10-26-2016

The roles of knowledge assets in promoting firm productivity and innovation in China

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MPHIL

LINGNAN UNIVERSITY

2016

THE ROLES OF KNOWLEDGE ASSETS IN PROMOTING FIRM PRODUCTIVITY AND INNOVATION IN CHINA

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A thesis
submitted in partial fulfillment
of the requirements for the Degree of Master of
Philosophy in Economics

Lingnan University

2016

ABSTRACT

THE ROLES OF KNOWLEDGE ASSETS IN PROMOTING FIRM PRODUCTIVITY AND INNOVATION IN CHINA

by

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Master of Philosophy

This paper investigates how intangible knowledge assets impact upon the firm's products and the output of new products through a large panel data set covering all manufacturing firms from the period of 1998-2007. We hypothesize that more knowledge assets have a positive impact on total factor productivity and the ratio of new products to total products, but only up to a point, due to the importance of complementary assets. The inverse quadratic relationship found in the relationship between the ratio of knowledge assets to total assets and TFP suggests that it is necessary to balance knowledge assets with complementary assets in order to achieve a higher degree of productivity. However, the positive effects of intangible asset ratio on the proportion of the output of new products in that of total products suggest that new products always increase with knowledge assets, because products are the prerequisite for one firm to benefit from its knowledge assets. The results are robust in all firms with different ownership types, including foreign, state-owned and private groups or all those with different motivations (international-market oriented vs. domestic-market oriented). These results are still robust after considering the effects of R&D expenditure whose effects on firms are discussed more in the literature, however, as an important channel for knowledge assets accumulation, R&D cannot be completely equal to the generated knowledge assets one firm has.

DECLARATION

I declare that this is an original work based primarily on my own research, and I warrant that all citations of previous research, published or unpublished, have been duly acknowledged.

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ACKNOWLEDGEMENT

I sincerely acknowledge my supervisors, Prof. Lin Pin, Prof. Jiang Liangliang, Prof. Zhang Yifan and Prof. Ho Lok-sang, who inspired me to do research and taught me a lot during the last two years in my Mphil study. Without their careful instructions and strong support, my thesis would not have reach its present form. Moreover, I want to extend my gratitude to all my seminar participants at Lingnan University for their helpful comments on my seminar participants at Lingnan Universtiy for their helpful comments on my research. Last but not least, I want to thank the staffs of the Department of economics, classmates in the research office, my friends and my family for their support throughout my period of study.

THE ROLES OF KNOWLEDGE ASSETS IN PROMOTING FIRM PRODUCTIVITY AND INNOVATION IN CHINA

Chapter 1 Introduction

Possession of technological knowledge is important for every firm. Firms have two channels to benefit from the technology. The first channel is exploring advanced technology, which will help firms to acquire competitive advantages in a market. The second one is exploiting their generated knowledge to improve the firms' products. Because the knowledge assets are accumulated by the firms from past experience for a long time, they are special and valuable to each firm. Some knowledge assets are codified, and some are tacit. Codified knowledge refers to knowledge that is transmittable in formal, symbolic language, whereas tacit knowledge is hard to articulate and is acquired through experience (Polanyi, 1966). Taking full advantage of current knowledge assets will also help reduce cost and have smaller risks than researching new technologies for one firm. To our knowledge, few empirical studies have noticed the difference between these two channels in productivity based on China's economy. Besides, complementary assets which should not be ignored are also important because they play the critical role in transferring knowledge assets into commercial value. Teece (1986) argues that the commercialization of an innovation "requires that the know-how in question be utilized in conjunction with other capabilities or assets. Services such as marketing, competitive manufacturing, and after-sales are almost always needed. These services are obtained from complementary assets, which are specialized". Our paper pays attention not just to the value of knowledge assets but to the ratio of the knowledge assets to total assets and the effects of knowledge asset ratio on firm-level productivity. We use the ratio of knowledge assets to total assets to measure the combination of knowledge assets and total assets. To our knowledge, only Denicolai, Zucchella and Strange (2014) deeply discuss this and provide theoretical arguments on the question why knowledge assets should have a positive, but diminishing impact, upon the firm's international performance, and empirically they find the non-linear relationship between knowledge intensity and international sales. Based on their discussion, we empirically investigate the relationship between knowledge assets and total factor productivity (TFP) and new products based on China's firm-level data.

The role of knowledge assets is a widely-debated topic. One firm can benefit from knowledge assets by integrating them into their current relationship and environment, and finally improve their advantage in a market (Grant, 1996; Kogut & Zander, 1992; Peteraf, 1993; Coervo-Cazurra, Maloney & Manrakhan; 2007). The embedding of knowledge assets into firms' activities and products also can help them adapt to a new market, and search and exploit new opportunities, enlarge their market shares and then improve their competitiveness (Oviatt & McDougall, 2005; Autio, Sapienza, & Almeida, 2000; Kylanheiko et al., 2011;). Finally, knowledge assets can simulate innovative activities, export, internationalization and firm growth (e.g. Wakelin, 1998; Oviatt & McDougall, 1994). It has been found the critical role of knowledge assets played in many aspects of firm performance, such as added value, sales, return on equity and number of patents (e.g Griliches, 1986; Goto & Suzuki, 1989; Bloodgood et al., 1996). Most of these results show the positive relationship, and only a small portion show a non-linear relationship between knowledge assets and international sales (Denicolai, Zucchella & Strange, 2014).

However, what is ignored by empirical research is knowledge assets alone cannot create value by themselves. Their value needs to be realized by complementary assets. Various authors give theoretical analysis that the combination of firm's difficult-to-trade assets and complementary assets, not the specific knowledge assets alone, plays the decisive role in profiting from new technology (Teece, 1996; Teece, Pisano and Shuen, 1997). The developers of new technology may suffer loss if they fail to own the necessary complementary assets, while the imitators may benefit due to their possession of these complementary assets. Therefore, increasing the knowledge assets without considering the needed complementary assets may lead to increase the input but fail to increase the output. In fact, one of the primary motivations for firms to invest in exploring technology is the belief that the special and advanced knowledge assets will create more values for them. Many firms need to be more effective in exploiting their owned knowledge assets if they are to improve the output brought by these knowledge assets. These requires one firm not only to consider what the value of the knowledge assets is but also how to commercialize these knowledge assets and then to really benefit from them, after all, exploring new technology needs a large amount of inputs. Therefore, we need not only to investigate the relationship between knowledge assets with firm performance, but, more importantly, to pay attention to combine knowledge assets and complementary assets.

The knowledge capital plays a critical role in economy growth. International technology spillover is one of major sources of productivity growth (e.g. Coe and Helpman, 1995; Eaton and Kortum, 1996; Keller, 2000). Human capital and R&D both use measurement of the host country's absorptive ability in learning technology spillovers from foreign firms (Borensztein, Gregorio, and Lee, 1998; Griffith, Redding, & Van Reneen, 2003). Besides, the role of knowledge assets in firms' performance has been emphasized in many empirical studies. Technology capability has positive effects on many aspects of firms performance, such as added value, sales growth, internationalization (Tsai and Wang, 2008; Denicolai, Zucchella, and Strange, 2014).

Another important thing is the difference between the role of knowledge stock and its associated absorptive capability. Knowledge stock and its absorptive capability are both important for firms' performance. Absorptive capability is defined as "a dynamic capability pertaining to knowledge creation and utilization that enhances a firm's ability to gain and sustain competitive advantage" (Zahra & George, 2002). Therefore, R&D expenditure is always considered as the critical factor in measuring absorptive capability. Knowledge stock cannot be equal to its absorptive capability. Besides, knowledge stock can affect its absorptive capability. Firstly, knowledge stock represents the experience competing with rivals and knowledge base accumulated in the past which can help one firm to take over advanced technology and adapt to the changing markets quickly. When knowledge capital needs to be considered, one method in the literature is using the perpetual inventory method to compute R&D stock as a measurement of knowledge stock. However, R&D expenditure is just an expense not a "generated asset" according to accounting standard IAS 38, while intangible assets include trade mark, patented technology and marketing rights. Therefore, intangible assets are more appropriate to be used to measure a firm's solo knowledge stock.

This paper examines the relationship of total factor productivity (TFP) and the combination of knowledge assets and relative complementary assets by using firm-level panel data from China's manufacturing sector. Our data set covers all state-owned firms, foreign firms and private firms with the sales of more than RMB 5 million Yuan from 1998 to 2007. The number of firms in our data set changes from 148, 685 in 1998 to 313,048 in 2007. China is of particular interest because its economy over last decades exhibits impressive growth rate which offers an amazing setting for doing economic research. The continuing reforms since the late 1970s and participating more in the world economy are both reasons for its rapid development. The increasing competition following the development drives the Chinese government and Chinese firms start to think about the importance of technological capability. Government has implemented the patent law on regularization of knowledge protection in 1985. And firms' aggressive activities on patent applications (Jefferson, Hu, Guan, & Yu, 2003) also reflect the importance of knowledge assets in the market.

The general approach in this paper is to regress firm-level total factor productivity with measurements of combination of knowledge assets and its related complementary assets. We use two methods to compute total factor productivity. Firstly, a semi-parametric estimation technique following Levinsohn and Petrin (2003) can offer us consistent estimates of TFP. This measurement has been widely used in previous studies (Pavcnik, 2002; Javorcik, 2004; Lin, Liu and Zhang, 2009). The second productivity measurement is a Törnqvist index number used by Brandt, Biesebroeck and Zhang (2012) as a benchmark measurement, which does not require the estimation of any parameters. For measuring of knowledge assets, the balance sheet of each firm in our data includes the value of intangible assets. We care more about the combination of knowledge assets and the complementary assets. Therefore, the ratio of intangible assets to total assets will be used as our key independent variable.

In the paper, we examine the effects of combination of intangible assets and complementary assets on total factor productivity and the output ratio of new products respectively, as well as analyze the market orientation of firms and the ownership of firms. The first finding in this paper is the inverse-U curve relationship between intangible asset ratio and TFP, which shows that there is an optimal combination between knowledge assets and its complementary assets and total factor productivity. TFP increases with knowledge assets only if there is enough and appropriate complementary assets, or TFP will decline because knowledge assets increase the input while the lack of complementary assets fails to bring the increase in total output. However, the linear relationship appears in intangible asset ratio and the output ratio of new products (new product output/total output). The reason for this may be that the new products are the antecedent of firms' profits obtained from its knowledge assets. Though they cannot definitely create profits or increase the total output. We find that in all foreign, state-owned and private groups there are two kinds of relationships. The magnitude of knowledge's effects on TFP is the largest before knowledge assets and complementary assets are equal to the best combination, though state-owned firms are thought as the least productive firms all the time. We find that these relationships in international-market-oriented firms are not very different from those in domestic-market-oriented firms while the same increase in knowledge will create larger improvement on TFP because the complementary assets are not enough to support to commercialize knowledge assets.

The rest of the paper is organized as follows. Chapter 2 provides an overview of the literature. Chapter 3 describes the two hypothesizes we provide. Chapter 4 discusses the data and the measurement issues. The empirical model is presented in Chapter 5. In Chapter 6, we report the results of the econometric test. Chapter 7 discusses our contributions. The paper concludes with Chapter 8.

Chapter 2 Literature Review

2.1 Importance of Knowledge Assets

One problem of investigating the impacts of knowledge assets is the method of quantifying the knowledge assets. Knowledge assets are difficult to define or measure because some knowledge assets are codified but some are tacit (Nonaka, 1994). Codified knowledge refers to knowledge that is transmittable in formal and symbolic language, whereas tacit knowledge is hard to articulate and is acquired through experience (Polanyi, 1966). Technological knowledge is more investigated by the literature because it is easier to be codified than social knowledge. However, for some knowledge, the difference between tacit and codified one is temporal (Edomondson, Winslow, Bohmer, and Pisno, 2003). And some knowledge assets are context-dependent but others are context-independent (Hansen, 1999).

Technological knowledge has been widely recognized as being important for economy growth in regional economy and for firm development. Kuo and Yang (2008) find that knowledge capital, both of R&D capital and technology imports, plays an important role in regional economic growth by systematically investigating productivity convergence in Chinese regions. Kinoshita (2000) also finds that one developing country’s innovative expenditure increases the level of spillover from FDI. Griffith, Redding and Van Reenen (2004) also find that two faces of R&D can stimulate innovation and absorptive capacity, which is statistically and economically important to the rates of productivity growth by using a panel of industries across twelve OECD countries.

At the firm level, the role of knowledge in firm performance has been emphasized in theoretical arguments. Teece, Pisano and Shuen (1997) highlight that one firm's specific asset position, which is construction of difficult-to-trade assets and complementary assets, plays a critical role in keeping its competitive advantages. The core of one firm's competence stems from knowledge assets it holds. These assets can be patents which have been officially protected, and also can be values, culture and organizational experience which cannot be clearly quantified or traded or built not in short time. The development of competence usually does not just require one kind of asset but the combination of assets across divisions. Peteraf (1993) uses a conceptual mode to identify that compared with their rivals, superior and especially special knowledge assets will be the foundation of firms' competitive ability. Lee and Pennings (2001) consider the quality of technological assets is a critical factor for new ventures' performance in the international market. Coervo-Cazurra, Maloney and Manrakhan (2007) also suggest, according to resource-based theory, technology assets can create advantages for firms' internationalization. Tuppura, Saarenketo, Puumalainen, Jantunen and Kylaheiko (2008) further show that the firm's accumulated knowledge assets have a large impact on its entry timing and international growth orientation. The Knowledge stock and its associated absorptive capability help one firm to identify and capture new opportunities in the developing world. The ownership of knowledge assets is recognized as a major driver of firm growth, both domestically and abroad (Teece, Pisano and Shuen, 1997).

Empirically, Kylanheiko et al. (2011) show that innovation is the decisive driver of firm growth. They prove that the ability to innovate can stimulate new products and then enlarge market shares. And they further show that the quantity and quality of technological assets contribute to firm growth. Wakelin (1998) finds that, comparison among firms with same size, non-innovative firms are more likely to export than innovative firms. Lu and Beamish (2001) suggest partners with local knowledge can effectively help firms to overcome the deficiencies they face in resources and capabilities. Autio, Sapienza and Almeida (2000) assert that firms with greater knowledge intensity will grow more rapidly in the international market.

2.2 The Role of Complementary Assets

Complementary assets include complementary manufacturing resources, such as the plants and equipment. Complementary assets are classified into two types: generic and specialized (Teece, 1986). Generic complementary assets do not need to be adjusted to the innovation, while specialized complementary assets exhibit unilateral dependence between the innovation and the complementary assets (Teece, 1986). Usually, specialized complementary assets need a long time to build, and thus they are context dependent (Teece et al. 1997).

The role of complementary assets has been widely emphasized no matter in theory or in empirical studies. In fact, there is theoretical support for the importance of complementary assets. Teece (1986) gives a conceptual model to suggest that complementary assets play a decisive role in whether firms can benefit from new technology. Developers of the intellectual property may not definitely benefit from innovation, if they fail to acquire specialized complementary assets which are necessary for converting a technological success into a commercial one. However, the profits may transfer to followers who are not the developer of technology but the owners of complementary assets. He also provides a theoretical foundation, highlighting that knowledge assets and complementary assets are both important for firms to profit from technological innovation, and that "innovative firms without the requisite to manufacture and related capacities may die, even though they are the best at innovation." Kogut and Zander (1992) also give the similar view that firms are a repository of knowledge. The critical function of one firm is merging knowledge into current relationship and environment, and finally improving the firm capability. Grant (1996) emphasizes that knowledge integration is necessary for firms to acquire competitive capability. Coervo-Cazurra, Maloney and Manrakhan (2007) also theoretically analyze that lacking complementary resources required operating abroad and keeping the advantage of its specific resources in a new market are both two main causes of the difficulties faced by firms when they expand businesses into new markets.

However, complementary assets fail to receive the same much notice as knowledge assets in empirical studies. Rothaermel and Hill (2005) empirically find that specialized complementary assets needing to commercialize new technology can help improve incumbent industry performance by using a panel data set over a 26-year period, while incumbent industry performance may decline if just generic complementary assets are needed to commercialize new technology. Denicolai et al. (2014) analyze a sample of 290 European listed companies and find the inverse quadratic relationship between knowledge assets and foreign sales intensity, suggesting that it is necessary to balance knowledge assets with complementary assets to achieve higher international performance. We will follow these studies to investigate the role of, not only the knowledge assets but also the complementary assets, in productivity based on Chinese data.

2.3 Measurement of Knowledge Assets

Another problem is the measurement of knowledge assets. Also, many papers use the patents one firm has to measure knowledge assets. In the literature, many authors measure technological ability with multiple survey items (Olk and Young, 1997; Simonin, 1997; Zander and Kogut, 1995; Zahra, Ireland and Hitt, 2000). R&D expenditure or R&D intensity (the ratio R&D to total assets or total sales) is the most used variable to measure knowledge assets one firm owns. Kinoshita (2000) uses R&D expenditure as a measurement for technological ability in investigating Czech manufacturing firms. And he finds that one country's R&D expenditure increases the level of spillover from FDI. Griffith, Redding and Reenen (2004) also employ R&D expenditure to research the role of absorptive ability in productivity growth. Kuo and Yang (2008) mainly investigate the role of knowledge capital in the economic growth. Most of these researches find there is a positive relationship between knowledge assets and the firm's performance. These studies fail to consider whether R&D can accurately and completely measure the knowledge assets, even though the accumulation of knowledge is the key determinant of the economic growth of one country other than R&D expenditure (Kinoshita, 2000).

R&D expenditure cannot completely represent the value of knowledge assets discussed by Denicolai et al. (2014). "It is just an input to the process of new knowledge generation and only can be a proxy for the technological intensity of the firm, besides, the accounting standard IAS 38 emphasizes that R&D expenditure must never be recognized as a generated asset, but as an expense in the period in which it occurred". R&D is just the knowledge flow which is an important channel to increase one firm's knowledge stock because its two faces, stimulating innovation and absorptive capability. Absorptive capability is defined as "a dynamic capability pertaining to knowledge creation and utilization that enhances a firm's ability to gain and sustain competitive advantage" (Zahra & George, 2002). Sometimes, R&D stock are used to replace knowledge stock by using the perpetual inventory method. However, R&D expenditure cannot completely be transferred into knowledge stock and there are other channels, such as technological diffusion (Kinoshita, 2000), for firms to increase their knowledge stock.

According to the relevant International Accounting Standard (IAS 38), intangible assets include 'scientific or technological knowledge, design and implementation of new processes or systems, licences, intellectual property, market knowledge and trademarks (including brand names and publishing titles). Common examples of items encompassed by these broad headings are patents, copyrights, motion picture films, customer lists, mortgage servicing rights, fishing licences, import quotas, franchises, customer or supplier relationships, customer loyalty, market share and marketing rights.' (IAS38, p.9) Identifiability, control over a resource, and the existence of future economic benefits are three criteria that intangible assets must meet (IAS38, p.10). The value of the intangible asset is computed according the 'costs incurred initially to acquire or internally generate an intangible asset and those incurred subsequently to add to, replace part of, or service' (IAS 38, p.18). In this meaning, intangible assets include all codified knowledge, such as patents and copyrights, and tacit knowledge assets that has transferred into codified knowledge assets. Therefore, the value of intangible assets is more appropriate to measure the value of knowledge stock. Prange and Verdier (2011) suggest that the knowledge stock and learning capability are both important for firm performance. A firm that just focus on exploring new technology will hardly profit from its knowledge stock, while one that just focus on exploiting its current knowledge will lose competitive capability in a market. In this definition, R&D is more about firms' exploring new technology. Also, in most papers, R&D is used to measure one firm absorptive capability for new technology (Kinoshita, 2000; Griffith, Redding, and Reenen, 2004; Kuo and Yang, 2008; Petersen, Petersen & Lyles, 2008). Moreover, these studies ignore the role of knowledge stock in considering technological capability.

However, knowledge stock is not only a critical factor in one firm's development, but also can enhance impacts of R&D. because it accumulates experiences by interacting with based (old) knowledge and exposure to diverse resources from various markets and cultural background (Hitt, Hoskisson & Kim, 1997). Besides, knowledge stock can improve learning ability by integrating knowledge with different markets. Delios and Beamish (2001) emphasize the crucial role of intangible asset in international expansion. Overall, only a few studies have used direct method to measure knowledge assets. In this paper, we will use direct data of intangible assets which is directly offered in each firm's balance sheet. We will use the term intangible asset ratio – the ratio of intangible assets to the total assets recorded in the balance sheet – to further investigate the role of combination of intangible assets and complementary assets.

2.4 Performance Measurement

A large number of existing papers study the relationship between knowledge assets and firm performance. Most of studies measure the performance by using profits, sales and added value. Denicolai, Zucchella and Strange, (2014) use foreign sales to measure firms' international performance, and they find the non-linear relationship between knowledge assets and their international sales. Tsai and Wang (2008) evaluate the effects of external technology acquisition on firms' performance by using added value to measure performance. Griliches (1986), Goto and Suzuki (1989) and Lichtenberg and Siegel (1991) also use added value to evaluate the effects of knowledge assets on the firm's performance. Besides general performance and the innovation output, for example, the number of patent is also used as a performance measurement. Sales growth and returns on equity (ROE) are both widely used to measure firms' performance (Bloodgood et al., 1996; Brush, 1995; Chandler & Hanks, 1993; Zahra, 1996). However, Brush & Vandrwerf (1992) show the drawbacks of the two measurements. Market share is another important measurement of performance, while it also has limitations because it is difficult to differentiate the market and industry boundaries. However, we do not follow them by using these to measure the performance. We prefer to know the respond of total factor productivity and new product output to knowledge assets.

2.5 Total Factor Productivity

Productivity differences have been used to explain much of differences in incomes worldwide, and technology plays a critical role in determining productivity (Keller, 2004). The effects of R&D and human capital on productivity have been investigated in various studies. Roberts and Xu (2011) prove that investments in R&D and export positively affect the firm's productivity. Griffith, Redding and Reenen (2004) empirically prove that R&D can positively affect productivity by directly stimulating innovative activity or indirectly stimulating technology transfer by using a panel data of industries across twelve OECD countries. R&D is showed to play a critical role in the convergence of TFP levels within industries. Lancheros, Milner and Yang (2015) investigate the productivity convergence in India, and their results show that globalization is an important factor in facilitating firms' productivity. In firm level, Doraszelski and Jaumandreu (2013) examine the impact of the investment in knowledge on the productivity of firms and find that R&D expenditures play a key role in determining the differences in productivity across firms and the evolution of firm-level productivity over time.

The factors affecting productivity are widely discussed in previous studies. Edwards (1998) uses openness indicator to show that more open countries experience faster productivity growth by using comparative data of 93 countries. Melitz (2003) analyzes the impact of trade on aggregate industry productivity, and shows that the aggregate industry productivity growth is contributed by reallocation to more productive firms due to exposure to trade. Criscuolo, Haskel and Slaughter (2005) use UK firm data to investigate that firms engaging in global market have higher productivity than those just engage in domestic market. The reason for that is that they learn more from international partners with more researchers than domestic competitors. Kraay (1999) finds that exporters experience higher labor productivity than non-exporters based on a data set of 2105 Chinese industrial enterprises between 1992-1998, while Ma, Tang and Zhang (2014) find firms are more productive after exporting by using the large panel data set of China's manufacturing firms between 1998 and 2007.

2.6. Contributions

As mentioned earlier, there are a number of empirical studies of the R&D effects on productivity in recent years. All of these studies examine the R&D effects without notice it cannot completely measure the "generated asset" (Accounting Standard IAS), actually, almost all of them use R&D represent firms' technological capability ignoring one firm's knowledge stock. However, knowledge stock not only cannot be accurately measured by R&D, but also will affect the amount of R&D expenditure. In fact, the benefits brought by knowledge stock is more about how one firm exploit its resources while those brought by knowledge investment are more about how one firm explore new resources.

We contribute to the literature in two ways. First, we explicitly separate knowledge stock and R&D expenditure which is more about knowledge flow and more focus on the effects of knowledge stock on productivity and new product output, by using the data about Chinese manufacturing firms for 1998-2007 period. Second, we more notice the role of complementary assets. Knowledge assets cannot create profits independently. To what extent one firm can benefit from its knowledge assets is depend on the combination of knowledge assets and complementary assets. We use the ratio of intangible assets to total assets to measure one firm's structure of assets and find that there is best asset combination for firm productivity and productivity growth.

Chapter 3 Hypothesis development

Knowledge assets affect one firm's performance in various aspects, such as the added value, return on equity, sales and internationalization. A firm as a repository of knowledge needs to integrate the special and superior knowledge into its current relationship and environment, and in this way, the firm can get advantages in domestic and international market. More papers in the literature focus on the impacts of R&D on the firm's performance and productivity. However, R&D is more about the knowledge flow, not completely equals to the knowledge stock. The channel access to external resources, past experience and social interaction are all factors that will affect firms' R&D. Moreover, well-developed capabilities of knowledge transformation, exploitation, acquisition and assimilation can help one firm to take over pivotal technology and integrate it into its own products, then enable it to achieve and sustain its competitive advantages. We suggest, based on the literature mentioned above, that the quantity and quality of knowledge assets stock possessed by one firm can stimulate its productivity.

On the other hand, knowledge assets cannot alone benefit one firm because complementary assets are also critical. Various authors agree on a view that the owner of knowledge assets cannot definitely benefit from them except he owns the relevant complementary assets at the same time, which is necessary for converting a technological success into a commercial one (Teece, 1986). Several authors ever discuss the role of complementary assets in timing, orientation and expansion of internationalization strategy (Cuervo-Cazurra, Maloney, and Manrakhan, 2007; Tuppura et al. 2008). Given that knowledge assets must be combined with complementary assets, the relationship between knowledge assets and total factor productivity may suffer diminishing returns.

Furthermore, there may come a point that a high ratio of knowledge assets to total assets may signally reduce interests in the firm productivity. First, a high ratio of knowledge assets means the decrease in the needed resources and facilities, and thus the complementary assets base is not enough to support the best exploitation of the knowledge assets (Cuervo-Cazurra et al., 2007; Hu, 1995). Secondly, one firm may externally acquire the knowledge assets, such as buying patents, but it may lack the appropriate facilities to transfer and enough ability to assimilate them, in the same way, the total factor productivity will suffer decrease.

H1: Other things being equal, the larger the proportion of knowledge asset of a firm is, the greater its TFP will be, provided that its knowledge assets are utilized in their combination with complementary assets.

One firm's competitive advantage is based on its products. Whether its products meet market demand, whether they are easily reproduced internally and whether they can be imitated by competitors are three critical questions on keeping its positions in the markets. Furthermore, only by converting a technological success into commercial products can one firm benefit from its knowledge assets (Teece. 1986). This means products are the prerequisite for one firm to benefit from its technology. One firm's specific asset position, which is the construction of difficult-to-trade assets and complementary assets, plays a critical role in keeping its competitive advantages

(Teece, Pisano and Shuen (1997)). Kylaheiko, Jantunen and Tuppura (2011) have shown that technological capabilities positively impact the firm's innovative activities. Various authors find that, technological capability can improve one firm's sales, added value and innovation output (Griliches, 1986; Goto & Suzuki, 1989; Lichtenber & Siegel, 1991; Tsai and Wang, 2008). Kylanheiko et al. (2011) have proved that the ability to innovate can stimulate new products and then enlarge market shares. However, one firm cannot definitely benefit from the application of intellectual property in international markets, due to increases in dynamic transaction cost of transferring and replicating (Langlois. 1992). Moreover, product innovation is a costly activity that needs to consume a substantial proportion of firm resources and to overstretch overall product development budgets (Rosenbusch, Brinckmann, and Bausch, 2011)

Based on the above discussions, when one firm holds more intangible assets, it is more likely it will utilize these knowledge assets to develop new products. On one hand, knowledge assets are a strong driver for a firm to produce more new products. On the other hand, a firm may fail to commercialize its knowledge assets due to limitations of complementary assets which provide necessary facilities, infrastructure, and the process for knowledge transfer.

H2: Other things being equal, the larger proportion of knowledge asset of a firm is, the more innovative it will be in developing new products, provided that its knowledge assets are utilized in combination with complementary assets.

Chapter 4. Data, Variables and Empirical Model

4.1 Data

We utilize firm-level data from the period of 1998-2007 that is surveyed annually by the National Bureau of Statistics (NBS). All state-owned or non-state firms with the sales of more than RMB 5 million Yuan are included in this survey. Brandt, Biesebroeck and Zhang (2012, 2014) provide the introduction to these data sets and the construction of information that is needed to use these data, including deflectors to match firms and construct a real capital stock series.

For matching firms over time, we use the method offered by Brandt, Biesebroeck and Zhang (2012). Except using unique numerical IDs to link firms, we also track firms by using information on the firm's name, industry, address, etc. In case that some firms receive a new ID due to a result of restructuring, merger, or acquisition. The fraction of firm's that can be linked to a firm in the previous year increases over time from 84.5% in the first two years (1998-1999) to 92.2% in the final two years (2006-2007). Overall, above 90% of all year-to-year matches are constructed by using firm IDs, and 4.1% by using other information of the firm. These other matches are still important as one-sixth of all firms included in database for more than one year once change their official ID over 1998-2007.

We follow Brandt, Biesebroeck and Zhang (2012) to focus only on manufacturing firms. This provides an unbalanced panel of firms that increases the number of firms from 148,685 firms in 1998 to 313,048 in 2007.

Finally, we drop firms without necessary variables for us to calculate productivity. The reason for this is because related information is not original, or because negative values of the real capital stock or values added for variables exist. We also delete firms with less than 8 employees because another law is for these firms.

Table 1 provides descriptive statistics for our sample, including information on the number of firms, intangible assets, total assets, added value, sales, etc. To match firms in different years, we use unique numerical IDs to link firms over time. Firms use identical ID except experiencing restructuring, merger or acquisition. By following what Brandt, Biesebroeck and Zhang (2012) regard, we also link the firms by using information of the firm's name, industry, address, etc.

4.2 The Dependent Variable

4.2.1 Total Factor Productivity (TFP) and Total Factor Productivity (TFPG)

The Cobb-Douglas production function is

$$Q_{it} = A_{it} L_{it}^{\alpha_l} K_{it}^{\alpha_k} \qquad (1)$$

Where α_l and α_k are the output elasticities of labor and capital, L is labor input and K is capital input and A is the total factor productivity parameter, so we write it as TFP. The accuracy of measuring productivity depends on the accuracy of measuring inputs and outputs and on estimating the substitution possibilities that the technology allows. In our paper, two methods are used to compute TFP. The first one is a straightforward Törnqvist index number following Caves et al. (1982) and the second is a semi-parametric estimation technique following Levinsohn and Petrin (2003).

The first measurement we use is a straightforward Törnqvist index number, which does not need any estimation for parameters. Many papers investigate the methods and apply these methods to different country's data. Coves et al. (1982a) explain why this can be used as an exact measurement of the relative productivity of two observations. Brandt, Biesebroeck and Zhang (2012) use this method as a benchmark measurement in computing firm-level total factor productivity in China's manufacturing sector. Our paper mainly follows their steps. The intuition is that the cost minimizing policy will require the relative factor price ratio to be equal to the local elasticity of substitution between inputs of the production technology. Therefore, input substitutability can use factor shares to control. The advantage of this method is that it allows for technology heterogeneity in input elasticity across observations (Brandt, Biesebroeck and Zhang (2012)).

Productivity growth is calculated in the usual way as

$$TFPG_{it} = (q_{it} - q_{it-1}) - S'_{it}(l_{it} - l_{it-1}) - \left(1 - S'_{it}\right)(k_{it} - k_{it-1}) \qquad (2)$$

Where $S'_{it} = (S_{it} + S'_{it-1})/2$ is the average wage bill in added value and one minus this value for capital. Three variables q, l and k is the logarithms for added value, labor, and capital. Except computing the total factor productivity, it also needs to compare the productivity level across firms in the same industry. Caves et al. (1982b) propose the following multilateral productivity measurements:

$$lnTFP_{it} = (q_{it} - q_t) - S'_{it}(l_{it} - l_t) - \left(1 - S'_{it}\right)(k_{it} - k_t) \qquad (3)$$

Where $S'_{it} = (S_{it} + S'_t)/2$ is the average wage bill in value added (Brandt, Biesebroeck and Zhang (2012)) and one minus this value for capital. Three variables q, l and k is the logarithms for value added, labor, and capital. l_t and k_t are the average of all firms' labor and capital in the industry. The weights are different among observations. This method makes a comparison between individual observation with one same benchmark and the same time which allows for technology heterogeneity.

To verify our robustness, we follow Levinsohn and Petrin (2003) to use a semi - parametric method to estimate TFP. This method has been a widely-used approach to estimate TFP with firm panel data (Pavcnik, 2002; Javorcik, 2004). One difficulty in accurately measuring productivity is that labor and intermediate inputs are not exogenous since they are chosen by firms after observing productivity (Griliches & Mairesse, 1998). Olley and Pakes (1996) suggest the investment can be used as a proxy for the un-observable productivity shock. They believe that investment increases with respect to the shock, based on capital. However, the data about investment is not available in our data. Levinsohn-Petrin procedure is more appropriate for us. They use intermediates instead of investment to solve endogenous issues argued by Griliches and Mairesse (1998). This method has two advantages for our computation (Lin, Liu and Zhang (2009)). First, in our data, many observations, which are used in Olley and Pakes (1996) procedure as the proxy for unobservable productivity shock, have zero investment. Second, intermediate inputs are better than investment because intermediate inputs with lower cost of adjusting investment respond more quickly to the productivity shock than investment.

By following Lin, Liu and Zhang (2009), we use Stata module "levpet" developed by Petrin, Poi, and Levinsohn (2004) to implement the Leveinsohn-Petrin procedure. We perform it for each industry to allow for different technologies across sectors. The function for computing the productivity level is as follows:

$$lnTFP_{it} = q_{it} - \alpha_l' l_{it} - \alpha_k' k_{it} \quad (4)$$

Where l_{it} and k_{it} are the estimated coefficients of labor and capital from Levinsohn-Petrin procedure. And the productivity growth is expressed as:

$$TFPG_{it} = lnTFP_{it} - lnTFP_{it-1} \quad (5)$$

4.2.2 New product output ratio

Another dependent variable in our paper is *new product output ratio* that is the ratio of new product output value to total output value. New product output should be the direct reflect of the one firm knowledge assets due to products is the manifestation of one firm technological capability. Only knowledge assets are transferred into products, knowledge assets can benefit one firm, such as increasing profits and improving productivity. Therefore, the changes on new product output should be the first reflection of one firm's knowledge assets. Our data offers the new products value for each firm, then make it possible for us to analyze.

4.3 The independent variable

In most literature, the knowledge assets are measured by using R&D expenditure every year. However, R&D is just a kind of contribution to new knowledge generation. R&D expenditure can be used to estimate one firm's technological intensity, but cannot exactly estimate the value of knowledge assets one firm has already grasp, although it is necessary for one firm to acquire its own technology knowledge. The definition for intangible assets according to China Accounting Standard is almost no difference with IAS38 which is mentioned above. According to this definition, intangible assets includes licenses, import quotas and goodwill according the old China Accounting Standard before 2006 which are not treated as knowledge assets in most literature. However, according to the opinion of B.Lev, the terms Intangible Assets and Knowledge Assets are interchangeable owing to the fact that two terms are "widely used: Intangible Assets in accounting literature, Knowledge Assets by economist; and on the whole they come to the same: to the future benefits that are not embodied materially" (Lev, 2003). In this paper, we prefer to use intangible assets to measure the knowledge stock. First, the intangible assets according to accounting standard include all the knowledge assets such as patents. Second, intangible assets can reflect the knowledge assets one firm has hold which different the knowledge flow represented by R&D. Moreover, complementary assets are also important for one firm. Therefore, we care more about the combination of intangible assets and complementary assets.

Thus, the key independent variable in this paper is the ratio of intangible assets to total assets (*intangible asset ratio*).

4.4 The Empirical Model

$$Y_{it} = \gamma_0 + \gamma_1 intangible\ asset\ ratio_{it-1} + \gamma intangible\ asset\ ratio_{it-1}^2 + X' + \{FE\} + \varepsilon_{it-1} \qquad (6)$$

Where Y_{it} is *TFP* and *TFPG* respectively and *intangible asset ratio = intangible asset/ total asset* and *intangible asset ratio square* is the square term of *intangible asset ratio*, in all regressions, we use the logarithms form for variables. X' is a vector of firm characteristics as control variables following Ma, Tang and Zhang (2014) which include the firm's wage, capital, employment, age and total assets, all in logarithms form. All independent variable lag one year. {FE} includes 4-digit industry, province and year fixed effects.

Chapter 5 Empirical Results

5.1 Baseline Results

In table 3, we report the estimation results of Eq.(6). The dependent variable is lnTFP in column1 (lnTFP1), which is calculated by using Tornqvist index number method, while the dependent variable lnTFP in column 2 is calculated through Levinsohn-Petrin procedure (lnTFP2). The coefficient of the intangible asset ratio is positive and statistically significant, whilst the coefficient of its square term is negative and very statistically significant. The results based on the balanced data in column 4 and column 5 are qualitatively similar to those based on unbalanced data. Again, the positive and significant coefficient on intangible asset ratio and the negative and significant coefficient on square term are found. **Therefore, this result supports our hypothesis 1**. The relationship between intangible asset ratio and TFP shows the inverse-U curve relationship. The TFP increases with intangible asset ratio just to a point, and then declines with this ratio. The coefficients on control variables are also similar to those in literature. Most literature (Madsen & Servais, 1997; Kuivalainen, Puumalainen & Cadogan; 2004) reports the linear relationship between knowledge-intensity and the firm's performance, however Stefano, Antonella and Roger (2014) find the non-linear relationship between knowledge-intensity and overseas sales ratio as being the results we have found. It shows as though more knowledge assets are advantageous to the international performance of the firm, but only to a point. In other words, before firms' possession of intangible assets portion amounting to the optimal point, intangible asset has a positive, but diminishing, impact upon their total factor productivity over a range of values that encompass most of the firms in the sample, then firms' TFP will suffer decrease due to the lack of complementary assets. These findings support our contention that firms need both intangible knowledge assets and complementary assets in order to pursue higher productivity.

[Insert Table 3 here]

To further support our Hypothesis1, we investigate the relationship between TFP growth (TFPG) and the intangible asset ratio. The result is shown in table 4 which supports our conclusion. The dependent variables for column1 and column 2 are both TFPG. TFPG1 is calculated by using Tornqvist index number method while the dependent variable TFPG2 in column 2 is calculated by using Levinsohn-Petrin procedure. Positive and significant results are found in the coefficient of intangible asset ratio, while the negative and significant result appears in the coefficient of square term in all columns of table 4. Total factor productivity growth and intangible asset ratio also exhibit a non-linear relationship as that of TFP and intangible asset ratio. The total factor productivity growth benefits from intangible assets but just to a point, then the increase in intangible assets will impair the total factor productivity due to the lack of enough complementary assets. As a result, these results support our suggestions that intangible assets and complementary assets need appropriate combination in order to bring higher total factor growth rate.

[Insert Table 4 here]

To make our results more comprehensive, we also check the relationship between knowledge assets with new product output ratio (new product output/total product output). The dependent variables in column 3 and 6 of table 3 are the output ratio of new products. The coefficients of intangible assets are positive and statistically significant. Different from results found in the relationship between intangible asset ratio and TFP, the linear result in the relationship between intangible asset ratio and the output ratio of new products shows that the increase in intangible assets will improve the proportion of the output of new products in that of total products. As what being mostly found in the literature, the increase in the intangible assets will improve the added value, sales and profits (Siegel, 1991; Zahra, 1996; Tsai & Wang, 2008), therefore o**ur hypothesis 2 is rejected.** We fail to observe that the output of new products decreases due to the lack of complementary assets. There may be two reasons for this. The first is that the dependent variable in our empirical model uses the ratio of the output of new products to that of total products, but not the absolute value of new products. Once there is new technology needed to be commercialized, firms can transfer complementary assets from old products to new products. Second, the increase in the ratio of the output of new products to that of total products does not definitely imply the improvement in performance. Developing innovative products is followed by higher risks and uncertainty, reduced synergy, and decreases customer familiarity which can lead to reduced performance (Droge, Calantone and Harmanciogu, 2008), even more seriously, which can disrupt existing operations (He and Wong, 2004). That's why we can observe the decrease in TFP but not in the output ratio of new products with the complementary assets.

[Insert Table 3 here]

5.2 Ownership of Firms

Enterprise reform is the critical problem in Chinese transition process (Naughton, 2007, Chapter 13). State-owned enterprises (SOE) have various advantages in the past planned economy, and even today State-owned firms still play the irreplaceable role in Chinese economy after thirty years of market reform. As the largest recipients of FDI, foreign enterprises are believed to benefit domestic firms because they usually have more advanced technology than most domestic firms. Private firms have been the fastest growing group in Chinese market. In our study of knowledge assets, it has an interest in knowing whether the contributions of knowledge assets to productivity are different in firms with different ownership. First, Jefferson, Rawski and Zhang (2008) find that SOEs are the least efficient firms in China in terms of productivity. However, backward firms can more easily improve their productivity by engaging in innovative activities or by learning from advanced firms. Griffith, Redding and Reenen (2004) find that backward industries can converge to the frontier through innovations and technology transfer, and that backward industries with larger gap to frontier converge more quickly to that through the two channels. The same things happen in different firms (Roberts & Xu, 2011; Lancheros et al. 2015). FDI is believed to have more valuable knowledge assets which have benefited domestic firms in China in past decades. Lin, Liu and Zhang (2009) have proved that SOEs have enough capabilities to learn from foreign invested suppliers and customers, and that FDI has spillover effects on Chinese firms. Therefore, China's domestic firms as the backward ones will have more channels to improve their knowledge level than foreign firms (technology transfers are likely to transfer from foreign firms to domestic firms) and more easily improve their productivity by increasing their knowledge assets. Second, SOEs, as the groups having more advantages in China's domestic market, are more easily to access appropriate complementary assets. This can improve SOEs' efficiency in commercializing its knowledge assets and then increase its productivity and the output of new products.

We divide firms into three sub-samples: foreign, state-owned and private firms based on their equity share. We estimate Eq.(6) separately for each sub-sample. The tables 5-8 report the estimation results. Columns 1-3 are for unbalance samples while columns 4-6 are for balanced samples. Table 5 and Table 7 report the relationship between total factor productivity and intangible asset ratio based on two different methods (Levinsohn-Petrin procedure in table 5 and Tornqvist index number method in table 7) for computing total factor productivity (TFP) respectively. Table 6 and table 8 are for total factor productivity growth (TFPG) based on two methods (Levinsohn-Petrin procedure and Tornqvist index number method). We get that the identical results in balanced and unbalanced samples are similar with those in the baseline regression. The coefficients on intangible asset ratio have positive signs and are statistically significant at the 1% level, while those on intangible asset ratio square term are significantly negative. All these show the clear inverse-U curve relationship between intangible asset ratio and TFP.

The coefficients are the largest in state-owned firms group. This suggests that the same increase of intangible assets will bring more contributions to TFP for SOEs group before the share of intangible assets to total assets amounting to optimal combination. The application of knowledge assets to private groups is not as good as that to foreign firms.

[Insert Table 5, Table 6, Table 7 and Table 8 here]

Different from TFP, the regression results in table 9 show the linear relationship between the output ratio of new products and intangible asset ratio, which suggests that once knowledge assets increase, firms will transfer them into commercial products. Furthermore, we can find that the coefficients are the largest in SOEs groups, second in private groups and the smallest in foreign groups, which means one unit increase in intangible asset ratio will lead to higher new product output ratio in SOEs groups and private groups. This may also because SOEs and private group have the advantages to access appropriate complementary assets due to smaller cultural distance.

[Insert table 9 here]

5.3 Export Orientation

It has been suggested that the market orientation of one firm is likely to affect its performance, including its sales, its growth rates and its profits. The markets oriented by firms will affect firms in two aspects. First, international-market-oriented firms have opportunities to access the larger market and more customers, then improve their performance. However, on the other hand, international-market-oriented firms face increasing dynamic transaction costs (Langlois, 1992), which have negative impacts on firms' performance.

To explore the impact of market orientation on TFP of firms in China, we divide our firms into three groups: (1) firms with export/sales ratio below 20% mainly orient towards the domestic market (Chinese market); (2) firms with export/sales ratio between 20% and 80% have no clear oriented market; and (3) firms with export/sales ratio exceeding 80% mainly focus on the international market (Lin, Liu and Zhang (2009).

The estimation results in tables 9-10 and table 11 show the productivity and the output of new products /that of total products ratio respectively. In tables 10-11, there are positive coefficients for intangible asset ratio and negative coefficients for intangible asset ratio, all at 1% level. International-market-oriented firms are not very different from domestic-market-oriented firms in that we find the intangible asset ratio have the same impacts as those on total factor productivity and the output of new products in table 12. As to the baseline regression, the total factor productivity and intangible asset ratio have an inverse-U curve relationship, while intangible asset ratio has positive impacts on the outputs of new products. However, in both the balanced and unbalanced data, the impacts of knowledge assets become stronger in international-market-oriented firms than in domestic-market-oriented firms regardless of their impacts on TFP or new product ratio. This indicates that the positive impacts brought by international market are stronger than the negative impacts.

[Insert Table 9, Table 10 and Table 11 here]

Chapter 6 Robustness Check

6.1 R&D full model

Our paper focuses on the effects of knowledge stock on firms' productivity and the output of new products. Except the intangible assets/total assets ratio which measures the knowledge stock of one firm, R&D expenditure is also an important factor that measures one firm's innovation capabilities, and it is a critical input for one firm to generate its own knowledge assets. Various authors have used R&D to measure one firm's knowledge assets (Kinoshita, 2000; Kuo and Yang, 2008). We believe R&D cannot accurately represent one firm's knowledge stock, however, R&D has been proved to play the critical role in total factor productivity and performance. Therefore, we add R&D variable by using 2005-2007 data to do the robustness check.

The results from the regressions are reported in table 13. The correlation between intangible assets and R&D is just about 0.31, which further show that R&D expenditure cannot completely represent the value of knowledge assets. "It is just an input to the process of new knowledge generation and only can be a proxy for the technological intensity of the firm, besides, the accounting standard IAS 38 emphasizes that R&D expenditure must never be recognized as a generated asset, but as an expense in the period in which it occurred" (Denicolai et al. (2014)). We can find that the coefficients for intangible asset ratio in columns 1-5 are positive, and that the coefficients for intangible asset ratio square term in columns 1-4 are negative as those shown in above tables. The relationship between intangible asset ratio and TFP or TFP growth is still inverse-U curve relationship after R&D being included. The coefficients of R&D in all five columns are positive and significant which are identical to those shown in the empirical literature, R&D expenditure always has positive effects on TFP, TFPG and the share of the output of new products in that of total products.[1]

[Insert Table 13 here]

6.2 Instrumental Variable Estimation

Although lagged values of independent variables have been used to address the concern of endogeneity, another way to address this problem is to use instrument-variable estimation. The industry's average ratio of intangible assets to total assets is used as the instrument for intangible asset ratio, while the industry average ratio square as the instrument for intangible asset square term. The higher the intangible asset ratio in an industry is, the more likely one firm in this industry will have higher intangible asset ratio.

I use two-stage least squares for panel-data model to mitigate the endogeneity problem. In the first stage, the firm ratio of intangible assets to total assets is used as the dependent variable, and the explanatory variables include all the control variables in table 3. The results shown in column 2 and column 3 in table 14 support that industry average ratio is correlated with the firm's intangible assets ratio. F-test reported at the bottom of first stage indicates the hypotheses that instruments, which can be excluded

[1] I also use Σ(R&D(I-depreciation)) to measure the knowledge stock based on 2005-2007 three year data. This method fail to show the inverse-u curve between R&D stock and TFP as the original method, but it show positive relationship between R&D and TFP. One reason for this results is the difference in R&D stock and intangible assets measuring knowledge assets as analyzed in paper. Another reason is that three year is a short period for using depreciation method to measure the knowledge stock.

from the first-stage regressions, are strongly rejected. In the second-stage regression, the predicted value of the firm's intangible assets ratio from the first stage is then used to replace the original firm's intangible assets ratio. The regression results are presented in the columns in table 14. The regression results are presented in column 1 of table 14. Comparing the results obtained from Table 14 with the corresponding results in table 3, we can know the coefficient estimates for intangible asset ratio are positive and those for intangible asset ratio square term are negative, and all of them are statistically significant. Therefore, my findings on the inverse-U curve relationship between total factor productivity are robust to the instrumental variable estimations.

[Insert Table 14 here]

Chapter 7. Conclusion and Limitations

This paper is among the first to analyze the effects of intangible asset ratio on productivity and new products output ratio by using firm-level panel data from Chinese manufacturing industries. We investigate the relationship between knowledge asset ratio (intangible assets / total assets) and productivity. The book value of intangible assets is used to measure the value of knowledge assets other than R&D expenditure because R&D is just a process of one firm's generating its own knowledge assets and cannot completely equal the value of knowledge assets one firm has already generated, though R&D is an important channel for firms to increase their knowledge stock by stimulating innovations or improving absorptive capability. Besides, intangible asset ratio not only shows the importance of knowledge assets, but more importantly it emphasizes the combination of knowledge asset and related complementary assets, which is not widely noticed in the literature.

Our estimation results produce robust findings that support our first hypothesis that productivity only increases with knowledge assets if there are enough complementary assets, or productivity will decrease with knowledge assets. However, our second hypothesis is rejected. The regression results suggest that the ratio of the output of new products to total output increases with knowledge assets. The negative effects of lacking complementary assets are not enough to offset the positive effects brought by knowledge assets based on our data set. We believe it also makes sense because products are the promise for firms to benefit from their innovation. There is a strong motivation for firms to transfer their technical capability into new products, and then the proportion of the output of new products in that of total products will increase.

We further find that these two kinds of relationships exist in all types of firms, regardless of the motivation of firms (exported oriented vs. domestic-market oriented) and the ownership type of firms (foreign, state-owned or private).

Overall, our findings represent evidence that knowledge assets cannot simply equal to R&D or improve productivity without necessary complementary. The complementary assets also play an important role in this process. However, the ratio of the output of new products to that of total products increases with the proportion of knowledge assets to total assets.

However, there are some limitations in this paper. First, based on our data, we cannot differentiate the knowledge assets in strict meaning from other intangible assets such as licenses, marketing rights and import quotas. Second, R&D cannot completely equal to knowledge stock, but R&D has been showed that it is an important driver for firms growth no matter in performance or in productivity. Though we include three years R&D data to do robust check, but the period is too short and we cannot use R&D stock to do further robust check.

Appendix

Table 1 Variable Definitions

Dependent Variables	
lnTFP1	Total Factor Productivity using Tornqvist index number method
lnTFP2	Total Factor Productivity using using Leveninsohn-Petrin procedure
TFPG1	Total Factor Productivity Growth using Tornqvist index number method
TFPG2	Total Factor Productivity Growth using using Leveninsohn-Petrin procedure
New product output/total output	The ratio of new products output to total products output
Independent Variables	
ln(intangible asset ratio)	The logarithm form for the ratio of intangible assets to total assets
ln(intangible asset ratio) square	The square of ln(intangible asset ratio)
ln(wage)	The logarithm form for wage
ln(capital)	The logarithm form for capital
ln(employment)	The logarithm form for employment
ln(age)	The logarithm form for age
ln(total assets)	The logarithm form for total assets

Table 2 Descriptive statistics of main variables

	Unbalanced					Balanced				
Variables	Number of observations	Mean	Standard deviation	Minimum	Maximum	Number of observations	Mean	Standard deviation	Minimum	Maximum
lnTFP1	900,276	0.0418	0.911	-8.831	7.508	371,488	0.0393	0.854	-8.831	6.990
lnTFP2	939,456	-1.067	1.165	-20.33	6.683	385,092	-1.020	1.091	-14.85	6.454
TFPG1	763,200	0.0815	0.683	-9.406	8.886	325,410	0.0918	0.630	-9.406	7.757
TFPG2	817,180	0.0969	0.780	-11.28	18.71	345,366	0.105	0.723	-11.28	13.64
new product output/total output	875,560	0.000831	0.00246	0	0.00816	359,961	0.000898	0.00243	0	0.00784
intangible asset ratio	991,679	0.0129	0.0249	0	0.0741	400,910	0.0152	0.0271	0	0.0799
Wage	996,283	2,577	2,645	300	8,590	400,910	3,790	3,937	462	12,800
Capital	996,283	12,605	15,564	710	49,241	400,910	19,383	23,633	1,251	74,781
employment	996,283	232.2	211.7	38	701	400,910	320.2	291.2	54	965
Age	996,083	13.31	9.825	4	35	400,752	15.77	10.95	5	39
total assets	996,892	41,340	47,923	4,043	154,017	400,910	63,123	73,411	6,346	235,503

Notes: The table shows descriptive statistics of main firm year variables for the period of 1998 to 2007. The variable definitions are the same as those in Table 1.

Table 3
Baseline regression

	Unbalanced sample			Balanced sample		
Dependent variable:	lnTFP1	TFPG1	New product output/total output	lnTFP1	TFPG1	New product output/total output
	(1)	(2)	(3)	(4)	(5)	(6)
ln(intangible asset ratio) $_{t-1}$	0.0139***	0.0131***	0.0145***	0.0113***	0.0112***	0.0130***
	(0.00163)	(0.00140)	(0.00121)	(0.00223)	(0.00189)	(0.00193)
ln(intangible asset ratio)$_{t-1}$	-0.00222***	-0.00210***		-0.00190***	-0.00178***	
Square	(0.000188)	(0.000162)		(0.000257)	(0.000218)	
ln(wage)$_{t-1}$	0.107***	0.0896***	0.139***	0.101***	0.0906***	0.173***
	(0.00171)	(0.00148)	(0.00667)	(0.00265)	(0.00225)	(0.0114)
ln(capital)$_{t-1}$	-0.0843***	-0.143***	0.00671	-0.0731***	-0.132***	0.0210**
	(0.00140)	(0.00121)	(0.00538)	(0.00223)	(0.00190)	(0.00960)
ln(employment)$_{t-1}$	-0.0973***	-0.0919***	0.137***	-0.117***	-0.103***	0.152***
	(0.00198)	(0.00171)	(0.00747)	(0.00301)	(0.00255)	(0.0127)
ln(age)$_{t-1}$	-0.0974***	-0.0689***	0.0694***	-0.0685***	-0.0446***	0.112***
	(0.00147)	(0.00126)	(0.00550)	(0.00209)	(0.00177)	(0.00890)
ln(total assets)$_{t-1}$	0.152***	0.0753***	0.381***	0.166***	0.0844***	0.468***
	(0.00205)	(0.00175)	(0.00768)	(0.00319)	(0.00269)	(0.0135)
Constant	-2.280***	0.678***	-13.65***	-2.394***	0.529***	-15.47***
	(0.0216)	(0.0180)	(0.0721)	(0.0343)	(0.0283)	(0.138)
Observations	808,736	775,487	731,979	344,682	332,714	314,604
Number of firm	122,824	122,053	123,560	40,054	39,998	40,081
Region FE	YES	YES	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES

Notes: This table presents the results of baseline regression. The results based on unbalanced panel data is shown in columns 1-3 while those on balanced in columns 4-6. The dependent variable for column 1 and column 4 is lnTFP1 computed using Tornqvist index number method. The dependent variable for column and column is TPFG1 computed using Tornqvist index number method. The dependent variable for column 3 and column 6 is new product output ratio (new product output/total product output). The variable definitions are the same as those in Table 1. The numbers in parentheses are the t-statistics. *, **, *** indicate the 10%, 5%， and 1% significance levels, respectively. Inclusion of industry, province and year fixed effects are indicated by “YES” or “No”.

Table 4
Alternative measure of TFP level and TFPG

	Unbalanced sample		Balanced sample	
Dependent variable:	lnTFP2	TFPG2	lnTFP2	TFPG2
	(1)	(2)	(3)	(4)
ln(intangible asset ratio) $_{t-1}$	0.00948***	0.00674***	0.0112***	0.00642***
	(0.00128)	(0.00115)	(0.00189)	(0.00149)
ln(intangible asset ratio)$_{t-1}$	-0.00144***	-0.00111***	-0.00178***	-0.000983***
square	(0.000146)	(0.000132)	(0.000218)	(0.000171)
ln(wage)$_{t-1}$	-0.00628***	-0.00104	0.0906***	-0.0116***
	(0.00148)	(0.00137)	(0.00225)	(0.00199)
ln(capital)$_{t-1}$	-0.0227***	-0.0390***	-0.132***	-0.0358***
	(0.00104)	(0.000970)	(0.00190)	(0.00146)
ln(employment)$_{t-1}$	0.00673***	-9.85e-05	-0.103***	0.00110
	(0.00164)	(0.00151)	(0.00255)	(0.00214)
ln(age)$_{t-1}$	-0.0842***	-0.0495***	-0.0446***	-0.0312***
	(0.00102)	(0.000925)	(0.00177)	(0.00132)
l ln(total assets)$_{t-1}$	0.0592***	0.0252***	0.0844***	0.0338***
	(0.00141)	(0.00127)	(0.00269)	(0.00188)
Constant	-0.622***	0.238***	0.529***	0.185***
	(0.0102)	(0.00904)	(0.0283)	(0.0125)
Observations	793,471	743,359	332,714	320,521
Number of firm	122,353	120,665	39,998	39,830
Region FE	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES

Notes: This table presents the results of alternative measure of TFP and TFPG. The results based on unbalanced panel data is shown in columns 1-3 while those on balanced in columns 4-6 The dependent variable for column 1 and column 3 is lnTFP2 computed using Leveninsohn-Petrin procedure. The dependent variable for column 2 and column 4 is TFPG2 computed using Leveninsohn-Petrin procedure. The variable definitions are the same as those in Table 1. The numbers in parentheses are the t-statistics. *, **, *** indicate the 10%, 5%，and 1% significance levels, respectively. Inclusion of industry, province and year fixed effects are indicated by “YES” or “No”.

Table 5
Ownership of firms

Dependent variable: $\ln TFP_1$

	Unbalanced sample			Balanced sample		
	Foreign invested firms (1)	State-owned firms (2)	Private firms (3)	Foreign invested firms (1)	State-owned firms (2)	Private firms (3)
ln(intangible asset ratio) $_{t-1}$	0.0222***	0.0287***	0.0116***	0.0147***	0.0237***	0.0113***
	(0.00387)	(0.00384)	(0.00204)	(0.00534)	(0.00470)	(0.00292)
ln(intangible asset ratio)$_{t-1}$	-0.00389***	-0.00383***	-0.00203***	-0.00290***	-0.00303***	-0.00200***
square	(0.000454)	(0.000451)	(0.000234)	(0.000628)	(0.000551)	(0.000334)
ln(wage)$_{t-1}$	0.0746***	0.150***	0.0889***	0.0707***	0.116***	0.0948***
	(0.00410)	(0.00346)	(0.00226)	(0.00595)	(0.00503)	(0.00369)
ln(capital)$_{t-1}$	-0.101***	-0.105***	-0.0781***	-0.0960***	-0.0877***	-0.0621***
	(0.00332)	(0.00325)	(0.00171)	(0.00510)	(0.00464)	(0.00293)
ln(employment)$_{t-1}$	-0.0793***	-0.0957***	-0.0989***	-0.0919***	-0.126***	-0.113***
	(0.00472)	(0.00381)	(0.00268)	(0.00673)	(0.00550)	(0.00431)
ln(age)$_{t-1}$	-0.0796***	-0.175***	-0.0655***	-0.0474***	-0.0900***	-0.0506***
	(0.00538)	(0.00355)	(0.00186)	(0.00847)	(0.00433)	(0.00259)
ln(total assets)$_{t-1}$	0.261***	0.141***	0.137***	0.287***	0.138***	0.147***
	(0.00473)	(0.00460)	(0.00253)	(0.00708)	(0.00650)	(0.00420)
Constant	-2.833***	-2.115***	-2.144***	-3.170***	-1.939***	-2.430***
	(0.0508)	(0.0387)	(0.0264)	(0.0748)	(0.0547)	(0.0445)
Observations	139,588	206,145	460,380	67,234	95,473	180,210
Number of firm	27,689	55,683	91,638	10,504	22,582	30,065
Region FE	YES	YES	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES

Notes: This table presents the results of subsamples by different ownership. The results based on unbalanced panel data is shown in columns 1-3 while those on balanced in columns 4-6. The dependent variable in this table is lnTFP1 computed using Tornqvist index number method. The variable definitions are the same as those in Table 1. The numbers in parentheses are the t-statistics. *, **, *** indicate the 10%, 5%， and 1% significance levels, respectively. Inclusion of industry, province and year fixed effects are indicated by “YES” or “No”.

Table 6
Ownership of firms

Dependent variable: $TFPG_1$

	Unbalanced sample			Balanced sample		
	Foreign invested firms	State-owned firms	Private firms	Foreign invested firms	State-owned firms	Private firms
	(1)	(2)	(3)	(1)	(2)	(3)
ln(intangible asset ratio) $_{t-1}$	0.0112***	0.0154***	0.00895***	0.00432	0.0150***	0.0108***
	(0.00334)	(0.00306)	(0.00174)	(0.00430)	(0.00359)	(0.00239)
ln(intangible asset ratio)$_{t-1}$ square	-0.00210***	-0.00203***	-0.00151***	-0.00122**	-0.00187***	-0.00170***
	(0.000389)	(0.000357)	(0.000198)	(0.000501)	(0.000419)	(0.000273)
ln(wage)$_{t-1}$	0.00174	0.0101***	-0.0290***	-0.00710	-0.0202***	-0.0362***
	(0.00379)	(0.00308)	(0.00209)	(0.00522)	(0.00431)	(0.00326)
ln(capital)$_{t-1}$	-0.0607***	-0.0360***	-0.0234***	-0.0622***	-0.0303***	-0.0166***
	(0.00281)	(0.00250)	(0.00141)	(0.00405)	(0.00344)	(0.00231)
ln(employment)$_{t-1}$	-0.0186***	0.0371***	0.0273***	-0.0306***	0.0225***	0.0316***
	(0.00414)	(0.00365)	(0.00240)	(0.00552)	(0.00499)	(0.00371)
ln(age)$_{t-1}$	-0.0983***	-0.0980***	-0.0577***	-0.0577***	-0.0577***	-0.0375***
	(0.00427)	(0.00233)	(0.00142)	(0.00677)	(0.00306)	(0.00206)
l ln(total assets)$_{t-1}$	0.168***	0.0417***	0.0573***	0.188***	0.0517***	0.0575***
	(0.00392)	(0.00343)	(0.00197)	(0.00550)	(0.00464)	(0.00313)
Constant	-1.447***	-0.562***	-0.756***	-1.553***	-0.464***	-0.739***
	(0.0341)	(0.0224)	(0.0160)	(0.0443)	(0.0290)	(0.0239)
Observations	136,303	201,906	455,522	65,900	93,535	178,230
Number of firm	27,430	55,121	91,241	10,436	22,413	29,963
Region FE	YES	YES	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES

Notes: This table presents the results of subsamples by different ownership. The results based on unbalanced panel data is shown in columns 1-3 while those on balanced in columns 4-6. The dependent variable in this table is TFPG1 computed using Tornqvist index number method. The variable definitions are the same as those in Table 1. The numbers in parentheses are the t-statistics. *, **, *** indicate the 10%, 5%， and 1% significance levels, respectively. Inclusion of industry, province and year fixed effects are indicated by “YES” or “No”.

Table 7
Ownership of firms

Dependent variable: $\ln TFP_2$

	Unbalanced sample			Balanced sample		
	Foreign invested firms	State-owned firms	Private firms	Foreign invested firms	State-owned firms	Private firms
	(1)	(2)	(3)	(1)	(2)	(3)
ln(intangible asset ratio) $_{t-1}$	0.0175***	0.0201***	0.0115***	0.0113***	0.0174***	0.0113***
	(0.00314)	(0.00312)	(0.00183)	(0.00422)	(0.00385)	(0.00258)
ln(intangible asset ratio)$_{t-1}$ square	-0.00318***	-0.00269***	-0.00194***	-0.00238***	-0.00221***	-0.00186***
	(0.000369)	(0.000368)	(0.000210)	(0.000496)	(0.000453)	(0.000296)
ln(wage)$_{t-1}$	0.0663***	0.114***	0.0774***	0.0685***	0.0964***	0.0854***
	(0.00334)	(0.00286)	(0.00204)	(0.00471)	(0.00415)	(0.00327)
ln(capital)$_{t-1}$	-0.156***	-0.157***	-0.142***	-0.149***	-0.144***	-0.126***
	(0.00272)	(0.00267)	(0.00154)	(0.00405)	(0.00383)	(0.00259)
ln(employment)$_{t-1}$	-0.0766***	-0.0883***	-0.0917***	-0.0796***	-0.113***	-0.0979***
	(0.00385)	(0.00315)	(0.00241)	(0.00534)	(0.00453)	(0.00381)
ln(age)$_{t-1}$	-0.0654***	-0.104***	-0.0418***	-0.0400***	-0.0640***	-0.0301***
	(0.00442)	(0.00262)	(0.00160)	(0.00674)	(0.00354)	(0.00230)
ln(total assets)$_{t-1}$	0.156***	0.0630***	0.0605***	0.174***	0.0637***	0.0652***
	(0.00389)	(0.00378)	(0.00226)	(0.00565)	(0.00535)	(0.00369)
Constant	0.281***	0.741***	0.823***	-0.0733	0.854***	0.586***
	(0.0423)	(0.0315)	(0.0230)	(0.0609)	(0.0451)	(0.0385)
Observations	133,109	191,257	451,408	64,338	90,322	176,294
Number of firm	27,452	54,646	90,956	10,446	22,344	29,852
Region FE	YES	YES	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES

Notes: This table presents the results of subsamples by different ownership. . The results based on unbalanced panel data is shown in columns 1-3 while those on balanced in columns 4-6. The dependent variable is lnTFP2 computed using Leveninsohn-Petrin procedure. The variable definitions are the same as those in Table 1. The numbers in parentheses are the t-statistics. *, **, *** indicate the 10%, 5%，and 1% significance levels, respectively. Inclusion of industry, province and year fixed effects are indicated by “YES” or “No”.

Table 8
Ownership of firms

Dependent variable: $TFPG_2$

	Unbalanced sample			Balanced sample		
	Foreign invested firms (1)	State-owned firms (2)	Private firms (3)	Foreign invested firms (1)	State-owned firms (2)	Private firms (3)
ln(intangible asset ratio) $_{t-1}$	0.00762**	0.0128***	0.00616***	-0.00171	0.0116***	0.00798***
	(0.00302)	(0.00265)	(0.00160)	(0.00391)	(0.00320)	(0.00219)
ln(intangible asset ratio)$_{t-1}$	-0.00151***	-0.00174***	-0.00111***	-0.000348	-0.00150***	-0.00122***
square	(0.000352)	(0.000311)	(0.000182)	(0.000455)	(0.000373)	(0.000249)
ln(wage)$_{t-1}$	0.0154***	0.000489	-0.0156***	0.00792	-0.0163***	-0.0239***
	(0.00352)	(0.00276)	(0.00197)	(0.00489)	(0.00391)	(0.00305)
ln(capital)$_{t-1}$	-0.0870***	-0.0490***	-0.0411***	-0.0879***	-0.0456***	-0.0324***
	(0.00265)	(0.00225)	(0.00133)	(0.00383)	(0.00316)	(0.00215)
ln(employment)$_{t-1}$	-0.0219***	0.0316***	0.0105***	-0.0237***	0.0194***	0.0199***
	(0.00382)	(0.00328)	(0.00223)	(0.00514)	(0.00455)	(0.00342)
ln(age)$_{t-1}$	-0.0751***	-0.0610***	-0.0343***	-0.0422***	-0.0379***	-0.0207***
	(0.00388)	(0.00204)	(0.00130)	(0.00618)	(0.00275)	(0.00188)
l ln(total assets)$_{t-1}$	0.0971***	0.00970***	0.0148***	0.121***	0.0190***	0.0158***
	(0.00357)	(0.00302)	(0.00178)	(0.00503)	(0.00419)	(0.00281)
Constant	0.0897***	0.409***	0.369***	-0.171***	0.426***	0.303***
	(0.0298)	(0.0196)	(0.0141)	(0.0390)	(0.0263)	(0.0208)
Observations	125,388	179,390	438,581	60,948	85,928	171,895
Number of firm	26,918	52,747	89,692	10,320	21,898	29,549
Region FE	YES	YES	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES

Notes: This table presents the results of subsamples by different ownership. The results based on unbalanced panel data is shown in columns 1-3 while those on balanced in columns 4-6. The dependent variable is TFPG2 computed using Leveninsohn-Petrin procedure. The variable definitions are the same as those in Table 1. The numbers in parentheses are the t-statistics. *, **, *** indicate the 10%, 5%, and 1% significance levels, respectively. Inclusion of industry, province and year fixed effects are indicated by "YES" or "No".

Table 9
Ownership of firms

Dependent variable: New product output/total output ratio						
	Unbalanced sample			Balanced sample		
	Foreign invested firms (1)	State-owned firms (2)	Private firms (3)	Foreign invested firms (1)	State-owned firms (2)	Private firms (3)
ln(intangible asset ratio) $_{t-1}$	0.00475*	0.0225***	0.0212***	0.000838	0.0219***	0.0215***
	(0.00261)	(0.00252)	(0.00164)	(0.00391)	(0.00387)	(0.00274)
ln(wage)$_{t-1}$	0.0621***	0.227***	0.163***	0.0619***	0.266***	0.226***
	(0.0140)	(0.0110)	(0.0100)	(0.0213)	(0.0195)	(0.0180)
ln(capital)$_{t-1}$	0.0102	0.0376***	-0.00814	0.0497***	0.0584***	-0.0174
	(0.0113)	(0.0104)	(0.00734)	(0.0183)	(0.0181)	(0.0140)
ln(employment)$_{t-1}$	0.0223	0.109***	0.160***	0.0253	0.132***	0.152***
	(0.0158)	(0.0118)	(0.0115)	(0.0240)	(0.0208)	(0.0204)
ln(age)$_{t-1}$	-0.0142	0.0787***	0.0703***	0.0132	0.111***	0.127***
	(0.0179)	(0.0101)	(0.00754)	(0.0301)	(0.0167)	(0.0124)
ln(total assets)$_{t-1}$	0.258***	0.398***	0.429***	0.265***	0.490***	0.549***
	(0.0160)	(0.0146)	(0.0105)	(0.0254)	(0.0254)	(0.0196)
Constant	-11.68***	-14.74***	-14.05***	-12.65***	-16.64***	-16.06***
	(0.167)	(0.118)	(0.0965)	(0.278)	(0.217)	(0.186)
Observations	125,759	197,901	410,043	61,183	89,673	162,192
Number of firm	27,754	54,979	91,579	10,409	22,171	29,806
Region FE	YES	YES	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES

Notes: This table presents the results of subsamples by different ownership. The results based on unbalanced panel data is shown in columns 1-3 while those on balanced in columns 4-6. The dependent variable is new product output ratio (new product output/total product output). The variable definitions are the same as those in Table 1. The numbers in parentheses are the t-statistics. *, **, *** indicate the 10%, 5%, and 1% significance levels, respectively. Inclusion of industry, province and year fixed effects are indicated by “YES” or “No”.

Table 10
Market orientation of firms

Dependent variable: lnTFP1						
	Export/sales ratio<20%		Export/sales ratio between 20% and 80%		Export/sales ratio>80%	
	(1) Unbalanced	(2) Balanced	(3) Unbalanced	(4) Balanced	(1) Unbalanced	(2) Balanced
ln(intangible asset ratio) $_{t-1}$	0.0152***	0.0134***	0.0220***	0.0147**	0.0267***	0.0312***
	(0.00210)	(0.00283)	(0.00462)	(0.00611)	(0.00312)	(0.00446)
ln(intangible asset ratio)$_{t-1}$	-0.00238***	-0.00208***	-0.00354***	-0.00255***	-0.00408***	-0.00462***
square	(0.000242)	(0.000326)	(0.000535)	(0.000708)	(0.000360)	(0.000516)
ln(wage)$_{t-1}$	0.128***	0.120***	0.0967***	0.103***	0.115***	0.100***
	(0.00215)	(0.00334)	(0.00580)	(0.00849)	(0.00338)	(0.00521)
ln(capital)$_{t-1}$	-0.0910***	-0.0704***	-0.108***	-0.106***	-0.116***	-0.106***
	(0.00177)	(0.00281)	(0.00482)	(0.00723)	(0.00254)	(0.00420)
ln(employment)$_{t-1}$	-0.120***	-0.140***	-0.116***	-0.128***	-0.133***	-0.140***
	(0.00250)	(0.00385)	(0.00601)	(0.00870)	(0.00380)	(0.00575)
ln(age)$_{t-1}$	-0.108***	-0.0734***	-0.0909***	-0.0690***	-0.143***	-0.0949***
	(0.00175)	(0.00248)	(0.00475)	(0.00650)	(0.00311)	(0.00491)
ln(total assets)$_{t-1}$	0.153***	0.154***	0.234***	0.253***	0.222***	0.240***
	(0.00257)	(0.00401)	(0.00655)	(0.00969)	(0.00354)	(0.00569)
Constant	-2.206***	-2.268***	-2.698***	-3.013***	-2.508***	-2.696***
	(0.0246)	(0.0392)	(0.0606)	(0.0886)	(0.0320)	(0.0509)
Observations	528,179	221,620	71,009	35,194	209,548	87,868
Number of firm	104,188	33,583	25,503	10,370	106,338	39,068
Region FE	YES	YES	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES

Notes: This table presents the results of different market orientation according to their export/sales ratio. The results based on unbalanced panel data is shown in columns 1-3 while those on balanced in columns 4-6. The dependent variable for in this table is lnTFP1 computed using Tornqvist index number method. The variable definitions are the same as those in Table 1. The numbers in parentheses are the t-statistics. *, **, *** indicate the 10%, 5%， and 1% significance levels, respectively. Inclusion of industry, province and year fixed effects are indicated by “YES” or “No”.

Table 11
Market orientation of firms

Dependent variable: lnTFP2	Export/sales ratio<20%		Export/sales ratio between 20% and 80%		Export/sales ratio>80%	
	(1) Unbalanced	(2) Balanced	(3) Unbalanced	(4) Balanced	(1) Unbalanced	(2) Balanced
ln(intangible asset ratio) $_{t-1}$	0.0104***	0.00587	0.00705*	0.00432	0.0104***	0.00587
	(0.00166)	(0.00511)	(0.00413)	(0.00430)	(0.00166)	(0.00511)
ln(intangible asset ratio)$_{t-1}$ square	-0.00151***	-0.00146**	-0.00124**	-0.00122**	-0.00151***	-0.00146**
	(0.000190)	(0.000593)	(0.000484)	(0.000501)	(0.000190)	(0.000593)
ln(wage)$_{t-1}$	-0.0190***	-0.0101	-0.0167***	-0.00710	-0.0190***	-0.0101
	(0.00216)	(0.00623)	(0.00577)	(0.00522)	(0.00216)	(0.00623)
ln(capital)$_{t-1}$	-0.0210***	-0.0601***	-0.0496***	-0.0622***	-0.0210***	-0.0601***
	(0.00157)	(0.00461)	(0.00464)	(0.00405)	(0.00157)	(0.00461)
ln(employment)$_{t-1}$	0.000821	-0.0300***	-0.00878	-0.0306***	0.000821	-0.0300***
	(0.00233)	(0.00652)	(0.00605)	(0.00552)	(0.00233)	(0.00652)
ln(age)$_{t-1}$	-0.0517***	-0.0673***	-0.0546***	-0.0577***	-0.0517***	-0.0673***
	(0.00146)	(0.00866)	(0.00541)	(0.00677)	(0.00146)	(0.00866)
ln(total assets)$_{t-1}$	0.0687***	0.181***	0.149***	0.188***	0.0687***	0.181***
	(0.00209)	(0.00628)	(0.00619)	(0.00550)	(0.00209)	(0.00628)
Constant	-0.602***	-1.492***	-1.225***	-1.553***	-0.602***	-1.492***
	(0.0142)	(0.0538)	(0.0422)	(0.0443)	(0.0142)	(0.0538)
Observations	339,444	44,631	53,079	65,900	339,444	44,631
Number of firm	40,021	7,170	9,231	10,436	40,021	7,170
Region FE	YES	YES	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES

Notes: This table presents the results of different market orientation according to their export/sales ratio. The results based on unbalanced panel data is shown in columns 1-3 while those on balanced in columns 4-6. The dependent variable for in this table is lnTFP2 computed using Leveninsohn-Petrin procedure. The variable definitions are the same as those in Table 1. The numbers in parentheses are the t-statistics. *, **, *** indicate the 10%, 5%， and 1% significance levels, respectively. Inclusion of industry, province and year fixed effects are indicated by “YES” or “No”.

Table 12
Market orientation of firms

Dependent variable: New products output / total output						
	Export/sales ratio<20%		Export/sales ratio between 20% and 80%		Export/sales ratio>80%	
	(1) Unbalanced	(2) Balanced	(3) Unbalanced	(4) Balanced	(1) Unbalanced	(2) Balanced
ln(intangible asset ratio) $_{t-1}$	0.0133***	0.0124***	0.0102**	0.0117*	0.0138***	0.0104**
	(0.00138)	(0.00224)	(0.00438)	(0.00640)	(0.00291)	(0.00428)
ln(wage)$_{t-1}$	0.162***	0.206***	0.116***	0.0899**	-0.00980	0.0170
	(0.00745)	(0.0133)	(0.0273)	(0.0422)	(0.0167)	(0.0245)
ln(fa_net)$_{t-1}$	-0.00253	0.00915	-0.0259	-0.0244	0.0407***	0.0810***
	(0.00604)	(0.0111)	(0.0225)	(0.0360)	(0.0126)	(0.0202)
ln(employment)$_{t-1}$	0.153***	0.184***	0.119***	0.174***	0.0526***	0.0318
	(0.00854)	(0.0153)	(0.0278)	(0.0427)	(0.0178)	(0.0259)
ln(age)$_{t-1}$	0.0649***	0.0971***	0.236***	0.329***	0.00869	0.0844***
	(0.00593)	(0.00989)	(0.0222)	(0.0324)	(0.0170)	(0.0259)
ln(total assets)$_{t-1}$	0.362***	0.438***	0.664***	0.762***	0.271***	0.310***
	(0.00863)	(0.0158)	(0.0303)	(0.0479)	(0.0178)	(0.0278)
Constant	-13.61***	-15.43***	-16.23***	-17.90***	-11.68***	-12.93***
	(0.0764)	(0.151)	(0.270)	(0.429)	(0.215)	(0.345)
Observations	550,964	228,812	73,006	35,963	108,009	49,829
Number of firm	105,167	33,673	25,913	10,474	26,226	9,453
Region FE	YES	YES	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES

Notes: : This table presents the results of different market orientation according to their export/sales ratio. The results based on unbalanced panel data is shown in columns 1-3 while those on balanced in columns 4-6. The dependent variable for in this table is new product output ratio (new product output/total product output). The variable definitions are the same as those in Table 1. The numbers in parentheses are the t-statistics. *, **, *** indicate the 10%, 5%， and 1% significance levels, respectively. Inclusion of industry, province and year fixed effects are indicated by “YES” or “No”.

Table 13
Robustness check

Dependent variable:	lnTFP1	lnTFP2	TFPG1	TFPG2	New product output/total output
	(1)	(2)	(3)	(4)	(5)
ln(intangible asset ratio) $_{t-1}$	0.0208***	0.0187***	0.0114**	0.00824*	0.0286***
	(0.00573)	(0.00502)	(0.00466)	(0.00439)	(0.00651)
ln(intangible asset ratio)$_{t-1}$	-0.00355***	-0.00334***	-0.00173***	-0.00143***	
square	(0.000650)	(0.000569)	(0.000526)	(0.000495)	
ln(wage)$_{t-1}$	0.154***	0.172***	0.00960	0.00780	0.0749
	(0.00885)	(0.00776)	(0.00740)	(0.00703)	(0.0502)
ln(capital)$_{t-1}$	-0.163***	-0.267***	-0.0369***	-0.000342	-0.188***
	(0.00533)	(0.00465)	(0.00426)	(0.00403)	(0.0294)
ln(employment)$_{t-1}$	-0.249***	-0.228***	-0.0471***	-0.0397***	0.284***
	(0.00958)	(0.00836)	(0.00783)	(0.00742)	(0.0534)
ln(age)$_{t-1}$	-0.0939***	-0.0714***	-0.0711***	-0.0491***	0.344***
	(0.00593)	(0.00510)	(0.00445)	(0.00416)	(0.0321)
ln(total assets)$_{t-1}$	0.317***	0.238***	0.0989***	0.0583***	0.377***
	(0.00736)	(0.00639)	(0.00591)	(0.00557)	(0.0403)
ln(rnd)$_{t-1}$	0.0484***	0.0417***	0.0225***	0.0156***	0.425***
	(0.00233)	(0.00205)	(0.00193)	(0.00182)	(0.0132)
Constant	-2.590***	-0.425***	-0.865***	-0.763***	-9.337***
	(0.0524)	(0.0450)	(0.0407)	(0.0381)	(0.279)
Observations	49,377	47,815	48,659	46,175	52,027
Number of firm	34,778	33,940	34,214	32,672	36,424
Region FE	YES	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES

Notes: This table presents the results of robustness check after adding R&D variable. The dependent variable for column 1 is lnTFP1 computed using Tornqvist index number method. The dependent variable for column 2 is lnTFP2 computed using Leveninsohn-Petrin procedure The dependent variable for column 3 is TFPG1 computed using Tornqvist index number method. The dependent variable for column 4 is TFPG2 computed using Leveninsohn-Petrin procedure. The dependent variable for column 5 is new product output ratio (new product output/total product output). The variable definitions are the same as those in Table 1. The numbers in parentheses are the t-statistics. *, **, *** indicate the 10%, 5%，and 1% significance levels, respectively. Inclusion of industry, province and year fixed effects are indicated by “YES” or “No”.

Table 14
Instrumental variables estimation

	Second stage	First stage		
Dependent variable:	lnTFP1	Dependent varibles:	ln(intangible asset ratio) $_{t-1}$	ln(intangible asset ratio)$_{t-1}$ square
	(1)		(2)	(3)
ln(intangible asset ratio) $_{t-1}$	1.949***	ln(iv)$_{t-1}$	0.854***	-8.828***
	(0.22554)		(0.00698)	(0.615)
ln(intangible asset ratio)$_{t-1}$ square	-0.235***	ln(iv)$_{t-1}$ square	0.306***	2.963***
	(0.0255)		(0.0145)	(0.128)
ln(wage)$_{t-1}$	0.228***	ln(wage)$_{t-1}$	0.232***	1.695***
	(0.00967)		(0.00626)	(0.0552)
ln(capital)$_{t-1}$	-0.0805***	ln(capital)$_{t-1}$	0.185	1.771***
	(0.00452)		(0.00494)	(0.0436)
ln(employment)$_{t-1}$	-0.321***	ln(employment)$_{t-1}$	-0.427***	-3.540 ***
	(0.00749)		(0.00668)	(0.0589)
ln(age)$_{t-1}$	-0.243***	ln(age)$_{t-1}$	-0.254***	-2.252***
	(0.00306)		(0.00485)	(0.0428)
ln(total assets)$_{t-1}$	0.150***	ln(total assets)$_{t-1}$	0.824***	6.464***
	(0.0220)		(0.00658)	(0.0580)
Constant	-1.321***	Constant	-5.559***	-40.844***
	(0.178)		(0.0381)	(0.279)
Observations	808,282	Observations	808,282	808,282
Number of firm	122,824	Number of firm	122,824	122,824
Region FE	YES	Region FE	YES	YES
Industry FE	YES	Industry FE	YES	YES
Year FE	YES	Year FE	YES	YES
		F-test of instruments	3412.27	3545.31

Notes, This table presents the results of instrumental variables estimation. The independent variable ln(iv) in column 2 and column 3 is the industry average ratio of intangible assets to total assets in logarithm form. The independent variable ln(iv) square is the square of ln(iv). All independent variables lag 1-year. The results of first stage are in column 2 and column 3. The results of second stage are in column 1. The numbers in parentheses are the t-statistics. *, **, *** indicate the 10%, 5%, and 1% significance levels, respectively. Inclusion of industry, province and year fixed effects are indicated by “YES” or “No”.

References

Aw B Y, Roberts M J, Yi Xu D. R&D investment, exporting, and productivity dynamics[J]. The American Economic Review, 2011, 101(4): 1312-1344.

Brandt L, Van Biesebroeck J, Zhang Y. Creative accounting or creative destruction? Firm-level productivity growth in Chinese manufacturing[J]. Journal of Development Economics, 2012, 97(2): 339-351.

Brandt L, Van Biesebroeck J, Zhang Y. Challenges of working with the Chinese NBS firm-level data[J]. China Economic Review, 2014, 30: 339-352.

Caves D W, Christensen L R, Diewert W E. The economic theory of index numbers and the measurement of input, output, and productivity[J]. Econometrica: Journal of the Econometric Society, 1982a: 1393-1414.

Caves D W, Christensen L R, Diewert W E. Multilateral comparisons of output, input, and productivity using superlative index numbers[J]. The economic journal, 1982b, 92(365): 73-86.

Chun-Chien K U O, Chih-Hai Y. Knowledge capital and spillover on regional economic growth: Evidence from China[J]. China economic review, 2008, 19(4): 594-604.

Criscuolo C, Haskel J E, Slaughter M J. Global engagement and the innovation activities of firms[J]. International Journal of Industrial Organization, 2010, 28(2): 191-202.

Cuervo-Cazurra, Alvaro, Mary M. Maloney, and Shalini Manrakhan. "Causes of the difficulties in internationalization." *Journal of International Business Studies*38.5 (2007): 709-725.

Denicolai S, Zucchella A, Strange R. Knowledge assets and firm international performance[J]. International business review, 2014, 23(1): 55-62.

Easterly W, Levine R. What have we learned from a decade of empirical research on growth? It's Not Factor Accumulation: Stylized Facts and Growth Models[J]. the world bank economic review, 2001, 15(2): 177-219.

Edwards S. Openness, productivity and growth: what do we really know?[J]. The economic journal, 1998, 108(447): 383-398.

Grant, R. M. (1996). Toward a knowledge-based theory of the firm. Strategic Management Journal, 17, 109 – 122.

Griffith R, Redding S, Van Reenen J. Mapping the two faces of R&D: Productivity growth in a panel of OECD industries[J]. Review of economics and statistics, 2004, 86(4): 883-895.

Goto A, Suzuki K. R & D capital, rate of return on R & D investment and spillover of R & D in Japanese manufacturing industries[J]. The Review of Economics and Statistics, 1989: 555-564.

Hitt M A, Hoskisson R E, Kim H. International diversification: Effects on innovation and firm performance in product-diversified firms[J]. Academy of Management journal, 1997, 40(4): 767-798.

Jefferson G, Albert G Z, Xiaojing G, et al. Ownership, performance, and innovation in China's large-and medium-size industrial enterprise sector[J]. China economic review, 2003, 14(1): 89-113.

Jefferson G H, Rawski T G, Zhang Y. Productivity growth and convergence across China's industrial economy[J]. Journal of Chinese Economic and Business Studies, 2008, 6(2): 121-140.

Kinoshita Y. R&D and technology spillovers via FDI: Innovation and absorptive capacity[J]. 2000.

Keller W. International technology diffusion[J]. Journal of economic literature, 2004, 42(3): 752-782.

Kogut, B., & Zander, U. (1996). What firms do? Coordination, identity, and learning. Organization Science, 7(5), 502 – 518.

Kraaya A. 12. Exports and economic performance: evidence from a panel of Chinese enterprises[J]. China and its Regions: Economic Growth and Reform in Chinese Provinces, 2002: 278.

Lancheros S, Milner C, Yang S. Globalisation and Regional Productivity Convergence: A Firm-level Analysis from India[J]. 2015.

Langlois R N. Transaction-cost economics in real time[J]. Industrial and corporate change, 1992, 1(1): 99-127.

Lee, C., Lee, K., & Pennings, J. M. (2001). Internal capabilities, external networks, and performance: a study on technology-based ventures. Strategic Management Journal, 22(6 – 7), 615 – 640.

Levinsohn J, Petrin A. Estimating production functions using inputs to control for unobservables[J]. The Review of Economic Studies, 2003, 70(2): 317-341.

Lichtenberg F R, Siegel D. The impact of R&D investment on productivity–New evidence using linked R&D–LRD data[J]. Economic inquiry, 1991, 29(2): 203-229.

Lin P, Liu Z, Zhang Y. Do Chinese domestic firms benefit from FDI inflow?: Evidence of horizontal and vertical spillovers[J]. China Economic Review, 2009, 20(4): 677-691.

Ma Y, Tang H, Zhang Y. Factor intensity, product switching, and productivity: Evidence from Chinese exporters[J]. Journal of International Economics, 2014, 92(2): 349-362.

Naughton B. The Chinese economy: Transitions and growth[M]. MIT press, 2007.

Olley G S, Pakes A. The dynamics of productivity in the telecommunications equipment industry[R]. National Bureau of Economic Research, 1992

Peteraf, M. A. (1993). The cornerstones of competitive advantage: A resource-based view. Strategic Management Journal, 14(3), 179–191.

Petrin A, Poi B P, Levinsohn J. Production function estimation in Stata using inputs to control for unobservables[J]. Stata journal, 2004, 4: 113-123.

Prange C, Verdier S. Dynamic capabilities, internationalization processes and performance[J]. Journal of World Business, 2011, 46(1): 126-133.

Rothaermel, Frank T., and Charles WL Hill. "Technological discontinuities and complementary assets: A longitudinal study of industry and firm performance."*Organization Science* 16.1 (2005): 52-70.

Teece D J. Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy[J]. Research policy, 1986, 15(6): 285-305.

Tsai K H, Wang J C. External technology acquisition and firm performance: A longitudinal study[J]. Journal of Business Venturing, 2008, 23(1): 91-112.