7. Intangible Capital and China's Economic Growth: Evidence from Input–Output Tables

Shenglang Yang and Yixiao Zhou[1]

Introduction

This study uses data from input–output tables and a methodology adopted from Corrado et al. (2009) to provide empirical evidence of the role of intangible capital in China according to industrial sector. In so doing, it offers a new methodology for measuring the role of intangible capital in a country where data on intangible capital are inadequate. It finds that growth in intangible capital explains almost 20 per cent of total factor productivity (TFP) growth in China over the period 1997–2012. Moreover, these effects of intangible capital remain robust under various forms of sensitivity analysis including bootstrap regressions, the Levinsohn and Petrin (LP) (2003) approach and changes in the depreciation rate. At the sectoral level, we find that research and development (R&D), which embodies innovation, plays a more important role in agriculture than do economic competency or computerised information, but the role of economic competency is more important in the services and light-industry sectors than are R&D and computerised information.

China has enjoyed rapid growth since its reform and opening-up policies were implemented in 1978. China's real gross domestic product (GDP) per capita in 1978 was only one-fortieth of the US level and one-tenth of the Brazilian level (Zhu 2012). By 2015, however, China had real GDP per capita that was equal to almost one-quarter of the US level and at the same level as Brazil.[2] Growth in total factor productivity (TFP) has played a critical role in China's growth miracle. According to Zhu (2012), positive change in TFP accounts for 78 per cent of the growth in China's GDP per capita between 1978 and 2007. The transition from

1 We much appreciate the helpful comments on earlier versions of this chapter from Ligang Song and the conference participants at the Crawford School of Public Policy, The Australian National University. All remaining errors are our own.

2 GDP per capita is calculated using the purchasing power parity (PPP) approach (constant 2011 international currency); data are from the World Bank International Comparison Program (www.worldbank.org/en/programs/icp).

a planned to a market economy is a major source of TFP growth and has significantly improved China's TFP, but this source of TFP growth cannot last forever as returns from earlier reforms are diminishing.

From 2012, Chinese economic growth has been slowing and has entered a stage called the 'new normal', the official definition of which is that China will maintain stable and relatively lower growth compared with earlier growth rates. What could be China's new source of growth in the new normal? Text on the back of any iPhone may provide a hint. It reads: 'Designed by Apple in California. Assembled in China.' Payments to Chinese workers and the profits of non-Apple companies account for only 1.8 per cent and 9.2 per cent, respectively, of the value added of an iPhone, while Apple's profits are 58.5 per cent of the total value added in 2010, according to Kraemer et al. (2011). This striking fact has an important implication: the distribution of value added in the global value chain favours those who own the product design and hold the market power, rather than those who manufacture the products.

Product design and market power embody a broader concept called intangibles (Corrado et al. 2009). Intangible capital consists of the stock of non-material resources that enter the production process and is important for the creation or improvement of products as well as production processes (Arrighetti et al. 2014). Intangible capital has been playing an increasingly important role in boosting productivity and economic growth since the 'information technology revolution'. In developed economies, the relative use of tangible capital is decreasing while the relative use of intangible capital—such as production technologies, product design, market power and intangibles embodied in employees and firm structure—has been increasing (Fukao et al. 2009; van Ark et al. 2009; Marrano et al. 2009; Corrado and Hulten 2010; Miyagawa and Hisa 2013; Chun and Nadiri 2016).

The literature on intangible capital is significant and includes the discussion of intangible capital as a source of growth in various countries at national and industry levels (Fukao et al. 2009; van Ark et al. 2009; Marrano et al. 2009; Corrado and Hulten 2010; Borgo et al. 2013; Corrado et al. 2013; Haskel and Wallis 2013; Miyagawa and Hisa 2013; Chun and Nadiri 2016), the discussion of intangible capital in the valuation and productivity of firms (Atkeson and Kehoe 2005; Tronconi and Marzetti 2011; Arato and Yamada 2012; Eisfeldt and Papanikolaou 2013, 2014; Gourio and Rudanko 2014b; Clausen and Hirth 2016) and the discussion of incorporating intangible capital to solve macroeconomic puzzles (McGrattan and Prescott 2010, 2014; Goodridge et al. 2013; Gourio and Rudanko 2014a). However, studies on intangible capital in China are scarce, due both to the lack of data and to the recent importance of intangible capital to the economy. Hulten and Hao (2012) calculate the intangible capital of China between 2000 and 2008 and conduct growth accounting of national data using the income-share method. The authors gather only nine observations, which is not sufficient for a comprehensive analysis. Given China's shifting growth model and the possibility of utilising alternative data sources, it is timely to further investigate the role of intangible capital in China's growth.

To the best of our knowledge, this study is the first empirical test of how intangibles enhance economic growth at the sectoral level in China. In contrast to national-level studies, an industry-level study has the advantage of generating more observations and thus allows more statistical freedom to analyse how different categories of intangible capital impact on economic growth. This will provide a better way to assess the role of intangibles in an economy.

We divided 100 sectors from China's input–output tables for 1997, 2002, 2007 and 2012[3] into four subgroups—agriculture, light industry, heavy industry and services—to alleviate the problem of parameter heterogeneity between sectors. The selected input–output tables are constructed using data from China's National Bureau of Statistics (NBS), based on input–output surveys, and are relatively reliable. The measurement of intangible investment in this study follows the literature in capitalising either the intangible intermediates or intangible expenditure. Use of intermediates from input–output tables to estimate intangibles is common in the literature,[4] including in Miyagawa and Hisa (2013), Haskel et al. (2014) and Chun and Nadiri (2016).

Unlike Corrado et al. (2009), Fukao et al. (2009) and Hulten and Hao (2012), however, this study uses a proxy approach—that is, we use the entries relevant to intangible investment as proxies and make the assumption that the ratios of intangible investments to the proxies remain constant over time. Using the proxy approach and assuming the ratio of true value to proxies is constant over time are also common in the literature on intangible capital. For example, Gourio and Rudanko (2014b) proxy selling, general and administrative expenses (S&GA) for investment in customer capital, while Tronconi and Marzetti (2011) and Eisfeldt and Papanikolaou (2014) proxy S&GA for investment in organisational capital. Although this assumption is often found to be invalid, it is the best this study could adopt based on the available data; and, if this assumption is true, the study will avoid the inaccurate measurement problems found in Corrado et al. (2009) and Fukao et al. (2009).

When conducting growth accounting, we adopt the Cobb–Douglas parameter estimation based on econometrics instead of income/cost shares, along the lines of Niebel et al. (2017). The advantage of this approach is to allow for the existence

3 The reason we exclude the input–output tables for 1987 and 1992 is that these two tables are inaccurate and include few of the intangible intermediates.

4 Intangible investment produced within firms is not reflected in input–output tables; however, as long as the ratio of actual intangible expenditure to the intangible expenditure manifest in the input–output tables remains constant over time, the coefficients in the empirical analysis will not be biased.

of error terms. In contrast, the income-share method used by Corrado et al. (2009), Fukao et al. (2009) and Hulten and Hao (2012) may underestimate the contribution of resource reallocation to economic growth when the economy is in disequilibrium, according to Nadiri (1970). A transitional economy such as China's is likely to remain in disequilibrium over time; therefore, the income-share method is not suitable here. Our choice of econometric approach allows for an error term, which alleviates the problems arising from disequilibrium.

Our study also conducts bootstrap regressions to confirm the robustness of the results, which is new to the existing literature. Limited by the time span (T = 4), the standard generalised method of moments (GMM) approach is not suitable for this study. Bootstrap regressions are the only feasible method given data limitations. Studies on intangible capital often suffer from small sample size. Bootstrap regressions alleviate this problem to some extent. Moreover, the depreciation rate of intangible capital is debatable. To confirm the significance of the impacts of intangible capital, we will conduct a sensitivity analysis by experimenting with various depreciation rates.

This study consists of five sections. In the next section, the methodology of growth accounting at the industry level is discussed and a traditional growth accounting approach excluding intangible capital is conducted. Section three provides empirical evidence of the relationship between intangible capital and TFP. In section four, a growth accounting approach incorporating intangible capital is conducted, while section five concludes.

How do we conduct growth accounting with sectoral data?

Growth accounting often utilises the Cobb–Douglas production function (Equation 7.1).

Equation 7.1

$$Y = AK^{ak}L^{al}$$

In Equation 7.1, Y is GDP, A is TFP and K is capital. If the object is a nation, we take the logarithm of both sides and run a regression. The parameters ak and al can be estimated in this way. However, with sectoral data, there is a problem: the parameters of each industry may vary from one another. If a pooled regression is conducted, the heterogeneity of parameters will cause bias of the estimates. Moreover, each industry may have its own initial TFP value, which implies different intercepts of various industries. To overcome the problem of parameter heterogeneity, we categorise the industries according to the similarities of parameters, following previous literature such as Harris and Robinson (2002). In this study, the subgroups are defined as follows: light industry, heavy industry, agriculture and services.[5] We then assume a Cobb–Douglas production function (Equation 7.2).

Equation 7.2

$$Y_{it} = A_{it} K_{it}^{ak} L_{it}^{al}$$

Y_{it} is the value added of sector i at time t; A_{it} is the TFP of sector i at time t; K_{it} is capital according to the traditional definition (excluding most intangibles); L_{it} is the level of labour inputs; and ak and al are the capital and labour elasticities of output, respectively. Due to sectoral heterogeneity, the initial values of TFP may be different across sectors. We therefore assume Equation 7.3.

Equation 7.3

$$A_{it} = A_{i0eyt}$$

Taking the logarithm of both sides, we get Equation 7.4.

Equation 7.4

$$\ln Y_{it} = \ln A_{it} + ak \ln k_{it} = al \ln L_{it}$$

Equation 7.4 can be estimated by either the fixed-effects (FE) model or the random-effects (RE) model, depending on whether A_{i0} varies from sector to sector within a subgroup.

A key issue in production function estimation is, however, correlation between the unobservable productivity shocks and input levels. An industry responds to positive productivity shocks by expanding output and input. Negative shocks lead an industry to reduce output and input usage. When true, ordinary least squares (OLS) estimations of production functions are likely to be biased, which leads to biased estimates of productivity. Olley and Pakes (1996) develop an estimation approach using investment as a proxy for these unobservable shocks. More recently, Levinsohn and Petrin (2003) point out that investment is lumpy. If this is true, the investment proxy may not respond smoothly to productivity shocks. Levinsohn and Petrin (2003) suggest that using intermediate inputs can solve this problem.

5 The list of subgroups is demonstrated in Appendix 7.1.

Therefore, here we also adopt growth accounting without intangibles[6] using the Levinsohn and Petrin (LP) approach. The proxy used in this study is the usage of electricity, heating, fuel and water intermediates at 1997 constant prices.[7]

The growth rate of TFP is backed out as Equation 7.5.

Equation 7.5

$$g\_tfp = g_y - akg_k - alg_l$$

Capital and labour inputs at the sectoral level as detailed as those in China's input–output tables are not available. Luckily, China's input–output tables have two variables: total wages for labour and capital depreciation. We adjust the nominated depreciation of capital to the real depreciation using the Price Index of Investment in Fixed Assets from the NBS.

We assume a constant depreciation rate, θ, as is the convention in the existing literature (Equation 7.6).

Equation 7.6

$$\theta K_{it} = \text{real depreciation}_{it}$$

It is clear that real depreciation$_{it}$ has a strictly linear relationship with K_{it} and therefore is a perfect proxy for capital. As for the quantity of labour, we have Equation 7.7.

Equation 7.7

$$L_{it} = \frac{\text{total wage}_{it}}{\text{average wage}_{it}}$$

Total wage$_{it}$ is from China's input–output table and average wage$_{it}$ is from the China Labour Statistical Yearbook (NBS various years); however, the sectoral classifications in these yearbooks are not as detailed as those in China's input–output tables. Therefore, the average wage in the upper level of classification is used as a proxy for the average wage in individual sectors.[8]

We substitute K_{it} in Equation 7.4 with Equation 7.6 (Equation 7.8).

6 This approach allows only one capital variable; however, when incorporating intangible capital, there are at least two capital variables. Therefore, we do not conduct growth accounting with intangible capital using the LP approach.

7 Deflators are obtained from the National Bureau of Statistics of China and the World Input Output Database (www.wiod.org/).

8 The proxy is based on an assumption that the ratio of the average wage in a lower sector to that in the upper-level sector remains constant over time. If this assumption holds, the constant ratio becomes a part of the intercept, similar to Equation 7.8. The coefficient of the proxy is then the same as the true coefficient.

Equation 7.8

$$\ln Y_{it} = \ln A_{it} - ak\ln(\theta) + ak\ln \text{Capital\_proxy}_{it} + al\ln L_{it}$$

It is clear that substituting the capital proxy (real depreciation$_{it}$) for K_{it} is appropriate because the coefficient of real depreciation$_{it}$ is the same as that of K_{it}. The depreciation rate, θ, becomes part of the intercept. The growth rate of K_{it} that is used for the calculation of TFP is exactly the same as the growth rate of real depreciation$_{it}$.

Table 7.1 reports the descriptive statistics of the variables used in regressions for the period 1998–2012. It is clear that the ranges of value added, capital proxy, labour and different categories of intangible capital are large. This sample consists of 100 sectors in China across 14 years and therefore has nearly 400 observations.

Table 7.1 Descriptive statistics

Variable		Mean	Std dev.	Min.	Max.	Observations
ln(Value added)	Overall	15.83	1.21	12.29	19.21	N = 400
	Between		1.07	13.10	18.55	n = 100
	Within		0.59	12.31	17.94	T-bar = 4
ln(Capital proxy)	Overall	13.99	1.30	9.71	18.86	N = 398
	Between		1.08	11.35	17.57	n = 100
	Within		0.75	9.92	16.87	T-bar = 3.98
ln(labour)	Overall	5.39	1.27	1.06	9.72	N = 398
	Between		1.22	1.33	9.63	n = 100
	Within		0.38	1.71	6.88	T-bar = 3.98
ln(Intangible capital)	Overall	13.22	1.85	8.58	17.79	N = 398
	Between		1.20	10.57	15.84	n = 100
	Within		1.41	10.20	16.97	T-bar = 3.98
ln(R&D capital)	Overall	10.22	2.38	2.67	15.65	N = 394
	Between		1.68	3.76	13.37	n = 99
	Within		1.70	6.57	13.48	T-bar = 3.98
ln(EC capital)	Overall	12.93	1.82	8.46	17.65	N = 398
	Between		1.18	10.24	15.56	n = 100
	Within		1.38	9.82	16.74	T-bar = 3.98
ln(CI capital)	Overall	9.94	2.26	1.07	15.55	N = 397
	Between		1.86	3.59	14.25	n = 100
	Within		1.29	5.86	13.24	T-bar = 3.97

EC = economic competency

CI = computerised information

Source: Authors' calculations.

Table 7.2 Regression results for growth accounting without intangibles

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Agriculture			Heavy industry			Light industry			Service		
Variables	RE	RE bootstrap	LP	RE	RE bootstrap	LP	FE	FE bootstrap	LP	FE	FE bootstrap	LP
ln(Capital)	0.42***	0.42***	0.62***	0.67***	0.67***	0.39**	0.70***	0.70***	0.60***	0.64***	0.64***	0.42**
	(0.14)	(0.14)	(0.18)	(0.08)	(0.07)	(0.17)	(0.03)	(0.03)	(0.06)	(0.05)	(0.05)	(0.19)
ln(Labour)	0.57***	0.57***	0.34**	0.26**	0.26*	0.30***	0.13**	0.13**	0.29***	0.22**	0.22**	0.44***
	(0.0979)	(0.133)	(0.133)	(0.123)	(0.147)	(0.116)	(0.0577)	(0.0577)	(0.0505)	(0.0796)	(0.0989)	(0.0585)
Constant	6.48***	6.48***		4.99***	4.99***		5.37***	5.37***		5.60***	5.60***	
	(1.27)	(1.11)		(0.87)	(0.65)		(0.50)	(0.50)		(0.48)	(0.62)	
Observations	20	20	20	138	138	138	144	144	144	96	96	96
R-squared	0.79	0.79		0.81	0.81		0.88	0.88		0.86	0.86	
Number of id	5	5		35	35		36	36		24	24	

*** $p < 0.01$

** $p < 0.05$

* $p < 0.1$

RE = random effects

FE = fixed effects

LP = Levinsohn and Petrin

Notes: Cluster robust standard errors are in parentheses. Number of bootstrap replications: 400 for normal bootstrap, 250 for LP. Number of id refers to the number of individuals within the sample.

Source: Authors' calculations.

The results for growth accounting are displayed in Table 7.2. According to Hausman tests, random-effects models are appropriate to study the agricultural and light-industry sectors, but fixed-effects models are used for the heavy industry and services sectors. Both labour and depreciation are highly significant economically and statistically, and remain robust when using bootstrap regressions. A 1 per cent change in capital stock is associated with a 0.42 per cent, 0.67 per cent, 0.70 per cent and 0.64 per cent change in value added in agriculture, heavy industry, light industry and services, respectively. A 1 per cent change in labour is associated with a 0.57 per cent, 0.26 per cent, 0.13 per cent and 0.22 per cent change in value added in agriculture, heavy industry, light industry and services, respectively. The growth rate of TFP is calculated according to Equation 7.5.

Intangible capital and TFP growth

According to Corrado et al. (2009), intangible investment includes investment in computerised information, innovative property and economic competency. Traditionally, intangible investment is classified as intermediate or expenditure and therefore is not manifest in national accounts. However, investment is the action of sacrificing today's consumption for increasing consumption in the future, according to Hulten (1979) and Corrado et al. (2009). Moreover, the effects of the intangible expenditure mentioned above last more than one year and those expenses should therefore be capitalised.

We follow the literature to measure intangibles by capitalising the intangible intermediates or intangible expenditure. Specifically, this study obtains relevant intermediate data from China's input–output tables and assumes that the ratio of the intermediate to the true intangible investment remains constant over time. The proxy approach is commonly adopted in measuring intangible investment and is well founded—for example, Gourio and Rudanko (2014b) proxy the S&GA for customer capital investment, and Tronconi and Marzetti (2011) and Eisfeldt and Papanikolaou (2014) proxy S&GA for organisational capital investment. Table 7.3 presents our proxies for intangible investment.

Table 7.3 Categories of intangible investment

	Proxy	Comments
1. Computerised information (mainly software)	Computer services and software intermediates	Includes software
2. Innovative property (a) Scientific R&D (b) Non-scientific R&D	Research industry intermediates	Includes R&D expenditure
3. Economic competencies (a) Brand equity (mainly advertising) (b) Firm-specific resources (organisational capital and staff training)	Culture, arts, radio, film and television industry intermediates	Includes parts of advertising expenditure
	Business service industry intermediates	Includes advertising expenditure and organisational investment
	Education industry intermediates	Includes staff training

Note: The intangible investment classification follows Corrado et al. (2009).

Source: Authors' construction.

Following Corrado et al. (2009), intangible investment is deflated to 1997 constant prices using the GDP deflator.[9] Since the interval of the input–output table is five years, we interpolate the missing data within the interval by assuming that the growth rate is constant within the five-year interval. The depreciation rate of intangible capital is set according to Corrado et al. (2009): 20 per cent for R&D, 33 per cent for computerised information, 60 per cent for brand equity and 40 per cent for firm-specific resources. Based on these, we assume 40 per cent for overall intangibles and 50 per cent for economic competency intangibles. Intangible capital in 1997 was set to zero and therefore 1998 is the first year for which this study calculates intangible capital. According to Corrado et al. (2009), the year in which initial capital stocks are zero has little effect on growth accounting analysis because the depreciation rates are high and much previous capital has been depreciated away by the date we start analysis—that is, 1998. Moreover, the amount of intangible capital in China was considerably smaller in the 1990s, as manifest by low R&D spending (0.57 per cent of GDP in 1996[10] and unavailable before that) and software use. Therefore, setting intangible capital in 1997 to zero will not cause significant problems.

9 The GDP deflator is obtained from the World Bank.

10 Data obtained from the World Bank.

Table 7.4 shows the trend of the sectoral average ratio of intangibles to tangibles. The amount of tangible capital is derived based on an assumed depreciation rate of 5 per cent.[11] The amount of intangible capital is calculated using the method explained above. Accompanying China's rapid economic growth over the past two decades has been a significant rise in its intangible–tangible ratio. However, compared with advanced economies, China's intensity of intangible capital use in production is still low and, therefore, there is plenty of room for catch-up in the future. For example, the intangible–tangible ratios of Japan, the United States and the United Kingdom in 2007 were 17 per cent, 22 per cent and 24 per cent,[12] respectively. Note that the parts of proxies include expenditure that is not intangible investment and excludes those that are produced within firms. This suggests that the actual intangible–tangible ratio might be lower or higher than the figures in Table 7.4.

Table 7.4 Increasing trend of intangibles in China (RMB thousand)

	1998	2002	2007	2012
Sectoral average intangibles	1,573,790	8,880,930	24,017,800	59,924,580
Sectoral average tangibles	216,289,200	333,212,600	697,231,200	1280,413,600
Ratio	0.7%	2.7%	3.4%	4.7%

Source: Authors' calculations using raw data from China's input–output tables.

Since TFP is the portion of output for which input cannot account (Comin 2004), we should be careful when linking TFP to intangible capital. Change in TFP is possibly caused by changes in human capital and institutional quality. The changes in human capital and institutions are often not sector-specific, which can be controlled for at the national level. To capture human capital and institutional quality changes, this study uses two proxies. The first is GDP per capita and the second is the time dummy that captures time effects. The positive correlation between economic development, human capital and institutional quality has been well documented (Weede and Kämpf 2002; Gwartney et al. 2004). The time dummy provides a different overall TFP growth rate for each year so we can separate the TFP growth at the national level from that caused by the change in intangible capital within individual industries. To control for the scale of an industry, the indicator of intangible capital is the ratio of intangibles to tangibles instead of the absolute amount of intangibles. Table 7.5 demonstrates the relationship between the growth rate of TFP and the growth rate of the intangible–tangible ratio. Note two types of TFP are used to check the robustness of our results: one is derived from RE/FE models and the other is LP derived from the LP models.

11 The most commonly used depreciation rate for the Chinese economy is 5 per cent.

12 Tangible capital data are obtained from the Penn World Table 8.1 (www.rug.nl/ggdc/productivity/pwt/pwt-releases/pwt8.1) and intangible capital data are from the cross-country intangible investment data website (www.intan-invest.net/).

Table 7.5 Relationship between the intangible–tangible ratio and TFP growth

	ΔIn(TFP)					ΔIn(TFP, LP)						
Variables	(1) OLS	(2) RE	(3) FE	(4) OLS	(5) RE	(6) FE	(7) OLS	(8) RE	(9) FE	(10) OLS	(11) RE	(12) FE
ΔIn(Intangible/tangible)	0.20***	0.20***	0.25***	0.20***	0.20***	0.25***	0.14***	0.14***	0.16***	0.14***	0.14***	0.16***
	(0.05)	(0.07)	(0.08)	(0.05)	(0.07)	(0.08)	(0.03)	(0.04)	(0.05)	(0.03)	(0.04)	(0.05)
ΔIn(GDP per capita)	0.42***	0.42**	0.56***				0.30**	0.30**	0.39***			
	(0.16)	(0.17)	(0.20)				(0.13)	(0.13)	(0.14)			
Constant	–0.33***	–0.33**	–0.45***	–0.16**	–0.16*	–0.23**	–0.12	–0.12	–0.19*	0.02	0.02	–0.02
	(0.12)	(0.14)	(0.17)	(0.07)	(0.09)	(0.11)	(0.09)	(0.10)	(0.11)	(0.05)	(0.06)	(0.07)
Observations	298	298	298	298	298	298	298	298	298	298	298	298
R-squared	0.18	0.18	0.23	0.27	0.27	0.32	0.11	0.11	0.15	0.25	0.25	0.30
Year fixed effects	NO	NO	NO	YES	YES	YES	NO	NO	NO	YES	YES	YES
Number of id		100	100		100	100		100	100		100	100

*** $p < 0.01$

** $p < 0.05$

* $p < 0.1$

Δ = first differenced

OLS = ordinary least squares

RE = random effects

FE = fixed effects

LP = Levinsohn and Petrin

Notes: Cluster robust standard errors in parentheses, except OLS; OLS is with robust standard error. Number of bootstrap replications: 400 for normal bootstrap, 250 for LP. TFP denotes the TFP derived from RE/FE models while 'TFP, LP' denotes TFP derived from LP models. Number of id refers to the number of individuals within the sample.

Source: Authors' calculations.

Importantly, the growth rate of the intangible–tangible ratio is economically and statistically significant across all specifications. A 1 per cent increase in the intangible–tangible ratio is associated with 0.26 per cent, 0.26 per cent, 0.31 per cent, 0.26 per cent, 0.26 per cent and 0.31 per cent growth in TFP according to models (1)–(6), respectively. A 1 per cent increase in the intangible–tangible ratio is associated with 0.14 per cent, 0.14 per cent, 0.16 per cent, 0.14 per cent, 0.14 per cent and 0.16 per cent growth in 'TFP, LP' according to models (7)–(12), respectively. Growth of the intangible–tangible ratio also explains a significant amount of TFP change, at 17 per cent according to model (4) and 11 per cent according to model (10).[13] The significant impact of intangibles on TFP is consistent with the findings of Haskel et al. (2014), who regress TFP on intangibles, information and communication technology and other variables and find that intangible capital is the only one that is significant. With GDP per capita and time effects as the control variables and the fixed-effects estimator, the intangible–tangible ratio is still statistically and economically significant, which suggests the finding is robust. Based on the above evidence, we thus conclude that intangible capital does play a significant role in China's productivity increase.

Another interesting question to ask is how the contributions of different categories of intangible capital to TFP growth differ. Table 7.6 shows the results of the effects of different intangible capital on TFP growth. When using the TFP derived from RE/FE models, all categories of intangible capital play important roles in the growth of TFP, being robust across all models. Specifically, according to model (4), a 1 per cent increase in the ratio of computerised information capital to tangible capital is associated with 0.08 per cent growth in TFP, 1 per cent growth in the ratio of R&D capital to tangible capital is associated with 0.11 per cent growth in TFP and 1 per cent growth in the ratio of economic competency capital to tangible capital is associated with 0.13 per cent growth in TFP. This is consistent with Chun et al. (2012), who find that innovative property is the most significant among all sorts of intangible investments when they are used to explain the growth of TFP in the Japanese economy. However, when the method of deriving TFP changes from FE/RE models to LP models, the results differ. Although the scale of the coefficients has not changed dramatically, the statistical significance has. The computerised information capital is no longer significant and the economic competency capital is insignificant when year effects are not controlled. R&D capital remains generally significant. When it comes to the scale of the effects, according to model (8), a 1 per cent increase in the ratio of computerised information capital to tangible capital is associated with a 0.03 per cent increase in 'TFP, LP', a 1 per cent increase

13 The square of partial correlation coefficient between Δln(TFP)/Δln(TFP, LP) and Δln(Intangible/tangible) is the percentage of variance in Δln(TFP)/Δln(TFP, LP) that can be explained by Δln(Intangible/tangible) in a model specification. Therefore, the 17 per cent and 11 per cent here are the squares of partial correlation coefficients between the two variables of interest in model (4) and model (10).

in the ratio of R&D capital to tangible capital is associated with a 0.04 per cent increase in 'TFP, LP' and a 1 per cent increase in the ratio of economic competency capital to tangible capital is associated with a 0.11 per cent increase in 'TFP, LP'.

Table 7.6 Impact of growth of different categories of intangible–tangible ratio on growth of TFP

	ΔIn(TFP)				ΔIn(TFP, LP)			
Variables	(1) OLS	(2) RE	(3) OLS	(4) RE	(5) OLS	(6) RE	(7) OLS	(8) RE
ΔIn(CI/Tangible)	0.07**	0.07**	0.06*	0.06*	0.05	0.05	0.03	0.03
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
ΔIn(R&D/ Tangible)	0.11***	0.11***	0.07**	0.07***	0.09***	0.09***	0.04	0.04*
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.02)
ΔIn(EC/Tangible)	0.08*	0.08*	0.12***	0.12***	0.05	0.05	0.11***	0.11***
	(0.04)	(0.04)	(0.04)	(0.04)	(0.03)	(0.03)	(0.03)	(0.03)
Constant	–0.05	–0.05	–0.14***	–0.14***	0.07*	0.07**	–0.05	–0.05
	(0.04)	(0.04)	(0.05)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
Observations	196	196	196	196	196	196	196	196
R-squared	0.30	0.30	0.35	0.35	0.21	0.21	0.31	0.31
Year fixed effects	NO	NO	YES	YES	NO	NO	YES	YES
Number of id		98		98		98		98

*** $p < 0.01$

** $p < 0.05$

* $p < 0.1$

OLS = ordinary least squares

RE = random effects

Notes: Cluster robust standard errors in parentheses except OLS; OLS is with robust standard error. Cluster robust standard error is unavailable when using FE models due to insufficient rank, so FE models are not used. CI is computerised information (mainly software); R&D is innovative property; EC is economic competency; TFP denotes TFP derived from RE/FE models; while 'TFP, LP' is TFP derived from LP models. Number of id refers to the number of individuals within the sample.

Source: Authors' calculations.

Growth accounting incorporating intangible capital

According to Corrado et al. (2009), the production function could be written as Equation 7.9 when intangible capital is incorporated.

Equation 7.9

$$Y = AK^{ak}I^{ai}L^{al}$$

In Equation 7.9, *I* is the intangible capital stock and *ai* is the output elasticity of intangible capital. When intangible expenditure is viewed as investment, it should be counted as value added according to its national accounts identity (Corrado et al. 2009). Therefore, when conducting growth accounting with intangible capital, an even more accurate measurement of intangible investment is required. In this study, however, we do not know the ratio of the true intangible investment to proxies. One feasible action is to assume 100 per cent as the base case.[14]

Table 7.7 demonstrates the results of growth accounting incorporating intangible capital. The impacts of intangibles on the economic growth of all subgroups are economically and statistically significant. A 1 per cent increase in intangible capital is associated with 0.16 per cent, 0.22 per cent, 0.14 per cent and 0.24 per cent output growth in agriculture, heavy industry, light industry and services, respectively. This indicates that intangible capital has become an important source of growth in the Chinese economy.

Table 7.7 Results of growth accounting with intangibles

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Agriculture		Heavy industry		Light industry		Services	
Variables	RE	RE bootstrap	RE	RE bootstrap	FE	FE bootstrap	FE	FE bootstrap
ln(Tangibles)	0.36***	0.36***	0.29***	0.29**	0.40***	0.40***	0.32***	0.32***
	(0.09)	(0.13)	(0.11)	(0.12)	(0.04)	(0.04)	(0.08)	(0.09)
ln(Labour)	0.54***	0.54***	0.44***	0.44***	0.37***	0.37***	0.39***	0.39***
	(0.04)	(0.09)	(0.11)	(0.10)	(0.06)	(0.06)	(0.07)	(0.10)
ln(Intangibles)	0.16***	0.15**	0.22***	0.22***	0.14***	0.14***	0.24***	0.24***
	(0.05)	(0.08)	(0.05)	(0.05)	(0.02)	(0.02)	(0.05)	(0.06)
Constant	5.68***	5.65***	6.56***	6.56***	6.36***	6.36***	6.09***	6.09***
	(0.38)	(0.54)	(0.74)	(0.83)	(0.39)	(0.39)	(0.49)	(0.68)
Observations	20	20	138	138	144	144	96	96
R-squared	0.87	0.87	0.88	0.88	0.92	0.92	0.93	0.93
Number of id	5	5	35	35	36	36	24	24

*** $p < 0.01$

** $p < 0.05$

* $p < 0.1$

RE = random effects

FE = fixed effects

Notes: Cluster robust standard errors in parentheses, except OLS; OLS is with robust standard error. Number of id refers to the number of individuals within the sample.

Source: Authors' calculations.

14 The value of proportion does not matter for the results. When varying the proportion, the results remain similar. For the details of how the proportion is changed, please see Appendix 7.2.

As mentioned earlier, intangible capital can be divided into computerised information, innovative property and economic competency. A question to be investigated is whether their roles differ across industries. To answer this question, we first assume a production function in which the intangible capital is decomposed (Equation 7.10).

Equation 7.10

$$Y = AK^{ak}CI^{ai1}RD^{ai2}EC^{ai3}L^{al}$$

In Equation 7.10, CI is computerised information (mainly software); RD is innovative property (R&D); EC is economic competency; and *ai*1, *ai*2 and *ai*3 are the output elasticities of the three inputs, respectively.

Table 7.8 shows the results of growth accounting using the above production function. Not all categories of intangible capital are significant (e.g. economic competency within the agricultural sector and R&D within the services sector). One reason might be the strong positive correlation between different categories of intangible capital due to their co-movement. However, from the results in Table 7.8, we are able to obtain some information about the roles of different intangible capital in different industries. In agriculture, R&D is significant and positive. A 1 per cent increase in R&D capital is predicted to increase a sector's value added by 0.15 per cent. The coefficients of economic competency and computerised information are small, which may indicate that their effects are trivial. In heavy industry, all are economically and statistically significant. A 1 per cent increase in R&D, economic competency and computerised information is associated with 0.13 per cent, 0.11 per cent and 0.04 per cent growth in value added, respectively. In light industry, both R&D and economic competency capital are significant. A 1 per cent increase in R&D and economic competency is correlated with a 0.08 per cent and 0.14 per cent increase in value added, respectively. The coefficient of computerised information capital is insignificant and small. Therefore, economic competency capital is likely to play the most important role in China's light industry of the three categories of intangible capital. In services, only economic competency is significant. A 1 per cent increase in economic competency capital is associated with 0.25 per cent of value-added growth. The coefficients of both R&D and computerised information capital are insignificant and small in value, which may imply that economic competency is the most important category of intangible capital in the services sector.

Table 7.8 Results of growth accounting with detailed intangible capital

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Agriculture		Heavy industry		Light industry		Services	
Variables	RE	RE bootstrap	RE	RE bootstrap	FE	FE bootstrap	FE	FE bootstrap
ln(Tangibles)	0.35***	0.35	0.22***	0.22**	0.30***	0.30***	0.29***	0.29***
	(0.08)	(0.27)	(0.09	(0.10)	(0.06)	(0.05)	(0.06)	(0.07)
ln(Labour)	0.52***	0.52**	0.49***	0.49***	0.44***	0.44***	0.39***	0.39***
	(0.06)	(0.21)	(0.07)	(0.07)	(0.08)	(0.08)	(0.07)	(0.11)
ln(RD)	0.15***	0.15	0.13***	0.13***	0.08**	0.08**	0.02	0.02
	(0.03)	(0.15)	(0.02)	(0.03)	(0.03)	(0.03)	(0.02)	(0.02)
ln(EC)	0.02	0.02	0.11***	0.11**	0.14***	0.14***	0.25***	0.25***
	(0.05)	(0.13)	(0.04)	(0.05)	(0.02)	(0.03)	(0.05)	(0.05)
Ln(CI)	–0.06***	–0.06	0.04**	0.04**	–0.01	–0.01	0.02	0.02
	(0.01)	(0.07)	(0.02)	(0.02)	(0.01)	(0.01)	(0.03)	(0.03)
Constant	6.57***	6.57***	7.02***	7.02***	6.78***	6.78***	6.05***	6.05***
	(0.81)	(1.70)	(0.60)	(0.79)	(0.39)	(0.43)	(0.41)	(0.67)
Observations	20	20	137	137	144	144	92	92
R-squared	0.99	0.99	0.93	0.93	0.94	0.94	0.94	0.94
Number of id	5	5	35	35	36	36	23	23

*** $p < 0.01$

** $p < 0.05$

* $p < 0.1$

RE = random effects

FE = fixed effects

Notes: Cluster robust standard errors in parentheses, except OLS; OLS is with robust standard error. CI is computerised information (mainly software); R&D is innovative property; and EC is economic competency. Number of id refers to the number of individuals within the sample.

Source: Authors' calculations.

Conclusion

Intangible capital and its various forms—technology, product design, marketing and organisational development—are the foundation of knowledge economies. According to our results, China, a transitional economy, has started to benefit from the rapid growth of intangible capital. Using China's input–output tables for various years, this study provides an important insight into the role of intangible capital in different industries in the context of an emerging knowledge economy. It is specifically found that the growth in intangible capital is significantly associated with TFP growth in China, and explains almost 20 per cent of TFP growth over the sample period. The results are generally robust across the different model specifications.

This study also reveals the relative importance of different categories of intangible capital in different industries. In agriculture, R&D is likely to play a critical role, but the role of other intangible capital is relatively trivial. In the heavy-industry sector, R&D, computerised information (mainly software) and economic competency are all important to growth, but R&D is the most important. While the effects of both economic competency and R&D are significant to the growth of light industry, R&D is more significant. Last but not least, in the services sector, the role of economic competency is critical while those of the other categories are relatively unimportant. In other words, the role of R&D is important across all non-service industries, while the role of economic competency is paramount across all non-agriculture industries.

The use of intangible capital in production in China, however, remains relatively small compared with that in advanced economies. In 2007, the intangible–tangible ratio in China was approximately 3.4 per cent, compared with 17 per cent in Japan, 22 per cent in the United States and 24 per cent in the United Kingdom. This is consistent with China's role at the assembly end of global value chains and the fact that investment in design, intellectual property and branding remains the preserve of more developed economies. Given that the productivity boost from China's reform and opening up is diminishing and the country has entered the new normal phase, it is clearly time for China to invest in new sources of growth—and intangible capital is one of them.

The transformation from 'made in China' to 'designed in China' has a long way to run, but the shifts in the intangible–tangible ratio identified here suggest that China is catching up with frontier economies. Given the gradually increasing intangible capital in China, there is every reason to believe that rapid growth in intangible capital will become an increasingly important driver of China's economic growth.

References

Arato, H. and Yamada, K. (2012), Japan's intangible capital and valuation of corporations in a neoclassical framework, *Review of Economic Dynamics* 15(4): 459–78. doi.org/10.1016/j.red.2012.01.001.

Arrighetti, A., Landini, F. and Lasagni, A. (2014), Intangible assets and firm heterogeneity: Evidence from Italy, *Research Policy* 43(1): 202–13. doi.org/10.1016/j.respol.2013.07.015.

Asker, J., Farre-Mensa, J. and Ljungqvist, A. (2015), Corporate investment and stock market listing: A puzzle? *Review of Financial Studies* 28(2)(February): 342–90. doi.org/10.1093/rfs/hhu077.

Atkeson, A. and Kehoe, P. J. (2005), Modeling and measuring organization capital, *Journal of Political Economy* 113(5): 1026–53. doi.org/10.1086/431289.

Awano, G., Franklin, M., Haskel, J. and Kastrinaki, Z. (2010), Measuring investment in intangible assets in the UK: Results from a new survey, *Economic & Labour Market Review* 4(7): 66–71. doi.org/10.1057/elmr.2010.98.

Borgo, M. D., Goodridge, P., Haskel, J. and Pesole, A. (2013), Productivity and growth in UK industries: An intangible investment approach, *Oxford Bulletin of Economics and Statistics* 75(6): 806–34. doi.org/10.1111/j.1468-0084.2012.00718.x.

Chun, H. and Nadiri, M. I. (2016), Intangible investment and changing sources of growth in Korea, *Japanese Economic Review* 67(1): 50–76. doi.org/10.1111/jere.12079.

Chun, H., Fukao, K., Hisa, S. and Miyagawa, T. (2012), *Measurement of intangible investments by industry and its role in productivity improvement utilizing comparative studies between Japan and Korea*, RIETI Discussion Paper Series 12-E-037, The Research Institute of Economy, Trade and Industry, Tokyo.

Clausen, S. and Hirth, S. (2016), Measuring the value of intangibles, *Journal of Corporate Finance* 40: 110–27. doi.org/10.1016/j.jcorpfin.2016.07.012.

Comin, D. (2004), Harrod–Domar model, in J. Segura and C. R. Braun (eds), *An Eponymous Dictionary of Economics: A guide to laws and theorems named after economists*, p. 105, Cheltenham, UK: Edward Elgar.

Corrado, C. A. and Hulten, C. R. (2010), How do you measure a 'technological revolution'? *The American Economic Review* 100(2): 99–104. doi.org/10.1257/aer.100.2.99.

Corrado, C., Haskel, J., Jona-Lasinio, C. and Iommi, M. (2013), Innovation and intangible investment in Europe, Japan, and the United States, *Oxford Review of Economic Policy* 29(2): 261–86.

Corrado, C., Hulten, C. and Sichel, D. (2009), Intangible capital and US economic growth, *Review of Income and Wealth* 55(3): 661–685. doi.org/10.1111/j.1475-4991.2009.00343.x.

Eisfeldt, A. L. and Papanikolaou, D. (2013), Organization capital and the cross-section of expected returns, *The Journal of Finance* 68(4): 1365–406. doi.org/10.1111/jofi.12034.

Eisfeldt, A. L. and Papanikolaou, D. (2014), The value and ownership of intangible capital, *The American Economic Review* 104(5): 189–94. doi.org/10.1257/aer.104.5.189.

Feenstra, R. C., Inklaar, R. and Timmer, M. P. (2015), The next generation of the Penn World Table, *The American Economic Review* 105(10): 3150–82. doi.org/10.1257/aer.20130954.

Fukao, K., Miyagawa, T., Mukai, K., Shinoda, Y. and Tonogi, K. (2009), Intangible investment in Japan: Measurement and contribution to economic growth, *Review of Income and Wealth* 55(3): 717–36. doi.org/10.1111/j.1475-4991.2009.00345.x.

Goodridge, P., Jonathan H., and Gavin W. (2013), Can intangible investment explain the UK productivity puzzle?, *National Institute Economic Review* 224(1): R48–R58. doi.org/10.1177/002795011322400104.

Gourio, F. and Rudanko, L. (2014a), Can intangible capital explain cyclical movements in the labor wedge? *The American Economic Review* 104(5): 183–8. doi.org/10.1257/aer.104.5.183.

Gourio, F. and Rudanko, L. (2014b), Customer capital, *The Review of Economic Studies* 81(3): 1102–36. doi.org/10.1093/restud/rdu007.

Gwartney, J. D., Holcombe, R. G. and Lawson, R. A. (2004), Economic freedom, institutional quality, and cross-country differences in income and growth, *Cato Journal* 24: 205.

Harris, R. and Robinson, C. (2002), The effect of foreign acquisitions on total factor productivity: Plant-level evidence from UK manufacturing, 1987–1992, *Review of Economics and Statistics* 84(3): 562–8. doi.org/10.1162/003465302320259556.

Haskel, J. and Wallis, G. (2013), Public support for innovation, intangible investment and productivity growth in the UK market sector, *Economics Letters* 119(2): 195–8. doi.org/10.1016/j.econlet.2013.02.011.

Haskel, J., Corrado, C. and Jona-Lasinio, C. (2014), *Knowledge spillovers, ICT and productivity growth*, Working Paper, Imperial College Business School, Imperial College, London.

Hayashi, F. and Prescott, E. C. (2002), The 1990s in Japan: A lost decade, *Review of Economic Dynamics* 5(1): 206–35. doi.org/10.1006/redy.2001.0149.

Hulten, C. R. (1979), On the 'Importance' of Productivity Change, *The American Economic Review* 69 (1): 126–36.

Hulten, C. R. and Hao, J. X. (2012), *The role of intangible capital in the transformation and growth of the Chinese economy*, NBER Working Paper No. 18405, National Bureau of Economic Research, Cambridge, Mass.

Hulten, C. R. and Hao, X. (2008), *What is a company really worth? Intangible capital and the 'market to book value' puzzle*, NBER Working Paper No. 14548, National Bureau of Economic Research, Cambridge, Mass.

Kraemer, K., Linden, G. and Dedrick, J. (2011), *Capturing value in global networks: Apple's iPad and iPhone*, Working Paper, Personal Computing Industry Center, University of California, Irvine. Available from: pcic.merage.uci.edu/papers/2011/value_ipad_iphone.pdf.

Levinsohn, J. and Petrin, A. (2003), Estimating production functions using inputs to control for unobservables, *The Review of Economic Studies* 70(2): 317–41. doi.org/10.1111/1467-937X.00246.

Marrano, M. G., Haskel, J., and Wallis, G. (2009), What happened to the knowledge economy? ICT, intangible investment, and Britain's productivity record revisited, *Review of Income and Wealth* 55(3): 686–716. doi.org/10.1111/j.1475-4991.2009.00344.x.

McGrattan, E. R. and Prescott, E. C. (2010), Unmeasured investment and the puzzling US boom in the 1990s, *American Economic Journal: Macroeconomics* 2(4): 88–123. doi.org/10.1257/mac.2.4.88.

McGrattan, E. R. and Prescott, E. C. (2014), A reassessment of real business cycle theory, *The American Economic Review* 104(5): 177–82. doi.org/10.1257/aer.104.5.177.

Miyagawa, T. and Hisa, S. (2013), Estimates of intangible investment by industry and productivity growth in Japan, *Japanese Economic Review* 64(1): 42–72. doi.org/10.1111/jere.12000.

Nadiri, M. I. (1970), Some approaches to the theory and measurement of total factor productivity: A survey, *Journal of Economic Literature* 8(4): 1137–77.

National Bureau of Statistics of China (NBS) (various years), *China Labour Statistical Yearbook*, Beijing: China Statistics Press.

Niebel, T., O'Mahony, M. and Saam, M. (2017), The contribution of intangible assets to sectoral productivity growth in the EU, *Review of Income and Wealth* 63(1). doi.org/10.1111/roiw.12248.

Olley, G. S. and Pakes, A. (1996), The dynamics of productivity in the telecommunications equipment industry, *Econometrica: Journal of the Econometric Society* 64(6): 1263–97. doi.org/10.2307/2171831.

Tronconi, C. and Marzetti, G. V. (2011), Organization capital and firm performance: Empirical evidence for European firms, *Economics Letters* 112(2): 141–3. doi.org/10.1016/j.econlet.2011.04.004.

van Ark, B., Hao, J. X., Corrado, C., and Hulten, C. (2009), Measuring intangible capital and its contribution to economic growth in Europe, *EIB papers* 14(1): 62–93. hdl.handle.net/10419/44905.

Weede, E. and Kämpf, S. (2002), The impact of intelligence and institutional improvements on economic growth, *Kyklos* 55(3): 361–80. doi.org/10.1111/1467-6435.00191.

Zhu, X. (2012), Understanding China's growth: Past, present, and future, *The Journal of Economic Perspectives* 26(4): 103–24. doi.org/10.1257/jep.26.4.103.

Appendix 7.1. Industry classification

	Name	Subgroup
1	Farming	Agriculture
2	Forestry	Agriculture
3	Livestock products	Agriculture
4	Fisheries	Agriculture
5	Agricultural services	Agriculture
6	Coalmining and processing	Heavy industry
7	Petroleum and natural gas extraction	Heavy industry
8	Ferrous metals mining and processing	Heavy industry
9	Non-ferrous metals mining and processing	Heavy industry
10	Non-metal minerals mining and processing	Heavy industry
11	Processing of petroleum and nuclear fuel	Heavy industry
12	Processing of coking coal	Heavy industry
13	Manufacture of chemical raw materials	Heavy industry
14	Manufacture of fertiliser	Heavy industry
15	Manufacture of pesticide	Heavy industry
16	Manufacture of organic chemical products	Heavy industry
17	Manufacture of rubber	Heavy industry
18	Manufacture of plastics	Heavy industry
19	Manufacture of cement and asbestos products	Heavy industry
20	Manufacture of non-metallic mineral products	Heavy industry
21	Iron and steel products	Heavy industry
22	Smelting of steel	Heavy industry

	Name	Subgroup
23	Smelting of iron alloys	Heavy industry
24	Smelting of nonferrous metals	Heavy industry
25	Processing of nonferrous metals	Heavy industry
26	Manufacture of boilers, engines and turbines	Heavy industry
27	Manufacturer of metal-working machines	Heavy industry
28	Manufacture of other general industrial machinery	Heavy industry
29	Manufacture of agricultural, forestry, animal husbandry and fishing machinery	Heavy industry
30	Manufacture of other special industrial equipment	Heavy industry
31	Manufacture of railway equipment	Heavy industry
32	Manufacture of automobiles	Heavy industry
33	Manufacture of ship equipment	Heavy industry
34	Manufacture of other transportation equipment	Heavy industry
35	Manufacture of generators	Heavy industry
36	Recycling and disposal of waste	Heavy industry
37	Production and distribution of electric power	Heavy industry
38	Production and distribution of gas	Heavy industry
39	Processing and distribution of tap water	Heavy industry
40	Construction	Heavy industry
41	Processing of crops, cooking oil and stock feed	Light industry
42	Manufacture of sugar	Light industry
43	Processing of meat	Light industry
44	Processing of aquatic products	Light industry
45	Processing of other food	Light industry
46	Manufacture of alcohol	Light industry
47	Manufacture of beverages and tea	Light industry
48	Manufacture of tobacco	Light industry
49	Manufacture of textiles from cotton	Light industry
50	Manufacture of textiles from wool	Light industry
51	Manufacture of textiles from fibre and silk	Light industry
52	Manufacture of knitted products	Light industry
53	Manufacture of textile products	Light industry
54	Manufacture of textile, apparel, footwear and caps	Light industry
55	Manufacture of leather, fur, feather and related products	Light industry
56	Processing of timber, manufacture of wood, bamboo, rattan, palm and straw products	Light industry
57	Manufacture of paper and paper products	Light industry
58	Printing and recorded media	Light industry
59	Manufacture of equipment for culture, education and sports activity	Light industry
60	Manufacture of chemical products for daily use	Light industry
61	Manufacture of other chemical products	Light industry

	Name	Subgroup
62	Manufacture of medicines	Light industry
63	Manufacture of chemical fibres	Light industry
64	Manufacture of glass and glass products	Light industry
65	Manufacture of pottery, china and earthenware	Light industry
66	Manufacture of fireproof products	Light industry
67	Manufacture of metal products	Light industry
68	Manufacture of household electrical appliances	Light industry
69	Manufacture of other electrical machinery and equipment	Light industry
70	Manufacture of computers	Light industry
71	Manufacture of communication and other electronic equipment	Light industry
72	Manufacture of other household electronic appliances	Light industry
73	Manufacture of electronic elements and devices	Light industry
74	Manufacture of measuring instruments	Light industry
75	Manufacture of articles for culture, education and sports activity	Light industry
76	Manufacture of artwork and other manufacturing	Light industry
77	Railway transport	Service
78	Road transport	Service
79	Pipeline transport	Service
80	Air transport	Service
81	Water transport	Service
82	Storage	Service
83	Postal services	Service
84	Telecommunications	Service
85	Catering	Service
86	Finance	Service
87	Insurance	Service
88	Real estate	Service
89	Accommodation	Service
90	Residential and other services	Service
91	Entertainment	Service
92	Polytechnic services	Service
93	Health care	Service
94	Education	Service
95	Sports	Service
96	Social welfare	Service
97	Culture, arts, radio and television	Service
98	Research and experimental development	Service
99	Geological prospecting	Service
100	Public administration and social organisation	Service

Source: Authors' construction.

Appendix 7.2. Sensitivity analysis

The depreciation rate of intangible capital is often not well grounded, in both this study and previous studies. To check the robustness of the results, a sensitivity analysis is conducted. The changes in parameters in this study are comprehensive and occur in two directions: either an increase or a decrease. If the changes in both directions make little difference, the contributions of intangible capital to economic growth are believed to be robust.

Table 7.A1 Changes of parameters in sensitivity analysis (per cent)

	Base case	Case									
		1	2	3	4	5	6	7	8	9	10
Proxy ratio	100	50	150								
δ(Intangible)	40			60	20						
δ(RD)	20					10	40				
δ(EC)	50							25	75		
δ(CI)	33									11	66

Notes: Proxy ratio refers to the ratio of the actual intangible investment to the proxy; δ is the depreciation rate; RD is R&D capital; EC is economic competency capital; and CI is computerised information capital (mainly software).

Source: Authors' construction.

All the sensitivity analysis results are available from the authors. The changes in parameters do not change the significance and signs of the intangibles and the changes in regression coefficient are small. Therefore, the impacts of intangible capital on productivity are considerably robust.

This text is taken from *China's New Sources of Economic Growth: Human Capital, Innovation and Technological Change, Volume 2*, edited by Ligang Song, Ross Garnaut, Cai Fang and Lauren Johnston, published 2017 by ANU Press, The Australian National University, Canberra, Australia.

dx.doi.org/10.22459/CNSEG.07.2017.07