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China's Investment in Intangible Assets by Industry: A Preliminary Estimation in an Extended Sources-of-Growth Framework*

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Abstract

This paper documents our major procedures in estimating China's intangible investment by industry for the period 1995-2013. The estimation is controlled by China's aggregate intangible investment estimated in Hulten and Hao (2012, revised and updated) and integrated with the industry-level estimates for tangible investment and value added of the national accounts constructed by the China Industry Productivity Data Project or CIP (Wu 2016). We show that China's intangible investment intensity, measured as the share of intangible investment in nominal value added, grew by 5.3 percent per annum. By 2013 China had reached 8.1 percent in this intensity, compared to 16.7 in the US and 13.9 in the UK. China caught up with the industrialized economies more quickly in the industrial sector than in the service sector. In the industrial sector, China achieved 12.2 percent in intangible intensity, about 90 percent of that of the U.K. (13.4) and 70 percent of that of the U.S. (19.4). In the service sector, China achieved 6.1 percent, about half of that of the U.K. (12.3) and 45 percent of that of the U.S. (14.1). We also show that among major types of intangible investment in the industrial sector, unlike advanced economies, China tended to focus more on computerized information such as software and R&D that are promoted together with government-engineered industrial and infrastructural projects, rather than economic competencies such as branding that rely more on firms competing in the marketplace.

Keywords: Intangible investment in gross capital formation; computerized information; innovative properties; economic competences; expanded sources of growth model

JEL Classification: C82, E22, L60, O4

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1. Introduction

China's substantial growth slowdown from the 14.2-percent peak in 2007 prior to the global financial crisis to the current 6.2 percent in 2019, suggested by the official account that has been criticized for upward biases, and more strikingly China's loss in total factor productivity (TFP) by about 1 percent per annum over the decade in the wake of the global financial crisis (Wu 2019), clearly show that China's challenge in shifting from a physical capital-driven to a productivity-led growth model is overwhelming. In two consecutive "Five-Year Plans", implemented in 2011 and 2016 respectively, especially in various strategies attached to these plans that aim at technologically advancing Chinese manufacturing industries, the government considered information and communication technologies and artificial intelligence the key to its goal.

In their 2017 article, Wu and Liang make the first ever attempt to account for the role of ICTs in the Chinese economy. In a state-of-the-art growth accounting framework *a la* Jorgenson (2001) that takes account the industry origin of growth and productivity performance, they find that over the period 1981-2012 Chinese ICT-producing industries and ICT-using industries in manufacturing were the major driver of China's productivity growth. While sharing only less than one third of China's over 9-percent annual growth, these industries contributed nearly 150 percent of China's 0.9-percent annual aggregate TFP growth. In fact, their superior productivity performance enabled the economy to compensate for efficiency losses caused by capital misallocation across industries and unproductive operations of industries that were prone to government interventions.

Wu and Liang (2017) also find that the productivity growth of ICT-using services was negative for most of the period in question. This appears to be contradictory to the performance of the ICT-using industries in manufacturing and hence raises a question about whether some important factor is missing in the analysis. This is nonetheless not atypical. When examining the slow productivity growth in the EU countries, van Ark (2004) advanced a hypothesis that the productivity gap between the EU and the US could have been attributable to the gap in the stock of intangible assets that was likely complementary to the ICT capital services (Jorgenson 2001). Motivated by Van Ark's problem, Fukao *et al*. (2009) further conjectured that it was the intangible assets-sensitive services that caused Japanese productivity gap with the US and provided convincing evidence with their estimates.

As explained in Corrado, Hulten and Sichel (2005, CHS henceforth), intangible assets are more "knowledge-intensive" and necessarily complementary to ICT and ICT-enhanced hardware investment, including software, design, market research, R&D, training and business processes in various aspects. They are "intangible" because they are in essence human-embodied and cannot be physically touched or seen albeit they are deemed critical to reap the productivity advantages of ICTs and thus the key assets of today's "knowledge-intensive economy". The CHS estimation suggests that in the US economy the investment in intangible assets since the 1990s might have been as large as or already surpassed the business spending on tangible capital (CHS, 2005; Corrado and Hulten, 2010). We are then convinced that China's performance in intangible investment may help explore not only the causes of China's slow productivity growth despite reforms, but also China's potential in innovation, particularly the efficiency of largely government-engineered technological advancement.

In this study, we follow the theory developed in CHS (2005) to measure China's investment in intangibles coherently in an expanded sources-of-growth framework that essentially adopts Hulten (1979)'s intertemporal choice model on growth accounting. Unlike CHS (2005), we propose a work that turns the aggregate estimation of intangible investment to the industry level. This is necessary because studies on the U.K., Germany, Japan, and Korea all show significant differences across industries (see Borgo *et al*. 2011; Hyunbae *et al*. 2012; Miyagawa *et al*. 2013; Crass *et al*. 2014) and hence suggests that treating industries homogeneously in intangible investment is inappropriate.

This study is benefitted from both the first-ever endeavor made by Hulten and Hao (2012), providing a measurement of China's aggregate intangible investment as a proper "control total" for our estimation of intangible assets for individual industries, and the first KLEMS-type China Industrial Productivity Database or CIP 3.0, developed by Wu and his associates (see Wu, 2019, and a brief introduction in the data section of the present work), providing industry-level investment in tangible assets in equipment and structures for economy-wide 37 industries that can facilitate our estimation by gauging the industry-specific relationship between tangible and intangible investments.

Our preliminary estimates show that China's intangible investment intensity, measured as a share of intangible investment in nominal value added, has caught up quickly with the leading industrialized economies in the West since the adoption of the "socialist market economy" in the mid-1990s, especially since the GFC. Based on such an intensity measure, China grew at

5.3 percent per annum over the period 1995-2013 under our investigation. By 2013, China had reached to 8.1 percent in intangible investment intensity for the total economy, compared to 13.9 in the U.K., 16.7 in the U.S., and 17.7 (2008) in Japan. However, China's performance between the industrial and the service sector presents a sharp contrast. In the industrial sector, China achieved 12.2 percent in this share, about 90 percent of that of the U.K. (13.4) and 70 percent of that of the U.S. (19.4). In the service sector, China achieved 6.1 percent, about half of that of the U.K. (12.3) and 40 percent of that of the U.S. (14.1). Besides, scrutinizing the intangible investment in categories for the industrial sector, we find that unlike advanced economies China was inclined to focus on policy-driven intangible assets, such as computerized information, rather than other assets such as brand equity that is likely more market competition induced. This is an interesting topic that may inspire further theoretical thinking of the role of different types of intangibles in different institutional settings.

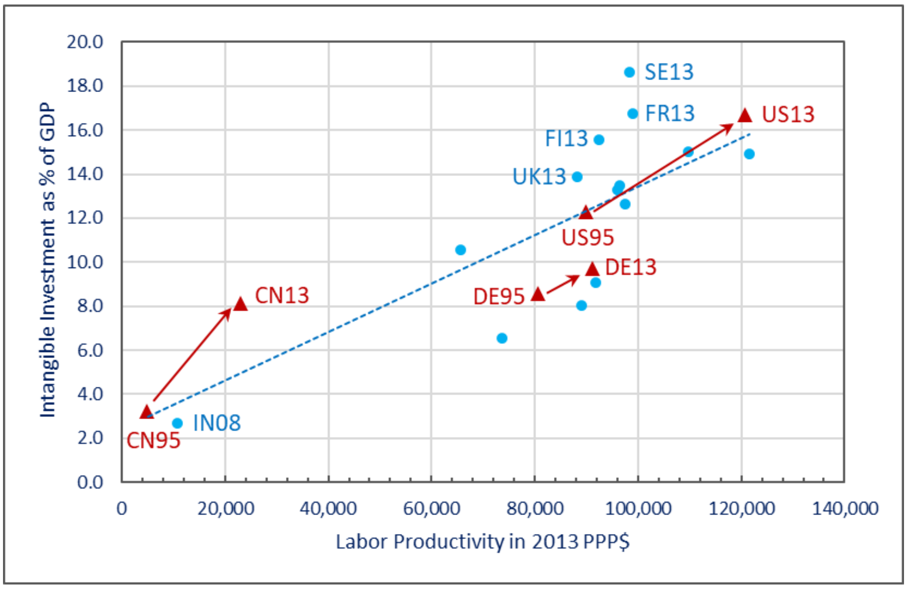
The rest of the paper is organized into seven sections. The next section overviews the national level of intangible investment of the countries available in the literature in comparison with China. Section 3 introduces the concept of intangible investment in the Hulten-CHS extended sources-of-growth framework to conceptually guide our estimation. Section 4 provides our data construction methodology and summarizes major data problems. Section 5 presents our estimation procedures for each type of intangible assets. Section 6 explores implications of our preliminary results. Section 7 concludes the study with major unsolved problems for future research.

2. Intangible Investment in China from an International Perspective

The first systematic measure of China's aggregate investment in intangible assets was pioneered by Hulten and Hao in their 2012 paper, motivated by the rising awareness of the importance of intangible assets in production in the expanding literature following the initial work by CHS in 2005 and China's acceleration in patents, engineers, research and development spending, and exports of ICT products after decades of its unprecedented rapid income growth. They conjectured that intangible capital formation may play an important role in China's reform-driven transformation to a more market-oriented economy because "the privatization of many state-owned enterprises requires an investment in new organizational capabilities and business models, as does progress along the global value chain to a more knowledge-intensive economy" (Hulten and Hao, 2012).

Hulten and Hao (2012) initially covered the period 1990-2006. Using newly available information, we update their series to 2013 with necessary revisions for a comparison with other economies that are available in Carol, Haskel, Jona-Lasinio and Iommi (2012), The Conference Board Total Economy Database (2017), unpublished updates of Hulten and Hao (2012) and Hulten, Hao and Jaeger (2012). It should be noted that judged by new information, we find that the Hulten-Hao estimates for China in the early 1990s are not compatible to those from the mid-1990s onwards and therefore decide to focus on the period 1995-2013 in the present work.

FIGURE 1
INTANGIBLE INVESTMENT VIS-À-VIS LABOR PRODUCTIVITY
(Data for 2013 unless otherwise indicated)



Sources: Updates to 2013 based on Corrado Carol, Jonathan Haskel, Cecilia Jona-Lasinio and Massimiliano Iommi (2012), The Conference Board Total Economy Database (2017), Hulten & Hao (2012, unpublished updates), and Hulten, Hao & Jaeger (2012).

Note: Countries not labeled are Portugal, Greece, Spain, Italy, Denmark, Netherlands, Austria, Belgium, and Ireland in ascending order of labor productivity.

To better understand China's post-reform catch up in intangible investment from an international perspective, based on these available studies and their updates, we make an international comparison in terms of the share of intangible investment in nominal GDP with respect to output per worker or labor productivity, measured in purchasing power parity or PPP terms (technically in EKS-PPP-converted 2017 US dollar, The Conference Board Total Economy Database, 2017). In Figure 1 we depict a simple or linear time path for China, Germany and the US for the period 1995-2013 and compare them with other countries in 2013, except for India shown for 2008 (IN08).

Figure 1 shows that despite a latecomer China appears to be quickly catching up with advanced economies in intangible investment. When China's labor productivity rose from about PPP$5,000 in 1995 to above PPP$20,000 in 2013 (at 2017 USD price), China was able to increase its investment on intangibles from 3.2 percent to 8.1 percent of its nominal value added, enjoying a 5.3-percent annual growth that was well above the universal trend as suggested by other economies in the chart. For example, the US and Germany raised their intangible-investment-to-GDP ratio by only 1.7 and 0.7 percent per annum, respectively. More strikingly, Figure 1 also shows that when the advanced countries were able to invest 8 to 9 percent of their GDP on intangibles, they typically achieved a level of labor productivity at about PPP$90,000 or four times that of China.

Not only does this suggest that China's rapid advancement in intangible capital formation was indeed associated with China's rapid income growth, it also supports the Hulten-Hao conjecture that market-oriented reforms and opening up would induce rising needs for investment in intangibles. Nevertheless, one cannot ignore that the government's agitated search for a new, more productivity and innovation-led growth mode in the wake of the global financial crisis (GFC) may have also helped explain China's aggressive expansion in intangible investment. The GFC obstructed the so-called "China model of growth" that had been heavily relying on the rapid expansion of export-oriented manufacturing, driven by local governments who fiercely competed for faster growth (Li and Zhou, 2005) through subsidized factor costs (Huang and Tao, 2010). Facing the post-GFC rising costs in labor, land and environment, severe overcapacity and mounting debt that was accumulated to support such a growth mode, the Chinese government is now anxiously seeking for a quick and effective shift to a more innovation-led growth mode. Since the mid-2010s, we have seen that ambitious and aggressive strategies have been laid out by the Xi-Li administration including "Made in China 2025" and a series of innovation-oriented blueprints through China's 13th Five-Year Plan (2016-2020) aiming to turn China into an "innovation nation" by 2020, an "international leader in innovation" by 2030, and a "world powerhouse in scientific and technological innovation" by 2050.

However, it appears that China has caught up quickly in size rather than productivity. Based on UNIDO and CIP data, by 2016 China's manufacturing sector had overtaken that of the US by about 60 percent in PPP$ GDP, yet its output per worker was only 14 percent of the US level.[1] Taking the Chinese ICT manufacturing as an industry-level example, notwithstanding the seemingly excessive investment in assembly lines that enabled China to quickly emerge as the world's largest producer of ICT parts and equipment in a very short period, by 2016 China's labor productivity was only about 16, 10 and 6 percent of that of the U.K., Japan and the U.S., respectively.[2]

It is therefore a sensible question what is the real role that has been played by the intangible capital formation in such an excessive expansion of manufacturing capacity alongside the increasingly government-engineered technological advancement and innovation drive. Yet, such a question cannot be satisfactorily addressed without accurately measuring intangible investment at the industry level and adjusting accordingly the biases in the output accounts that excluded such investment. The present work is an important initiative for the construction of industry-specific indicator for China's intangible capital stock, hence its services in an extended growth accounting framework to improve our understanding of China's growth and productivity performance.

3. THE INTANGIBLE CAPITAL CONCEPT IN SNA

Theoretically, it is not difficult to treat any output (i.e. real value added produced in a given period of time) that is used for future income rather than current consumption as investment regardless of whether it is in the form of tangible or intangible assets. But it is not easy for national accounting practice to closely conform to such a principle. The System of National Accounts (SNA) emphasizes on how to "achieve an economically meaningful and feasible set of accounting procedures for the assets acquired through gross fixed capital formation within an integrated coherent set of accounts encompassing past and future periods as well as the present" (CEC *et al.*, 1993, para. 1.55), because most of intangibles are human-embodied and cannot be physically touched or seen, hence hardly being able to measure directly. It has therefore taken four decades for SNA to work out proper accounting principles and guidelines

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[1] Estimated based on the CIP/China KLMES database (for details see Wu and Ito, 2015; Wu, Yue and Zhang, 2015; Wu, 2015) and the UNIDO (United Nations Industrial Development Organization) manufacturing database (https://www.unido.org/researchers/statistical-databases).

[2] This could be well exemplified with the case of iPhone. Chinese assembly factories gained merely about 2 percent of the revenue whereas the US Apple Headquarters captured about 60 percent of the revenue of each mobile phone assembled in 2010 (Kraemer *et al*. 2011).

to treat intangible assets as produced output on the one hand and as capital investment on the other, rather than intermediate inputs.[3]

Following CHS (2005), intangible assets can be grouped in three broad categories, namely, computerized information or data, innovative properties and economic competencies including software, database, design, market research, R&D activities, training and business processes in various aspects. It is no longer disputable whether intangible assets are productive, rather they are now deemed increasingly critical to reap the productivity advantage of ICTs as well as the key assets of today's "knowledge-intensive economy". A conceptualization of intangible capital formation following the neoclassical capital theory (Jorgenson 1963) is however deemed necessary and fundamental so that it can expand the growth accounting framework (Solow 1957; Jorgenson and Griliches, 1967) to explicitly include intangible capital, hence guiding both data construction and measurement in growth and productivity analysis for the modern economy.

Let us conceptualize intangible investment for an economy whose long-run growth is assumed typically neoclassical, given by a stable aggregate production function that is subject to competitive equilibrium in which the costs of tangible capital, intangible capital and labor are accordingly determined by the marginal products of these factors. Apparently, the sources of growth of the economy as described by the aggregate production function should be extended to incorporate intangible capital stock. Moreover, we also need to extend the sources of demand of the economy by the same logic. Like tangible capital, intangible capital is also produced by the economy; we thus need to bring it back to the total value of the final demand of the economy via the goods and services that are devoted in intangible investment. This idea is expressed in the following "meta production function" form in the spirit of CHS (2005):

(1) $$Q_t(C_t, I_t, N_t) = A_t f(L_t, K_t, X_t)$$

where the real output Q is produced by the services of labor input L, tangible capital input K, and intangible capital input X and assumed to be finally used in three forms, i.e. consumption expenditure C, investment in tangible capital I, and intangible investment N, all indexed by

[3] For example, the 1968 SNA treats expenditures on software which is bought as an integral part of a major hardware purchase as capital formation, but software that is purchased or developed independently should be treated as intermediate consumption. This is finally revised in the 1993 SNA to treat all systems and applications of computer software as well as large databases that a producer expects to use in production for more than one year as intangible fixed assets, no matter whether they are purchased in the market, separately or together with the hardware, or developed in-house. A further improvement in the 2008 SNA includes all databases.

time *t*. In Equation (1) a Hicksian total factor productivity (TFP) term *A* is included to allow for costless changes in the efficiency with which the inputs are used. Theoretically, after considering that intangible capital goods are *produced* and hence their services are *paid* by producers, the estimated TFP growth should be slower but nonetheless less biased, *ceteris paribus*.

The expression in Equation (1) also implies a relationship between the investment and accumulation of both tangible and intangible assets, which could be assumed by the following perpetual inventory method or PIM equations:

(2) $$K_t = I_t + K_{t-1}(1-\delta) \text{ , and}$$

(3) $$X_t = N_t + X_{t-1}(1-\gamma)$$

where δ is depreciation rate of *K* and γ is depreciation rate of *X*, if both tangible and intangible capital stocks follow a geometric depreciation function (Hulten and Wykoff, 1981).

Now with the assumptions of constant returns to scale and marginal cost pricing, denoted as factor-specific *P*, the aggregate expenditure and the aggregate income of an economy must be still identical after extended with intangibles, that is:

(4) $$P_t^C C_t + P_t^I I_t + P_t^N N_t = P_t^L L_t + P_t^K K_t + P_t^X X_t$$

Equation (4) is an extended form of the well-known national accounts identity between Gross Domestic Expenditure (GDE) and Gross Domestic Income (GDI) on which national accounting practice is based. As pointed out in CHS (2005), because these accounts have traditionally omitted most intangibles from both sides of the accounting identity, their inclusion has the effect of increasing GDP as conventionally measured. Moreover, when both sides of this identity are divided by the nominal value of the (expanded) GDP, or $P_t Q_t$, the identity can be expressed as:

(4')

$$\frac{P_t^C C_t}{P_t Q_t} + \frac{P_t^I I_t}{P_t Q_t} + \frac{P_t^N N_t}{P_t Q_t} = \frac{P_t^L L_t}{P_t Q_t} + \frac{P_t^K K_t}{P_t Q_t} + \frac{P_t^X X_t}{P_t Q_t}$$

The prices on the left-hand side of (4') are product prices, but as noted in CHS only the first two prices, P_t^C and P_t^I, are determined by market transactions because the bulk of intangible investment is produced within the firm. Thus, P_t^N must be interpreted as a shadow price hence being imputed. Yet "finding an appropriate imputation procedure is one of the most unsettled issues in the emerging literature on macro intangibles" (CHS, 2005). The prices on the right-hand side of (4') are input prices, with P_t^L denoting the wage and P_t^K and P_t^X representing the Jorgensonian user costs of capital, imputed as per Jorgenson (1963) and Jorgenson and Griliches (1967). Equation (4') can also be expressed in terms of the cost shares of each side that are summed to unity:

(4")
$$S_t^C + S_t^I + S_t^N = S_t^L + S_t^K + S_t^X$$

where *S* denotes the share of each type of product in the nominal GDE on the left-hand side and the share of each type of factor in the nominal GDI on the right-hand side of (4"). Under the neoclassical competitive market assumptions, the model implies that the input prices are equal to the corresponding value of marginal product and the income shares are therefore equal to the corresponding output elasticities.

In this study, we aim mainly to estimate China's intangible investment *N* by industry and adjust the industry-level nominal factor income *X* accordingly in a coherently integrated national accounts for the Chinese economy reconstructed by China Industrial Productivity (CIP) Data Project (Wu, 2016 and 2019).

4. Methodology and Data

This study is inevitably heavily data driven. The literature has shown that despite its rising importance for the modern economy, data on investment in intangible assets are often not readily available even in advanced economies. It is therefore more challenging for anyone who would like to construct internationally compatible data for China. We devote our endeavor to searching and organizing the information that are required for the construction of industry-specific measures of major types of intangible assets for China. In this section, we briefly introduce the CHS (2005) methodology for intangible investment data construction and explain how the available estimates of the aggregate measure of intangible assets by type by Hulten and Hao (2012) and CIP industry productivity accounts data are used in this work.

Measuring intangible investment by industry

In this study we estimate nine types of intangible investment under the three categories following CHS (2005) and 37 industries of the Chinese economy, classified in the CIP data system, as summarized in Table 1. Following Equation (4), our data construction methodology can be expressed by Equation (5):

(5)

$$P_t Q_t - P_t^C C_t - P_t^I I_t = P_t^N N_t = \sum_{j=1}^{37} \sum_{k=1}^{9} P_{jk,t}^{N_{jk,t}} N_{jk,t}$$

$j = 1, 2, \ldots 37;\ k = 1, 2, \ldots 9$

where the far-left part of (5) shows that aggregate intangible investment can be first treated as a "residual" of the extended national accounts, i.e., $P_t^N N_t$ after deducting expenditures on aggregate consumption $P_t^C C_t$ and tangible investment $P_t^I I_t$. The value of $P_t^N N_t$ then serves as the "control total" over the far-right part of (5) that is decomposable into the nine types of intangibles across our economy-wide 37 industries. This methodology also highlights how the estimation of intangible investment by type and by industry is conceptually governed by a SNA framework.

In practice, $P_t^N N_t$ does not exist either in any aggregative form or in any level of breakdown of intangible asset type by industry. We consider the pioneer work by Hulten and Hao (2012) a conceptually sound one, hence a proper aggregate measure of each type of intangible investment for the Chinese economy. For industry breakdown of each intangible asset, we need two sources of data, with one providing basic production indicators for individual industries required for gauging the intangibles, such as output, tangible investment and labor employment and compensation, and one providing information on intangible assets that may be related to such production data at industry level. We rely on the CIP data for the production data of individual industries and construct each type of intangible investment data by industry through other official sources, many of which are used in Hulten and Hao (2012) as listed in Table 1.

TABLE 1
THE CHS CATEGORIZATION OF TYPES OF INTANGIBLE INVESTMENT AND CHINESE DATA STATUS

Type of CHS (2005) Intangible Investment	Official and Other Data Sources*
A. Computerized Information	
1) Software	National level: *Statistical Report of National Software Industry* (MIIT 2016); *China Input-Output Table 2007* (DNEA, NBS, 2009). Industry distribution: CIP 37 industry productivity accounts with updates (CIP Database 3.0 hereafter; see Wu and Ito, 2015; Wu, Yue and Zhang, 2015; Wu, 2015 and 2016).
B. Innovative Property	
2) R&D including social sciences and humanities	National level: *China Statistical Yearbook on Science and Technology* (various issues, NBS); *National Comprehensive Statistics on the 2009 R&D Census* (NBS, 2011) Industry distribution: CIP Database 3.0 (CIP, 2015 with updates).
3) Mineral exploration and evaluation	National level: *Communique on Land and Resources of China* (various issues, MNR). Industry distribution: *China Mining Yearbooks* (various issues, Editorial Committee of CMY); CIP Database 3.0 (CIP, 2015 with updates).
4) Copyright and license costs	National level: *National Overview of News and Publishing Industry* (various issues, SAPPRFT); *China Statistical Yearbook on Science and Technology* (various issues, NBS). Industry distribution: CIP Database 3.0 (CIP, 2015 with updates).
5) Development costs in financial industry	National level: *China Statistical Yearbook* (various issues, NBS); *China Input-Output Table* (various issues, NBS). Industry distribution: CIP Database 3.0 (CIP, 2015 with updates).
6) New architectural and engineering designs	National level: *National Yearbook of Engineering Survey and Design Companies* (various issues, MHURD). Industry distribution: CIP Database 3.0 (CIP, 2015 with updates).
C. Economic Competencies	
7) Brand equity (advertisement only)	National level: *China Advertising Yearbook* (various issues, CAA). Industry distribution: *National Economic Census 2008* (NBS, 2009); CIP Database 3.0 (CIP, 2015 with updates).
8) Training	National and industry levels: *General Principles of Corporate Finance* (MOF Order No. 41, 2006); *Continuing Vocational Training Survey* (Eurostat, 2010); Wu, Yue and Zhang (2015); *China Labor Statistical Yearbook* (various issues, NBS); *National Economic Census 2004* unpublished data.
9) Organizational structure (own account only)	National level: *IPUMS International Database* (IPUMS); *Wage Guide for Beijing Labor Market & Status of Labor Costs for Companies 2009* (BMHRSSB, 2009). Industry distribution: *China Labor Statistical Yearbook* (various issues, NBS); CIP Database 3.0 (CIP, 2015 with updates).

Note: *Data sources listed under "National level" are used in the unpublished revision of Hulten & Hao (2012) with updates.

Data sources of value added, employment, and tangible investment

In this sub-section, we brief the key variables used that are deemed crucial to ensure the measurement of intangible investment using mostly scattered and anecdotal information to be coherently connected within the established systems of national output, labor and capital accounts. The key variables, as already elaborated in the conceptualization section of the paper, are value added, employment by type as educated and skilled labor types are more important in development of knowledge assets, and investment in tangible capital to which some intangible assets are economically attached and connected.

China has a serious problem of data availability and quality. Some key data that are widely available for advanced economies are not available at the industry level in China. It might be surprising to some readers that Chinese official statistical agency or National Bureau of Statistics (NBS) does not provide economy-wide value added and employment data at high-enough-level of industry details for the present research,[4] and for example the most detailed breakdown of value added is by 9 sectors with no internal breakdowns for the industrial sector.[5]

We take advantage of the first China KLEMS-type growth accounts at the industry level developed under the CIP project by Wu and his associates (Wu 2015 and 2016; Wu and Ito, 2015; Wu, Yue and Zhang, 2015). This allows our present work to be conducted in a coherent framework as given in (5) despite various data deficiencies.

Industrial classification

We measure intangible investment for 37 industries following the industrial classification adopted in the CIP database that is made in line with the ISIC rev.4 in principle. The CIP 37-industry classification is first a compromise solution between the broad sectors of national accounts with 6 to 9 sectors historically in annual series and detailed 3 to 4-digit level classification of population and economic censuses and input-output matrices that are available every five to ten years, and then anchored by approximate 2-digit industry statistics for enterprises that are above the NBS sales, location and ownership thresholds, changed over time.

[4] NBS does provide some data for urban units by industries, but we are interested the total value added by industry (urban and rural), not just urban value added.

[5] We combine financial and real estate sectors and get 8 sectors in our research, to make our list of sectors at a more comparable level of aggregation. The financial industries and the real estate industry are detailed industries because they belong to, for example, the sector of "Finance, insurance, real estate, rental and leasing" in the U.S. statistics. In contrast, the industrial sector is an aggregate of mining, manufacturing, and utilities industries.

Wu and Ito (2015) explain in detail how to reconcile the CIP classification with that of broad-sector national accounts and the CSIC/2011 (Chinese Standard of Industrial Classification 2011) used in censuses and input-output matrices, as well as how to compare it with that of EU-KLEMS.

Although we work on the details of the 37 industries, we group the results into eight broad sectors for easy examination, presentation and comparison with other studies. We use the estimated intangible investment by Hulten and Hao (2012), revised and updated for 1995 to 2013, as the "control total". We breakdown and distribute the Hulten-Hao aggregate into individual industries after necessary information is collected, organized and processed. Finally, the estimates of 37 industries are regrouped into eight sectors, namely agriculture, industrial, construction, wholesale & retail, hotels & catering, transport, storage & post, financial service (or finance) & real estate, and other services.[6]

Years covered and periodization

Given the limitation of data and the preliminary stage of this type of research for the Chinese economy, we confine our time horizon to the period 1995-2013, a period that began with China's most detailed 1995 census on the industrial sector and ended one year after China's latest full input-output accounts for 2012, which is also best covered by the CIP database.[7] We chose not to cover years before 1995, because the data on many types of intangible investment is hard to find.[8]

In order to better understand the growth of intangible investment over time we seek for more macroeconomic meaningful periodization by dividing the entire period into three subperiods, that is, 1995-2000, 2001-2007, and 2008-2013, which can be characterized correspondingly by China's deepening reforms in state and urban economies following the official adoption of the "socialist market economy" in 1993, China's WTO entry in 2001 that

[6] The sector of other services includes (1) ICT services, (2) leasing, technical, science & business services, (3) public administration & defense, (4) education services, (5) health & social security services, and the rest of services non-identified in this classification.

[7] CIP 3.0 (2015) covers the period 1980-2010 and is now being updated to 2012 (see the forthcoming CIP 4.0, 2021). Justified by the quality of the available official statistics, the data series that is end-controlled by 1992 and 2012 full input-output matrices that are arguably more reliable than the earlier IO accounts.

[8] Moreover, because the intangible investment is relatively new compared to tangible investment, and grew fast in the past two decades, the level of intangible investment before 1995 is much smaller than that in 2013. In the case of China, as we show in this study, the intangible investment, measured as a ratio to nominal GDP, was 3.3 in 1995, compared to 8.7 in 2013.

began a period of unprecedented expansion of exports and foreign direct investment, and the substantial growth and productivity slowdown following the GFC in 2008.

5. Measuring Intangible Investment in China

This section will go through our procedures of measuring each type of the intangible investment under the three broad categories. Despite limited data, we still attempt to measure the investment in each type of the intangible assets as introduced in Table 1, except the database that is included in the first category Computerized Information. We focus on software but drop database because of data restriction. Yet, based on CHS (2005), we expect the omission of database to have a trivial impact on our understanding of China's performance in the field of computerized information. CHS (2005) show that of the annual average investment of $155 billion in computerized information in the U.S. between 1998 and 2000, only less than 2 percent or $3 billion is attributable to databases.

Software

The software industry in China includes software products, information technology services, and embedded system software. However, only purchased embedded system software is treated as *capital investment* tin the national accounts, leaving the rest over 80 percent software investment uncounted. Purchased software and own-account software are all considered *intermediate inputs*, hence not included in investment (Xu, 2008).

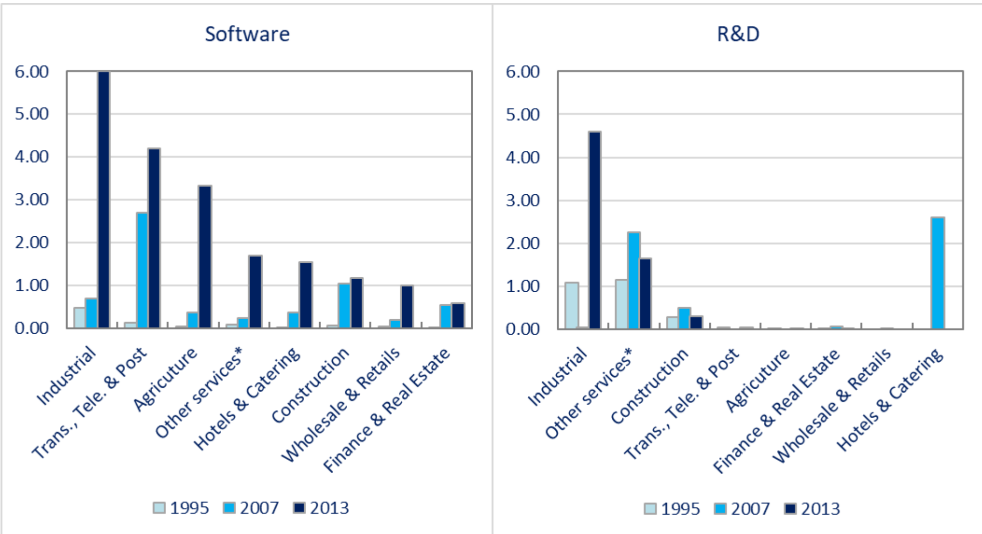
We use the estimates of national total software investment from the recent unpublished updates and revisions of Hulten and Hao (2012) and distribute it among 37 CIP industries. The revised Hulten-Hao estimates are based on the software investment from the revenue of the software industry excluding export revenue and no longer related to the consumption of households and government.[9] Since there is little information available on software investment at industry level, we use industry-specific equipment investment as weights available in the CIP database to distribute the national total software investment into 37 industries in Wu (2016). A drawback of such weights is that equipment investment is only related to embedded system software but not necessarily to the distribution of other software products or information

[9] The method of estimation is revised from Hulten and Hao (2012). Hulten and Hao (2012) do not exclude the software revenues arising from household and government consumption. The unpublished revised updates assume that 30 percent of software revenues are related to household and government consumption based on 2007 China Input-Output Table.

technology services by industry.[10] As a result, for example, we cannot gauge the impact of e-commerce on 37 industries. In the absence of better weights, we only use these weights as a placeholder for the time being and suggest not to over interpret the preliminary estimates.

As summarized in Table 2, our estimates show that by 2013 Chinese industrial sector had achieved the highest software investment intensity (ratio of software investment to value added), 6.0 percent, followed by the transport, storage, and post sector, 4.2 percent, and then the agricultural sector 3.3 percent,[11] leaving the finance and real estate sector at the bottom, 0.57 percent. In Figure 2, we depict changes of the intensity by sector over time for three benchmarks, 1995, 2007 and 2013 and show a significant shift of software investment from services to the industrial sector over the post-GFC period 2007-2013.

FIGURE 2
Investment in Software and Research & Development
(As % of value added, ranked by 2013 data)



Source: Authors' estimates. Value added data are from Wu and Ito (2015, revised and updated), not adjusted for intangibles.

Note: *"Other Services" includes (1) ICT services, (2) leasing, technical, science & business services, (3) public administration & defense, (4) education services, (5) health & social security services, and the rest of services non-identified in this chart.

[10] Embedded system software only accounts for a small portion of the revenues of the software industry. Revenues from embedded system software are 0.7 trillion Yuan in 2015, compared with the total revenues of the software industry, 4.3 trillion Yuan (MIIT, 2016).

[11] We are still searching for more information on why agriculture has such a high investment in software.

TABLE 2
INTANGIBLE INVESTMENT IN EIGHT SECTORS OF THE CHINESE ECONOMY IN 2013
(Percent of value added in current prices)

	Agriculture	*Industrial*	*Construction*	*Wholesale & Retail*	*Hotels & Restaurants*	*Transport, Storage & Post*	*Finance & Real Estate*	*Other Services**
Computerized Information								
...Software	*3.33*	*6.02*	*1.17*	*1.00*	*1.55*	*4.20*	*0.57*	*1.69*
Innovative Property								
...R&D	*0.02*	*4.60*	*0.30*	*0.00*	*0.00*	*0.04*	*0.00*	*1.65*
...Mineral Exploration	*0.00*	*0.56*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
...Copyright & Licenses	*0.00*	*0.08*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.16*
...Design	*0.18*	*0.67*	*0.13*	*0.20*	*0.64*	*1.69*	*1.60*	*0.77*
Economic Competencies								
...Brand Equity	*0.00*	*1.00*	*0.08*	*0.21*	*0.66*	*0.10*	*0.48*	*0.32*
...On-the-job Training	*0.04*	*0.86*	*0.86*	*0.22*	*0.29*	*0.53*	*0.26*	*0.86*
...Organizational Structures	*0.11*	*0.63*	*1.55*	*0.34*	*0.65*	*0.70*	*0.25*	*1.15*
Total-China	3.68	13.96	4.09	1.98	3.79	7.26	9.65	6.60
*...Reduced form**	*3.36*	*12.25*	*1.55*	*1.21*	*2.21*	*4.34*	*1.05*	*3.82*
Total-U.S.	0.42	19.41	3.74	14.83	8.13	7.43	18.20	19.10
*... Reduced form**	*0.16*	*14.95*	*0.41*	*5.70*	*2.60*	*1.98*	*5.91*	*10.56*
Total-U.K.	1.73	13.41	8.98	10.87	6.72	8.20	18.57	15.92
*... Reduced form**	*0.74*	*6.95*	*0.85*	*3.84*	*1.56*	*3.62*	*4.83*	*8.29*

Source: Authors' estimates. Value added data are from Wu and Ito (2015, revised and updated), not adjusted for intangibles.
Note: *"Reduced form" includes investment in software, R&D, mineral exploration, copyright & licenses, and brand equity only. Estimation for this subgroup is to focus on assets with more reliable information so that it is compatible internationally. See discussion on the estimation of the subgroup in Section 6.

Research and Development (R&D)

To the surprise of many, the relatively easy-collecting data on R&D spending from China's stringent statistical reporting system are far from ideal. We rely on national R&D spending data from *China Statistical Yearbook*, published by the National Bureau of Statistics (NBS), and two other official sources on such spending by industry, *China Statistical Yearbook on Science and Technology* (CSYST) for the period 2006-2013 and the *2009 National R&D Census*. For years before 2006, we have no choice but use the industry distribution of R&D spending in 2006 as a proxy. Besides, we also do not have sufficient data at the industry level to minimize the double counting problem by excluding R&D that is already included in software investment and mineral exploration.

The CSYST lists R&D spending of about 40 industries under three broad categories, mining, manufacturing, and utilities. For 2013, the total spending covers about 70 percent of national R&D spending. To find out the industry distribution of the rest of the 30 percent of national R&D spending in non-industrial sectors, we use R&D spending in service industries from the 2009 National R&D Census that covers the agricultural sector and 11 service industries. We find that according to the census, R&D spending is negligible in hotel and catering, wholesales and retails, real estate, and public administration.

Our results show the following observations. By 2013, China's R&D intensity, measured as the share of R&D spending in value added, was the highest in the industrial sector, 4.6 percent, followed by the sector of "other services" (see footnote 6), 1.7 percent, and construction, 0.3 percent (Table 2). There are four sectors that invested little of their value added in R&D, namely, transport, storage & post, agriculture, finance & real estate and wholesale & retail. Nonetheless, the negligible spending on R&D by the wholesale & retail industry may imply that recent innovations such as e-commerce do not necessarily need to be driven by R&D. Interestingly, an overview at major sectors through the three benchmarks in Figure 2 demonstrates that like what shown by the software investment intensity, the R&D investment intensity also indicates a significant shift from services to the industrial sector in the wake of the GFC in the period 2007-2013, perhaps indicating that the government's unprecedented infrastructural investment to sustain growth played an indirect role in promoting R&D.

Mineral exploration

Data on the national spending on mineral exploration are obtained from *Communique on Land and Resources of China* (various years) issued by the Ministry of Land and Resources, as of the unpublished updates of Hulten and Hao (2012). To distribute the national spending into 37 industries, we use various issues of *China Mining Yearbook*. Assuming mineral exploration is only carried out by the mining sector, we need to break down the total exploration spending into 4 mining industries, using the spending on different types of minerals in 1996, 1997, 2002 and 2003. We use the breakdown of 1996 for the years before 1996 and that of 2003 for the years after 2003, and for the years between 1996 and 2003 we apply some interpolation to fill the gap. We show that national spending on mineral exploration was 0.56 percent of GDP in 2013 (Table 2) and among the total spending, unsurprisingly 65 percent is on oil and gas and 22% on metal mining, leaving only 7% on non-metallic mining and 5% on coal mining.

Copyrights and licenses

In measuring spending on copyrights and licenses, we opt for a somewhat different method from CHS (2005). CHS (2005) relied on development costs of movies to estimate this type of intangibles, while we estimate copyright fees as royalty costs of the publishing industry and transfer or license fees from patents. Our data sources are *National Overview of the News and Publishing Industry* and *China Statistical Yearbooks on Science and Technology*.

More specifically, copyright fees are estimated using the royalty costs of books, magazines, newspapers, audios, and videos published in China, based on the recent unpublished revision of Hulten and Hao (2012). We assign the royalty of textbooks to the industry of education services and assign the royalty of the rest types of publications to the industry of information and communications. Based on the royalty of books in the U.S, we gauge royalty costs in China at 7 percent of the list prices.[12]

We rely on data on license revenues from patents from the *2009 National R&D Census* for license costs at both the national level and at the industry level.[13] It is not a surprise that most

[12] HM Publishing Corporation (2005) shows that royalties are about 7 percent of listing prices of books.

[13] Considering data on licenses is an improvement of Hulten and Hao (2012) that is used in an unpublished revision of Hulten and Hao (2012).

of transfer and license costs incur in the manufacturing sector, education, R&D and technical services, and mineral exploration industries. Data for years other than 2009 are gauged by ratios of license revenues to R&D spending by industry in 2009.

By 2013, national spending on copyright and license fees was 0.06 percent (Table 2), not much different from that of 1995 (0.05). This spending is allocated to two sectors in our classification, i.e., the industrial sector, which includes R&D-intensive manufacturing industries, accounted to 0.08 percent of its value added, and the other services sector, which includes education, R&D and technical services, and mineral exploration, accounted to 0.16 percent of its value added.

Development costs in financial industry

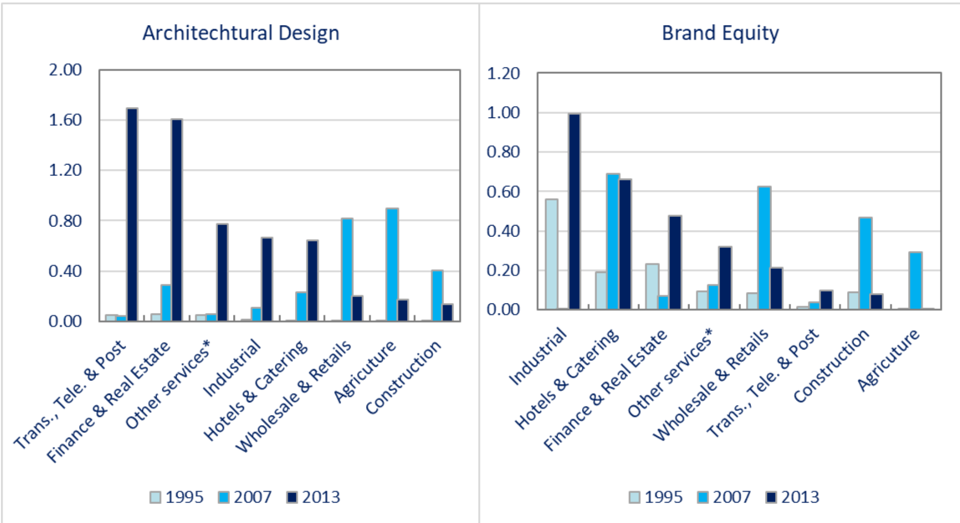
Hulten and Hao (2012, revised and updated) show that development costs in financial industry amounts to 0.84% of China GDP in 2013. We assign all the development costs to financial intermediations which belongs to the sector of finance and real estate. The data sources used in Hulten and Hao are issues of *China Statistical Yearbook* for the value added of the financial sector and *China Input Output Tables* for the ratio of intermediates to value added, both provided by NBS. This estimate is obviously a rough proxy because the practices of the US financial industry can be quite different from those of the Chinese counterpart.

Architectural designs

For investment on designs, the CHS method requires a measure of both architectural and engineering designs. However, in the absence of information on spending on engineering designs in China, we can only measure architectural designs. There has been a large spending on architectural designs in China, thanks to the increasingly booming if not yet bubbled real estate industry. At a quick glance, we see that floor space completed per year increased from 1.5 billion square meters in 1995 to 3.5 billion square meters in 2013 (NBS, 2014). The increase in investment in structures is huge, compared with the relatively stable number of the population. In 2013 alone, China completed over 2 square meters of structures for each person of its 1.3 billion population. This obviously drives up the demand for architectural designs.

We rely on two data sources from NBS, *China Statistical Yearbook* and *Yearbook of Engineering Survey and Design Companies*. These yearbooks provide revenues of architectural design under the title of “companies and institutes of engineering survey and design”. Hulten and Hao (2012, revised and updated) show investment in architectural designs as revenues of the designs.[14] The investment increased from 0.21 to 0.72 percent of GDP over the period 2003-2014. We allocate the total revenues of architectural designs into industries by the NBS fixed asset investment weights in structures for 2003-2011. All industries invested some shares of value added in architectural design, because each industry build structures for business, and some companies, still following the old socialist welfare way under central planning, hire construction teams to build residential structures for their employees.

FIGURE 3
Investment in Architectural Design and Brand Equity
(As % of value added, ranked by 2013 data)



Source: Authors' estimates. Value added data are from Wu and Ito (2015, revised and updated), not adjusted for intangibles.
Note: *See note to Figure 2 for "other services".

Not surprisingly, finance and real-estate services, investing heavily in residential and non-residential structures, and transport, storage, and post services, investing heavily in many government funded railway, highway, and other infrastructural projects, are most architectural-design-intensive industries in investment. As shown in Table 2, these two groups of industries invested 1.7 and 1.6 percent of their value added in architectural design in 2013. With Figure 3, we still observe a significant shift of the investment in designs, as a share of value added, from services to the industrial sector. Nevertheless, since we are not able to estimate products-oriented engineering designs, we are careful do not intend to interpret the investment in

[14] The 2012 version of Hulten and Hao (2012) estimate investment in architectural design as the revenues of Engineering Survey and Design Companies including revenues from various services other than just architectural design service.

architectural designs as the investment in product innovation aiming to move up the global value chains.

Brand equity

In the CHS (2005) principle, spending on brand equity should be measured by spending on both advertisement and market research. Furthermore, CHS treats 60 percent of advertising spending as investment in brand equity. In the absence of sufficient information on market research,[15] we rely on the turnover of the advertising industry to gauge the spending on brand equity in China.

The main data sources are *China Advertising Yearbook* for national total advertising spending, CEIC database for advertising spending on 19 aggregate groups of products and services, CEIC database for sales and distribution costs, and the *Third National Economic Census* in 2008 for general and administrative costs (SG&A) by industries.

We allocate the national advertising spending on 19 types of products & services into their corresponding industries. The allocation is far from prefect because most aggregate groups of products or services belong to a relatively small number of industries and the spending on "other services" covers multiple service industries. We then break down the spending into more detailed industries, using the sales and distribution costs for the industrial sector and total SG&A costs for services. We have no data on advertisement spending of the government though the government heavily influences the content of news and movies and TV programs, largely political. Finally, following CHS (2005) we adjust the advertising spending by deducing 40% for the measure of investment in brand equity.

China's investment in brand equity of value added increased from 0.27 percent in 1995 to 0.52 percent in 2013. As shown in Table 2, by 2013 the ratio was the highest in the industrial sector, 1.0 percent, followed by the sectors of hotels and catering, 0.66 percent, finance and real estate services, 0.48 percent (Figure 3). Within the industrial sector, the automobile industry accounted for 14.2 percent of the national advertising spending, food products and food supplement for 15.7 percent, cosmetics 10.7 percent, and medicines, 5.5 percent. We find that the most heavily advertised service among all services is the real estate service, accounting

[15] With extremely limited information, Hao & Hulten (2012) shows that China's spending on market research is as trivial as less than 0.03% of GDP.

for 13.8 percent of national advertising spending, followed by information services, 4.1 percent, and financial and insurance services, 3.5 percent.

Firm-specific human capital (training)

We mainly rely on the following sources to measure firm-specific human capital training: *General Principles of Corporate Finance* (Ministry of Finance, 2006 and 2007), *2010 Continuing Vocational Training Survey*, provided by OECD, the industry-level labor compensation data from Wu (2015 with updates) and unpublished detailed data on urban wage bills and on labor training costs from the *2004 National Economic Census*, provided by NBS.

In its *General Principles of Corporate Finance* China's Ministry of Finance states that companies should allocate fund amounting to 1.5 percent of total wage bills for education and training of employees. If companies fail to do so, that fund will be confiscated (State Council, 2002). We assume that all companies, at least in well monitored urban areas, obey that regulation.[16] We use the unpublished details of *2004 Economic Census* and estimate that training costs are equivalent to respectively 1.42, 1.59 and 1.12 percent of total urban wage bills of the mining, manufacturing, and utilities sectors, implying that companies do follow the regulation.

Total spending on firm-specific human capital is measured as the sum of direct training costs and personal absence-from-duty costs. We estimate direct training costs at the industry level by the total urban wage bills of 37 industries and the ratio of training costs to total urban wages in each industry.[17] First, we allocate the urban wage bills of manufacturing sector and the mining sector using labor compensation data from Wu (2015). NBS provides data on urban wages at the industry level for the agricultural sector, the utilities sector, and the service sector, but not the manufacturing the mining sectors. Second, we estimate the direct training costs as 1.5 percent of urban wages for the agricultural and the service sector (the ratio defined in the regulation), and we estimate direct training costs as respectively 1.42, 1.59 and 1.12 percent of total urban wages of the mining, manufacturing, and utilities sectors, based on unpublished data from the *2004 Economic Census*. The indirect training costs are personal absence-from-

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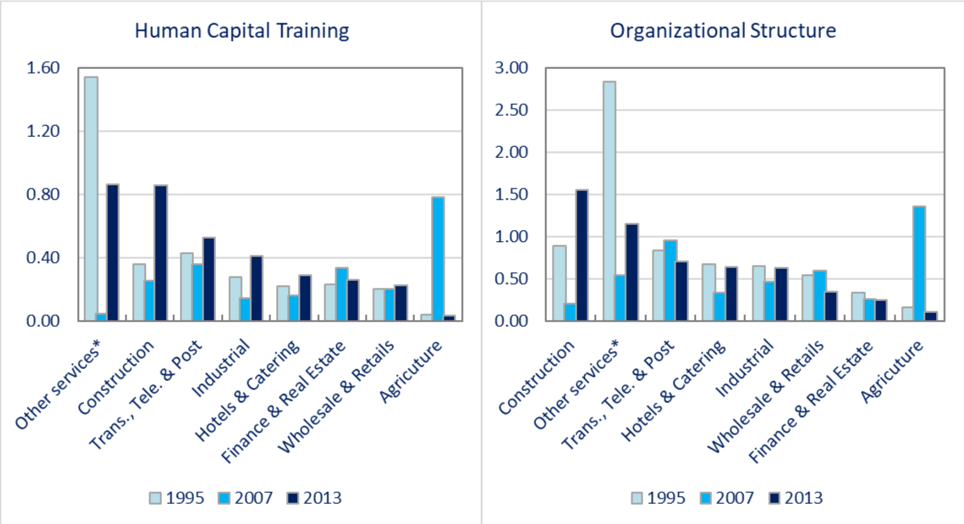
[16] Rural population in the agricultural industry often do not organize as companies and have little organizational structure.

[17] This method is an improvement from Hulten and Hao (2012) because they use the annual surveys of the industrial (mining, manufacturing, and utilities) firms. The surveys cover industrial firms only, and many firms do not report training costs in the surveys.

duty costs, which are 0.89 of the direct training costs in the European Union in 2010. We use this ratio of 0.89 for China.

FIGURE 4
Investment in Human Capital Training and Organizational Structure
(As % of value added, ranked by 2013 data)



Source: Authors' estimates. Value added data are from Wu and Ito (2015, revised and updated), not adjusted for intangibles.
Note: *See note to Figure 2 for "other services".

In 2013, sectors are estimated to invest between 0.2 and 1.0 percent of their value added in human capital training (Table 2). As shown in Figure 4, the sectors that invested most in on-the-job training are sectors of construction, "other services" (see note to Figure 2), and transport, storage & post, while the sectors that invested little in such training are agriculture, wholesale & retails, and finance & real estate. Intuitively, as demonstrated in Figure 4, despite opposite changes in the investment in the training as a share of value added between the periods 1995-2007 and 2007-2013, the sectors of other services and construction still play a dominant role.

Organizational structure

In the CHS principle, the measure of spending on organizational structure based on 20 percent of manager's compensation (CHS, 2005), in which 80 percent is treated as intangible investment. Hulten and Hao (2012, unpublished and revised updates) estimate that China invested 0.66 percent of valued added in organizational structure in the total economy in

2013.[18] We allocate the national total investment in organizational structure into 37 industries using urban employment of industries (*China Labour Statistical Yearbook*) as weights.[19]

We show that among all the eight sectors construction invested the most, 1.55 percent of its value added, followed by the other services sector (see footnote 6), 1.15 percent, and the transport, storage & post sector, 0.70 percent (Table 2). China's relatively small spending on organizational capital compared to that of the U.S. is likely because Chinese companies are not organizationally structured as their U.S. counterparts. However, as shown in Figure 4, except for the construction sector, the decline in the investment in organizational structure, as a ratio of the investment to value added, over the period 2007-2013 compared to that of the period 1995-2007 is a bit puzzling, which is likely caused by data problem.

6. Results and Implications

After going through all the procedures we have taken to measure the investment in each intangible asset listed in Table 1, aiming to allocate the available aggregate estimates based mainly on the early work by Hulten and Hao (2012) and following improvements, into the 37 industries of the CIP production accounts system that is constructed in coherence with the Chinese national accounts, we are now in a position to organize our preliminary estimates and explore their implications for China's ongoing economic transition from the perspective of technological innovation and upgrading.

Considering the challenge to the conventional SNA system in general, the practice of Chinese statistical system that does not closely follow the international standards, and the nature of unsolved data problems in particular, we can only speculate the role of intangible investment in China's transition from a centrally planned to a market economy over the two decades from the mid-1990s, but not yet ready for a complete vision about that role from a coherently revised Chinese national output and expenditure accounts with a high confidence. In what follows, we will concentrate on growth and structure changes in intangible investment in time and space with the examination of assets and sectors that have played an important role.

[18] In a recent unpublished revision, Hulten and Hao adjusted the estimates of organizational structure in their 2012 paper. Instead of using 5 percent of management expenses based on NBS annual surveys of industrial firms, they raised it to 20 percent following the CHS method based on information from the IPUMS International for the number of managers and the *2009 Wage Guide for Beijing Labor Market and the Status of Labor Costs for Companies* (Beijing Municipal Human Resources and Social Security Bureau, 2009) for the level of managers' compensation relative to the compensation of other occupations.

[19] The majority of Chinese farmers are household production-based rather than corporatized; thus their production involves little organizational structure problems as their counterparts in the West.

For those who are interested in more detailed results by industry and over time, please see Appendix Table 1 for the estimated value of intangible investment at the industry level for selected years and Appendix Table 2 for the annual changes of intangible investment as a share of value added by sector.

Growth and structural changes

If our estimates are acceptable, we can first use them to substantiate the CHS hypothesis about the increasing importance of intangible investment in economic development with the case of China. Together with the revised and updated CIP industry data on tangible investment (Wu, 2015), in Table 3 we show the investment in intangible assets as a share of China's total investment, now the sum of tangible and intangible investments, and its annual change by sector. We expect the share of intangibles in total investment to rise over time and cross sectors, and this seems indeed the case except for the sector of hotels & catering and the sector of financial and real estate services, yet we cannot rule out data problems for these sectors and their industries. For the total economy, the intangible investment share rose from 9.2 percent in 1995 to 16.4 percent in 2013, accelerated from 2.1 percent per annum in 1995-2001 to 4.7 percent per annum in 2007-2013. This implies that the growth of intangible investment outpaced the growth of tangible investment over the entire period in question at an enhanced speed. It would inevitably distort researchers' vision if intangible investment were ignored, hence being excluded in the growth accounting analysis.

TABLE 3
SHARE OF INTANGIBLES IN CHINA'S TOTAL INVESTMENT AND ITS ANNUAL CHANGE BY SECTOR

	Share of intangibles in total investment (Total investment=100)				Annual change of the share of intangibles (% p.a.)			
	1995	2001	2007	2013	1995-2001	2001-2007	2007-2013	*1995-2013*
Total Economy	*9.2*	*10.4*	*12.4*	*16.4*	*2.1*	*2.9*	*4.7*	*3.2*
Agriculture	5.1	6.7	10.1	16.5	4.5	7.2	8.5	*6.7*
Industrial	8.5	11.6	16.4	32.3	5.3	5.9	12.0	*7.7*
Construction	22.0	28.3	30.4	38.6	4.3	1.2	4.0	*3.2*
Wholesale & Retail	8.8	7.9	9.1	11.9	-1.9	2.4	4.7	*1.7*
Hotels & Catering	12.7	9.9	8.6	9.4	-4.2	-2.2	1.4	*-1.7*
Transport, Storage, Post	5.9	5.3	8.5	11.0	-2.0	8.4	4.4	*3.5*
Finance, Real Estate	7.7	6.8	6.3	6.4	-2.0	-1.2	0.1	*-1.0*
Other Services*	28.4	25.4	17.8	11.9	-1.8	-5.8	-6.4	*-4.7*

Source: Authors' estimates. Total investment = sum of intangible and tangible investment, see Wu (2015 revised and updated) for tangible investment.

Note: *"Other Services" includes (1) ICT services, (2) leasing, technical, science & business services, (3) public administration & defense, (4) education services, (5) health & social security services, and the rest of services non-identified in this chart.

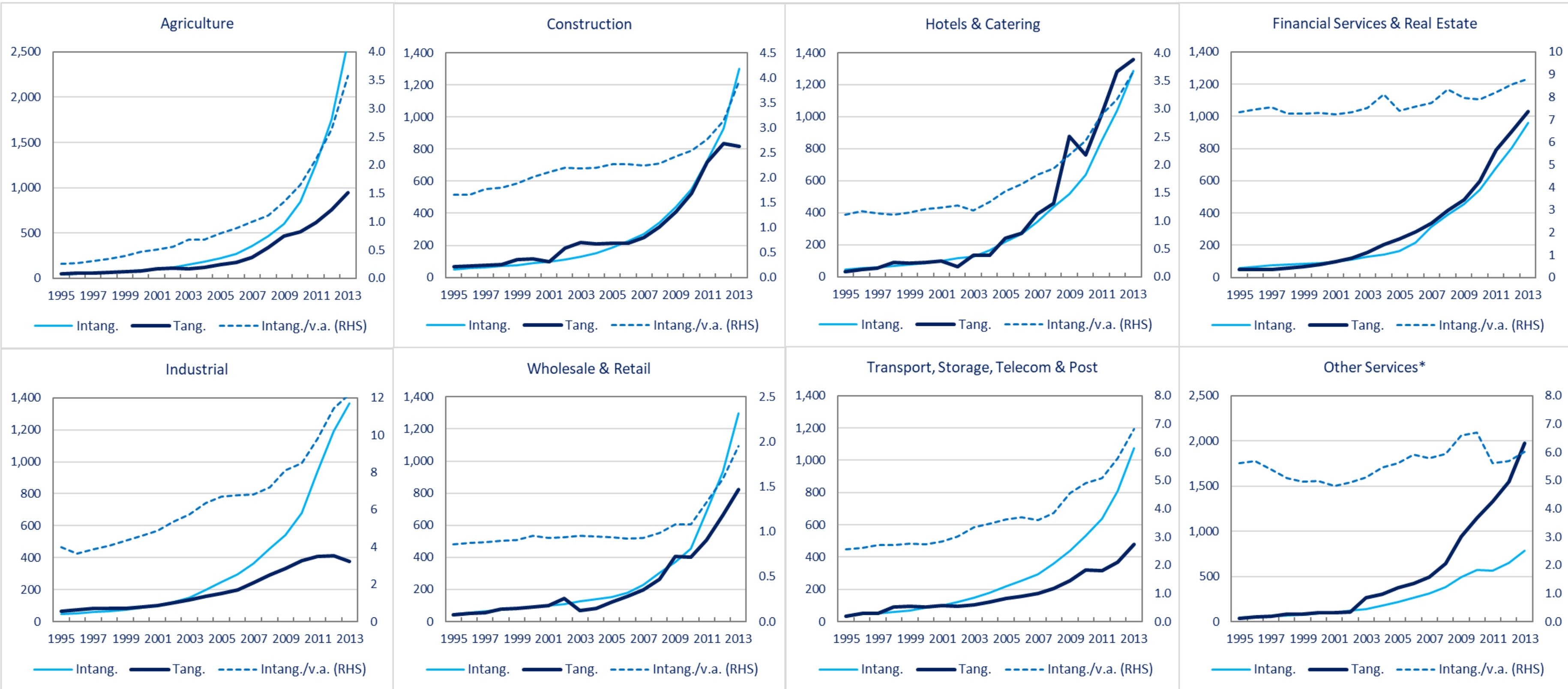
In Table 3, some sectors are worth a particular attention, especially the construction and the industrial sector, of which the former was most intangible-intensive in investment by 2013 with 38.6 percent of investment in intangibles, whereas the later was most rapid growing in that regard post GFC at 7.7 percent per annum in 2007-2013. Table 3 also shows that the construction sector had already overtaken the sector of other services and become most intangible-intensive in investment by 2001. That not only it maintained that position ever since but accelerated following the GFC as what the industrial sector did may indicate a connection between intangible assets and tangible assets in investment. One may hence argue that competition between local governments aiming to achieve faster growth in general and to maintain growth in particular in the wake of the GFC played a key role in promoting investment in intangible assets required by the state large industrial and infrastructural projects that led to a severe over capacity problem. Therefore, it is simply naïve if complementing the role of government pro-growth policies in driving up intangible investment and based on which speculating its positive impact on China's future technological advancement without understanding the wasteful usage of resources and its huge impact on the world given China's size effect.

As demonstrated by the indices of tangible and intangible investments and intangible intensity measured as the ratio of intangible investment to value added by sector in Figure 5, what we have observed in the construction and industrial sectors is quite universal across sectors for the period under our investigation, even if for the questionable sectors of hotels & catering and financial & real estate services. We may reasonably speculate that this should have been continuing to the present because intangible investment is closely related to investment in new technologies and innovations that is a key growth strategy emphasized by the Chinese government in its new two "five-year plans" for the periods 2016-2020 and 2021-2025. We can also conjecture that in such a process the growth of the intangible assets defined as computerized information, i.e., software in this study, and R&D will be faster than others that are not closely monitored by the state agencies such as brand equity, human capital training and organizational structures.

FIGURE 5

Indices of Tangible and Intangible Investment and Share of Intangible Investment in Value Added by Sector

(Indices: 2001 = 100; Share: Percent of nominal value added**)

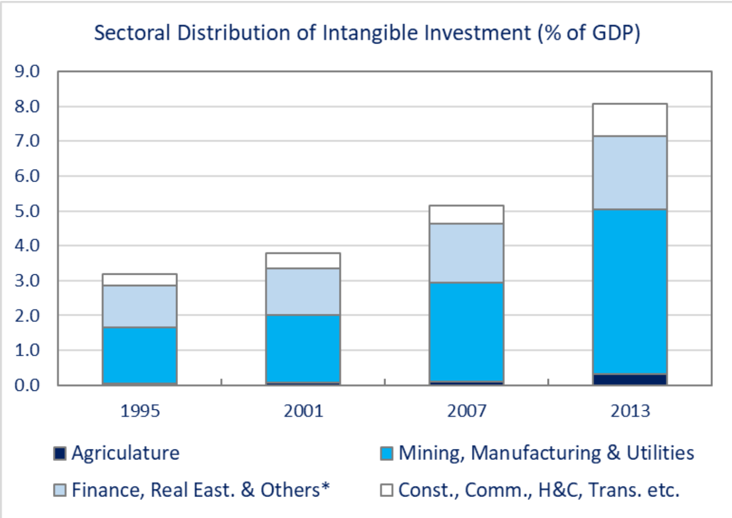


Source: Authors' estimates. See Wu (2015, revised and updated) for estimates on tangible investment and Wu and Ito (2015, revised and updated) for value added.

Note: *See note to Figure 2 or Table 3 for "other services". **Value added is adjusted for investment in intangibles.

To enhance our understanding of the rising role of investment in intangible assets, we depict the sectoral and asset distributions of intangible investment in Figures 6 and 7, respectively, for the key benchmarks in our investigation. Sectoral structure wise, although the relative changes between sectors appear to be insignificant (calculated based on the percentage points in the figure), the share of the industrial sector rose unceasingly and all services declined, especially financial, real estate and those categorized as "other services" (see note to the figure) in this study.

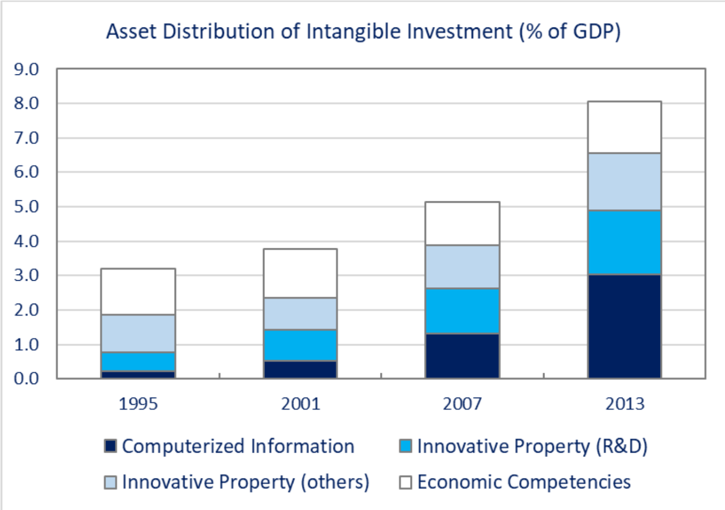
FIGURE 6
Sectoral Distribution of Intangible Investment in China
(Measured as % of nominal GDP**)



Source: Authors' estimates. See Wu and Ito (2015, revised and updated) for value added.
Note: *See note to Figure 2 or Table 3 for "other services". ** Value added is adjusted for investment in intangibles.

Nevertheless, unlike the sectoral distribution exhibited in Figure 6, the asset distribution of intangible investment as presented in Figure 7 implies a significant structural change over time. Particularly, it clearly picks out the important and rising role of computerized information (software) and R&D among all intangible assets for the benchmarks and over the underlying period in question, which confirms our speculation that government-engineered growth through huge industrial and infrastructural project, added by favorable policy supports, would tend to encourage investment in some intangibles in computerized information and innovative property that are more physical projects-embedded, while discouraging investment in some intangibles, especially in those of economic competencies that are not directly driven by state interventions.

FIGURE 7
Asset Distribution of Intangible Investment in China
(Measured as % of nominal GDP)



Source: Authors' estimates. See Wu and Ito (2015, revised and updated) for value added.

Note: *See note to Figure 2 or Table 3 for "other services". ** Value added is adjusted for investment in intangibles.

An international perspective

In Table 4 we focus our examination of our results on China's industrial sector and the service sector, with selected service industries to reduce international incompatibility. In 2013 China's industrial sector accounted for 37 percent of total value added, 30 percent of total tangible investment, excluding investment in dwellings, and 21 percent of total employment in the economy. This is the sector that the government outlines an imperative plan to upgrade in *Made in China 2025* in which technological upgrading and innovation are at the core.[20] Our estimation for intangible investment can help us evaluate the commitment of the industrial sector to the call of the government. As shown in Table 4, in 2013 China's industrial sector invested 14 percent of its value added in intangible assets, indeed committing a significant amount of resources into building innovation capacity and moving up the global value chain. The international comparison suggests that the Chinese level of intangible investment is similar or even slightly more than that of the U.K. and about 70 percent of the U.S. in the industrial sector for the same year, yet about 80 percent of that of Japan back to 2008.

[20] Made in China 2025. http://www.miit.gov.cn/n973401/n1234620/n1234622/c4409653/content.html

However, compared to other economies in the comparison the Chinese investment is strongly skewed toward computerized information, narrowly defined by software, as a co-investment together with equipment and possibly driven by investment in ICT equipment. This implies that although China's industrial sector may have well upgraded itself with ICT-related equipment, it may not have accumulated enough capability of competing with its peers in advanced economies in terms of technological innovation, brand equity, human capital, and modern organization structure.

TABLE 4

CROSS-COUNTRY COMPARISON OF INTANGIBLE INVESTMENT IN SELECTED SECTORS

(Percent of value added in current prices*)

Sectors & Countries	Computerized Information	Innovative Property	Economic Competencies	Total
The Industrial Sector:				
China	6.02	5.91	2.04	13.96
Japan (2008)	3.36	12.01	2.30	17.66
U.K.	1.75	6.44	5.23	13.41
U.S.	1.53	13.39	4.50	19.41
Services (subgroup):*				
China	1.43	3.94	1.44	6.80
Japan (2008)	2.47	2.27	1.93	6.67
U.K.	1.82	1.84	8.68	12.33
U.S.	2.38	3.67	8.01	14.06

Source: Authors' estimates; Data on Japan, the U.K. and the U.S. are from CHS (2005).
Note: Subgroup* includes 4 sectors: (1) Wholesale & Retail, (2) Hotels & Restaurants, (3) Transport, Storage & Post, and (4) Finance & Real Estate.

Having seen that the industrial sector suffers from surplus capacity, slowing productivity growth and rising labor cost, the Chinese government increasingly expects the service sector to play an important role in helping the economy restructure and hence move up quickly the global value chain.[21] When the GDP share of service sector surpassed that of the industrial sector in 2014, the National Bureau of Statistics stated that the service sector had become a new growth driver of the economic.[22] The 13th Five-Year Plan (2016-2020) states that the government plans to make the service sector of higher quality. In this regard, Table 4 may help

[21] "服务业已成我国就业最大容器 (Services are the biggest absorber of China's employment)". 国家发展和改革委员会, http://www.ndrc.gov.cn/fzgggz/jyysr/jqyw/201604/t20160429_800555.html , and "中国经济能否靠服务业力挽狂澜？德媒：专家看法相左 (Can Chinese services save the Chinese economy? Experts disagree with each other, said German medias)" , http://m.cankaoxiaoxi.com/finance/20160926/1315631.shtml "服务业是中国经济的大救星 (Services are the savior of the Chinese economy)？" 德国之声 (Deutsche Welle), www.dw.com

[22] 服务业：中国经济增长新动力--- 解读《2014 年国民经济和社会发展统计公报》http://www.stats.gov.cn/tjsj/sjjd/201503/t20150305_689566.html

set up a starting point for China's service-led growth journey. Obviously, China's services do not commit much of their resources for such a purpose. In 2013, China's intangible investment in all services is merely about half of that in the U.K. and the U.S., but similar to that of Japan back to 2008. We remove architectural design and development costs in financial industry from the comparison, the Chinese intangible investment in service sector would be even significantly lower than its international peers because as we mentioned before, investment in architecture design is likely driven by the real estate bubble and the estimates of development costs of financial industry is only a rough proxy.

Furthermore, we can use the investment in brand equity of the wholesale and retail sector as an example to enhance this point. Brand equity helps service sectors to move up the value chain in that good brands could allow premium pricing which transform the competition among companies from competition through low prices (thus low costs) to competition of high quality, product differentiation and so on. In addition, brand equity facilitates product innovation in that new products under a good known brand are more likely to be welcomed by the market during the launch of new products. Let us base on the data of the reduced form of intangibles introduced in Table 2 to reduce the incompatibility in intangible assets measured. It shows that the U.S. wholesale and retail sector spends 5.7 percent of its value added in 5 types of intangible assets listed as adjusted intangible investment, the Chinese wholesale & retail sector spends only 1.21 percent, and the gap is mostly from the investment in brand equity (5.1 percent of value added in the U.S. vs. 0.2 percent in China). This China vs. the U.S. comparison indicates that Chinese services, those of which can be represented by wholesale & retail, would need to invest more heavily in building strong brands to catch up with their U.S. counterparts.

7. Concluding Remarks

Investment delays consumption and builds capital stock that will improve productivity in the future. Investment in today's intangible capital assets can be a good indicator of the power of creativity and innovation in the future. China's insufficient investment in intangible assets, other things being equal, may imply a weak intangible capital stock that affects China's moving up the global value chain in a progressively competitive international market. The famous iPhone story is quite convincing in this regard. China should have felt the rising pressure by realizing that although China has worked hard to learn how to assemble the entire iPhone, it can capture merely 2 percent of the iPhone's total revenue, whereas Apple receives about 60 percent of that revenue (Kraemer, Linden, and Dedrick, 2011). After 40 years of rapid growth, China has arrived at a crucial stage in which only further technological advancement can help China better face the rise of labor cost and the slowdown of productivity growth.

In this study we have tried extremely hard to collect and organize, piecemeal and scattered information to measure China's intangible investment at the industry level, the first of its type, yet far from satisfactory and complete. We must rely on many strong assumptions to fill the gaps or use rough placeholders. We need to develop more systematic data handling approach to organize poor data on intangibles. Trying to develop an approach to establish the underlying relationship between expenditures on intangibles and investment in tangibles, and intangibles and productivity may be a way out, which may make a better use of the CIP industry productivity accounts coherently reconstructed in the framework of the Chinese national accounts.

We conclude this study mainly with our understanding of the data problems through this exercise. Our reasoning for a "reduced form" of intangibles to improve the compatibility in Table 2 may help explain the data challenge. The "reduced form" estimation excludes spending on designs, development costs in financial industry, and organizational structures to account for data difficulties on the one hand and to increase China's international compatibility when more accurate measurement for intangible investment is impossible for China. We explain the situation as follows with caveats.

First, the investment in design as measured for China is architectural design only, unlike that of the U.S. which includes both architectural and industrial designs. Considering that China has been undergoing a prolonged real estate bubble with many sold but unoccupied apartments, if we measure investment architectural design, we are mostly measuring the real estate bubble and over-investment in architectural design including that for empty apartments. Second, Chinese financial industry operates in different ways from its U.S. counterpart. The CHS principles followed in Hulten and Hao (2012, revised and updated) are based on the U.S. practices, thus the estimates for China are inevitably rough proxies. Third, in measuring investment in organizational structures, the CHS method uses 20 percent of managers' time as a placeholder, but there is no such data for China not to mention different management traditions and organizational structures between the two economies.

On top of these is our biggest caveat that about half of the intangible investment is on software that is largely determined by investment in machines and equipment in government engineered growth. We nonetheless have no choice but keep the spending on software in estimation, but we ask researchers to bear it in mind that overinvestment in the Chinese industrial sector was a serious problem. This means that the software investment might need to be seriously discounted for wasteful over-investment and misallocation of resources once more information is available.

Given all the unsolved data problems, although in Section 6 we have presented our estimates with adjusted value added as suggested by our extended national accounts framework that treats the estimated intangible investment coherently with the existing national accounts, we are not yet ready to present adjusted GDP estimates for China in a systemic way.

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APPENDIX TABLE 1
CHINA'S INTANGIBLE INVESTMENT BY 8 SECTORS AND 37 INDUSTRIES
(Million RMB in current prices)

Industry & Sector	1995	2001	2007	2013
Agricultural Sector	3,142	8,041	28,903	209,905
Industrial Sector	101,994	222,306	807,389	3,033,504
coal mining	*3,592*	*8,241*	*31,518*	*111,364*
oil & gas excavation	*24,402*	*27,813*	*82,798*	*192,334*
metal mining	*1,794*	*1,510*	*11,107*	*53,007*
non-metallic minerals mining	*1,033*	*1,094*	*4,262*	*19,643*
Food and kindred products	*5,628*	*14,897*	*41,862*	*170,267*
Tobacco products	*565*	*1,459*	*3,732*	*9,350*
Textile mill products	*3,727*	*6,870*	*20,717*	*63,918*
Apparel and other textile products	*1,463*	*3,148*	*8,481*	*33,438*
Leather and leather products	*673*	*1,408*	*4,408*	*18,326*
Sawmill products, furniture, fixtures	*622*	*1,646*	*7,198*	*33,808*
Paper products, printing & publishing	*1,803*	*5,179*	*13,140*	*53,802*
Petroleum and coal products	*1,225*	*3,170*	*19,577*	*68,315*
Chemicals and allied products	*11,299*	*25,677*	*80,975*	*366,436*
Rubber and plastics products	*1,780*	*5,362*	*12,571*	*51,307*
Stone, clay, and glass products	*3,991*	*6,183*	*26,039*	*134,199*
Primary & fabricated metal industries	*5,855*	*16,425*	*87,686*	*291,060*
Metal products (excluding rolling products)	*1,669*	*3,377*	*10,992*	*59,794*
Industrial machinery and equipment	*7,987*	*16,109*	*60,761*	*247,778*
Electric equipment	*5,051*	*13,385*	*46,096*	*189,023*
Electronic and telecommunication equipment	*5,116*	*20,574*	*74,896*	*242,087*
Instruments and office equipment	*811*	*2,090*	*7,455*	*30,903*
Motor vehicles & other transportation equipment	*6,031*	*13,922*	*63,284*	*264,588*
Misc. manufacturing industries	*1,087*	*1,148*	*5,184*	*17,664*
Power, steam, gas and tap water supply	*4,790*	*21,621*	*82,653*	*311,094*
Construction Sector	6,278	12,845	35,087	166,905
Wholesale & Retail Sector	4,125	8,598	19,732	111,650
Hotels & Restaurants Sector	1,341	3,007	10,256	38,749
Transport, storage & post services sector	4,842	12,768	42,147	189,097
Financial & real estate sector	43,945	77,452	242,785	744,801
Financial intermediations	*41,882*	*68,271*	*197,762*	*542,468*
Real estate services	*2,063*	*9,181*	*45,023*	*202,333*
Other Services sector	35,895	88,761	270,759	681,887
Information and communications	*4,726*	*13,107*	*34,312*	*88,730*
Leasing, technical, science & business services	*5,509*	*19,863*	*89,326*	*198,881*
Public administration and defense	*7,102*	*13,286*	*38,428*	*131,893*
Education services	*12,307*	*27,843*	*66,184*	*125,882*
Health and social security services	*3,835*	*9,166*	*24,537*	*64,874*
Other	*2,415*	*5,496*	*17,972*	*71,627*
Total	201,561	433,779	1,457,058	5,176,497

Source: Authors' estimates.

APPENDIX TABLE 2
CHINA'S INTANGIBLE INVESTMENT AS SHARE OF CURRENT VALUE ADDED BY SECTOR, 1995-2013
(Percent of value added in current prices)

	Total	Agriculture	Industrial	Construction	Wholesale & Retail	Hotels & Restaurants	Transport, Storage & Post	Finance & Real Estate	Other Services*
1995	3.20	0.25	3.98	1.65	0.86	1.10	2.55	7.32	5.62
1996	3.10	0.27	3.66	1.65	0.88	1.17	2.62	7.47	5.69
1997	3.25	0.30	3.86	1.77	0.88	1.13	2.71	7.54	5.37
1998	3.31	0.34	4.05	1.80	0.90	1.11	2.72	7.27	5.07
1999	3.47	0.39	4.35	1.89	0.91	1.14	2.77	7.28	4.96
2000	3.66	0.46	4.61	2.02	0.96	1.21	2.74	7.29	4.98
2001	3.78	0.50	4.87	2.12	0.93	1.24	2.84	7.25	4.81
2002	4.06	0.56	5.38	2.19	0.94	1.27	3.01	7.34	4.93
2003	4.34	0.68	5.76	2.19	0.95	1.18	3.35	7.52	5.10
2004	4.66	0.68	6.35	2.19	0.95	1.34	3.47	8.10	5.45
2005	4.90	0.80	6.69	2.27	0.94	1.53	3.63	7.39	5.60
2006	5.09	0.89	6.78	2.27	0.92	1.65	3.71	7.58	5.92
2007	5.14	1.00	6.81	2.24	0.93	1.82	3.60	7.73	5.78
2008	5.41	1.11	7.22	2.28	0.99	1.94	3.85	8.33	5.94
2009	5.94	1.35	8.12	2.43	1.08	2.18	4.56	7.96	6.59
2010	6.17	1.66	8.49	2.53	1.08	2.43	4.90	7.89	6.70
2011	6.69	2.10	9.80	2.77	1.33	2.89	5.07	8.21	5.62
2012	7.51	2.63	11.45	3.14	1.58	3.17	5.79	8.57	5.69
2013	8.06	3.58	12.19	3.93	1.95	3.66	6.83	8.81	6.00

Source: Authors' estimates. Value added data by industry are from Wu and Ito (2015, revised and updated).