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Estimating Capital Formation and Capital Stock by Economic Sector in China

The Implications for Productivity Growth

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Abstract

This paper aims to fill a gap in the literature on capital formation in China by estimating the capital stock in four economic sectors: business, infrastructure, government, and housing. Such a breakdown is necessary for the purpose of analysis of economic development in China, as the normal models of economic development are based on a competitive economy, which is clearly not the case for the country's infrastructure and government sectors. Moreover, the contribution of housing to gross domestic product in China is very poorly measured. Although the results of this analysis can only be approximate, as the required detailed information for a better estimate is not published, they nonetheless suggest that there has not been overinvestment in the Chinese business sector—its capital-output ratio has risen only slightly over the past 40 years. Yet, there have been surges in the stocks of housing and infrastructure in the past decade. These sectors account nearly all the recent increase in the capital-output ratio in China.

This is a background paper for the Development Research Center of the State Council and the World Bank's 2019 report "Innovative China: New Drivers of Growth", produced for the Macroeconomics, Trade and Investment Global Practice of the World Bank. It is part of a larger effort by the World Bank to provide open access to its research and make a contribution to development policy discussions around the world. Policy Research Working Papers are also posted on the Web at http://www.worldbank.org/prwp. The author may be contacted at rherd@herdassociates.com.

Estimating Capital Formation and Capital Stock by Economic Sector in China:

The Implications for Productivity Growth

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This paper has been produced as background for the Development Research Center of the State Council and the World Bank's 2019 report *"Innovative China: New Drivers of Growth"*. The dataset is available in World Bank's Development Data Hub (https://datacatalog.worldbank.org/).

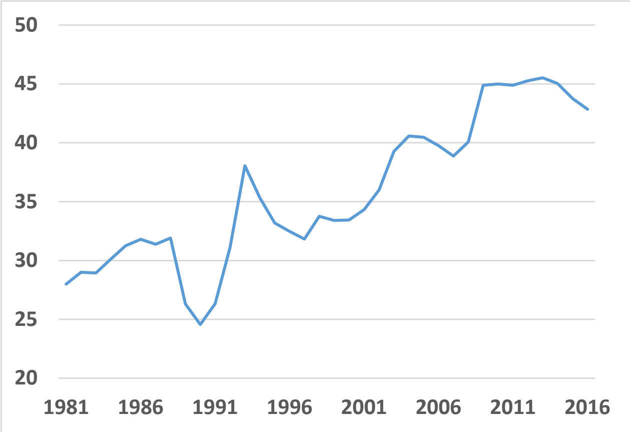
JEL Codes: E010, E220, O110, O530.

Keywords: China, capital stock, incremental capital-output ratio, fixed asset investment

The official Chinese national accounts do not contain any estimate for the capital stock for the whole economy. Yet such a figure is necessary in order to determine past performance of the economy and its likely future path. This is the more so in China where the level of investment is particularly high (Figure 1). Concerns have been raised that there has been over-investment so reducing rates of return and the growth of productivity. Changes in the structure of the capital stock over time can change the average rate of return and the productivity of capital, so obscuring the underlying changes in productivity. This is particularly the case in China where the national accounts measure of the rate of sectoral return is assumed to be zero for most of the housing, infrastructure and government sectors. Thus, the question of whether there has been over-investment requires evidence both on the overall capital stock and its distribution across different sectors of the economy.

Figure 1 Investment rate

Current prices, % GDP



Source: NBS and author estimates

There have been many attempts to estimate the total capital stock of the economy, given the absence of official estimates. They have all been faced with similar problems. Even though investment data are available since 1952 on an internationally agreed basis, there is uncertainty about the initial value of the capital stock at that date, following a long period when the economy had been impacted by war and revolution. Moreover, in contrast to the aggregate data, the most detailed figures on investment continued to be gathered under the principles set out in the early 1950s rather than using the internationally agreed System of National Accounts (SNA). In addition, the gathering of economic data during the 1960s was sparse and sometimes was interrupted completely. Despite these problems, the Chinese authorities have made considerable efforts to produce standardized economic accounts back to 1950. However, for investment, the official macroeconomic data lack the granularity that is found in the accounts of many countries, forcing analysts to use a variety of supplementary data.

The absence of granularity for investment data is of particular concern given the high and rising level of investment. It is well-known that this rise has been driven by infrastructure and housing. Some also maintain that it has been driven by investment by state-owned enterprises, giving rise to excess capacity. This note attempts to improve the granularity of data for gross fixed capital formation in China by focusing on four sectors: housing, infrastructure, government and the business sector. By providing corresponding estimates of capital stock, a judgement can be made on the extent of over-investment and the movement in the productivity of capital in the business sector of the economy

Until recently, capital stock estimates for China have oscillated between providing estimates for the whole economy and for the non-residential sector. While earlier studies used the non-residential sector data (Chow, 1993), with the publication of aggregate official data for gross fixed capital formation, attention switched to estimates for the whole economy. Recently attention has switched back to disaggregated data. Bailliu et al. (2016) considered the non-residential capital stock. Others have estimated capital stocks by province and for three types of asset (Holz and Sun, 2017). There appears to be only two studies that provide estimates of gross fixed capital formation and capital stock on a sectoral basis. (Wu, 2015) provides a breakdown into 37 sectors with two assets per sector but it is limited to the period 1980 to 2010. The Penn World Tables provide a breakdown of the capital stock into four assets but with no sectoral breakdown. The objective of this note is to provide estimated of capital formation and the capital stock for four sectors (housing, infrastructure, government and business) for the period 1952 to 2016.

Estimating the capital stock

An estimate of the capital stock has been made using by cumulating gross fixed capital formation from a base year and deducting the extent to which the capital stock falls in value as time passes.

This methodology, known as the perpetual inventory method, requires the following information:

- The value of the capital stock in an initial year.
- A continuous series for the value of investment (known technically as gross fixed capital formation) broken down into sectoral detail.
- A set of price indices that can be used to convert nominal investment outlays into real outlays.
- A measure of the extent to which different types of assets fall in value over time.

The nature of the dependence of the capital stock on investment, the growth rate of investment and the depreciation rate is shown in Box 1. The inherent nature of the perpetual inventory means that for periods of time long-removed from its starting point, the current value of the capital stock is almost independent of the initial value of the capital stock. In addition, when there have been long periods of rapid growth in capital formation, as in China, the impact of different rates of depreciation on the estimates of the current growth rate of the capital stock is very limited – though the level of the capital stock does depend on the depreciation rate to a limited extent.

Initial capital stock

A number of authors have presented estimates of the capital stock over time. All have made an estimate for the capital stock in 1952 when investment data first became available (Table 1). Several researchers used material published in Chinese sources while others use estimates based on cross-country comparisons or based on estimates derived from investment flows and depreciation rates. Others preferred to make an assumption based on introspection.

Previous estimates

The coverage and methodology used in these studies is very variable. About half of the studies focus on the economy-wide capital stock and so include both the housing stock and government investment in assets such as offices, schools, hospitals and roads. Overall, the variation of the estimates is too large to be a guide (Table 2). Moreover, many of the estimates are based on introspection rather than original sources. In addition, only four studies provide a sectoral breakdown of capital stock in 1952 (Table 3). One book provides a compendium of economic statistics (Chen) with data on investment and capital stocks for the period 1948 to 1958. This book provides the details of the original Chinese sources which are either in the form of articles by the statistical bureau or academics or reports in official newspapers. None of the reported sources provides an estimate for the capital stock in the government sector.

Box 1 The dynamics of creating an estimated capital stock for China

The evolution of the capital stock over time is given by the formula shown below

$$K_t = K_0(1-\delta_1)^t + I_0(1-\delta_1)^t + I_1(1-\delta_1)^{t\text{-}1} + I_2(1-\delta_1)^{t\text{-}2} \dots\dots$$

where K_0 *is the initial capital stock,* I_t *is the level of gross fixed capital formation at time* t *and* δ *is the depreciation rate.*

For simplicity, let $I_t = I_0(1+\gamma)^t$, *for all* t.

Then

$$K_t = K_0(1-\delta_1)^t + I_0(1+\gamma)^0(1-\delta_1)^t + I_1(1+\gamma)^1(1-\delta_1)^{t\text{-}1} + I_2(1+\gamma)^2(1-\delta_1)^{t\text{-}2} \dots\dots$$

Or

$$K_t = K_0(1-\delta_1)^t + I_0(1+\gamma)^t \left[\frac{(1+\gamma)^0(1-\delta_1)^t}{(1+\gamma)^t} + \frac{(1+\gamma)^1(1-\delta_1)^{t\text{-}1}}{(1+\gamma)^t} + I_2\frac{(1+\gamma)^2(1-\delta_1)^{t\text{-}2}}{(1+\gamma)^t} \dots\dots\right]$$

Or

$$K_t = K_0(1-\delta_1)^t + I_0(1+\gamma)^t \sum_{t=0}^{t}\left[\frac{(1-\delta_1)}{(1+\gamma)}\right]^t$$

Given that

$$\lim_{t\to\infty} K_0(1-\delta_1)^t = 0$$

and that

$$\lim_{t\to\infty}\sum_{t=0}^{t}\left[\frac{(1-\delta_1)}{(1+\gamma)}\right]^t = \frac{1}{\left\{1-\left[\frac{(1-\delta_1)}{(1+\gamma)}\right]\right\}}$$

It follows that

$$\lim_{t\to\infty} K_t = \frac{I_0(1+\gamma)^t}{\left\{1-\left[\frac{(1-\delta_1)}{(1+\gamma)}\right]\right\}}$$

Hence, after a sufficiently long period, and for a fixed path of investment, the growth rate of the estimated capital stock is not affected by the choice of the depreciation rate. However, the choice of the depreciation rate will generate an eventual difference in the estimated level of the capital stock (d) *which is given by*

$$d = \frac{1-\left[\frac{(1-\delta_2)}{(1+\gamma)}\right]}{1-\left[\frac{(1-\delta_1)}{(1+\gamma)}\right]}$$

In the case of China, where the average compound growth rate of investment between 1952 and 2015 was 9.7%, the eventual difference (d) in the estimated level of the capital stock, with depreciation rates of 5% and 10%, will be equal to

$$d = \frac{1-\left[\frac{(1-0.05)}{(1+0.097)}\right]}{1-\left[\frac{(1-0.1)}{(1+.097)}\right]} = \frac{1-\left[\frac{(0.95)}{(1.097)}\right]}{1-\left[\frac{(0.9)}{(1.097)}\right]} = \frac{1-0.865998}{1-0.820419} = \frac{0.134002}{0.179851} = 0.746193$$

Table 1 Studies on capital formation in China

Author	Year of Publication	Methodology
Liu and Yeh	1963	Based on capital stock data for 1955 published by the State Statistical Bureau in 1957, back-cast to 1952 using investment data.
Chow	1993	Based on data for 1952 of the original value of the fixed capital stock of state-owned units published in the Statistical Yearbook.
Wu	2016	Partially based on the 1951 census of national assets
Baillu, Kruger *et al*	2016	Based on growth rate of investment and depreciation rate
Maddison	2007	Based on his own estimates of investment in the pre-revolutionary period.
Perkins and Rawski	2008	Capital-output ratio set at an assumed level
Perkins	1998	Capital stock set a multiple of net material product in 1952
Wu Yarwi	2016	Assumes capital stock of zero in 1900, uses an estimated series for investment between 1900 and 1952 to generate a capital stock in 1952.
Jun *et al*	2004	Based on growth rate of investment and assumed depreciation rate
Feenstra *et al*	2016	Based on cross-country analysis for Penn World Tables

Table 2 Estimates of the capital stock in 1952

Author	Capital Stock current prices 1952	Capital-output ratio 1952	Comments
Studies that exclude housing			
Liu and Yeh	55.9	0.7	Excludes government
Chow	76.6	0.9	Excludes government
Wu	160.0	1.9	Includes government
Maddison	254.0	1.2	Based on his own GDP
Studies including housing and government			
Perkins and Rawski	82.4 or 164.8	1.0 or 2.0	
Perkins	202.1	2.5	
Wu Yarwi	133.8	1.6	
Zhang *et al*	74.8	0.9	
Feenstra *et al*	175.6	2.6	Capital stock is broken down into four asset types

Table 3 Estimates of the capital stock by sector in 1952

Billion yuan, current prices

	Chow	Liu and Yeh	Chen	Feenstra *et al.*	Wu
Published estimates					
Agriculture	45.0	40.9	45.0	..	48.0
Industry	15.9	8.7	15.8	..	12.8
Trade	1.2	1.0	0.2	..	..
Construction	0.3	0.7	..	..	..
Other service sectors and transport	..	..	..	..	99.2
Business sector	62.4	49.9	61.0	..	..
Transport	14.2	13.9	13.9	..	..
Business sector and infrastructure	76.6	63.8	74.9	..	160.0
Supplementary estimates				..	
Government[1]	13.6	13.6	13.6	..	16.5
Housing[2]	69.4	69.4	69.4	..	69.4
Estimates by asset type					
Structures	..	..	..	148.6	..
Machinery	..	..	..	20.3	..
Transport equipment	..	..	..	6.8	..
Whole economy	159.6	146.8	157.9	175.6	281.9
Calculated capital-output ratios					
Business sector	0.9	0.7	0.9	..	..
Infrastructure	0.2	0.2	0.2	..	..
Business sector plus transport	1.1	0.9	1.1	..	2.4
Government	0.2	0.2	0.2	..	0.2
Housing	1.0	1.0	1.0	..	1.0
Structures	..	..	..	2.2	..
Machinery	..	..	..	0.3	..
Transport equipment	..	..	..	0.1	..
Total	2.3	2.2	2.3	2.6	3.6
Memorandum item					
GDP	67.9	67.9	67.9	67.9	67.9

Notes: 1 The capital-output ratio for government is assumed to be the same as that in India in 1975 as calculated in Arestoff and Hurlin (2006).

2 Estimate taken from Herd (2013) adjusted for revisions in data.

Source: See bibliography

Choice of initial capital stock

Three sources have been chosen as giving apparently reliable estimates of the capital stock by Chow, Liu and Leh and Chen. Two further, often quoted sources are also considered: The Penn World Tables (Feenstra *et al.)* and those from Wu (Table 4). The estimates by Chow and Liu and Yeh are firmly based on original sources. They differ markedly in their estimates of the capital stock in the industrial sector. The reason for the difference appears to be that Chow has taken data for the original value of industrial fixed assets (see Chen, 1966, Table 3.2). In Chinese economic series, such data correspond to the concept of the gross capital stock (that is, the original cost of all assets currently in use). Such a definition ignores the impact of depreciation of the value of the asset. However, Liu and Yeh start from a 1955 official estimate of the net capital stock and work backwards to the end of 1952 by deducting net investment. Their estimate can be compared to the original value of the assets and implies a deduction for depreciation of 45%. The estimates for the business sector and infrastructure made by Liu and Yeh have been used in this paper.

These studies have to be complimented by estimates of the capital stock in the housing and government sectors. Estimates for the *residential housing stock* are taken from Liu (1968) based on an extrapolation of estimates of the 1933 rural housing stock together with the ratio of urban to rural rents. His estimate corresponds almost exactly to an estimate of the replacement cost of urban and rural housing after allowance of an arbitrary 50% for depreciation (Herd et al, 2013). Finally, an estimate has been made of the capital stock used in the *government sector*. It is based on estimates of the capital-output ratio for the Indian economy in 1975 (Arestoff and Hurlin). Overall, the preferred estimate for the initial capital stock is CNY 147 billion in 1952 prices, representing an overall capital-output ratio of 2.2.

Depreciation rates

In the absence of published deprecation rates, it has been necessary to make assumptions about the appropriate depreciation rates for capital in China. Depreciation rates serve to measure the extent to which capital is used in a given period. Ideally, this can be measured through collecting the prices of the same type of asset as the asset ages. Here it has been assumed that assets decline in value at a constant geometric rate. In this case, the complete retirement of an asset only occurs after an infinite time period. However, given the observed rate with which price declines with age, the proportion of assets in use after a decade is small except for structures. Many studies have used accounting data to estimate the depreciation rate. This is inappropriate as such figures are a reflection of arbitrary rates set by the tax authorities.

Comparison with other estimates of depreciation in China

Analyses of the performance of the Chinese economy needed to assume a depreciation rate in order to transform annual investments into a capital stock. A literature search found 36 studies (Table 4). These papers presented 42 estimates or assumptions for the national depreciation rate as some studies had different depreciation rates for different periods. Eleven of the studies were in Chinese, the remainder in English. The average depreciation in the English language studies was 5.6%.

A simple meta-regression of the results suggests that there are several trends in the reported assumptions for the depreciation rate. *First*, there is a significant tendency for assumptions about depreciation rates to increase in papers published more recently. The estimated coefficients from the meta-regressions suggest a depreciation rate of 3.2% in 1988, rising to 7.3% for papers published in 2017. Secondly, there is a marked difference in the depreciation rate used between papers published in Chinese (including English language papers that cite Chinese papers as source for their data) and papers in English: the papers published in Chinese or using Chinese sources have an average depreciation rate 3.4 percentage points higher than those in English. The estimates in Chinese papers appear too high to be reasonable. For example, Bai (2006) quotes a depreciation rate of 8% for structures and 24% for equipment, based in service lives of 38 years for buildings and 12 years for machinery (Wang and Wu, 2003).

Table 4 Depreciation rates used to calculate capital stocks

	Authors	Publication date	Depreciation rate	Time period
Chinese language				
	Meng and Wang	2000	5.0%	
	Wang and Fan	2000	5.0%	1952-1999
	Wang and Wu	2003	10.0%	
	Gong and Xie	2004	10.0%	1970-1999
	Zhang *et al.*	2004	9.6%	1952-2004
	Bai *et al.*	2007	10.0%	1952-2005
	Shan	2008	11.0%	1952-2006
	Lei	2009	9.7%	1952-2007
	Ye	2010	10.0%	1952-2008
	Fan	2012	11.3%	1952-2009
	Bai *et al.*	2016	10.0%	1998-2007
	Zhao and Zhong	2017	11.0%	1952-2006
English language				
	Chen *et al.*	1988	3.9%	1952 -1985
	Perkins	1988	5.0%	1953-1985
	Hu and Khan	1997	3.6%	1952-1994
	World Bank	1997	4.0%	1978-1995
	Woo	1998	5.0%	1979-1993
	Hall and Jones	1999	6.0%	1988
	Wang and Yao	2001	5.0%	1952-1999
	Chow and Li	2002	4.0%	1978-1992
	Wang and Yao	2003	5.0%	1952-1999
	Chow and Li	2003	5.4%	1993-1998
	Young	2003	6.0%	1978-1998
	Wu	2004	7.0%	1952-2000
	Islam *et al.*	2006	3.0%	1952-1978
	Holz	2006	3.7%	1953-1977
	Islam *et al.*	2006	4.0%	1979-1992
	Islam *et al.*	2006	5.0%	1993-2003
	Holz	2006	5.9%	1978-2003
	Wu	2007	4.5%	1952-2005
	Zhang	2008	9.6%	1952-2004
	Perkin and Rawski	2008	7.0%/9.6%	1952-2005
	Bulman *et al.*	2011	7.0%	1952-2008
	Cheremhukin *et al.*	2015	5.0%	1953-2012
	Wu	2015	5.2%	1952-2010
	Wang and Zhou	2016	6.5%	1952-1999
	Ma et al.	2016	7.0%	1978-2014
	Bailliu *et al.*	2016	7.6%	1978-2014
	Wang and Zhou	2016	10.0%	2000-2015
	Hong and Li	2017	6.0%	
	Holz and Sun	2017	7.1%	1953-2005
	Holz and Sun	2017	8.5%	2006-2015

Source: Google search.

Approach in this study

None of the depreciation rates in the above studies have firm empirical basis. As a result, the depreciation rates used here have been taken from figures published by the Bureau of Economic Affairs in the United States (Table 5), with the exception of housing where official Chinese depreciation rates are available. The US data distinguish three types of assets at the aggregate level:

- Structures
- Equipment
- Intellectual property

In addition, it distinguishes between the capital stock of general government and the rest of the economy.

Table 5 Non-residential depreciation rates in the United States

Average 1990 to 2015, % per year

	Private sector	Government
Non-residential	8.7	4.6
Equipment	13.9	13.2
Structures	3.0	1.9
Intellectual property	25.1	16.7
Equipment and structures	6.8	3.2

Source: Bureau of Economic Affairs,
https://www.bea.gov//national/FA2004/DownSS2.asp

In this study it has been assumed that the depreciation rates for the Chinese business sector are the same as those for the private sector in the United States. The rates for the US government sector have been used for the government and infrastructure sectors in China, with the same depreciation rate being used for both sectors as the split of investment between structures and equipment is very similar in the two sectors. The US data, however, show intellectual property assets as a separate category, while for China such assets are included in equipment.

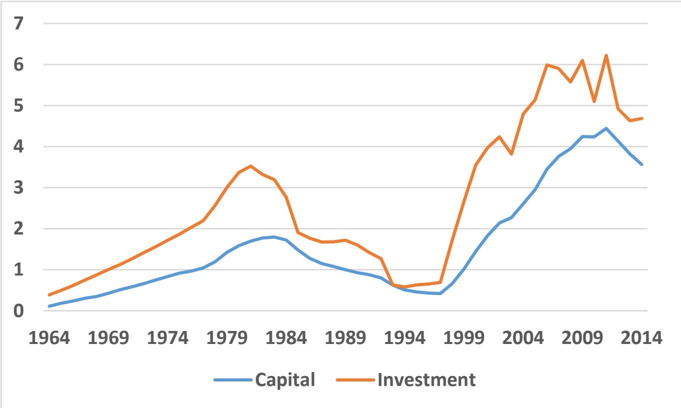
Accounting for software and intellectual property in the capital stock

The official Chinese investment data split investment into two assets: structures and equipment. A growing share of investment in most countries has been in items such as computer software and other items of intellectual property. This type of investment has a very high deprecation rate so, if the growing importance of this type of investment is not allowed for, the depreciation rate for equipment will be understated and the capital stock over-stated.

No official estimates of investment in software and intellectual property are available for China. The authors of the Penn World Tables have estimated the investment flow in such assets by using the commodity flow methodology. Using this approach, for a given product, investment is determined as the sum of production plus net exports less consumption. The authors have also estimated a price index for this type of asset and assumed an average depreciation rate of just over 31% for these assets. On the basis of these assumptions, they find that though the share of this type of asset in the overall investment has grown rapidly, its share of the capital stock of equipment and software is nonetheless quite small (Figure 2). It is, moreover, at 4% much lower than the equivalent share in the United States, which was 34% in 2015. Thus, it would be incorrect to adopt the overall US non-residential depreciation rate for China, but it would be inappropriate to completely ignore the depreciation of the software component of the capital stock in China.

Figure 2 Share of Intellectual property in the capital stock and capital formation in investment

Intellectual property as % of machinery, transport equipment and intellectual property



Source: Penn World Tables version 9.0

Assumptions for depreciation rates

The depreciation rate from the BEA for equipment has been modified to allow for both the share of software investment and research and development in China. It is set as a weighted average of the software depreciation rate used in the Penn World Tables, the depreciation rate for R&D estimated by Li and Hall (2017) and the BEA depreciation rate for equipment in the private sector and government sectors. The weights are the shares of software and R&D in the stock of equipment and software as estimated in the Penn World Tables plus an estimate of the stock of R&D capital (see below). To obtain the overall depreciation for each sector, the modified depreciation rate for equipment is weighted with the BEA rate for structures. The weights reflect the average shares for each type of asset for investment in each sector in urban areas in 2010 (Table 6).

Table 6 Investment share by asset in urban areas

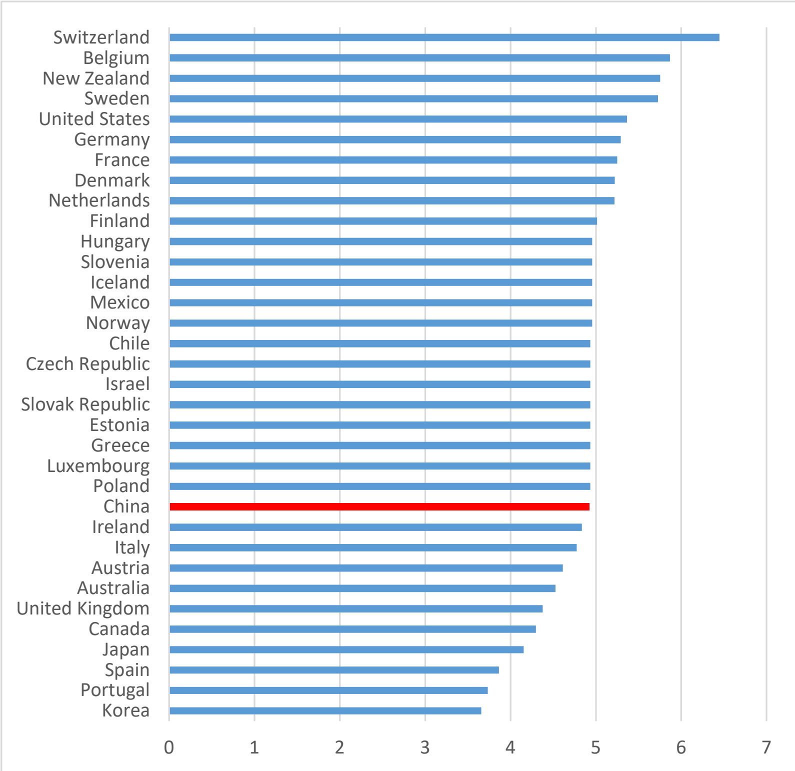
	Business	Government	Infrastructure
Equipment	0.279	0.110	0.110
Structures	0.721	0.890	0.890

Source: CEIC

In 2016, the resulting aggregate depreciation rate for the business sector is estimated at 7.8%, while the rates in the government and infrastructure sectors are estimated at 2.7% and 3.5%, respectively. The impact of including a higher deprecation rate for software and R&D outlays is minimal at around 0.3 percentage point. For the non-residential sector, combining business, government and infrastructure, these assumptions generate a depreciation rate that averaged 4.9% over the decade to 2016. Such a rate is very similar to that observed in countries that are members of the OECD: almost 60% of that group of countries had non-residential depreciation rates that were between 5.2% and 4.8% in the 10 years ending in 2016 (Figure 3).

Figure 3 Non-residential depreciation rates in OECD countries

% per year



Source: OECD Economic Outlook Database, June 2017

Estimates of non-residential gross fixed asset investment by sector

The official Chinese statistics provide estimates for the total nominal value of gross fixed capital formation from 1952 to 2016. There is not any breakdown of the total by sector or by the type of asset. It should be noted, though, that the definition of gross fixed capital formation differs from that found in the standard implementation of the System of National Accounts. In particular, expenditure on a project is counted as capital formation from the start of the project rather than as work-in-progress and being assigned to fixed capital formation when the project is completed and handed over to the final user.

Different measures of capital formation

There is another statistical concept that, superficially, appears close to the concept of fixed capital formation: namely total fixed asset investment (FAI). It has the advantage of being broken down by asset and by sector since 2004 and by asset since 1981. The coverage of this concept is wider than that of capital formation. Most of the items that do not count as part of gross fixed capital formation are included under the heading "other" assets as opposed to being either a structure or equipment. According to Chao (1974), the principal elements included as investment in the category of "other" assets are:

- Cost of acquiring land leases by property developers and factory owners.
- Cost of compensating farmers and village collectives for land acquired for infrastructure.
- Cost of acquiring secondhand assets.

- Labor and training costs during the period between the delivery of an asset and its full entry into service.
- Costs due to the closure or relocation of a facility.

On the other hand, there are two elements of GFCF that are not included in FAI. *First*, residential FAI is measured at the cost of the construction to the property developer. In GFCF, however, it is measured at the cost to the acquirer of the asset. The difference between these two concepts is the gross margin of the property developer (the difference between the construction cost and the selling price). The level residential investment has been corrected by adding this margin to residential FAI (Herd, 2013). *Second*, since July 2016, research and development expenditure has been partially reclassified as a form of final capital expenditure rather than a cost element that is written off against profit in the year when the expenditure occurs. The overall result was to raise the level of GDP by 1.3% in 2016 and to increase the growth rate by 0.06 percentage point in the decade to 2015.

The NBS has not published a detailed breakdown of R&D spending by sector or type of expenditure. However, a comparison of the revisions to fixed capital formation in the 2015 and 2016 Statistical Yearbooks shows that the estimate of R&D expenditure included in GFCF was substantially lower than the estimate of R&D outlays published in the Science and Technology Yearbook. In the decade to 2014, just under 35% of outlays in the latter Yearbook were not classified as R&D. This presumably reflects a decision that a significant portion of development expenditure by companies should be regarded as a cost of production rather than an asset from which future benefits will flow.

A further measure of gross fixed investment can be derived from the data included in the Main Economic Indicators of Industrial Enterprises. This publication gives the results of a monthly census of financial data of all industrial enterprises with sales of over a threshold value that changes over time. The available series includes the balance sheet data for the depreciated historic cost of fixed assets, the cumulated depreciation of the fixed assets and the original value of the assets. The latter series is the sum of the depreciated value of the assets and the cumulative deprecation of the assets. The net value of fixed assets cannot be used as a measure of the capital stock of industrial enterprises because the assets are valued at the historic acquisition cost, though assets acquired before 1998 were revalued to 1998 prices in that year. However, the difference between the original value of the assets at the end of two adjacent years represents the gross increase in fixed capital between the two years less the amount of fixed assets that were scrapped in that year. When assets are scrapped, as opposed to being fully depreciated, the depreciated value is removed from net assets, the original cost of the asset is removed from the original value series and a deduction is made from cumulated depreciation. The scrapping rate has been estimated by Holz (2006). He suggests that if the average asset life is 40 years (which appears reasonable given a depreciation rate of around 6% in the business sector), then the scrapping rate will be 0.2% per year. This scrapping rate has been used in the calculation of investment in the industrial sector using the following identity:

$$\text{Gross fixed capital formation}_t = \text{Original value of assets}_t - \text{original value assets}_{t-1} + \text{scrapping}_t$$

Sectoral estimates prior to 2002

The analytical problem is how to combine the various sectoral investment series in way that generates a series that corresponds to the published overall data for gross fixed capital formation. The methodology adopted here differs for the periods before and after 2003, as definitions of sectors were changed in 2003 and more data on expenditure on different assets has been published since 2003.

Prior to 2003, fixed asset investment (or capital construction prior to 1981) has been calculated from published data for the infrastructure, government and business sectors. A separate estimate has been made for housing GFCF (Herd *et al*., 2013). The sum of these four estimates has then been scaled to be equal to the published data for GFCF.

Sectoral estimates from 2003

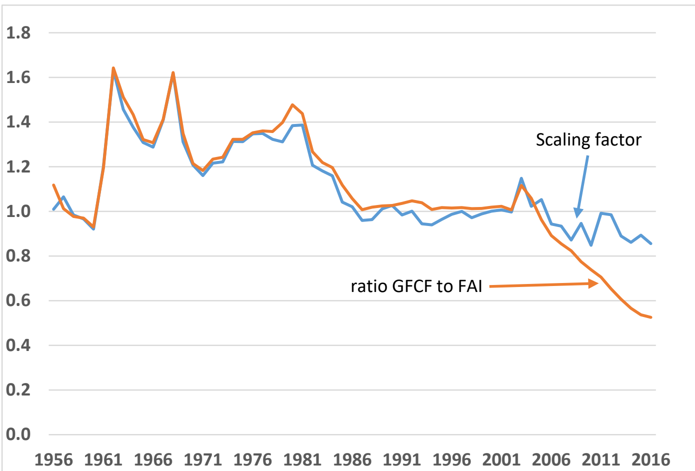
From 2003, the movements in the aggregate data for fixed asset investment are no longer a reliable guide for investment in the national accounts. To obtain sectoral estimates of GFCF, the following methodology has been adopted

- Industrial sector investment is set equal to the change in the original value of fixed assets, plus an allowance for scrapping.
- Service sector investment (excluding housing) is set equal to FAI in urban areas, excluding FAI in the asset type *other.*
- Rural FAI is added to above urban estimates.
- Housing investment is taken from Herd *et al*. (2013).

Comparison of estimates with official data

The resulting estimate for aggregate investment is then scaled to be equal to the official estimate of gross fixed capital formation. Given that the estimate of GFCF includes R&D expenditure, this scaling factor incorporates an estimate of R&D expenditure not included in FAI. The reliability of the sectoral estimates can, to some extent, be judged from the overall scaling factors that have to be applied to the data (Figure 4). The scaling factor is quite large prior to the 1980s but it reflects the same error as in published data and cannot be resolved. For the period between 1980 and 2002, the sectoral estimates are close to the GFCF data. After 2002, the method used to estimate sectoral GFCF generates data that is much closer to the GFCF data than the FAI series, which by 2016 was almost double the official data for gross fixed capital formation. By contrast, the difference between the sectoral estimate of GFCF and the published data was smaller at 17% in the same year. Indeed, the cumulated sectoral estimate of GFCF from 2011 to 2016 was only 12% greater than the published estimate of GFCF, while cumulated FAI in the same period was 75% greater than GFCF. The adopted methodology has thus removed most of the discrepancy between the FAI data and that for GFCF.

Figure 4 Scaling factor applied to estimated sector GFCF and ratio of GFCF to total fixed asset investment



Source: NBS and author estimates.

Choosing sectoral price deflators

An official price deflator for sectoral gross fixed capital formation is not available for the whole of the period since 1952. Even at the aggregate level, a deflator is only available for the period 1952 to 2004. Since then the NBS has only published a deflator for the sum of fixed capital and inventory investment. On the other hand, it has published a national price index for fixed asset investment continuously since 1989. This series has sub-indices for three separate assets: construction, equipment and other assets. Given the difficultly in interpreting whether such investment should be included in GFCF, the price index for *other assets* has been ignored.

The price trends for equipment and construction have differed markedly. Between 1995 and 2016, equipment prices fell by 1.1% annually, while construction prices rose by 2.6%. Such large differences in the movement of prices mean that a price index using the base-period expenditure shares for equipment and construction will gradually resemble an index based only on the price of construction expenditure. It will thus understate the extent of differences in the movement of prices between the four sectors of capital formation that should reflect the different shares of construction and equipment in each sector.

There are several methods available to overcome this so-called substitution bias. One method is to change the weights annually, another is to use a Törnqvist price index, which is calculated as the weighted geometric average of the price relatives using arithmetic averages of the value shares in adjacent years. Data for the share of construction and equipment in fixed asset investment exist since 1981. They show a stable trend in the share of construction in national total fixed asset investment over the period 1981 to 2007. After that date, the share of construction reflects the increase in the share of construction intensive sectors in total FAI, as the shares by sector have remained stable. It is only possible to calculate the asset structure of investment by sector in urban areas (which account for almost all FAI) since 2004.

The split the two types of asset (construction and equipment) varies considerably between the four sectors of investment. At the two extremes, construction assets account for almost all real estate investment while equipment accounts for nearly 40% of business sector investment in 2010. Moreover, the value share of different types of assets in total fixed asset investment has remained quite stable over time. Consequently, the price index for the fixed asset investment of the four sectors has been calculated by assuming the shares of different asset types in investment by sector have remained constant since 1981 at their 2010 levels (Table 7).

Table 7 Share of type of fixed asset by economic sector

2010

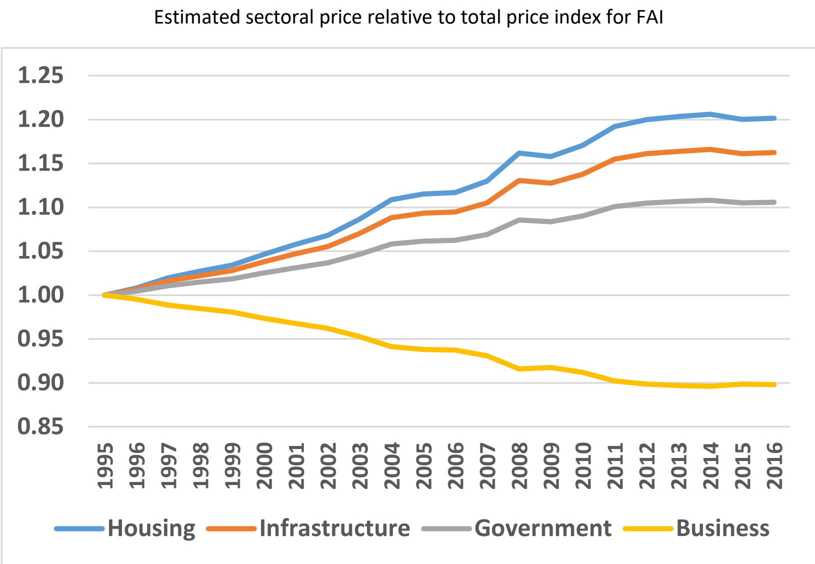
	Construction	Equipment
Business	0.602	0.398
Infrastructure	0.938	0.062
Government	0.873	0.127
Real Estate	0.981	0.019
Overall	0.742	0.258

Source: NBS

Given constant expenditure shares, the sectoral Törnqvist price index reduces to a geometrically weighted average of the construction and equipment indices using the 2010 weights. In the two decades ending in 2016, housing investment rose in price by 0.9% per year relative to all investment goods as a result of consisting almost entirely of structures (Figure 5). At the other extreme, business sector prices fell in relative terms by 0.5% per year due to the high share of expenditures on equipment. The relative prices of investment in the infrastructure and government sectors rose by 0.7% and 0.5% per year, respectively.

There is thus a substantial gain in accuracy from using sector specific price indices rather than using the same price index to deflate the investment of each sector. For the period prior to 1981 when the price indices for equipment and construction are not available, sectoral deflators have been calculated by assuming that the price of each sector follows the same trend relative to the published deflator for GFCF as did the movement of sectoral price indices relative to the overall price index of fixed asset investment in the period 1995 to 2016.

Figure 5 Sectoral price indices for fixed asset investment



Source: Author estimates based on NBS data.

Results

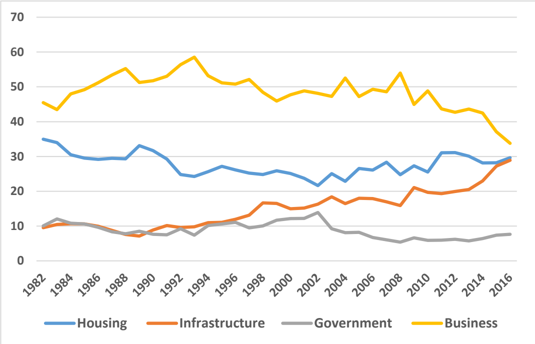
Investment flows

The estimates of sectoral investment flows quantify the marked re-orientation of the structure of capital formation in China in the past decade. There has been a shift away from investment in the business sector towards investment in housing and infrastructure (Figure 6, Panel A). A number of factors have driven this change. In the business sector, the rate of investment depends crucially on the expected growth of the economy. A fall in the expected growth rate of the economy will result in business sector investment dropping until it reaches a level that brings the growth of the capital stock to be once again in line with the lower expected growth of the economy. Indeed, in the period 2008 to 2016, economic growth slackened, from around 9.6% to about 6.7%. With growth slackening, enterprises lowered their expected need for capital and this resulted in a sharp drop in business sector investment from an estimated 20% of GDP in 2008 to 16% in 2016 (Figure 6, Panel B).

Figure 6 Share of investment in different sectors

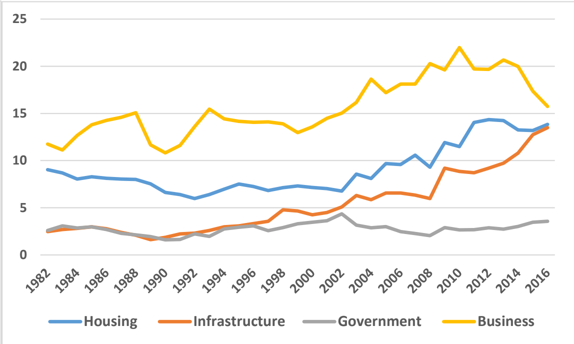
A. Share of total gross fixed capital formation (GFCF)

%



B. Sectoral GFCF as share of GDP, constant prices

%



Source: Author estimates

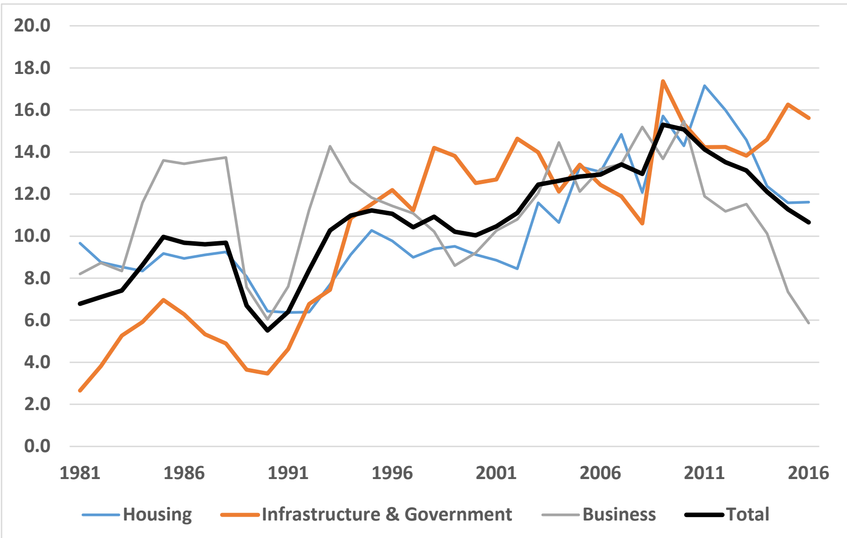
However, the fall in business investment has been offset by a surge in capital formation in other sectors of the economy. Following the introduction of a private housing market at the turn of the century, private capital formation in the residential sector started to increase rapidly from 2004 onwards. By 2015, capital formation in the residential sector was greater than that in the business sector of the economy. Rising demand for new housing generates a strong demand for infrastructure outlays in urban areas as the public finance laws force the profits made by local governments from land sales to be largely invested in urban infrastructure and government-owned land has been used as security for borrowing to finance further infrastructure outlays.

Capital stock

The estimates show an acceleration in the growth of capital starting in 2000. This acceleration was most pronounced following the investment package introduced in 2009 (Figure 7). In the five years to 2011, capital grew by 14% annually with similar increases in the business sector and the rest of the economy. As the impact of the stimulus on the economy faded, economic growth slipped and brought a marked decline in the growth rate of the capital stock in the business sector. However, in the remainder of the economy, the very rapid growth of the capital stock did not slacken. The gap between the growth of the capital stock in housing, infrastructure and government and that of GDP rose from 3.7 percentage points between 2006 and 2011 to 6.7 percentage points in the five years ending in 2016.

Figure 7 Growth of the capital stock by economic sector

% per year



Source: Author estimates

Capital-output ratio

The consequence of these very different sectoral trends has been that the overall capital-output stock of government assets (schools, hospitals and offices *etc*.) has only grown slightly faster than GDP, with the ratio of the capital stock to overall GDP remaining low at between 0.2 and 0.3 (Figure 8, Panel A). The increase in the overall capital-output ratio has been driven by the significant rise in the capital-output ratio in the infrastructure sector, predominately related to assets for transport and urban development.

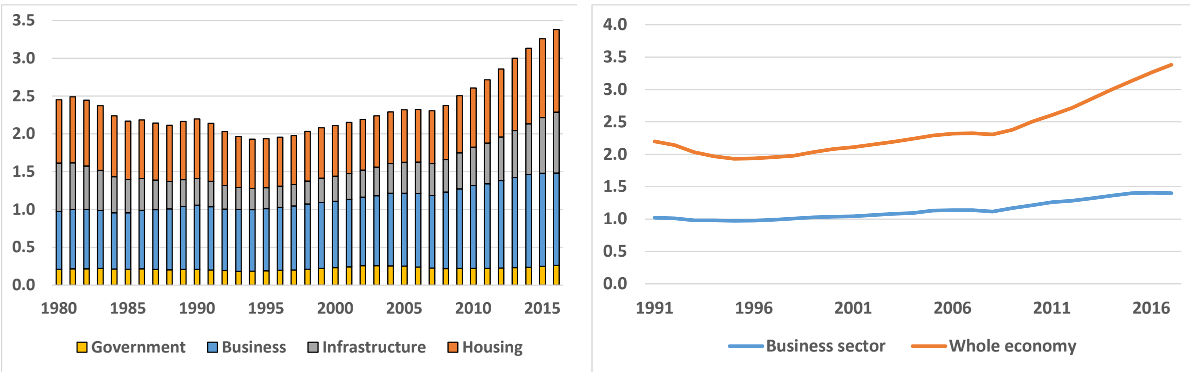
The housing sector has been the other source of the rise in the overall capital-output ratio. Prior to the reform of the housing sector at the turn of the century, investment in housing had been neglected. Housing investment picked up markedly a decade ago. Given the rapid increase in GDP after the country's entry into the WTO, the pickup in growth of housing stock did not, at first, generate an increase in the ratio of the housing stock to GDP. Housing investment rose to a new high in 2007, fueled by expectations that rapid price rises would continue. This coupled with a slackening in the growth of GDP has resulted in a steady increase in the ratio of the housing stock to GDP from 2007 onwards (Figure 8, Panel A). The business sector capital-output ratio has increased somewhat whether measured relative to total GDP (Figure 8, Panel A) or relative to GDP in the business sector (Figure 8, Panel B).

Figure 8 Capital-output ratio by economic sector

Constant prices

A. Capital stock by sector as ratio of total GDP

B. Capital stock by sector as ratio of sectoral GDP

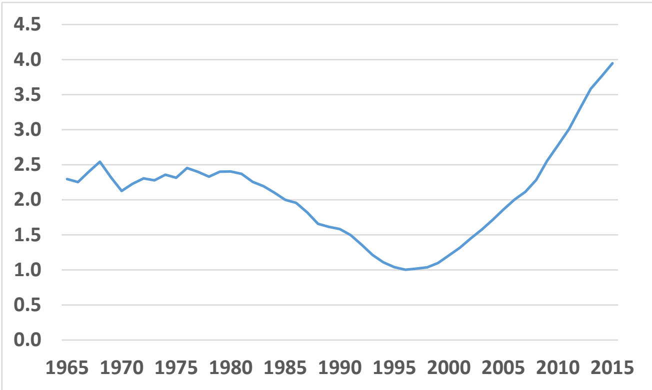


Source: Author estimates using NBS data

The above estimates include an estimate for the stock of R&D capital. The stock of this type of capital is, however, quite small. Using the revisions to the estimates GFCF published in 2016 and the estimate of the average depreciation rate for R&D expenditures in the United States, which Li and Hall (2017) put at 28% per year, the stock of R&D capital can be estimated for China. Over the past two decades, the stock has risen sharply but still amounts to only slightly below 4% of GDP, accounting for about 2½% of the capital stock in the business and government sectors (Figure 9).

Figure 9 R&D capital stock

% of GDP, constant 2010 prices



Source: NBS (2016), Statistical Yearbook 2016 and 2015, Science and Technology Yearbook

The definition of infrastructure used in the above estimates attempts to exclude investment in the vehicles purchased to use transport infrastructure by enterprises in the transport sector. It assumes that the higher ratio of investment in equipment in the transport sector relative to other infrastructure sectors is due to investment in vehicles. This investment is reassigned from the infrastructure sector to the services sector.

Incremental capital-output ratios

The rise in the overall capital-output ratio is associated with a rise in the incremental capital-output ratio (ICOR) – a measure of the productivity of capital. It is measured as the investment share divided by the growth rate. Conceptually investment should be measured net of depreciation but here it is measured on a gross basis, following a methodology used in many cross-country studies. In order to calculate sectoral ICORs, estimates have been made of sectoral GDP.

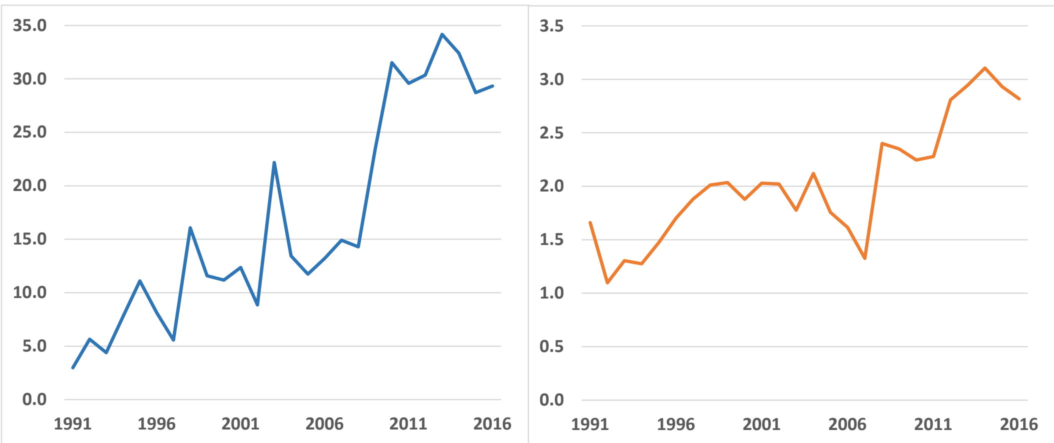
This rise in the overall ICOR has been driven by very different trends in the various sectors of the economy (Figure 10). The contrast between the ICOR in the housing, infrastructure and government sectors and the business sector is very striking both in terms of the level and the trend. The housing, infrastructure and government sectors have an ICOR that was nearly 14 times higher than in the business sector in 2016. During the recent slowdown in the economy, the incremental capital-output ratio in the business sector has risen, despite the fall in the growth rate of investment.

Figure 10 Incremental Capital-Output ratio by sector

Four year moving average

A. Infrastructure, government and housing

B. Business sector (**scale changes**)



Source: Author estimates

Sensitivity of the estimates to assumptions

General sensitivity with respect to depreciation

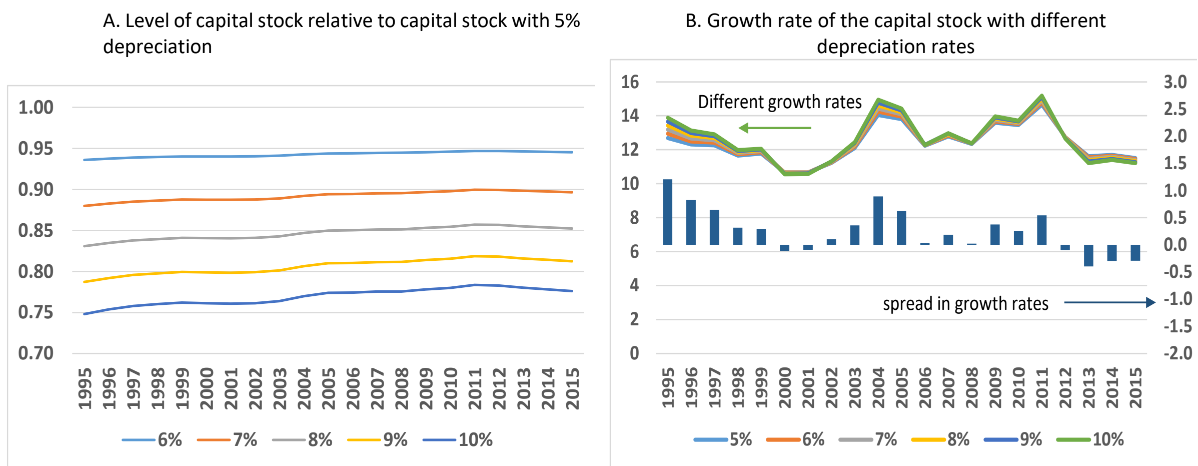
There are a large number of assumptions for both the depreciation rate and the initial capital stock in the literature. For depreciation, the estimates vary between 3% and 10%. A meta-regression for the 42 identified published estimates suggests that assumptions about the depreciation rate have drifted upwards over time: from 3% in 1988 to 7.2% in 2017, with an average for English language estimates of just over 5%, consistent with the international experience and with the estimates used in this paper. If the published paper is in Chinese, or directly cites Chinese sources, then the estimate of the depreciation is 3.4 percentage points higher than the estimates in English language papers.

Given these differences, the sensitivity of the capital stock estimated in this paper to different assumptions about the initial capital stock and depreciation rates has been estimated. The estimates of the capital stock in the past two decades are almost completely unaffected by estimates of the initial capital stock given the rapid growth of investment in China since 1952 and the impact of the depreciation of the initial capital stock over time. Indeed, a doubling of the capital stock in 1952 would raise the estimated level of the capital stock in 2016 by only 0.02%.

The estimated level of the capital stock is more sensitive to the depreciation rate than to the initial value of the capital stock. The extent of the dispersion in estimates of the capital stock using the perpetual inventory method depends on the growth rate of investment over the time period for which the capital stock is estimated as well as the depreciation rates. A high growth rate of investment moderates the difference in estimated capital stocks due to assumptions about depreciation to a significant extent. For example, with a 5% depreciation rate and zero investment growth, the estimate of the capital stock will eventually converge to be half the estimate with a 10% depreciation rate. However, if the annual compound growth rate of investment is 10% (close to the 63 year average growth in Chinese capital formation), the difference in the eventual level of the capital stock will be reduced to one-quarter (see Box 1 for the derivation of this result). Moreover, the convergence to the long-run difference will be much quicker with the 10% investment growth rate than with zero growth.

With the path of sectoral investment estimated in this paper, the difference in the levels of the capital stock had converged to close to their expected long-run values by 2005 (Figure 11, Panel A). The consequence of this quick convergence of the ratio of the different estimates of the capital stock to the estimate with 5% depreciation is that over the period 1995 to 2015, there is very little difference in the growth rates of the different estimates of the capital stock contingent on different depreciation rates. From 1998 onwards, the spread between the highest and lowest estimated growth rates is rarely greater than 0.5% (Figure 11, Panel B).

Figure 11 Sensitivity of capital stock estimates to changes in the depreciation rate



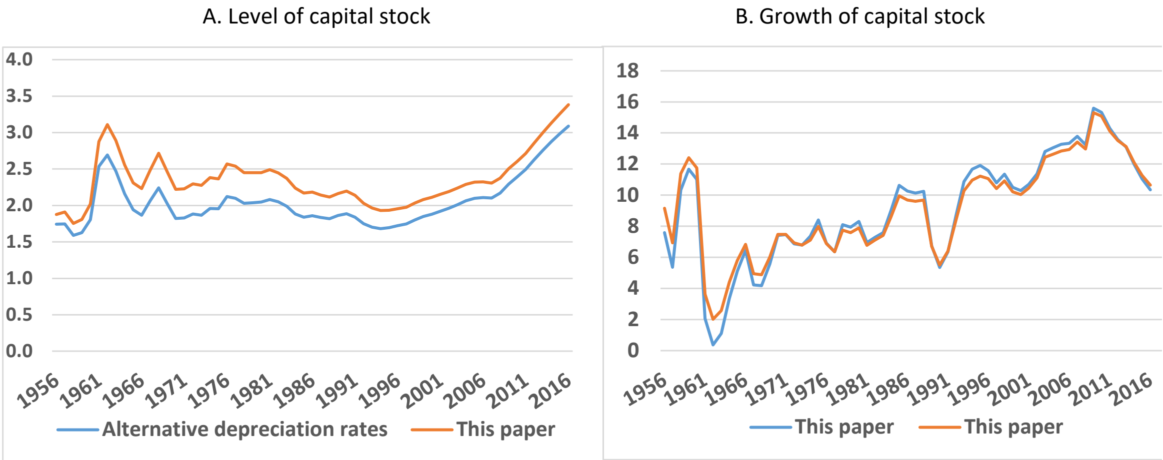
Source: Author estimates using data defined above

Results using the depreciation rate of Holtz and Sun

Although, the theoretical arguments above suggest a limited impact of the depreciation rate on the evolution of the aggregate estimated capital stock, there could nonetheless be more sensitivity at the sectoral level. Among recent papers, one by Holz and Sun (2017) is particularly complete both in terms of the different models of depreciation that have been used and for building national data from provincial level data. The authors use the three assets enumerated in official sources (structures, equipment and other). In their standard geometric depreciation rate model, the authors assume a depreciation rate of 5% for structures, 12.5% for equipment and 8% for the asset category "other."[1] However, it is doubtful that the asset category "other" represents gross fixed capital formation (see above). Sectoral depreciation rates consistent with these asset depreciation rates have been calculated using the sectoral shares of each asset, giving a depreciation rate for housing of 5.0%, infrastructure and government of 6.2%, while that for the business sector is slightly higher at 7.3%. In aggregate, this study generates a time-varying depreciation rate that rises to an average of 4.9% in the decade to 2016.

The impact of using the Holz and Sun depreciation rates, weighted sectorally, on the estimated capital state stock is small (Figure 12). By 2016, the estimated capital stock using the alternative depreciation rates is just 9.5%. However, most of this difference emerged before 1970. Indeed, by 1995, the estimates based on alternative depreciation rates were already 11.2% below the estimates in this paper. As a result, the difference in the growth rates of these two estimates of the capital stock was only 0.08% per year in the past decade.

Figure 12 Impact of differing depreciation rates on estimates of capital stock in this paper



Source: Author estimates,

Note: The alternative depreciation rates are those suggested by Holz and Sun (2017).

Comparison with alternative estimates of the capital stock

Estimates by Holz and Sun

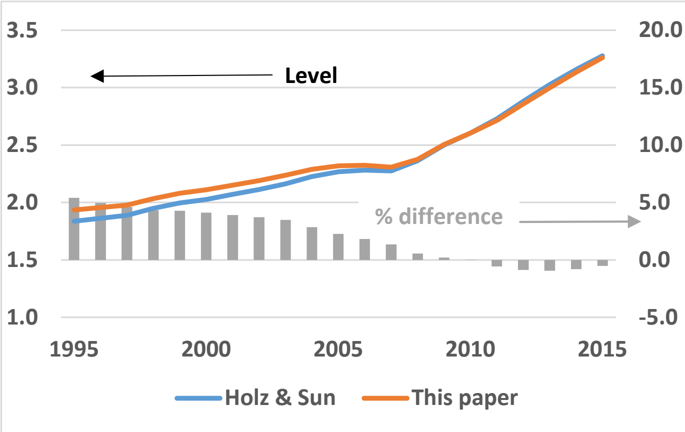
The sectorally-based capital stock estimates made in this paper can be compared to the asset and province based estimates by Holz and Sun. In fact, for the 20 years ending in 2015, the estimates for the total capital stock in this paper are very similar to the overall capital stock produced by Holz and Sun (Figure 13). However, for the period 1952 to 1972, the estimates differ very sharply from those estimated in this paper due to the much lower estimate of the initial capital stock. Once this difference has been eroded due to depreciation of the initial capital stock and rapid growth of investment, the estimates of the capital stock correspond quite closely to those presented in this paper. In terms of

[1] Holz and Sun (2017), footnote 27.

the capital-output ratio, by 2016, the estimates presented here are less than 1% different from those generated by H&S. Moreover, over the period 1995 to 2005, the average compound growth rate of the capital-output ratio differed by just 0.2% per year (2.9% against 2.7%).

Figure 13 Two estimates of the capital-output ratio

This paper and Holz and Sun



Source: Holz and Sun (2017) and author estimates

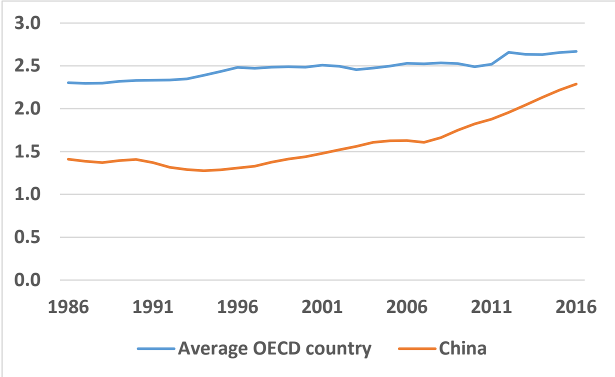
Estimates by Wu et al.

While the estimates in this paper agree with those of Holz and Sun, there are substantial differences relative to the estimates published by Wu *et al.* (2016) and Bailliu *et al.* In the former case, the non-residential capital stock is shown as growing more rapidly than the estimates in this paper (Wu *et al.* put the average annual compound growth between 1990 and 2010 at 15% against an estimate of 12% in this paper). While the estimates for the non-residential capital stock in Bailliu et al. for the period 2004 to 2014 are similar to those in this paper, their estimates for both the growth and level of the total capital stock are lower than those in this paper and grow less rapidly – indicating a difference in the estimate of the capital stock in the housing sector. By 2014, the capital stock in this paper is estimated to be 5% higher than the estimates in the Penn World Tables.

International comparisons of capital-output ratios

The extent to which there has possibly been over-investment in China can be judged domestically by the rates of return, but cross-country comparisons of capital-output ratios can also provide evidence to judge the level of Chinese investment. The OECD publishes data on the non-residential capital stock covering 28 of its member countries for the past two decades and data for somewhat fewer countries for the previous decade. The OECD data show that the average non-residential capital-output ratio for its members was around 2.6 for the five years ending 2016. However, this estimate is based on a capital-services definition of the capital stock rather than the balance sheet estimate definition used in this paper. While the comparable capital-output ratio for China has steadily increased over the 20 years prior to 2016, as infrastructure investment rose, its level is nonetheless slightly below that in the OECD area at 2.3 (Figure 14).

Figure 14 Non-residential capital-output ratios in the OECD area and China



Source: Author estimates and OECD Economic Outlook Database

Infrastructure and government and residential sector capital-output ratios

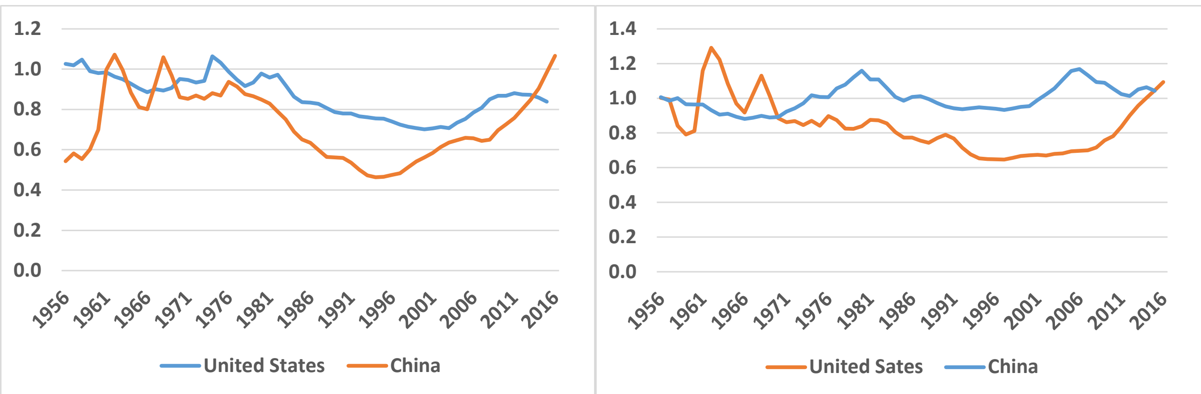
Across countries, there is much less information available that would permit a comparison of the capital stock in the government and infrastructure sectors. Information is available for investment in the general government sector but not all infrastructure is undertaken by the general government sector. Moreover, at the industry level, few countries publish detailed capital stock data that would enable an exact comparison to be made with these estimates for China. Cross-country comparisons are complicated by the differences in the classification of infrastructure investment across countries. One country, the United States, does publish estimates for the non-residential capital stock in the private sector by industry and for the total government sector. However, some of the sectors shown as infrastructure in China are in the private sector in the United States. Moreover, even in the United States, no industrial breakdown of the private sector capital stock has been published for the years after 2001.

An approximate comparison between China and the United States of the combined capital stock in the government and infrastructure sectors can be made. It requires an assumption that private infrastructure has remained a constant share of private non-residential investment since 2001. On this basis, the capital-output ratio for the infrastructure and government sector in China had reached the same level as in the United States by the beginning of this decade (Figure 15, Panel A). Since then, it has moved steadily above the level in the United States.

Figure 15 Capital-output ratios in the United States and China

A. Infrastructure and government

B. Housing



Source: BEA Fixed Asset Database and author estimates for China

In the housing sector, the capital-output ratio was below that in the United States until 2010 (Figure 15, Panel B). Since then the ratio for the housing sector in China has moved above that in the United States and this development will continue unless there is an abrupt fall in housing investment in China.

Total factor productivity growth by sector

The incremental capital-output ratio is one measure of the efficiency with which capital is used but it is only a partial measure of the productivity of the economy. The overall efficiency of the economy is better measured by the productivity of both labor and capital – total factor productivity. Most growth accounting studies use the total amount of employment as the labor input and add a separate variable that measures the qualifications of the overall labor force. But the overall labor force is far from being homogenous. The growth accounting analysis assumes competitive markets, so employee compensation is assumed to reflect marginal productivity.

There is a long history of not using just the numbers employed as a measure of labor input. Kendrik (1956) argued for weighting physical labor inputs by a baes-period average compensation which, as Denison (1961) pointed out, enables the contribution of structural change in the distribution of labor in the economy to productivity growth be, at least partially, eliminated. Jorgenson (1991) argued for a much fuller decomposition of labor input covering education, age and gender with each input weighted by compensation.

Labor quality indicators

A full decomposition of labor inputs by sector would be difficult to achieve in China due to lack of underlying data and restricted publication of data from labor market surveys. However, Wu *et al.* (2015) have published estimates of average employee compensation by industry, which can be taken as a proxy of the quality of labor input by sector. Such data permit a breakdown of employee compensation by the sectors used in the analysis of capital formation (business and government/infrastructure). However, the business sector itself is far from homogenous. In particular it contains two extreme sectors, agriculture and sectors dominated by industrial SOEs (coal mining, petroleum extraction, tobacco, petroleum refining, transport equipment and utilities). The wage levels in these two sectors differ by a factor of over five. Consequently, changes in the share of employment in agriculture will change the average level of compensation, which is being taken as measure of the quality of the labor force.

Table 8 Employment growth absolute and weighted by sectoral employee compensation

	Employee compensation	Employment	Employment	Employment weighted by average compensation
	level, CNY per year, 2010	Millions, 2010	Growth pa 1990-2016	Growth pa 1990-2016
Business	20,031	687.3	0.6	1.2
Agriculture	15,383	279.3	-2.3	--
Remainder	20,650	408.0	3.5	--
Government and Infrastructure	29,871	73.7	1.1	--
Whole economy	21,523	761.1	0.7	1.2

Source: NBS and Wu (2015) for Industrial SOEs and government/infrastructure

Labor input into the business sector on a weighted basis grows faster than the unweighted series as there is a move out of agriculture into the rest of the business sector (Table 8). Hence the growth in business sector productivity is slightly faster when measured with a weighted labor input than when measured with an unweighted input. Similarly, in the whole economy quality adjusted labor input grows faster than the numbers employed.

In addition to the impact of changes in the industrial structure of employment, the skill level of the labor force has been steadily increasing, with the average number of years of schooling of the population aged 25 to 64 rising by 1.2% per year. International experience suggests that an additional year of education raises the level of earnings (hence productivity) by 7%.[2] On this basis, the years of education series has been transformed to a human capital index by exponentiating the rate of return by the number of years of education. Such a transformation halves the growth rate of human capital relative to the growth of earnings.

Income shares

A measure of total factor productivity also requires a weighting system to combine capital and labor, usually taken to be the share of value-added coming from labor and capital. Such data are provided by the Chinese input-output table but not in enough detail to isolate the sectors used in this study. Wu et al (2015) have provided a slightly more granular IO table covering 37 industries from 1990 to 2010, with nine observations corresponding to the published IO tables. These sectors do not correspond exactly to those used in this paper for two reasons: culture, entertainment and household services are classified as one sector by the CIP data while this paper has allocated culture and entertainment to the government sector. As the bulk of value-added in the CIP sector comes from household services, this sector has been allocated to the business sector. Secondly, the housing sector is kept as part of the real estate sector in the CIP data. In this paper, the housing sector is excluded from real estate by deducting capital consumption of housing from the CIP real estate sector and its addition to the government and infrastructure sectors. The overall result is to show the compensation share to be just over half between 1990 and 2010 with a falling trend between 1997 and 2007 as reforms steadily raised efficiency and profitability (Table 9). Over the following five years there was a slight recovery in the labor share in business sector value-added.

Table 9 Share of value added at basic prices

Average 1990 to 2010

	Business	Government, Infrastructure, housing	Whole economy
Compensation of employees	0.544	0.595	0.554
Operating surplus	0.287	0.136	0.261
Capital consumption	0.169	0.269	0.185
Value added at basic prices	1.000	1.000	1.000
Production taxes	0.198	0.056	0.189

Source: Wu *et al.* (2015) CIP project and NBS.

Using these shares, the total factor input for the two sectors and the whole economy has been calculated and so the level of total factor productivity has been calculated year by year from 1990 to 2016. The resulting series can be volatile depending on the cyclical position of the economy. To view

[2] In China, empirical estimates suggest that the average increase in earnings per year of schooling increased from around 2.5% per year in 1990 to 10% by 2004 and has remained at that level since then. On average, this time path corresponds to the average increase in earnings of 8.0% per year (Wang and Yue, 2009, quoted in ADB 2015).

the underlying trends better, the original data have been smoothed using an HP filter in an attempt to extract the underlying trend in total factor productivity.[3]

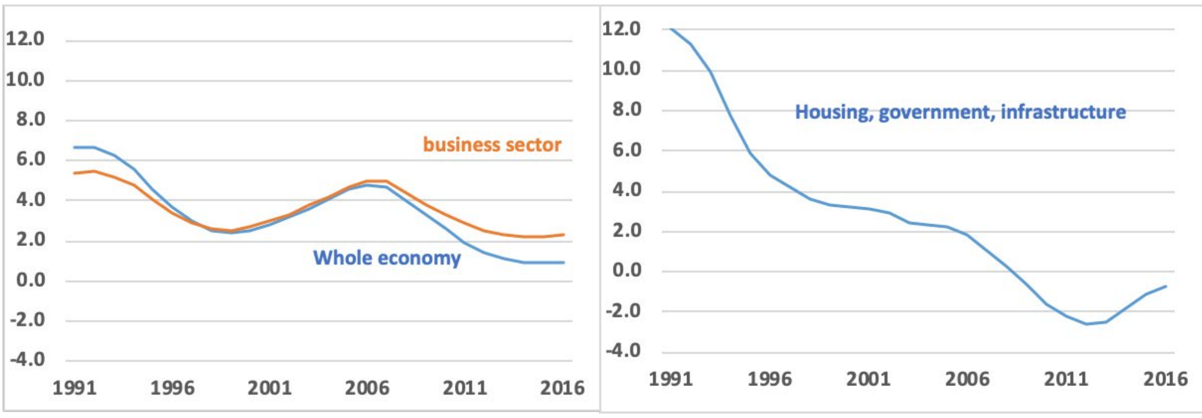
Sectoral estimates of total factor productivity

The results of the disaggregated analysis of TFP show that the business sector of the economy has shown much less of a deterioration of productivity than the whole economy where the decline in TFP growth has been massive (Figure 16). In the business sector, the pattern of trend TFP growth appears to be driven by the evolution of economic reform over time. The initial impact of the reforms of the 1980s and early 1990s had petered out by the end of the 1990s with TFP growth in the business sector dropping to 2¾% pa, once allowance is made for the positive impact of the move of labor out of agriculture and the increase in skill levels of workers. The new wave of reform was underway at the turn of the century and TFP growth picked up, peaking in 2006. As new reform initiatives were not forthcoming, the underlying growth of TFP in the business sector eased, dropping below its pre-reform pace by 2016.

For the economy as a whole, the decline in underlying TFP growth has been even more dramatic. In the period of the 12th Plan, it only grow by 1% pa, far worse than the performance in the four previous plan periods. Indeed, the growth was only slightly faster than that seen in the period before 1978 when the economy was still under centralized control. The first year of the 13th Plan did not show any significant signs of an improvement in the growth of productivity, after allowing for the impact of human capital and structural change.

Figure 16 Trend TFP growth by economic sector, allowing for structural shifts and human capital

% change per year



Source: Author estimates

Such an evolution suggests that the structural reforms of the economy started in 1998 have not generated a long-term increase in the growth of TFP but rather generated a once-and-for all increase in the level of TFP in the business sector. The cumulative increase in the level of TFP, above what it might have been had not TFP growth risen, is estimated to amount to just under 30% – about one and a half points per year during the period when reform was having an impact. This does not represent the full impact of the reform on business sector GDP as reforms facilitated the movement of labor from agriculture so boosting labor quality. In addition, reform generated new investment opportunities as integrating with the world economy become easier, so raising its growth.

[3] The use of an HP filter has often been criticized for its problem in inadequately handling end and beginning points of data series. Hamilton (2016) provides both a summary of the drawbacks of the HP filter and a proposal for a different methodology to extract trends.

The fall in the growth of total factor productivity in the whole economy has been much greater than that in the business sector. This is attributable to the poor growth of total factor productivity in the government, infrastructure and housing sectors and their increasing share of total GDP. During the 12th Plan, the growth of total factor productivity in the whole economy was barely greater than 1% per year – half of the growth rate in the 9th Plan, itself a period when the poor performance of state-owned enterprises was holding back growth (Table 10). In the business sector, productivity also fell to below the pace seen during the 9th Plan, emphasizing the need for a new boost to efficiency in the business sector.

Structural change in the economy and the education level of the population have both been powerful factors offsetting the falling growth rate of the labor force. The movement out of agriculture added nearly 0.9 percentage point to the growth rate of the business sector between the 9th Plan period and 2016. Going forward facilitating this ongoing transformation will be a key to offsetting the likely decline in the labor force. The continuing improvement in the average level of education of the labor force is likely to continue as the poorly-educated older age groups retire and are replaced by better educated young people. This process will continue even in the absence of any increase in the proportion of young people in higher education.

Table 10 Sources of growth in the business sector and the whole economy

	8th Plan	9th Plan	10th Plan	11th Plan	12th Plan	
	1990-1995	1995-2000	2000-2005	2005-2010	2010-2015	2016
	Percentage points per year					
Business Sector						
Capital	5.08	4.49	5.27	6.23	4.62	2.63
Labour	0.65	0.65	0.36	0.17	-0.03	0.08
Structural shift	0.65	-0.10	0.00	0.60	0.35	0.77
Education	0.63	0.55	0.31	0.23	0.45	0.49
Total factor productivity	4.99	2.83	3.80	4.28	2.44	2.29
GDP (business)	12.47	8.63	10.00	11.90	8.00	6.40
Whole economy						
Capital	3.95	4.40	4.95	5.77	5.32	4.45
Labour	0.55	0.64	0.39	0.21	0.19	0.11
Structural shift	0.48	0.26	0.42	0.58	0.61	0.30
Education	0.65	0.58	0.30	0.19	0.49	0.49
Total factor productivity	6.19	2.53	3.48	4.21	1.11	1.25
GDP	12.26	8.63	9.80	11.31	7.87	6.70

Source: Author estimates

Conclusion

The growth in TFP in the whole economy has followed a similar pattern to that in the business sector except that, in the past decade, its slowdown has been far more marked. This slowdown can be traced to the evolution of TFP in the economy outside the business sector, which consists of the housing, government and infrastructure sectors. As outlined in previous sections, the growth in the capital stock in these areas has been very rapid and has accelerated in the past decade. This has resulted in measured TFP ceasing to grow and even falling in some years. Most of the investment in these sectors is debt financed. It is the absence of TFP growth in this sector that has generated the need for greater credit growth for the same increase in GDP. Of course, part of the decline in TFP reflects inadequate measurement of output in the sector. Capital used in housing and government-related infrastructure produces a real return but, by design, this return is not included in the official measure of GDP.

Overall, these estimates of sectoral trend growth rates combine to show a potential growth rate of the whole economy in line with government target for overall GDP growth of around 6½ percent (Table 11). A noteworthy feature of these estimates is that while the level of business sector employment has been flat for the past decade, the quality-adjusted labor force has risen by nearly 7%. This reflects the continuing out movement from agriculture.

Table 11 Estimated trend GDP growth rate by sector

	Business sector	Housing, Government, Infrastructure	Whole economy
2012	8.2	7.1	8.1
2013	8.3	6.7	8.1
2014	7.8	6.4	7.6
2015	6.5	6.6	6.5

Source: Author estimates

Note: The whole economy trend is the result of adding the estimated level of trend GDP in the two sectors.

In the next decade, the latest UN population projections suggest a marked fall in the labor force aged 20-54. The scale of outflows from agriculture will need to increase in order to give a bigger boost to the quality of the labor force. In addition, policies designed to keep people in the labor force longer could take advantage of the increase in the 54 to 64 age-group likely in the next decade. The activity rate in this age-group is lower than the younger age-group but even so, it is likely to be sufficiently high to ensure that the quality-adjusted labor force available continues to grow in the period to 2030, with a slowdown of only a few tenths of a percentage point.

The prospects for the growth of the capital stock are more difficult to evaluate since they are clearly endogenous to the performance of the economy. The growth of the business sector capital stock was abnormally low in 2015 due to a poor performance in the industrial sector, some rebound is likely in the short-term, but in the longer-term a rebound in capital formation in the business has to be driven by an increase in total factor productivity.

Annex: Methodology used in the estimations

Definition of sectors

The analysis of capital formation here covers four sectors: businesses, infrastructure, government and housing. National accounts in China distinguish a government sector and a sector that covers non-financial enterprises. It is appealing, but incorrect to use the non-financial corporate sector as a proxy for the business sector. It is wrong because there are three sub-sets of firms in the non-financial sector, a private sector and two sets of which are controlled by the government. Of these two, there are enterprises, across all sectors of the economy, that operate commercially and often have minority shareholders from the private sector but which take into account government policies as well as returns to shareholders. In addition, there is a second group of state-owned companies that provide public services and infrastructure, some of which are known as local government financing vehicles or urban development corporations. These companies rely on subsidies from the government to continue their operations. Under the newer versions of the SNA, such companies should be classed as being part of the government sector, but in the Chinese practice they are still classified as being in the non-financial corporate sector. Moreover, businesses run by their owners are included in the household sector of the economy. As a result, the non-financial sector of the national accounts cannot be used as a proxy for the business sector. Rather, the analysis in this paper is based on an allocation of the economic sectors, as defined in the most recent Chinese Industrial Classification to sectors covering businesses, infrastructure, government and housing. Thus, the sector definition of government here is narrower than the normal definition of general government. Wholly government financed highways, for example, would be allocated to the infrastructure sector. The precise definitions are set out in Table A1.

The definition of infrastructure in this paper is narrow and focusses on services that are provided on a non-commercial basis. Thus, electricity and telecommunications are allocated to the business sector rather than to infrastructure. They are provided on a commercial basis in China, with most of the value-added being created by firms that are listed on either the Shanghai or Hong Kong SAR, China, stock exchanges. On the other hand, railways, toll highways, urban and environmental services are allocated to infrastructure. Enterprises in these are generally publicly-owned and not generally required to cover their full cost of capital. The allocation of industries to the four sectors also has to take into account that data are only available at a high level of aggregation. This leads to some sectors, such as air transport and storage, being allocated to infrastructure rather than to the business sector.

The definition of the government sector used here is also relatively wide in that it includes all scientific research, cultural activities and the activities of non-governmental organizations (NGOs). In the case of cultural and entertainment, this reflects government control of the bulk of these activities. The apparently paradoxical inclusion of NGOs in the government sector is merely a reflection of the Chinese Industrial Classification rather than a statement on the independence of NGOs.

Table A1 Definition of sectors

Business sector
Agriculture, Forestry, Animal Husbandry and Fishery
Secondary sector
Mining
Manufacturing
Production and Supply of Electricity, Heat, Gas and Water
Construction
Service sector
Information Transmission, Software and Information Technology
Wholesale and Retail Trades
Hotels and Catering Services
Financial Intermediation
Leasing and Business Services
Service to Households, Repair and Other Services
Part of Real Estate
Infrastructure
Transport, Storage and Post
Railway Transport
Road Transport
Water Transport
Air Transport
Transport Via Pipelines
Loading, Unloading and Forwarding Agency
Storage
Post
Management of Water Conservancy, Environment and Public Facilities
Management of Water Conservancy
Ecological Protection and Environmental Treatment
Management of Public Facilities
Government
Education
Health and Social Service
Scientific Research and Technical Services
Culture, Sports and Entertainment
Radio, Television, Motion Picture and Video Production
Cultural and Art Activities
Sports Activities
Entertainment
Public Management, Social Security and Social Organization
Organs of Communist Party of China
Government Agencies
People's Political Consultative Conference and Democratic Parties
Social Security
Non-Governmental Organizations, Social Organizations and Membership organisations
Grass Roots Self-Governing Organizations
Housing
Part of Real Estate

Estimating investment flows

Estimates for the period 2003 to the present

For the period after 2002, the steps taken to generate sectoral series for gross fixed capital formation are as follows:

- For the industrial sector, use the industrial enterprise data to measure gross investment in fixed assets measured as the difference between the original value of fixed assets in adjacent years.
- For the service sectors in urban areas, GFCF has been estimated using the fixed asset investment data for outlays on structures and equipment. Outlays on the asset class "other" have been excluded as they are largely outside the scope of the SNA definition of gross fixed capital formation. No data for the asset type "other" could be found for 2003 and so it was assumed that the share of "other" investment in total fixed asset investment in urban areas was the same in 2003 as in 2004 for all sectors.
- For agriculture, the national data for FAI have been used.
- For the industrial and service sectors in rural areas, the difference between the national and urban FAI data has been added to the urban series as defined above. Since 2011, the extent of this additional investment has fallen to a very low level following a change in definitions used by the NBS. No explanation is available for this change but it may be that the NBS has adopted a functional definition of urban and rural areas (as in the population data) rather than a definition based on the administrative status of the local area. Thus, most industrial investment in rural areas may have been reclassified as being in urban areas, reflecting the population density in the area where the enterprise is located.
- The business sector is estimated as the sum of the four estimates above.
- For the government and infrastructure sectors, the FAI data for urban areas have been used excluding the category "other" investment.

Estimates for the period 1981 to 2002

For the period prior to 2003, two different methodologies have been adopted. Between 1981 and 2002, sectoral FAI data have been used as a proxy for gross fixed capital formation without any adjustment, including for the industrial sector. Between 1952 and 1980, data for new capital construction have been used. The growth rate for this series has been used to generate a hypothetical FAI series prior to 1981, as the level of the capital construction series and that for FAI in each sector were different in 1981.

One problem with the data prior to 2003 is that the sectoral definitions used in the published data do not correspond exactly with the definitions used after 2002. Data for FAI in telecommunications are not available prior to 2003. They are included in the transport and telecommunications sector. However, the definition of infrastructure used here excludes telecom investment. A series for FAI in transport has been created by assuming that the share of telecoms in FAI is the same as in capital construction.

In the published official data for the period prior to 1981, data for the capital construction in the public administration sector (government, parties and social organizations) are amalgamated with the sector "other". According to Chao (1974), the sector "other" refers to all of the "non-productive" investment by state-owned enterprises. Such outlays cover residential and dormitory accommodation, schools, health clinics and hospitals provided by state-owned enterprises. For the period 1959 to 1980, it has been assumed that the capital construction in the public administration sector was half the aggregate amount, based on the share in the first year for which separate data were available. For the 1950s, data have been taken from Chao rather than using the data published in the Fixed Asset Yearbook. For the period 1966 to 1974, no annual data are available for capital construction in the government or infrastructure sector. The available data for plan periods have been divided equally across the years concerned.

The data for the business sector have been estimated as the difference between the non-residential FAI and the government and infrastructure FAI.

Estimates of capital formation in the residential sector

A particular effort is needed to estimate capital formation in the housing sector due to the importance of land purchases in the cost of housing construction. The purchase of existing assets should be excluded from estimates of gross fixed capital formation, but the Chinese practice is to include land purchases in fixed asset investment. The scale of the bias introduced by these differences between FAI data and the SNA basis of estimates of gross fixed capital formation has been growing over time. In the 1980s and 1990s, there was little bias, as there was no market in real estate. The bias became more important during the decade starting in 2000 as market-based transactions dominated the housing market.

The NBS has published its methodology for overcoming this bias. The steps it takes are set out below:

Gross fixed capital formation =

Residential fixed asset investment

Less land purchases (which includes the costs of land improvement)

Plus difference between sales prices and construction cost multiplied by sales quantity

Plus investment in land improvement.

Effectively, this means that GFCF is being measured as property sales less the cost of unimproved land purchased for residential development. This definition is not quite compliant with the SNA, as the deduction for land purchases is made when the developer buys the land rather than when the land is sold to the final purchaser. Thus, if the land has increased in value between the date at which the developer made the purchase and when it is sold to a final purchaser, this increase in value will be included in GFCF. Equally, the quantity of land purchased refers to land bought in a given year rather than the quantity of land sold to the final purchaser.

Adjusting sectoral estimates to agree with the published aggregate data

The extent of the differences between the published measures of total fixed asset investment and gross fixed capital formation varies according the time period considered. Four different periods can be identified:

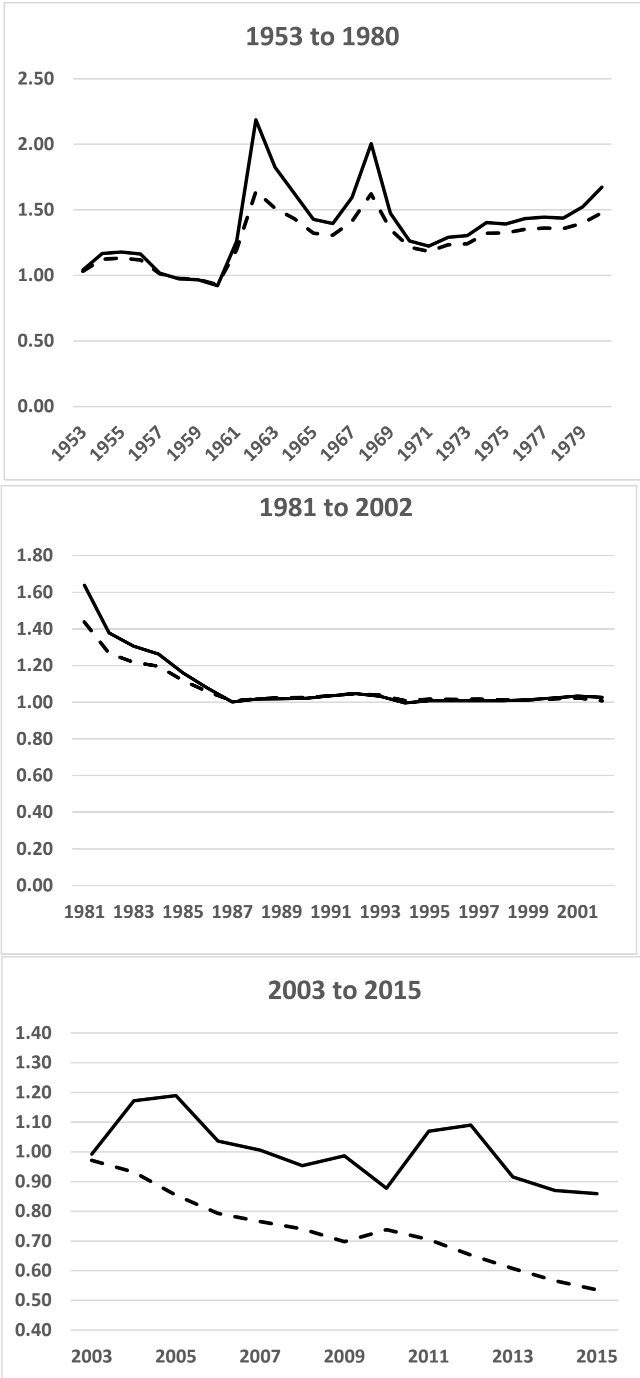
1953 to 1960	Close correspondence between fixed asset investment and gross fixed capital formation.
1961 to 1984	Fixed asset investment averages three-quarters of gross fixed capital formation.
1985 to 2002	Fixed asset investment and gross fixed capital formation are essentially equal.
2003 to 2015	Fixed asset investment becomes persistently and increasing larger than gross fixed capital formation.

The extent to which the methodology used here results in a reduction of the gap between fixed asset investment and gross fixed capital formation can be judged by comparing the ratio of the sectoral estimates of GFCF to aggregate GFCF and the ratio of total FAI to aggregate GFCF (Figure A1).

Figure A1 Sectoral GFCF and Total FAI as a ratio to official Gross Fixed Capital Formation, by period

Solid line: estimated sectoral GFCF/aggregate GFCF

Dotted line: Fixed asset investment/aggregate GFCF



Source: Author estimates using NBS data

Prior to 1984, the measurement errors in the FAI are essentially reproduced in the sectoral data. The only information available for a sectoral breakdown comes from the FAI data. Consequently, there is no possibility to reduce the differences between the data for fixed asset investment and that for GFCF.

Between 1985 and 2002, residential property development became increasingly important. So, using an estimate of residential GFCF rather than residential FAI results in the sectoral estimates of GFCF moving slightly closer to the aggregate GFCF data.

Between 2003 and 2015, the aggregate FAI data become essentially useless as a measure of gross fixed capital formation, but the estimated sector GFCF tracks aggregate GFCF quite well. On average, the yearly estimates of sectoral GFCF are less than 2% different from the aggregate GFCF data. Over the whole period, the cumulated sectoral GFCF is practically equal to the cumulated aggregate GFCF series – the difference being just 0.02%. However, in the two most recent years (2014 and 2015), the difference has become much larger: rising to 10% for reasons that cannot be determined. However, this difference will have little impact on the estimates of the capital stock.

Overall, between 1985 (when the reliability of investment data improved) and 2015, the annual sectoral estimates of GFCF differ from the aggregate estimate of GFCF by just 1.7%, though the standard deviation of the difference is 4.7%. Thus, the methodology for estimating sectoral GFCF gives a good basis for evaluating the development of the sectoral capital stock over the medium term but does not accurately reflect the annual year-to-year changes in GFCF and the capital stock.

In order to remove both the year-to-year differences, a uniform scaling factor has been applied to the sectoral estimates to ensure that they sum to the aggregate GFCF data.

Measuring GDP by sector

The above estimates of investment and capital stock have to be put into the context of the value-added that is generated by the capital stock. The sectoral classification used here does not correspond to an official breakdown published by the NBS. There are two problems: there are no estimates of the value-added of the housing sector and the breakdown of the service sector in constant price terms is inadequate to measure the value-added of the infrastructure and government sectors.

For housing, the NBS defines the gross value-added of the housing sector to be equal to the depreciation of the housing stock. The depreciation rates used are 2% per year for urban housing and 4% per year for rural housing. However, neither the stock of housing nor the value of depreciation are published by the NBS. This paper follows Herd (2013) in making an estimate of nominal and real housing depreciation, which are set equal to the value added of the housing sector.

In the Chinese national accounts, the infrastructure and government sectors are subsumed into the sector "Other" in the breakdown of the GDP in the tertiary sector, both in real and nominal terms. From 2004 onwards, more detail is available for the sub-sectors of the "Other" grouping. In particular, the data show nominal values for the following sectors:

- Information Transmission, Software and Information Technology
- Leasing and Business Services
- Service to Households, Repair and Other Services.

Once these sectors have been removed from the "Other" grouping, the remaining sectors correspond to the definition of infrastructure and government used in this paper. The coverage of the value-added in this sector extends beyond the value added created by infrastructure itself and includes the value added generated by services using this infrastructure. In particular for transport infrastructure both the capital stock estimates include investment in vehicles that use transport infrastructure (aircraft, trains and trucks) and the value added of transport services.

Generating a clean series for value-added in government and services is not without problems. The aggregate estimates for the service sector “Other” in the statistical yearbook only correspond exactly to disaggregated data for the period after 2010. Prior to that date there are differences that are particularly large in 2006 and 2007. Moreover, prior to 2004 there are no official published official estimates. For this period, the sectoral GDP breakdown produced for the China Industrial Productivity (CIP) project have been used. The IT/Telecom sector corresponds exactly to the requirement for this paper. However, the other two sectors are parts of larger sectors in the CIP. In these cases, it has been assumed that the two sectors used in this paper remained a constant share of the sectors of which they are a part prior to 2004. Even then, the data in CIP for the sector cultural and household services appear to have a break in 1994. Real value-added for IT/Telecom has been estimated by deflating value-added by the gross output price for telecommunication services. Household services have been deflated by the overall service sector deflator. The two discontinuities in the data series mentioned above mean that the derived growth rates for real value added in 1994, 2006 and 2007 appear to be incorrect. The estimated growth rates for 2006 and 2007 for government and infrastructure have been averaged, while the growth rate of real value-added in the household services sector has been set at 10% per year between 1990 and 1994.

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