Determinants and impacts of intangible investment: Evidence from Chinese private manufacturing firms

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Determinants and impacts of intangible investment: Evidence from
Chinese private manufacturing firms

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Abstract: Determinants of investment in intangibles by firms and the effects of intangible investment on firm productivity have been documented for developed economies. Evidence on these issues in emerging economies, however, is scarce. Using data from China Enterprise Survey 2012 conducted by the World Bank, this study examines the determinants and impacts of intangible investment by private manufacturing firms in China, thus shedding light on recent development of intangibles in one of the largest emerging economies in the world. It is found that more human capital, larger firm size and better institutional quality generally increase the propensity and the amount of intangible investment, and yet fiercer market competition decreases both the propensity and the amount to invest in intangibles. We also provide evidence that the three components of intangibles including research and development (R&D) investment, software investment and organization investment as well as ICT investment are positively correlated with firm productivity. Furthermore there is complementarity between software investment and organization investment. Implications for policies to enhance investment in intangibles are identified from the empirical results.

Keywords: intangible investment, firm productivity, Chinese manufacturing firms, firm-level data
JEL classification: O31, L22, C12
1. Introduction
Intangible capital consists of the stock of immaterial resources that enter the production process and are important for the creation or improvement of products as well as production process (Arrighetti et al., 2014). Examples of intangible capital include research and development (R&D) investment, advertising, organization capital, staff training, technology licenses, patents, and copyrights (Corrado et al., 2013). It has been identified in the existing literature that intangible capital is playing a growing role in determining firm productivity and thus the performance of local economies (Marrocu et al., 2012). These mechanisms are at play especially strongly in developed economies where competition is mainly based on ideas and innovation and hence firms are incentivized to invest resources in developing intangibles. Corrado et al. (2009) estimate that the total value of intangible capital in the United States was approximately $3.6 trillion by the early 2000s, suggesting that intangible investment accounted for over 10-20% of US output growth during that period. Similar phenomena are found in other developed countries including Japan, Korea and a number of OECD economies (Awano et al., 2010; Borgo et al., 2013; Corrado & Hulten, 2010; Corrado et al., 2013; Chun & Nadiri. 2016; Fukao et al., 2009; Haskel & Wallis, 2013; Marrano et al, 2009; Miyagawa & Hisa, 2013; van Ark et al., 2009). Therefore, it is not surprising that recent literature has devoted an increasing effort to defining and measuring intangible capital and studying its effects on productivity growth (Bontempi et al., 2008; Marrocu et al., 2012).

Apart from measuring intangible capital and its effects on productivity, the mechanisms that drive firms to invest in intangibles have increasingly received attention from researchers and policymakers (Hughes et al., 2006; OECD, 2010; OECD, 2011; Ebner et al., 2015). Arrighetti et al. (2014) use data for Italian firms to examine the determinants of firms’ investment in intangibles and reveal that a firm with a larger size, more human capital and more organizational complexity is more likely to invest in intangibles. However, studies on why firms invest in intangibles in emerging economies are scarce. Compared with developed economies, emerging economies are often regarded to be operating at the lower end of the global value chain, thus requiring a relatively small intangible capital stock for production activities. In order to climb up the global value chain, however, firms in developing economies needs to increase their intangible capital stock, which helps boost competitiveness of product as well as productivity of firms. Therefore, understanding the drivers underlying firms’ investment in intangibles in an emerging economy provides useful information to policy makers who hope to spurt firms’ investment in intangibles and enhance technological and industrial upgrading of the economy. Another motivation that prompts us to examine intangible investment in an emerging
economy is that market environment of emerging economies is often different from that in developed economies. Emerging economies tend to have lower human capital and underdeveloped institutions. Moreover, because of the lack of core technology and patents, firms herein tend to be faced with intense competition on a cost-cutting basis. It is therefore important that we examine the determinants of firms’ intangible investment in an emerging economy and reveal how the mechanisms may differ from those in developed economies.

China, one of the largest emerging economies in the world, shares many characteristics featured in other emerging economies. To be specific, China has a relatively low human capital, an underdeveloped institution, and most of its products face a highly competitive market. China has a relatively low intangible capital stock as well. The intangible tangible ratios\(^1\) of Japan, the United States, and the United Kingdom are 17%, 22%, and 24%\(^2\) respectively, while that of China is less than 4% in 2007\(^3\). Using firm-level data from China Enterprise Survey 2012 conducted by the World Bank, this study identifies the theoretical framework underlying firms’ intangible investment, tests the determinants of firm’s intangible investment derived from the theoretical framework, and lastly examines the relationship between intangible investment and firm productivity.

To our best knowledge, this study is the first to examine the determinants of intangible investment by Chinese firms and to provide a comprehensive analysis of how various components of intangible investment impact on firm-level productivity. Different from previous studies on developed economies such as Arrighetti et al. (2014), this study highlights the importance of institutional quality and market competition in the context of an emerging and developing economy, and reveals that both factors significantly affect the decision to invest in intangibles.

The paper is organized as follows: the next section provides a theoretical framework for analysing the determinants of intangible investment by a firm. Section 3 describes data and the empirical strategy and provides summary statistics. Section 4 presents the pattern of intangibles investment in China. Section 5 presents the empirical results on the determinants of intangible investment and how this investment impacts on firm productivity. Section 6 draws the conclusion and policy implications from our findings.

\(^{1}\) Intangible tangible ratio refers to the ratio of intangible capital to tangible capital.  
\(^{2}\) Tangible capital data is obtained from the Penn World Table 8.1 and intangible capital data is obtained from the cross-country intangible investment data website (http://www.intan-invest.net/).  
\(^{3}\) Unpublished manuscript of the authors of this paper.
2. Theoretical framework for analysing firms’ behaviour in intangible investment

In this section, we develop a theoretical framework on firms’ intangible investment and derive the hypotheses to be tested with firm-level data in the next section.

Assume that a firm produces goods and services according to the following production function:

$$Y = A(IC, H, \theta)F(L, K)$$

where $Y$ is value added produced by the firm; $H$ is human capital; $L$ is labour; $K$ is physical capital; $A$ is total factor productivity; $IC$ is intangible capital; and $\theta$ represents other factors determining total factor productivity. $F$ is a continuous function of $L$ and $K$ with $F' > 0$ and $F'' < 0$, which reflects diminishing marginal return of labour and capital input. Total factor productivity $A$ is an increasing function of intangible capital, human capital and other factors, which reflects the fact that intangible capital and human capital improve the efficiency and total factor productivity of a firm. The productivity boost from intangible capital and human capital follows diminishing marginal return. That is,

$$\frac{\partial A}{\partial IC} > 0, \frac{\partial^2 A}{\partial^2 IC} < 0, \frac{\partial A}{\partial H} > 0, \frac{\partial^2 A}{\partial^2 H} < 0 \text{ and } \frac{\partial A}{\partial IC \partial H} = \frac{\partial A}{\partial H \partial IC} > 0.$$ 

$$IC \to 0, \frac{\partial A}{\partial IC} \to +\infty \text{ and } \frac{\partial A}{\partial IC \partial H} \to +\infty; \quad H \to 0, \frac{\partial A}{\partial H} \to +\infty \text{ and } \frac{\partial A}{\partial H \partial IC} \to +\infty$$

The quality of the human resources employed by firms is a key condition both for the generation of new intangible assets and the exploitation of existing intangible assets (Abramovitz and David, 2000; Galor and Moav, 2004). Given the fact that the production of intangible capital such as R&D and organization capital requires high-skilled workers, increase in human capital lowers the costs of investing in new intangible capital as well as the cost of using existing intangible capital.

If a firm has sufficient funds, whether it invests in intangible capital or not depends on the relative marginal return of intangible capital compared with that of tangible capital.4

The marginal return from investing in intangible capital is

$$\frac{\partial Y}{\partial IC} = F(L, K) \frac{\partial A(IC, H, \theta)}{\partial IC}$$

4 Tangible capital is also called physical capital.
The marginal return from investing in tangible capital is
\[ \frac{\partial Y}{\partial K} = A(IC, H, \theta)F_K(L, K) \]

Then the difference in marginal return between intangible and tangible capital (DMR) is
\[ DMR = F(L, K) \frac{\partial A(IC, H, \theta)}{\partial IC} - A(IC, H, \theta)F_K(L, K) \]

Higher DMR indicates that a firm is more likely to invest in intangible capital instead of tangible capital.

From this, we obtain
\[ \frac{\partial DMR}{\partial K} = F_K(L, K) \frac{\partial A(IC, H, \theta)}{\partial IC} - A(IC, H, \theta)F_KK(L, K) > 0 \]

Intuitively, as tangible capital of a firm is increased, the marginal return of tangible capital falls. Meanwhile, as intangible capital improves productivity, that is \[ \frac{\partial A(IC, H, \theta)}{\partial IC} > 0 \], return of an additional unit of intangible capital increases as the amount of tangible capital increases. Both these two effects cause an increased DMR as tangible capital grows. As a result, a higher tangible capital leads to an increase in DMR, making it more likely that the firm invests in intangibles.

This mechanism is summarized as Hypothesis 1 below:

**Hypothesis 1.** A larger firm is more likely to invest in intangible capital, with firm size measured by the total assets of the firm.

Higher human capital lowers the costs of producing new intangible capital and improves the efficiency of using existing intangible capital and therefore raises the probability of investing in intangible capital. One example that can reflect such complementarities between human capital and intangible capital is the large amount of human resources employed in direct R&D activities (Liu et al., 2000). More examples include the use of advanced software education and the introduction of new management practices, which all need to be carried out by people with high level of education.

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5 Noting that \( F_{KK}(L, K) < 0 \) and \( A(IC, H, \theta) > 0 \) and therefore \( F_K(L, K) \frac{\partial A(IC, H, \theta)}{\partial IC} \) and \( -A(IC, H, \theta)F_{KK}(L, K) \) are both positive.
With \( F(L, K) > F_K(L, K) \)\(^6\) and \( \frac{∂A}{∂IC∂H} > \frac{∂A}{∂H} \)\(^7\), we obtain

\[
\frac{∂DMR}{∂H} = \frac{∂A}{∂IC} F(L, K) - \frac{∂A}{∂H} F_K(L, K) > 0
\]

**Hypothesis 2.** A firm with more human capital is more likely to invest in intangible capital.

Institutional quality is also another important factor influencing the investment in intangible capital. The features of innovation activities as a form of risky investment make them particularly sensitive to institutional quality (Jorde and Teece, 1990). Zhou (2014) finds that low institutional quality is harmful to R&D investment using data from Chinese firms: in an area where the intellectual property is not properly protected, a firm has a higher probability of losing some of the intangible capital it produces because its designs, R&D and business secrets are more likely to be stolen, which in turn deters R&D investment. Mathematically, we add the institutional component into Equation (1) by modelling it as a rate of survival, and then we have

\[
DMR = IQ \times F(L, K) \frac{∂A}{∂IC} - A(IC, H, \theta)F_K(L, K)
\]

where \( IQ \) is the institutional quality, which indicates the survival rate of the intangible capital vulnerable to thefts or knockoffs and enters the equation as a probability and hence a multiplicative term. Therefore, \( IQ \times F(L, K) \frac{∂A}{∂IC} \) is the expected marginal return of intangible investment. Then we obtain

\[
\frac{∂DMR}{∂IQ} = F(L, K) \frac{∂A}{∂IC} > 0
\]

**Hypothesis 3.** Lower institutional quality reduces the probability for a firm to invest in intangible capital vulnerable to thefts or knockoffs.

Another factor is market competition. The impact of competition on firms’ effort to innovate is not yet conclusive in the literature. Some studies have found that market competition exerts a negative effect on firms’ incentives to increase their R&D efforts (Loury, 1979; Martin, 1993), while others find that only firms with low R&D

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\(^6\) This is often true in this context. Use the Cobb-Douglas form production function as an example: \( F(L, K) = L^\alpha K^\beta \) and \( F_K(L, K) = \beta L^\alpha K^{\beta-1} \). Noting that \( \beta < 1 \) and \( K > 1 \), so we have \( F(L, K) > F_K(L, K) \).

\(^7\) This is likely to be true because this study focuses on whether a firm invests in intangible capital or not. For those that have not invested in intangible capital yet, \( IC = 0 \) and thus \( \frac{∂A}{∂IC∂H} \) is likely to be sufficiently large to ensure \( \frac{∂A}{∂IC∂H} > \frac{∂A}{∂H} \).
productivity tend to exhibit a lower level of R&D efforts when facing increased market competition (Lee, 2009). Firms facing a competitive market are likely to belong to an industry with low entry barriers and have relatively low levels of R&D productivity, which indicates that they often have fewer incentives to invest in intangible capital. These firms are also likely to earn zero economic profit under fierce market competition and hence are not able to fund investment in intangibles. This mechanism is summarized in Hypothesis 4.

**Hypothesis 4.** Firms facing a competitive market are less likely to invest in intangible capital.

### 3. Data and empirical strategy

Data used in this study were retrieved from China Enterprise Survey 2012 conducted by the World Bank. This dataset covers data in 2011 and consists of 1,523 private sector manufacturing firms from 25 major cities in China, with observations covering all manufacturing industries. The observations distribute relatively evenly across cities, with approximately 50 observations per city and 100 observations per stratified sector. The sample was selected using stratified random sampling, which ensures that the sample is unbiased. This data set provides valuable measurements of intangible investment as well as firm-level information necessary for the estimation of production function.

The definition of intangible investment used in this study follows that of Corrado et al. (2009). The advantage of using this definition is that it covers a broad range of expenditure that boosts firm productivity and is therefore a relatively comprehensive definition. According to Corrado et al. (2009), intangible capital consists of three main categories: computerized information (mainly software), intellectual property (R&D) and economic competency (advertising, staff training and organization capital). Regarding firms’ intangible investment behaviour, there are two interesting questions to answer. One is what determines whether a firm invests in a specific type

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8 Using firms from the private sector has the advantage to better reflect the economic incentives of firms because state-owned firms may invest in intangibles for political purposes.
9 The 25 cities are as follows: Hefei, Beijing, Guangzhou, Shenzhen, Foshan, Dongguan, Shijiazhuang, Tangshan, Zhengzhou, Luoyang, Wuhan, Nanjing, Wuxi, Suzhou, Nantong, Shenyang, Dalian, Jinan, Qingdao, Yantai, Shanghai, Chengdu, Hangzhou, Ningbo, Wenzhou.
10 The industry classification is as follows: food, tobacco, textiles, garments, leather, wood, paper, recorded media, refined petroleum product, chemicals, plastics & rubber, non-metallic mineral products, basic metals, fabricated metal products, machinery and equipment, electronics, precision instruments, transport machines, furniture, recycling.
11 Stratified sector classification is a less detailed classification that includes Food, Textiles, Garments, Chemicals, Plastics & rubber, Non-metallic mineral products, Basic metals, Fabricated metal products, Machinery and equipment, Electronics, Motor vehicles and Other manufacturing. The use of stratified sectors is to avoid the problems of insufficient observations in certain industries.
of intangible or not and the other is what determines the amount of investment in a specific type of intangible. The unique feature of this firm-level survey is that it includes various questions that are highly related to intangible investment. For example, whether a firm invests in internal R&D or not is manifested by the question “In the last three years, did this establishment spend on research and development activities within the establishment?” Table 1 summarizes different measurements of intangible investment to facilitate future use of the dataset by other researchers.

Table 1 Measuring intangible investment behaviour

<table>
<thead>
<tr>
<th>Category</th>
<th>Variable types</th>
<th>Relevant questions in the questionnaire</th>
</tr>
</thead>
<tbody>
<tr>
<td>R&amp;D (Overall)</td>
<td>Dichotomous and continuous</td>
<td>CNO.3, CNO.4, CNO.5, CNO.6</td>
</tr>
<tr>
<td>R&amp;D (Internal)</td>
<td>Dichotomous and continuous</td>
<td>CNO.3, CNO.4</td>
</tr>
<tr>
<td>R&amp;D (Outsourced)</td>
<td>Dichotomous and continuous</td>
<td>CNO.5, CNO.6</td>
</tr>
<tr>
<td>Organization investment</td>
<td>Dichotomous and continuous</td>
<td>CNo14b, CNo14c, CNo14d, CNo15b, CNo15c, CNo15d</td>
</tr>
<tr>
<td>Software investment</td>
<td>Dichotomous</td>
<td>CNo12e</td>
</tr>
</tbody>
</table>


Before we start to explore the intangible investment of firms, it is helpful to examine the relationship between intangible investment and firm productivity. Assume a typical firm has two inputs - physical capital and labour. The translog approach (Kim, 1992) is used to estimate total factor productivity (TFP) of the firm. Compared with the Cobb-Douglas approach, the translog approach removes the assumptions of constant output elasticities. To be specific, the model specification is as follows:

\[
y_i = \beta_k k_i + \beta_l l_i + \beta_{lk} l_i k_i + \beta_{ll} l_i^2 + \beta_{kk} k_i^2 + a + \epsilon_i
\]  

(2)

All variables are in natural logarithm values. \(y\) is the value added, measured as revenue minus cost of intermediate input; \(k\) is physical capital; \(l\) is labour; \(a\) is the intercept term, which captures average productivity of all firms. Physical capital is measured by the reported fixed assets, and labour is measured by the reported number of employees.

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12 Organization investment is defined as investment in operation and management improvement as well as staff training. Advertising has not been included due to insufficient data.
of full-time employees. TFP is measured by the error term $\varepsilon_i$.

As discussed in Section 2, firm-level evidence for emerging countries on how intangible capital contributes to TFP growth is rare. Therefore, it is necessary to examine the relationship between TFP and intangible investment using data from Chinese firms. Due to data availability, software investment and organization investment are in the form of dummy variables. Besides intangibles, information and communication technology (ICT) capital has also been found to have significant impacts on firms’ productivity (Atzeni et al., 2006) and therefore a control variable for ICT investment is necessary for the empirical model. Moreover, Brynjolfsson et al. (2002) argue that the use of new software is often accompanied by organizational redesign and changes in the skill mix of employees, and they test this hypothesis using data from US firms. It is important to examine whether such a complementary relationship is present in the case of Chinese firms. Therefore, the interaction term between organization investment and software investment is also included in the empirical model. The model specification is hence as follows:

$$TFP_i = \beta_1 IT_{\text{intensity}}_i + \beta_2 R&D_{\text{intensity}}_i + \beta_3 software_i + \beta_4 organization_i + \beta_5 organization_i \times software_i + industry\_effects + a + \varepsilon_i$$

where $IT_{\text{intensity}}$ is the annual costs of IT equipment investment divided by the fixed assets; $R&D_{\text{intensity}}$ is internal R&D expenditure\(^{13}\) divided by the fixed assets; $software$ is a dummy variable indicating whether a firm invests in software or not; $organization$ is a dummy indicating whether a firm invests in organization capital or not; $organization \times software$ is the interaction term between $organization$ and $software$; $industry\_effects$ consists of a number of dummies indicating the industry that a firm belongs to; $a$ is the intercept term. Of all the variables, $IT_{\text{intensity}}$ and $R&D_{\text{intensity}}$ are in natural logarithm values.

To study the determinants of intangible investment, we adopt two steps. The first is to study the propensity of investing in intangibles and the second is to study the quantity of investment where investment is positive. Four factors discussed in Section 2 will be examined. They include human capital, market competition, firm size and institutional quality. That is,

$$Intangible\_d_{p,i} = \beta_1 human\_capital_i + \beta_2 market\_competition_i + \beta_3 size_i + \beta_4 institution_i + industry\_effect + a + \varepsilon_i$$

\(^{13}\) The reason we exclude the outsourced R&D is that it significantly limits the number of observations.
\[ \text{Intangible}_q_{p,i} = \beta_1 \text{human\_capital}_i + \beta_2 \text{market\_competition}_i + \beta_3 \text{size}_i + \beta_4 \text{institution}_i + \text{industry\_effect} + a + \varepsilon_i \] (4)

\( \text{Intangible\_d}_{p,i} \) stands for whether firm i invests in intangible investment p or not; \( \text{Intangible\_q}_{p,i} \) refers to the amount that firm i invests in intangible investment p; \( \text{human\_capital}_i \) is the average human capital of a firm, measured by the average educational years of permanent workers; \( \text{market\_competition}_i \) is a dummy indicating whether a firm faces a competitive market or not, measured by whether a firm reports its number of competitors as too many to count; \( \text{size}_i \) is the firm size, measured by fixed asset of a firm; \( \text{institution}_i \) is local institutional quality, measured by the NERI Index of Marketization for China’s provinces published by the National Economic Research Institute (NERI)\(^{14} \) (Fan et al., 2011). The surveyed enterprises are all located in the capital city or major cities of a province and therefore it is appropriate to use the provincial index to represent the institutional quality of a city. Of all the variables, \( \text{human\_capital}_i, \text{size}_i \) and \( \text{institution}_i \) are in natural logarithm values while others are dummies.

Table 2 shows the descriptive statistics of the variables of interest. Heterogeneity of firms in their investment in intangibles can be seen from the range of the statistics. 40% of the firms have invested in R&D recently and most of the R&D is internal since the ratio of firms with overall R&D investment and the ratio of firms with internal R&D investment are considerably close. When it comes to organization and software investment, respectively 76% and 45% of the firms have invested. 75% of the firms face a competitive market, and the variation of the firm size as manifested by labour quantity and tangible quantity is large.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Obs</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>R&amp;D (Overall, dichotomous)</td>
<td>1,523</td>
<td>0.40</td>
<td>0.49</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>R&amp;D (Overall, continuous)</td>
<td>135</td>
<td>8.06E+06</td>
<td>2.90E+07</td>
<td>0</td>
<td>2.65E+08</td>
</tr>
<tr>
<td>R&amp;D (Internal, dichotomous)</td>
<td>1,523</td>
<td>0.38</td>
<td>0.49</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>R&amp;D (Internal, continuous)</td>
<td>586</td>
<td>3.32E+06</td>
<td>1.39E+07</td>
<td>0</td>
<td>2.20E+08</td>
</tr>
<tr>
<td>R&amp;D (Outsourced, dichotomous)</td>
<td>1,523</td>
<td>0.11</td>
<td>0.31</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>R&amp;D (Outsourced, continuous)</td>
<td>163</td>
<td>2.54E+06</td>
<td>7.38E+06</td>
<td>0</td>
<td>5.00E+07</td>
</tr>
<tr>
<td>Organization investment (Dichotomous)</td>
<td>1,523</td>
<td>0.77</td>
<td>0.42</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

\(^{14}\) The NERI index is an assessment system for relative progress in marketization for China’s provinces. It is commonly used as a measurement of the institutional quality in China.
4. **Pattern of intangibles investment in China**

To shed more light on the pattern of Chinese firms’ investment in intangibles, we look at both the geographical and sectoral distribution of intangibles. Figures 1-3 demonstrate percentage of firms investing in intangibles in various cities of China. The larger the size of the circle, the higher the percentage of firms with positive investment in intangibles. From Figure 1, we can see that the percentage of firms investing in R&D is higher in Pearl River Delta and Yangtze River Delta that those in northern China. Firms in Chengdu, Shenyang, Qingdao, Tianjin and Shijiazhuang have a significantly lower percentage compared with other cities in this sample. Figure 2 shows that the percentage of firms investing in organization is relatively more even across different cities. Figure 3 shows that software investment has a similar pattern as R&D investment. Overall, firms in Chengdu, Shenyang, Qingdao, Tianjin and Shijiazhuang have low intangible investment percentage among all cities.

<table>
<thead>
<tr>
<th></th>
<th>Organization investment</th>
<th>Software (Dichotomous)</th>
<th>ln(VA)</th>
<th>ln(K)</th>
<th>ln(L)</th>
<th>ln(Human capital)</th>
<th>MC</th>
<th>ln(IQ)</th>
<th>ln(RD_intensity)</th>
<th>ln(IT_intensity)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous</td>
<td>1,523</td>
<td>1,523</td>
<td>1,519</td>
<td>1,321</td>
<td>1,523</td>
<td>1,503</td>
<td>1,361</td>
<td>1,523</td>
<td>444</td>
<td>1,147</td>
</tr>
<tr>
<td>(Continuous)</td>
<td>1.63</td>
<td>0.45</td>
<td>16.30</td>
<td>15</td>
<td>4.42</td>
<td>2</td>
<td>0.75</td>
<td>2.26</td>
<td>-2.50</td>
<td>-3.81</td>
</tr>
<tr>
<td></td>
<td>0.86</td>
<td>0.50</td>
<td>1.61</td>
<td>2</td>
<td>1.26</td>
<td>0</td>
<td>0.43</td>
<td>0.17</td>
<td>1.86</td>
<td>2.14</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>0</td>
<td>11.29</td>
<td>5.71</td>
<td>1.61</td>
<td>0.00</td>
<td>0.00</td>
<td>1.98</td>
<td>-6.96</td>
<td>-10.60</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>1</td>
<td>24.16</td>
<td>25.11</td>
<td>10.31</td>
<td>2.89</td>
<td>1.00</td>
<td>2.47</td>
<td>3.35</td>
<td>7.41</td>
</tr>
</tbody>
</table>

Source: Authors’ own calculation
Figure 1 Percentage of firms investing in R&D (City level)

Source: Authors’ own construction

Figure 2 Percentage of firms investing in organization capital (City level)

Source: Authors’ own construction
Figure 3 Percentage of firms investing in software (City level)

Source: Authors’ own construction

Figure 4 depicts percentage of firms investing in intangibles in various sectors. Amongst the three components of intangibles, organization investment is most evenly distributed across sectors and is most commonly made by firms compared with the other two components, with about 70% of firms investing in organization capital. Software investment is less evenly distributed across sectors compared with organization investment and around 50% of firms invest in software. There is higher variation between sectors in the percentage of firms with positive R&D investment. Among all sectors, fabricated metal products, basic metals, garments and textiles have low percentages of R&D investment.

Figure 4 Percentage of firms investing in intangibles (sectoral level)
With the above knowledge of the overall pattern of intangibles investment by firms in China, we will now conduct firm-level analysis to delve into the underlying economic mechanisms of firms’ investment in intangibles.

5. Firm-level evidence

In this section, we report the empirical findings on testing the four hypotheses about the determinants of intangible investment developed in Section 2 and on how intangibles impact of firm productivity.

Table 3 illustrates the determinants of intangible investment. Probit regressions are used to examine how determinants influence the probability of investing in intangibles, while Tobit regressions are adopted to examine how determinants affect the amount of intangible investment to account for the zero-value observations of intangible investment. All the factors mentioned in Section 2 play an important role in determining intangible investments. On Hypothesis 1, the results show that a firm of a larger size is more likely to invest in intangibles. On average, a 1% increase in firm size is respectively associated with a 0.05% increase in the probability of investing in software, a 0.07% increase in the probability of investing in R&D, a 0.07% increase in the probability of investing in internal R&D, a 0.027% increase in the probability of investing in outsourced R&D and a 0.042% increase in the probability of investing in organization capital according to models (1) - (5). Intangible capital can be used firm-wide and therefore has an economy of scale.

On Hypothesis 2, it is found that human capital significantly increases the propensity of investing in software and internal R&D but insignificantly increases the overall R&D and significantly decreases the outsourced R&D. On average, a 1% increase in average educational years of permanent workers is respectively associated with a 0.30% increase in the probability of investing in software, a 0.09% increase in the probability of investing in R&D, a 0.15% increase in the probability of investing in internal R&D, a 0.20% decrease in the probability of investing in outsourced R&D and a 0.09% increase in the probability of investing in organization capital according to model (1) - (5) in Table 4. While human capital generally promotes intangible investment, it encourages a firm to internalize its R&D. A possible reason is that human capital lowers the costs of R&D and therefore a firm is less likely to outsource its R&D.

15 All reported figures on the probit regressions in the text are the marginal effects at sample average. The tables on the marginal effects of the probit regressions are available upon contacting the authors.
Looking at Hypothesis 3, we find that institutional quality significantly affects intangible investment. A 1% increase in institutional quality is associated respectively with a 0.21% increase in the probability of investing in software, a 0.33% increase in the probability of investing in R&D, a 0.34% increase in the probability of investing in internal R&D, a 0.034% increase in the probability of investing in outsourced R&D and a 0.17% decrease in the probability of investing in organization capital, according to models (1) - (5). While better institutional quality is correlated with a higher propensity of investing in intangibles, better institutional quality decreases the propensity of investing in organization capital. One possible reason for this is that the baseline operation efficiency is correlated with the external institutional quality. Firms do not exist in vacuum and therefore are influenced by the external environment. The effects of external environment on firms’ innovation activities or organization investment have been well documented (Damanpour et al., 2006; Kong, 2007). However, the effects of external institutional quality on organization investment have not been well studied. Institutional quality including the degree of government intervention in enterprise activities, spillover effects of the advanced management practices from FDI, law enforcement and rule awareness are likely to significantly impact on the baseline operation efficiency. To be specific, when governments constantly intervene the operational activities of enterprises, when the spillover effects of advanced management practices from FDI are high, or when the rule awareness of workers is low, enterprises are more likely to invest in organization to improve operation efficiency. Therefore, when external institutional quality is low, the return from organization investment is likely to be high and thus the probability of investing in organization capital is high; when external institutional quality is high, the return from organization investment is likely to be low and thus the probability of investing in organization capital is low.

In terms of Hypothesis 4, the results suggest that a firm facing a competitive market has a lower probability of investing in intangibles as well as a lower investment amount of intangibles than a firm facing a non-competitive market. On average, a firm facing a competitive market respectively has a 16.5% lower probability of investing in software, a 18.3% lower probability of investing in R&D, a 19% lower probability of investing in internal R&D, a 6% lower probability of investing in outsourced R&D and a 6% lower probability of investing in organization capital according to model (1) - (5). A possible reason for this is that the boost to product markup from intangible capital is smaller when market is competitive. Existing literature has intensively discussed the impacts of market competition on innovation. Some argue that fierce market competition erodes the return from innovations (Louy,
1979; Martin, 1993; Roberts, 1999) while others argue that the effects of market competition are beneficial for innovations (Lee & Wilde, 1980; Bertschek, 1995; Blundell et al., 1995; Nickell, 1996) or the effects are two-sided (Aghion et al., 2005; Lee, 2009). However, empirical evidence for emerging economies is lacking. This finding contributes to this strand of literature by providing new evidence from Chinese firms.

When it comes to the amount of intangible investment, the results are similar. According to models (6) to (9), size remains significant, which indicates a positive correlation between size and the amount of intangible investment. As for human capital, it generally increases the amount of intangible investment but its effect is either weakly significant or insignificant. Higher institutional quality is likely to increase R&D expenditure, including overall, internal and outsourced expenditure, but the effect is either insignificant or weakly significant. However, higher institutional quality significantly reduces the intensity of organization investment, which is consistent with model (5). The effects of market competition on intangible investment are generally insignificant except on organization investment: a firm facing a competitive market on average is 0.15 lower in intensity of organization investment than a firm facing a non-competitive market.
### Table 3 Determinants of intangible investments

<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>(1) Software</th>
<th>(2) R&amp;D</th>
<th>(3) internal R&amp;D</th>
<th>(4) outsourced R&amp;D</th>
<th>(5) Organization</th>
<th>(6) R&amp;D</th>
<th>(7) internal R&amp;D</th>
<th>(8) outsourced R&amp;D</th>
<th>(9) Organization</th>
</tr>
</thead>
<tbody>
<tr>
<td>HC</td>
<td>0.830***</td>
<td>0.266</td>
<td>0.476**</td>
<td>-1.192***</td>
<td>0.282</td>
<td>2.152e+07*</td>
<td>6.209e+06*</td>
<td>2.189e+06</td>
<td>0.310*</td>
</tr>
<tr>
<td></td>
<td>(0.199)</td>
<td>(0.218)</td>
<td>(0.219)</td>
<td>(0.311)</td>
<td>(0.208)</td>
<td>(1.114e+07)</td>
<td>(3.699e+06)</td>
<td>(2.410e+06)</td>
<td>(0.167)</td>
</tr>
<tr>
<td>CM</td>
<td>-0.460***</td>
<td>-0.545***</td>
<td>-0.582***</td>
<td>-0.353***</td>
<td>-0.208**</td>
<td>6.367e+06</td>
<td>-601,046</td>
<td>865,296</td>
<td>-0.147**</td>
</tr>
<tr>
<td></td>
<td>(0.0874)</td>
<td>(0.0901)</td>
<td>(0.0909)</td>
<td>(0.113)</td>
<td>(0.0970)</td>
<td>(5.986e+06)</td>
<td>(1.636e+06)</td>
<td>(1.257e+06)</td>
<td>(0.0728)</td>
</tr>
<tr>
<td>Size</td>
<td>0.139***</td>
<td>0.220***</td>
<td>0.218***</td>
<td>0.161***</td>
<td>0.133***</td>
<td>7.216e+06***</td>
<td>2.733e+06***</td>
<td>1.542e+06***</td>
<td>0.181***</td>
</tr>
<tr>
<td></td>
<td>(0.0220)</td>
<td>(0.0259)</td>
<td>(0.0259)</td>
<td>(0.0361)</td>
<td>(0.0227)</td>
<td>(1.259e+06)</td>
<td>(406,637)</td>
<td>(279,963)</td>
<td>(0.0174)</td>
</tr>
<tr>
<td>Institution</td>
<td>0.574**</td>
<td>0.988***</td>
<td>1.049***</td>
<td>0.205</td>
<td>-0.544**</td>
<td>1.469e+07</td>
<td>884,155</td>
<td>7.673e+06*</td>
<td>-0.923***</td>
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<td></td>
<td>(0.228)</td>
<td>(0.234)</td>
<td>(0.237)</td>
<td>(0.300)</td>
<td>(0.248)</td>
<td>(2.165e+07)</td>
<td>(4.873e+06)</td>
<td>(4.243e+06)</td>
<td>(0.189)</td>
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<tr>
<td>Constant</td>
<td>-5.241***</td>
<td>-6.210***</td>
<td>-6.854***</td>
<td>-1.143</td>
<td>-0.674</td>
<td>-1.775e+08***</td>
<td>-5.215e+07***</td>
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<td>(0.820)</td>
<td>(0.896)</td>
<td>(0.905)</td>
<td>(1.125)</td>
<td>(0.851)</td>
<td>(6.351e+07)</td>
<td>(1.657e+07)</td>
<td>(1.394e+07)</td>
<td>(1.235)</td>
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<td>1,175</td>
<td>1,175</td>
<td>1,175</td>
<td>1,175</td>
<td>1,175</td>
<td>1,175</td>
<td>1,176</td>
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<tr>
<td>Industry FE</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
</tbody>
</table>

HC stands for human capital; CM refers to whether a firm faces a competitive market or not; Size is the size of a firm, measured by the amount of fixed asset; Institution stands for the institution score of a city.

Source: Authors’ own calculation.
Table 4 shows the relationship between various intangible investments and the TFP of firms. The contributions of various intangible investments to the TFP\textsuperscript{16} are generally significant across all models.

According to model (1) to (4) in Table 3, a 1% increase in IT equipment intensity and R&D intensity is respectively associated with a 0.09% and a 0.14% increase in firm productivity; a firm with software investment on average has a 11% higher productivity than that without; a firm with organization investment on average has a 13% higher productivity than that without. If all types of intangible investments are incorporated in the estimation, software investment becomes insignificant. Moreover, the interaction between software investment and organization investment is also significant, which indicates a complementary effect between these two factors. To be specific, the productivity boost from organization investment of a firm with software investment is 58% higher than that of a firm without software investment and vice versa; investing in software without investing in organization capital even has a negative effect on firm productivity.

Table 4 Intangible investment and TFP

<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
<th>(7)</th>
<th>(8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>log(IT_intensity)</td>
<td>0.0916***</td>
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<td></td>
<td>0.0764**</td>
<td>0.0754**</td>
<td>0.0799**</td>
<td>0.0865***</td>
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<tr>
<td></td>
<td>(0.0143)</td>
<td></td>
<td></td>
<td>(0.0336)</td>
<td>(0.0336)</td>
<td>(0.0329)</td>
<td>(0.0331)</td>
<td></td>
</tr>
<tr>
<td>log(R&amp;D_intensity)</td>
<td>0.144***</td>
<td>0.0881**</td>
<td>0.0849**</td>
<td>0.0847**</td>
<td>0.0805**</td>
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<tr>
<td></td>
<td>(0.0252)</td>
<td>(0.0358)</td>
<td>(0.0358)</td>
<td>(0.0355)</td>
<td>(0.0355)</td>
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</tr>
<tr>
<td>software</td>
<td>0.110**</td>
<td>0.138*</td>
<td>0.0710</td>
<td>-0.465**</td>
<td></td>
<td></td>
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<td></td>
<td>(0.0522)</td>
<td>(0.0825)</td>
<td>(0.0858)</td>
<td>(0.236)</td>
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<tr>
<td>Organization</td>
<td>0.128**</td>
<td>0.370***</td>
<td>0.242**</td>
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<td></td>
<td>(0.0559)</td>
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<td>Organization*software</td>
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<td></td>
<td>0.577**</td>
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<td>(0.253)</td>
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<tr>
<td>Constant</td>
<td>0.176**</td>
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<td>-</td>
<td>-</td>
<td>0.763***</td>
<td>0.652**</td>
<td>0.389</td>
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<tr>
<td></td>
<td>(0.0831)</td>
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<td>(6.90e-07)</td>
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<td>(0.280)</td>
<td>(0.275)</td>
<td>(0.277)</td>
<td>(0.280)</td>
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<tr>
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<td>443</td>
<td>1,318</td>
<td>1,318</td>
<td>392</td>
<td>392</td>
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<tr>
<td>R-squared</td>
<td>0.068</td>
<td>0.126</td>
<td>0.029</td>
<td>0.029</td>
<td>0.142</td>
<td>0.147</td>
<td>0.160</td>
<td>0.165</td>
</tr>
<tr>
<td>Industry FE</td>
<td>YES</td>
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<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
</tbody>
</table>

\textsuperscript{16} TFP of firms is calculated using the translog approach according to Equation (2) and results are available upon request from the authors.
Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1.
Source: authors’ own calculation

6. Conclusion and policy implications
Intangibles have been identified as an important source of productivity improvement and economic growth for developed economies. The determinants of firms’ investment in intangibles are mostly researched for these economies as well. In this paper, we make the contribution to this literature by focusing on the case of China, one of the largest emerging economies. We describe the pattern of intangible investment by Chinese firms, reveal the determinants of intangible investment and analyse how intangibles affect firm productivity.

The results of our estimates confirm the four hypotheses developed from the theoretical framework in Section 2. We find that human capital, size and institutional quality generally increase both the propensity and quantities of intangible investment while market competition decreases both the propensity and amount of intangible investment. Evidence on the propensity is more statistically robust than that on quantities. One interesting finding is that higher human capital is associated with a lower propensity for outsourced R&D, which is consistent with the assumption in Section 2 that higher human capital can lower the costs of producing intangible investment. Another interesting discovery is that better institutional quality is associated with lower organization investment. A possible reason for this is that institutional quality is associated with the baseline organization capital and further investment is unlikely to improve productivity much if the baseline capital is high.

Having explored the determinants of investment in intangibles, this study continues to examine the positive impacts of various intangible investment and ICT investment on the productivity of Chinese firms. It is found that the three components of intangibles, that is software investment, R&D investment and organization investment, as well as ICT investment, are significantly positively correlated with firm productivity, and there is a complementary effect between organization investment and software investment.

Our findings also provide important implications for policy-making in emerging economies. Emerging economies are often trying to climb up the global value chain and therefore need to accumulate intangible capital to improve value-added of product and productivity. Policies that encourage firms to build up proprietary technology and knowledge of production and thus to enable firms to move away from highly competitive segments of the markets, increase education and human capital, and
improve institutional quality such as strengthened protection of property rights in
general and intellectual property rights in particular, are likely to encourage intangible
investment by firms and boost the productivity of firms as a result.

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