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Impact of knowledge-based capital on firm productivity: The contingent effect of ownership

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ABSTRACT

Using account data from an unbalanced panel of Chinese listed companies from 2013 to 2018, this study examines the productivity effect of knowledge-based capital (KBC) and its three subcategories, which include computerised information, innovative property, and economic competency, as well as the contingent effects of ownership. Our findings show that first KBC has a positive effect on firm productivity and that only computerised information and economic competency contribute significantly to firm productivity among the subcategories. Second, KBC's productivity gains are linked to firm ownership. KBC utilisation in SOEs is less efficient than in private firms, and computerised information only affects the productivity of SOEs. Third, across different samples, the most significant effect is generated by economic competency, which is primarily driven by organisational capital and brand equity, but this is not robust in SOEs. The findings highlight the importance of carefully assessing the productivity-enhancing effects of various KBC items.

1. Introduction

Since the dawn of the knowledge economy, the relationship between knowledge-based capital (KBC), which also equates to intangible assets in some studies (Di Ubaldo and Siedschlag, 2021), and firm productivity has piqued the interest of many researchers (Bontempi & Mairesse, 2015; Chappell & Jaffe, 2018; Crass & Peters, 2014; Di Ubaldo & Siedschlag, 2021; Kengatharan, 2019; Marrocu, Paci, & Pontis, 2011; Rico & Cabrer-Borrás, 2020; Yang, Zhou, & Song, 2018). KBC includes computer software and data sets, research and development (R&D), organisational structure, human capital, brand, designs, and other forms of intellectual property (Corrado et al., 2005), which are valuable, rare, inimitable, and non-substitutable resources that allow firms to gain a competitive advantage (Barney, 1991).

Due to measurement challenges, many studies investigate the productivity effects of specific KBC, such as R&D, information and communications technology (ICT), and human capital, in isolation (Hall et al., 2010). Recently, some researchers have made efforts to investigate the effect of specific KBCs on firm productivity simultaneously, as a result of new progress made by Corrado et al. (2005) in developing new concepts for improving KBC measurement (Marrocu et al., 2011, European companies; Crass and Peters, 2014, Germany; Añón Higón et al., 2017, Spain; Yang et al., 2018, China; Chappell and Jaffe, 2018, New Zealand; Di Ubaldo and Siedschlag, 2021, Ireland). Firm-level evidence is primarily obtained from developed countries, while evidence from transition economies, such as China, is scarce. Although Yang et al. (2018) try to provide evidence from China, the data they use is from the 2012 China Enterprise survey, which is out of date.

China's economy has experienced rapid growth for more than three decades and has now entered the new normal stage, which is characterised by slower but higher-quality growth, since the 2010s. In response to the new normal, the Chinese government has proposed an innovation-driven development strategy (NDDS) for comparative advantage, long-term growth, and high productivity. One important aspect of the NDDS is the promotion of a development mode that is based on continuous knowledge accumulation, technological progress, and labour quality improvement, which requires the contributions of a board range of KBC rather than R&D to build the national innovation capacity (Carrillo, Schiuma, & Lerro, 2008). Although KBCs were partially disclosed in firm balance sheets following the reform of China's accounting system in 2006, a border range of KBCs are typically omitted from standard accounts of firms, leading to an underestimation of the importance of KBCs on firm productivity gains.

It is well known that there is a high degree of heterogeneity in

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productivity at the firm level, even within the same industry. Some studies have discovered contingent effects, such as firm size (small, medium, and large), firm industry context (service and manufacturing, high-technology and low-technology), and ownership (indigenous and foreign-owned) (Añón Higón et al., 2017; Chappell and Jaffe, 2018; Di Ubaldo and Siedschlag, 2021). However, they overlooked a distinctive feature of transition economies: the coexistence of state-owned enterprises (SOEs) and private enterprises (Peng and Luo, 2000; Javalgi et al., 2018), which has been identified as a key institutional factor in transition economies influencing firms' strategic management (He et al., 2020).

To address these research gaps, this study provides novel evidence by investigating a variety of KBC, including computerised information (refer to software), innovative property (R&D, patent and non-patent technology), and economic competency (brand equity, firm-specific human capital, and organisation capital), using Corrado et al. (2005)'s comprehensive framework and a sample of Chinese listed companies over the period 2013 to 2018. Another novel aspect is that we compare the relationship between KBC and firm productivity in SOEs and private firms, which is related to the transition economy setup. In addition, firm-level evidence is better to capture own-account KBC created in firm compared to the national level (Ilmakunnas and Piekkola, 2014). This study also contributes to the literature on the effects of KBC by questioning whether we can see the same kinds of productivity gains seen in macro data (Hulten and Hao, 2012; Li and Wu, 2018) when we focus on the micro level.

The remainder of this paper is organised as follows. Section 2 conducts a literature review and hypothesis development. The empirical strategy is described in Section 3, which includes describing the data and measurements of KBC at the firm level, as well as explaining the econometric methodology. Section 4 discusses the empirical findings, while Section 5 summarises the main findings and discusses policy implications.

2. Literature review and hypothesis development

2.1. Productivity-enhancing effect of KBC

The productivity-enhancing effect of KBC has been extensively researched at several levels, including national (Corrado et al., 2005; Jona-Lasinio, Manzocchi, & Meliciani, 2019; Hulten & Hao, 2012; Mas, Hofman, & Benages, 2020), regional (Carrillo et al., 2008; Grillitsch & Nilsson, 2017; Li & Wu, 2018) , industry (Goodridge et al., 2017; McGrattan, 2020), and firm level (Marrocu et al., 2011; Yang et al. 2018; Chappell and Jaffe, 2018; Martin and Javalgi, 2019; Rico and Cabrer-Borrás, 2020; Di Ubaldo and Siedschlag, 2021). Although the categories of KBC vary between studies, scholars and policymakers agree that KBC are critical for increasing business productivity and generating firm competitive advantages. Economics-related theories propound that KBC is an input in firm's production function in addition to physical capital and labour (Marrocu et al., 2011; Crass and Peters, 2014), which consists of the stock of immaterial resources that enter the production process and are important for products creation or improvement (Arrighetti et al., 2014). Management-related theories claim that a firm is a unique bundle of complex, intangible, and dynamic resources, and that this bundle of resources is valuable, rare, inimitable, and non-substitutable, allowing enterprises to develop and preserve competitive advantages (Barney, 1991). KBC are thought to be a firm's prospective strategic resources that are positive in comparison to measured performance (Canibano et al., 2004, Nadeem et al., 2018), while the knowledge-based view emphasises that a firm's performance is dependent on the tacit collective knowledge embedded in the firm's routines to successfully integrate, coordinate, and mobilise those resources and capabilities (Teece, 1998; Han and Li, 2015; Bendig et al., 2018). As a result, the firm's specific knowledge, converted into knowledge-based capital, as well as the ability to create and transfer it, serve as the foundation for innovating and improving efficiency and are regarded as a key strategic asset that may be positively associated with higher levels of performance (Davenport & Prusak, 1998), like productivity in this study. In this study, KBC refers to computerised information (software), innovative property (R&D, patent and non-patent technology), and economic competency (brand equity, firm-specific human capital, and organisational capital), which represent various capabilities for creating, disseminating, and utilising knowledge, which could improve the firm's productivity efficiency. Accordingly, we hypothesise:

H1: KBC positively affects firm productivity.

2.2. Productivity-enhancing effect of KBC's subcategories

2.2.1. Computerised information

Business investment in computerised information is mostly made up of business investment in computer software (Corrado et al., 2005), which is one of the most important investments in information and communications technology items (Aboal and Tacsir, 2018). Without a doubt, software has long played an essential role within organisations and their IT infrastructure (Nagle, 2019), but the benefits of software investment vary greatly. Typically, software, such as Enterprise systems, is regarded as a critical resource because it allows a company to better integrate functions, such as production, distribution, financial accounting, cost control, and human resource management, into decision making, resulting in cost savings and productivity gains (Shin, 2006; Relich, 2017). Enterprise Resource Planning (ERP) investments, despite their high cost, may aid in the development of regular work routines and practices, as well as the facilitation of organisational structure, which constitute a firm-specific capability that provides a competitive advantage and can be sustained over long periods of time (Ram et al., 2014). Other authors claim that using new software does not always result in a competitive advantage (Seddon, 2005) and that the key is how the new software is integrated into the production and management processes (Brynjolfsson et al., 2002; Yang et al., 2018). According to Brynjolfsson, Rock, and Syverson (2021), the shape of the movements in the standard productivity growth as a result of the new technology used resembles a J-curve. It was not until they made intangible investments to supplement their IT efforts that productivity growth truly set forth. Accordingly, we hypothesise:

H2: Computerised information (referring to software) positively affects firm productivity.

2.2.2. Innovative property

Innovative property refers to the resources devoted by firms to innovation and new product/process R&D (Corrado et al., 2005). Beginning with Griliches' (1979) seminal contribution, substantial literature has investigated the productivity effects of R&D. Investment in R&D is critical for developing new products, improving product quality, and providing innovative solutions to customers, which leads to a productivity boost by increasing sales while decreasing costs (Hall et al., 2010). Furthermore, R&D investments strengthen the firm's knowledge base, resulting in a high absorptive capacity to exploit the firm's external and internal resources and allow for more efficient use of these inputs (Cohen and Levinthal, 1990). While R&D activity may harm firms' short-term performance due to its high risk (Lev and Gu, 2016), it may also show a threshold effect in the form of an inverted U-shaped correlation, indicating a negative long-term effect (Leung and Sharma, 2021). Accordingly, we hypothesise:

H3: Innovative property positively affects firm productivity.

2.2.3. Economic competencies

Economic competencies are the knowledge embedded in strategic planning, redesigning, or reconfiguring existing products in existing markets, and retaining or gaining market share (Corrado et al., 2005). They primarily include investment in organisational capital, firm-specific human capital, and brand equity.

Firm organisational capital is defined as firm-specific institutionalised knowledge captured within systems, processes, routines, patents, manuals, structures, designs, culture, and know-how that develop production systems (Youndt et al., 2004). That is, organisational capital is a firm's tacit knowledge, which is difficult for competitors to copy and imitate. Firms gain the ability to combine new and different skills with existing ones, allowing them to generate a higher level of returns from a given resource endowment, both consistently and efficiently.

Human capital distinguishes between general-purpose training and firm-specific skills, with the latter having the potential to transform intangible resources into sources of competitive advantage (Barney, 1991; Kianto et al., 2017; Al-Tal and Emeagwali, 2019; Ployhart, 2021). Firm-specific human capital refers to worker-level knowledge, skills, and abilities that are only applicable within the context of the focal firm. It enables focus firms to capture some of the value created by converting existing knowledge into production and management practice while restricting employee mobility (Raffiee and Coff, 2016).

Brand equity represents the consumers' knowledge, perceptions, and awareness of the products and services produced by a firm (Aaker, 1996). A strong brand means that consumers are more aware of and loyal to the brand, making them price insensitive; that is, a product with a strong brand gains a higher price premium than one without, implying greater productivity. The strong consumer relationship can provide feedback to improve existing products and generate new product ideas, allowing them to perform better in rapidly changing environments (He et al., 2020). Taken as a whole, brand equity is critical for focus firm gains.

Accordingly, we hypothesise:

H4: Economic competencies positively affects firm productivity.

H4a: Firm organisational capital positively affects firm productivity.

H4b: Firm-specific human capital positively affects firm productivity.

H4c: Firm brand equity positively affects firm productivity.

2.3. The contingent effect of firms' ownership

According to the contingency perspective, the contribution of strategic resources may be determined by their fit with their respective environments (Sirmon and Hitt, 2009). The coexistence of state-owned enterprises (SOEs) and private enterprises is an idiosyncratic feature of transition economies, such as China (Peng & Luo, 2000), and its significant impact on firms' heterogeneous strategic management cannot be overlooked (He et al., 2020). One of the key distinctions between SOEs and private firms is that the sole goal of SOEs is to achieve the economic goals of the central or local government, rather than to maximise profits (Peng et al., 2016). Driven by the national strategy of innovation-driven development, SOEs will reallocate more resources on KBC to align with the government's interests, allowing them to obtain additional finance and policy support. SOEs play a pivotal role in the innovation process in China (Landoni, 2020). However, agency problems between their controlling shareholder and their minority shareholders, as well as information asymmetry between the decision maker and the executors of daily operations as a result of the hierarchical structure in SOEs, can lead to inefficient use of the KBC resource (Lin et al., 2020). In contrast to SOEs, private firms have more severe resource constraints and lower market competition positions but a more flexible structure. In order to survive in the fierce market competition, private firms must become more efficient to overcome resource constraints.

As a result, we propose the following hypothesis:

H5: The effects of KBC and its subcategories on private firm productivity are greater than those in SOEs.

3. Empirical strategy

3.1. Sample

Our sample includes the firms listed on the Shanghai and Shenzhen stock exchanges from 2013 to 2018. The National Innovation Driven Development Strategy was proposed at the end of 2012, and the Chinese economy's new normal has nearly begun since 2013. The sample period fully accounts for China's new background. We pretreat the sample by removing firms that (1) have missing data, (2) are in the financial industry, and (3) have ST/*ST stock, resulting in a sample of 7,808 (5,552 one lag) firm-year observations. To eliminate the impact of price changes, the consumer price index and the price index of fixed asset investment are used. We get the data from the China Stock Market and Accounting Research (CSMAR) database, which offers data on the China stock markets and the financial statements of China's listed companies. To ensure the authenticity and reliability of the data, cross validation is performed using data provided by WIND (a financial data and analysis tool service provider in China). Except for ROA and age, logarithmic treatment of continuous variables reduces the impact of heteroscedasticity.

3.2. Econometric methodology

Our econometric methodology is based on a two-step procedure, as used by (Añón Higón et al., 2017). The first step is to use the Cobb–Douglas production function to estimate firm-level total factor productivity (hereafter TFP). The model specification is as following:

$$Y_{it} = A_{it} K_{it}^{\alpha} L_{it}^{\beta} M_{it}^{\gamma} \tag{1}$$

where Y is the gross output, K is the fixed capital input, L is the labour input, and M is the intermediate input. i represents the ith firm, and t represents year. Then the TFP gets in logarithm form

$$TFP_{it} = \ln Y_{it} - \alpha \ln K_{it} - \beta \ln L_{it} - \gamma \ln M_{it} \tag{2}$$

Ordinary least squares (OLS) estimators, fixed-effect estimators, Olley-Pakes estimators, and Levinsohn-Petrin estimators are some of the estimation methods for Eq. (2). Our study uses the Levinsohn-Petrin estimators to address the simultaneity problem between inputs and productivity, with the advantage that proxy variables can be chosen flexibly based on data availability. As a robustness check, we also use Wooldridge's (2009) generalised method of moments (GMM) estimation with the moment conditions outlined in Levinsohn and Petrin (2003).

The second step is investigating the contribution of knowledge-based capital to firm-level TFP. With the TFP retrieved from the first step, we construct the following two models:

$$TFP_{it} = \gamma_0 + \gamma_1 KBC_{it-1} + \alpha' control_{it-1} + \mu_i + \varepsilon_{it} \tag{3}$$

$$TFP_{it} = \beta_0 + \beta_1 CI_{it-1} + \beta_2 INNOVA_{it-1} + \beta_3 ECOCOMP_{it-1} + \alpha' control_{it-1} + \mu_i + \varepsilon_{it} \tag{4}$$

$$TFP_{it} = \beta_0 + \beta_1 FHC_{it-1} + \beta_2 BRAND_{it-1} + \beta_3 ORG_{it-1} + \alpha' control_{it-1} + \mu_i + \varepsilon_{it} \tag{5}$$

where *KBC* represents for the whole knowledge-based capital measured with the framework of Corrado et al. (2005). *CI* represents the computerised information capital. *INNOVA* represents innovative property capital. *ECOCOMP* represents economic competencies capital. *FHC* represents the firm-specific human capital. BRADN refers to the brand equity. ORG represents the firm organisation capital. *control* represents the control variables usually included in empirical research, and age and debt-to-assets ratio (ROA) are considered in our work. u_i represents the unobserved individual effect. ε_{it} is a mean zero random error term.

This study employs an unbalanced panel data sample, and there are unobservable individual factors and temporal shocks that will affect the validity of the estimated parameter. The two most commonly used estimation methods to solve the problem are the fixed-effect model and the random effect model. Based on the Hausman test, we employ a fixed-effects model. To mitigate the effects of unobservable variables and omitted variable bias, we use the two-way fixed-effects model control for unobservable year effects and individual effects. We also employ the "lagging independent variable" approach to address any endogeneity issues that may arise as a result of simultaneity and reversed causality (Leung and Sharma, 2021). Some researchers have confirmed that the impact of KBC assets on firm productivity has a time lag (Brynjolfsson et al., 2002), whereas our study's implicit assumption is that the KBC transfer into productivity takes one year.

3.3. Measurements of variables

3.3.1. Dependent variable

In order to get the TFP, we measure the variables in Eq. (1) with the data extract from the firm's financial statements. To be specific, Y is the gross output measured by firm sales revenue, K is the fixed capital input measured by net value of fixed assets, L is the labour input measured by number of employees at the end of each year, and M is the intermediate input measured by the cash outflow for products and service purchases in the chart of cash flow.

3.3.2. Independent variables

Accounting standards account for different types of knowledge-based capital. China has been implementing new accounting standards since 2006 in order to standardise the recognition and measurement of intangible assets, as well as the disclosure of relevant information. However, according to the disclosed information, land-use rights are the most important intangible asset in Chinese listed companies, resulting in a relatively low "knowledge content." This study employs the framework proposed by Corrado et al. (2005) at the national level to measure firm level knowledge-based capital, which includes a more comprehensive list, in order to fully reflect the importance of different categories of KBC in firm operations. The categories and measurements are as follows:

(1) Computerised information refers to knowledge embedded in computer software and databases, whereas this study only considers software in the absence of database information. As a result, the stock of computerised information capital is measured by the book value of software at the end of the fiscal year as disclosed in the balance sheet. Book value refers to the net amount of the book balance of an account minus relevant allowance items (such as accumulated depreciation and impairment provision).

(2) Innovative properties indicate knowledge acquired through innovation activities, as well as Corrado et al. (2005) group scientific R&D and nonscientific R&D (e.g. mineral exploration, copyright and license costs, and other product development, design, and research expenses), and relatively little is known into this category. According to the definition, R&D, patent, and non-patent technology are included into this category in this paper. The stock of R&D ($R\&D_{it}$) is measured from R&D expenditures by using the perpetual inventory method for ith firm in period t:

$$R\&D_{it} = (1-\delta_R)R\&D_{it-1} + R_{it} \tag{6}$$

$$R\&D_{i0} = \frac{R_{i0}}{\delta_R + g_R} \tag{7}$$

where R_{i0} is ith firm's R&D investment measured by R&D expenditures in first year in the sample. g_R is the average growth rate of R&D expenditures over the sample period. δ_R is the depreciation rate ranges from 8% to 25% in empirical studies, and we set the *it* as 15%, which is commonly used by researchers. Patent is measured by the book value of patent in balance sheet, and non-patent technology is measured by the book value of non-patent technology. Then the stock of innovative property capital is the sum of R&D stock, patent, and non-patent technology.

(3) Economic competencies denote knowledge embedded in firm-specific competency properties, such as brand equity, firm-specific human capital, and organisational capital, all of which are quantifiable in our work.

Corrado et al. (2005) use 20% of the value of executive time spent on in-house organisational development and use management consultant fees for purchased organisational investment. Due to the lack of data, we exclude management consulting fees and use 20% of management fees as the cost of in-house organisational development. Therefore, the organisational capital (OC_{it}) is calculated from 20% of management fees by using the perpetual inventory method as following:

$$OC_{it} = (1-\delta_O)OC_{it-1} + org\_inv_{it} \tag{8}$$

$$\mathrm{OC}_{i0} = \frac{org\_inv_{i0}}{g_O + \delta_O} \tag{9}$$

org_inv_{i0} is ith firm's organisational investment measured by 20% of management fees in first year in the sample. g_O is the average growth rate of organisational investment over the sample. δ_A is the depreciation rate varying and set it as 15% equal to that of R&D by following Eisfeldt and Papanikolaou (2013).

Employee educational level and expenditure for firm-specific training are two proxies for measuring firm-specific human capital. Employee labour union dues and employee education expenses are used as proxies in this study because they are disclosed on the balance sheet as a whole. Employee labour union dues are primarily used to fund staff services and labour union activities. Employee education costs are incurred in order for employees to learn advanced technology and improve their working skills. It is, to some extent, a good proxy for firm-specific human capital.

According to Corrado et al. (2005), the primary investments in building brand equity are advertising and market research, whereas we believe that trademark investments both protect and enhance brand equity. As a result, in the absence of market research data, advertising and publicity expenditures, as well as trademarks, are used to measure brand equity.

Corrado et al. (2005) assumed that 60% of advertising and publicity expenditures have long-term effects in building a firm's brand equity. Following this assumption, we use 60% of advertising and publicity expenditures as a proxy for brand equity investment. Then we capitalise advertising and publicity expenditures (cap_ad_{it}) by using the perpetual inventory method as following:

$$cap\_ad_{it} = (1-\delta_A)cap\_ad_{it-1} + ad_{it} \tag{10}$$

$$cap\_ad_{i0} = \frac{ad_{i0}}{\delta_A + g_A} \tag{11}$$

ad_{i0} is ith firm's advertising and publicity expenditures in first year in the sample. g_A is the average growth rate of advertising and publicity expenditures over the sample period. δ_A is the depreciation rate varying from 30% to 60% in empirical studies, and we set it as 45% following Villalonga (2004). The stock of trademark is measured by the book value of trademark in balance sheets. As a result, the stock of brand equity is the sum of capitalised advertising and publicity expenditures and trademark stock.

The stock of economic competency is the sum of organisational capital, firm-specific human capital, and brand equity.

(4) The total knowledge-based capital is the sum of the stock of computerised information, innovative property, and economic competency.

3.3.3. Control variables

Referring to the practice of existing studies, we include four control

Table 1
Descriptive statistics.

	Full (7808)			SOEs (2427)			Private (5381)		
VAR\Obs.	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
TFP	6.751	4.777	8.943	6.861	5.662	8.824	6.702	4.777	8.943
K	20.064	12.723	26.667	20.877	15.095	26.667	19.698	12.723	24.339
KBC	19.603	16.069	25.124	20.122	16.069	25.124	19.369	16.397	23.804
CI	14.732	4.287	23.061	15.280	4.287	23.061	14.485	4.963	20.937
INNOVA	18.617	−0.091	24.540	18.821	7.423	24.540	18.525	−0.091	23.470
ECOCOMP	18.814	14.951	24.398	19.438	16.060	24.398	18.533	14.951	23.432
CI/KBC	0.021	0.000	0.716	0.022	0.000	0.581	0.021	0.000	0.716
INNOVA/KBC	0.484	0.000	0.962	0.423	0.000	0.950	0.512	0.000	0.962
ECOCOMP/KBC	0.495	0.038	0.999	0.556	0.048	0.998	0.467	0.038	0.999
KBC/K	1.716	0.008	188.138	0.997	0.008	43.864	2.040	0.020	188.138
CI/K	0.057	0.000	35.139	0.026	0.000	2.958	0.071	0.000	35.139
INNOVA/K	0.912	0.000	108.461	0.523	0.000	31.462	1.087	0.000	108.461
ECOCOMP/K	0.747	0.005	172.016	0.447	0.005	17.638	0.882	0.013	172.016

Data source: calculated by the author with WIND and CSMAR database.
Note: TFP, K, KBC, CI, INNOVA, ECOCOMP is in log form. CI/KBC, INNOVA/KBC, ECOCOMP/KBC, KBC/K, CI/K, INNOVA/K, ECOCOMP/K are the ratios.

variables considering the firm's characteristics. According to Rico and Cabrer-Borras (2020), firm size is measured by the number of employees. Firm age accounts for experience and reflects that new entrants and established firms are likely to experience different performance, which is measured by years of establishment up to the year of study. The asset liability ratio (DOA) is measured by dividing total assets by total liabilities. We also control of firms' capital density by including the ration of fixed assets on total assets.

4. Empirical results

4.1. Descriptive statistics

Table 1 shows descriptive statistics for the main variables. The total sample size is 7,808 firm-year observations, of which 2,427 are SOEs, accounting for 31.1% of the sample. We begin by examining the level of KBC and its heterogeneity across SOE and private firm subgroups. When it comes to the level of KBC, it is on average lower than physical capital, and this is consistent across SOEs and private firms. However, when it comes to the relative level of KBC in comparison to physical capital (KBC/K), the reality is the polar opposite. On average, the KBC is nearly 1.7 times that of physical capital, with some variation between subgroups. Because of the high dispersion within private firms, the relative value of KBC in private firms (2.040) is greater than that in SOEs (0.997). It should be noted that the amount of KBC in SOEs is nearly equal to the physical capital, as the KBC/K values are 0.997.

The level and relative level of KBC subcategories compared to physical capital, as well as their heterogeneity, are then discussed within sub-groups. When it comes to the level of KBC subcategories, economic competency capital has the highest amount, followed by innovative property capital and computerised information capital on average across the entire sample and sub-samples. When it comes to the relative level of KBC subcategories compared to physical capital, we find that, despite the degree difference, the largest one is innovative property capital, followed by economic competency capital and computerised information capital on average across the entire sample, as well as within SOEs and private firms. The KBC and its subcategories in SOEs are all larger than those in private firms, as expected, while the relative level exactly does the opposite. For private firms, they allocate more resources to KBC than physical capital to gain a competitive advantage with resource constraints in a knowledge economy.

The results of both level and relative level show another fact that all of Chinese list companies allocate most of the resource to invest innovative property and economic competency capital, and only a small part to invest computerised information capital. The proportion of computerised information capital of KBC is almost 2.1%, while that of innovative property capital (economic competency capital) ranges from 42.3% in SOEs (46.7%, private firms) to 51.2% in private firms (55.6%,

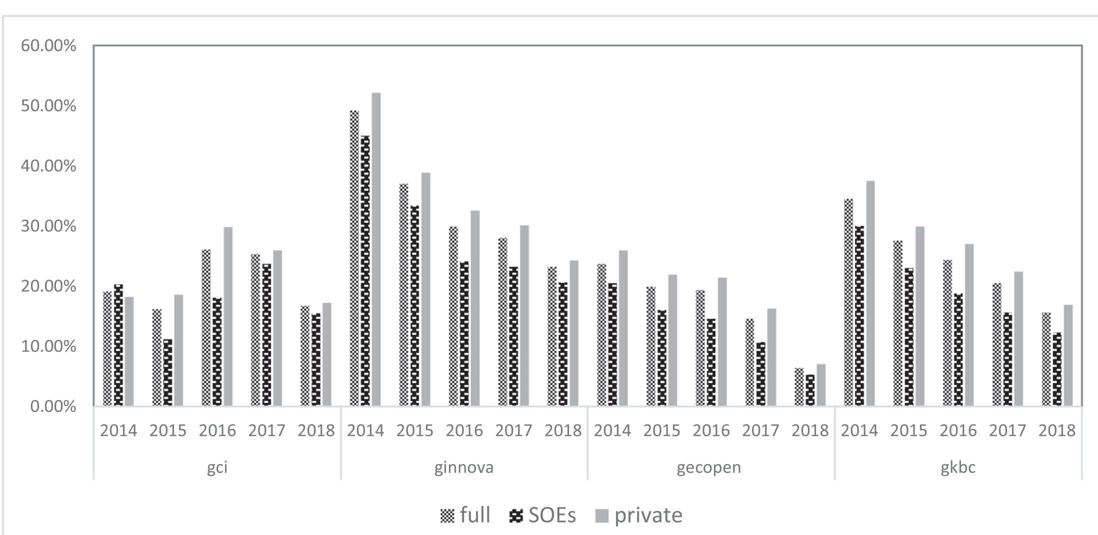

Fig. 1. The growth rate of KBC and its three subcategories among different samples. Data source: calculated by the author with WIND and CSMAR database.

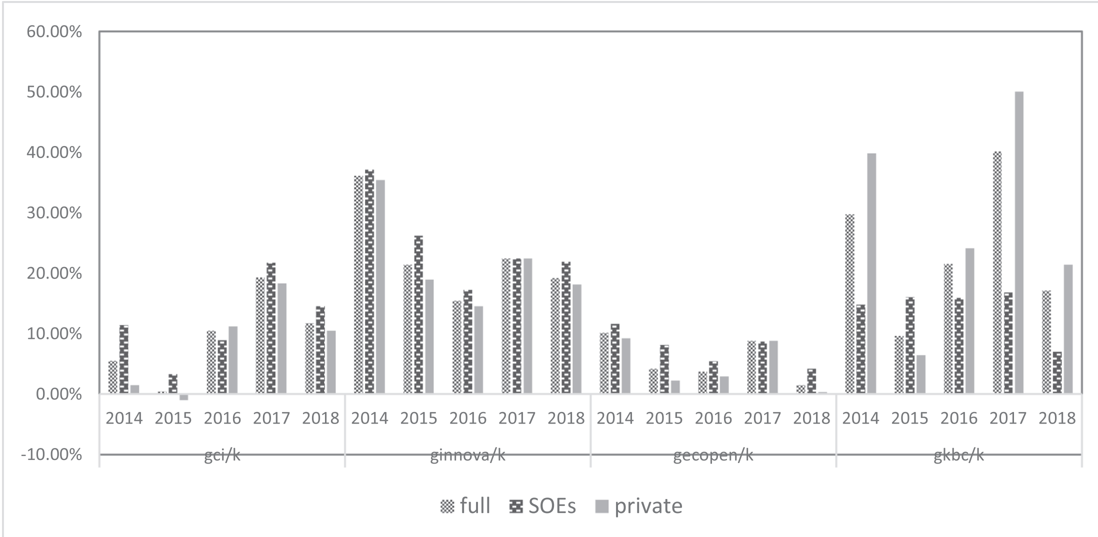

Fig. 2. The growth ratios of knowledge capital and its sub-items compared to physical capital. Data source: calculated by the author with WIND and CSMAR database.

SOEs). It is depressing to note that the contribution of economic competency capital to firm productivity is ignored, especially in the case of China.

4.2. The dynamic changes of KBC and its subcategories

To investigate the dynamic changes of KBC and the heterogeneity between SOEs and private firms, we look at the growth rate of the level and the relative level compared to physical capital to shed more light on the KBC and its subcategories. Fig. 1 shows the growth rate of KBC and its three subcategories among different samples. As illustrated in Fig. 1, although the growth rate of SOEs is lower than that of private firms, all growth rates were positive from 2014 to 2018, indicating an increasing trend for KBC and its three subcategories within the full sample, as well as between SOEs and private firms. The average growth rate of innovative properties is highest, followed by computerised information capital and economic competency capital. As China's economic development model shifts from investment-driven to innovation-driven, businesses devote more resources to R&D activities rather than other forms of knowledge creation, which is consistent with national policy guidelines. It is worth noting that, except for computerised information capital, the rate of growth of innovative properties and economic competencies is decreasing year by year, indicating that the increasing trend has slowed. To ensure the continued progress of economic transformation and upgrading, we must delve deeper into the causes of the decline.

Fig. 2 shows the growth rate the relative level of KBC, and its three subcategories compared to physical capital among different samples. As shown in Fig. 2, all relative level growth rates were highly fluctuated but generally positive from 2014 to 2018. Except for 2015, the growth of KBC/K in SOEs is lower than that in private firms, while the subcategories are in a different situation. With the exception of the growth rate of CI/K in 2016, the growth rate of the subcategories of KBC compared to physical capital in private firms is lower. We state that capital structure adjustment occurs larger fluctuation and faster speed in private firms than in SOEs. Again, the average growth rate of INNOVA/K is highest, which is mainly due to the great emphasis laid on innovation in China and regarding the main driver of economic growth in the period of China's new normal economy.

Table 2
The effect of KBC and its subcategories on firm productivity (LP estimator).

VARIABLES	(1) LP	(2) LP	(3) LP	(4) LP
	TWFE	TWFE	TWFE	TWFE
KBC(-1)	0.1170***			
	(0.0245)			
CI(-1)		0.0090**		0.0098**
		(0.0046)		(0.0046)
INNOVA(-1)		0.0028		0.0037
		(0.0129)		(0.0133)
ECOPEN(-1)		0.1242***		
		(0.0266)		
ORG(-1)			0.1211***	0.1050***
			(0.0333)	(0.0352)
FHC(-1)			0.0052	0.0050
			(0.0040)	(0.0040)
BRAND(-1)			0.0132***	0.0127***
			(0.0048)	(0.0047)
size(-1)	−0.0238	−0.0272	−0.0230	−0.0270
	(0.0184)	(0.0180)	(0.0184)	(0.0183)
kratio(-1)	−0.0818	−0.0774	−0.0830	−0.0794
	(0.0631)	(0.0630)	(0.0642)	(0.0630)
doa(-1)	0.0012***	0.0011**	0.0011**	0.0011**
	(0.0005)	(0.0005)	(0.0005)	(0.0005)
age(-1)	0.0003	0.0043	0.0038	0.0033
	(0.0066)	(0.0062)	(0.0059)	(0.0065)
Constant	4.6371***	4.3672***	4.3349***	4.4710***
	(0.3281)	(0.3737)	(0.4779)	(0.4773)
Observations	5,552	5,552	5,552	5,552
R-squared	0.0967	0.1008	0.0940	0.0962
Number of id	1,651	1,651	1,651	1,651

Note: Robust standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$
Data source: calculated by the author with WIND and CSMAR database.

4.3. Econometric results

In this section, we report the estimates of Eqs. (3)–(5), exploring the relation between KBC and firm productivity. The effect of KBC and its subcategories on firm productivity is discussed first, followed by the contingent effect of firm ownership. The firm productivity is gain by Levinsohn-Petrin estimator. The results are estimated using a two-way fixed-effect model (TWFE) with robust standard errors to eliminate heteroscedasticity. STATA 15.0 is used for all estimations.

Table 3
The contingent effect of firms' ownership (LP estimator).

VARIABLES	(1) LP	(2) LP	(3) LP	(4) LP	(5) LP	(6) LP	(7) LP	(8) LP
	SOE	Private	SOE	Private	SOE	Private	SOE	Private
KBC(-1)	0.0826*	0.1161***						
	(0.0447)	(0.0297)						
CI(-1)			0.0245***	0.0022			0.0247***	0.0028
			(0.0078)	(0.0055)			(0.0079)	(0.0055)
INNOVA(-1)			0.0097	−0.0032			0.0118	−0.0034
			(0.0149)	(0.0199)			(0.0166)	(0.0203)
ECOPEN(-1)			0.1014**	0.1221***				
			(0.0483)	(0.0312)				
ORG(-1)					0.1154*	0.1043***	0.0674	0.1041**
					(0.0622)	(0.0384)	(0.0640)	(0.0419)
FHC(-1)					0.0121	0.0042	0.0114	0.0041
					(0.0092)	(0.0044)	(0.0087)	(0.0044)
BRAND(-1)					−0.0003	0.0170***	0.0006	0.0169***
					(0.0075)	(0.0059)	(0.0073)	(0.0059)
size(-1)	−0.0635*	−0.0054	−0.0834**	−0.0019	−0.0733**	−0.0019	−0.0831**	−0.0025
	(0.0348)	(0.0199)	(0.0342)	(0.0196)	(0.0367)	(0.0193)	(0.0352)	(0.0197)
kratio(-1)	0.1134	−0.1512**	0.1051	−0.1575**	0.1229	−0.1551**	0.1026	−0.1535**
	(0.1084)	(0.0761)	(0.0989)	(0.0755)	(0.1089)	(0.0754)	(0.0994)	(0.0755)
doa(-1)	0.0015*	0.0011**	0.0014*	0.0010*	0.0016*	0.0010*	0.0014*	0.0010*
	(0.0008)	(0.0005)	(0.0008)	(0.0005)	(0.0009)	(0.0005)	(0.0008)	(0.0005)
age(-1)	0.0078	0.0000	0.0025	0.0076	0.0097	0.0048	0.0070	0.0055
	(0.0110)	(0.0087)	(0.0096)	(0.0085)	(0.0095)	(0.0077)	(0.0099)	(0.0087)
Constant	5.5050***	4.5138***	4.9081***	4.3763***	4.7984***	4.4354***	5.2638***	4.4563***
	(0.6366)	(0.3895)	(0.7265)	(0.4228)	(0.8888)	(0.5495)	(0.8738)	(0.5511)
Observations	1,782	3,770	1,782	3,770	1,782	3,770	1,782	3,770
R-squared	0.0713	0.1136	0.0892	0.1154	0.0727	0.1118	0.0876	0.1120
Number of id	486	1,165	486	1,165	486	1,165	486	1,165

Note: Robust standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$
Data source: calculated by the author with WIND and CSMAR database.

4.3.1. Effects of KBC and its subcategories on firm productivity

Table 2 reports the results of the effect KBC and different subcategories on firm productivity. Column (1) only contains the aggregate of all KBC and control variables. KBC is, as expected, a positive and significant driver of firm productivity. A one-percentage-point increase in KBC is associated with a 0.117-percentage-point increase in firm productivity gain. The outcome validates Hypothesis 1. Our results are consistent with many other empirical studies (Crass and Peters, 2014; Chappell and Jaffe, 2018; Rico and Cabrer-Borrás, 2020; Di Ubaldo and Siedschlag, 2021).

Column (2) includes the three subcategories of KBC and control variables. Computerised information, innovative property, and economic competency all have positive effects on firm productivity, while innovative property has a statistically insignificant effect. A one-percentage-point increase in CI is associated with a 0.009-percentage-point increase in firm productivity gain. A one-percentage-point increase in ECOPEN is associated with a 0.124-percentage-point increase in firm productivity gain. The findings support Hypotheses 2 and 4 but reject Hypothesis 3. According to Leung and Sharma (2021), the relationship between R&D activity and firm performance may have a threshold effect, where only a certain amount of stock can generate a positive effect. Despite rapid growth, the foundation of innovative property is relatively weak with few breakthrough innovations in China.

Economic competency contributes the most to firm productivity and has been largely ignored for a long time. To better understand the source of firm productivity, we examine the sub-items of economic competency. Column (3) contains three subcategories for economic competency and control variables. Firm productivity is positively influenced by organisational capital, firm-specific human capital, and brand equity, while firm-specific human capital has a statistically insignificant effect. Column (4) also includes computerised information and innovative property. The effect degree has changed but the significance has not, indicating that the results are robust. A one-percentage-point increase in organisation capital is associated with a 0.121-percentage-point increase in firm productivity gain. A one-percentage-point increase in brand equity is associated with a 0.013-percentage-point increase in firm productivity gain. The results support Hypotheses 4a and 4c while rejecting Hypothesis 4b. According to our findings, which are consistent with those of Kryscynski and Ulrich (2015), practitioners in China do not perceive or care about firm-specific human capital at the moment.

4.3.2. Contingent effects of ownership on relationship between KBC and firm productivity

Table 3 shows the results of the effect of KBC and different subcategories on firm productivity when the contingent effect of firm ownership is considered. Columns (1) and (2) compare the impact of the KBC as a whole on firm productivity. The effect in private firms is larger (0.1161) than in SOEs (0.0826), and the significant level in SOEs is only 10%. As previously discussed, the degree of KBC in SOEs is greater than that in private firms, while the contribution is lower in private firms. Our findings suggest that the use of KBC in SOEs is less efficient than in private firms, despite the fact that the Chinese government has effectively launched its SOE reform to address inefficiency. Hypothesis 5 is partly confirmed.

Columns (3) and (4) compare the effects of the three subcategories of the KBC on firm productivity. Computerised information and economic competency have a significant impact on the productivity of SOEs, but only economic competency has a significant impact on the productivity of private firms. Although not statistically significant, there is even a negative impact of innovative property on the productivity of private firms. Vithessonthi and Racela (2016)'s findings may provide a possible explanation. They found that R&D investment is benefit a firm in the long run, but it could have a negative effect on short-term performance due to the high initial cost. However, due to the short sample period, we are unable to test it, which should be investigated further in the future. Our findings confirm that the effects of economic competency on private firm productivity are greater than those on SOE productivity. Hypothesis 5 is further partly confirmed.

Columns (5) and (6) show the results of comparing the impacts of sub-items of economic competency to better understand the source of

Table 4
The effect of KBC and its subcategories on firm productivity (WRDG estimator).

VARIABLES	(1) WRDG	(2) WRDG	(3) WRDG	(4) WRDG
KBC(-1)	0.1175***			
	(0.0245)			
CI(-1)		0.0090**		0.0098**
		(0.0046)		(0.0046)
INNOVA(-1)		0.0029		0.0037
		(0.0129)		(0.0133)
ECOPEN(-1)		0.1245***		
		(0.0266)		
ORG(-1)			0.1217***	0.1056***
			(0.0333)	(0.0352)
FHC(-1)			0.0052	0.0050
			(0.0040)	(0.0040)
BRAND(-1)			0.0132***	0.0128***
			(0.0048)	(0.0047)
Controls	✓	✓	✓	✓

Note: Robust standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
Data source: calculated by the author with WIND and CSMAR database.

firm productivity. Only organisation capital has a significant impact on SOEs' productivity of SOEs, but organisation capital and brand equity have a significant impact on private firms' productivity. However, the effect of organisational capital in SOEs is not robust, as it becomes insignificant when CI and INNOVA are included in the model (column 7). Our findings confirm that the effects of brand equity on private firm productivity are greater than those on SOE productivity. Hypothesis 5 is further partly confirmed.

We obtain some novel results by conducting separate analyses of SOEs and private firms. Productivity is more responsive to investment in KBC in private firms than SOEs. According to Martin et al. (2018), Martin and Goodrich (2018) firm-level capabilities are an important source of heterogeneity in KBC investment. To survive in the fierce market competition, private firms are more committed to improving their capabilities to fully utilise KBC to overcome resource constraints. Second, productivity responses to KBC subcategories differ significantly between SOEs and private firms. Innovative properties and firm-specific human capital have no significant impact on both SOEs and private firms, which is contrary to expectations, implying that R&D activity in China may not have reached the threshold to contribute to productivity and practitioners in China do not perceive firm-specific human capital. Computerised information only has a positive effect on SOE productivity, whereas brand equity only has a positive effect on private firm productivity, which partially rejects H5.

4.4. Robustness check

As a robustness test, we change the estimator of firm productivity using Wooldridge's (2009) approach, abbreviated WRDG estimator. The advantage of WRDG estimator is correct for the simultaneous determination of inputs and productivity (Añón Higón et al., 2017). Tables 4 and 5 show the results of Eqs. (3)–(5) when the firm productivity is estimated using the WRDG estimator. In terms of size and significance, the results are very similar to those obtained with the LP estimator. As can be seen, the results of the study are robust.

5. Conclusion

This study uses an unbalanced panel of Chinese listed companies over to period 2013 to 2018 and investigates the productivity effect of a more comprehensive list of KBC proposed by Corrado et al. (2005), including computerised information (software), innovative property (R&D, patent, and non-patent technology), and economic competency (brand equity, firm-specific human capital, and organisational capital). In addition, we fully consider the distinctive feature of transition economies by investigating the contingent effects of ownership. There are several theoretical contributions and managerial implications.

5.1. Theoretical contributions

According to the findings of this study, KBC assets are strongly related to firm productivity. When it comes to KBC sub-categories, only computerised information and economic competency have a significant positive effect on firm productivity, whereas innovative property has no significant effect, which is inconsistent with most traditional views of R&D investments leading to greater productivity (Yang et al., 2018; Leung and Sharma, 2021). Meanwhile, the largest contribution is from economic competency, which is driven by organisational capital and brand equity, reminding us that we should carefully evaluate the productivity and enhancing effects of various KBC items. The productivity effect of KBCs is influenced by firm ownership, with private firms having a larger effect than SOEs. Computerised information only contributes to the productivity of SOEs. The contribution of economic competency in SOEs is not robust, whereas it is primarily driven by organisational capital and brand equity in private firms.

5.2. Managerial implications

The conclusion has not only provided an important reference significance for firm's strategic resource management, but also an

Table 5
The contingent effect of firms' ownership (WRDG estimator).

VARIABLES	(1) WRDG	(2) WRDG	(3) WRDG	(4) WRDG	(5) WRDG	(6) WRDG	(7) WRDG	(8) WRDG
	SOE	Private	SOE	Private	SOE	Private	SOE	Private
KBC(-1)	0.0833*	0.1165***						
	(0.0447)	(0.0297)						
CI(-1)			0.0246***	0.0022			0.0247***	0.0029
			(0.0078)	(0.0055)			(0.0079)	(0.0055)
INNOVA(-1)			0.0098	−0.0031			0.0119	−0.0034
			(0.0149)	(0.0199)			(0.0166)	(0.0203)
ECOPEN(-1)			0.1022**	0.1223***				
			(0.0483)	(0.0312)				
ORG(-1)					0.1165*	0.1046***	0.0684	0.1044**
					(0.0622)	(0.0385)	(0.0640)	(0.0419)
FHC(-1)					0.0121	0.0042	0.0113	0.0041
					(0.0092)	(0.0044)	(0.0087)	(0.0044)
BRAND(-1)					−0.0003	0.0171***	0.0006	0.0169***
					(0.0075)	(0.0059)	(0.0073)	(0.0059)
Controls	✓	✓	✓	✓	✓	✓	✓	✓

Note: Robust standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$
Data source: calculated by the author with WIND and CSMAR database.

important practical basis and decision support basis for adjusting innovation support policies to promote high-quality development in China. Firms should carefully evaluate the productivity-enhancing effects of various KBC items and make the best use of limited resources to gain more comparative advantages. The government should consider the heterogeneity of private firms and SOEs when implementing targeted adjustment policies.

5.3. Limitations and future research

A few limitations that could be addressed in future research. According to the study, the innovative properties have no significant impact on the productivity of both SOEs and private firms. The stock of innovative properties may not have reached the threshold, or they may have a short-term negative effect due to high initial costs. However, due to the short sample period, we were unable to test it, which should be looked into further in the future. Furthermore, a firm is a collection of resources that can help it gain a competitive advantage, but it also needs invest in complementary resources (Añón Higón et al., 2017). As a result, future research could examine the complementary effect of various types of KBC.

CRediT authorship contribution statement

Qiuqin He: Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Conceptualization. **Maria Guijarro-Garcia:** Data curation, Methodology, Writing – original draft. **Juan Costa-Climent:** Writing – original draft, Formal analysis, Data curation.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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