. First, university–enterprise joint projects and ventures, academic conferences, and professional training for enterprise employees serve to promote firm innovation [25,26]. Second, universities can provide firms with highly skilled personnel [27,28]. In fact, most high-tech development zones in China are located in cities with many universities and scientific research institutions, especially excellent ones.

3. Methodology and Data

3.1. Methodology

Econometric models are typically employed when exploring the causal relationships between education and income, firm innovation, or corporate financial performance [1,10,17,24]. To explore the causal relationship between higher education and firm innovation, with reference to the previous studies listed above, we developed the following econometric model to investigate the impact of higher education on firm innovation:

$$Y_{it} = \alpha_0 + \alpha_1 \text{HigherEdu}_{it} + \alpha_2 X_{it} + a_i + b_t + \gamma_{ind} + \epsilon_{it}, \quad (1)$$

where the dependent variable $Y_{it}$ represents the level of innovation of firm $i$ in year $t$, including innovation quantity and innovation quality; and $\text{HigherEdu}_{it}$ denotes the level of higher education in the province where firm $i$ is located in year $t$.

The methodology used is multiple linear regression. We employed a fixed-effect model. To alleviate possible endogeneity issues, we used a two-way fixed-effects model, in which $a_i$ represents the firm’s fixed effects and $b_t$ represents yearly fixed effects. To control for the innovation gap among industries, we further added two-digit industry fixed effects $\gamma_{ind}$. The Stata 15 software (StataCorp LLC, Texas, USA) was utilized to handle the data and carry out the regressions.

$X_{it}$ is a series of control variables that may affect firm innovation. On the basis of our data sets and the innovation literature, we selected five control variables: (1) firm size ($\text{Size}$) [29]; (2) value of firm exports [30,31]; (3) firm age ($\text{Age}$) [29]; (4) capital intensity ($\text{Intensity}$), in general, compared to labor-intensive industries such as food and textiles, capital-intensive industries such as chemical and telecommunications industries usually account for a greater proportion of total patents applied or granted. As a result, firms with a higher capital intensity may generate more patents than those with a lower capital intensity; and (5) firm ownership ($\text{Ownership}$). State-owned enterprises are usually considered to have low innovation efficiency, compared to other types of firms [32]. Finally, $\alpha_0$ is the intercept term and $\epsilon_{it}$ is the error term.

To calculate firm innovation, we matched the Chinese Industrial Enterprise Database (1995–2013) with the Chinese Patent Census Database (1991–2018), using firm name as the linking variable. Considering the possible irregularity of firm names, we conducted some treatments for firm names before matching. The Chinese Patent Census Database was obtained from the State Intellectual Property Office of China, which contains more than 22.13 million patent publications. We thank TEKGLORY
Co., Ltd. for providing the original patent data. The Chinese Industrial Enterprise data is annually collected by the NBS of China, covering all state-owned industrial enterprises and non-state-owned industrial enterprises above a designated size. The $a_i$ and $X_i$ values, at the firm level, were taken from the Chinese Industrial Enterprise Database.

Education variables at the provincial level were collected from the EPS Database [33]. Education variables are matched with the Chinese Industrial Enterprise Database, based on the province where the firm is located. Therefore, the final data set we obtained was provincial-level panel data from the period of 1995–2013.

3.2. Variables and Data

3.2.1. Firm Innovation

There are three main steps in relation to patents in China: application, publication, and authorization. The data used in this study include only published patents and do not include patents that had not been published after application. The Chinese Patent Census Database we used was unique, as it is the first to include indicators of innovation quality, such as patent citations and patent claims, which were not included in the versions of the Chinese Patent Census Database used in other studies [34–36].

The three types of patents in China are industrial design, utility model, and invention patents, all of which are included in our patent database. In general, invention patents, which require strict examination, are of the highest quality. The proportions of industrial design, utility model, and invention patents with citations are 0.02%, 23.44%, and 30.13%, respectively. Therefore, we focused on invention patents and, hereafter, the term “patent” refers to an invention patent.

We constructed two indicators to measure firm innovation. The first was innovation quantity ($IN_{qn}$), defined as the total number of patents of a firm in a certain year. The number of patents of a firm has frequently been used to measure the level of innovation of a firm [34–36]. However, quality varies among patents, which must also be taken into account if we are to measure innovation in a more proper way [37,38]. Patents with more claims have higher quality [39,40]. Therefore, we further constructed a second indicator of innovation: innovation quality ($IN_{ql}$), which was measured as the claim-weighted patent quantity, following [41].

Some studies have also used the number of patent citations to measure patent quality [42,43]. However, there are truncation issues in relation to patent citations [44]. Furthermore, there were numerous patents without citations, resulting in large numbers of missing values for the dependent variable. In brief, the claim-weighted patent quantity might be a more appropriate measure of innovation quality.

3.2.2. Education

To capture the impact of higher education, we constructed three indicators: First, we calculated $HigherEdu$ using the number of colleges and universities in each province. As a robustness test, we also used the number of graduates from colleges and universities to measure $HigherEdu$. These two indicators are often used to measure the higher education resources available in a region [45].

Second, we computed elite higher education2 using two indicators. $Elite$ 1 was measured by the number of colleges and universities under the direct administration of the central government (hereafter, “central university”). There are 124 central universities, which were expected to take the lead in educational reform and play a leading role in improving teaching quality, promoting scientific research, and serving society. These colleges and universities must be the first to respond to the national education policies and major national strategies proposed by the central government. For example, the Chinese government decided to include innovation factors in relation to education in their higher education reforms of 2010, and the central universities were used as pilots. Furthermore, all of the
colleges and universities in the abovementioned “985 Project” are under the administration of the central government.

Elite 2 was measured by the number of colleges and universities in the abovementioned “211 project” (hereafter, “211-universities”). There are around 100 211-universities in total. The “211 project” is part of the Strategy of Developing the Country through Science and Education and, thus, one of the main goals of 211-universities is to promote innovation. Compared with ordinary colleges and universities, the central and local governments provide more subsidies and other support to develop the 211-universities, in relation to their teaching quality and scientific research. As exemplary universities in each province, 211-universities are always more active than ordinary ones in implementing and responding to national policies, especially those related to higher education reform. All but 29 of the central universities are included in the 211 project.

3.2.3. Control Variables

The control variables were constructed as follows: Following [29,46], the firm size (Size) was measured by the sales of a firm, while firm age (Age) was measured as the number of years since a firm had commenced operations. Capital intensity (Intensity) was calculated by dividing the total assets of the firm by the number of employees. Value of firm exports (Export) were measured as the real value of exports (taking 2011 as the basis year) and type of firm ownership (Ownership) was assigned a value representing one of the six types of ownership; namely, state-owned enterprises (1); collectively owned enterprises (2); Hong Kong-, Macao-, and Taiwan-funded enterprises (3); foreign-owned enterprises (4); legal-person enterprises (5); and privately owned enterprises (6). Size, Age, Export, and Intensity were winsorized by 1% to reduce the impact of outliers. Table 1 shows the descriptive statistics for the main variables used in this study.

| Variable  | Definition                          | Measurement                                      | Mean    | SD      | Mix  | Max      |
|-----------|-------------------------------------|--------------------------------------------------|---------|---------|------|----------|
| IN_qn     | Innovation quantity                 | ln(number of patent publications + 1)             | 2.9049  | 21.9251 | 0.0000 | 903.9196 |
| IN ql     | Innovation quality                  | ln(claim-weighted patent quantity + 1)            | 6.0589  | 42.2747 | 0.0000 | 1148.4730 |
| HigherEdu | Higher education                    | ln(number of colleges and universities + 1)      | 5.4631  | 1.1168  | 1.1239 | 7.4648   |
| Elite 1   | Elite higher education1             | ln(number of colleges and universities under the central government + 1) | 1.4852  | 0.7276  | 0.0000 | 3.3109   |
| Elite 2   | Elite higher education2             | ln(number of colleges and universities in the list of “211 Project” + 1) | 4.2685  | 0.5192  | 1.3863 | 4.9904   |
| nonElite1 | Non-elite higher education1         | ln(number of colleges and universities under non-central government + 1) | 4.2769  | 0.5145  | 1.3863 | 4.9972   |
| nonElite2 | Non-elite higher education2         | ln(number of colleges and universities not in the list of “211 Project” + 1) | 4.2736  | 0.5182  | 1.0986 | 4.9836   |
| Size      | Firm size                           | ln(sales+1)                                      | 10.0383 | 2.1073  | 0.0000 | 14.2101  |
| Age       | Firm age                            | ln(number of years since the establishment of a firm + 1) | 2.0380  | 0.8725  | 0.0000 | 3.9512   |
| Export    | Value of export                     | ln(real value of export + 1)                     | 2.0433  | 4.0068  | 0.0000 | 12.5945  |
| Intensity | Capital intensity                   | ln(total assets/number of employees + 1)         | 3.7747  | 1.3786  | 0.0697 | 7.3860   |
| Ownership | Firm ownership                      | Six types of ownership (1, 2, 3, 4, 5, 6)       | 4.4206  | 1.7762  | 1.0000 | 6.0000   |

Note: Logarithms were used for all variables except Ownership.

4. Empirical Results and Discussion

4.1. The Impact of Higher Education on Firm Innovation

Table 2 shows the estimation results of the impact of higher education on innovation quantity using HigherEdu as the independent variable. Columns (1)–(3) show the results of gradually adding control variables with IN_qn as the dependent variable. For example, with IN_qn as the dependent variable, column (1) shows the results of not adding any control variables, column (2) shows the results of only adding Size and Intensity, and column (3) shows the results of adding all control variables. As innovation quantity does not necessarily capture firm innovation, we also considered innovation
quality, which is the claim-weighted patent quantity. Columns (4)–(6) show the results of gradually adding control variables with \( \text{IN}_{ql} \) as the dependent variable.

**Table 2. Impact of higher education on firm innovation.**

| \( \text{IN}_{qn} \) | \( \text{IN}_{ql} \) |
|----------------------|----------------------|
| \( \text{HigherEdu} \) | \( -3.5590 ** \) | \( -3.6466 ** \) | \( -6.6688 ** \) | \( -7.0161 ** \) | \( -7.1809 ** \) |
| \( \text{Size} \) | \( 0.4060 ** \) | \( 0.3987 ** \) | \( 0.8579 ** \) | \( 0.8351 ** \) |
| \( \text{Intensity} \) | \( 0.6454 ** \) | \( 0.6405 ** \) | \( 1.2067 ** \) | \( 1.1990 ** \) |
| \( \text{Export} \) | \( 0.3123 ** \) | \( 0.6197 ** \) |
| \( \text{Age} \) | \( -0.8094 ** \) | \( -1.4502 ** \) |
| \( \text{Ownership} \) | \( -0.0846 ** \) | \( -0.1772 ** \) |
| Firm fixed effects | YES | YES | YES | YES | YES | YES |
| Year fixed effects | YES | YES | YES | YES | YES | YES |
| Industry fixed effects | YES | YES | YES | YES | YES | YES |
| Observations | 4,855,860 | 4,664,779 | 4,587,842 | 4,855,860 | 4,664,779 | 4,587,842 |
| \( R^2 \) | 0.0258 | 0.0271 | 0.0285 | 0.0266 | 0.0280 | 0.0294 |

Note: The value in the parentheses is standard error; ***, **, * respectively represent the significance levels of 1%, 5%, and 10%.

In columns (1) and (4), regardless of whether the dependent variable was \( \text{IN}_{qn} \) or \( \text{IN}_{ql} \), the coefficients of \( \text{HigherEdu} \) were significantly negative at the 1% level of significance. After further adding control variables, the sign of the coefficients of \( \text{HigherEdu} \) remained the same as those shown in columns (2) and (5), and columns (3) and (6), which indicates the robustness of our results. Therefore, it can be concluded that, in general, higher education stifles innovation in China.

Regarding the control variables, the coefficients of \( \text{Size} \) were significantly positive, meaning that larger firm sizes resulted in higher innovation quantity and innovation quality, consistent with the results of Fang et al. [29]. The coefficients of \( \text{Intensity} \) were significantly positive, indicating that higher capital intensity resulted in higher innovation quantity and innovation quality. The coefficients of \( \text{Export} \) were significantly positive, consistent with the conclusion of Martins and Yang [30,31]. However, the coefficients of \( \text{Age} \) were significantly negative, indicating that younger firms were more innovative. This is consistent with the result of Fang et al. [29]. The coefficients of \( \text{Ownership} \) were significantly negative. The results with \( \text{IN}_{ql} \) as the dependent variable were similar.

Based on the results listed in column (3), we can write the equation that demonstrates the relationship between innovation quantity and higher education as

\[
\text{IN}_{qn_{it}} = -3.6466 \text{HigherEdu}_{it} + 0.3987 \text{Size}_{it} + 0.6405 \text{Intensity}_{it} + 0.3123 \text{Export}_{it} \\
-0.8094 \text{Age}_{it} - 0.0846 \text{Ownership}_{it} + \text{fixed effects} + \varepsilon_{it} 
\] (2)
Similarly, based on the results listed in column (6), we also can write the equation that demonstrates the relationship between innovation quality and higher education as

\[
IN_{qlit} = -7.1809 HigherEdu + 0.8351 Size + 1.990 Intensity + 0.6197 Export \\
-1.4502 Age - 0.1772 Ownership + \text{fixed effects} + \epsilon_{it}
\]  

(3)

We also used the number of graduates from colleges and universities as a measure of higher education. The regression results obtained were similar, and were not listed for simplicity.

Subramaniam and Yount [47] also found a negative relationship between human capital and innovation with data on 919 organizations. They further found that the interaction of human capital and social capital significantly promoted innovation, which could explain the negative impact of human capital on innovation when there is a lack of networking and knowledge-sharing among individuals.

It is also worth mentioning that the above results suggest that provincial-level higher education reduces the average innovation outcomes of firms within a province but does not necessarily inhibit the total firm innovations of a province. The reason for this is that the dependent variable is at the firm level, while the independent variable HigherEdu is at the provincial level. Therefore, the negative impact of higher education on firm innovation may be attributed to the increase in the number of people with higher education working in firms with innovative capability below the average.

4.2. The Role of Elite and Non-Elite Higher Education

To explore the above issue further, we distinguished between Elite higher education and non-Elite higher education. In China, compared with elite higher education, non-elite higher education focuses more on training employment-ready skills and less on research skills. In addition, compared with people with non-elite higher education, those with elite higher education are more likely to work in companies with high innovative capability which, in general, have higher requirements and salaries and, thus, attract more workers with elite higher education.

The past few decades have witnessed the rapid quantity expansion of higher education in China; however, this does not necessarily indicate the expansion of high-quality education [13]. In fact, the scale of elite higher education grew at a far lower level than that of non-elite higher education. In China, the education quality has fallen far behind education quantity, in terms of growth. It was not until 2010 that China proposed to use quality promotion as the core of developing higher education in the Outline of the National Long- and Mid-term Education Reform and Development Plan (2010–2020). Furthermore, it was not until 2012—when the central government of China proposed the innovation-driven development strategy—that educational reform started to pay attention to innovation factors.

Therefore, if the impact of elite higher education on firm innovation is positive, while that of non-elite higher education is negative, we can tentatively conclude that the negative impact of higher education on firm innovation should be attributed to the increasing number of people with non-elite higher education, who generally have low innovative capability and are inclined to work in firms with innovative capability below the average.

First, we used a central university as a measure of Elite higher education. The estimation results are shown in Table 3. Columns (1)–(3) show the results with IN_{ql} as the dependent variable: Column (1) lists the results of only adding Elite 1, column (2) presents the results of only adding nonElite1, and column (3) lists the results of adding Elite 1 and nonElite1 simultaneously. The coefficient of Elite 1 was significantly positive before and after adding nonElite1, as shown in columns (1) and (3). The coefficient of nonElite1 was significantly negative before and after adding Elite 1, as shown in columns (2) and (3). Columns (4)–(6) show similar results when IN_{ql} is used as the dependent variable. In short, the results were robust.
Table 3. Innovation effects of elite and non-elite higher education (central universities).

|          | IN_qn   | IN ql   |
|----------|---------|---------|
|          | (1)     | (2)     | (3)     | (4)     | (5)     | (6)     |
| Elite 1  | 8.6668 ** (4.4052) | 8.7237 ** (4.4003) | 15.6984 ** (6.8853) | 15.8056 ** (6.8766) | 
| nonElite1| −2.4186 *** (0.2276) | −2.4239 *** (0.2275) | −4.5478 *** (0.4325) | −4.5576 *** (0.4321) | 
| Size     | 0.3953 *** (0.0182) | 0.3960 *** (0.0182) | 0.8298 *** (0.0335) | 0.8310 *** (0.0335) | 
| Intensity| 0.6415 *** (0.0210) | 0.6391 *** (0.0210) | 1.2010 *** (0.0387) | 1.1964 *** (0.0387) | 
| Export   | 0.3120 *** (0.0090) | 0.3123 *** (0.0090) | 0.6194 *** (0.0165) | 0.6199 *** (0.0165) | 
| Age      | −0.8152 *** (0.0432) | −0.8082 *** (0.0432) | −1.4652 *** (0.0786) | −1.4515 *** (0.0786) | 
| Ownership| −0.0771 *** (0.0264) | −0.0813 *** (0.0264) | −0.1615 *** (0.0491) | −0.1694 *** (0.0491) | 

Firm fixed effects | YES | YES | YES | YES | YES | YES |
Year fixed effects  | YES | YES | YES | YES | YES | YES |
Industry fixed effects | YES | YES | YES | YES | YES | YES |
Observations        | 4,590,917 | 4,587,842 | 4,587,842 | 4,590,917 | 4,587,842 | 4,587,842 |
R²                   | 0.0284 | 0.0284 | 0.0285 | 0.0292 | 0.0292 | 0.0292 |

Note: The value in the parentheses is standard error; ***, **, * respectively represent the significance levels of 1%, 5%, and 10%.

Based on the results listed in column (3), the model demonstrating the relationship between innovation quantity and different types of higher education, in numerical terms, can be written as follows:

\[
IN_{qnit} = 8.7237 Elite1 - 2.4239nonElite1 + 0.3955Size + 0.6390Intensity + 0.3123Export - 0.8074Age - 0.0816Ownership + fixed effects + \varepsilon_{it} \tag{4}
\]

Similarly, based on the results listed in column (6), the model demonstrating the relationship between innovation quality and different types of higher education, in numerical terms, can be written as follows:

\[
IN_{qlit} = 15.8056Elite1 - 4.5576nonElite1 + 0.8301Size + 1.1962Intensity + 0.6199Export - 1.4500Age - 0.1700Ownership + fixed effects + \varepsilon_{it} \tag{5}
\]

Next, we used a 211-university as the measure of Elite higher education. The estimation results are shown in Table 4, which are similar to those shown in Table 3. For simplicity, the models (in numerical terms) are not listed.

Therefore, our finding is that the negative impact of higher education on firm innovation mainly comes from non-elite higher education, while elite higher education continues to have a positive effect on firm innovation.

Why do elite higher education and non-elite higher education have opposite effects on firm innovation? In China, elite higher education institutions are oriented towards national strategies and receive much more attention from the government. Therefore, elite higher education institutions usually have abundant educational resources, high-quality teaching, advanced scientific research conditions, and are given priority in educational reform. These characteristics of elite higher education institutions make it possible for them to provide better intellectual support and attract more firms to collaborate with.
Table 4. Effect on innovation of elite and non-elite higher education (211-universities).

|                  | \( IN_{qn} \)                      | \( IN_{ql} \)                      |
|------------------|-----------------------------------|-----------------------------------|
|                  | (1)                               | (2)                               | (3)                               | (4)                               | (5)                               | (6)                               |
| **Elite**        | 8.6605 ** (3.9107)                | 8.6875 ** (3.9236)                | 15.8199 ** (6.3955)               | 15.8720 ** (6.4218)               |                                   |                                   |
| **nonElite**     |                                   | -2.5639 *** (0.2384)              | 0.3955 *** (0.0182)               | 0.6415 *** (0.0210)               |                                   |                                   |
| **Size**         | 0.3955 *** (0.0182)               | 0.3965 *** (0.0182)               | 0.3963 *** (0.0182)               | 0.3963 *** (0.0182)               |                                   |                                   |
| **Intensity**    | 0.6415 *** (0.0210)               | 0.6393 *** (0.0210)               | 0.6391 *** (0.0210)               | 0.6391 *** (0.0210)               |                                   |                                   |
| **Export**       | 0.3120 *** (0.0090)               | 0.3122 *** (0.0090)               | 0.3121 *** (0.0090)               | 0.3121 *** (0.0090)               |                                   |                                   |
| **Age**          | -0.8156 *** (0.0433)              | -0.8089 *** (0.0433)              | -0.8085 *** (0.0432)              | -0.8085 *** (0.0432)              |                                   |                                   |
| **Ownership**    | -0.0772 *** (0.0264)              | -0.0817 *** (0.0264)              | -0.0822 *** (0.0264)              | -0.0822 *** (0.0264)              |                                   |                                   |
| Firm fixed effects | YES                          | YES                               | YES                               | YES                               | YES                               | YES                               |
| Year fixed effects | YES                          | YES                               | YES                               | YES                               | YES                               | YES                               |
| Industry fixed effects | YES                          | YES                               | YES                               | YES                               | YES                               | YES                               |
| Observations     | 4,590,917                       | 4,587,842                        | 4,587,842                        | 4,590,917                        | 4,587,842                        | 4,587,842                        |
| \( R^2 \)        | 0.0284                          | 0.0284                            | 0.0285                            | 0.0292                            | 0.0292                            | 0.0292                            |

Note: The value in the parentheses is standard error; ***, **, * respectively represent the significance levels of 1%, 5%, and 10%.

4.3. Endogeneity Issues

Biasi et al. [12] pointed out that technological innovation could affect education by reducing the cost of education and improving teaching efficiency and quality. Hence, provinces with more innovation activities may be more willing to develop their provision of higher education.

To alleviate the possible effect of reverse causality between higher education and innovation, we lagged the key independent variables, \( HigherEdu_1 \), \( Elite_1 \) and \( nonElite_1 \), by 1 year. The estimation results are shown in Table 5.

Column (1) shows the results of the relationship between \( IN_{qn} \) and \( HigherEdu_1 \). Columns (2)–(4) show the results of the relationship between \( IN_{qn} \) and the different types of higher education (i.e., \( Elite_1 \) or \( nonElite_1 \)). Columns (5)–(8) show similar results when \( IN_{ql} \) is used as the dependent variable. Elite higher education is measured with central universities here. The results with the one-year lag of \( Elite_2 \) and \( nonElite_2 \) as independent variables were similar and not listed for simplicity.

Table 5. One-year lag of key independent variables.

|                  | \( IN_{qn} \)                      |
|------------------|-----------------------------------|
|                  | (1)                               | (2)                               | (3)                               | (4)                               |
| \( HigherEdu_1 \)| -3.2144 *** (0.3028)              |                                   |                                   |                                   |
| \( Elite_1 \)    | 9.3805 * (5.2159)                 | 9.3877 * (5.2128)                 |                                   |                                   |
| \( nonElite_1 \)| -1.8345 *** (0.2551)              | -1.8347 *** (0.2548)              |                                   |                                   |
5. Heterogeneity Analysis

5.1. Different Ownership Types

Enterprises under different types of ownership differ in terms of their business objectives, talent needs, and existing talent base, all of which can potentially impact their innovation activities. We reclassified the initial six ownership types into three types: state-owned and collectively owned enterprises were reclassified as SOEs; Hong Kong-, Macao-, and Taiwan-owned enterprises and foreign-owned enterprises were reclassified as FOEs; and legal-person and privately owned enterprises were reclassified as POEs.

The estimation results are shown in Table 6. Columns (1), (3), and (5) show the results of the relationship between firm innovation and higher education. Columns (2), (4), and (6) show the results of the relationship between firm innovation and different types of higher education. Columns (1) and (2) investigated only SOEs, Columns (3) and (4) analyzed only FOEs, and Columns (5) and (6) focus on POEs.

The coefficients of HigherEdu and nonElite1 were all significantly negative, confirming that higher education—in particular, non-elite higher education—stifles innovation in all firms, regardless of ownership type. Elite higher education is measured with central universities here. The results with Elite2 and nonElite2 as independent variables were similar and not listed for simplicity.

In terms of the coefficients of Elite1, while the coefficients for SOEs and FOEs were insignificant, the coefficient of Elite1 for POEs was significantly positive. This indicates that elite higher education promoted innovation in POEs, but not in SOEs or FOEs. SOEs are generally subject to significant government intervention, which likely limits opportunities for talented employees to engage in innovation-related activities. Meanwhile, innovation in FOEs may be transferred from their parent enterprises outside China. For simplicity, the models in numerical terms are not listed.
Table 6. Heterogeneity analysis 1: Different ownership types.

|       | SOEs (1) | FOEs (2) | POEs (3) | SOEs (4) | FOEs (5) | POEs (6) |
|-------|----------|----------|----------|----------|----------|----------|
| HigherEdu | \(-1.6149^{***}\) (0.3595) | \(-3.9822^{***}\) (0.6338) | \(-5.4952^{***}\) (0.4018) | \(-3.2790^{***}\) (0.6443) | \(-7.8445^{***}\) (1.1742) | \(-10.2955^{***}\) (0.7479) |
| Elite 1 | 8.4047 (6.0499) | 0.9838 (1.2126) | 7.3070 ** (3.0380) | 14.3576 (10.7491) | 2.7840 (2.9753) | 15.5694 ** (7.1558) |
| nonElite1 | \(-0.8798^{***}\) (0.2806) | \(-3.3222^{***}\) (0.5794) | \(-3.7975^{***}\) (0.3404) | \(-1.7488^{***}\) (0.5013) | \(-6.5105^{***}\) (1.0828) | \(-6.9925^{***}\) (0.6380) |

Control Variables: YES YES YES YES YES YES
Firm fixed effects: YES YES YES YES YES YES
Year fixed effects: YES YES YES YES YES YES
Industry fixed effects: YES YES YES YES YES YES

N 877,044 877,044 855,372 855,372 2,855,426 2,855,426

Note: The value in the parentheses is standard error; ***, **, * respectively represent the significance levels of 1%, 5%, and 10%.

5.2. High-Tech and Non-High-Tech Enterprises

Grimpe and Sokfa [26] pointed out that knowledge in non-high-tech enterprises is mainly derived from customers and competitors while, in high-tech enterprises, it is mainly derived from universities and suppliers. They also pointed out that knowledge from universities exhibits a higher degree of innovativeness than that from competitors. Innovation in high-tech enterprises is usually based on the latest scientific and technological knowledge [48], which is most likely to be generated by colleges and universities, especially those with a higher degree of innovativeness. Therefore, we believe that Elite higher education may better promote the innovation activity of high-tech enterprises.

We identified high-tech enterprises based on the Checklist of High-tech Industry (Manufacturing Industry) Classifications (2013) and the Statistics Catalogue of High-technology Industry Classifications (2002). The nuclear fuel processing industry was excluded, in order to enable uniform identification of high-tech enterprises using these slightly different high-tech industry classification systems. The remaining enterprises were classified as non-high-tech enterprises.

The estimation results, in relation to low- and high-tech enterprises, are shown in Table 7. Columns (1) and (3) show the results of the relationship between firm innovation and higher education. Columns (2) and (4) show the results of the relationship between firm innovation and different types of higher education. Columns (1) and (2) investigated only high-tech enterprises, while Columns (3) and (4) analyzed only non-high-tech enterprises. The signs and significance of HigherEdu, Elite 1 and nonElite1 were the same as those presented in Section 4. Here, Elite higher education is measured with central universities. The results with Elite 2 and nonElite2 as independent variables were similar and not listed for simplicity.
Table 7. Heterogeneity analysis 2: High-tech and non-high-tech enterprises.

|                  | High-Tech | Non-High-Tech |
|------------------|-----------|---------------|
|                  | (1)       | (2)           | (3)           | (4)           |
| \( IN_{qn} \)    |           |               |               |               |
| HigherEdu        | -5.8806 *** | -1.9249 ***   |               |               |
|                  | (0.9004)  | (0.2142)      |               |               |
| Elite 1          | 25.8492 ** | 4.1756 **     |               |               |
|                  | (11.2188) | (1.6744)      |               |               |
| nonElite1        | -3.8781 *** | -1.2353 ***   |               |               |
|                  | (0.7705)  | (0.1834)      |               |               |
| \( IN_{ql} \)    |           |               |               |               |
| HigherEdu        | -11.0222 *** | -3.6821 ***   |               |               |
|                  | (1.6363)  | (0.4017)      |               |               |
| Elite 1          | 42.1044 ** | 9.2733 **     |               |               |
|                  | (15.7469) | (3.6060)      |               |               |
| nonElite1        | -6.9310 *** | -2.3032 ***   |               |               |
|                  | (1.4107)  | (0.3455)      |               |               |
| Control Variables| YES       | YES           | YES           | YES           |
| Firm fixed effects| YES      | YES           | YES           | YES           |
| Year fixed effects| YES     | YES           | YES           | YES           |
| Industry fixed effects| YES | YES           | YES           | YES           |
| N                | 996,689   | 996,689       | 3,591,153     | 3,591,153     |

Note: The value in the parentheses is standard error; ***, **, * respectively represent the significance levels of 1%, 5%, and 10%.

Our main finding was that the coefficient of Elite 1 was much larger for high-tech enterprises than for non-high-tech enterprises, suggesting that elite higher education had a greater impact on firm innovation in high-tech industries than in non-high-tech industries. Generally speaking, firms of high-tech enterprises are more innovative, compared with those of non-high-tech enterprises. In other words, people with elite higher education are more likely to work in firms with high innovative capability. Therefore, the result provides further evidence for the abovementioned conclusion: that the negative impact of higher education on firm innovation should be attributed to the increasing number of people with non-elite higher education, who generally have low innovative capability and are inclined to work in firms with innovative capability below the average.

6. Conclusions

The United Nations proposed 17 sustainable development goals in 2015, most of which are highly related. Quality education and innovation are among these goals, where innovation helps to reduce poverty, promote economic growth, and produce clean energy. This paper focuses on the impact of higher education on firm innovation, including innovation quantity and innovation quality. The data sets used for the empirical analysis were the Chinese Industrial Enterprise Database (1995–2013), the unique Chinese Patent Census Database (1991–2018), and provincial-level education data.

Several conclusions can be drawn from the empirical results: First, provincial-level higher education hindered the average innovation outcomes of firms at the province level in China. The reason for this could be that the number of people with non-elite higher education has experienced rapid expansion, compared with that relating to elite higher education. People with non-elite higher education generally have relatively low innovative capability and are inclined to work in firms with innovative capability below the average. In contrast, people with elite higher education are more likely to work in high-tech industries. In other words, education expansion in China has paid too much attention to quantity expansion and too little attention to quality improvement. Second, elite higher education had a positive impact on firm innovation, while non-elite higher education had a negative
impact on firm innovation. The possible explanation for this is that elite higher education institutions receive more subsidies (and other support) from the Chinese government and are often used as pilot zones for innovative education reform policies, which focuses more on improving innovation capability. Generally, compared with elite higher education, non-elite higher education in China focuses more on employment and less on scientific research and innovation. Third, elite higher education had a significantly positive impact on innovation by POEs but had little impact on innovation by SOEs and FOEs. In fact, while SOEs in China are generally subject to significant government intervention and provide few incentives for talented employees to innovate, FOEs might obtain technology from their parent enterprises outside China.

Our empirical results have a number of implications, for both theory and practice. First, we determined the mixed realities behind endogenous growth theories. Higher education does not necessarily promote innovation; in reality, it depends on the types of higher education institutions. Second, as for the education administration of the government, after successfully expanding the higher education sector, the Chinese government should shift its focus from education quantity to quality and pay more attention to improving innovative capabilities in both teaching and research, especially for non-elite higher education institutions. Meanwhile, the importance of elite higher education for promoting innovation in developing countries still greatly matters.

The existing literature has only studied the impact of the education of employees, which thus failed to capture the spillover effects that education may have on industries and other macro-level institutions. This study expands the literature by examining the macro-level impact of higher education institutions on firm level innovation. It should be noted that this research has certain limitations, such as not considering the mobility of talent between regions, which could serve as a topic for future studies.

Author Contributions: Introduction, literature review, X.P. and W.C.; methodology and data, W.C. and X.P.; empirical results and discussion, X.P., W.C., and D.G.; heterogeneity analysis, X.P. and W.C.; conclusion, W.C., X.P., and D.G.; writing—original draft Preparation, X.P., W.C., Y.G., and D.G.; writing—review and editing, X.P., W.C., Y.G., and D.G. All authors have read and agreed to the published version of the manuscript.

Funding: This research received funding from the General Program of the National Natural Science Foundation of China (No. 71873075), as a Key Project of the National Natural Science Foundation of China (No. 71733003), and from the National Office for Philosophy and Social Sciences of China (No. 20155010298).

Conflicts of Interest: The authors declare no conflict of interest.

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