Physical Capital Estimates for China's Provinces, 1952-2015 and Beyond[1]

Carsten A. Holz[2]
SUN Yue[3]

Capital estimates are widely used in economic growth and productivity studies, for profitability considerations and wealth accounting exercises. Yet the calculation of "capital" frequently receives only cursory attention, despite the challenges posed by conceptual difficulties, the complexity of calculations, and the extensive data requirements. This paper (i) calculates long-run provincial (and national) physical capital series for China, (ii) distinguishes between capital services and wealth capital stock, and (iii) applies the most recent methodology advanced by the OECD, the U.S. Bureau of Labor Statistics, and the Australian Bureau of Statistics. The complete set of data is available online and is expected to be updated on an annual basis in the future.

Journal of Economic Literature classification codes. all China:
E01 Measurement and Data on National Income and Product Accounts and Wealth, Environmental Accounts
E22 Investment, Capital, Intangible Capital, Capacity
O11 Macroeconomic Analyses of Economic Development
O53 Economywide Country Studies — Asia including Middle East

Keywords (all: China): capital services, wealth capital stock, capital concepts

Highlights:
- Calculation of provincial (and national) capital series for China
- Distinction between capital services and wealth capital stock
- Updated long-run capital series data available online

3 May 2017

[1] The authors gratefully acknowledge financial support from the National Natural Science Foundation of China (grants number 70973147 and 71273288), the support of the Central University of Finance and Economics, and the help of graduate students at the Center for Human Capital and Labor Market Research at the Central University of Finance and Economics, Beijing, in compiling raw data and constructing the first set of capital measures in 2014 and 2015.
[2] Corresponding author. Professor, Social Science Division, Hong Kong University of Science & Technology, Clear Water Bay, Kowloon, Hong Kong, email carstenholz@gmail.com, tel. +852.5261.6046; Fellow, China Center for Human Capital and Labor Market Research, Central University of Finance and Economics, Beijing.
[3] Doctoral student at the China Center for Human Capital and Labor Market Research at the Central University of Finance and Economics.

Table of Contents

A. Introduction

This paper explains a dataset of physical capital measures currently maintained by the China Center for Human Capital and Labor Market Research (CHLR) at the Central University of Finance and Economics, Beijing, People's Republic of China. The dataset is compiled following the methodology proposed by the Organisation for Economic Co-operation and Development (OECD, 2009) and comprises provincial (and national) wealth capital stock and capital services for the years 1952-2015 and beyond. The dataset is publicly available (as of 3 May 2017: will soon be available) at the CHLR website, and at the first author's website (http://ihome.ust.hk/~socholz/Capital).

Measures of physical capital are indispensable in a wide variety of economic analyses. Measures of capital services are needed for the calculation of productivity change, potential output, capital–output ratios (and incremental capital–output ratios), and rates of return on capital. They are also needed for the estimation of investment demand and for identification of the causes of economic growth. Wealth capital stock is used in comparisons to human capital stock, and in public finance with the taxation of income from capital.

The Chinese provincial physical capital stock data in the literature do not meet these diverse needs: they typically do not distinguish between wealth capital stock and capital services, often are not available publicly (let alone easily available online), rarely cover a long time horizon, and none of the published data are being kept up-to-date. The articles that venture into capital services tend to gloss over the finer points of the methodology, such as not derive the age-price profile from the age-efficiency profile in the case of a non-geometric age-efficiency profile, or to simplify by assuming a geometric age-efficiency profile. Our provincial (and national) physical capital dataset seeks to address these shortcomings: it provides data on wealth capital stock and on capital services, follows rigorous methodological procedures, is easily available online, and is expected to be updated annually.[4]

The key distinction is between wealth capital stock (also called "net" capital stock) and capital services. Wealth capital stock measures the value of the capital stock, i.e., the (hypothetical) value that would be achieved if the complete capital stock were sold at today's market prices, or, following the asset market equilibrium condition, the present value of future rental income from the assets. This is the capital stock measure familiar to economists as the previous period's capital stock less depreciation (typically expressed as a fixed share of the previous period's capital stock), plus new additions to the capital stock in form of investment in this period.

For many purposes, wealth capital stock is not the appropriate measure of capital. In particular, wealth capital stock is not the appropriate measure for use in production function estimations or in growth accounting because production functions embody a quantity flow concept: combining labor hours, machine hours, and a quantity of intermediate inputs yields a quantity of output. The number of machine hours is a capital service provided in this period, for the production of output in this period, and not the present value of future rental income, just as labor is a measure of labor hours used in the production of output in this period, and not a measure of the future lifetime work hours of the current work force, let alone the present value of future income from labor.

[4] Updating comprises extension by a further year (or by further years), and revisions. As the NBS revises earlier data—such as to include research and development expenditures (see, for example, http://www.stats.gov.cn/tjsj/zxfb/201607/t20160705_1373924.html, accessed 13 April 2017)—and these revised data are incorporated into our database, the capital measures will be adjusted to remain fully in line with China's official national income and product accounts data.

The concept of capital services has been promoted in the first and second edition of the *OECD Manual: Measuring Capital* (OECD, 2001 and 2009).[5] Capital service measures are currently being provided by the statistics offices of several countries, including by the Bureau of Labor Statistics (BLS) in the U.S. and the Australian Bureau of Statistics (ABS). For China, no official capital service measures are available.[6]

While capital stock calculations abound across the China literature (for example, ZHANG, 1991; Chow, 1993; Holz, 2006), the literature that considers specifically capital services is more limited.[7] The literature calculating some measure of *national* capital services includes SUN and REN (2005) with a capital services index for 1980–2002, CAI (2009) with a capital services index for 1978–2007, and CAO et al. (2012) with a capital services index for 1978-2010. SUN and REN (2014) provide national and 33 (exhaustive) sector capital services indices for 1981-2005, and Wu (2015) calculates a national capital services index with a breakdown into an exhaustive 37 sectors for 1980-2010. ZHANG et al. (2004) estimate *provincial* wealth capital stock for 1952-2000, and Wu (2016) does so for 1978-2013 with a further breakdown into agriculture, manufacturing, and services. Provincial capital services indices are estimated by CAO et al (2013) for 1994-2010. Wang and Szirmai (2012) estimate provincial productive capital stock for industry (1953–2007) and national productive capital stock economy-wide (1985-2007) and for manufacturing (1985-2007).

Across this literature, the raw data used, the methods, and the assumptions vary greatly. Only CAO et al. (2013) estimate provincial capital services. Only CAI (2009) and CAO et al. (2012), calculating national capital services, and CAO et al. (2013), calculating provincial capital services, consider the equivalency relationship between age-efficiency profile and age-price profile and derive the age-price profile from a hyperbolic age-efficiency profile. Only Zhang et al. (2004) provide estimates for pre-1978 years (and these are for wealth capital stock only and end in 2000).

This paper differs in that it conscientiously follows OECD, BLS, and ABS methodology. The raw data are the most up-to-date official data, incorporating economic census revisions. We document our choice of raw data, sources, and the manipulations made to address data complications. We calculate measures of both capital services and wealth capital stock through one consistent procedure. The underlying assumptions are varied to include versions with geometric and hyperbolic age-efficiency profiles for capital services (while consistency of the age-price profile is maintained). We provide provincial and national results. The estimates start in 1952, thereby including the pre-reform period for which data compilation is particularly cumbersome, and run through the present (currently 2015).

B. Measurement

1. The Concept of Capital Services

How are capital services to be measured? While it is clear that work hours of labor mean work hours of human beings and not of a combination of human beings and aliens, it is less clear what is meant by work hours of capital where capital combines such diverse items as

---

[5] The OECD manuals are preceded by a large, typically more specialized academic literature. For an overview, see, for example, Jorgenson (1995).

[6] An undated early version of Feenstra et al. (2015) acknowledges that ideally their latest revision of the Penn World Table would include capital services, but given the data requirements the authors had to settle for capital *stock* values.

[7] Holz (2006) presents a variation on capital services with a measure of productive capital stock.

computers, hammers, and buildings. Making the measurement of capital services tractable involves a number of conceptual arguments and choices.

Starting point is the available investment data, adjusted to constant prices. Following the perpetual inventory method, past (and current-period) investment is then accumulated into a current-period capital measure.

- ***Asset categories.*** Homogeneous assets are grouped into distinct asset categories. In the case of provincial Chinese data, this means the use of three asset categories: structures, equipment, and the category officially labeled "others." While it would be preferable to have a finer breakdown to account for the reallocation of capital services across industries, including by economic sector and institutions, at the provincial level three types of assets is all that the available data allow.

  Homogeneity of assets within an asset category implies that all assets within this category have the same average service life. This matters in that it allows the purchasing price of an asset to serve as a measure of the initial efficiency level. If asset A costs twice as much as asset B, and both belong to the same asset category (with, by definition, the same average service life), then it must be the case that asset A is twice as good as asset B (twice as efficient), for otherwise why would one be willing to pay twice as much for asset A?
- ***Age-efficiency profile.*** Each asset category contains assets of different vintages,[8] and these assets of different vintages within any one asset category are aggregated in any one year based on their current-period levels of efficiency. The number of efficiency units at the time of purchase of a new asset is set equal to the original investment value in constant prices (or any fixed fraction or multiple thereof). In subsequent years, as the asset ages, efficiency declines as described by an age-efficiency profile, specific to each asset category.[9] Efficiency units are a quantity measure and thus cannot be added up *across* asset categories (one cannot meaningfully sum efficiency units of buildings and hammers), but they can be added up across vintages of the same type of asset.

  While in the calculation of wealth capital stock the assumption of a fixed depreciation rate yields a geometric age-price profile—a $100,000 truck at a 20% depreciation rate is worth $80,000 at the end of the first period, $64,000 at the end of the second period, and $51,200 at the end of the third period—in the case of capital services the decline in efficiency is likely much slower. A truck will still run at the same speed and carry the same load at the end of the first year as it did at the beginning of the first year, and that is unlikely to change much over many years. Gradually, the time needed for repairs may increase, and perhaps over time one may feel less secure driving at maximum speed or exhausting the load limit. In the case of a light bulb or a computer (whose hard disk is periodically reformatted, with the original software re-installed) the asset works at 100% or near-100% efficiency until the light bulb or the computer, one day, stop working.[10] The shape of the age-efficiency profile, thus, tends to be one-hoss shay (efficiency is at 100% until the asset is retired), or at least strongly hyperbolic.
- ***Retirement function.*** While the age-efficiency profile describes how the efficiency of an asset declines over an (assumed) period of twice the average service life, by definition not all assets survive to twice the average service life. Therefore, the age-

[8] "Vintage" describes one age cohort, i.e., a group of capital goods acquired at the same point in time.

[9] The age-efficiency profile for a particular asset category is assumed to be vintage-independent. One asset category-specific age-efficiency profile applies equally to all vintages of that asset.

[10] The time out needed to reformat the computer hard disk constitutes a small decrease in efficiency.

efficiency profile is augmented by a retirement or survival function. Each year, a share of the assets of each vintage is retired, whether that is due to accident, sudden obsolescence (typically due to technological progress), or simply product failure. A normally distributed retirement function with an assumed standard deviation of one-quarter around the average service life describes the assumed retirement of an age cohort over time. One minus the cumulative retirement probability density function yields the survival function. Conditional on an asset surviving, it contributes to production a fraction of its original efficiency level; the fraction is described by the age-efficiency profile.

Adding up, in any one year, for any one asset category, the efficiency units available in this year from all vintages of this type of asset (comprising only the surviving assets) yields the (constant-price) productive capital stock value of that asset category. This is the sum of asset category-specific efficiency-adjusted, surviving, mid-year constant-price past (and half of current-period) annual investment.

- ***Capital services as share of productive capital stock.*** Every year, the productive capital stock (total number of efficiency units) of a particular asset category provides a certain level of capital services. Capital services are assumed to be a (asset category-specific) fixed proportion of the productive capital stock.
- ***Aggregation.*** Efficiency units in structures are not comparable to efficiency units in equipment, and thus the productive capital stocks of different asset categories cannot simply be added up. A final choice therefore is to aggregate the *growth rates* of the productive capital stocks of the different asset categories, and to do so using a Törnqvist index. The weights of the Törnqvist index reflect how one values the services provided by the productive capital stock of a particular asset category relative to the services provided by the productive capital stock of all types of assets together.

The growth rate of aggregate capital services, given the assumption that capital services are proportional to productive capital stock, equals the growth rate of aggregate productive capital stock. The growth rate of capital services is typically all that is needed in production function estimations or growth accounting. A constant-price nominal-value capital services series can be derived by applying the capital services growth rates to a base-year user cost value (value of annual capital services), and a current-price series by further multiplying by the investment in fixed assets price index.

2. Derivation of wealth capital stock and capital services growth

Figure 1 summarizes the steps involved in the construction of capital measures. In the case of China, starting point is provincial gross fixed capital formation (GFCF), the national income and product accounts measure of investment. No breakdown by type of asset is available. Provincial GFCF is split into the three asset categories structures, equipment, and "others" using the proportions of these asset categories in "fixed asset investment," a data series distinct from GFCF.[11]

In a first step, investment (GFCF) in each of the three asset categories is deflated to constant 1985 prices. (The year 1985 is chosen as base year to match the human capital research conducted at the China Center for Human Capital and Labor Market Research.) In a

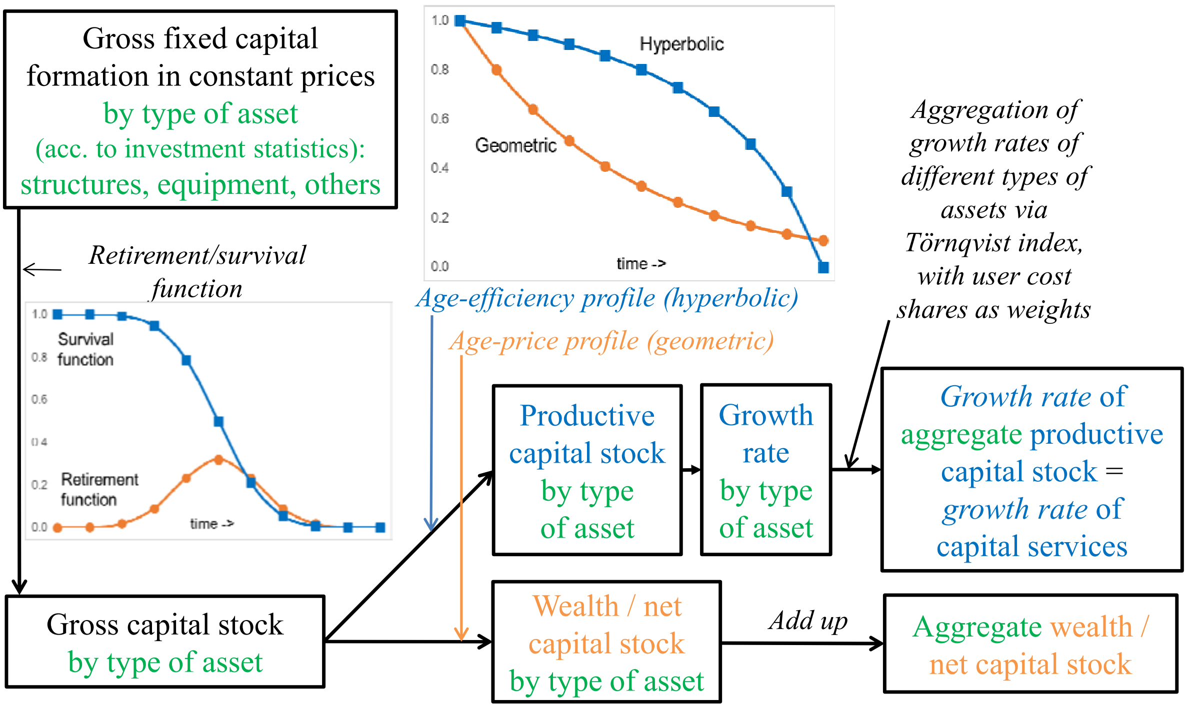
[11] For details on fixed asset investment statistics, and also on the relationship between GFCF and fixed asset investment, see Holz (2017).

second step, a survival function specific to each asset category is applied to each vintage of assets in each asset category.

For the derivation of the wealth capital stock, the third step involves applying an asset category-specific age-price profile to the surviving proportion of each (past) year's constant-price investment value. All constant-price past investment in each asset category, adjusted for survival and price decline, is then added up to a current-period constant-price wealth capital stock of this asset category. Adjusting to current prices and summing across the asset categories yields aggregate wealth capital stock in current prices. A wealth capital stock *growth* index can be obtained via a Laspeyres volume index of asset category-specific real growth rates with previous-year current-price values as weights.

For the derivation of capital services, an age-efficiency rather than an age-price profile is applied to the surviving proportion of each (past) year's constant-price investment value in order to obtain the productive capital stock of each asset category. This productive capital stock reflects the quantity of efficiency units available in the current period. The final step of aggregation occurs for *growth rates* of the productive capital stock of the different types of asset categories, with user cost shares as weights.

Figure 1. From Investment to Wealth Capital Stock and Capital Services



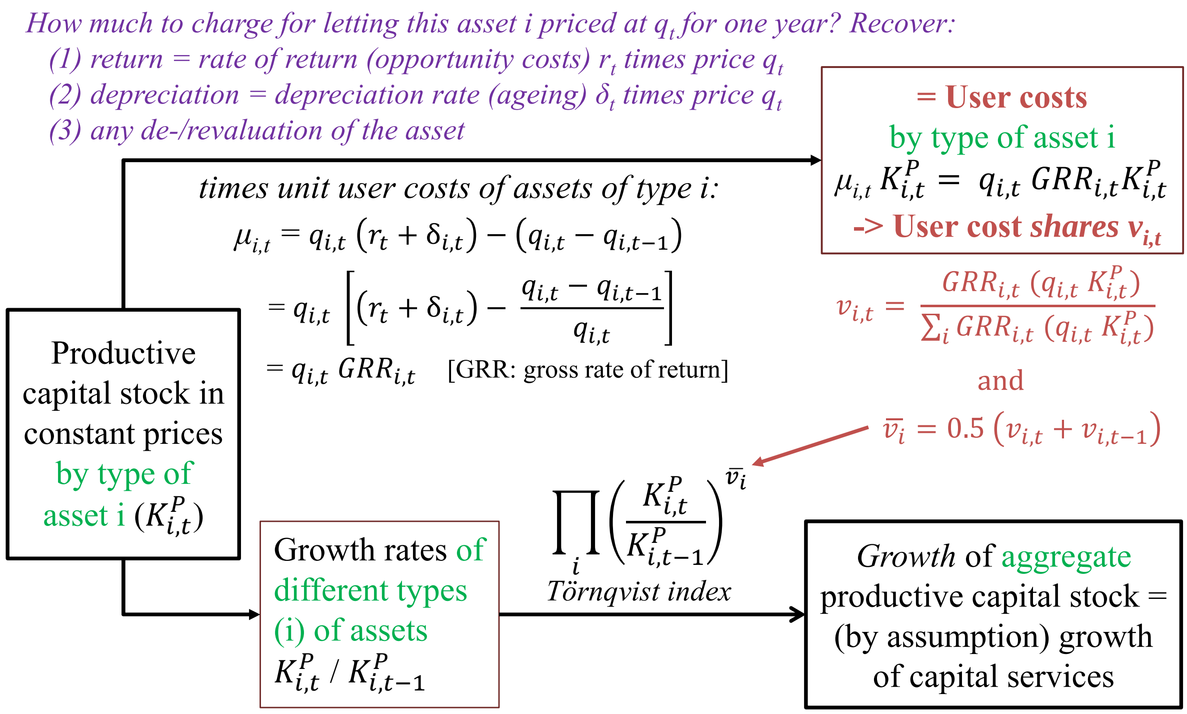
3. Aggregation in the case of capital services

In the case of capital services, aggregation involves the aggregation of the real growth rates of the different types of productive capital stock, using a Törnqvist index with user cost shares as weights. The derivation of user cost shares is based on an endogenous rate of return that is solved for ex-post (i.e., using data available ex-post). Figure 2 summarizes the individual steps.

The user costs of one unit of productive capital stock—what the capital owner would charge to let one unit of productive capital stock for one period—comprise three components:[12] (i) opportunity costs, measured as the rate of return times the price of one unit of productive capital stock; plus (ii) depreciation, measured as the depreciation rate times the price of one unit of productive capital stock; less (iii) any revaluation of the asset. For any one type of asset, multiplying the user costs of one unit of productive capital stock ("unit user costs") by the number of units of productive capital stock (constant-price productive capital stock) yields the user costs of this type of asset.[13] Dividing the user costs of this type of asset by the sum of the user costs of all types of assets—this sum being available as gross operating surplus in the income data—yields the user cost share of this type of asset. The average of last period's and this period's user cost share of this type of asset then enters the Törnqvist index as weight for the growth rate of the constant-price productive capital stock of this type of asset.

The (unknown) rate of return is assumed to be the same for all types of assets (otherwise capital owners would shift to the type of asset with the highest return). Depreciation rates and revaluation are specific to each type of asset; the depreciation rate follows from the age-price profile, and revaluation from the (ex-post) asset-specific price index.

Figure 2. Aggregation of Productive Capital Stock (or Capital Services) by Asset Type



The derivation of user cost shares starts with the aggregate value of user costs U_t published in the income statistics, i.e., with gross operating surplus. This aggregate value equals the sum of the (unknown) user costs of the different types of assets:

[12] To further elaborate on user costs: "User costs of capital are the price that the owner-user of a capital good "pays to himself" for the service of using his own assets. Alternatively, user costs correspond to the marginal returns generated by the asset during one period of production." (OECD (2009), p. 180)

[13] The multiplication of unit user costs (price times gross rate of return, Figure 2) times units of constant-price productive capital stock is easiest done by rearranging the three terms as gross rate of return times price times units of productive capital stock, and then as the gross rate of return times *current-price* productive capital stock.

$$U_t = \sum_{i=1}^{3} U_{it} = \sum_{i=1}^{3} \left(r_t + \delta_{it} - \frac{q_{it} - q_{it-1}}{q_{it}} \right) * q_{it} K_{it} \quad (1)$$

Inserting, for any one year, for each type of asset the depreciation rate, revaluation, price, and the value of productive capital stock leaves as only unknown, for which the equation can be solved, the (not asset-specific) annual rate of return. Once the rate of return is known, the user costs of each type of asset can be obtained, and thereby the user cost shares of each type of asset. The averages of the previous- and current-period user cost shares of each type of asset constitute the weights in the Törnqvist index.[14]

4. The relationship between age-efficiency profile and age-price profile

Age-efficiency profile and age-price profile are related and the choice of a particular age-efficiency profile implies a particular age-price profile. The two profiles, thus, cannot be chosen independently.

Following the asset market equilibrium condition, the current year's value of an asset equals the summed discounted stream of future rental income from the asset, where each future period's rental income depends on the productive capacity (efficiency) of the asset at that point in time. A series of current-year present values constitutes the age-price profile of the asset.

In detail, derivation of the (constant-price) age-price profile proceeds by writing out the age-efficiency profile for one unit of one type of asset (standardized to one in the first year) and then to, for any one year (or age) discount the future efficiency units (times a constant price) to a current-period summed value (current-period value of the asset, at constant prices). I.e., the year 1 price of the asset is the sum of all discounted future returns (discounted to year 1); the year 2 price of one and the same asset is the sum of all discounted future returns starting in year 2 (discounted to year 2), etc. This sequence of values, normalized to one at the beginning of year 1 (end of year 0) is the age-price profile. The choice of discount rate reflects the long-run (assumed constant) average rate of return.

Deriving the age-price profile from the age-efficiency profile (or vice versa) introduces an element of endogeneity: In order to obtain an age-price profile from the age-efficiency profile, a discount rate (rate of return) needs to be assumed. From the age-price profile follows the depreciation rate, which, once inserted into the total user cost equation (equation 1), allows calculation of the current-period rate of return (and then user cost shares). I.e., in order to obtain the current-period rate of return, needed to calculate user cost *shares*, one first needs to assume a long-run (constant) average rate of return.

Alternatively, one could violate the equivalency between age-efficiency and age-price profiles and separately assume an age-efficiency profile and an age-price profile (or, in the latter case, a depreciation function, such as a geometric decline with an X% depreciation rate, which then yields the age-price profile).

The OECD manual (OECD, 2009) in the final instance goes a step further, following some of the academic literature (for example, Jorgenson, 1995). It recommends to simplify by assuming that the age-efficiency profile and the age-price profile are geometric (and identical). In this case, the endogeneity problem disappears. The geometric age-efficiency /

[14] As an alternative to the various steps outlined for the derivation of capital services, one could simply work with the annual gross operating surplus as the value of user costs and thus the value of total capital services provided, which would seem much simpler as these data are readily available in the national income and product accounts. However, gross operating surplus tends to fluctuate significantly between years (while capital services are likely provided in almost unchanged fashion); and it typically does not come with a breakdown by asset category or industry, when a capital services series may be desirable for each of the various breakdowns.

age-price profile can then further be assumed to comprise the retirement function. With an identical geometric age-efficiency and age-price profile, asset-specific productive capital stock and wealth capital stock are identical. In this case, capital services (growth) and wealth capital stock differ only in the method of aggregation of different types of assets.

The gain in simplicity of calculation is tremendous. The fact that efficiency of an asset in the first years of use declines only minimally is ignored. (The productive capital stock of an asset should be much larger than the wealth capital stock of an asset in the early years of an asset). However, once different cohorts of assets within any one asset category are aggregated, this aggregate productive capital stock, while likely larger in value than the corresponding wealth capital stock, may *grow* at a similar rate.

C. Two Sets of Derivations

We adopt two approaches to calculating capital measures. The first one adapts an OECD model spreadsheet. The second is our own construction of an elaborate spreadsheet to calculate capital measures, including the derivation of age-price profiles from age-efficiency profiles.

While the calculation of capital measures is conceptually straightforward, spreadsheet work adds a layer of complexity due to timing choices within a year. For example, GFCF is assumed to occur mid-year; other variables, such as wealth capital stock, are end-year (or beginning-year) values.

1. OECD model calculations

The OECD provides an online Excel spreadsheet to illustrate its calculation of capital services growth and of wealth capital stock.[15] This spreadsheet is based on the assumption of an identical geometric age-efficiency / age-price profile (without separate retirement function) and can be adapted for use with the China data.

The OECD spreadsheet incorporates a more involved user cost equation than presented here (equation 1), based on two elaborations.[16] First, the price difference between an n-year old asset at the beginning of the period and an n+1 year old (same) asset at the end of the period is broken down into depreciation and revaluation, which, considering that depreciation is based on the average price of the asset during the period, leads to depreciation comprising a depreciation rate being multiplied by "one plus half the percentage rate of revaluation," and to revaluation with a percentage rate of revaluation being multiplied by "one minus half the depreciation rate" (the beginning of the year price of an asset is corrected for half a year's depreciation).[17] Second, the OECD user cost equation switches to "real" rates of return and real revaluation by multiplying and dividing by the ratio of the end-period consumer price index (CPI) to the beginning-period CPI. (This does not affect the outcome in terms of user cost shares, but will lead to "real" rather than "nominal" rates of return and revaluation.)

This is not the place to repeat the extensive considerations and derivations of the user cost equation presented in Chapter 19 of OECD (2009) and incorporated into the OECD spreadsheet; the interested reader may consult this source. The differences in outcomes

---

[15] See www.oecd.org/dataoecd/57/55/44076555.xls, last accessed 7 April 2017.

[16] The original OECD spreadsheet also uses the Fischer index instead of the Törnqvist index, with virtually no difference in outcome; the OECD spreadsheet has been adapted to use the Törnqvist index.

[17] The price difference between an n-year old asset at the beginning of the period and an n+1 year old asset at the end of the period, itself, together with another term that reflects the return on investment, is derived from a present value equation of future rental income.

compared to the "nominal" version presented in equation (1) is minimal.[18] In our own spreadsheet we work with equation (1).[19]

2. Own derivations

While the OECD recommends use of an identical geometric age-efficiency / age-price profile, both the BLS and the ABS calculate their capital services series under assumption of a hyperbolic age-efficiency profile, which then implies the need to derive the age-price profile from the age-efficiency profile. Correspondingly, in calculating capital services growth and wealth capital stock, we derive age-price profiles from age-efficiency profiles. For the derivation of the age-price profile from the age-efficiency profile the BLS and ABS assume a long-run (constant) average rate of return of 4%, a practice which we follow.

We work with two different age-efficiency functions, one of hyperbolic shape and one of geometric shape, with values set equal to one at the beginning of the year. The hyperbolic age-efficiency function (only) is augmented by a survival function. At twice the lifetime of the asset, age-efficiency (or the survival function) is set equal to zero.

The asset category-specific average annual productive capital stock (in constant prices) equals the sum of efficiency units of all age cohorts, which is obtained as the average annual aggregate efficiency of assets already existing prior to this year, and half of the efficiency units newly added in this year. The average annual productive capital stock in current prices is obtained by multiplying by the asset category-specific investment in fixed assets price index.

For each of the two age-efficiency functions, an age-price profile is derived from the age-efficiency function. At any given point in time, the price of an asset equals the present value V_t (in constant prices) from all future annual rental income in constant prices (assumed to be obtained at the end of the period, and discounted by the long-run average, constant rate of return r), where rental incomes depend on mid-year efficiency f_t (times a constant price, chosen to be one):

$$V_t = \sum_{\tau=1}^{T} \frac{f_{t+\tau-1}}{(1+r)^t} \quad (2)$$

The summed discounted future rentals at the beginning of year 1 are set equal to one. In the case of the hyperbolic age-efficiency profile, the resulting age-price profile differs significantly in shape. In the case of the geometric age-efficiency profile, the resulting age-price profile is identical up to the third decimal for some years, then varies in the third decimal and during the last approximately one-fifth of the service life in the second decimal (with a 0.01–0.02 difference). (The necessary approximations of various half-year values here in the derivation of the age-price profile from the age-efficiency profile introduces the tiny

[18] The original OECD spreadsheet uses constant-price instead of current-price capital stock in the derivation of the rate of return, and then further in the derivation of asset category-specific user cost. This has been corrected in our calculations using the OECD spreadsheet. (Also, the user cost equation presented in the head rows of columns BK and BY of the first two OECD worksheets confuses division with multiplication for the CPI-related part, while the calculations are correct; similarly in item 19.8.7 in OECD, 2009, p. 194.)

[19] The OECD spreadsheet offers three alternative procedures for deriving the rate of return; we adhere to the one presented prominently in OECD (2009) and described above. The three alternative procedures in deriving capital services growth rates are: (i) as described above ("ex post, endogenous real rate of return, ex-post real asset price changes"); (ii) a simplification, dropping the revaluation term ("ex post, endogenous real rate of return, simplified method"); and (iii) using ex ante expectations of CPI and investment in fixed asset price index based on past averages and an assumed, fixed 4% rate of return ("ex-ante, exogenous real rate of return, ex-ante (average) real asset price changes").

discrepancy. In contrast, the OECD approach is to work with an identical age-efficiency/age-price profile.)

Constant-price end-year wealth capital stock by type of asset is obtained as the sum of the age-price profile-adjusted constant-price values of the assets of all age cohorts at the end of the year. Focusing on one age cohort: Applying the asset category-specific age-price profile to GFCF at constant prices (where GFCF is assumed to occur mid-year), GFCF of the first year loses *half* of the first year's loss in price following the age price profile by the end of the first year, and is of age 1.5 years (in terms of the age-price profile) at the end of the second year, and of age 2.5 years at the end of the third year, etc. Current-price wealth capital stock of each type of asset is obtained by multiplying constant-price wealth capital stock by the investment in fixed asset price index.

From the asset category-specific constant-price wealth capital stock follows the corresponding depreciation rate.[20] Given the asset category-specific (and year-specific) depreciation rates, investment in fixed asset price index, and current-price productive capital stock (as well as gross operating surplus as the measure of total user costs), the annual rate of return can be obtained. From that follow the user cost shares, and with the growth rates of the constant-price productive capital stock, via the Törnqvist index, the capital services growth rates.[21]

D. Data Sources and Data Manipulation

For each province (and at the national level), the following data are needed:

(1) Investment values in form of gross fixed capital formation, with a breakdown by type of asset adopted from the investment statistics;
(2) investment in fixed assets price index, with a breakdown by type of asset;
(3) CPI;
(4) gross operating surplus, to be derived from aggregate income with a breakdown into labor remuneration, operating surplus, depreciation, and net taxes on production.

The source of the data for the most recent years is the statistical database on the NBS website (http://www.stats.gov.cn). Historical data are obtained from the compendia *GDP 1952-1995* and *Sixty Years*. Occasionally the *China Statistical Yearbook* and provincial statistical yearbooks are consulted. All constant-price values are in 1985 prices, and real growth indices use 1985 as base year (with value one).

For many provinces, missing data in the early years is an issue. Missing data are addressed through approximations, as far as possible following fixed rules (included below). Obvious typos in a source were corrected on an individual basis; to the greatest extent possible, cross-checks were run (including against additional data). Very minor discrepancies, such as gross fixed capital formation and inventory investment not perfectly adding up to gross capital formation, were ignored as long as they were of small magnitude

[20] The depreciation rate is obtained by dividing this year's depreciation by the end-year wealth capital stock. (The OECD's depreciation rate relates depreciation to the *current-period* end-period wealth capital stock, and we follow that practice.) This year's depreciation consists of two parts: the change in value of the beginning-of-year wealth capital stock (by the end of the year) plus the change in value of the assets newly added in this period. The change in value of the assets newly added in this period, which are assumed to have been added mid-year, is the change in value between mid-year and end-year.

[21] For some data series, assumptions had to be made for first year values (typically, for 1951 or 1952). This includes an assumption that the 1952 depreciation rate is the same as that of 1953, and that the prices of investment in fixed assets did not change in 1951.

(such as below 1% of gross capital formation in this example).[22] Tibet's data involve a high degree of approximations, to an extent that one may not want to use the results for Tibet.

1. Investment by type of asset

Provincial values of gross fixed capital formation (GFCF) are obtained from the NBS website and supplemented by data for the early years provided in *Sixty Years*. These are the most up-to-date values that incorporate all benchmark revisions, up to and including the benchmark revision following the 2013 economic census in as far as they have been incorporated in the NBS online database by February 2017 (when the dataset was last updated).[23]

Missing data on GFCF are substituted for using this province's aggregate expenditures (or otherwise production approach GDP values) and a neighboring province's ratio of GFCF to aggregate expenditure (or GDP). (Across years and provinces, aggregate expenditures and production approach GDP tend to be identical.)

GFCF values do not come with a breakdown by type of asset. The fixed asset investment statistics provide a breakdown of total investment by three types of asset: structures, equipment, and "others." These province- and year-specific proportions of structures, equipment, and "others" in total investment are applied to the provincial annual GFCF values.

Investment data by type of asset are available since 2003 (NBS website). For each province, values for 1951–2002 are estimated by establishing the 1950 proportions, and then connecting these 1950 proportions linearly to the average 2003–2005 proportions. Approximated 1950 proportions of the three types of assets in total economy-wide (national) investment are uniformly used for all provinces (structures 75%, equipment 20%, and "others" 5%).[24]

GFCF captures produced capital in a given period. It does not include land or other natural resources. Given the difficulty of valuing natural resources, no attempt is made to address this limitation of GFCF; price changes in structures may move similarly to price changes in land, and price changes in structures enter into current-price wealth capital stock and into the weights used for the aggregation of capital services. GFCF also offers no distinction between "productive" investment and "non-productive" investment (such as in residential housing). The inclusion of all investment seems immediately appropriate for wealth capital stock. It is also appropriate for capital services because, in the context of production function estimations, an aggregate output value such as gross regional product also includes imputed housing services. GFCF, finally, excludes inventories. This is an exclusion by choice: fixed capital formation, including inventories, could have been used instead of GFCF, but inventories need not reflect any contribution to production, nor wealth, if these are excess inventories that cannot be used or sold, or only be sold at heavily discounted prices.

2. Investment in fixed assets price index

Data on the investment in fixed assets price index are available for the years since 1991 (at the national level since 1990), including by type of assets (NBS website). For earlier years,

[22] A detailed write-up of which data are missing for which province, and how they were proxied, is available in Chinese language at the website of the dataset.

[23] *Sixty Years* incorporates the benchmark revisions through 2008 (and is needed as data source typically only for the years prior to 1993).

[24] Official investment data for 1950 cover "capital construction" only. In 1953, "technological updating and transformation" appears as an additional series in the statistics, with a value approximately equal to 1% of capital construction.

price changes are obtained from nominal GFCF values together with GFCF real growth rates, both published in *GDP 1952-1995*. This implicit GFCF deflator is applied equally to all three types of assets (structures, equipment, "others") in the years up through 1990 (1989 for national data).[25]

In the case of provinces / years with missing nominal GFCF values and/or missing GFCF real growth rates, the default is to use the implicit deflator of industry value-added as proxy (with values from *Sixty Years*). Charts of the implicit GFCF deflator and (since 1991) the investment in fixed assets price index vs. the implicit deflator of industry value-added show a very close match in the overlapping years, even through periods of high variation. If an implicit industry value-added deflator cannot be derived, the implicit GFCF deflator of a neighboring province is used.

3. CPI data

CPI data are obtained from the NBS website. If CPI data for early years are not available, the default is to use the urban CPI. Charts show an extremely close match in the overlapping years, to the point where it is plausible that provinces report the urban CPI as (total) CPI in early years, when rural price surveys may not yet have been in place. If no urban CPI is available, the CPI of a neighboring province is used.

4. Income data

Income data are obtained in two steps in order to ensure that income and aggregate expenditure data—GFCF is a component of aggregate expenditures—are consistent. (Income, aggregate expenditures, and production approach GDP are in theory identical, but in practice income may show small differences.) First, the share of each income component in income is calculated. In a second step, absolute values are obtained by multiplying the share values by aggregate expenditures (using aggregate expenditure data from the same sources as reported above for GFCF).

The income data for the years since 1993 are from the NBS website, and for the years 1978 through 1992 from *GDP 1952-1995*. For each province, shares of the years 1952-1977 are set equal to the average 1978-1982 shares. National-level income data are not available and are proxied by share values obtained from summed provincial values, multiplied by national aggregate expenditures.

Income comprises labor remuneration, operating surplus, depreciation, and net taxes of production. An economy-wide (province-specific) value of user costs (gross operating surplus) is obtained as the sum of operating surplus, depreciation and a proportion of net taxes on production. The proportion of net taxes to include is obtained as "operating surplus plus depreciation" divided by "operating surplus plus depreciation plus labor remuneration." I.e., total income is attributed to labor (labor remuneration) and capital (operating surplus

---

[25] The explanations accompanying the official price data do not clarify if the annual investment in fixed asset price index and the annual CPI measure average annual price increases or end-year price increases. A double-check is possible for the annual investment in fixed asset price index against the quarterly investment in fixed asset price index for the years 2003-2015. (No monthly investment in fixed asset price index data are available, and no monthly or quarterly CPI data except for monthly CPI data since 2016, a year for which no annual CPI has yet been published in the NBS database.) The double-check, conducted for the national data, shows that the annual investment in fixed asset price index is identical to the arithmetic mean of the four quarterly price indices. Assuming that the quarterly price index captures the average price increase of the quarter (such as the arithmetic mean of the unknown three monthly price increases), this suggests that the annual investment in fixed asset price index is an average annual price index.

plus depreciation), and the remaining income component of net taxes on production is split proportionally between labor and capital.[26]

5. Technical details

For a number of basic technical issues we follow the practice in the literature and in the OECD Manual (2009) on *Measuring Capital* and the physical capital chapter in the OECD Manual (2001) on *Measuring Productivity*.

a. Initial capital stock

The initial year of the asset category-specific capital stock series is 1952. The (province-specific, constant-price) capital stock value W_{1952} is obtained equally for all measures of capital as

$$W_{1952} = \frac{GFCF_{1953}}{\delta+\theta} - GFCF_{1953}, \text{ where} \qquad (3)$$

$GFCF_{1953}$ is GFCF of the year 1953 in constant prices, θ is the asset-specific average annual (geometric) real growth rate of GFCF between 1953 and 1957, and δ is the asset-specific depreciation rate (using the double-declining balance method, explained below).[27] No distinction is made between wealth capital stock and productive capitals stock for 1952; W_{1952} could be viewed as an efficiency and constant-price wealth measure of GFCF in 1952 with no investment in any earlier year.

For some but not all provinces, GFCF values would have been available for 1950-1952 (or a subset thereof). A judgment was made that the first somewhat reliable (non-erratic) post-war GFCF value is probably the value of 1953.

b. Average service lives and retirement function

Following other countries' experiences (as reported in OECD, 2009) and our evaluation of the circumstances in China, average service lives of physical assets are taken to be 40 years for structures, 16 years for equipment, and 25 years for "others." The maximum service life is taken to be twice the average service life.

The retirement function is a normal distribution with asset-specific average service lives and standard deviation equal to one-quarter of the average service life. The survival function is 1 minus the asset-specific cumulative normal retirement distribution.

c. Age-efficiency and age-price profile

The formula for the geometric age-efficiency and/or age-price decline of a vintage of assets of specific asset-type is

[26] The national income data undergo statistical breaks in 2003–2004 and 2008–2009 with changing accounting practices for "financial intermediation services indirectly measured" and for mixed income in the individual-owned economy. Changes to the sectoral classification system, given income accounting practices in different sectors, further contribute to (minor) statistical breaks in other years. For details, see QIAN (2013). These statistical breaks affect the values of gross operating surplus. It is impossible to plausibly correct for the statistical breaks. The implications for the calculation of weights to be used in the aggregation of growth rates of productive capital stock of different asset categories in the calculation of capital services are likely negligible because the impact of the statistical breaks is on the rate of return, which is identically used in the calculation of the weight of each asset category and constitutes just one component in the calculation of the weights. Other implications are more severe: the time series of gross operating surplus values is not a reliable proxy for capital services, and the time series of the rate of return is inconsistent. (For discrepancies between labor remuneration as reported in the income statistics vs. in the flow of funds statistics, see XIAO and ZHOU, 2010.)

[27] The resulting depreciation rates are 5%, 12.5%, and 8% for structures, equipment, and "others.

$$g_n = (1 - \delta)^n, \quad (4)$$

where n denotes age and δ the rate of efficiency decline or the depreciation rate. The rate of efficiency decline or the rate of depreciation is obtained using the double-declining balance method, as 2 divided by the average service life. Starting at twice the average service life, efficiency or the price are set equal to zero.

The formula for the hyperbolic age-efficiency profile is

$$g_n = \frac{(T-n)}{(T-b*n)}, \quad (5)$$

where n denotes age, T is twice the average service life, and b is a shape parameter that takes the value 0.75 in the case of structures, and 0.5 otherwise.

d. Negative rates of return

The endogenous current-period rate of return derived in the user cost equation can be negative. Negative rates of return are favored by a relatively small gross operating surplus (relative to the productive capital stock), high depreciation rate, and low value of revaluation.[28] In practice, a negative rate of return is not plausible. (Why would anyone invest in capital goods if the return is negative?) In the case of the Chinese provincial data, this is exclusively an issue of a few pre-reform years for some provinces. The national income and product accounts data were compiled only in the 1990s, with retrospectively estimated values for the earlier years. Quite likely, some of the early gross operating surplus values are not reliable.

If negative rates of return in any one year for any one province are adjusted, the user cost shares of the three asset categories no longer sum to one. Therefore, the user cost shares are adjusted. In the first three years (1952-1954), the following user cost shares are imposed on structures, equipment, and others: 0.8, 0.15, and 0.05. In subsequent years, the arithmetic average of the previous three years' user cost shares is imposed.

E. Data Series

We calculate wealth capital stock and a capital services index under the following three scenarios:

- (A) Identical geometric age-efficiency/age-price profile (OECD scenario, referring to the adaptation of the model OECD spreadsheet).
- (B.1) Hyperbolic age-efficiency profile (with consistently derived age-price profile).
- (B.2) Geometric age-efficiency profile (with consistently derived, virtually identical age-price profile). The results are near-identical to A.

In the final dataset, available online, we provide a range of results for each province (and nationwide) for each of the above scenarios.

For wealth capital stock (in each of the three scenarios), we provide the following results:

(i) Current-price end-year wealth capital stock.

[28] In the case of one province, Tibet, gross operating surplus itself is negative in 1985, and operating surplus is negative in 1985-1991.

(ii) Constant-price end-year wealth capital stock (in average 1985 prices).
(iii) An index of constant-price end-year wealth capital stock with 1985=1 (and also as annual growth rate in form of 1.X), based on a Laspeyres volume index.

For capital services (in each of the three scenarios), we provide the following results:

(i) An index of annual capital services with 1985=1 (and also as annual growth rate in form of 1.X), based on the Törnqvist index with user cost shares as weights.
(ii) A constant-price annual capital services series in 1985 prices based on the index in (i) and the 1985 value of gross operating surplus (user costs) in the national income and product accounts.[29]
(iii) A current-price annual capital services series based on (ii) and the investment in fixed assets price index.

For each of A, B.1, and B.2, for each province (and nationwide), we provide additional data: end-year wealth capital stock in average 1985 prices by type of asset; mid-year productive capital stock in average 1985 prices—and, separately, in average prices of each period—by type of asset; user cost shares by type of asset; rate of return; depreciation rates by type of asset; and in the case of (A) also the real price index of GFCF by type of asset. We finally include for each province (and nationwide) the following original data: aggregate expenditures, GFCF, gross operating surplus (obtained from raw data as explained in the relevant section above), investment in fixed assets price index by type of asset, and the CPI.

F. Findings and Interpretation

The resulting capital series allow a number of conclusions. Some of the variables used in the calculation of capital measures are of interest in themselves. The capital series can also be used to derive other, economically meaningful results.

1. Results

Figure 3 and Figure 4 report the growth indices of capital measures for one province (provincial-level city), Shanghai, focusing on the years since 1985. (With 1985=1, the series are indistinguishable for the pre-1985 years in a chart extending to the present.) The fastest growing capital measure is capital services based on the hyperbolic age-efficiency profile, followed by capital services based on the geometric age-efficiency profile (OECD); wealth capital stock grows slowest, and the results of the OECD approach of an identical geometric age-efficiency/age-price profile are undistinguishable from the results of our approach of deriving the age-price profile from a geometric age-efficiency profile (Figure 3). The differences between the different types of capital measures are significant: by 2015, the capital services index (hyperbolic age-efficiency) is 20% higher than the wealth capital stock index.

Dropping the OECD results from the chart and including our capital services measure based on a geometric age-efficiency profile as well as our wealth capital stock measure based on a hyperbolic age-efficiency profile (Figure 4), the capital services index based on a

[29] Inspection of all provincial user cost series suggests that the provincial 1985 value is not an outlier in any province, expect for Tibet. Tibet's negative user cost value for 1985 is replaced by a value linearly interpolated between the 1980 and 1995 values. (This value then also enters the calculation of user cost shares, while for several other years with negative rates of return, triggering user cost shares to not add up, user cost shares were proxied according to the rule stated in the section on negative rates of return.)

hyperbolic age-efficiency profile still grows fastest, followed by the capital services index based on a geometric age-efficiency profile; wealth capital stock based on a hyperbolic age-efficiency profile (the key innovation of this chart) grows slightly faster than wealth capital stock based on a geometric age-efficiency profile.

The precise ordering of the different capital measures (in terms of growth rates) varies across provinces. The pattern observed for Shanghai—our model "province," with the data of which our model spreadsheet was developed—is the exception. The dominant pattern across provinces in a figure such as Figure 3 has capital services based on the geometric age-efficiency profile (OECD) growing fastest. The two wealth capital stock measures, based on geometric age-efficiency profiles, are always indistinguishable.

Figure 3. Shanghai Capital Measures I (1985=1)

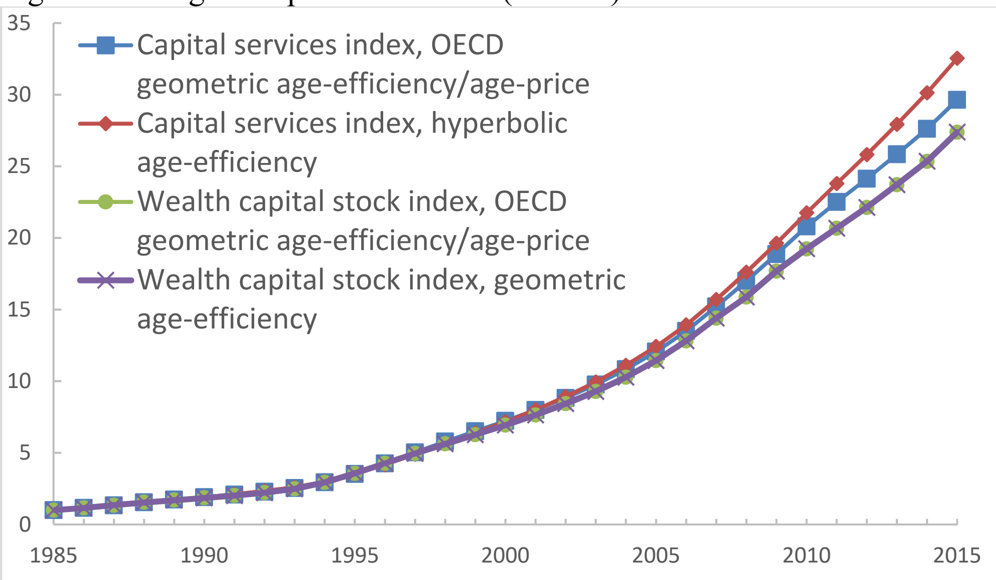
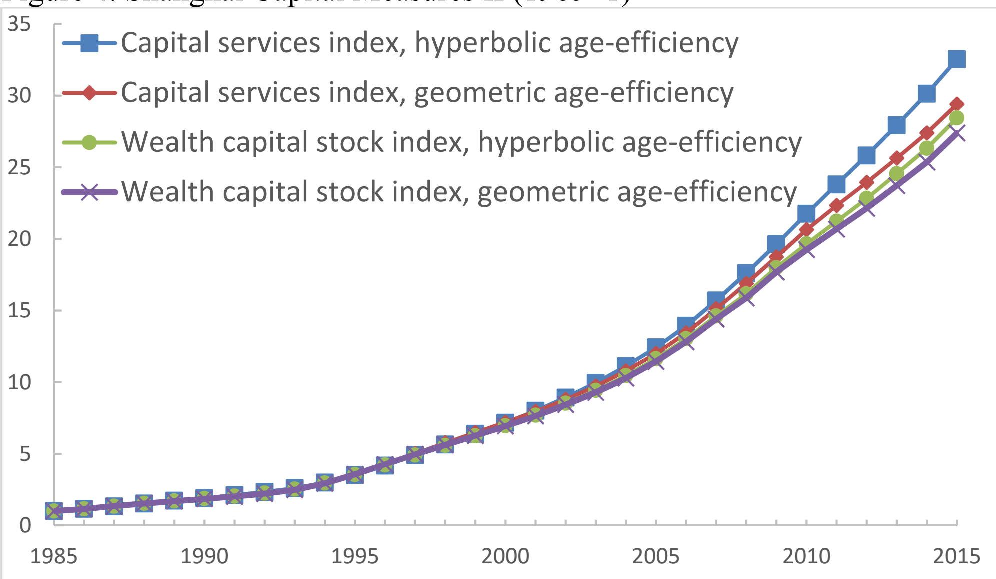


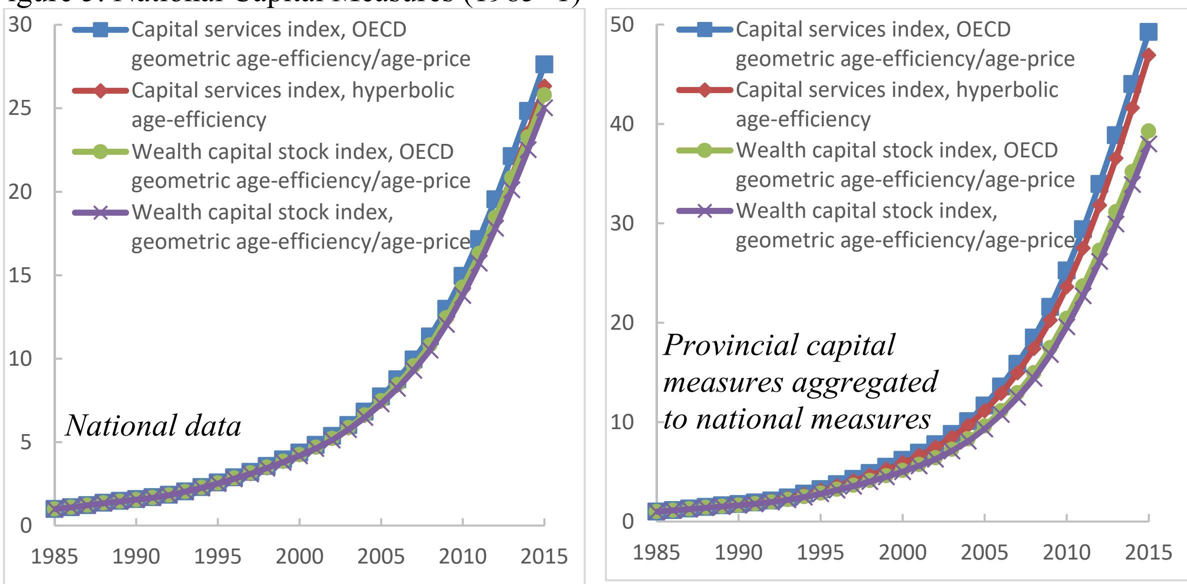
Figure 4. Shanghai Capital Measures II (1985=1)



At the national level, with Figure 5 replicating Figure 3, the capital measure indices are almost indistinguishable (left side of Figure 5); capital services based on the geometric age-efficiency profile (OECD) grow fastest, followed by capital services based on the hyperbolic age-efficiency profile. These national indices are aggregates of national investment in structures, equipment, and others.

Alternative national capital measures can be derived from the provincial results. I.e., national capital services can be obtained via a Törnqvist of provincial capital services growth, with provincial user cost shares (in summed provincial user costs) as weights, and similarly for national wealth capital stock via a Laspeyres index of provincial real growth rates of wealth capital stock (with previous-year current-price provincial wealth capital stocks as weights). The right-hand side of Figure 5 reports the results. The ranking is unchanged, but the capital services indices now grow significantly faster than the wealth capital stock indices. Furthermore, the growth rates are significantly higher than in the case where national data are used to derive national capital measures (left side of Figure 5, compare scale of vertical axis). This means, for example, that in growth accounting total factor productivity (TFP) growth based on a national capital services measure which constitutes an aggregate of provincial capital services is significantly lower than TFP growth based on national data.

Figure 5. National Capital Measures (1985=1)



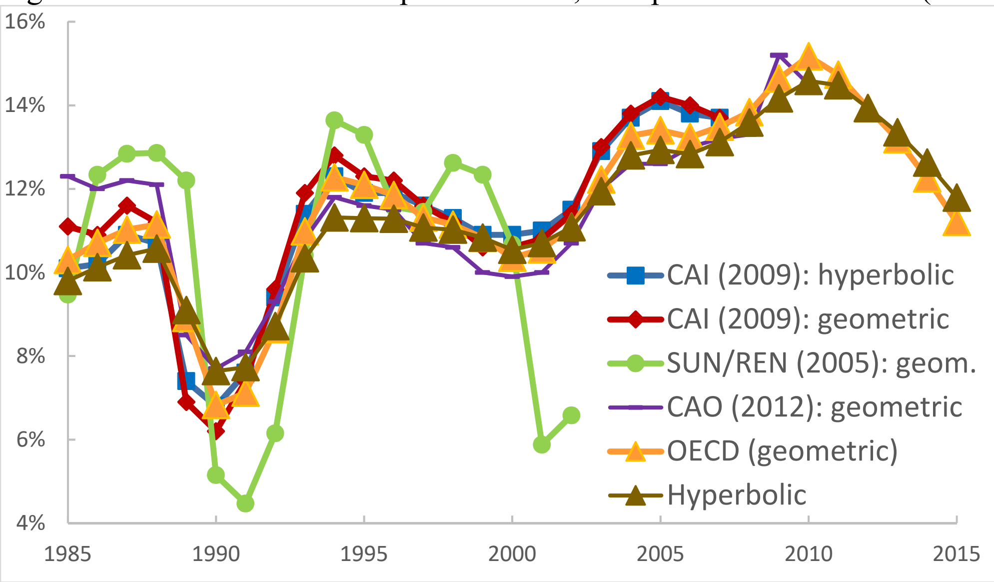
Overall, the reader who prefers the scenario of identical geometric age-efficiency/age-price profiles may wish to work with the "OECD" results.[30] The reader who prefers the scenario of a hyperbolic age-efficiency profile, would use those results.

2. Comparisons to the literature

Using national data, our results can be compared to capital measures derived in the literature. Figure 6 provides a comparison of four series of capital services in the literature to our series based on geometric age-efficiency/age-price profile (OECD) and based on hyperbolic age-efficiency. Our two series, with slightly enlarged markers for better visibility in the chart, are smoother than any of the other series. The smoothest series is the one based on the hyperbolic age-efficiency profile. To the extent that one would expect capital services to fluctuate little over time (beyond the growth trend), this is a sign of the quality of our series.

[30] Alternatively, and virtually equivalent, the 'own' derivations under the assumption of a geometric age-efficiency profile can be used. These are based on the simplified user cost equation and explicitly grapple with mid- vs. end-year values while deriving the age-price profile from the age-efficiency profile, rather than assuming the two to be identical.

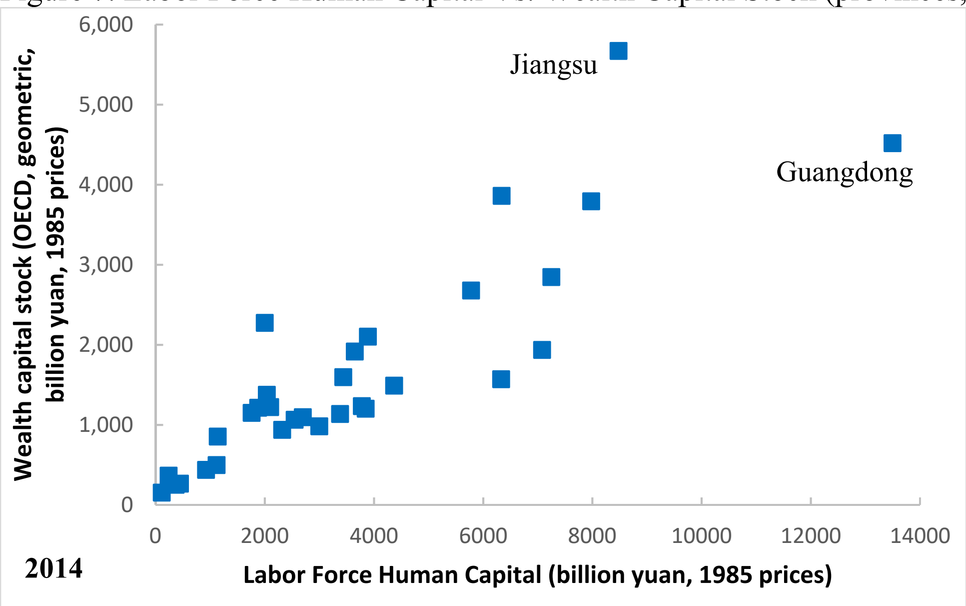
Figure 6. Annual Growth in Capital Services, Comparison to Literature (national data)



3. Physical vs. human capital

Across provinces, human capital and wealth capital stock are highly correlated (Figure 7, with data for 2014, the most recent year for which human capital data are available, and using labor force human capital). This suggests that human capital and wealth capital stock are complements rather than substitutes.

Figure 7. Labor Force Human Capital Vs. Wealth Capital Stock (provinces, 2014)

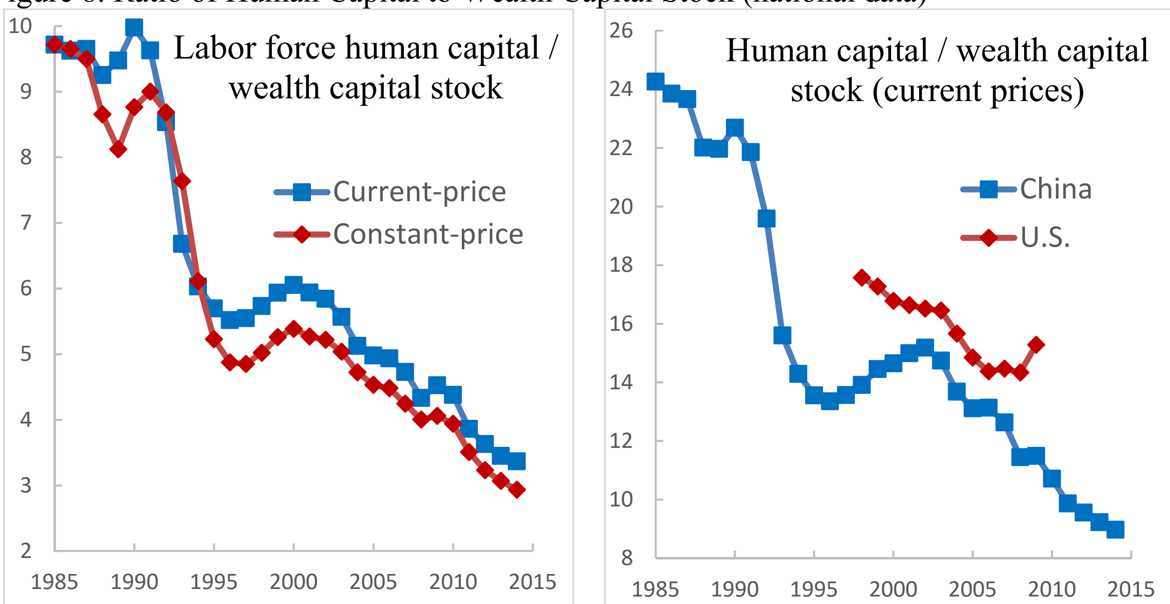


Notes: Wealth capital stock is based on a geometric age-efficiency/age-price profile (OECD). Labor force human capital data are obtained from the CHLR Human Capital Index Project (2016).

Over time, the ratio of (labor force) human capital to the wealth capital stock has been decreasing, indicating slow growth of human capital relative to the growth of wealth capital stock (Figure 8, left). The national wealth capital stock (OECD, geometric age-efficiency/age-price profile) has been growing at an average annual (real) rate of 11.7% between 1985 and 2015. Given that human capital reflects both the quality of labor and the price that labor can achieve today and throughout all remaining years of work (present value of future income), the relative decline in human capital likely reflects not only slow growth in the quality of labor (not directly measurable) but also relatively slow growth in income per particular quality of labor and slow growth (or negative growth) in the number of remaining cumulative work years of the labor force (ageing of the labor force).

The decrease in the ratio of China's labor force human capital to wealth capital stock is matched by a corresponding decrease in the ratio of China's (total) human capital to wealth capital stock (Figure 8, right). The pattern of decline, and the level of the ratio, matches that for the U.S., at least in the 2000s for which the U.S. data are available.

Figure 8. Ratio of Human Capital to Wealth Capital Stock (national data)



Notes: Wealth capital stock is based on a geometric age-efficiency/age-price profile (OECD). Labor force human capital data are obtained from the CHLR Human Capital Index Project (2016). U.S. data on human capital are from Christian (2012), while net fixed assets are from the Bureau of Economic Analysis (http://www.bea.gov), with both series in current prices.

4. Capital-Output Ratio

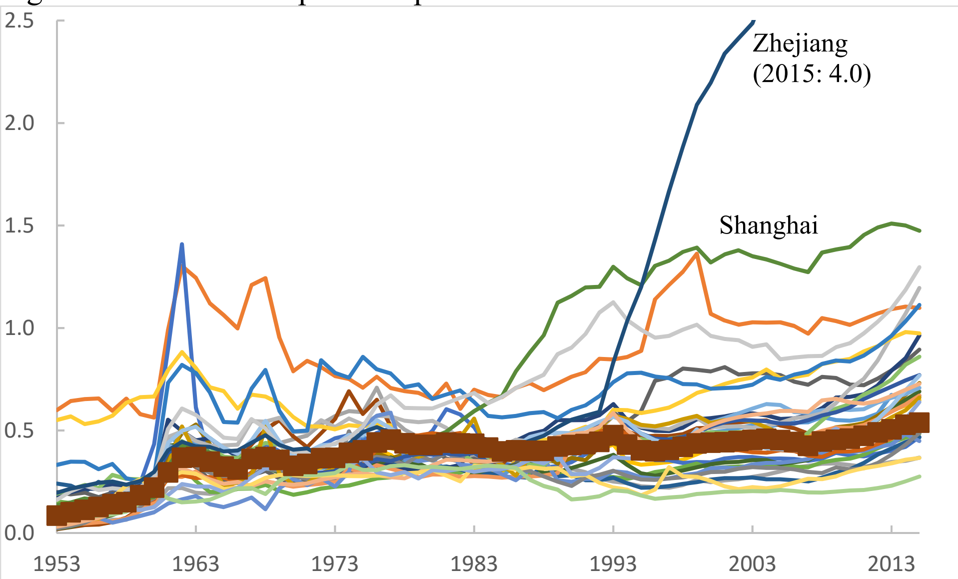
China's national capital-output ratio—with capital measured as capital services—increased from 0.08 in 1953 to 0.54 in 2015. Much of that increase occurred in the 1950s, with a 1962 value of 0.37 (Figure 9, including the national series as collection of bold squares). By 1977, the value was 0.46. Overall, while there may be a slight upward trend since the mid-2000s, there is no drastic increase in the capital-output ratio in recent years.

The provincial capital-output ratios vary significantly across provinces. Two provinces with particular high capital-output ratios are Shanghai and Zhejiang. (Zhejiang's ratio is driven by an explosion in capital values that is consistent across all capital measures, including wealth capital stock.)

5. Related findings

A by-product of the calculation of capital services is the rate of return. Figure 10 for 1953-2015 and Figure 11 for 1985-2015 report the rates of return based on the hyperbolic age-efficiency profile. The included national values are in bold squares. Significant statistical breaks occur in gross operating surplus (and therefore in the rate of return) in 2003–2004 and in 2008–2009, rendering interpretation in recent years difficult (note 26).

Figure 9. Provincial Capital-Output Ratios



Note: Capital is measured as capital services based on a hyperbolic age-efficiency profile with the resulting capital services index applied to the 1985 gross operating surplus, and that series then turned into current prices. Output is aggregate expenditures.

In the 1950s, the rates of return are extraordinarily high, presumably by design of the planned economy. The rates of return of Shanghai and Zhejiang are consistently high through the 1980s (Shanghai) and the 1990s (Zhejiang), a perfect match to the finding of the previous section of particularly high capital-output ratios in these provinces. The national rate of return shows little movement between the 1960s and today. A slight downward trend is noticeable since 1985 (Figure 11). It is as yet uncertain if the declines of the last four years signal a permanent decline or a fall within the range of historical variation.

Figure 10. Rates of Return (1953-2015)

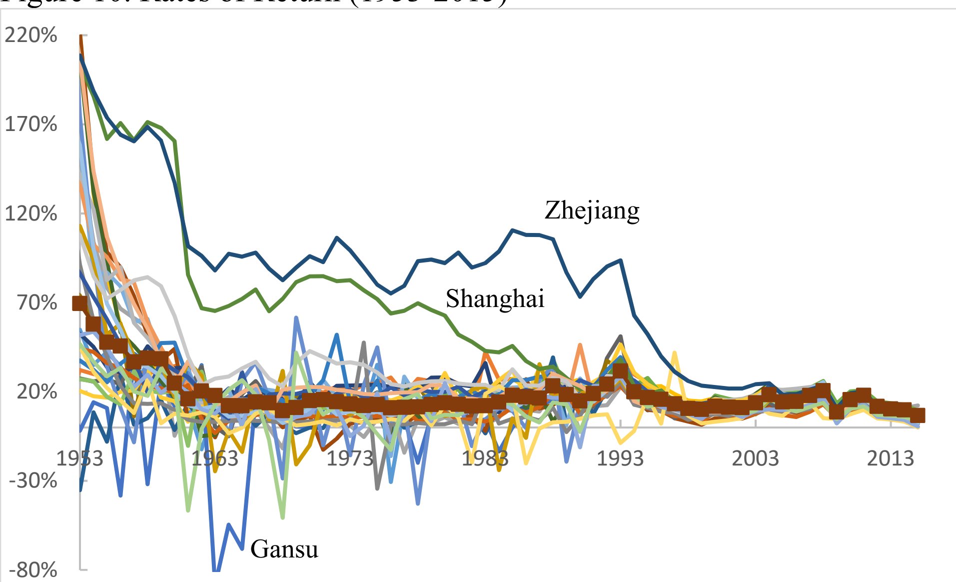
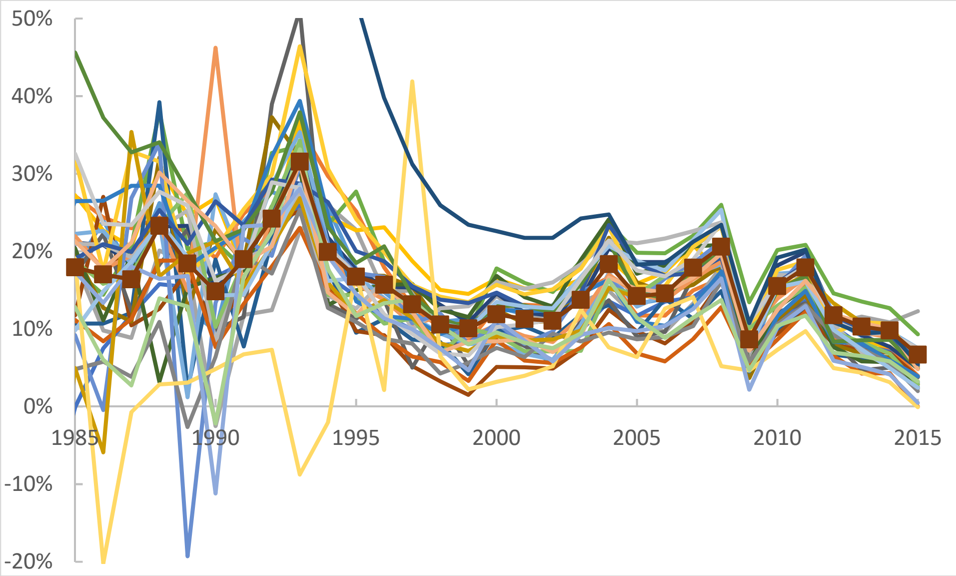


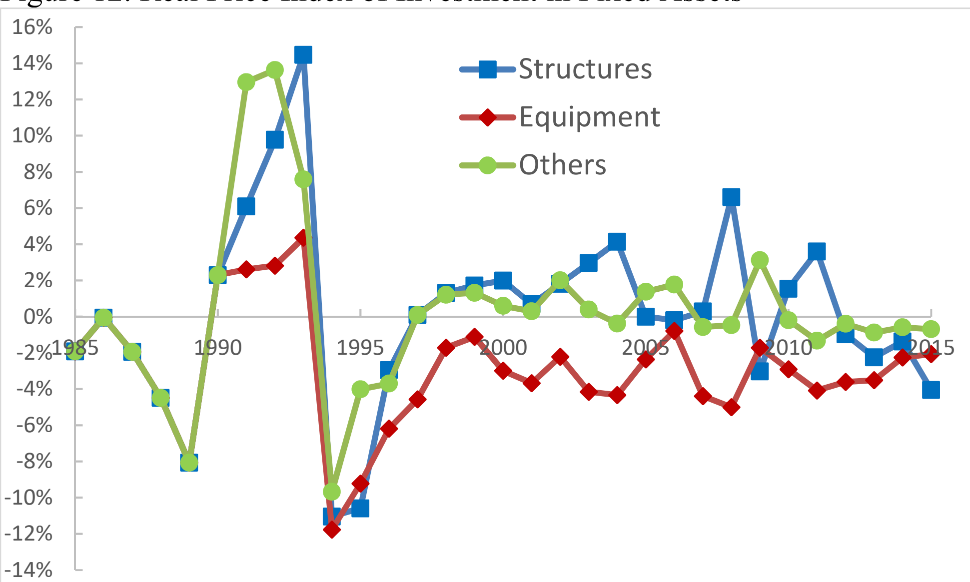
Figure 11. Rates of Return (1985-2015)



Another by-product of the calculation of capital services is the real price index of investment in fixed assets (for structures, equipment, and "others"). This is the ratio of the increase in the investment in fixed asset price index (by type of asset), expressed in form of 1.X, divided by the increase in the CPI, expressed in form of 1.Y, turned into a percentage. The percentage states by how many percentage points investment prices in any one year increased more than the CPI.

Figure 12 shows the national values since 1985. (Provincial values undergo larger fluctuations, making the discernment of the variation from the 0% value difficult.) In the period of price liberalization 1990-1992 and the subsequent investment boom of 1993-1994, prices of investment goods rose significantly faster than the CPI. A reversal followed in 1994-1996. Since then, the prices of structures tend to grow slightly faster than the CPI (though not in 2011-2015), while the prices of equipment consistently rise slower than the CPI.

Figure 12. Real Price Index of Investment in Fixed Assets



G. Conclusions

This paper introduces and explains the derivation of capital measures for Chinese provinces (and nationwide) for the years since 1952. In comparison to other studies, the data series cover both wealth capital stock and capital services growth, follow OECD (and BLS and ABS) methods, cover a long-run time period starting 1952, are available online (for link see first paragraph of this article), and are expected to be updated annually. A number of intermediate measures and related data are also provided online.

Across provinces, capital services tend to grow faster than wealth capital stock, indicating that the use of wealth capital stock in growth accounting biases total factor productivity (TFP) upward. A measure of national capital services derived from the provincial capital measures (rather than directly from national raw data) shows the difference between capital services growth and growth of wealth capital stock (all in real terms) to be particularly large, and capital growth in general to be particularly fast, reducing any national TFP measure yet further.

In a comparison of the series of capital services derived here to other capital services series in the literature, our series tend to be smoother; the smoothest series is the one based on the hyperbolic age-efficiency profile. This inspires confidence in our series because capital services should not change drastically from one year to the next.

Human capital and wealth capital stock are highly correlated across provinces. A ratio of human capital to wealth capital is declining over time (and similarly so in the U.S. during the short period for which data on the U.S. are available). Exemplary applications of our dataset of capital measures show that capital-output ratios are not rising drastically in recent years, that the rate of return is quite stable (though with a decline in 2012-2015), and that over the past two decades the price increase for equipment is consistently less than the increase in the CPI. Some of these findings, such as the declining ratio of human capital to wealth capital stock, or the variation across provinces in the capital-output ratio and the rate of return, invite further research. Our capital service measures beg to the used in productivity and growth studies.

References

CAI Xiaochen. “China’s Capital Inputs, 1978-2007” (*Zhongguo ziben touru: 1978-2007*). *Guanli shijie*, no. 11 (2009): 11-20.

CAO Yuequn, Qin Zengqiang, Qi Qian. “Estimates of China’s Capital Services” (*Zhongguo ziben fuwu gusuan*). *Tongji yanjiu 29*, no. 12 (2012): 45-52.

CAO Yuequn, Qin Zengqiang, Qi Qian. “Measurement of China’s Provincial Capital Services: Concept, Framework, and Index Construction” (*Zhongguo shengji ziben fuwu celiang: gainian, kuangjia he zhishu goujian*). *Shuliang jingji jishu jingji yanjiu 30*, no. 12 (2013): 35-50.

China Statistical Yearbook. *Zhongguo tongji nianjian* (Statistical Yearbook of China). Beijing: Zhongguo tongji chubanshe, various years.

CHLR Human Capital Index Project (2016). China Center for Human Capital and Labor Market Research. Data available at: http://humancapital.cufe.edu.cn/en/Human_Capital_Index_Project/Project_2016.htm, last accessed 15 April 2017.

Chow, Gregory C. (1993). “Capital Formation and Economic Growth in China.” *The Quarterly Journal of Economics 108*, no. 3 (1993): 809-842.

Christian, Michael S. “Human Capital Accounting in the United States: Context, Measurement, and Application.” Mimeo, July 2012. Available at http://users.nber.org/confer/2012/CRIWf12/program.html, accessed 16 April 2017.

Feenstra, Robert C., Robert Inklaar, and Marcel P. Timmer. “The Next Generation of the Penn World Table.” *The American Economic Review 105*, no. 10 (October 2015): 3150-82.

GDP 1952-1995. *Zhongguo guonei shengchan zongzhi hesuan lishi ziliao* (Historical Material on China’s GDP Accounting). Compiled by China’s National Bureau of Statistics, National Income Accounts Division. Dalian: Dongbei caijing daxue chubanshe, 1997.

Holz, Carsten A. “New Capital Estimates for China.” *China Economic Review 17*, no. 2 (2006): 142–185.

Holz, Carsten A. “Understanding China’s Investment Statistics.” Mimeo, April 2017.

Jorgenson, Dale W. “Productivity and Economic Growth,” Chapter I, Volume II, in Dale W. Jorgenson (ed.), *Productivity*, Volumes I and II, Cambridge: MIT Press, 1995, pp. 1-98.

NBS website. http://www.stats.gov.cn (data section)

OECD. *OECD Manual: Measuring Productivity – Measurement of Aggregate and Industry-Level Productivity Growth*. Paris: OECD, 2001.

OECD. *OECD Manual: Measuring Capital*. Paris: OECD, 2001, and second edition 2009.

QIAN Zhenjie. “Implications of GDP Accounting for Factor Income Share in China.” *China Economic Review 30* (September 2014): 370-82.

Sixty Years. *Xin zhongguo liushi nian tongji ziliao huibian* (Comprehensive Statistical Material on 60 years of the New China [1949-2008]). Beijing: Zhongguo tongji chubanshe, 2010.

SUN Linlin, and REN Ruo’en. “Estimates of China’s Capital Input and Total Factor Productivity” (*Zhongguo ziben touru he quan yaosu shengchanlv de gusuan*). *Shijie jingji*, no. 12 (2005): 3-13.

SUN Linlin, and REN Ruo’en. “China’s Sector Capital Accumulation during the Transition Period—Calculation of Capital Stocks and Flows” (*Zhuangui shiqi woguo hangye cengmian ziben jilei de yanjiu—ziben cunliang he ziben liuliang de cesuan*). *Jingjixue (jikan) 13*, no. 3 (2014): 837-62.

Wang, Lili, and Szirmai, Adam. Capital Inputs in the Chinese Economy: Estimates for the Total Economy, Industry and Manufacturing. *China Economic Review* 23, no. 1 (March 2012): 81-104.

Wu, Harry X. "Constructing China's Net Capital and Measuring Capital Services in China, 1980-2010. RIETI Discussion Paper Series 15-E-006, January 2015.

WU Yanrui. "China's Capital Stock Series by Region and Sector." *Frontiers of Economics in China 11,* no. 1 (2016): 156-72.

XIAO Wen, and ZHOU Minghai. "Structural reasons for the change in the share of labor remuneration" (*Laodong shouru fen'e biandong de jiegou yinsu*). *Dangdai jingji kexue 32*, no. 3 (May 2010): 69-76, 126.

ZHANG Junkuo. "Comprehensive Analysis of the Economic Benefits of the Seventh Five-Year Plan Period—Estimation of Different Factors' Contribution to Economic Growth" (*'Qi wu' qijian jingji xiaoyi de zonghe fenxi—ge yaosu dui jingji zengzhang gongxian lv de cesuan*). *Jingji yanjiu 8*, no. 4 (1991): 8-17.

ZHANG Jun, WU Guiying, and ZHANG Jipeng. "Estimation of China's Provincial Capital Stock 1952-2000" (*Zhongguo shengji wuzhi ziben cunliang gusuan 1952-2000*). *Jingji yanjiu*, no. 10 (2004): 35-44.