Improving the SNA: Alternative Measures of Output, Input, Income, and Productivity

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Abstract:

The current System of National Accounts (SNA) Gross Domestic Product (GDP) concept does not measure the *income* generated by the production sector since it includes depreciation and excludes capital gains and losses on assets used in the production sector. The paper suggests an accounting framework that measures the income generated by the production sector of an economy and implements this measure using the Augmented Productivity Database (APDB) developed by Asian Productivity Organization and Keio University for China over the years 1970–2020. Real gross and real net income generated by the Chinese production sector are decomposed into explanatory factors including TFP growth using the framework suggested by Jorgenson and Diewert and Morrison. TFP growth is further decomposed into technical progress and inefficiency components using the nonparametric approach developed by Diewert and Fox. The APDB has estimates for the price and quantity of agricultural, industrial, commercial, and residential land used in China. The paper argues that changes in land use should be treated in the same manner as inventory change and added to the alternative output measures. It turns out that Jorgensonian user costs for land are frequently negative. The problems associated with negative user costs are discussed in the paper.

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1. INTRODUCTION

The production accounts in the current international System of National Accounts (SNA) serve many useful purposes but the Gross Domestic Product (GDP) concept in these accounts does not measure the *income generated by the country's production sector* for two main reasons:

- The GDP concept includes depreciation as part of output and
- The GDP concept excludes capital gains or losses that accrue to productive assets held over the accounting period.

It is obvious that depreciation is not part of "income" as conceived by the public. However, including capital gains or losses on assets used by the production sector as part of the income generated by domestic producers is more controversial and has been resisted by national income accountants due to the volatility of capital gains and losses on assets used in production. However, the inclusion of capital gains in income measures has a long history in economics, dating back to Marshall:

> "When a man is engaged in business, his profits for the year are the excess of his receipts from his business during the year over his outlay for his business. The difference between the value of his stock of plant, material, etc. at the end and at the beginning of the year is taken as part of his receipts or as part of his outlay, according as there has been an increase or decrease of value. What remains of his profits after deducting interest on his capital at the current rate (allowing, where necessary, for insurance) is generally called his earnings of undertaking or management. The ratio in which his profits for the year stand to his capital is spoken of as his rate of profits. But this phrase, like the corresponding phrase with regard to interest, assumes that the money value of the things which constitute his capital has been estimated: and such an estimate is often found to involve great difficulties." Alfred Marshall (1920, p. 62).

Marshall essentially defined the nominal income generated by a production unit over the accounting period as the period's cash flow plus the end of the period capital stock minus the beginning of the period capital stock. This residual is decomposed into interest payments plus pure profits. To this residual, we add payments to labour plus tax payments to governments to obtain a useful measure of the nominal income generated by the production unit over the accounting period. In section 6 of the paper, we will essentially use this definition of nominal income to measure the nominal income generated by the production sector of the Chinese economy.

Haig's net income concept was similar to Marshall's concept:

> "More simply stated, the definition of income which the economist offers is this: Income is the *money value of the net accretion to one's economic power between two points of time*. It will be observed that this definition departs in only one important respect from the fundamental economic conception of income as a flow of satisfactions. It defines income in terms of power to satisfy economic wants rather than in terms of the satisfactions themselves. It has the effect of taxing the recipient of income when he receives the power to attain satisfactions rather than when he elects to exercise that power." Robert Haig (1921, p. 7).

However, Haig took Marshall's definition one step further by recognizing that income received at two points in time may not have the same purchasing power. He recognized that finding the "right" deflator to convert nominal income into real income was not a trivial task:

> "The prospect for a complete solution of the difficulty pointed out, however, is identical with the prospect for a perfect monetary standard. But an approximate solution might be realized if we were able to evolve

> a satisfactory index of the level of prices. If it were accurately known what the change in price level in a given year had been, it might be possible to qualify the results shown by a comparison of the balance sheets for the beginning and the end of the period in such a way as to eliminate the influence of the changing standard. But even this refinement is not likely to be introduced soon. Indeed, the desirability and urgency of its introduction is dependent largely upon the complete solution of the accounting problem, which solution is certainly not imminent." Robert Haig (1921, p. 17).

The "accounting problem" Haig referred to is the problem of valuing production unit assets (in current market values) at the beginning and end of the accounting period. Indeed Marshall also noted this problem in the above quotation. Because capital stocks are not bought and sold at the end of every accounting period, current values for produced assets at a point in time must be estimated and these estimates rest on assumptions about the form of depreciation. For non-produced assets in production, like land, transactions are typically sparse for commercial and industrial properties and, as an added complication, sales of land are usually bundled with structures on the land and so again, beginning- and end-of-period current values for land assets used in production will generally be imputations rather than market transactions.

The fact that nominal measures of gross domestic output (or value added) can be produced (largely) without the use of imputations is the reason why the GDP concept has become the measure of output that is largely used around the world. Thus while Hicks favoured the use of a net measure of output and the corresponding measure of input or income, he recognized that the above argument for the use of GDP or GNP had some validity:[1]

> "There are items, of which Depreciation and Stock Appreciation are the most important, which do not reflect actual transactions, but are estimates of the changes in the value of assets which have not yet been sold. These are estimates in a different sense from that previously mentioned. They are not estimates of a statistician's true figure, which happens to be unavailable; there is no true figure to which they correspond. They are estimates relative to a purpose; for different purposes they may be made in different ways. This is of course the basic reason why it has become customary to express the National Accounts in terms of Gross National Product (before deduction of Depreciation) so as to clear them of contamination with the 'arbitrary' depreciation item; though it should be noticed that even with GNP another arbitrary element remains, in stock accumulation." John R. Hicks (1973, p. 155).

Hicks noted that including the change in the value of inventory stocks in the definition of GNP was an imputation since the value of inventory stocks held by the production unit at the beginning and end of the accounting period had to be estimated and then deflated by a suitable price index and then differenced to form real inventory change.

The above discussion can be summarized as follows:

- GDP is favoured over a net measure of output (NDP) because it can be produced largely without using imputations.[2]
- NDP is favoured over GDP because NDP best approximates a measure of the *income* generated by the production unit.

Measures of nominal income have to be converted into real income measures to be meaningful. Following Haig, we could choose a consumer price index to deflate nominal gross or net income into real gross or net

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[1] This point of view is also expressed in the *1993 SNA*: "As value added is intended to measure the additional value created by a process of production, it ought to be measured net, since consumption of fixed capital is a cost of production. However, as explained later, consumption of fixed capital can be difficult to measure in practice and it may not always be possible to make a satisfactory estimate of its value and hence of net value added." (Eurostat, International Monetary Fund, OECD, United Nations, and World Bank, 1993, p. 121).

[2] While the output based estimates for GDP are largely free from imputations, the companion input based measure requires imputations for forming Jorgensonian user costs of capital and for decomposing Gross Operating Surplus into labour and capital components.

income. However, a consumer price index is not the only choice for the deflator. In making comparisons of a country's per capita real income across time or space, nominal GDP is usually deflated by the GDP deflator and then divided by population to generate measures of per capita real income. However, the use of the GDP deflator in this context is not recommended: the quantity of imports enters the GDP deflator with a negative sign and this means if the price of imports *increases* (other prices held constant), the GDP deflator will *decrease*, which is not a good property in the measurement of real income context.[3] Thus we recommend deflation of nominal income by a consumer price index rather than by the GDP deflator.

There are other controversies surrounding the measurement of real income from the production perspective. Consider the following quotation:

> "At once we run into the difficulty that if Net Investment is interpreted as the difference between the value of the Capital Stock at the beginning and end of the year, the transformation would not be possible. It is only in the special case when the prices of all sorts of capital instruments are the same (if their condition is the same) at the end of the year as at the beginning, that we should be able to measure the money value of Real Net Investment by the increase in the Money value of the Capital stock. In all probability these prices will have changed during the year, so that we have a kind of index number problem, parallel to the index number problem of comparing real income in different years. The characteristics of that other problem are generally appreciated; what is not so generally appreciated is the fact that before we can begin to compare real income in different years, we have to solve a similar problem within the single year—we have to reduce the Capital stock at the beginning and end of the years into comparable real terms." John R. Hicks (1942, pp. 175–176).

When we move from the gross output model of production to the net output model, gross investment is replaced by some measure of net investment or by some measure of the difference between the end of the period capital stock minus the beginning of the period capital stock. In the above quotation, Hicks recognized that there was a "kind of index number problem" in comparing capital stocks at the beginning and end of the period. Thus instead of deflating capital stock values by a consumer price index, a capital stock price index could be used as the deflator. *Real financial capital is held constant* (or increased) if the end-of-period nominal value of the capital stock employed divided by an end of the period consumer price index minus the beginning of the period value of the capital stock employed by the production unit divided by the beginning of the period consumer price index is equal to (or greater than) zero. *Real physical capital is held constant* (or increased) if the end-of-period nominal value of the capital stock employed divided by an end of the period capital stock price index minus the beginning of the period value of the capital stock divided by the beginning of the period capital stock price index is equal to (or greater than) zero. Pigou (1941, pp. 273–274) favored the second approach which is called the *maintenance of physical capital approach* while Haig (1921) and Hayek (1941, pp. 276–277) favored the first approach, the *maintenance of real financial capital approach* to the measurement of income. In this paper, we will take the approach which can be traced back to Haig. However, we will provide indexes of real physical capital input for the Chinese economy in passing. The details of our approach to measuring the net income generated by an economy will be spelled out in section 6.[4] We note that our chosen measure of national net income is not the only measure that could be used to measure the income generated by the production sector of an economy. There is a huge inflation accounting literature on the measurement of income for a business enterprise which could be adapted to measure real national income.[5]

We will illustrate the difference between our theoretical gross and net measures of national income by using the Augmented Productivity Database (APDB) on the People's Republic of China for the years 1970–

[3] This point was emphasized by Kohli (1982, p. 211, 1983, p. 142) and Diewert (2002, p. 556).
[4] For additional details on alternative economic approaches to the measurement of net income, see Samuelson (1961) and Diewert and Fox (2023).
[5] See Middleditch (1918), Sweeney (1934, 1935), Edwards and Bell (1961), Baxter (1975), Sterling (1975), Whittington (1980), Carsberg (1982), and Tweedie and Whittington (1984).

2020, developed by the Asian Productivity Organization (APO) and Keio University. The APDB has price and quantity (or volume) information on 16 capital stock components including four types of land: agricultural, industrial, commercial, and residential. We will use this data base to construct estimates of China's gross output Total Factor Productivity (TFP) for these years in section 3.[6]

In section 4, the Chinese *real gross income* over the years 1970–2020 will be decomposed into explanatory factors using the decomposition suggested by Diewert and Morrison (1986), Kohli (1990) and Diewert and Lawrence (2006). In section 5, an alternative (nonparametric) decomposition of the Chinese real gross income into explanatory factors due to Diewert and Fox (2018) is implemented using our Chinese data. This alternative framework further decomposes TFP growth into technical progress and inefficiency terms. We typically think of TFP growth as a measure of technical progress but when a recession occurs in a country, TFP invariably becomes negative due to the existence of fixed factors that cannot be sold easily. Using the Diewert and Fox methodology, technical progress never becomes negative but inefficiency can cause TFP to become negative.

Section 6 presents the *real net income* TFP estimates for China. The accounting framework we use in this section is primarily due to Hicks (1961) and Edwards and Bell (1961).[7] Instead of using user costs and gross investment as our measurement concepts, we use waiting services[8] in place of capital services and we use the difference between the end of period and beginning of the period capital stock in place of gross investment. An alternative measure of TFP emerges in this section. The decompositions explained in sections 4 and 5 are also adapted to the net product context. Section 7 concludes.

National estimates of TFP when land is an input are fairly scarce due to the lack of national data on the price and quantity of land. This lack of data on land is perhaps partly due to the belief that land is not a very important input into production and partly due to the difficulties in decomposing market property prices into land and structure components. Thus the APDB on land input by type of use for 25 countries fills an important gap in the international statistical system.[9]

With the availability of land data by type of land, a new problem with traditional measures of GDP arises. At present, changes in land use do not appear in the GDP measure as currently compiled by countries. But using the APDB, we can see that agricultural land is being converted into commercial and residential land; i.e., the quantity of land in the different categories is changing over time (even if the total land area remains constant). We think that these changes in land use should appear in the GDP measures produced by countries; these changes are entirely analogous to changes in inventories, which do appear in GDP measures. Thus our Chinese measures of gross output include changes in land use.

Adding land use changes to GDP did not materially change our estimates of Chinese GDP. However, adding capital gains on land stocks used by the production sector do lead to Chinese estimates of Net Domestic Product (NDP) or Net Income that materially differ from the corresponding GDP estimates. Many advanced countries have experienced huge increases in land prices over the past 20 years. These increases translate into increased income generated by the production sector of the economy but these increases do not show up in country estimates of GDP. This is why supplementary measures of NDP should be constructed by National Statistical Offices.[10]

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[6] The APDB has similar data for 25 Asian countries. However, it is not currently available to the public. We chose China to illustrate the differences between gross and net income measures because the Chinese economy is now the largest economy in Asia and hence "explaining" its tremendous growth is of some interest.

[7] It is further developed in Diewert and Fox (2023).

[8] This term is due to Rymes (1968, 1983).

[9] For a summary of land shares in total asset value by country for 25 Asian countries in 2021, see APO (2023; p. 118). The land shares of Hong Kong, Singapore, Republic of China, Korea, and Japan were: 79%, 75%, 73%, 59%, and 38%.

[10] To be clear, we are not advocating that national statistical offices cease producing estimates of GDP. We are advocating that *supplementary estimates* of the net income produced by the domestic production sector be produced along with estimates of GDP. A straightforward deduction of

However, the increased availability of data on land use by country does lead to some additional problems. It turns out that land prices are very volatile. Thus at times, increases in land prices will cause Jorgensonian user costs to become negative. Negative user costs create some conceptual problems: if they are anticipated, investors should immediately buy the asset because the asset will generate a one-period return which exceeds the cost of capital. Moreover, user costs are supposed to approximate rental prices for the underlying assets. We do not observe negative rental prices in the real world. Section 2 explains and discusses the negative user cost problem. Section 2 also discusses the construction of the productivity data for China. Appendix A has more detail on the problems associated with the data construction.

3. USER COST THEORY AND DATA CONSTRUCTION

In this section and the following section, we use the APDB to construct estimates of China's gross output TFP for the years 1970–2020 using the methodology developed by Jorgenson and his coworkers.[11] A key aspect of this methodology is the construction of a *user cost of capital* to measure the services provided by the use of a capital stock asset over the course of a year. We explain how a user cost can be constructed from the APDB.

Suppose the beginning of the year t price of a new unit of capital stock n is P_{Kn}^t and the production unit faces an annual cost of capital at the beginning of year t of r^t. Suppose further that asset n in year t has a geometric depreciation rate equal to δ_n^t. Then the net discounted (to the beginning of year t) cost of purchasing a new unit of asset n, using it during year t and then selling it at the end of year t (most likely to the same production unit) is equal to:[12]

$$(1)\ P_{Kn}^t - (1-\delta_n^t)P_{Kn}^{t+1}/(1+r^t) = P_{Kn}^t - (1-\delta_n^t)(1+i_n^t)P_{Kn}^t/(1+r^t)$$
$$= (1+r^t)^{-1}[(1+r^t) - (1-\delta_n^t)(1+i_n^t)]P_{Kn}^t$$
$$= (1+r^t)^{-1}[r^t - i_n^t + \delta_n^t(1+i_n^t)]P_{Kn}^t.$$

The *asset n year t inflation rate* i_n^t which appears in (1) is defined by the following equation:

$$(2)\ 1+i_n^t \equiv P_{Kn}^{t+1}/P_{Kn}^t.$$

The *user cost of capital* defined by the right hand side of equation (1) discounts costs (the purchase price P_{Kn}^t) and benefits (the selling price of the used asset at the end of year $(1-\delta_n^t)P_{Kn}^{t+1}$ equal to $(1-\delta_n^t)(1+i_n^t)P_{Kn}^t$) to the beginning of year t. This is a beginning of the year perspective. If we take an end of the year perspective, then the end of the year benefits are no longer discounted and the beginning of the year costs are anti-discounted to their end of the period equivalents by multiplying P_{Kn}^t by $(1+r^t)$.[13] The resulting *end-of-year user cost of capital* for asset n, U_n^t, is defined as follows:[14]

$$(3)\ U_n^t \equiv (1+r^t)P_{Kn}^t - (1+i_n^t)(1-\delta_n^t)P_{Kn}^t$$
$$= [r^t - i_n^t + \delta_n^t(1+i_n^t)]P_{Kn}^t.$$

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the value of depreciation from the value of nominal GDP does not equal our suggested measure of the value of net income. We replace estimates of the value of gross investment at the average prices of investment during the period by estimates of the end of period capital value of the capital stock minus estimates of the beginning period of the capital stock at end and beginning of the period prices and we replace estimates of user costs by estimates of waiting services.

[11] See Jorgenson (1963), Jorgenson and Griliches (1967, 1972), Christensen and Jorgenson (1969), and Jorgenson (1989).

[12] This is the method used by Diewert (1974, p. 504, 1980, pp. 472–473) to derive a user cost formula. Note that the price P_{Kn}^{t+1} is the price of a new unit of the capital stock at the end of year t.

[13] The end of year perspective is used in accounting theory where current year revenues and costs are cumulated over the year (or quarter) and regarded as taking place at the end of the accounting period; see Peasnell (1981).

[14] This user cost formula was also derived by Christensen and Jorgenson (1969) using a different method of derivation.

The user cost formula defined by equation (3) makes sense from the viewpoint of accounting theory: if a production unit purchases a unit of capital stock n at the beginning of year t, it has to raise capital from investors to finance the purchase so the all inclusive cost of the purchase is not only the purchase price but the implicit or explicit interest that the unit has to pay to investors to tie up their financial capital for a year. Thus, the total cost associated with the purchase of a capital input is not P_{Kn}^t but $(1+r^t)P_{Kn}^t$.

In many countries, land and structure assets are taxed. These property taxes need to be added to the corresponding user costs. Thus let τ_n^t be the year t property tax rate that applies to asset n. The *new end-of-period user cost of capital for asset n* is defined as follows:

$$(4)\ U_n^t \equiv (1+r^t + \tau_n^t)P_{Kn}^t - (1+i_n^t)(1-\delta_n^t)P_{Kn}^t$$
$$= [r^t + \tau_n^t - i_n^t + \delta_n^t(1+i_n^t)]P_{Kn}^t.$$

The Jorgenson methodology uses the *geometric model of depreciation*. This methodology relates the end of the year quantity of capital for asset n in year t, Q_{Kn}^{t+1}, to the corresponding beginning of the year capital stock for asset n, Q_{Kn}^t, as follows:

$$(5)\ Q_{Kn}^{t+1} = (1-\delta_n^t)Q_{Kn}^t + Q_{In}^t$$

where Q_{In}^t is the production unit's *gross investment* in asset n in year t. Assumption (5) allows us to apply the user cost formula (4) to the aggregate capital stock for asset n (and not just to new units of the capital stock).

We apply the above methodology to the data for the People's Republic of China in the APDB. The data for the years 1970–2020 are explained more fully in Appendix A. We have data on the usual macroeconomic variables, C+G+I+X−M, which are consumption, government, gross investment, exports and (minus) imports. The year t prices and quantities for these variables are denoted by P_C^t, P_G^t, P_I^t, P_X^t and P_M^t and Q_C^t, Q_G^t, Q_I^t, Q_X^t and Q_M^t respectively. The price indexes have been normalized to equal 1 in 1970 and the quantities or volumes are measured in units of trillions of 1970 yuan. The corresponding values (in trillions of current yuan) are V_C^t, V_G^t, V_I^t, V_X^t and V_M^t where V_C^t equals $P_C^tQ_C^t$ and so on. These output price and quantity indexes for China are listed in Appendix A Tables A5 and A6, respectively.[15]

The APDB has information on quality-adjusted labour input for China (price, quantity, and value in year t are P_L^t, Q_L^t, and $V_L^t = P_L^tQ_L^t$) and on beginning of the year capital stocks for 16 assets China (price, quantity, and value in year t for asset n are P_{Kn}^t, Q_{Kn}^t and $V_{Kn}^t = P_{Kn}^tQ_{Kn}^t$ for n = 1, …, 16). The 16 assets are as follows: (1) IT hardware; (2) Communications equipment; (3) Transport equipment; (4) Other machinery and equipment; (5) Dwelling structures; (6) Non-residential buildings; (7) Other structures; (8) Cultivated assets; (9) Research and development; (10) Computer software; (11) Other intangible assets; (12) Net increase in inventory stocks; (13) Agricultural land; (14) Industrial land; (15) Commercial land, and (16) Residential land. The price indexes have been normalized to equal 1 in 1970 and the quantities or volumes are measured in units of trillions of 1970 yuan. The APDB also has information on the corresponding gross investments. The price and quantity indexes for investment in asset n and the value of investments in trillions of yuan are denoted by P_{In}^t, Q_{In}^t, and $V_{In}^t = P_{In}^tQ_{In}^t$, respectively for n = 1, …, 12. The APDB also has estimated depreciation rates δ_n^t for the depreciable assets 1–11 (inventory assets are

[15] The price and quantity indexes for gross investment in year t, P_I^t and Q_I^t, include land investment which is not included in the APDB because the international SNA does not include land investment as part of gross fixed capital formation (GFCF). The price indexes in table A5 have been adjusted for indirect taxes on consumption and imports; i.e., consumption taxes have been subtracted from the final demand output prices to obtain the prices that producers receive for their outputs and added to import prices because we follow Kohli (1978) in assuming that all imports flow through the country's production sector. The importance of making these indirect tax adjustments was noted by Jorgenson and Griliches (1972).

assumed to have zero depreciation rates) and the Q_{Kn}^t, Q_{In}^t, and δ_n^t satisfy equation (5) for n = 1, …, 11 and t = 1970, …, 2020.

Note that the APDB follows standard SNA conventions by setting investment in land assets equal to zero for each year. We believe that this is a problem with the current SNA methodology which ignores land investments. The reason for this omission may be the assumption that at the national level, the stock of land is fixed and therefore there is no real investment in land where investment is defined as the change in the stock of land. However, as soon as we have information on alternative uses of land (as is available in the APDB, we see that there are considerable changes in the composition of the land subaggregates. In general, agricultural land is converted to commercial and residential land and other uses.[16] as population grows or as economic development proceeds. Since inventory change is accepted as part of gross investment in the SNA, it seems reasonable to also include changes in land use as part of gross investment. Thus, we define *land investment* in year t for the four types of land, Q_{In}^t for n=13, …, 16, as follows:

(6) $Q_{In}^t \equiv Q_{Kn}^{t+1} - Q_{Kn}^t$; n = 13, …, 16 ; t = 1970, …, 2020.

The investment prices P_{In}^t for the produced assets are "objective" but the beginning of the year prices for the corresponding stocks could be chosen to be closer to year end prices for the investment goods rather than being an annual average of the year's investment prices. For example, the APDB could have set the beginning of the year price of asset n equal to $P_{Kn}^t \equiv (1/2)[P_{In}^t+P_{In}^{t-1}]$, an average of the year t and t–1 investment prices for the nth asset. The choice of the "right" beginning of the year price for an asset is more or less up to the national income accountant. However, in this paper, we follow the APDB conventions and set the beginning of the year t asset prices equal to the corresponding year t investment price for assets 1–11. For assets 13–16, we do not have APDB investment prices so we will simply set the year t investment price equal to the corresponding the end of the year asset price in APDB.[17] The depreciation rates for inventory stocks and the land assets are set equal to 0; i.e., we have:

(7) $\delta_n^t \equiv 0$; n = 12, …, 16 ; t = 1970, …, 2020.

To summarize the above relationships between the investment flows Q_{In}^t and the corresponding beginning of the year stocks Q_{Kn}^t and depreciation rates δ_n^t: all 16 assets satisfy equation (5) for years t = 1970, …, 2020 and n = 1, …, 16. The asset price indexes, P_{Kn}^t, are listed in Table A1 and the corresponding beginning of the year quantities are listed in Table A2 of Appendix A. The depreciation rates for all assets are reported in Table A3 of Appendix A.

In order to reduce the size of our data tables, we will work with a more aggregated model where there are only five types of capital: (i) *Aggregate Machinery and Equipment* (M&E as an aggregate of assets 1–4), with year t price, quantity and value indexes equal to P_{KM}^t, Q_{KM}^t and $V_{KM}^t \equiv P_{KM}^tQ_{KM}^t$; (ii) *Aggregate Structures* (an aggregate of assets 5–7) with year t price and quantity indexes equal to P_{KS}^t and Q_{KS}^t; (iii) *Aggregate Other Capital* (an aggregate of assets 8–11) with year t price and quantity indexes equal to P_{KO}^t and Q_{KO}^t; (iv) *Inventory Stocks* (equal to asset 12) which we label as P_{KI}^t, Q_{KI}^t and $V_{KI}^t \equiv P_{KI}^tQ_{KI}^t$, and (v) *Land Assets* (an aggregate of assets 13–16) with price and quantity indexes P_{KL}^t and Q_{KL}^t for t=1970, …,

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[16] We note that our decomposition of land use into four categories omits some addition important categories such as forest land and some forms of government land such as parks. See Eurostat (2017) for a comprehensive description of possible land use categories. Another note is that the land stock value may reflect the accumulated value of land improvements, which are included in GFCF. The issue of such double-counting possibilities is a problem in equation (6) and also in the definition of land stock prices.

[17] In order to account for investment in inventories using Jorgensonian user cost theory, it turns out it is necessary to value inventory investment over the accounting period at end of the period prices for the inventory item; see Diewert and Smith (1994, p. 338). The same logic applies to land investments. Thus we use end of the period prices to value investment in assets 12–16.

2021. The aggregation is done using chained Törnqvist price indexes.[18] Table A4 in Appendix A lists these aggregate beginning of the year capital stocks and their corresponding aggregate price indexes. The values of these five capital stock aggregates, V_{KM}^t, V_{KS}^t, V_{KO}^t, V_{KI}^t and V_{KL}^t, along with the total value of the total capital stock V_K^t, are listed in Table B1 in Appendix B along with the shares of the five subaggregate capital stocks in the total value of the capital stock, s_{KM}^t, s_{KS}^t, s_{KO}^t, s_{KI}^t and s_{KL}^t, where $s_{KM}^t \equiv V_{KM}^t/V_K^t$. V_K^t can be defined by summing the V_{Kn}^t or by summing the subaggregate values; i.e., we have the following equalities:

$$(8)\quad V_K^t \equiv \Sigma_{n=1}^{16} V_{Kn}^t = V_{KM}^t + V_{KS}^t + V_{KO}^t + V_{KI}^t + V_{KL}^t\,; \qquad t = 1970, \ldots, 2020.$$

Figure 1 plots the five shares over time. The share of structures is clearly the dominant share. On average, the biggest share of the value of the Chinese capital stock is in Structures with an average share of 50.55%. The next highest share is Land with an average share of 25.99% followed by Inventory Stocks at 7.46%. However, in recent years, the share of inventories has fallen from a peak of 10.10% in 1997 to 4.15% in 2021. This very large drop reflects the growth of just in time delivery of inventories and more efficient management of inventories. The share of M&E has varied between a high of 17.71% in 1976 to a low of 9.96% in 1985 and finished at 13.09% in 2021. Figure 1 indicates that it is important to include land in the list of productive assets used in production.

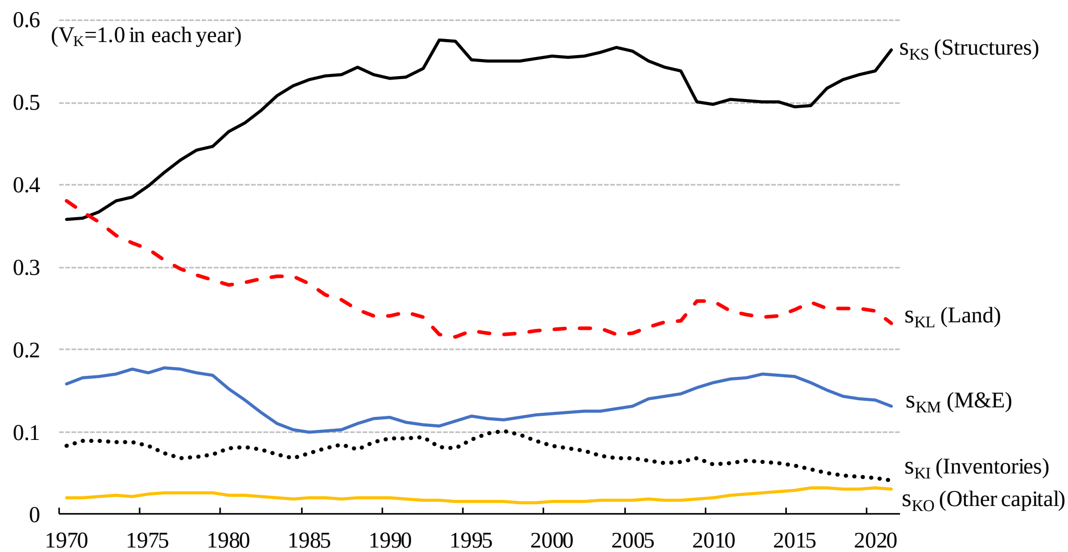

Figure 1. Asset Shares for Five Asset Classes

We use Törnqvist price aggregation to form price and quantity indexes for the capital stock. Denote these indexes by P_K^t and Q_K^t with $V_K^t=P_K^tQ_K^t$. Use Törnqvist price aggregation to form price and quantity

[18] The Törnqvist bilateral price index is defined as follows. Let $p^t \equiv [p_1^t, \ldots, p_N^t]$ and $q^t \equiv [q_1^t, \ldots, q_N^t]$ be the period t price and quantity vectors. Denote the inner product of the vectors p^t and q^t as $p^t \cdot q^t \equiv v^t$ where v^t is the period t aggregate value. Define the period t shares as $s_n^t \equiv p_n^t q_n^t / p^t \cdot q^t$ for n=1, …, N. Denote the Törnqvist price index that links the prices of period t−1 to the prices of period t by $P_T(p^{t-1},p^t,q^{t-1},q^t)$. The logarithm of $P_T(p^{t-1},p^t,q^{t-1},q^t)$ is defined as $\Sigma_{n=1}^N (1/2)(s_n^{t-1}+s_n^t)\ln(p_n^t/p_n^{t-1})$. The sequence of aggregate chained price levels starting at period 1, P_T^t, t=1, 2, 3, … is defined as follows: $P_T^1 \equiv 1$; $P_T^2 \equiv P_T(p^1,p^2,q^1,q^2)$; $P_T^3 \equiv P_T(p^1,p^2,q^1,q^2)P_T(p^2,p^3,q^2,q^3)$; and so on. The corresponding sequence of aggregate quantity levels Q_T^t is defined by deflating the period t value by the period t price index; i.e., $Q_T^t \equiv v^t/P_T^t$ for t=1, 2, 3, …. All prices must be positive and the value aggregate must also be positive for each period in order to calculate chained Törnqvist price indexes. Some quantities can be negative. When we are aggregating outputs and capital stocks, we will use chained Törnqvist price indexes. However, when aggregating capital services and labour services, we will use chained Törnqvist quantity indexes because it can happen that some user costs may be negative. The chained Törnqvist quantity indexes are defined in the same manner as their price counterparts but the role of prices and quantities is reversed. Thus price indexes in this case are defined by deflating values by the chained Törnqvist quantity indexes. In order to apply this second method of aggregation, we require that all quantities be positive and the value aggregates must also be positive in each period. For the relationship of the Törnqvist indexes to functional forms for unit cost functions and linearly homogeneous aggregator functions, see Diewert (1976) and Diewert and Morrison (1986).

indexes, P_I^t and Q_I^t, for all 16 investments with the aggregate value of investment defined as $V_I^t = P_I^tQ_I^t$. Finally, use Törnqvist price aggregation to aggregate over consumption Q_C^t, government Q_G^t, comprehensive aggregate investment Q_I^t, exports Q_X^t and (minus) imports $-Q_M^t$ to form price and quantity indexes for GDP at producer prices, P_Y^t and Q_Y^t, with the value of gross output $V_Y^t = P_Y^tQ_Y^t$. Using these estimates for gross output and for the capital stock, calculate real and nominal capital output ratios for China for year t, KY^t and VKY^t, defined as follows:

(9) $KY^t \equiv Q_K^t/Q_Y^t$; $VKY^t \equiv V_K^t/V_Y^t$; t=1970, …, 2020.

The price and quantity indexes for gross output, labour, and the capital stock (and the corresponding values in trillions of current yuan) are listed in Table B2 in Appendix B along with the real and nominal capital output ratios defined by equation (9). The GDP deflator P_Y^t grew 10.5 fold over the sample period. The investment price index P_I^t and the labour price index P_L^t grew 5.7 fold and 83.2 fold respectively over the five decades. Thus, real wages increased enormously over the sample period.

The nominal and real capital output ratios started out at the fairly low level of 2.5. The real capital output ratio barely increased over the sample period to end up at 2.6 while the nominal capital output ratio ended up at 4.3. Thus, it took on average a stock of 4.3 yuan in 2020 to produce 1 yuan of output. The lower is the nominal capital output ratio, the more internationally competitive the economy is. For many advanced countries, the nominal capital output ratio[19] in 2020 is likely to be in the 6 to 8 range so the Chinese economy in 2020 is very competitive.

We are now in a position where we can calculate an approximation to the aggregate cost of capital in year t, r^t. Once we have an estimate for r^t, the Jorgensonian user costs U_n^t defined by equation (4) can be calculated using the Chinese data on the beginning of the year capital stocks P_{Kn}^t, on depreciation rates δ_n^t, on ex post asset inflation rates i_n^t, and on specific property taxes on assets τ_n^t for n=1, …, 16. Consider the following equation for the year t data which sets the value of gross output V_Y^t equal to the sum of labour earnings V_L^t plus the sum of User costs U_n^t times the corresponding beginning of the year capital stocks Q_{Kn}^t:

(10) $V_Y^t = V_L^t + \Sigma_{n=1}^{16} [r^{t*} + \tau_n^t - i_n^t + \delta_n^t(1+i_n^t)]P_{Kn}^tQ_{Kn}^t$; t = 1970, …, 2020.

All of the variables in equation (10) for year t are known except for the national average cost of capital, r^{t*}. Since the equation is linear in r^{t*}, it can be solved for r^{t*} for each year t. Once r^{t*} is known, the user costs defined by equation (4), U_n^t for n=1, …, 16, can be calculated for each year t.

The resulting ex post rates of return on Chinese assets, r^{t*} for t = 1970, …, 2020 are listed in Table 1. The sample average of these rates of return was 17.25% per year. This is a gigantic average rate of return on assets! However, these rates of return are quite volatile and as a result, the user costs defined by equation (4) turn out to be very volatile as well and, in particular, these fluctuations in r^{t*} led to many negative user costs for assets 12–16. There was one negative user cost for inventory services, one for agricultural land services, 15 for industrial land services, 15 for commercial land services and 9 for residential land services. This is not very satisfactory.[20] We would like user costs to approximate the corresponding rental prices for

[19] Note that our capital aggregate includes the value of land. From Table A4 in Appendix A, the price of the five types of aggregate capital in 2020 showed that the price increases over the sample period were 2.1 fold for M&E, 10.5 fold for structures, 3.9 fold for Other types of capital (Cultivated assets, Research and development, Computer software and Other intangible assets), 5.2 fold for Inventories and 308.7 fold for Land assets. Thus, including Land in the capital aggregate will tend to *increase* the nominal capital output ratio for a country. Since quality-adjusted land tends to grow more slowly than output and produced assets over time, the inclusion of land in the aggregate capital stock will tend to *decrease* the real capital output ratio relative to the nominal capital output ratio over time.

[20] The aggregate user cost of capital turned out to be positive for each year. Thus the negative user cost problem tends to show up only when working with more disaggregated data. This "fact" may explain why the negative user cost of capital problem is rarely discussed in the aggregate productivity literature. In the industry level measurement, this problem has been considered more explicitly. For example, Jorgenson and Nomura

the various assets (but of course, these rental prices are not available to us) and rental prices are rarely negative.

The volatility in the ex post rates of return is largely caused by the volatility in ex post asset inflation rates i_n^t defined by equation (2). Equation (10) is the "right" equation to determine year to year ex post aggregate rates of return on assets but it is not the "right" equation to determine longer run rental prices for assets. In what follows, we will smooth the ex post rates of return in an attempt to find ex ante rates of return which are more suitable to insert into a user cost formula that is supposed to approximate a market rent for the use of asset. Owners of assets that rent the services of these assets to firms use the logic of user costs to form estimates for appropriate rental rates. However, the owners cannot forecast exactly what the ex post inflation rate on the asset will be. Thus, their forecasts for asset inflation rates will probably be extrapolations of past asset inflation rates. We will simply smooth actual ex post asset inflation rates to approximate these forecasts. We use the nonparametric Lowess smoothing method in Shazam (with smoothing parameter Smooth set equal to 0.4) for all 16 assets. The resulting smoothed annual asset inflation rates i_n^t are listed in Table A7 in Appendix A.

Now use the smoothed inflation rates i_n^t in equation (10) in order to determine the smoothed rates for return r^t as solutions to equation (10). The resulting smoothed balancing rates of return r^t are listed in Table 1. The average rate of return using the smoothed r^t turned out to be 17.22% per year which is slightly below than the average ex post rate of return which was 17.25%. We used the smoothed r^t and the smoothed i_n^t in equation (4) to define new smoothed user costs, U_n^t for n=1, …, 16. These smoothed user costs are listed in Table A8 in Appendix A. The use of smoothed asset inflation rates and smoothed rates of return did not eliminate negative user costs: there were 11 negative user costs for industrial land and 9 negative user costs for commercial land. A negative user cost is unlikely to approximate a real world rental price for the use of a land asset. However, our method for forming expected asset inflation rates is subject to a considerable amount of error and our highly aggregated estimated cost of capital may not be close to the actual cost of financial capital in particular industries. Moreover, markets for land assets are often not very liquid and hence, the actual user cost of a land asset may well be negative. For very liquid assets, a negative user cost should induce investors to quickly bid up the price of the asset to eliminate the negative user cost. However, the transactions costs of purchasing land can often be large and the lack of sellers of land can cause negative user costs. Thus, we left the negative user costs in our data base. These negative user costs become *user benefits*.

We use the data on the smoothed user costs, U_1^t, …, U_{16}^t, along with the data on the beginning of the year asset stocks, Q_{K1}^t, …, Q_{K16}^t, to form *five capital services aggregates* for our five types of aggregate capital. Denote the prices and quantities for these aggregate capital services by P_{UM}^t, P_{US}^t, P_{UO}^t, P_{UI}^t and P_{UL}^t and Q_{UM}^t, Q_{US}^t, Q_{UO}^t, Q_{UI}^t and Q_{UL}^t. These aggregate user costs are listed in Table 1 (with prices normalized to equal 1 in 1970) and the corresponding capital services aggregates are listed in Table 2.[21] The year t price and quantity of *aggregate capital services*, P_U^t and Q_U^t, were formed by aggregating P_{UM}^t, P_{US}^t, P_{UO}^t, P_{UI}^t, and P_{UL}^t and Q_{UM}^t, Q_{US}^t, Q_{UO}^t, Q_{UI}^t and Q_{UL}^t.[22] Finally, the year t price and quantity of *aggregate input*, P_Z^t and Q_Z^t, were calculated by aggregating the five capital services subaggregates with aggregate labour, P_L^t and Q_L^t. These aggregate input prices are listed in Table 1 and the corresponding aggregate input quantities are listed in Table 2.[23]

(2005) eliminated the occurrence of negative user costs during the Japanese bubble economy with considerable land price appreciation by accounting for differences in risk premiums across assets in the user cost of capital formula.

[21] These capital services input subaggregates were formed using Törnqvist direct aggregation of input quantities; i.e., bilateral chained quantity indexes were formed first (quantities were always positive) and then the corresponding aggregate price indexes were calculated by deflating total value by the quantity index.

[22] The year t capital services aggregate price and quantity, P_U^t and Q_U^t, were calculated using Törnqvist direct aggregation of input quantities as were the overall input aggregates, P_Z^t and Q_Z^t.

[23] We are using two stage aggregation to form our input aggregates. We also used single stage aggregation of the original 16 capital services. The differences between the single stage and two stage aggregates were insignificant.

Table 1: Ex Post and Smoothed Rates of Return and Aggregate Output and Input Price Indexes

Year	r^t	r^{t*}	$P_Y{}^t$	$P_Z{}^t$	$P_L{}^t$	$P_U{}^t$	$P_{UM}{}^t$	$P_{US}{}^t$	$P_{UO}{}^t$	$P_{UI}{}^t$	$P_{UL}{}^t$
1970	0.124	0.141	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1971	0.123	0.126	1.024	0.999	1.010	0.981	0.977	0.985	0.985	0.969	0.981
1972	0.121	0.138	1.041	1.018	1.062	0.947	0.938	0.959	0.988	0.938	0.936
1973	0.122	0.118	1.071	1.026	1.069	0.958	0.952	0.982	1.055	0.922	0.916
1974	0.121	0.110	1.092	1.017	1.072	0.932	0.954	0.949	1.026	0.889	0.861
1975	0.130	0.116	1.113	1.042	1.084	0.974	0.962	0.997	1.162	0.938	0.930
1976	0.114	0.094	1.125	1.008	1.092	0.886	0.924	0.945	1.179	0.785	0.651
1977	0.141	0.127	1.154	1.070	1.111	1.002	0.970	1.045	1.345	0.975	0.926
1978	0.151	0.151	1.193	1.138	1.185	1.060	1.016	1.104	1.424	1.026	1.007
1979	0.159	0.181	1.257	1.214	1.280	1.112	1.043	1.158	1.525	1.082	1.097
1980	0.155	0.153	1.323	1.284	1.429	1.091	1.010	1.162	1.480	1.078	1.015
1981	0.157	0.150	1.365	1.299	1.446	1.102	1.008	1.180	1.490	1.089	1.038
1982	0.174	0.166	1.409	1.368	1.479	1.208	1.053	1.279	1.591	1.215	1.326
1983	0.197	0.194	1.454	1.479	1.521	1.393	1.100	1.487	1.631	1.392	1.839
1984	0.216	0.219	1.524	1.685	1.741	1.577	1.175	1.674	1.745	1.552	2.362
1985	0.218	0.223	1.673	1.861	2.010	1.651	1.220	1.755	1.871	1.596	2.494
1986	0.207	0.194	1.772	1.972	2.284	1.596	1.206	1.724	1.884	1.545	2.128
1987	0.216	0.236	1.886	2.124	2.485	1.696	1.224	1.832	1.922	1.698	2.447
1988	0.225	0.215	2.051	2.477	2.912	1.964	1.371	2.150	2.167	1.842	3.004
1989	0.211	0.190	2.260	2.564	3.179	1.898	1.371	2.084	2.259	1.826	2.453
1990	0.205	0.202	2.481	2.729	3.464	1.957	1.460	2.156	2.451	1.785	2.282
1991	0.220	0.258	2.689	3.167	3.781	2.450	1.687	2.749	2.669	2.141	3.664
1992	0.219	0.356	2.915	3.597	4.283	2.792	1.875	3.188	2.887	2.254	4.384
1993	0.208	0.229	3.408	4.378	5.207	3.402	2.216	4.131	3.304	2.261	4.484
1994	0.206	0.219	3.924	5.420	6.920	3.902	2.419	4.757	3.603	2.644	5.940
1995	0.222	0.212	4.537	6.458	8.154	4.704	2.671	5.569	4.048	3.836	10.155
1996	0.219	0.189	4.947	7.106	9.048	5.133	2.743	6.127	4.236	4.421	11.852
1997	0.215	0.166	5.076	7.411	9.677	5.229	2.697	6.234	4.155	4.641	13.167
1998	0.209	0.159	5.074	7.619	9.995	5.354	2.710	6.498	3.899	4.554	13.502
1999	0.204	0.170	5.048	7.667	10.419	5.227	2.586	6.365	3.762	4.361	14.138
2000	0.211	0.191	5.159	8.009	10.752	5.515	2.597	6.711	3.877	4.569	17.739
2001	0.202	0.184	5.289	8.148	11.369	5.442	2.537	6.630	3.956	4.551	17.422
2002	0.198	0.193	5.243	8.308	11.959	5.413	2.462	6.638	3.756	4.553	18.166
2003	0.189	0.213	5.345	8.621	13.325	5.306	2.359	6.623	3.777	4.332	16.682
2004	0.183	0.202	5.667	9.149	15.076	5.338	2.291	6.805	3.880	4.271	15.717
2005	0.178	0.189	5.939	9.617	16.587	5.395	2.252	6.965	3.927	4.437	15.242
2006	0.185	0.207	6.327	10.723	19.297	5.801	2.303	7.517	4.083	4.772	21.982
2007	0.190	0.231	6.702	12.268	23.473	6.310	2.333	8.302	4.118	5.121	31.617
2008	0.187	0.157	7.079	13.757	27.709	6.790	2.352	9.169	4.118	5.386	38.626
2009	0.183	0.184	7.092	14.121	30.771	6.543	2.258	8.552	3.978	5.764	45.787
2010	0.176	0.203	7.419	14.562	32.584	6.603	2.222	8.758	4.039	5.330	49.421
2011	0.159	0.147	8.005	15.418	37.848	6.467	2.121	8.810	3.992	5.263	42.991
2012	0.142	0.119	8.221	15.724	43.034	5.974	1.998	8.061	3.770	5.014	36.228
2013	0.133	0.117	8.387	16.153	47.859	5.678	1.905	7.587	3.632	4.710	37.639
2014	0.121	0.096	8.545	16.395	52.664	5.305	1.804	6.990	3.468	4.335	36.458

2015	0.120	0.104	8.761	17.208	58.596	5.241	1.768	6.713	3.392	4.341	51.873
2016	0.122	0.147	8.965	17.847	61.386	5.381	1.773	6.741	3.449	4.298	75.792
2017	0.134	0.157	9.379	19.941	66.109	6.211	1.868	7.900	3.567	4.822	128.819
2018	0.129	0.125	9.789	20.900	71.559	6.344	1.852	8.101	3.562	4.960	143.161
2019	0.118	0.096	10.176	21.179	78.310	6.046	1.778	7.597	3.443	4.780	142.438
2020	0.111	0.134	10.470	21.240	83.210	5.781	1.714	7.047	3.346	4.643	150.998
Mean	0.172	0.173	4.428	7.519	17.958	3.688	1.747	4.558	2.821	3.088	24.466

As was noted earlier, the average of the ex post rates of return on assets (the average of the r^{t*}) was 17.25% and the average of the smoothed rates of return (the average of the r^t) was 17.22%. There is a downward trend in the smoothed rates of return from 22.17% in 1995 to 11.13% in 2020. The GDP deflator, P_Y^t, increased 10.47 fold over the sample period while the aggregate input price index, P_Z^t, increased 21.24 fold, and the quality-adjusted price index for labour, P_L^t, increased 83.21 fold. The aggregate price index for capital services P_U^t increased only 5.78 fold over the sample period. The price increases for our five main components of capital services increased 1.71 fold (M&E), 7.05 fold (Structures), 3.35 fold (Other capital services), 4.64 fold (Inventory services), and 151.00 fold (Land services).

Note that the aggregate land user cost is always positive; i.e., when we aggregate over the four types of land services, the negative user costs are outweighed by positive user costs so that aggregate land services are always positive for China. The quantity or volume indexes that match up with the above price indexes are listed in Table 2 in the following section.

The rate of return on all assets used in production is an important statistic that measures the efficiency of an economy. Another important indicator of efficiency is the level of TFP for the economy. In the following section, we use the data developed in this section to measure the Gross Output TFP for the Chinese economy.

3. TFP ESTIMATES FOR CHINA USING GROSS OUTPUT

Following Jorgenson and Griliches (1967), year t *Gross Output TFP* for the Chinese economy, TFP^t, is defined as the output quantity index Q_Y^t divided by the input quantity index Q_Z^t:

(11) $TFP^t \equiv Q_Y^t/Q_Z^t$; $t = 1970, \ldots, 2020.$

Year t *TFP Growth* (relative to year t−1), TFP_G^t, is defined as follows:

(12) $TFP_G^t \equiv TFP^t/TFP^{t-1}$; $t = 1971, \ldots, 2020.$

Gross output TFP for China are listed in Table 2. It can be seen that gross output TFP growth in China was largely negative for the 1970s. The initial level of TFP in 1970 was not attained until 1983. From the 1983 level of productivity equal to 1.0178, the TFP level grew to 2.1350 in 2018 before falling to 2.0287 in 2020 partly due to the adverse effects of Covid.

Table 2: Gross Output TFP Levels and GDP Quantity Indexes for China

Year	TFP^t	Q_Y^t	Q_Z^t	Q_L^t	Q_U^t	Q_{UM}^t	Q_{US}^t	Q_{UO}^t	Q_{UI}^t	Q_{UL}^t
1970	1.000	0.236	0.236	0.147	0.089	0.025	0.033	0.003	0.006	0.022
1971	0.976	0.246	0.252	0.155	0.097	0.029	0.036	0.004	0.007	0.022

1972	0.978	0.257	0.263	0.158	0.105	0.032	0.039	0.004	0.008	0.022
1973	0.957	0.265	0.276	0.164	0.113	0.035	0.043	0.005	0.009	0.022
1974	0.932	0.270	0.290	0.170	0.121	0.039	0.047	0.005	0.009	0.022
1975	0.936	0.285	0.304	0.176	0.129	0.042	0.051	0.005	0.009	0.022
1976	0.896	0.286	0.319	0.182	0.140	0.046	0.056	0.006	0.009	0.022
1977	0.928	0.308	0.332	0.187	0.147	0.049	0.061	0.006	0.009	0.022
1978	0.954	0.331	0.347	0.193	0.157	0.051	0.067	0.006	0.010	0.022
1979	0.966	0.353	0.366	0.200	0.169	0.055	0.073	0.006	0.011	0.022
1980	0.971	0.374	0.386	0.208	0.181	0.057	0.081	0.007	0.013	0.022
1981	0.952	0.386	0.405	0.216	0.194	0.057	0.090	0.007	0.014	0.022
1982	0.971	0.412	0.424	0.226	0.204	0.056	0.100	0.008	0.014	0.022
1983	1.018	0.450	0.442	0.232	0.216	0.057	0.110	0.008	0.015	0.022
1984	1.105	0.519	0.470	0.246	0.231	0.059	0.121	0.009	0.015	0.023
1985	1.112	0.562	0.506	0.260	0.253	0.066	0.133	0.010	0.019	0.023
1986	1.113	0.604	0.543	0.272	0.282	0.077	0.147	0.011	0.023	0.023
1987	1.126	0.653	0.579	0.283	0.311	0.090	0.160	0.012	0.026	0.023
1988	1.208	0.746	0.618	0.295	0.342	0.107	0.175	0.014	0.027	0.023
1989	1.135	0.741	0.653	0.300	0.379	0.125	0.192	0.015	0.032	0.023
1990	1.100	0.749	0.681	0.307	0.406	0.132	0.206	0.016	0.037	0.023
1991	1.178	0.834	0.708	0.315	0.428	0.138	0.218	0.017	0.040	0.023
1992	1.234	0.918	0.744	0.327	0.457	0.147	0.232	0.019	0.048	0.023
1993	1.285	1.020	0.794	0.341	0.500	0.167	0.251	0.020	0.053	0.023
1994	1.382	1.165	0.843	0.347	0.556	0.201	0.275	0.023	0.057	0.024
1995	1.424	1.282	0.901	0.357	0.619	0.241	0.303	0.026	0.062	0.024
1996	1.437	1.392	0.969	0.370	0.689	0.277	0.338	0.029	0.069	0.024
1997	1.460	1.508	1.033	0.380	0.761	0.314	0.374	0.032	0.077	0.024
1998	1.502	1.642	1.094	0.384	0.840	0.363	0.412	0.037	0.082	0.024
1999	1.519	1.768	1.164	0.395	0.921	0.416	0.452	0.041	0.085	0.024
2000	1.553	1.940	1.249	0.412	1.011	0.476	0.496	0.046	0.090	0.024
2001	1.541	2.062	1.339	0.426	1.114	0.550	0.544	0.053	0.096	0.024
2002	1.585	2.263	1.428	0.435	1.232	0.640	0.597	0.060	0.103	0.024
2003	1.613	2.483	1.539	0.450	1.371	0.760	0.655	0.072	0.109	0.024
2004	1.614	2.689	1.666	0.464	1.546	0.926	0.722	0.084	0.118	0.025
2005	1.619	2.967	1.833	0.494	1.747	1.125	0.800	0.097	0.127	0.025
2006	1.695	3.313	1.955	0.495	1.967	1.376	0.877	0.114	0.134	0.025
2007	1.831	3.780	2.065	0.485	2.210	1.662	0.958	0.134	0.148	0.025
2008	1.943	4.275	2.200	0.481	2.493	2.006	1.051	0.159	0.172	0.026
2009	1.991	4.722	2.371	0.489	2.818	2.415	1.150	0.202	0.193	0.027
2010	1.963	5.245	2.672	0.536	3.246	2.944	1.288	0.264	0.215	0.028
2011	1.926	5.638	2.927	0.554	3.737	3.579	1.438	0.338	0.246	0.030
2012	1.913	6.041	3.159	0.564	4.252	4.133	1.620	0.424	0.276	0.030
2013	1.926	6.549	3.400	0.576	4.823	4.808	1.806	0.535	0.303	0.031
2014	1.919	6.887	3.589	0.571	5.424	5.410	2.023	0.661	0.333	0.031
2015	1.964	7.317	3.725	0.556	6.017	5.913	2.262	0.797	0.360	0.031
2016	1.991	7.763	3.899	0.557	6.584	6.293	2.520	0.940	0.381	0.032
2017	2.126	8.615	4.052	0.548	7.172	6.777	2.783	1.073	0.405	0.032
2018	2.135	9.047	4.237	0.544	7.818	7.354	3.052	1.208	0.428	0.034
2019	2.081	9.146	4.394	0.533	8.493	7.964	3.338	1.361	0.444	0.035

2020	2.029	9.275	4.572	0.532	9.138	8.501	3.639	1.536	0.461	0.035

In Table B3 in Appendix B, we list the annual GDP productivity growth rates defined by equation (12). We also list the aggregate value of GDP, V_Y^t (which is equal to the aggregate value of input V_Z^t by construction) and the other macroeconomic input aggregates for labour and the five types of capital services, V_L^t, V_{UM}^t, V_{US}^t, V_{UO}^t, V_{UI}^t, and V_{UL}^t. Define the input shares in year t GDP for labour and the five types of capital services for t = 1970, …, 2020 as follows:

(13) $s_L^t \equiv V_L^t/V_Y^t$; $s_{UM}^t \equiv V_{UM}^t/V_Y^t$; $s_{US}^t \equiv V_{US}^t/V_Y^t$; $s_{UO}^t \equiv V_{UO}^t/V_Y^t$; $s_{UI}^t \equiv V_{UI}^t/V_Y^t$; $s_{UL}^t \equiv V_{UL}^t/V_Y^t$.

These input shares of GDP are also listed in Table B3.

The arithmetic average of the TFP growth rates over the years 1970–2020 was 1.48% per year which is very good by international standards.[24] The average shares of labour and the five types of capital services in GDP were 0.5198, 0.1271 (M&E), 0.2535 (Structures), 0.0241 (Other Capital Services), 0.0313 (Inventories), and 0.0441 (Land). There are some big changes in these shares over time. In particular, the share of labour in GDP has dropped from 0.6247 in 1970 to 0.4561 in 2020. The relatively low average share of labour near the end of the sample period is not a surprise, given the tremendous amount of investment and capital accumulation that has taken place in the Chinese economy over the past five decades. There are other large shifts in GDP shares over the five decades. The average share of land services is only 0.0431 but it has grown from 0.0254 to 0.0548 during the past five years.

The average TFP growth rates by decade are as follows: 0.9973 or – 0.27% per year during the 1970s; 1.0135 or 1.35% per year during the 1980s; 1.0353 or 3.53% per year during the 1990s; 1.0241 or 2.41% during the 2000s, and 1.0037 or 0.37% per year during the 2010s. Thus from 1980–2010, the TFP performance of the Chinese economy has been very good by international standards. However, there has been a pronounced productivity slowdown over the years 2018–2020. In the following section, we decompose real gross income growth into explanatory factors.

4. DECOMPOSITION OF CHINESE REAL GROSS INCOME GROWTH

In this section, we divide the value of year t gross output V_Y^t by the year t price index for consumption P_C^t in order to obtain a measure of the year t *real gross output* generated by the Chinese production sector. Since the nominal gross output is equal to nominal gross income V_Z^t, V_Y^t/P_C^t is equal to V_Z^t/P_C^t. In order to simplify our notation for the various explanatory factors, we introduce some new notation for prices and quantities. Define the vectors of *real output prices* p^t and *real input prices* w^t for year t as follows for t=1970, …, 2020:

(14) $p^t \equiv [p_1^t, \ldots, p_5^t] \equiv (1/P_C^t)[P_C^t,P_G^t,P_I^t,P_X^t,P_M^t]$; $w^t \equiv [w_1^t,..,w_6^t] \equiv (1/P_C^t)[P_L^t,P_{UM}^t,P_{US}^t,P_{UO}^t,P_{UI}^t,P_{UL}^t]$.

Thus, the real prices are equal to our existing macroeconomic prices divided by the price of consumption.

Define the vector of year t (net) outputs y^t and the year t vector of inputs z^t as follows for all years t:

(15) $y^t \equiv [y_1^t,..,y_5^t] \equiv [Q_C^t,Q_G^t,Q_I^t,Q_X^t,- Q_M^t]$; $z^t \equiv [z_1^t,..,z_6^t] \equiv [Q_L^t,Q_{UM}^t,Q_{US}^t,Q_{UO}^t,Q_{UI}^t,Q_{UL}^t]$.

[24] See the APO (2023, pp. 61 and 139) for average TFP growth rates over the period 1970–2021 for 25 Asian countries plus the US. Note that land was included as a factor of production in these APO estimates.

Using the above definitions, we see that *year t real income* is equal to $RI^t \equiv V_Y{}^t/P_C{}^t = p^t \cdot y^t = V_Z{}^t/P_C{}^t = w^t \cdot z^t$ for all years t. Define (one plus) *real income growth* going from year t–1 to year t, $RI_G{}^t$, as follows:

$$(16)\ RI_G{}^t \equiv p^t \cdot y^t / p^{t-1} \cdot y^{t-1}\ ; \qquad t = 1971, \ldots, 2020.$$

Table B4 in Appendix B lists the real gross incomes RI^t (in trillions of 1970 yuan), the real output prices p^t and the real input prices w^t.

Real gross income in China grew 37.58 fold over the 51 years in our sample. This is a spectacular achievement. Real consumption growth over the sample period was lower; from Table A6 in Appendix A, real consumption grew 20.8 fold over the sample period. Real wages grew much slower; a 7.60 fold increase over the sample period. The real user cost growth factors were 0.157 for M&E, 0.643 for Structures, 0.306 for Other Capital Services, 0.424 for Inventory and 13.8 for Land Services. Real consumption prices, $p_1{}^t$, are not listed in Table B4 because they are always equal to 1. Real Government Output prices grew 3.28 fold over the sample period which is much lower than real wage growth.[25] The real price levels for gross investment, exports, and imports in 2020 (relative to the corresponding 1970 levels) were 0.519, 0.531 and 0.480 respectively.

We use the new notation to define the logarithm of the *Törnqvist output price index* for year t, $P_T(p^{t-1},p^t,y^{t-1},y^t)$, and the logarithm of the *Törnqvist input quantity index* for year t, $Q_T(w^{t-1},w^t,z^{t-1},z^t)$ as follows:

$$(17)\ \ln P_T(p^{t-1},p^t,y^{t-1},y^t) \equiv \Sigma_{n=1}{}^5\ (1/2)[(p_n{}^t y_n{}^t/p^t \cdot y^t) + (p_n{}^{t-1} y_n{}^{t-1}/p^{t-1} \cdot y^{t-1})]\ln(p_n{}^t/p_n{}^{t-1})\ ; \qquad t = 1971, \ldots, 2020;$$

$$(18)\ \ln Q_T(w^{t-1},w^t,z^{t-1},z^t) \equiv \Sigma_{n=1}{}^6\ (1/2)[(w_n{}^t z_n{}^t/w^t \cdot z^t) + (w_n{}^{t-1} z_n{}^{t-1}/w^{t-1} \cdot z^{t-1})]\ln(z_n{}^t/z_n{}^{t-1})\ ; \qquad t = 1971, \ldots, 2020.$$

Define the year t *real output price change n contribution factor*, $\alpha_n{}^t$, as follows:

$$(19)\ \ln\alpha_n{}^t \equiv (1/2)[(p_n{}^t y_n{}^t/p^t \cdot y^t) + (p_n{}^{t-1} y_n{}^{t-1}/p^{t-1} \cdot y^{t-1})]\ln(p_n{}^t/p_n{}^{t-1})\ ; \qquad n = 1, \ldots, 5\ ;\ t = 1971, \ldots, 2020.$$

Comparing equations (17) and (19), it can be seen that the product over n of the year t output price contribution factors $\alpha_n{}^t$ is equal to the year t Törnqvist output price index; i.e.:

$$(20)\ P_T(p^{t-1},p^t,y^{t-1},y^t) = \Pi_{n=1}{}^5\ \alpha_n{}^t\ ; \qquad t = 1971, \ldots, 2020.$$

Define the year t *input n contribution factor*, $\beta_n{}^t$, as follows:

$$(21)\ \ln\beta_n{}^t \equiv (1/2)[(w_n{}^t z_n{}^t/w^t \cdot z^t) + (w_n{}^{t-1} z_n{}^{t-1}/w^{t-1} \cdot z^{t-1})]\ln(z_n{}^t/z_n{}^{t-1})\ ; \qquad n = 1, \ldots, 6\ ;\ t = 1971, \ldots, 2020.$$

Comparing equations (18) and (21), it can be seen that the product over n of the year t input contribution factors $\beta_n{}^t$ is equal to the year t Törnqvist input quantity index, i.e.:

$$(22)\ Q_T(w^{t-1},w^t,z^{t-1},z^t) = \Pi_{n=1}{}^6\ \beta_n{}^t\ ; \qquad t = 1971, \ldots, 2020.$$

[25] In the international SNA, the government output price index is typically set equal to a government input price index which consists of a price index for intermediate input purchases, government labour input and depreciation on government produced assets. There is no imputation for the opportunity cost of government capital in the present SNA. However, we calculated Jorgensonian user costs for all government assets, including government land which led to an overall government input price index that grew more slowly than government wages. As was seen in section 2, Jorgensonian user costs include an imputation for the cost of capital.

Define year *t productivity growth* τ^t *using real prices as weights* as the implicit Törnqvist output quantity index, $[p^t \cdot y^t / p^{t-1} \cdot y^{t-1}] / P_T(p^{t-1},p^t,y^{t-1},y^t) = p^t \cdot y^t / [p^{t-1} \cdot y^{t-1} P_T(p^{t-1},p^t,y^{t-1},y^t)]$, divided by the direct Törnqvist input quantity index $Q_T(w^{t-1},w^t,z^{t-1},z^t)$; i.e., we have the following definitions:

(23) $\tau^t \equiv p^t \cdot y^t / [p^{t-1} \cdot y^{t-1} P_T(p^{t-1},p^t,y^{t-1},y^t) Q_T(w^{t-1},w^t,z^{t-1},z^t)]$; t = 1971, …, 2020.

Using the fact that $P_T(p^{t-1},p^t,y^{t-1},y^t)$ is homogeneous of degree 1 in the components of p^t and homogeneous of degree -1 in p^{t-1} as well as the fact that $Q_T(w^{t-1},w^t,z^{t-1},z^t)$ is homogeneous of degree 0 in the components of w^t and homogeneous of degree 0 in the components of w^{t-1}, it can be shown that τ^t is equal to the measure of productivity growth $TFP_G{}^t$ defined in the previous section for all t.[26]

Rearrange equation (23) to give us the following expression for year t *real income growth* over the prior year, $RI_G{}^t = p^t \cdot y^t / p^{t-1} \cdot y^{t-1}$:

(24) $RI_G{}^t = \tau^t P_T(p^{t-1},p^t,y^{t-1},y^t) Q_T(w^{t-1},w^t,z^{t-1},z^t)$; t = 1971, …, 2020.
$= \tau^t (\Pi_{n=1}{}^5 \alpha_n{}^t)(\Pi_{n=1}{}^6 \beta_n{}^t)$ using (20) and (22).

The above expression gives us a nice decomposition of year t real income growth into the following explanatory variables: TFP growth $\tau^t = TFP_G{}^t$, year t real output price contribution factors, $\alpha_2{}^t$–$\alpha_5{}^t$, and year t input contribution factors, $\beta_1{}^t$–$\beta_6{}^t$. Table B5 in Appendix B lists the real income growth factors, $RI_G{}^t$, and the 11 contribution factors.

On average, real gross income growth generated by the Chinese economy was 7.63% per year. This is an extraordinarily high rate of growth. The sample averages of the factors that contributed to this growth are as follows in annual percentages: 1.48% (TFP change); 0.38% (government real price change); –0.50% (real investment price change); –0.22% (export price change); 0.31% (import price change); 1.40% (quality-adjusted labour growth); 1.53% (M&E capital services growth); 2.44% (structures services growth); 0.31% (other capital services growth); 0.28% (inventory growth services) and 0.04% (land services growth). Real export prices fell and real import prices fell even more over the sample period which when taken together as a *terms of trade effect* slightly increased overall real gross income growth. Note that since population growth is turning into population decline for China and relatively high levels of education have been achieved, it is unlikely that quality-adjusted labour growth will be very high in the future. This will lead to a significant slowdown in future growth for China.

Rather than look at year to year increases in real income growth, it is useful to convert the above annual rates of increase into levels. Thus, we express the *level of real income* in year t in terms of an *index of the level of TFP* in year t, TFP^t, of the *level of real output price* n in period t, $A_n{}^t$, and of the *level of primary input quantity* n in period t, $B_n{}^t$.[27] We use the growth factors $TFP_G{}^t$, $\alpha_n{}^t$, and $\beta_n{}^t$ to define the corresponding levels TFP^t, $A_n{}^t$, and $B_n{}^t$:

(25) $TFP^{1970} \equiv 1$; $TFP^t \equiv TFP^{t-1}\, TFP_G{}^t$; t = 1971, …, 2020;
(26) $A_n{}^{1970} \equiv 1$; $A_n{}^t \equiv A_n{}^{t-1} \alpha_n{}^t$; n = 2, …, 5 ; t = 1971, …, 2020;
(27) $B_n{}^{1970} \equiv 1$; $B_n{}^t \equiv B_n{}^{t-1} \beta_n{}^t$; n = 1, …, 6 ; t = 1971, …, 2020.

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[26] Diewert and Morrison (1986) and Kohli (1990) provide economic interpretations for $TFP_G{}^t$ and the counterparts to $\alpha_n{}^t$ and $\beta_n{}^t$ that used un-normalized prices. Thus the decomposition given by (24) is not only a growth accounting decomposition but the various components on the right hand side of (24) can be given economic interpretations in terms of the underlying GDP function. Diewert and Lawrence (2006) extended the analysis to the case where normalized prices were used to measure the real gross income generated by the Australian production sector.

[27] This type of levels presentation of the data is quite instructive when presented in graphical form. It was suggested by Kohli (1990) and used extensively by him; see Kohli (1991, 2003, 2004a, 2004b) and Fox and Kohli (1998).

Using the above definitions, we can establish the following relationships for the level of *real gross income* in year t relative to 1970, RI^t/RI^{1970}, and the year t levels for technology, real output prices and input quantities:

$$(28)\ RI^t/RI^{1970} = TFP^t A_2^t A_3^t A_4^t A_5^t B_1^t B_2^t B_3^t B_4^t B_5^t B_6^t\ ; \qquad t = 1970, \ldots, 2020.$$

The levels decomposition for relative real gross income for China is shown in Table B6 in Appendix B.

As was indicated above, real gross income grew 37.578 fold over the sample period.[28] The growth factors for 2020 that contributed to this overall growth of real income are as follows: 2.029 (TFP growth); 1.207 (Government real price growth); 0.775 (Gross investment real price growth); 0.886 (Export real price growth)[29]; 1.154 (Import real price growth)[30] ; 1.994 (Quality-adjusted labour input growth); 2.135 (M&E services growth); 3.327 (Structures services growth); 1.168 (Other capital services growth); 1.148 (Inventory services growth); 1.020 (Land services growth). Multiplication of all of these 2020 growth factors equals real gross income sample period growth of 37.578. Figure 2 plots the 11 growth factors over the sample period.

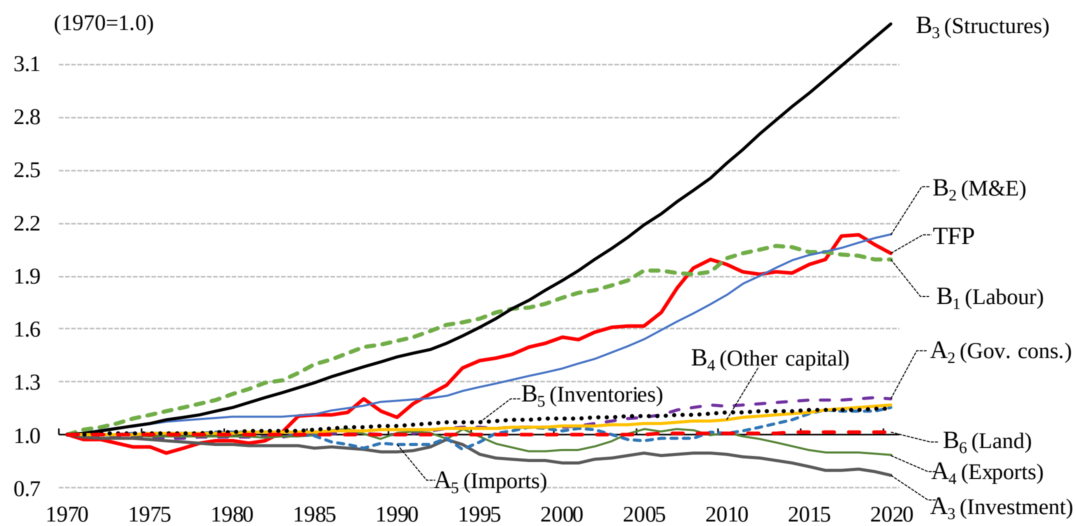

Figure 2. Explanatory Factors for Real Gross Output Growth

The top four explanatory factors for 2020 are B_3 (Structure services), B_2 (M&E services), TFP, and B_1 (Labour). Note that TFP was near or below one for the first 13 years of our sample. Note also that the contribution of Labour services is slowly declining over the past decade. It can be seen that the growth in structures services is the largest contributor to real GDP growth over the sample period. Population decline in China is leading to a decline in quality-adjusted labour input and it will likely lead to a slowdown in the demand for structures in the not too distant future. There is also a decline in TFP growth in recent years which may or may not continue. These trends point to a future slowdown in the rate of real income growth for the Chinese economy.

It can be seen that our measure of TFP can show declines over time. Thus, it is difficult to interpret TFP as technical progress, which is an outward shift of the production possibilities set. It seems unlikely that technical progress can be regressive in the sense that producers forget methods of production over time

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[28] Per capita real gross income increased 23.2 fold over the sample period.

[29] This growth factor ended up less than one which indicates that real export prices fell over the sample period.

[30] The fact that this growth factor ended up greater than one indicates that real import prices fell over the sample period. If we combine the export and import growth terms, we find that China's terms of trade improved over the sample period.

which could lead to a contraction of the aggregate production possibilities set. It is likely that the declines in TFP that we see at times in almost all countries are due to recessions, which lead to decreases in outputs. However, some capital stocks cannot be reduced in the short run, so typically, recessions lead to production taking place in the interior of the national production possibilities set and to declines in measured TFP. In the following section, we will implement a nonparametric method for decomposing TFP into technical progress and inefficiency components.

5. A NONPARAMETRIC DECOMPOSITION OF GROSS OUTPUT GROWTH FOR CHINA

The analysis in this section is based on Diewert and Fox (2018). There are two key concepts that this analysis is based on:

- An approximation to the aggregate production possibilities set for an economy can be formed by using linear multiples of past net output and primary input vectors and
- The *cost constrained value added function* can be used to form measures of efficiency, output price change, input price change, input quantity change and technology change.

We use the notation that was introduced in section 4 for the net output vector in year t, y^t, and the corresponding primary input vector x^t. As in the previous section, we will work with the year t real price vectors, p^t and w^t, that were defined in the previous section along with the observed net output vectors y^t and primary input quantity vectors x^t.

The basic assumption that Diewert and Fox make is that the year t national technology set can be approximated by assuming it consists of past observed output and input vectors, (y^s,x^s), and linear multiples of these vectors for past periods and the current period t. Let S^t denote the resulting period t production possibilities set. Thus $S^1 \equiv \{(y,x) : y = \lambda y^1, x = \lambda x^1; \lambda \geq 0\}$, $S^2 \equiv \{(y,x) : y = \lambda_1 y^1, x = \lambda_1 x^1; \lambda_1 \geq 0,\ y = \lambda_2 y^2, x = \lambda_2 x^2; \lambda_2 \geq 0\}$, …, $S^t \equiv \{(y,x) : y = \lambda_s y^s, x = \lambda_s x^s; \lambda_s \geq 0,\ s = 1, 2, ..., t\}$. These definitions for the S^t mean that we are assuming that S^t is a constant return to scale technology set for each period.[31]

The year t *cost constrained value added function* for the Chinese economy, $R^t(p,w,x)$, is defined as follows for the positive real price vectors p and w, positive primary input vector x and period t production possibilities set S^t:[32]

$$(29)\quad R^t(p,w,x) \equiv \max_{y,z}\{p\cdot y : (y,z)\in S^t ;\ w\cdot z \leq w\cdot x\}; \qquad t = 1970, \ldots, 2020.$$
$$= \max_s \{p\cdot y^s\, w\cdot x/w\cdot x^s : s = 1,2,...,t\}$$
$$= w\cdot x\ \max_s \{p\cdot y^s/w\cdot x^s : s = 1,2,...,t\}.$$

Given the period t technology set S^t, nominal output prices P, nominal input prices W and the constraint that primary input costs should not exceed cost $W\cdot x$, we assume that producers choose the output vector y and input vector z to maximize national value added, $P\cdot y$, subject to total primary input cost $W\cdot z$ to be equal to or less than the given input cost $W\cdot x$. The real price vectors p and w in definition (29) are used in place of the nominal price vectors (P,W): if producers solve constrained maximization problem defined by equation (29) using nominal prices, the (y^*,z^*) solution to this problem will also solve the same problem

[31] It is obvious that the Diewert and Fox production possibilities sets S^t are only very rough approximations to the true sets: returns to scale may not be constant and the true technology will contain many more output and input combinations than current period and past period output and input vectors. Moreover, the analysis ignores the role of markups. However, the methodology generates estimates of TFP which are very close to the corresponding index number estimates, but the new methodology has the advantage of decomposing TFP growth into technical progress and inefficiency components.

[32] The cost constrained value added function and its properties are discussed in Diewert and Fox (2018) with references to the literature. It is a relabeling of Diewert's (1983, p. 1086) *balance of trade restricted value added function*.

where nominal prices for outputs and inputs are replaced by the corresponding real prices $p^t \equiv P^t/P_C^t$ and $w^t \equiv W^t/P_C^t$. Thus we assume that the p^t and w^t which appear in the cost constrained value added functions defined below are the real price vectors defined in the previous section.

Due to our assumptions on the year t national production possibilities set S^t, the year t cost constrained value added function $R^t(p,w,x)$ can be calculated for any hypothetical p, w, and x by solving the very simple maximization problem, $\max_s \{p \cdot y^s/w \cdot x^s: s=1, 2, ..., t\}$, which involves taking the maximum of t numbers.

The cost constrained value added function defined by equation (29) can be used to decompose real GDP growth from year t−1 to year t, $p^t \cdot y^t/p^{t-1} \cdot y^{t-1}$, into various explanatory growth factors. The explanatory factors are as follows:

- efficiency changes,
- changes in real output prices,
- changes in primary inputs,
- changes in real input prices, and
- technical progress.

We now define the above explanatory factors using the observed data and the function $R^t(p,w,x)$ defined by equation (29). Following the example of Balk (1998, p. 143), we define the *value added efficiency* of the sector for year t, e^t, as follows:

$$(30)\ e^t \equiv p^t \cdot y^t/R^t(p^t,w^t,x^t) \leq 1\ ; \qquad t = 1970, \ldots, 2020.$$

where the inequality in equation (30) follows using definition (29).[33] Thus if $e^t=1$, then production is allocatively efficient in year t and if $e^t < 1$, then production for the sector during period t is allocatively inefficient. Note that the above definition of value added efficiency is a net revenue counterpart to Farrell's (1957, p. 255) cost based measure of *overall efficiency*.

Define an index of the *change in real value added efficiency* ε^t for the production sector over the years t−1 and t as follows:

$$(31)\ \varepsilon^t \equiv e^t/e^{t-1} = [p^t \cdot y^t/R^t(p^t,w^t,x^t)]/[p^{t-1} \cdot y^{t-1}/R^{t-1}(p^{t-1},w^{t-1},x^{t-1})]; \qquad t = 1971, \ldots, 2020.$$

Thus if $\varepsilon^t > 1$, then real value added efficiency has *improved* going from year t−1 to t whereas it has *fallen* if $\varepsilon^t < 1$.

We turn our attention to defining nonparametric measures of *real output price change* going from year t−1 to t. Following the example of Konüs (1939) in his analysis of the true cost of living index, it is natural to single out two special cases of a family of real output price indexes: one choice is α_L^t where we use the year t−1 technology and set the reference input prices and quantities equal to the year t−1 real input prices w^{t-1} and primary input quantities x^{t-1} (which gives rise to a *Laspeyres type real output price index*) and another choice is α_P^t where we use the year t technology and set the reference input prices and quantities equal to the year t real input prices and quantities w^t and x^t (which gives rise to a *Paasche type real output price index*). We then define an overall measure of real output price change α^t by taking the geometric mean of these two indexes. These indexes are defined as follows:

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[33] Use the fact that (y^t,x^t) is a feasible solution for the maximization problems in equation (29).

(32) $\alpha_L{}^t \equiv R^{t-1}(p^t,w^{t-1},x^{t-1})/R^{t-1}(p^{t-1},w^{t-1},x^{t-1})$; t = 1971, …, 2020;
(33) $\alpha_P{}^t \equiv R^t(p^t,w^t,x^t)/R^t(p^{t-1},w^t,x^t)$; t = 1971, …, 2020;
(34) $\alpha^t \equiv [\alpha_L{}^t\,\alpha_P{}^t]^{1/2}$; t = 1971, …, 2020.

Two natural measures of *input quantity change* are the Laspeyres and Paasche input quantity indexes. Denote the year t indexes as $\beta_L{}^t$ and $\beta_P{}^t$. Again, it is natural to take the geometric average of these two indexes which gives rise to the Fisher ideal input quantity index, β^t. These indexes are defined as follows:

(35) $\beta_L{}^t \equiv w^{t-1}\cdot x^t/w^{t-1}\cdot x^{t-1}$; t = 1971, …, 2020;
(36) $\beta_P{}^t \equiv w^t\cdot x^t/w^t\cdot x^{t-1}$; t = 1971, …, 2020;
(37) $\beta^t \equiv [\beta_L{}^t\,\beta_P{}^t]^{1/2}$; t = 1971, …, 2020.

We now consider indexes which measures the effects on cost constrained value added of a change in real input prices going from period t–1 to t. Thus we consider measures of the change in cost constrained value added of the form $R^s(p,w^t,x)/R^s(p,w^{t-1},x)$. Since $R^s(p,w,x)$ is homogeneous of degree 0 in the components of w, it can be seen that we cannot interpret $R^s(p,w^t,x)/R^s(p,w^{t-1},x)$ as an input price index. If there is only one primary input, $R^s(p,w^t,x)/R^s(p,w^{t-1},x)$ is equal to $R^s(p,1,x)/R^s(p,1,x) = 1$ and this measure of input price change will be independent of changes in the price of the single input. In the case where the number of primary inputs is greater than 1, it is best to interpret $R^s(p,w^t,x)/R^s(p,w^{t-1},x)$ as measuring the effects on cost constrained value added of a change in the relative proportions of primary inputs used in production or in the *mix* of inputs used in production that is induced by a change in relative input prices when there is more than one primary input. As usual, we will consider two special cases of this family of input mix indexes, Case 1 and Case 2. The first case index, $\gamma_1{}^t$, will use the period t cost constrained value added function and the period t–1 reference vectors p^{t-1} and x^{t-1} while the second case index, $\gamma_2{}^t$, will use the period t–1 cost constrained value added function and the period t reference vectors p^t and x^t. As usual, we take the geometric mean of these two indexes γ^t to provide a measure of the overall effects of a change in input prices.[34]

(38) $\gamma_1{}^t \equiv R^t(p^{t-1},w^t,x^t)/R^t(p^{t-1},w^{t-1},x^t)$; t = 1971, …, 2020;
(39) $\gamma_2{}^t \equiv R^{t-1}(p^t,w^t,x^{t-1})/R^{t-1}(p^t,w^{t-1},x^{t-1})$; t = 1971, …, 2020;
(40) $\gamma^t \equiv [\gamma_1{}^t\gamma_2{}^t]^{1/2}$; t = 1971, …, 2020.

Finally, we use the cost constrained value added function in order to define measures of *technical progress* going from period t–1 to t. These measures hold p, w, and x constant and only change the technology from the period t–1 technology to the period t technology.[35] Thus, these measures are of the form $R^t(p,w,x)/R^{t-1}(p,w,x)$. If there is positive technical progress going from period t–1 to t, then the production possibilities set S^t will be larger than the period t–1 set, S^{t-1}, and thus $R^t(p,w,x)$ will be equal to or greater than $R^{t-1}(p,w,x)$ and our measures of technical progress will be equal to or greater than 1. Our measures of technical progress cannot fall below 1.

We consider two measures of technical progress, a Laspeyres measure $\tau_L{}^t$ and a Paasche measure $\tau_P{}^t$. However, the Laspeyres case $\tau_L{}^t$ will use the period t input vector x^t as the reference input vector and the period t–1 reference real output price and real input price vectors p^{t-1} and w^{t-1} while the Paasche case $\tau_P{}^t$ will use the period t–1 input vector x^{t-1} as the reference input and the period t reference real output and

[34] These choices of the reference vectors will make our decomposition of value added growth an exact one. Usually, these input mix growth factors are close to one for all periods.
[35] These measures of technical progress measures were defined by Diewert and Morrison (1986, p. 662) using the country's GDP function. A special case of the family was defined earlier by Diewert (1983, p. 1063). Balk (1998, p. 99) also used this definition and Balk (1998, p. 58), following the example of Salter (1960), used the joint cost function to define a similar family of technical progress indexes.

input price vectors p^t and w^t.[36] As usual, we take our overall year t measure of technical change τ^t to be the geometric mean of the Laspeyres and Paasche measures of technical change.

(41) $\tau_L{}^t \equiv R^t(p^{t-1},w^{t-1},x^t)/R^{t-1}(p^{t-1},w^{t-1},x^t)$; t = 1971, …, 2020;
(42) $\tau_P{}^t \equiv R^t(p^t,w^t,x^{t-1})/R^{t-1}(p^t,w^t,x^{t-1})$; t = 1971, …, 2020;
(43) $\tau^t \equiv [\tau_L{}^t\tau_P{}^t]^{1/2}$; t = 1971, …, 2020.

Finally, as in the previous section, we define $RI_G{}^t$ to be year t *real gross income growth*. Thus define $RI_G{}^t$ as follows:

(44) $RI_G{}^t \equiv p^t{\cdot}y^t/p^{t-1}{\cdot}y^{t-1}$; t = 1971, …, 2020.

Diewert and Fox (2018) show that the following *exact decomposition of nominal income growth into explanatory growth factors* holds:

(45) $RI_G{}^t = \varepsilon^t\,\alpha^t\,\beta^t\,\gamma^t\,\tau^t$; t = 1971, …, 2020.

Table 3 lists $RI_G{}^t$ and the growth components on the right hand side of equation (45).

A new measure of *TFP growth* for the economy going from period t−1 to t can be defined (following Jorgenson and Griliches (1967)) as an index of output growth divided by an index of input growth. An appropriate index of output growth is the net revenue ratio divided by the net revenue price index α^t. An appropriate index of input growth is β^t. Thus define the *nonparametric year t TFP growth rate*, $NTFP_G{}^t$, for the Chinese economy as follows:

(46) $NTFP_G{}^t \equiv \{[p^t{\cdot}y^t/p^{t-1}{\cdot}y^{t-1}]/\alpha^t\}/\beta^t = \varepsilon^t\,\gamma^t\tau^t$; t = 1971, …, 2020.

where the last equality in equation (46) follows from equation (45). Thus in general, the nonparametric period t TFP growth, $NTFP_G{}^t$, is equal to the product of period t efficiency change ε^t, a period t input mix index γ^t (which typically will be small in magnitude) and a period t measure of technical progress τ^t. The nonparametric measure of TFP growth, $NTFP_G{}^t$, and our old index number measure of TFP growth, $TFP_G{}^t$, are listed in Table 3.

Table 3: A Nonparametric Decomposition of Real GDP Growth for China

Year	$RI_G{}^t$	ε^t	α^t	β^t	γ^t	τ^t	e^t	$NTFP_G{}^t$	$TFP_G{}^t$
1971	1.028	0.976	0.988	1.066	1.000	1.000	0.976	0.976	0.976
1972	1.038	1.003	0.991	1.045	0.999	1.000	0.979	1.001	1.002
1973	1.031	0.979	1.001	1.051	1.001	1.000	0.958	0.980	0.979
1974	1.013	0.974	0.993	1.048	1.000	1.000	0.933	0.974	0.973
1975	1.047	1.004	0.993	1.050	1.000	1.000	0.937	1.004	1.005
1976	0.996	0.954	0.992	1.050	1.002	1.000	0.894	0.956	0.958
1977	1.070	1.036	0.995	1.039	0.999	1.000	0.926	1.035	1.036
1978	1.077	1.030	1.000	1.047	0.998	1.000	0.954	1.028	1.028
1979	1.059	1.017	0.994	1.052	0.996	1.000	0.970	1.013	1.013
1980	1.060	1.013	1.000	1.055	0.992	1.000	0.982	1.005	1.005
1981	1.021	0.979	0.993	1.051	0.999	1.000	0.962	0.979	0.981

[36] In our case where the reference technology is subject to constant returns to scale, $\tau_L{}^t$ turns out to be independent of x^t and $\tau_P{}^t$ turns out to be independent of x^{t-1}. These "mixed" indexes of technical progress are then true Laspeyres and Paasche type indexes.

1982	1.065	1.021	0.998	1.047	0.999	1.000	0.982	1.020	1.020
1983	1.092	1.019	1.000	1.042	1.000	1.028	1.000	1.048	1.048
1984	1.162	1.000	1.007	1.063	1.000	1.086	1.000	1.086	1.086
1985	1.069	1.000	0.988	1.076	1.000	1.006	1.000	1.006	1.006
1986	1.074	1.000	1.002	1.074	0.999	1.000	1.000	0.998	1.001
1987	1.063	1.000	0.986	1.067	0.999	1.011	1.000	1.011	1.012
1988	1.076	1.000	0.942	1.066	1.000	1.072	1.000	1.072	1.072
1989	0.979	0.941	0.985	1.057	0.999	1.000	0.941	0.940	0.940
1990	1.044	0.976	1.027	1.043	0.999	1.000	0.918	0.975	0.969
1991	1.129	1.070	1.012	1.039	1.003	1.000	0.983	1.073	1.071
1992	1.149	1.018	1.043	1.052	1.000	1.029	1.000	1.047	1.048
1993	1.154	1.000	1.039	1.067	1.000	1.041	1.000	1.041	1.041
1994	1.126	1.000	0.985	1.062	1.000	1.076	1.000	1.076	1.075
1995	1.027	1.000	0.933	1.069	1.000	1.030	1.000	1.030	1.030
1996	1.060	1.000	0.977	1.076	1.000	1.009	1.000	1.009	1.009
1997	1.069	1.000	0.987	1.066	1.000	1.016	1.000	1.016	1.016
1998	1.087	1.000	0.998	1.059	1.000	1.029	1.000	1.029	1.029
1999	1.063	1.000	0.987	1.065	1.000	1.011	1.000	1.011	1.011
2000	1.088	1.000	0.991	1.073	1.000	1.022	1.000	1.022	1.022
2001	1.078	0.993	1.014	1.071	0.999	1.000	0.993	0.993	0.992
2002	1.143	1.007	1.041	1.067	0.999	1.022	1.000	1.029	1.029
2003	1.130	1.000	1.030	1.078	1.000	1.018	1.000	1.018	1.018
2004	1.128	1.000	1.041	1.082	1.000	1.001	1.000	1.001	1.001
2005	1.155	1.000	1.047	1.100	1.000	1.003	1.000	1.003	1.003
2006	1.122	1.000	1.005	1.067	1.000	1.047	1.000	1.047	1.047
2007	1.188	1.000	1.041	1.056	1.000	1.080	1.000	1.080	1.080
2008	1.149	1.000	1.016	1.066	1.000	1.062	1.000	1.062	1.062
2009	1.121	1.000	1.015	1.078	1.000	1.025	1.000	1.025	1.025
2010	1.101	0.986	0.992	1.127	1.000	1.000	0.986	0.985	0.986
2011	1.063	0.986	0.988	1.096	0.996	1.000	0.973	0.982	0.981
2012	1.074	1.004	1.001	1.079	0.990	1.000	0.977	0.995	0.993
2013	1.075	1.021	0.990	1.077	0.987	1.000	0.997	1.008	1.007
2014	1.027	1.002	0.977	1.056	0.995	1.000	0.999	0.996	0.996
2015	1.061	1.001	0.998	1.038	1.000	1.023	1.000	1.024	1.024
2016	1.032	1.000	0.973	1.047	1.000	1.014	1.000	1.014	1.014
2017	1.109	1.000	1.000	1.039	1.000	1.068	1.000	1.068	1.068
2018	1.061	1.000	1.010	1.046	1.000	1.004	1.000	1.004	1.004
2019	0.988	0.977	0.977	1.037	0.998	1.000	0.977	0.975	0.975
2020	0.996	0.979	0.982	1.041	0.996	1.000	0.956	0.975	0.975
Mean	1.076	0.999	0.999	1.061	0.999	1.017	0.983	1.015	1.015

Our nonparametric estimate of average TFP growth rates is 1.49% per year whereas our index number estimate of average TFP growth rates was 1.48%. Table 3 shows that there is very little difference between the two sets of estimates.

On average, real GDP grew at 7.63% per year. Real output price inflation averaged –0.07% per year which is negligible. Our measure of efficiency, e^t, was below 1 for the years 1971–1982, 1986, 1989–1991, 2001, 2010–2014, and 2019–2020. The inefficiency in the early years of our sample reflect the problems that China faced in going from a command economy to a more decentralized market economy in the late 1970s and early 1980s. The inefficiency in subsequent years is due to recessions.

Aggregate input growth averaged 6.12% per year which is remarkable.[37] The input mix growth factor, γ^t, was on average equal to 0.9989 which indicates a very small negative contribution to GDP growth over the sample period. The average rate of technical progress τ^t was 1.67% per year which is very high.[38] Note that when efficiency e^t is below 1, τ^t is equal to 1, which indicates no technical progress. Conversely, when technical progress is greater than 1, then efficiency e^t is equal to 1.

We again follow the example of Kohli (1990) in order to obtain a levels decomposition for the observed level of real GDP in year t, $p^t \cdot y^t$, relative to its observed value in year 1 of our sample, $p^1 \cdot y^1$. Define the cumulated explanatory variables as follows:

(47) $E^{1970} \equiv 1;\ A^{1970} \equiv 1;\ B^{1970} \equiv 1;\ C^{1970} \equiv 1;\ T^{1970} \equiv 1.$

For t=1971, ..., 2020, define the above variables recursively as follows:

(48) $E^t \equiv \varepsilon^t E^{t-1};\ A^t \equiv \alpha^t A^{t-1};\ B^t \equiv \beta^t B^{t-1};\ C^t \equiv \gamma^t C^{t-1};\ T^t \equiv \tau^t T^{t-1}$; t = 1971, …, 2020.

Using the above definitions, it can be seen that we have the following *levels decomposition* for the level of period t observed real GDP or real gross income RI^t to its level in 1970:

(49) $RI^t/RI^{1970} \equiv p^t \cdot y^t/p^{1970} \cdot y^{1970} = A^t\ B^t\ C^t\ E^t\ T^t$; t = 1971, …, 2020.

Define the period t level of (gross output) Nonparametric TFP, $NTFP^t$, as follows:

(50) $NTFP^{1970} \equiv 1;\ NTFP^t \equiv (NTFP_G{}^t)(NTFP^{t-1})$; t = 1971, …, 2020

where $NTFP_G{}^t$ is defined by equation (46). Using equations (47)–(50), it can be seen that we have the following *levels decomposition for Nonparametric TFP* using the cumulated explanatory factors defined by equations (47) and (48):

(51) $NTFP^t = [p^t \cdot y^t/p^1 \cdot y^1]/[A^t\ B^t] = C^t\ E^t\ T^t$; t = 1970, …, 2020.

The components of the decomposition of real GDP relative to its 1970 level into explanatory factors which is given by equation (49) are listed in Table B7 in Appendix B along with our nonparametric estimates of TFP levels relative to 1970, $NTFP^t$.

Recall that RI^t/RI^{1970} is real GDP in year t relative to 1970 real GDP. From Table B7, Chinese real GDP grew an amazing 37.6 fold over the 51 year sample period. Real output prices grew 0.952 fold over the sample period, an aggregate of labour and capital services grew 19.4 fold, the input mix overall growth factor was 0.945 which means the input mix factor subtracted from GDP growth, the overall efficiency growth factor was 0.956, and finally, the technical progress growth factor in 2020 was 2.25 which was a substantial positive contribution to nominal GDP growth. The explanatory variables that appear on the right hand side of equation (49) are plotted on Figure 3.

[37] As the population of China starts to decline more noticeably, we can expect input growth to slow down in the future.
[38] Technical efficiency growth is higher than TFP growth but when we subtract inefficiency growth from technical efficiency growth, we get TFP growth.

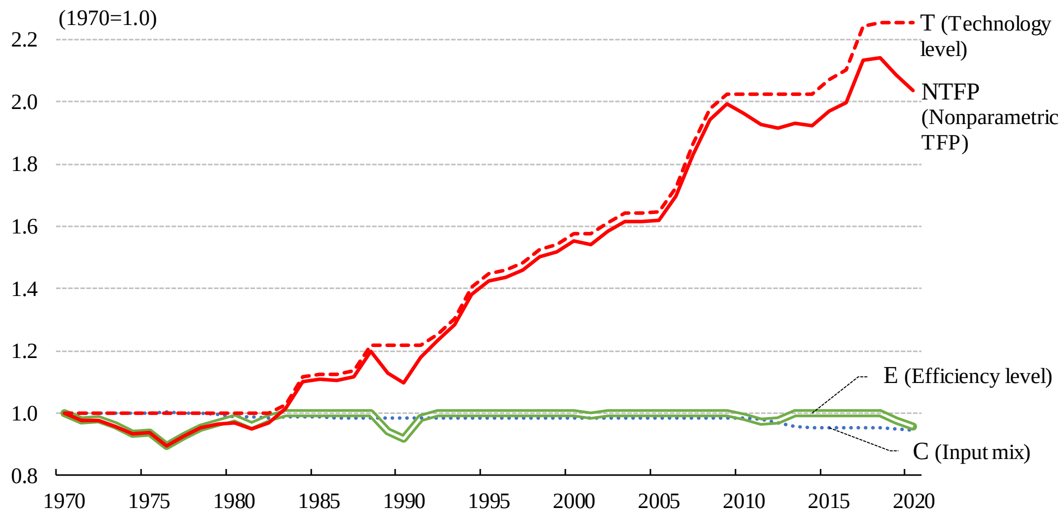

Figure 3. Decomposition of Chinese Gross Output Nonparametric TFP into Explanatory Factors

The top line in Figure 3 plots the level of technology T^t while the line just below it plots the level of (Nonparametric) TFP, $NTFP^t$. The efficiency level line E^t almost coincides with the $NTFP^t$ line for the years 1970–1982 but then is close to the level 1 for most of the rest of the sample period with noticeable dips for the years 1989–1991 and 2019–2020. When E^t dips below 1, it drags $NTFP^t$ below T^t. The input mix line C^t stays very close to the level 1 throughout the sample period but does steadily decline over the sample period.

It can be seen that the decompositions presented in this section and the previous section have their advantages and disadvantages. The index number decomposition can measure the contributions of individual output prices and input quantities but cannot measure inefficiency. The nonparametric decomposition can measure inefficiency but can only provide the aggregate contributions of output price change and input quantity change.[39] Both decompositions generate the same measures of TFP growth to a high degree of approximation.

The above decompositions of real and nominal GDP are fine for many purposes, but they do not accurately reflect the growth of real and nominal *income* for the Chinese economy. The gross income measure includes depreciation (which is not income) and excludes possible long-term real capital gains on assets (which are part of income). Thus, in the following section, we will look at an alternative income concept which adjusts gross income into a more realistic measure of actual income.

6. DECOMPOSING NET INCOME GROWTH

In this section, we attempt to define a more realistic income concept that does not count depreciation as income and, in addition, allows longer term capital gains on assets to become a component of income generated by the production sector. The model we use is a generalization of the Austrian model of production that dates back to Böhm-Bawerk (1891).[40] This Neo-Austrian model of production is based on a well established model of production that is used both by economists and accountants as the following two quotations will show:

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[39] The nonparametric approach to the measurement of TFP could be generalized to include individual price and quantity effects but the resulting decomposition is not as straightforward as the one given by the index number methodology.

[40] Further contributions to this model were made by Hicks (1946, p. 230, 1973, pp. 27–35) and Diewert (1977, pp. 108–111, 1980, pp. 472–474).

"We must look at the production process during a period of time, with a beginning and an end. It starts, at the commencement of the Period, with an Initial Capital Stock; to this there is applied a Flow Input of labour, and from it there emerges a Flow Output called Consumption; then there is a Closing Stock of Capital left over at the end. If Inputs are the things that are put in, the Outputs are the things that are got out, and the production of the Period is considered in isolation, then the Initial Capital Stock is an Input. A Stock Input to the Flow Input of labour; and further (what is less well recognized in the tradition but is equally clear when we are strict with translation), the Closing Capital Stock is an Output, a Stock Output to match the Flow Output of Consumption Goods. Both input and output have stock and flow components; capital appears both as input and as output." John R. Hicks (1961, p. 23).

"The business firm can be viewed as a receptacle into which factors of production, or inputs, flow and out of which outputs flow...The total of the inputs with which the firm can work within the time period specified includes those inherited from the previous period and those acquired during the current period. The total of the outputs of the business firm in the same period includes the amounts of outputs currently sold and the amounts of inputs which are bequeathed to the firm in its succeeding period of activity." Edgar O. Edwards and Philip W. Bell (1961, pp. 71–72).

Hicks, Edwards and Bell obviously had the same model of production in mind: in each accounting period, the business unit combines the capital stocks and goods in process that it has inherited from the previous period with "flow" inputs purchased in the current period (such as labour, materials, services, and additional durable inputs) to produce current period "flow" outputs as well as end of the period depreciated capital stock components which are regarded as outputs from the perspective of the current period (but will be regarded as inputs from the perspective of the next period).

In what follows, we use the notation that was used in section 2. In the new measurement framework, gross investment disappears from the list of outputs produced by the production sector.[41] It is replaced by the end of the period value of the capital stock less the beginning of the period value of the capital stock. This difference corresponds to the nominal value of net investment. On the income side of the accounts, the value of capital services using user costs is replaced by the value of *waiting services* which is essentially the value of direct and implicit interest payments for the use of capital plus specific property taxes (if applicable). The counterpart to equation (10) in section 2 is now equation (52), which determines a new balancing rate of return on assets for each year t, r^{t**}:[42]

$$(52)\ P_C{}^tQ_C{}^t + P_G{}^tQ_G{}^t + P_X{}^tQ_X{}^t - P_M{}^tQ_M{}^t + \Sigma_{n=1}{}^{16} P_{Kn}{}^{t+1}Q_{Kn}{}^{t+1} - \Sigma_{n=1}{}^{16} P_{Kn}{}^t Q_{Kn}{}^t$$
$$= P_L{}^tQ_L{}^t + \Sigma_{n=1}{}^{16} P_{Kn}{}^t(r^{t**}+\tau_n{}^t)Q_{Kn}{}^t\ ; \qquad t = 1970, \ldots, 2020.$$

We use ex ante or *expected prices* to value the end of the year capital stocks. Recall that $i_n{}^t$ is the year t smoothed asset n inflation rate for n = 1, …, 16. We assume that the expected year-end price for asset n in year t is $(1+i_n{}^t)$ times the beginning of year t price of asset n:

$$(53)\ P_{Kn}{}^{t+1} \equiv (1+i_n{}^t)P_{Kn}{}^t\ ; \qquad n = 1, \ldots, 16\ ;\ t = 1970, \ldots, 2020.$$

Substitute definition (53) into equation (52) and solve the resulting equations for the *new balancing rates of return on assets* for year t, r^{t**}, for t=1970, …, 2020. These new rates of return are listed in Table 4. These new rates of return on assets will differ somewhat from our smoothed balancing rates of return r^t (also listed in Table 4) because we are valuing the gross investment at end of the year prices instead of average for the year prices for assets 1–11.

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[41] See Diewert and Fox (2023) for a more detailed explanation and justification for the use of equation (52).

[42] Note that $Q_{Kn}{}^t$ appears on both sides of equation (52). Thus we have decomposed the consolidated cost of purchasing a unit of capital stock n at the beginning of period t, $(1+r^{t**}+\tau_n{}^t)P_{Kn}{}^t$, into two terms in order to provide a measure of period t income that is defined by the right hand side of equation (52). This measure of income is in theory distributed to workers, governments, and owners of the capital inputs.

In this new model of production, year t user costs $U_n{}^t$ are replaced by year t *waiting costs*,[43] $P_{Wn}{}^t$, defined as follows:

$$(54)\ P_{Wn}{}^t \equiv (r^{t**} + \tau_n{}^t)P_{Kn}{}^t\ ; \qquad n = 1, \ldots, 16\ ;\ t = 1970, \ldots, 2020.$$

Since the year t rates of return r^{t**} are positive for China, the waiting costs, $P_W{}^t$, are also positive. Thus, using our Chinese data, we do not encounter the *negative user cost problem* that we encountered earlier. This is an advantage of the net income accounting framework.

We use the data on the waiting costs, $P_{W1}{}^t, \ldots, P_{W16}{}^t$, along with the data on the beginning of the year asset stocks, $Q_{K1}{}^t, \ldots, Q_{K16}{}^t$, to form *five waiting services aggregates* for our five types of aggregate capital. Denote the prices and quantities for these aggregate waiting services by $P_{WM}{}^t$, $P_{WS}{}^t$, $P_{WO}{}^t$, $P_{WI}{}^t$ and $P_{WL}{}^t$ and $Q_{WM}{}^t$, $Q_{WS}{}^t$, $Q_{WO}{}^t$, $Q_{WI}{}^t$ and $Q_{WL}{}^t$. These aggregate waiting costs are listed in Table 4 (with prices normalized to equal 1 in 1970) and the corresponding quantities and values for the waiting services aggregates are listed in Table 5.[44] Finally, the year t price and quantity of *aggregate input*, $P_Z{}^{t*}$ and $Q_Z{}^{t*}$, were calculated by aggregating the five waiting services subaggregates with aggregate labour, $P_L{}^t$ and $Q_L{}^t$.[45] These aggregate input prices and quantities are listed in Table 4.

Table 4: Balancing Rates of Return and Price Indexes for Labour and Waiting Services

Year	r^{t**}	r^t	$P_L{}^t$	$P_{WM}{}^t$	$P_{WS}{}^t$	$P_{WO}{}^t$	$P_{WI}{}^t$	$P_{WL}{}^t$
1970	0.124	0.124	1.000	1.000	1.000	1.000	1.000	1.000
1971	0.123	0.123	1.010	0.987	1.007	0.985	0.996	1.050
1972	0.122	0.121	1.062	0.954	1.001	0.994	0.992	1.085
1973	0.123	0.122	1.069	0.979	1.052	1.072	1.003	1.145
1974	0.122	0.121	1.072	0.990	1.045	1.037	0.998	1.187
1975	0.132	0.130	1.084	1.036	1.138	1.219	1.078	1.330
1976	0.116	0.114	1.092	0.910	1.015	1.148	0.947	1.201
1977	0.143	0.141	1.111	1.119	1.268	1.495	1.176	1.516
1978	0.154	0.151	1.185	1.211	1.378	1.630	1.255	1.702
1979	0.161	0.159	1.280	1.290	1.481	1.781	1.345	1.941
1980	0.158	0.155	1.429	1.267	1.553	1.726	1.415	2.116
1981	0.161	0.157	1.446	1.299	1.621	1.777	1.501	2.420
1982	0.178	0.174	1.479	1.441	1.843	2.003	1.708	2.983
1983	0.202	0.197	1.521	1.602	2.196	2.176	1.956	3.799
1984	0.222	0.216	1.741	1.787	2.559	2.443	2.185	4.720
1985	0.226	0.218	2.010	1.880	2.812	2.676	2.298	5.396
1986	0.215	0.207	2.284	1.871	2.926	2.693	2.354	5.805
1987	0.225	0.216	2.485	1.982	3.284	2.861	2.657	6.917
1988	0.234	0.225	2.912	2.278	3.867	3.323	2.958	8.363
1989	0.219	0.211	3.179	2.309	3.882	3.449	3.177	9.076
1990	0.212	0.205	3.464	2.445	4.020	3.691	3.233	10.108
1991	0.229	0.220	3.781	2.807	4.742	4.081	3.707	12.814

[43] Rymes (1968, 1983) appears to have introduced this terminology. He was a strong advocate for replacing user costs by waiting costs.
[44] These capital services input subaggregates were formed using Törnqvist direct aggregation of input quantities; i.e., bilateral chained quantity indexes were formed first (quantities were always positive) and then the corresponding aggregate price indexes were calculated by deflating total value by the quantity index.
[45] The year t aggregate price and quantity, $P_Z{}^{t*}$ and $Q_Z{}^{t*}$, were calculated using Törnqvist direct aggregation of input quantities. The year t total value of net income is $V_Z{}^{t*} \equiv P_Z{}^{t*}Q_Z{}^{t*}$.

1992	0.228	0.219	4.283	3.089	5.525	4.395	3.822	15.097
1993	0.216	0.207	5.206	3.448	6.902	4.841	3.794	17.438
1994	0.214	0.206	6.920	3.657	7.534	5.117	4.201	20.669
1995	0.228	0.222	8.154	4.113	8.445	5.870	5.634	27.133
1996	0.225	0.219	9.048	4.079	8.756	6.023	6.307	30.838
1997	0.221	0.215	9.677	3.950	8.830	5.797	6.448	34.094
1998	0.213	0.209	9.995	3.768	8.549	5.289	6.208	36.483
1999	0.208	0.204	10.419	3.571	8.349	5.002	5.784	39.135
2000	0.214	0.211	10.752	3.592	8.663	5.182	5.811	44.645
2001	0.205	0.202	11.369	3.422	8.428	5.166	5.663	47.869
2002	0.201	0.198	11.959	3.303	8.460	4.790	5.567	52.625
2003	0.192	0.189	13.325	3.093	8.444	4.767	5.314	56.480
2004	0.186	0.183	15.076	3.006	8.865	4.875	5.332	62.052
2005	0.181	0.178	16.587	2.943	9.116	4.909	5.685	70.776
2006	0.188	0.185	19.297	3.100	9.855	5.260	6.143	87.557
2007	0.193	0.190	23.473	3.199	10.801	5.385	6.541	107.987
2008	0.190	0.187	27.709	3.185	11.561	5.218	6.841	129.334
2009	0.188	0.183	30.771	3.108	11.049	5.009	7.269	151.831
2010	0.179	0.176	32.584	2.982	11.058	5.011	6.568	165.511
2011	0.162	0.159	37.848	2.761	10.995	4.744	6.414	168.897
2012	0.145	0.142	43.034	2.461	10.042	4.185	6.105	169.468
2013	0.136	0.133	47.859	2.284	9.441	3.938	5.673	175.065
2014	0.124	0.121	52.664	2.078	8.708	3.613	5.145	180.329
2015	0.123	0.120	58.596	2.041	8.398	3.586	5.015	201.956
2016	0.124	0.121	61.386	2.045	8.412	3.765	4.815	228.314
2017	0.137	0.134	66.109	2.275	10.009	4.221	5.268	276.030
2018	0.132	0.129	71.559	2.216	10.344	4.135	5.317	287.658
2019	0.120	0.118	78.310	2.027	9.720	3.755	4.994	280.409
2020	0.114	0.111	83.210	1.907	9.147	3.509	4.757	280.390
Mean	0.176	0.172	17.958	2.356	6.100	3.581	3.968	69.289

The average of the new balancing rates of return r^{t**} is 17.62%, which is somewhat higher than our previous average (smoothed) rate of return for the gross output model which was 17.22%. There is an 83.2 fold increase in quality-adjusted wage rates over the sample period and a 280.4 fold increase in the price of waiting services for land. For Table 5, the units of measurement for the quantity indexes are in trillions of 1970 yuan and in trillions of current yuan for the value estimates.

Table 5: Quantity Indexes and Current Yuan Values for Labour and Waiting Services

Year	Q_L^t	Q_{WM}^t	Q_{WS}^t	Q_{WO}^t	Q_{WI}^t	Q_{WL}^t	V_L^t	V_{WM}^t	V_{WS}^t	V_{WO}^t	V_{WI}^t	V_{WL}^t
1970	0.147	0.011	0.026	0.002	0.006	0.028	0.147	0.011	0.026	0.002	0.006	0.028
1971	0.155	0.013	0.028	0.002	0.007	0.028	0.156	0.013	0.028	0.002	0.007	0.029
1972	0.158	0.015	0.031	0.002	0.008	0.028	0.168	0.014	0.031	0.002	0.008	0.030
1973	0.164	0.016	0.034	0.002	0.008	0.028	0.175	0.016	0.036	0.002	0.008	0.032
1974	0.170	0.018	0.037	0.002	0.009	0.028	0.182	0.018	0.038	0.002	0.009	0.033
1975	0.176	0.019	0.040	0.002	0.009	0.028	0.191	0.020	0.046	0.003	0.010	0.037
1976	0.182	0.021	0.045	0.003	0.009	0.028	0.198	0.019	0.045	0.003	0.008	0.034

1977	0.187	0.023	0.048	0.003	0.008	0.028	0.208	0.025	0.061	0.004	0.010	0.043
1978	0.193	0.024	0.053	0.003	0.009	0.028	0.229	0.029	0.073	0.004	0.012	0.048
1979	0.200	0.025	0.058	0.003	0.011	0.028	0.255	0.033	0.086	0.005	0.014	0.055
1980	0.208	0.026	0.065	0.003	0.012	0.028	0.297	0.033	0.100	0.005	0.017	0.060
1981	0.216	0.026	0.072	0.003	0.013	0.029	0.313	0.034	0.116	0.006	0.020	0.069
1982	0.226	0.026	0.079	0.003	0.014	0.029	0.334	0.037	0.146	0.007	0.024	0.085
1983	0.232	0.026	0.087	0.003	0.014	0.029	0.353	0.042	0.192	0.007	0.027	0.109
1984	0.246	0.027	0.096	0.004	0.015	0.029	0.428	0.048	0.245	0.009	0.032	0.136
1985	0.260	0.030	0.105	0.004	0.018	0.029	0.523	0.056	0.296	0.011	0.041	0.157
1986	0.272	0.035	0.116	0.005	0.022	0.029	0.621	0.065	0.340	0.013	0.052	0.170
1987	0.283	0.040	0.127	0.005	0.025	0.029	0.704	0.080	0.417	0.015	0.066	0.203
1988	0.295	0.048	0.139	0.006	0.026	0.029	0.858	0.109	0.536	0.019	0.077	0.246
1989	0.300	0.056	0.152	0.006	0.030	0.030	0.955	0.129	0.589	0.022	0.096	0.268
1990	0.307	0.059	0.163	0.007	0.035	0.030	1.064	0.144	0.654	0.025	0.114	0.300
1991	0.315	0.061	0.173	0.007	0.039	0.030	1.193	0.172	0.819	0.029	0.143	0.382
1992	0.327	0.065	0.184	0.008	0.046	0.030	1.399	0.202	1.014	0.033	0.175	0.452
1993	0.341	0.074	0.199	0.008	0.051	0.030	1.776	0.255	1.374	0.039	0.195	0.524
1994	0.347	0.089	0.218	0.009	0.055	0.030	2.402	0.324	1.643	0.046	0.230	0.624
1995	0.357	0.106	0.240	0.010	0.059	0.030	2.907	0.434	2.027	0.059	0.333	0.823
1996	0.370	0.121	0.267	0.011	0.067	0.030	3.350	0.492	2.341	0.067	0.419	0.938
1997	0.380	0.137	0.296	0.012	0.074	0.031	3.673	0.539	2.613	0.071	0.477	1.040
1998	0.384	0.157	0.326	0.014	0.079	0.031	3.837	0.590	2.785	0.074	0.488	1.116
1999	0.395	0.180	0.357	0.016	0.082	0.031	4.112	0.644	2.984	0.078	0.473	1.201
2000	0.412	0.206	0.392	0.018	0.086	0.031	4.432	0.739	3.395	0.091	0.501	1.372
2001	0.426	0.235	0.430	0.020	0.092	0.031	4.843	0.805	3.624	0.104	0.522	1.474
2002	0.435	0.270	0.472	0.023	0.099	0.031	5.198	0.892	3.991	0.110	0.550	1.623
2003	0.450	0.314	0.517	0.027	0.105	0.031	5.995	0.972	4.369	0.129	0.555	1.763
2004	0.464	0.377	0.570	0.031	0.114	0.032	6.989	1.132	5.055	0.153	0.606	1.959
2005	0.494	0.454	0.631	0.036	0.122	0.032	8.198	1.335	5.750	0.178	0.695	2.260
2006	0.495	0.552	0.691	0.042	0.129	0.032	9.545	1.712	6.810	0.220	0.791	2.832
2007	0.485	0.667	0.755	0.049	0.142	0.033	11.388	2.133	8.158	0.261	0.931	3.534
2008	0.481	0.808	0.829	0.057	0.165	0.033	13.333	2.572	9.578	0.298	1.131	4.277
2009	0.489	0.974	0.906	0.071	0.186	0.035	15.044	3.027	10.010	0.357	1.351	5.274
2010	0.536	1.190	1.014	0.092	0.207	0.036	17.476	3.549	11.210	0.462	1.359	5.994
2011	0.554	1.449	1.131	0.116	0.237	0.037	20.964	3.999	12.434	0.551	1.519	6.307
2012	0.564	1.673	1.274	0.142	0.266	0.038	24.262	4.117	12.797	0.595	1.623	6.453
2013	0.576	1.945	1.420	0.174	0.292	0.038	27.542	4.442	13.402	0.685	1.656	6.722
2014	0.571	2.187	1.590	0.208	0.321	0.039	30.069	4.545	13.847	0.753	1.651	7.013
2015	0.556	2.392	1.778	0.243	0.347	0.039	32.566	4.882	14.935	0.872	1.738	7.867
2016	0.557	2.548	1.981	0.279	0.367	0.039	34.159	5.211	16.663	1.049	1.768	8.999
2017	0.548	2.744	2.187	0.311	0.390	0.040	36.244	6.241	21.892	1.313	2.052	10.984
2018	0.544	2.978	2.399	0.344	0.412	0.042	38.958	6.597	24.815	1.423	2.190	12.055
2019	0.533	3.226	2.625	0.382	0.428	0.044	41.717	6.540	25.515	1.432	2.135	12.263
2020	0.532	3.447	2.862	0.425	0.443	0.044	44.287	6.571	26.179	1.491	2.109	12.270

We need to form a new net investment aggregate. The year t value of this investment aggregate is V_I^{t*} which is defined as follows:

(55) $V_I^{t*} \equiv \Sigma_{n=1}^{16} (1+i_n^t)P_{Kn}^t Q_{Kn}^{t+1} - \Sigma_{n=1}^{16} P_{Kn}^t Q_{Kn}^t$; t = 1970, …, 2020.

The year t price index for this net investment aggregate is P_I^{t*} which is calculated as the direct Törnqvist price index of the 32 components of this aggregate. The Q_{Kn}^{t+1} enter the index number formula with plus signs and the Q_{Kn}^t enter the index formula with minus signs. The new year t net investment aggregate quantity Q_I^{t*} is defined as V_I^{t*}/P_I^{t*}. Once the P_I^{t*} and Q_I^{t*} have been defined, a new year t net output aggregate V_Y^{t*} can be defined as follows:

(56) $V_Y^{t*} \equiv P_C^tQ_C^t + P_G^tQ_G^t + P_I^{t*}Q_I^{t*} + P_X^tQ_X^t - P_M^tQ_M^t$; t = 1970, …, 2020.

The year t price index for this net output aggregate is P_Y^{t*} which is calculated as the direct Törnqvist price index of the five components of this aggregate. The quantities enter the index number formula with plus signs except for imports, Q_M^t, which enters the index formula with a minus sign. The new year t net output aggregate quantity Q_Y^{t*} is defined as V_Y^{t*}/P_Y^{t*}. The new net investment aggregates and the new measures of net output (and net income) are compared with our old gross investment and gross output measures in Table 6.

Table 6: Net Output, Gross Output and Investment Aggregates for China

Year	P_Y^{t*}	P_Y^t	Q_Y^{t*}	Q_Y^t	V_Y^{t*}	V_Y^t	P_I^{t*}	P_I^t	Q_I^{t*}	Q_I^t	V_I^{t*}	V_I^t
1970	1.000	1.000	0.220	0.236	0.220	0.236	1.000	1.000	0.049	0.066	0.049	0.066
1971	1.038	1.024	0.227	0.246	0.235	0.251	1.066	1.006	0.049	0.067	0.052	0.068
1972	1.072	1.041	0.236	0.257	0.253	0.268	1.129	1.001	0.049	0.070	0.055	0.070
1973	1.117	1.071	0.241	0.265	0.269	0.283	1.227	1.028	0.049	0.072	0.060	0.074
1974	1.155	1.092	0.244	0.270	0.282	0.295	1.317	1.037	0.050	0.076	0.066	0.079
1975	1.197	1.113	0.256	0.285	0.306	0.317	1.405	1.039	0.056	0.086	0.079	0.089
1976	1.227	1.125	0.250	0.286	0.307	0.322	1.502	1.049	0.049	0.085	0.074	0.089
1977	1.278	1.154	0.274	0.308	0.350	0.355	1.602	1.057	0.061	0.097	0.098	0.103
1978	1.341	1.193	0.294	0.331	0.394	0.395	1.711	1.073	0.070	0.112	0.119	0.120
1979	1.435	1.257	0.312	0.353	0.448	0.444	1.848	1.102	0.074	0.121	0.138	0.133
1980	1.550	1.323	0.331	0.374	0.513	0.495	2.097	1.152	0.077	0.124	0.160	0.143
1981	1.640	1.365	0.340	0.386	0.558	0.526	2.335	1.178	0.074	0.120	0.172	0.141
1982	1.739	1.409	0.364	0.412	0.633	0.580	2.607	1.208	0.080	0.129	0.208	0.155
1983	1.848	1.454	0.395	0.450	0.730	0.654	2.934	1.245	0.088	0.145	0.258	0.181
1984	1.994	1.524	0.451	0.519	0.899	0.792	3.317	1.304	0.107	0.191	0.356	0.249
1985	2.238	1.673	0.484	0.562	1.084	0.941	3.774	1.395	0.124	0.232	0.467	0.323
1986	2.441	1.772	0.516	0.604	1.259	1.071	4.325	1.501	0.127	0.240	0.548	0.360
1987	2.673	1.886	0.555	0.653	1.484	1.231	4.873	1.578	0.132	0.248	0.645	0.392
1988	2.969	2.051	0.621	0.746	1.845	1.529	5.666	1.771	0.151	0.303	0.853	0.537
1989	3.319	2.260	0.620	0.741	2.059	1.674	6.340	1.899	0.143	0.273	0.904	0.519
1990	3.651	2.481	0.630	0.749	2.301	1.858	6.918	2.045	0.138	0.251	0.957	0.514
1991	3.979	2.689	0.688	0.834	2.737	2.241	7.577	2.205	0.157	0.315	1.191	0.695
1992	4.322	2.915	0.758	0.918	3.275	2.676	8.461	2.494	0.181	0.373	1.530	0.931
1993	5.027	3.408	0.828	1.020	4.163	3.476	10.215	3.118	0.205	0.450	2.091	1.403
1994	5.683	3.924	0.927	1.165	5.269	4.570	10.979	3.431	0.228	0.524	2.498	1.799
1995	6.496	4.537	1.013	1.282	6.582	5.818	11.587	3.624	0.256	0.607	2.965	2.200
1996	7.022	4.947	1.083	1.392	7.607	6.885	11.926	3.758	0.270	0.666	3.225	2.503
1997	7.163	5.076	1.175	1.508	8.414	7.654	11.945	3.808	0.283	0.688	3.381	2.621
1998	7.111	5.074	1.250	1.642	8.891	8.331	11.671	3.779	0.297	0.768	3.463	2.904
1999	7.033	5.048	1.350	1.768	9.491	8.926	11.390	3.744	0.320	0.822	3.641	3.077

2000	7.163	5.159	1.470	1.940	10.530	10.006	11.326	3.743	0.350	0.920	3.968	3.443
2001	7.368	5.289	1.544	2.062	11.372	10.907	11.532	3.772	0.379	1.035	4.370	3.905
2002	7.398	5.243	1.671	2.263	12.364	11.867	11.943	3.787	0.421	1.195	5.023	4.525
2003	7.663	5.345	1.799	2.483	13.783	13.270	12.635	3.860	0.486	1.459	6.144	5.630
2004	8.253	5.667	1.926	2.689	15.895	15.241	13.787	4.067	0.540	1.671	7.450	6.795
2005	8.828	5.939	2.086	2.967	18.416	17.624	14.932	4.212	0.573	1.845	8.563	7.771
2006	9.565	6.327	2.291	3.313	21.910	20.957	16.019	4.342	0.631	2.107	10.101	9.148
2007	10.272	6.702	2.571	3.780	26.405	25.330	17.175	4.512	0.719	2.498	12.344	11.269
2008	10.998	7.079	2.836	4.275	31.187	30.263	18.662	4.766	0.825	3.035	15.387	14.463
2009	11.217	7.092	3.126	4.722	35.063	33.484	19.006	4.682	0.989	3.678	18.799	17.220
2010	11.754	7.419	3.407	5.245	40.050	38.912	19.792	4.858	1.082	4.176	21.422	20.284
2011	12.681	8.005	3.610	5.638	45.774	45.132	21.027	5.158	1.140	4.524	23.976	23.333
2012	13.115	8.221	3.801	6.041	49.847	49.667	21.467	5.194	1.185	4.863	25.440	25.261
2013	13.426	8.387	4.056	6.549	54.450	54.928	21.604	5.192	1.283	5.430	27.713	28.191
2014	13.743	8.545	4.211	6.887	57.877	58.844	21.822	5.197	1.300	5.646	28.374	29.341
2015	14.196	8.761	4.428	7.317	62.860	64.101	21.674	5.091	1.351	5.995	29.278	30.519
2016	14.594	8.965	4.649	7.763	67.847	69.589	21.801	5.076	1.413	6.410	30.794	32.537
2017	15.312	9.379	5.142	8.615	78.726	80.793	23.065	5.336	1.635	7.452	37.701	39.768
2018	16.022	9.789	5.370	9.047	86.038	88.559	24.319	5.595	1.695	7.818	41.222	43.743
2019	16.681	10.176	5.371	9.146	89.601	93.065	24.836	5.703	1.591	7.535	39.509	42.972
2020	17.186	10.470	5.406	9.275	92.908	97.109	24.771	5.687	1.610	7.750	39.878	44.079
Mean	6.651	4.428	1.720	2.600	19.525	19.505	10.744	3.068	0.494	1.870	9.172	9.152

It can be seen that switching from a gross output measure to a net output measure makes a big difference in the price and quantity (or volume) of net investment relative to gross investment. The price of net investment ended up at 24.77 while the price of gross investment ended up at 5.69. The volume of net investment ended up at 1.61 while the volume of gross investment ended up at 7.75. Net investment value for 2020 was 39.88 trillion yuan in 2020 while gross investment value was 44.08 trillion yuan, a difference of 11.5%. Our net investment aggregate adds (smoothed) capital gains (or losses) on all assets over the course of each year whereas the gross investment model does not include these gains. However, gross investment does not deduct depreciation whereas net investment does. On average, the effects of increasing asset capital gains and increasing depreciation over the sample period largely cancel each other out in value terms. However, for some years, the difference between the value of gross and net output is quite high: in 1990, the value of net output was 23.9% higher than the value of gross output, which translates into a 23.9% difference in net income over gross income for that year.[46]

The shares of labour and the five types of waiting services in net income in year t are defined as follows:[47]

$$(57)\quad s_L^{t*} \equiv V_L^t/V_Z^{t*};\ s_{WM}^t \equiv V_{WM}^t/V_Z^{t*};\ s_{WS}^t \equiv V_{WS}^t/V_Z^{t*};\ s_{WO}^t \equiv V_{WO}^t/V_Z^{t*};\ s_{WI}^t \equiv V_{WI}^t/V_Z^{t*};$$
$$s_{WL}^t \equiv V_{WL}^t/V_Z^{t*};\qquad t = 1970, \ldots, 2020.$$

These income shares of total net income are listed in Table B8 in Appendix B.

Having defined new measures of year t net output and input, Q_Y^{t*} and Q_Z^{t*}, a new measure of (Net Output) *TFP* for year t, TFP^{t*}, can be defined by dividing Q_Y^{t*} by Q_Z^{t*}:

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[46] The differences in the volumes of net and gross investments and outputs are large: the investment ratios Q_I^{t*}/Q_I^t for t=1970 and 2020 were 0.751 and 0.207 respectively and the output volume ratios Q_Y^{t*}/Q_Y^t for t=1970 and 2020 were 0.931 and 0.583 respectively. The gross over net output value ratios V_Y^{t*}/V_Y^t for t=1970 and 2020 were 0.931 and 0.957 respectively.

[47] Note that $V_Y^{t*}=V_Z^{t*}$ for all t.

(58) $TFP^{t*} \equiv Q_Y^{t*}/Q_Z^{t*}$; t = 1970, …, 2020.

A new measure of *Net Output TFP growth* is defined as follows:

(59) $TFP_G^{t*} \equiv TFP^{t*}/TFP^{t-1*}$; t = 1971, …, 2020.

These TFP measures are listed in Table 7. Gross Output TFP^t is also listed for comparison purposes. The level of Net Output TFP^{t*} finished at 1.9153 which is somewhat lower than the final level for Gross Output TFP^t which was 2.0287. On average, the Net Output TFP growth rate TFP_G^{t*} was 1.36% per year whereas the average growth rate for Gross Output TFP was 1.48% per year. The labour share of net income, s_L^{t*}, was quite variable. It started at 67.11% in 1970, decreased to 42.04% in 2002, increased to 51.95 in 2014 and then declined to 47.67% in 2020. Thus over the entire sample period, the net income share of capital increased enormously which is perhaps not surprising given the very large rates of gross investment for the Chinese economy. The net income share of M&E varied between 5.1% and 8.9% and the Land share varied between 10.9% and 15.2%. The income share of structures increased from 11.8% in 1970 to 28.2% in 2020, which is a very large increase. The share of inventories started at 2.7%, increased to 5.7% in 1997 and then decreased steadily to end up at 2.3% in 2020. The average share of Other Capital was small at 1.04%. The average annual rates of Net Output TFP growth over the five decades were as follows: –0.22% (1970s), 1.15% (1980s), 3.11% (1990s), 2.31% (2000s), 0.44% (2010s).

Table 7: Net TFP Levels and Growth, Input Aggregates, and Input Shares

Year	TFP^{t*}	TFP^t	TFP_G^{t*}	P_Z^{t*}	Q_Z^{t*}	V_Z^{t*}	s_L^{t*}	s_{WM}^t	s_{WS}^t	s_{WO}^t	s_{WI}^t	s_{WL}^t
1970	1.000	1.000	1.000	1.000	0.220	0.220	0.671	0.052	0.118	0.007	0.027	0.125
1971	0.976	0.976	0.976	1.013	0.232	0.235	0.665	0.055	0.120	0.007	0.030	0.123
1972	0.978	0.978	1.003	1.048	0.241	0.253	0.666	0.056	0.123	0.007	0.030	0.119
1973	0.957	0.957	0.978	1.069	0.252	0.269	0.652	0.059	0.133	0.008	0.031	0.118
1974	0.930	0.932	0.972	1.075	0.262	0.282	0.645	0.062	0.136	0.008	0.031	0.117
1975	0.934	0.936	1.004	1.118	0.274	0.306	0.623	0.065	0.150	0.009	0.031	0.121
1976	0.878	0.896	0.940	1.078	0.285	0.307	0.645	0.063	0.147	0.009	0.026	0.109
1977	0.929	0.928	1.058	1.186	0.295	0.350	0.593	0.072	0.175	0.011	0.028	0.122
1978	0.954	0.954	1.027	1.279	0.308	0.394	0.580	0.072	0.186	0.011	0.029	0.122
1979	0.968	0.966	1.015	1.388	0.323	0.448	0.570	0.073	0.192	0.011	0.032	0.123
1980	0.973	0.971	1.006	1.508	0.340	0.513	0.580	0.064	0.195	0.010	0.034	0.117
1981	0.953	0.952	0.979	1.563	0.357	0.558	0.561	0.061	0.208	0.010	0.036	0.124
1982	0.973	0.971	1.021	1.692	0.374	0.633	0.528	0.058	0.231	0.010	0.038	0.135
1983	1.016	1.018	1.043	1.877	0.389	0.730	0.483	0.057	0.263	0.010	0.037	0.149
1984	1.093	1.105	1.077	2.180	0.412	0.899	0.476	0.054	0.272	0.010	0.036	0.152
1985	1.098	1.112	1.004	2.458	0.441	1.084	0.483	0.052	0.273	0.010	0.038	0.145
1986	1.095	1.113	0.997	2.673	0.471	1.259	0.493	0.052	0.270	0.010	0.041	0.135
1987	1.111	1.126	1.015	2.970	0.500	1.484	0.474	0.054	0.281	0.010	0.044	0.137
1988	1.175	1.208	1.057	3.488	0.529	1.845	0.465	0.059	0.291	0.010	0.042	0.134
1989	1.113	1.135	0.947	3.693	0.558	2.059	0.464	0.062	0.286	0.011	0.047	0.130
1990	1.084	1.100	0.974	3.956	0.582	2.301	0.462	0.063	0.285	0.011	0.050	0.130
1991	1.139	1.178	1.052	4.533	0.604	2.737	0.436	0.063	0.299	0.011	0.052	0.140
1992	1.196	1.234	1.050	5.170	0.634	3.275	0.427	0.062	0.310	0.010	0.053	0.138
1993	1.232	1.285	1.030	6.195	0.672	4.163	0.427	0.061	0.330	0.010	0.047	0.126
1994	1.309	1.382	1.062	7.440	0.708	5.269	0.456	0.062	0.312	0.009	0.044	0.118

1995	1.350	1.424	1.031	8.771	0.750	6.582	0.442	0.066	0.308	0.009	0.051	0.125
1996	1.351	1.437	1.001	9.488	0.802	7.607	0.440	0.065	0.308	0.009	0.055	0.123
1997	1.383	1.460	1.024	9.908	0.849	8.414	0.437	0.064	0.311	0.009	0.057	0.124
1998	1.402	1.502	1.014	9.972	0.892	8.891	0.432	0.066	0.313	0.008	0.055	0.126
1999	1.435	1.519	1.023	10.088	0.941	9.491	0.433	0.068	0.314	0.008	0.050	0.127
2000	1.470	1.553	1.025	10.532	1.000	10.530	0.421	0.070	0.322	0.009	0.048	0.130
2001	1.457	1.541	0.991	10.736	1.059	11.372	0.426	0.071	0.319	0.009	0.046	0.130
2002	1.497	1.585	1.027	11.075	1.116	12.364	0.420	0.072	0.323	0.009	0.045	0.131
2003	1.517	1.613	1.013	11.620	1.186	13.783	0.435	0.071	0.317	0.009	0.040	0.128
2004	1.525	1.614	1.005	12.583	1.263	15.895	0.440	0.071	0.318	0.010	0.038	0.123
2005	1.526	1.619	1.001	13.471	1.367	18.416	0.445	0.073	0.312	0.010	0.038	0.123
2006	1.596	1.695	1.046	15.268	1.435	21.910	0.436	0.078	0.311	0.010	0.036	0.129
2007	1.720	1.831	1.077	17.665	1.495	26.405	0.431	0.081	0.309	0.010	0.035	0.134
2008	1.807	1.943	1.051	19.869	1.570	31.187	0.428	0.083	0.307	0.010	0.036	0.137
2009	1.870	1.991	1.035	20.978	1.671	35.063	0.429	0.086	0.286	0.010	0.039	0.150
2010	1.840	1.963	0.984	21.632	1.851	40.050	0.436	0.089	0.280	0.012	0.034	0.150
2011	1.811	1.926	0.984	22.971	1.993	45.774	0.458	0.087	0.272	0.012	0.033	0.138
2012	1.795	1.913	0.991	23.535	2.118	49.847	0.487	0.083	0.257	0.012	0.033	0.130
2013	1.810	1.926	1.009	24.304	2.240	54.450	0.506	0.082	0.246	0.013	0.030	0.124
2014	1.807	1.919	0.998	24.832	2.331	57.877	0.520	0.079	0.239	0.013	0.029	0.121
2015	1.855	1.964	1.026	26.328	2.388	62.860	0.518	0.078	0.238	0.014	0.028	0.125
2016	1.877	1.991	1.012	27.395	2.477	67.847	0.504	0.077	0.246	0.016	0.026	0.133
2017	2.016	2.126	1.074	30.874	2.550	78.726	0.460	0.079	0.278	0.017	0.026	0.140
2018	2.024	2.135	1.004	32.427	2.653	86.038	0.453	0.077	0.288	0.017	0.026	0.140
2019	1.964	2.081	0.970	32.762	2.735	89.601	0.466	0.073	0.285	0.016	0.024	0.137
2020	1.915	2.029	0.975	32.918	2.822	92.908	0.477	0.071	0.282	0.016	0.023	0.132
Mean	1.366	1.426	1.014	10.876	1.055	19.525	0.496	0.068	0.258	0.010	0.038	0.130

The index number decomposition of GDP that was undertaken in section 4 can be repeated using the new data for the Net Income model that was explained above in this section. Using the new data, the computations are the same as in section 4. The net income counterparts to Tables B4, B5, and B7 that applied to the Gross Income model discussed in section 4 are Tables B8 and B9 in Appendix B and Table 8. There are some substantial differences between the Net Output real waiting costs listed in Table B8 compared to their user cost counterparts in Table B4. For example, the land real waiting cost w_6^{t*} is equal to 25.61 for t = 2020 but the corresponding land real user cost w_6^{2020} was only equal to 13.79.

The sample average Net Real Income growth listed in Table B9 was 7.69% per year which is somewhat greater than the corresponding average Gross Real Income growth which was 7.63% per year. The biggest changes in the contribution factors going from the gross output model to the net output model took place in investment prices (the average contribution factor changed from –0.50% to +0.52% per year) and in M&E input services (the average contribution factor changed from 1.53% to 0.80% per year). The contribution of land services increased from 0.04% to 0.13% per year. Thus moving from the gross output measurement framework to the net output framework did lead to some substantial changes in the explanatory variables for real gross and net income growth.

Table 8 is the net output counterpart to the gross output Table B6 discussed in section 4. It cumulates the contribution factors listed in Table B9 into levels.

Table 8: The Levels Decomposition for Real Net Income Growth in China

Year	RI^t/RI^{1970}	TFP^{t*}	A_2^t	A_3^t	A_4^t	A_5^t	B_1^t	B_2^t	B_3^t	B_4^t	B_5^t	B_6^t
1970	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1971	1.034	0.976	0.995	1.006	0.998	1.003	1.033	1.008	1.010	1.001	1.005	1.000
1972	1.081	0.978	0.994	1.013	0.997	1.004	1.049	1.015	1.022	1.002	1.007	1.001
1973	1.121	0.957	0.993	1.026	0.997	1.007	1.073	1.020	1.034	1.002	1.009	1.001
1974	1.145	0.930	0.989	1.037	0.998	1.008	1.097	1.025	1.045	1.003	1.011	1.001
1975	1.211	0.934	0.988	1.046	0.996	1.010	1.123	1.031	1.059	1.003	1.012	1.002
1976	1.191	0.878	0.982	1.059	0.994	1.012	1.145	1.037	1.075	1.004	1.011	1.002
1977	1.315	0.929	0.983	1.068	0.993	1.012	1.165	1.041	1.089	1.004	1.010	1.003
1978	1.433	0.954	0.987	1.078	0.994	1.013	1.188	1.045	1.108	1.005	1.013	1.003
1979	1.537	0.968	0.988	1.084	0.993	1.016	1.211	1.050	1.127	1.005	1.017	1.004
1980	1.669	0.973	0.990	1.110	0.991	1.018	1.241	1.052	1.149	1.006	1.022	1.004
1981	1.745	0.953	0.988	1.133	0.990	1.017	1.269	1.053	1.174	1.006	1.025	1.004
1982	1.912	0.973	0.987	1.161	0.989	1.019	1.298	1.051	1.201	1.007	1.027	1.005
1983	2.138	1.016	0.989	1.196	0.990	1.015	1.316	1.052	1.230	1.007	1.027	1.006
1984	2.526	1.093	0.999	1.233	0.995	1.006	1.353	1.054	1.260	1.008	1.029	1.006
1985	2.742	1.098	1.002	1.245	1.001	0.997	1.391	1.060	1.293	1.009	1.037	1.007
1986	3.005	1.095	1.004	1.288	1.023	0.967	1.421	1.068	1.328	1.010	1.045	1.008
1987	3.277	1.111	1.006	1.311	1.026	0.959	1.449	1.077	1.361	1.012	1.050	1.009
1988	3.529	1.175	1.006	1.315	1.004	0.939	1.477	1.087	1.396	1.013	1.052	1.009
1989	3.522	1.113	1.002	1.316	0.982	0.964	1.490	1.097	1.432	1.014	1.059	1.010
1990	3.703	1.084	1.003	1.331	1.011	0.956	1.505	1.101	1.462	1.014	1.067	1.010
1991	4.123	1.139	1.008	1.345	1.017	0.956	1.523	1.104	1.487	1.015	1.072	1.011
1992	4.745	1.196	1.018	1.389	1.013	0.960	1.546	1.108	1.515	1.016	1.082	1.011
1993	5.359	1.232	1.027	1.437	0.979	0.983	1.575	1.117	1.555	1.016	1.088	1.012
1994	5.810	1.309	1.038	1.380	1.031	0.932	1.587	1.129	1.601	1.017	1.091	1.012
1995	5.857	1.350	1.032	1.281	0.991	0.969	1.606	1.142	1.649	1.018	1.095	1.013
1996	6.063	1.351	1.031	1.237	0.955	1.011	1.634	1.152	1.705	1.019	1.102	1.013
1997	6.451	1.383	1.033	1.218	0.935	1.027	1.652	1.161	1.759	1.020	1.109	1.014
1998	6.809	1.402	1.035	1.206	0.916	1.046	1.660	1.171	1.813	1.021	1.112	1.014
1999	7.209	1.435	1.037	1.191	0.916	1.037	1.680	1.182	1.866	1.022	1.115	1.014
2000	7.760	1.470	1.037	1.175	0.926	1.028	1.711	1.193	1.922	1.023	1.118	1.015
2001	8.289	1.457	1.042	1.178	0.924	1.040	1.735	1.205	1.980	1.024	1.121	1.015
2002	9.463	1.497	1.055	1.218	0.940	1.030	1.750	1.217	2.040	1.025	1.125	1.015
2003	10.659	1.517	1.068	1.253	0.967	1.006	1.776	1.230	2.101	1.027	1.127	1.017
2004	12.071	1.525	1.080	1.293	1.010	0.977	1.799	1.246	2.167	1.028	1.131	1.018
2005	13.973	1.526	1.090	1.341	1.039	0.969	1.851	1.262	2.237	1.030	1.134	1.020
2006	15.690	1.596	1.101	1.349	1.027	0.986	1.852	1.281	2.301	1.031	1.136	1.021
2007	18.586	1.720	1.126	1.382	1.037	0.985	1.836	1.301	2.365	1.033	1.140	1.023
2008	21.119	1.807	1.141	1.412	1.032	0.985	1.830	1.321	2.434	1.035	1.146	1.024
2009	24.053	1.870	1.152	1.435	1.001	1.022	1.842	1.342	2.499	1.037	1.151	1.032
2010	26.035	1.840	1.151	1.425	1.015	1.008	1.918	1.366	2.580	1.040	1.156	1.038
2011	27.271	1.811	1.156	1.405	0.994	1.028	1.945	1.390	2.659	1.043	1.161	1.043
2012	28.986	1.795	1.165	1.402	0.981	1.046	1.962	1.407	2.744	1.045	1.166	1.045
2013	30.764	1.810	1.171	1.386	0.964	1.065	1.982	1.424	2.820	1.048	1.169	1.046
2014	31.345	1.807	1.174	1.364	0.937	1.089	1.974	1.438	2.898	1.050	1.172	1.048
2015	33.150	1.855	1.182	1.343	0.920	1.127	1.946	1.448	2.977	1.052	1.175	1.048
2016	34.012	1.877	1.179	1.315	0.904	1.146	1.948	1.455	3.055	1.054	1.177	1.050
2017	37.711	2.016	1.185	1.322	0.903	1.139	1.934	1.463	3.135	1.056	1.179	1.051

2018	39.874	2.024	1.192	1.335	0.902	1.136	1.928	1.473	3.219	1.058	1.180	1.059
2019	39.030	1.964	1.194	1.310	0.896	1.139	1.908	1.482	3.303	1.060	1.181	1.065
2020	38.625	1.915	1.190	1.282	0.889	1.158	1.908	1.489	3.385	1.062	1.182	1.065

Figure 4 plots the 11 explanatory factors that explain real net income growth for China. It can be seen that the main factors which explain real net income growth are (i) B_3 (Structure waiting services), (ii) B_1 (Labour services), (iii) TFP Growth, (iv) B_2 (M&E waiting services), and (v) A_3 (Real net investment prices). B_5 (Inventory waiting services) was a small but steady contributor to real income growth. A_4 (Real export prices) fell below 1 for most of the last half of the sample period, indicating declining real export prices and a drag on real income growth. However, this negative effect was offset by declining A_5 (Real import prices) since the early 2010s, leading to a terms of trade effect which was negligible for the Chinese economy.

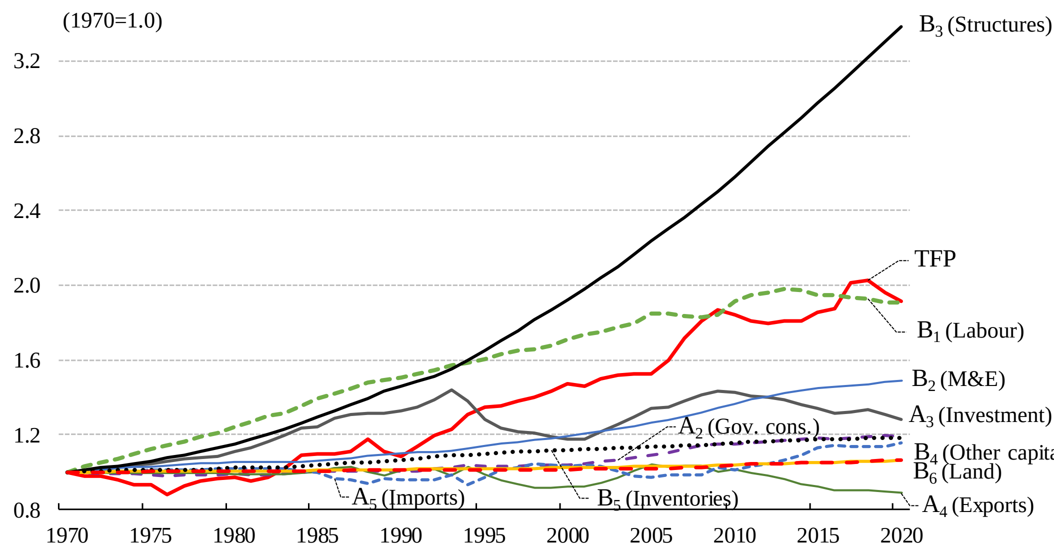

Figure 4. Explanatory Factors for Chinese Real Net Income Growth

As was mentioned earlier, Chinese real gross income grew 37.58 fold over our 51 year sample period. It turns out that real net income grew 38.63 fold over the same period[48] The average annual growth rate for real net income was 7.69% which is very close to 7.63%, the average growth rate for real gross income. Several of the explanatory factors explaining net and gross real income growth changed but the overall growth rates turned out to be almost identical.

It is possible to implement the Diewert and Fox nonparametric productivity model using the net output (real) price and quantity data in place of the corresponding gross output price and quantity data. The algebra in the previous section is exactly the same: only the input and output data have changed. Denote the resulting Nonparametric TFP level for year t by $NTFP^{t*}$ and the corresponding year t growth factor by $NTFP_G^{t*} \equiv NTFP^{t*}/ NTFP^{t-1*}$ for t=1971, …, 2020. The counterparts to Table 3 in the previous section and Table B7 in Appendix B are Tables 9 and B10. Recall that TFP_G^{t*} is the year t index number estimate for TFP Growth using the net output accounting framework. This series is also listed in Table 9 so that it can be compared with the nonparametric estimates of real net income defined by $NTFP_G^{t*}$.

[48] In absolute terms, real net income grew from 219.68 billion Yuan in 1970 to 8485.33 billion Yuan in 2020 while real gross income grew from 236.02 billion Yuan in 1970 to 8869.05 billion Yuan in 2020. Per capita real net income grew from 264.70 Yuan in 1970 to 6008.93 Yuan in 2020 (22.7 fold increase) while real gross income grew from 284.39 Yuan in 1970 to 6280.67 Yuan in 2020 (22.1 fold increase). The units are in 1970 Yuan. To convert these estimates into 2020 Yuan, multiply them by 10.94922, the price of consumption in 2020.

Table 9: A Nonparametric Decomposition of Real Net Output Growth for China

Year	RI_G^{t*}	ε^{t*}	α^{t*}	β^{t*}	γ^{t*}	τ^{t*}	e^{t*}	$NTFP_G^{t*}$	TFP_G^{t*}
1971	1.034	0.975	1.003	1.058	1.000	1.000	0.975	0.975	0.976
1972	1.046	1.003	1.007	1.037	0.999	1.000	0.978	1.002	1.003
1973	1.037	0.978	1.015	1.045	1.000	1.000	0.956	0.978	0.978
1974	1.021	0.973	1.009	1.042	0.999	1.000	0.930	0.972	0.972
1975	1.057	1.003	1.009	1.044	1.001	1.000	0.933	1.003	1.004
1976	0.984	0.942	1.007	1.042	0.996	1.000	0.878	0.938	0.940
1977	1.105	1.050	1.010	1.035	1.006	1.000	0.922	1.057	1.058
1978	1.089	1.030	1.014	1.044	0.999	1.000	0.950	1.029	1.027
1979	1.073	1.020	1.007	1.048	0.997	1.000	0.969	1.017	1.015
1980	1.086	1.014	1.024	1.053	0.993	1.000	0.983	1.007	1.006
1981	1.045	0.982	1.019	1.050	0.996	1.000	0.965	0.977	0.979
1982	1.096	1.022	1.025	1.047	0.999	1.000	0.986	1.021	1.021
1983	1.118	1.014	1.031	1.041	1.000	1.028	1.000	1.043	1.043
1984	1.181	1.000	1.036	1.059	1.000	1.077	1.000	1.077	1.077
1985	1.085	1.000	1.010	1.070	1.000	1.004	1.000	1.004	1.004
1986	1.096	0.998	1.030	1.068	0.999	1.000	0.998	0.997	0.997
1987	1.091	1.002	1.013	1.061	1.000	1.012	1.000	1.014	1.015
1988	1.077	1.000	0.962	1.059	1.000	1.057	1.000	1.057	1.057
1989	0.998	0.948	1.000	1.054	0.999	1.000	0.948	0.947	0.947
1990	1.051	0.979	1.031	1.043	0.998	1.000	0.928	0.978	0.974
1991	1.114	1.052	1.019	1.038	1.001	1.000	0.977	1.053	1.052
1992	1.151	1.024	1.045	1.049	0.999	1.025	1.000	1.049	1.050
1993	1.130	1.000	1.034	1.061	1.000	1.030	1.000	1.030	1.030
1994	1.084	1.000	0.968	1.054	1.000	1.063	1.000	1.063	1.062
1995	1.008	1.000	0.922	1.060	1.000	1.032	1.000	1.032	1.031
1996	1.035	1.000	0.968	1.068	1.000	1.001	1.000	1.001	1.001
1997	1.064	1.000	0.981	1.059	1.000	1.024	1.000	1.024	1.024
1998	1.056	1.000	0.992	1.050	1.000	1.014	1.000	1.014	1.014
1999	1.059	1.000	0.981	1.055	1.000	1.023	1.000	1.023	1.023
2000	1.076	1.000	0.988	1.063	1.000	1.025	1.000	1.025	1.025
2001	1.068	0.992	1.017	1.060	0.999	1.000	0.992	0.992	0.991
2002	1.142	1.008	1.054	1.054	0.999	1.020	1.000	1.028	1.027
2003	1.126	1.000	1.047	1.063	1.000	1.013	1.000	1.013	1.013
2004	1.133	1.000	1.058	1.065	1.000	1.005	1.000	1.005	1.005
2005	1.158	1.000	1.069	1.082	1.000	1.001	1.000	1.001	1.001
2006	1.123	1.000	1.023	1.050	1.000	1.046	1.000	1.046	1.046
2007	1.185	1.000	1.056	1.042	1.000	1.077	1.000	1.077	1.077
2008	1.136	1.000	1.030	1.050	1.000	1.050	1.000	1.050	1.051
2009	1.139	1.000	1.033	1.065	1.000	1.035	1.000	1.035	1.035
2010	1.082	0.985	0.993	1.108	0.999	1.000	0.985	0.984	0.984
2011	1.048	0.989	0.988	1.076	0.997	1.000	0.973	0.985	0.984
2012	1.063	1.002	1.007	1.063	0.991	1.000	0.975	0.993	0.991
2013	1.061	1.021	0.993	1.058	0.990	1.000	0.996	1.011	1.009

2014	1.019	1.004	0.981	1.040	0.994	1.000	1.000	0.999	0.998
2015	1.058	1.000	1.006	1.024	1.000	1.026	1.000	1.026	1.026
2016	1.026	1.000	0.977	1.037	1.000	1.012	1.000	1.012	1.012
2017	1.109	1.000	1.003	1.030	1.000	1.074	1.000	1.074	1.074
2018	1.057	1.000	1.012	1.041	1.000	1.004	1.000	1.004	1.004
2019	0.979	0.973	0.978	1.031	0.998	1.000	0.973	0.971	0.970
2020	0.990	0.979	0.983	1.032	0.996	1.000	0.953	0.976	0.975
Mean	1.077	0.999	1.009	1.053	0.999	1.016	0.982	1.014	1.014

Our nonparametric estimate of average net output TFP growth rates is 1.37% per year whereas our index number estimate of average net output TFP growth rates was 1.36%. Table 9 shows that there is very little difference between the two sets of estimates. On average, real net output and income grew at 7.69% per year. Nonparametric real net output price inflation averaged 0.93% per year whereas the real gross output price inflation averaged –0.07% per year. The big difference is due to the replacement of gross investment by net investment (including real capital gains and losses on assets held over the accounting period). Our measure of efficiency using net income, e^t, was below 1 for the years 1971–1981, 1986, 1989–1991, 1998, 2005, 2010–2012, and 2019–2020. Aggregate input growth averaged 5.25% per year which is remarkable. The input mix growth factor, γ^{t*}, was on average equal to 0.9989 which indicates a small negative contribution to GDP growth over the sample period. The average rate of net output technical progress τ^{t*} was 1.56% per year which is quite good.

We again follow the example of Kohli (1990) and obtain a levels decomposition for the observed level of real NDP in year t, $p^t \cdot y^t$, relative to its observed value in year 1 of our sample, $p^1 \cdot y^1$. The cumulated explanatory variables are again defined by equations (47) and (48) and as in the previous section, we obtain the following *levels decomposition* for the level of period t observed real NDP or real net income RI^{t*} to its level in 1970:

$$(60)\ RI^{t*}/RI^{1970*} \equiv p^t \cdot y^t / p^{1970} \cdot y^{1970} = A^{t*}\, B^{t*}\, C^{t*}\, E^{t*}\, T^{t*}\ ; \qquad t = 1970, \ldots, 2020.$$

The year t level of Nonparametric Net Output TFP, $NTFP^{t*}$, is defined as follows:

$$(61)\ NTFP^{t*} = [p^t \cdot y^t / p^1 \cdot y^1]/[A^{t*}\, B^{t*}] = C^{t\,*} E^{t*}\, T^{t*}\ ; \qquad t = 1970, \ldots, 2020.$$

The components of the decomposition of real NDP relative to its 1970 level into explanatory factors which is given by equation (60) are listed in Table B10 in Appendix B along with our nonparametric estimates of TFP relative to 1970, $NTFP^{t*}$.

Recall that RI^{t*}/RI^{1970*} is real NDP in year t relative to 1970 real NDP. From Table B10, Chinese real NDP grew 38.6 fold over the 50 year sample period. Real output prices grew 1.557 fold over the sample period, an aggregate of labour and capital waiting services grew 12.851 fold, the final input mix overall growth factor was 0.945 which means the input mix factor subtracted from GDP growth, the overall efficiency growth factor was 0.953 and the technical progress growth factor in 2020 was 2.145. Net output TFP ended up at 1.931, which is lower than the corresponding level of technical progress due to the fact that C^{2020*} and E^{2020*} were less than one; see equation (61) for t = 2020. The explanatory variables that appear on the right hand side of equation (61) are plotted on Figure 5. It can be seen that Figure 5 is similar to Figure 3: Gross output TFP is close to net output TFP and their decompositions into explanatory factors is much the same.

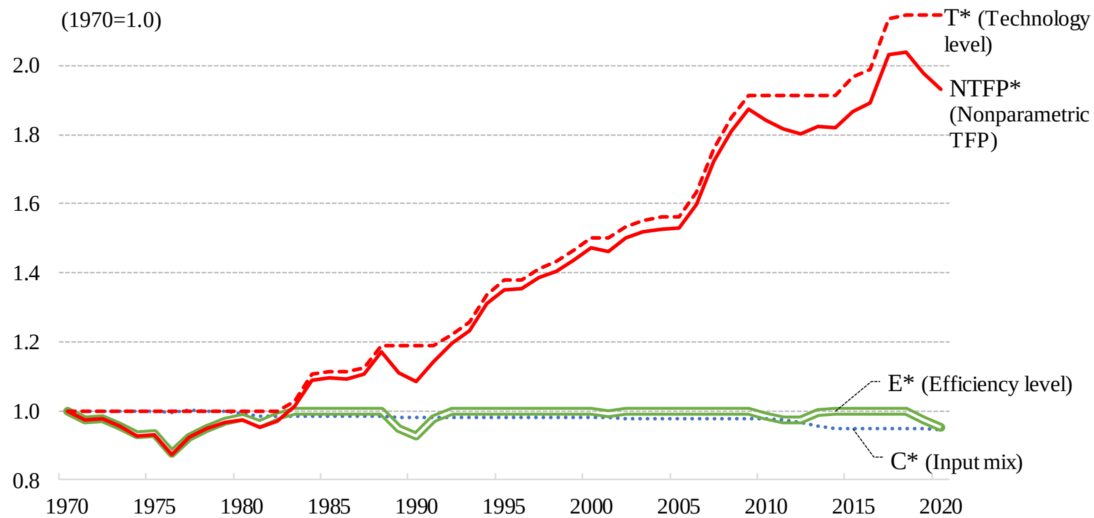

Figure 5. Decomposition of Chinese Net Output Nonparametric TFP into Explanatory Factors

7. CONCLUSION

Over the past 50 years, depreciation of machinery and equipment has grown in importance and at the same time, capital gains on land used in production have also grown in importance. Thus the Gross Domestic Product measure of a nation's output is no longer a reliable measure of the income generated by the nation's domestic production sector. The accounting framework suggested by Hicks (1961) and Edwards and Bell (1961) provides a better framework for measuring income. We implemented this income measurement framework for China and found substantial differences between our measures of income and GDP. It would be useful if national statistical offices provided similar income measures as supplements to their usual GDP estimates.

The APDB on the price and volume of land used in production indicates that land is an input that is growing in importance.[49] A big problem with existing estimates of TFP and many macroeconomic models is that they ignore land. Some possible reasons for this omission are:

- The current SNA does not assign much of a role to changes in land use in the flow accounts and as a result, most countries do not collect or publish data on the price and quantity of land broken down by different categories of land use.
- It is difficult to decompose market prices for properties into their land and structure components.[50] This hinders the production of land price and quantity indexes.
- Transactions in commercial and industrial land are sparse, making the construction of indexes difficult.
- The aggregate land stock is constant and hence it is thought that land does not play much of a role as a contributor to economic growth. But once land is subdivided into different categories of land use, we see that land usage changes significantly over time. In general, agricultural land is converted into other land uses.

[49] From Table 1, we see that the average share of land in the total value of the Chinese capital stock was 23%. But several countries have higher land shares; see APO (2023, p. 118) for 2021 land shares for 25 Asian countries.
[50] Methods are available to decompose property prices into structure and land components; see Eurostat (2013, 2017), Diewert, de Haan, and Hendriks (2015) and Diewert and Shimizu (2015, 2017, 2019, 2022). However, these decomposition methods involve nonlinear hedonic regressions and hence are difficult to implement at scale.

The work of the APO and Keio University (led by Koji Nomura) has led to the development of a useful data base on national stocks of 4 types of land for 25 Asian countries. We utilized this data base for China to develop alternative measures of TFP Growth. Our work indicates that land is an important factor of production and neglecting land inputs into production can lead to substantial measurement differences. We also argued that changes in land use by type of land should be recorded as part of investment. This would put land stocks on the same footing as inventory stocks. Changes in inventory stocks are routinely regarded as current output. We argue that changes in land stocks should also be recorded as part of current output and we implemented this approach using our data for China.

Over the past 20 years, business land prices have increased substantially. It seems likely that this fact can help to explain the *productivity slowdown* that has affected most advanced countries. High land prices imply high capital output ratios. Using our data in Tables A6 and B1, we can calculate the Chinese capital output ratios (in value terms) for 2000, 2010, and 2020. These ratios are 2.84, 3.18, and 4.81 respectively. Thus in 2020, an investment of 4.81 yuan in land and reproducible capital would generate on average an output of 1 yuan. In 2000, it took only 2.84 yuan to generate an output of 1 yuan. Thus even in China, the high price of land is crowding out productive investments in reproducible capital. This *crowding out effect* is much worse in other advanced countries.

There is another important reason why National Statistical Offices should supply information on the price and quantity of land by type of land. The growth in the value of land relative to other assets has led taxation experts to take a new look at land taxes.[51] The case for taxing land rents (over other forms of taxation) dates back to Henry George and his single tax theory:

> "Taxes levied upon the value of land cannot check production in the slightest degree, until they exceed rent, or the value of land taken annually, for unlike taxes upon commodities, or exchange, or capital, or any of the tools or processes of production, they do not bear upon production. The value of land does not express the reward of production, as does the value of crops, of cattle, of buildings, or any of the things which are styled personal property and improvements. It expresses the exchange value of monopoly. It is not in any case the creation of the individual who owns the land; it is created by the growth of the community. Hence the community can take it all without in any way lessening the incentive to improvement or in the slightest degree lessening the production of wealth. Taxes may be imposed upon the value of land until all rent is taken by the State, without reducing the wages of labor or the reward of capital one iota; without increasing the price of a single commodity, or making production in any way more difficult.
> …
> It is sufficiently evident that with regard to production, the tax upon the value of land is the best tax that can be imposed. Tax manufactures, and the effect is to check manufacturing; tax improvements, and the effect is to lessen improvement; tax commerce, and the effect is to prevent exchange; tax capital, and the effect is to drive it away. But the whole value of land may be taken in taxation, and the only effect will be to stimulate industry, to open new opportunities to capital, and to increase the production of wealth."
> Henry George (1935, pp. 413–414)

Until recent times, land values in most countries were not high enough to yield enough tax revenue to fund a large portion of government expenditures. This is no longer the case for many countries.

Here are some important measurement problems which require more research:

- How exactly should expected asset inflation rates be estimated?
- What is the "right" cost of capital to use in user costs and in waiting costs?

[51] See the recent (excellent) paper by Kumhof, Tideman, Hudson, and Goodhart (2021) who make a strong case for increasing taxes on land.

- Why does the current SNA not impute a rate of return for the user cost of capital applied to government assets? Only depreciation is regarded as a cost of using a government asset and so there is no opportunity cost assigned to the use of land in the government sector in the SNA.
- How fine should we make the land classification? There is forest land, park land, and land that is tied up in roads. Commercial land includes a wide variety of different uses of land. And of course, land should be disaggregated by geographical location.
- How do we deal with negative user costs?
- What about including other missing assets such as forest land, natural resource stocks,[52] environmental stocks, and business holdings of money?

The above research questions also indicate that our efforts to better measure the income generated by the production sector of a country (and the associated measures of TFP) suffer from some weaknesses. However, many of the above weaknesses also apply to the measures of capital services that are used by all countries that provide TFP measures to the public. Hopefully, in the future, at least some of the above weaknesses will be addressed and the economic measurement of production and income will gradually improve over time.

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[52] See Brandt, Schreyer, and Zipperer (2017) and Freeman, Inklaar, and Diewert (2021) on the importance of resources stocks in measuring wealth and productivity. The World Bank (2021) has estimates of natural resource stocks by country that cover the years 1970–2018. However, there are some methodological problems with their estimates, so we did not use this data base. Diewert and Fox (2016) outlined how user cost theory could be applied to resource stocks. The latest APO (2023) publication does include estimates of some resource stocks in the asset data base.

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APPENDIX A: DATA ON OUTPUTS AND INPUTS FOR CHINA

In this paper, we used the APDB developed by APO and Keio University dated December 22, 2022.[53] This database has current yuan and constant yuan estimates for the main economic aggregates for the People's Republic of China as well as detailed investment data for 12 types of capital for the years 1970–2020. The implicit price indexes were formed by dividing the current yuan series by the corresponding constant yuan series. The database has current and constant yuan estimates for the 12 corresponding beginning of the year capital stocks as well as current and constant yuan estimates for 4 types of land. The APDB also has detailed information on hourly wage rates and annual hours worked for many types of labour classified by age, sex, education, and type of worker (employee or self-employed). We will not make use of the detailed labour information: we simply used the resulting aggregate quality-adjusted price and quantity of labour for year t, P_L^t and Q_L^t, which are listed in the APDB.

The price indexes for the output aggregates for year t are defined as P_C^t (private consumption), P_G^t (government consumption), P_I^t (gross investment), P_X^t (exports of goods and services), and P_M^t (imports of goods and services). The corresponding quantity or volume indexes are defined as Q_C^t, Q_G^t, Q_I^t, Q_X^t and Q_M^t. The 12 components of the investment series are as follows: (1) IT hardware; (2) Communications equipment; (3) Transport equipment; (4) Other machinery and equipment; (5) Dwelling structures; (6) Non-residential buildings; (7) Other structures; (8) Cultivated assets; (9) Research and development; (10) Computer software; (11) Other intangible assets, and (12) Net increase in inventory stocks.[54] Denote the year t price index for investment good n by P_{In}^t and the corresponding quantity or volume index by Q_{In}^t for n = 1, …, 12 and t = 1970, …, 2020.

The corresponding beginning of the year t capital stocks for the above 12 investment assets are also available in the APDB. Denote the asset n and year t stock price index by P_{Kn}^t and the corresponding quantity index by Q_{Kn}^t for n = 1, …, 12 and t =1970, 1971, …, 2021. The APDB also has current and constant yuan series for four types of land used by the Chinese production sector: (13) Agricultural land, (14) Industrial land, (15) Commercial land and (16) Residential land. Denote the beginning of the year t price index for these land assets by P_{Kn}^t and the corresponding quantity index by Q_{Kn}^t for n = 13, …, 16 and t = 1970, …, 2020.[55]

Assets 12–16 are non-depreciable assets so we set the period t depreciation rate for these assets, δ_n^t, equal to 0 for n = 12, …,16 and t = 1970, …,2020. Since the APDB uses the geometric model for depreciation for assets 1–11, the depreciation rates should satisfy the following equation:

$$\text{(A1)}\quad Q_{Kn}^{t+1} = (1-\delta_n^t)Q_{Kn}^t + Q_{In}^t\,; \qquad n = 1, \ldots, 11;\ t = 1970, \ldots, 2020.$$

[53] The methodology for constructing the productivity accounts for Asian countries is explained in APO (2022, pp. 165–188). The APDB includes estimates adjusted for official national accounts. In particular imputed rents (including land) for free housing and owner-occupied housing, which are not included in Chinese official national accounts, are estimated in the APDB and added to the official estimates of the household consumption and GDP. It was about 15% of the official nominal GDP in the late 1970s and has tended to diminish to about 4% in recent years. These adjustments have the effect of revising the official GDP growth rate downward. The Chinese national accounts and balance sheet data are far from being completely comprehensive and accurate, so our estimates are provisional.

[54] The APDB estimates inventory stocks by assuming a time-variant disposal rates to suppress the size of inventory stocks estimated from the net increase in inventory in Chinese official national accounts to a realistic level. We differenced the APDB real inventory stocks to obtain our estimates of inventory change. We set the price of inventory change equal to the end of year price of inventory stock. These conventions allowed us to apply user cost theory to the stock of inventories.

[55] The APDB land price estimates for China are primarily based on the cost of long-term leases for the land uses (e.g., 70 years for residential use, 50 years for industrial use, and 40 years for commercial use) in *China Land and Resource Statistical Yearbook* (Ministry of Natural Resources of People's Republic of China). The land prices for agricultural use are approximated by the discounted present value of the capital incomes, which are estimated based on Mixed Income, in the agricultural sector. Intra-regional and inter-regional price differences are significant in China. Total land values are adjusted based on comparisons with countries with better data quality, such as Japan. Improvements to China's land data in the latest APDB were made after the publication of APO (2022), and we thank to Sho Inaba (Keio Economic Observatory, Keio University) for his patient assistance.

Since we can obtain estimates for the Q_{Kn}^t and Q_{In}^t for the years t and assets n listed at the end of equation (A1), we can solve equation (A1) for the depreciation rates δ_n^t for the years 1970–2020 for assets 1–11. The resulting estimates for the depreciation rates were quite reasonable and are fairly smooth except that the depreciation rates for asset 1 showed unusual volatility for 4 observations so we smoothed the rates δ_1^t using the Lowess nonparametric smoothing method in Shazam.[56] Equation (A1) enabled us to determine depreciation rates for assets 1–11 for the years 1970–2020. The depreciation rates for inventory stocks, δ_{12}^t, were assumed to be equal to 0 as indicated earlier. The nonzero depreciation rates are listed in Table A3.

Land prices turn out to be very volatile. Rather than use short run fluctuations in land prices to value the opportunity costs of holding land, we chose to smooth the land prices to capture longer run trends in the value of land assets used in production. Again, we used the Lowess nonparametric smoothing method to smooth the land prices P_{K13}^t, P_{K14}^t, P_{K15}^t, and P_{K16}^t using the Smooth parameter set equal to 0.25.[57] The smoothed land price indexes are listed in Table A1 along with the APDB beginning of the year prices for assets 1–12.

Table A1: Beginning of Year Capital Stock Price Indexes

Year	P_{K1}^t	P_{K2}^t	P_{K3}^t	P_{K4}^t	P_{K5}^t	P_{K6}^t	P_{K7}^t	P_{K8}^t
1970	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1971	0.960	0.943	0.993	0.996	1.012	1.009	1.043	0.923
1972	0.873	0.895	0.990	0.972	1.022	0.997	1.043	0.895
1973	0.752	0.820	0.965	0.994	1.073	1.011	1.053	0.954
1974	0.756	0.730	0.891	1.024	1.058	1.034	1.114	0.863
1975	0.698	0.707	0.956	0.981	1.060	1.055	1.159	0.974
1976	0.762	0.688	0.960	0.978	1.076	1.062	1.167	1.026
1977	0.753	0.660	0.933	0.977	1.089	1.069	1.181	1.091
1978	0.662	0.634	0.937	0.988	1.098	1.082	1.224	1.043
1979	0.586	0.632	0.936	1.006	1.130	1.099	1.239	1.086
1980	0.452	0.595	0.891	1.015	1.207	1.169	1.333	1.018
1981	0.382	0.578	0.897	1.020	1.224	1.207	1.391	0.979
1982	0.338	0.562	0.902	1.026	1.261	1.239	1.436	0.999
1983	0.296	0.532	0.870	1.009	1.326	1.299	1.506	0.934
1984	0.277	0.527	0.877	1.025	1.405	1.378	1.595	0.943
1985	0.276	0.532	0.902	1.063	1.523	1.490	1.715	1.050
1986	0.272	0.532	0.942	1.111	1.667	1.619	1.867	1.074
1987	0.251	0.520	0.945	1.132	1.801	1.721	1.989	1.071
1988	0.247	0.548	1.034	1.252	2.037	1.943	2.246	1.178
1989	0.259	0.579	1.092	1.362	2.189	2.077	2.394	1.326
1990	0.275	0.618	1.172	1.496	2.339	2.222	2.561	1.437
1991	0.279	0.638	1.226	1.607	2.565	2.439	2.810	1.351
1992	0.293	0.694	1.359	1.774	3.008	2.846	3.278	1.422
1993	0.306	0.810	1.594	2.089	4.001	3.715	4.282	1.496
1994	0.318	0.860	1.694	2.250	4.439	4.077	4.718	1.589

[56] The smoothing parameter was chosen to be 0.15. Equation (A1) for n=1 was used recursively to generate new estimates for the Q_{K1}^t; i.e., we assumed that the APDB beginning of 1970 capital stock Q_{K1}^{1970} was the "correct" estimate along with the investments in asset 1 (the Q_{I1}^t were also assumed to be correct) and the new smoothed depreciation rates δ_1^t were also correct.

[57] The lower is the Smooth number, the less severe is the smoothing. Thus, we did a fair amount of smoothing of the land prices at this stage of the data construction process.

1995	0.302	0.891	1.779	2.370	4.631	4.288	4.948	1.725
1996	0.267	0.839	1.801	2.384	4.866	4.504	5.193	1.858
1997	0.245	0.783	1.788	2.362	5.025	4.619	5.341	1.803
1998	0.236	0.740	1.767	2.336	5.020	4.606	5.381	1.611
1999	0.225	0.677	1.721	2.277	5.040	4.601	5.384	1.531
2000	0.211	0.635	1.674	2.239	5.111	4.541	5.521	1.575
2001	0.180	0.604	1.679	2.231	5.208	4.596	5.597	1.724
2002	0.162	0.564	1.672	2.197	5.416	4.655	5.645	1.523
2003	0.138	0.522	1.650	2.166	5.725	4.781	5.889	1.687
2004	0.122	0.504	1.672	2.186	6.263	5.120	6.384	1.872
2005	0.109	0.489	1.695	2.213	6.792	5.409	6.531	1.997
2006	0.103	0.475	1.725	2.260	7.227	5.626	6.628	2.086
2007	0.099	0.452	1.739	2.277	7.820	5.953	6.963	2.032
2008	0.090	0.438	1.769	2.319	8.375	6.226	7.947	1.830
2009	0.078	0.413	1.773	2.292	8.086	5.997	7.644	1.837
2010	0.074	0.389	1.810	2.314	8.454	6.294	8.042	2.069
2011	0.071	0.367	1.857	2.369	9.137	6.987	8.756	2.201
2012	0.067	0.340	1.855	2.373	9.244	7.103	8.930	2.145
2013	0.066	0.336	1.867	2.345	9.305	7.122	8.928	2.364
2014	0.066	0.338	1.863	2.331	9.397	7.127	8.984	2.508
2015	0.068	0.340	1.847	2.302	9.145	6.924	8.749	2.773
2016	0.064	0.331	1.830	2.294	9.096	6.885	8.689	3.381
2017	0.065	0.330	1.839	2.309	9.837	7.424	9.385	3.528
2018	0.065	0.323	1.854	2.341	10.542	7.952	10.071	3.630
2019	0.064	0.320	1.857	2.353	10.798	8.182	10.378	3.604
2020	0.063	0.315	1.857	2.342	10.840	8.127	10.350	3.238
2021	0.063	0.315	1.859	2.372	11.739	8.801	11.208	3.264

Year	P_{K9}^{t}	P_{K10}^{t}	P_{K11}^{t}	P_{K12}^{t}	P_{K13}^{t}	P_{K14}^{t}	P_{K15}^{t}	P_{K16}^{t}
1970	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1971	1.065	0.949	1.078	1.033	1.051	1.117	1.117	1.051
1972	1.134	0.899	1.153	1.030	1.089	1.234	1.234	1.089
1973	1.215	0.838	1.219	1.103	1.128	1.361	1.361	1.128
1974	1.247	0.682	1.249	1.015	1.165	1.499	1.499	1.165
1975	1.329	0.655	1.355	1.131	1.199	1.636	1.636	1.199
1976	1.437	0.645	1.513	1.237	1.211	1.818	1.818	1.211
1977	1.508	0.625	1.613	1.421	1.205	2.067	2.067	1.205
1978	1.593	0.606	1.710	1.192	1.229	2.399	2.399	1.229
1979	1.659	0.619	1.744	1.073	1.308	2.794	2.794	1.308
1980	1.686	0.592	1.760	1.109	1.436	3.223	3.223	1.436
1981	1.742	0.598	1.862	1.218	1.598	3.700	3.700	1.598
1982	1.781	0.609	1.890	1.193	1.755	4.327	4.327	1.755
1983	1.724	0.588	1.864	0.945	1.920	5.205	5.205	1.920
1984	1.770	0.591	1.908	0.961	2.103	6.343	6.343	2.103
1985	1.881	0.606	1.978	1.060	2.282	7.695	7.695	2.282
1986	2.021	0.627	2.095	1.158	2.476	9.365	9.365	2.476
1987	2.078	0.644	2.164	1.244	2.722	11.366	11.366	2.722

1988	2.334	0.712	2.404	1.338	3.035	13.716	13.716	3.035
1989	2.567	0.740	2.722	1.497	3.421	16.454	16.454	3.421
1990	2.889	0.773	2.966	1.638	3.818	19.390	19.866	3.846
1991	3.145	0.816	3.171	1.746	4.283	26.135	23.907	4.234
1992	3.474	0.848	3.551	1.901	4.775	33.096	30.417	4.665
1993	4.280	1.006	4.302	2.143	5.588	42.551	41.183	5.170
1994	4.596	1.080	4.676	2.610	6.749	53.330	52.239	5.682
1995	4.887	1.153	4.962	2.928	8.182	63.618	52.993	8.182
1996	4.960	1.151	5.021	3.158	9.683	70.662	56.974	9.987
1997	4.964	1.109	4.979	3.289	11.021	72.627	59.570	12.371
1998	4.910	1.082	4.965	3.345	12.019	71.428	62.597	14.891
1999	4.856	1.054	4.914	3.311	12.697	71.313	68.066	17.293
2000	4.849	1.029	4.878	3.303	13.262	75.232	76.867	19.670
2001	4.873	1.013	4.924	3.423	13.920	85.204	87.975	21.942
2002	4.862	0.986	4.935	3.459	14.898	101.877	99.746	23.916
2003	4.897	0.948	4.940	3.530	16.417	122.229	112.497	25.995
2004	5.026	0.945	5.052	3.666	18.355	143.835	126.492	29.051
2005	5.118	0.937	5.123	3.940	20.699	177.167	144.500	33.579
2006	5.276	0.941	5.211	4.043	23.745	230.999	166.580	38.672
2007	5.330	0.932	5.249	4.135	27.390	292.255	193.858	44.974
2008	5.477	0.932	5.316	4.480	31.305	348.397	233.428	54.741
2009	5.225	0.897	5.289	4.924	35.892	396.683	280.616	66.052
2010	5.407	0.892	5.397	4.860	41.452	427.686	326.207	76.909
2011	5.641	0.900	5.629	5.122	47.706	440.303	370.643	88.478
2012	5.633	0.876	5.605	5.558	54.353	453.485	412.897	100.818
2013	5.540	0.842	5.510	5.731	61.156	475.436	447.990	113.789
2014	5.519	0.815	5.478	5.818	67.568	500.438	487.797	132.294
2015	5.398	0.783	5.374	5.811	73.287	524.914	545.552	157.344
2016	5.381	0.778	5.415	5.658	78.618	543.252	623.402	183.025
2017	5.474	0.772	5.463	5.654	84.235	553.993	718.681	205.320
2018	5.624	0.769	5.558	5.976	90.853	569.713	828.066	222.615
2019	5.647	0.759	5.575	6.395	99.055	603.293	945.293	231.670
2020	5.599	0.770	5.613	6.714	107.368	637.173	1062.647	239.653
2021	5.644	0.776	5.658	6.782	115.891	673.805	1179.841	246.717

It can be seen that land prices increased very rapidly during the past three decades. The price of commercial land increased 1180 fold over the five decades. At the other extreme, the prices of IT hardware and Communications equipment, assets 1 and 2, fell dramatically over the sample period. The corresponding constant yuan beginning of the year capital stocks, $Q_{Kn}{}^t$ are listed in Table A2. The units of measurement are in 10 billions of 1970 yuan. Values for these capital stocks (in units of 10 billion current year yuan) can be obtained as $V_{Kn}{}^t=P_{Kn}{}^tQ_{Kn}{}^t$.

Table A2: Beginning of Year Capital Stocks in Constant 10 Billions 1970 Yuan

Year	$Q_{K1}{}^t$	$Q_{K2}{}^t$	$Q_{K3}{}^t$	$Q_{K4}{}^t$	$Q_{K5}{}^t$	$Q_{K6}{}^t$	$Q_{K7}{}^t$	$Q_{K8}{}^t$
1970	0.014	0.034	1.023	8.093	16.057	2.211	2.573	0.606
1971	0.015	0.037	1.188	9.393	17.311	2.462	2.865	0.649
1972	0.017	0.042	1.346	10.539	18.762	2.840	3.265	0.712
1973	0.019	0.048	1.487	11.521	20.155	3.340	3.777	0.766
1974	0.025	0.057	1.668	12.555	21.415	3.860	4.322	0.809
1975	0.030	0.071	1.890	13.467	22.845	4.599	5.046	0.868

Year	Q_{K9}^t	Q_{K10}^t	Q_{K11}^t	Q_{K12}^t	Q_{K13}^t	Q_{K14}^t	Q_{K15}^t	Q_{K16}^t
1976	0.041	0.091	2.153	14.834	24.580	5.433	5.854	0.925
1977	0.046	0.106	2.329	15.620	25.850	6.306	6.703	0.940
1978	0.052	0.123	2.506	16.290	27.450	7.412	7.776	0.954
1979	0.068	0.152	2.786	17.352	29.545	8.407	8.764	1.014
1980	0.081	0.170	2.952	17.760	31.923	9.726	10.042	1.055
1981	0.102	0.187	3.090	17.855	34.249	11.500	11.699	1.104
1982	0.117	0.194	3.074	17.379	36.362	13.545	13.592	1.131
1983	0.161	0.228	3.207	17.540	38.355	15.800	15.701	1.211
1984	0.212	0.280	3.479	18.057	40.651	17.962	17.795	1.329
1985	0.356	0.406	4.071	19.547	43.027	20.596	20.319	1.521
1986	0.756	0.627	5.584	21.973	45.987	23.480	23.123	1.801
1987	0.932	0.804	6.912	25.078	48.901	26.366	25.986	2.141
1988	1.271	1.117	8.335	29.443	52.208	29.259	28.937	2.549
1989	1.698	1.421	9.858	34.155	56.006	32.548	32.260	3.010
1990	1.785	1.485	10.429	36.265	59.477	35.075	35.077	3.175
1991	1.956	1.530	10.900	37.704	62.300	37.385	37.786	3.397
1992	2.238	1.670	11.779	39.964	65.318	40.000	40.750	3.808
1993	2.505	2.163	13.586	44.919	68.758	44.446	45.258	4.287
1994	3.459	3.184	19.217	51.316	73.028	49.920	50.653	5.120
1995	4.616	4.797	25.264	58.818	78.575	55.939	56.571	6.124
1996	5.578	7.028	28.745	66.723	85.857	63.251	63.699	7.105
1997	7.479	9.248	32.063	75.257	92.979	71.199	71.458	8.036
1998	9.330	13.150	35.918	86.179	100.426	79.347	79.635	9.389
1999	9.341	14.694	37.211	102.542	108.862	87.748	87.983	10.289
2000	11.586	18.511	39.744	118.436	118.848	96.387	96.826	11.599
2001	17.253	28.939	43.366	134.605	129.601	106.382	106.532	12.973
2002	29.179	44.247	50.202	150.537	141.041	117.510	117.281	14.457
2003	72.759	60.081	60.287	168.815	152.934	130.054	129.411	16.717
2004	145.555	76.509	74.599	196.070	164.806	146.055	144.094	18.399
2005	223.837	92.543	92.612	231.405	178.024	164.825	161.030	19.633
2006	321.614	108.331	116.008	277.820	189.338	184.194	179.502	20.621
2007	405.534	123.979	143.966	333.035	201.380	204.485	199.732	21.480
2008	460.422	140.703	179.233	402.565	215.743	227.072	222.427	22.537
2009	537.017	158.530	223.991	482.207	230.821	252.667	245.248	27.442
2010	598.098	181.057	285.098	584.554	249.800	290.256	277.541	35.342
2011	694.453	206.686	361.276	703.555	270.536	330.781	312.677	43.773
2012	774.493	234.419	431.456	802.747	299.905	377.286	353.949	49.226
2013	893.105	268.346	521.386	918.530	326.858	425.753	397.603	53.673
2014	1000.702	299.140	598.573	1023.987	356.582	484.179	449.720	55.378
2015	1065.743	320.968	662.844	1114.794	385.934	551.064	509.007	55.446
2016	1088.365	333.830	711.185	1185.650	413.318	625.671	575.294	53.870
2017	1165.972	354.428	771.436	1273.514	439.466	701.901	644.580	50.385
2018	1254.034	380.162	842.853	1378.613	465.259	779.995	716.939	46.323
2019	1317.218	403.971	919.234	1491.123	492.860	862.810	794.334	43.170
2020	1351.066	418.199	987.157	1592.308	522.301	948.961	875.870	40.610
2021	1335.264	419.173	1038.576	1672.832	552.239	1036.069	959.698	38.787

1970	0.570	0.008	0.010	4.817	2.552	1.473	1.339	16.733
1971	0.655	0.009	0.012	5.670	2.585	1.477	1.341	16.746
1972	0.736	0.010	0.013	6.153	2.618	1.480	1.343	16.760
1973	0.801	0.012	0.013	6.625	2.652	1.485	1.346	16.787
1974	0.857	0.014	0.013	7.069	2.692	1.491	1.349	16.815
1975	0.924	0.019	0.013	7.122	2.740	1.497	1.353	16.844
1976	1.006	0.023	0.013	6.850	2.774	1.503	1.358	16.872
1977	1.055	0.028	0.012	6.671	2.816	1.509	1.363	16.899
1978	1.101	0.035	0.011	7.389	2.859	1.516	1.369	16.925
1979	1.159	0.043	0.012	8.472	2.902	1.523	1.376	16.951
1980	1.238	0.053	0.012	9.864	2.935	1.529	1.383	16.976
1981	1.316	0.068	0.011	10.761	2.968	1.536	1.391	17.002
1982	1.367	0.085	0.010	11.160	3.006	1.543	1.399	17.027
1983	1.422	0.104	0.010	11.243	3.076	1.550	1.407	17.053
1984	1.532	0.129	0.011	11.933	3.151	1.558	1.416	17.079
1985	1.681	0.167	0.012	14.484	3.235	1.566	1.426	17.105
1986	1.824	0.222	0.015	17.585	3.320	1.575	1.435	17.132
1987	1.956	0.304	0.018	19.955	3.364	1.584	1.443	17.158
1988	2.070	0.408	0.023	20.971	3.403	1.592	1.450	17.184
1989	2.152	0.541	0.027	24.381	3.443	1.600	1.457	17.210
1990	2.221	0.698	0.028	28.314	3.487	1.609	1.462	17.235
1991	2.266	0.901	0.028	31.020	3.532	1.618	1.468	17.259
1992	2.327	1.130	0.029	36.829	3.573	1.629	1.474	17.282
1993	2.408	1.369	0.032	41.257	3.595	1.640	1.480	17.304
1994	2.471	1.590	0.038	44.035	3.623	1.652	1.487	17.326
1995	2.568	2.002	0.046	47.611	3.656	1.664	1.495	17.347
1996	2.678	2.477	0.053	53.461	3.656	1.674	1.503	17.368
1997	2.837	3.046	0.060	59.463	3.656	1.684	1.511	17.388
1998	3.104	3.698	0.067	63.253	3.656	1.692	1.520	17.408
1999	3.397	4.431	0.076	65.838	3.656	1.700	1.528	17.427
2000	3.820	5.133	0.085	69.394	3.623	1.707	1.537	17.445
2001	4.462	5.934	0.094	74.202	3.589	1.714	1.545	17.462
2002	5.210	6.914	0.106	79.496	3.560	1.721	1.554	17.479
2003	6.188	8.623	0.121	84.054	3.516	1.748	1.580	17.686
2004	7.362	10.544	0.166	91.473	3.472	1.775	1.605	17.876
2005	8.889	12.995	0.255	98.387	3.464	1.801	1.630	18.051
2006	10.787	16.102	0.427	103.591	3.456	1.830	1.657	18.253
2007	13.032	19.515	0.733	114.491	3.454	1.857	1.683	18.430
2008	15.835	24.134	1.191	132.962	3.453	1.882	1.707	18.584
2009	19.278	33.422	1.669	149.517	3.513	1.987	1.802	19.486
2010	24.054	47.835	2.264	166.436	3.573	2.126	1.929	19.827
2011	29.432	67.358	2.918	190.515	3.629	2.240	2.032	20.044
2012	35.655	96.691	3.357	213.798	3.685	2.320	2.107	20.132
2013	43.027	139.652	4.030	234.820	3.741	2.358	2.153	20.091
2014	51.467	194.634	4.757	258.100	3.762	2.392	2.208	20.237
2015	59.615	261.019	5.473	278.723	3.783	2.418	2.227	20.134
2016	68.304	337.642	6.103	295.293	3.781	2.452	2.268	20.321

2017	77.602	411.377	6.854	313.302	3.778	2.480	2.295	20.500
2018	87.510	487.385	7.538	331.357	3.691	2.623	2.431	21.620
2019	97.790	576.277	7.935	343.897	3.603	2.748	2.548	22.587
2020	109.358	676.716	8.228	356.597	3.603	2.751	2.552	22.594
2021	122.021	765.055	8.432	375.129	3.603	2.753	2.555	22.599

It can be seen that there are very large growth rates in the capital stocks for many of the assets. Table A3 lists the depreciation rates δ_n^t for the produced assets, n = 1, …, 11. Assets 12–16 have 0 depreciation rates.

Table A3: Annual Geometric Depreciation Rates for Produced Assets

Year	δ_1^t	δ_2^t	δ_3^t	δ_4^t	δ_5^t	δ_6^t	δ_7^t	δ_8^t	δ_9^t	δ_{10}^t	δ_{11}^t
1970	0.358	0.295	0.160	0.134	0.037	0.056	0.018	0.182	0.190	0.414	0.334
1971	0.367	0.298	0.158	0.132	0.037	0.056	0.018	0.184	0.187	0.425	0.327
1972	0.375	0.299	0.155	0.130	0.037	0.056	0.018	0.182	0.184	0.433	0.315
1973	0.384	0.309	0.157	0.130	0.037	0.056	0.018	0.180	0.182	0.436	0.312
1974	0.390	0.313	0.158	0.129	0.037	0.056	0.018	0.182	0.183	0.452	0.309
1975	0.388	0.320	0.158	0.131	0.037	0.056	0.018	0.181	0.184	0.442	0.313
1976	0.385	0.316	0.165	0.138	0.047	0.066	0.028	0.188	0.181	0.440	0.303
1977	0.383	0.302	0.153	0.127	0.037	0.056	0.018	0.177	0.180	0.440	0.302
1978	0.383	0.314	0.156	0.128	0.037	0.056	0.018	0.181	0.181	0.443	0.316
1979	0.385	0.297	0.152	0.126	0.037	0.056	0.018	0.179	0.182	0.441	0.312
1980	0.386	0.295	0.151	0.125	0.037	0.056	0.018	0.180	0.182	0.452	0.309
1981	0.390	0.288	0.150	0.125	0.039	0.058	0.020	0.180	0.180	0.444	0.296
1982	0.401	0.305	0.151	0.125	0.037	0.056	0.018	0.182	0.180	0.439	0.312
1983	0.428	0.313	0.154	0.126	0.037	0.056	0.018	0.184	0.183	0.443	0.319
1984	0.450	0.344	0.160	0.129	0.037	0.056	0.018	0.188	0.185	0.454	0.332
1985	0.452	0.358	0.176	0.133	0.038	0.056	0.018	0.192	0.184	0.460	0.351
1986	0.440	0.324	0.168	0.136	0.040	0.059	0.021	0.195	0.183	0.467	0.350
1987	0.411	0.335	0.163	0.135	0.037	0.056	0.018	0.192	0.181	0.463	0.350
1988	0.388	0.321	0.163	0.136	0.039	0.057	0.019	0.193	0.180	0.459	0.341
1989	0.378	0.289	0.154	0.131	0.039	0.058	0.020	0.183	0.179	0.452	0.317
1990	0.370	0.287	0.153	0.129	0.039	0.058	0.020	0.184	0.178	0.453	0.312
1991	0.373	0.300	0.160	0.134	0.043	0.062	0.024	0.193	0.179	0.445	0.318
1992	0.384	0.323	0.160	0.133	0.038	0.057	0.019	0.188	0.179	0.437	0.330
1993	0.393	0.351	0.182	0.137	0.041	0.059	0.021	0.197	0.179	0.427	0.342
1994	0.399	0.357	0.176	0.139	0.042	0.061	0.023	0.198	0.180	0.446	0.344
1995	0.401	0.349	0.161	0.136	0.040	0.059	0.021	0.193	0.180	0.442	0.336
1996	0.394	0.333	0.164	0.140	0.044	0.063	0.025	0.195	0.182	0.441	0.334
1997	0.387	0.342	0.159	0.135	0.039	0.057	0.019	0.192	0.185	0.438	0.331
1998	0.387	0.307	0.160	0.145	0.046	0.064	0.026	0.194	0.185	0.434	0.333
1999	0.399	0.320	0.155	0.136	0.039	0.058	0.020	0.189	0.187	0.427	0.330
2000	0.436	0.360	0.155	0.133	0.037	0.056	0.018	0.186	0.191	0.426	0.330
2001	0.485	0.356	0.160	0.133	0.038	0.056	0.018	0.186	0.191	0.428	0.331
2002	0.509	0.332	0.163	0.133	0.038	0.056	0.018	0.190	0.193	0.444	0.335
2003	0.503	0.322	0.168	0.137	0.039	0.058	0.020	0.187	0.193	0.439	0.370
2004	0.468	0.311	0.166	0.136	0.038	0.056	0.018	0.182	0.195	0.441	0.395
2005	0.425	0.306	0.168	0.138	0.038	0.057	0.019	0.181	0.195	0.442	0.418
2006	0.398	0.302	0.166	0.138	0.038	0.056	0.018	0.180	0.195	0.437	0.424

2007	0.382	0.300	0.166	0.138	0.038	0.056	0.018	0.180	0.195	0.442	0.410
2008	0.374	0.304	0.172	0.142	0.042	0.061	0.023	0.200	0.195	0.471	0.375
2009	0.371	0.301	0.168	0.138	0.037	0.056	0.018	0.201	0.198	0.480	0.368
2010	0.369	0.301	0.168	0.138	0.038	0.056	0.018	0.197	0.196	0.476	0.357
2011	0.369	0.300	0.162	0.133	0.037	0.056	0.018	0.187	0.195	0.481	0.336
2012	0.367	0.301	0.164	0.134	0.037	0.056	0.018	0.184	0.195	0.483	0.344
2013	0.364	0.298	0.160	0.132	0.038	0.056	0.018	0.179	0.194	0.473	0.341
2014	0.359	0.291	0.156	0.130	0.037	0.056	0.018	0.176	0.190	0.463	0.336
2015	0.356	0.286	0.153	0.128	0.037	0.056	0.018	0.173	0.189	0.453	0.330
2016	0.355	0.290	0.155	0.130	0.038	0.056	0.018	0.171	0.188	0.438	0.332
2017	0.355	0.291	0.155	0.130	0.037	0.056	0.018	0.169	0.188	0.432	0.328
2018	0.352	0.290	0.155	0.130	0.037	0.056	0.018	0.170	0.187	0.431	0.321
2019	0.349	0.286	0.153	0.129	0.037	0.056	0.018	0.171	0.187	0.430	0.318
2020	0.345	0.281	0.152	0.127	0.037	0.056	0.018	0.172	0.187	0.421	0.316
Mean	0.394	0.312	0.160	0.133	0.039	0.057	0.019	0.185	0.186	0.446	0.336

In the main text, we worked with a more aggregated model where there are only five types of capital: (i) *Aggregate M&E* (an aggregate of assets 1–4), with year t price, quantity, and value indexes equal to P_{KM}^t, Q_{KM}^t, and $V_{KM}^t \equiv P_{KM}^t Q_{KM}^t$; (ii) *Aggregate Structures* (an aggregate of assets 5–7) with year t price and quantity indexes equal to P_{KS}^t and Q_{KS}^t; (iii) *Aggregate Other Capital* (an aggregate of assets 8–11) with year t price and quantity indexes equal to P_{KO}^t and Q_{KO}^t; (iv) *Inventory Stocks* (equal to asset 12) which we label as P_{KI}^t, Q_{KI}^t, and $V_{KI}^t \equiv P_{KI}^t Q_{KI}^t$, and (v) *Land Assets* (an aggregate of assets 13–16) with price and quantity indexes P_{KL}^t and Q_{KL}^t for t=1970, …, 2021. The aggregation is done using chained Törnqvist price indexes. Table A4 lists these aggregate beginning of the year capital stocks and their corresponding aggregate prices. The units of measurement for the quantity indexes are now in units of trillions of 1970 yuan. The aggregate price of land grew 308.7 fold over the sample period while the price of M&E capital grew only 2.1 fold. The price of structures grew 10.5 fold.

Table A4: Prices and Quantities for Five Beginning of the Year Aggregate Capital Stocks

Year	P_{KM}^t	P_{KS}^t	P_{KO}^t	P_{KI}^t	P_{KL}^t	Q_{KM}^t	Q_{KS}^t	Q_{KO}^t	Q_{KI}^t	Q_{KL}^t
1970	1.000	1.000	1.000	1.000	1.000	0.092	0.208	0.012	0.048	0.221
1971	0.995	1.015	0.994	1.005	1.059	0.106	0.226	0.013	0.057	0.221
1972	0.974	1.022	1.014	1.013	1.107	0.119	0.249	0.015	0.062	0.222
1973	0.990	1.063	1.084	1.014	1.158	0.131	0.273	0.016	0.066	0.223
1974	1.007	1.063	1.055	1.015	1.208	0.143	0.296	0.017	0.071	0.223
1975	0.978	1.074	1.150	1.018	1.255	0.154	0.325	0.018	0.071	0.224
1976	0.975	1.088	1.230	1.015	1.288	0.171	0.359	0.020	0.069	0.225
1977	0.971	1.100	1.297	1.020	1.315	0.181	0.389	0.020	0.067	0.226
1978	0.981	1.116	1.319	1.016	1.378	0.189	0.427	0.021	0.074	0.227
1979	0.995	1.142	1.374	1.037	1.497	0.203	0.468	0.022	0.085	0.228
1980	0.996	1.221	1.356	1.112	1.663	0.209	0.518	0.024	0.099	0.228
1981	1.001	1.250	1.369	1.157	1.865	0.211	0.577	0.025	0.108	0.229
1982	1.006	1.287	1.399	1.192	2.083	0.206	0.638	0.026	0.112	0.230
1983	0.986	1.352	1.340	1.204	2.339	0.209	0.703	0.027	0.112	0.231
1984	1.001	1.433	1.368	1.223	2.643	0.218	0.769	0.030	0.119	0.232
1985	1.036	1.549	1.474	1.266	2.972	0.239	0.846	0.033	0.145	0.234
1986	1.082	1.690	1.557	1.361	3.356	0.279	0.934	0.037	0.176	0.235

1987	1.098	1.811	1.584	1.471	3.827	0.324	1.022	0.042	0.200	0.236
1988	1.210	2.047	1.765	1.571	4.400	0.383	1.115	0.046	0.210	0.237
1989	1.309	2.192	1.955	1.800	5.088	0.447	1.220	0.051	0.244	0.238
1990	1.430	2.343	2.160	1.892	5.860	0.475	1.310	0.054	0.283	0.239
1991	1.527	2.571	2.220	2.016	6.910	0.494	1.389	0.056	0.310	0.240
1992	1.687	3.007	2.400	2.087	8.162	0.526	1.476	0.061	0.368	0.241
1993	1.983	3.958	2.785	2.183	9.946	0.595	1.602	0.065	0.413	0.242
1994	2.129	4.369	2.979	2.445	11.896	0.713	1.755	0.072	0.440	0.243
1995	2.238	4.576	3.194	3.065	14.638	0.849	1.931	0.080	0.476	0.244
1996	2.250	4.805	3.321	3.477	16.871	0.970	2.151	0.089	0.535	0.245
1997	2.225	4.947	3.265	3.631	19.056	1.097	2.381	0.099	0.595	0.245
1998	2.196	4.953	3.083	3.618	21.092	1.260	2.621	0.113	0.633	0.246
1999	2.136	4.960	2.992	3.459	23.220	1.450	2.875	0.125	0.658	0.247
2000	2.092	5.010	3.018	3.383	25.797	1.654	3.153	0.141	0.694	0.247
2001	2.080	5.087	3.140	3.441	28.877	1.892	3.460	0.161	0.742	0.248
2002	2.046	5.198	2.966	3.447	32.300	2.172	3.796	0.184	0.795	0.248
2003	2.006	5.426	3.089	3.443	36.195	2.526	4.164	0.218	0.841	0.251
2004	2.014	5.884	3.264	3.569	41.005	3.028	4.589	0.252	0.915	0.254
2005	2.026	6.211	3.377	3.910	47.981	3.647	5.076	0.291	0.984	0.257
2006	2.056	6.463	3.486	4.071	57.152	4.440	5.561	0.337	1.036	0.260
2007	2.062	6.880	3.468	4.212	68.108	5.360	6.079	0.390	1.145	0.263
2008	2.086	7.480	3.414	4.476	81.953	6.490	6.669	0.459	1.330	0.266
2009	2.056	7.207	3.312	4.805	96.898	7.827	7.293	0.574	1.495	0.279
2010	2.074	7.561	3.483	4.564	110.283	9.565	8.161	0.741	1.664	0.291
2011	2.116	8.260	3.633	4.911	122.748	11.642	9.105	0.934	1.905	0.300
2012	2.110	8.394	3.586	5.230	135.597	13.444	10.261	1.143	2.138	0.306
2013	2.096	8.418	3.612	5.202	149.002	15.631	11.432	1.398	2.348	0.309
2014	2.087	8.465	3.627	5.163	166.489	17.582	12.807	1.676	2.581	0.313
2015	2.066	8.236	3.628	5.072	189.308	19.225	14.325	1.955	2.787	0.313
2016	2.052	8.186	3.776	4.827	213.405	20.476	15.961	2.240	2.953	0.317
2017	2.064	8.840	3.828	4.776	236.022	22.053	17.628	2.502	3.133	0.320
2018	2.087	9.477	3.892	5.004	256.959	23.934	19.339	2.768	3.314	0.337
2019	2.094	9.746	3.876	5.154	274.746	25.932	21.163	3.068	3.439	0.351
2020	2.086	9.722	3.836	5.201	291.889	27.704	23.081	3.418	3.566	0.352
2021	2.104	10.528	3.867	5.167	308.670	29.062	25.035	3.768	3.751	0.352

We turn our attention to the components of output and investment. The investment quantity indexes Q_{In}^t, the capital stock quantity indexes Q_{Kn}^t and the non-zero depreciation rates δ_n^t are all consistent with equation (A1) for assets n=1, …, 11. For the zero depreciation assets, we define the corresponding investments by differencing the beginning and end of year capital stocks listed in Table A2. Thus define the investments for the non-depreciable assets 12–16 as follows:

(A2) $Q_{In}^t \equiv Q_{Kn}^{t+1} - Q_{Kn}^t$; n = 12, …, 16 ; t = 1970, …, 2020.

Differencing the stock of inventories to obtain an estimate for investment in inventories is acceptable from the viewpoint of the international SNA. The same logic should apply to land stocks, i.e., estimates for investment in the different types of land can be obtained by differencing the stocks as we have done in definition (A2). However, the current SNA does not follow the inventories example and ignores changes in land use in the definition of aggregate investment. It may be that the logic behind this decision is that land as a whole does not change from year to year and hence there is no investment in land by definition. But it can be seen that when we decompose land use into different components, agricultural land is frequently converted into more valuable types of land and hence investment in land should be included in aggregate investment. Thus, the definition of aggregate investment used in this paper will differ from the APDB estimate for aggregate investment because we have included land investment (as defined above) in our investment aggregate.

We can now construct a new investment aggregate that includes land investment. Use chained Törnqvist price indexes to construct the new aggregate investment price P_I^t and the corresponding implicit quantity index Q_I^t by aggregating over all 16 types of investment that are defined above for the years t = 1970–2020. Define the corresponding year t value of aggregate investment as $V_I^t \equiv P_I^t Q_I^t$. Define a produced-asset investment aggregate that aggregates investments over the first 12 types of investment (call this aggregate $V_{IR}{}^t = P_{IR}{}^t Q_{IR}{}^t$) and a land investment aggregate that aggregates over the 4 types of land (call this aggregate $V_{IL}{}^t = P_{IL}{}^t Q_{IL}{}^t$) using chained Törnqvist price indexes. The aggregate investment price indexes P_I^t, $P_{IR}{}^t$ and $P_{IL}{}^t$ are listed in Table A5 and the corresponding quantity indexes and the values V_I^t, $V_{IR}{}^t$ and $V_{IL}{}^t$ are listed in Table A6.

Table A5 also lists the APDB price indexes for P_C^t (private consumption),[58] P_G^t (government consumption), P_X^t (exports of goods and services) and P_M^t (imports of goods and services). The corresponding quantity or volume indexes are defined as Q_C^t, Q_G^t, Q_X^t and Q_M^t and are listed in Table A6. The Q_M^t are listed with a negative sign since they are a cost to producers whereas the other outputs are a source of revenue.

Table A5: Output Price Indexes for the Main Aggregates for China

Year	P_Y^t	P_C^t	P_G^t	P_I^t	P_X^t	P_M^t	$P_{IR}{}^t$	$P_{IL}{}^t$
1970	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1971	1.023	1.036	0.997	1.006	0.956	0.961	1.006	1.043
1972	1.041	1.063	1.008	1.001	0.960	0.939	1.000	1.088
1973	1.071	1.092	1.030	1.028	0.988	0.908	1.027	1.134
1974	1.092	1.120	1.020	1.037	1.040	0.919	1.035	1.177
1975	1.113	1.151	1.042	1.039	1.015	0.905	1.038	1.207
1976	1.125	1.175	1.009	1.049	0.998	0.906	1.047	1.235
1977	1.153	1.212	1.049	1.057	1.009	0.921	1.055	1.298
1978	1.193	1.252	1.127	1.073	1.064	0.941	1.070	1.416
1979	1.257	1.327	1.202	1.102	1.109	0.944	1.098	1.578
1980	1.323	1.398	1.289	1.152	1.142	0.977	1.147	1.775
1981	1.364	1.455	1.311	1.178	1.161	1.020	1.172	1.992
1982	1.409	1.506	1.352	1.208	1.193	1.039	1.200	2.247
1983	1.454	1.555	1.424	1.245	1.244	1.121	1.235	2.543

[58] The consumption price has been adjusted downward by the amount of indirect taxes paid on outputs and the imports price has been adjusted upward by indirect taxes on imports in APDB. The required tax information is also available in the APDB. Thus, we adjust the APDB final demand prices to obtain prices that producers actually pay for inputs and obtain revenues for the outputs that they produce. Jorgenson and Griliches (1972) noted the importance of making these tax adjustments when constructing productivity estimates for the economy.

1984	1.524	1.620	1.603	1.304	1.380	1.316	1.292	2.864
1985	1.673	1.800	1.832	1.395	1.650	1.586	1.381	3.238
1986	1.772	1.907	1.983	1.501	2.199	2.080	1.484	3.712
1987	1.886	2.062	2.169	1.578	2.432	2.412	1.560	4.303
1988	2.051	2.380	2.512	1.771	2.331	3.284	1.749	5.005
1989	2.260	2.660	2.713	1.899	2.107	2.981	1.875	5.775
1990	2.481	2.828	2.907	2.045	2.850	3.371	2.017	6.950
1991	2.688	3.022	3.229	2.205	3.150	3.605	2.171	8.341
1992	2.915	3.142	3.680	2.494	3.202	3.638	2.454	10.473
1993	3.408	3.536	4.450	3.118	2.889	3.536	3.068	12.916
1994	3.924	4.128	5.642	3.431	4.448	5.445	3.374	15.093
1995	4.537	5.115	6.693	3.624	4.597	5.614	3.563	16.916
1996	4.946	5.711	7.386	3.758	4.287	5.045	3.694	18.048
1997	5.076	5.937	7.775	3.808	4.019	4.795	3.742	18.921
1998	5.074	5.944	7.941	3.779	3.649	4.296	3.713	20.197
1999	5.048	5.993	8.088	3.744	3.672	4.537	3.677	22.583
2000	5.159	6.177	8.355	3.743	3.972	4.895	3.674	26.430
2001	5.289	6.245	8.707	3.772	3.984	4.691	3.700	30.986
2002	5.243	5.947	8.937	3.787	4.083	4.666	3.709	35.429
2003	5.345	5.887	9.554	3.860	4.476	5.049	3.771	40.292
2004	5.667	5.994	10.502	4.067	5.185	5.652	3.965	47.438
2005	5.939	5.999	11.193	4.212	5.602	5.797	4.094	56.975
2006	6.327	6.357	12.673	4.342	5.774	5.828	4.207	68.318
2007	6.702	6.467	14.944	4.512	6.012	5.957	4.358	82.312
2008	7.079	6.722	16.982	4.766	6.169	6.192	4.576	97.245
2009	7.092	6.636	17.908	4.682	5.537	5.309	4.443	109.892
2010	7.419	7.002	18.857	4.858	6.126	5.904	4.596	119.743
2011	8.005	7.641	21.090	5.158	6.258	6.015	4.876	129.290
2012	8.221	7.828	22.630	5.194	6.129	5.798	4.904	138.344
2013	8.387	8.057	24.008	5.192	5.950	5.581	4.895	149.747
2014	8.545	8.405	25.434	5.197	5.612	5.335	4.895	148.059
2015	8.761	8.632	27.100	5.091	5.366	4.745	4.787	150.609
2016	8.964	9.080	28.216	5.076	5.241	4.605	4.762	166.808
2017	9.379	9.503	30.324	5.336	5.462	4.971	4.994	181.861
2018	9.789	9.822	32.453	5.595	5.612	5.189	5.227	194.257
2019	10.176	10.450	34.779	5.703	5.789	5.456	5.317	208.593
2020	10.470	10.949	35.878	5.687	5.821	5.258	5.302	225.163

The corresponding aggregate quantity indexes are measured in units equal to trillions of 1970 yuan. The product of the price and corresponding quantity indexes listed in Tables A5 and A6 are equal to current yuan values in trillions of current yuan. Thus $V_Y^t = P_Y^t Q_Y^t$ is year t Chinese (Augmented) GDP in trillions of yuan.[59] Table A6 also includes the year t current yuan value of produced asset (or "regular") gross

[59] The GDP estimate is "augmented" because it includes land investments which are not included in "regular" estimates of GDP.

investment V_{IR}^t and the year t net investment in land V_{IL}^t in trillions of yuan. It can be seen that net land investment for China is in general not large.

Table A6: Output Quantity Indexes and Current Yuan Values for Gross Output

Year	Q_Y^t	Q_C^t	Q_G^t	Q_I^t	Q_X^t	Q_M^t	Q_{IR}^t	Q_{IL}^t	V_Y^t	V_{IR}^t	V_{IL}^t
1970	0.236	0.147	0.025	0.066	0.006	-0.008	0.065	0.001	0.236	0.065	0.001
1971	0.246	0.149	0.030	0.067	0.008	-0.008	0.067	0.001	0.251	0.067	0.001
1972	0.257	0.157	0.031	0.070	0.009	-0.010	0.069	0.001	0.268	0.069	0.001
1973	0.265	0.163	0.031	0.072	0.013	-0.015	0.071	0.001	0.283	0.073	0.001
1974	0.270	0.164	0.034	0.076	0.015	-0.021	0.075	0.001	0.294	0.078	0.001
1975	0.285	0.168	0.034	0.086	0.016	-0.021	0.085	0.001	0.317	0.089	0.001
1976	0.286	0.167	0.038	0.085	0.015	-0.018	0.084	0.001	0.322	0.088	0.001
1977	0.308	0.176	0.039	0.097	0.015	-0.019	0.097	0.001	0.355	0.102	0.001
1978	0.331	0.185	0.042	0.112	0.018	-0.025	0.111	0.001	0.395	0.119	0.001
1979	0.353	0.195	0.047	0.121	0.022	-0.031	0.120	0.001	0.444	0.132	0.001
1980	0.374	0.210	0.049	0.124	0.028	-0.037	0.123	0.001	0.495	0.141	0.001
1981	0.386	0.223	0.050	0.120	0.036	-0.045	0.119	0.001	0.526	0.139	0.002
1982	0.412	0.232	0.052	0.128	0.041	-0.043	0.127	0.001	0.580	0.153	0.002
1983	0.450	0.250	0.059	0.145	0.041	-0.046	0.144	0.001	0.654	0.178	0.003
1984	0.519	0.273	0.068	0.191	0.050	-0.060	0.190	0.001	0.792	0.246	0.004
1985	0.562	0.303	0.071	0.232	0.058	-0.097	0.231	0.001	0.941	0.319	0.004
1986	0.604	0.319	0.072	0.240	0.060	-0.083	0.240	0.001	1.071	0.356	0.004
1987	0.653	0.336	0.074	0.248	0.071	-0.077	0.249	0.001	1.231	0.388	0.004
1988	0.746	0.350	0.076	0.303	0.087	-0.071	0.305	0.001	1.529	0.533	0.004
1989	0.740	0.363	0.084	0.273	0.103	-0.085	0.274	0.001	1.674	0.514	0.005
1990	0.749	0.372	0.089	0.251	0.116	-0.087	0.252	0.001	1.857	0.507	0.006
1991	0.833	0.395	0.095	0.315	0.134	-0.106	0.316	0.001	2.241	0.687	0.008
1992	0.918	0.428	0.107	0.373	0.164	-0.142	0.376	0.001	2.676	0.922	0.009
1993	1.020	0.468	0.115	0.450	0.208	-0.196	0.453	0.001	3.476	1.391	0.012
1994	1.165	0.496	0.121	0.524	0.270	-0.214	0.529	0.001	4.570	1.785	0.014
1995	1.282	0.534	0.122	0.607	0.308	-0.240	0.614	0.001	5.818	2.187	0.013
1996	1.392	0.581	0.128	0.666	0.347	-0.272	0.674	0.001	6.885	2.490	0.013
1997	1.508	0.609	0.141	0.688	0.440	-0.301	0.697	0.001	7.654	2.609	0.013
1998	1.642	0.643	0.160	0.768	0.479	-0.330	0.779	0.001	8.331	2.891	0.013
1999	1.768	0.696	0.183	0.822	0.514	-0.373	0.834	0.000	8.926	3.067	0.010
2000	1.940	0.763	0.202	0.920	0.605	-0.457	0.934	0.000	10.005	3.432	0.011
2001	2.062	0.806	0.209	1.035	0.646	-0.517	1.052	0.000	10.907	3.891	0.014
2002	2.263	0.865	0.219	1.195	0.768	-0.621	1.193	0.003	11.866	4.424	0.101
2003	2.483	0.906	0.220	1.459	0.932	-0.786	1.464	0.003	13.270	5.522	0.108
2004	2.689	0.961	0.225	1.671	1.093	-0.947	1.681	0.003	15.241	6.668	0.127
2005	2.967	1.028	0.248	1.845	1.274	-1.073	1.856	0.003	17.624	7.597	0.174
2006	3.312	1.102	0.257	2.107	1.525	-1.245	2.129	0.003	20.957	8.957	0.191
2007	3.780	1.223	0.264	2.498	1.774	-1.421	2.538	0.003	25.330	11.061	0.208
2008	4.275	1.328	0.272	3.034	1.861	-1.491	2.899	0.012	30.263	13.265	1.197
2009	4.721	1.472	0.287	3.678	1.707	-1.525	3.610	0.011	33.484	16.041	1.179
2010	5.245	1.616	0.319	4.176	2.005	-1.860	4.196	0.008	38.912	19.287	0.997
2011	5.638	1.760	0.353	4.524	2.251	-2.190	4.639	0.006	45.132	22.619	0.714

2012	6.041	1.882	0.375	4.863	2.401	-2.334	5.083	0.002	49.667	24.926	0.335
2013	6.549	2.002	0.392	5.430	2.623	-2.583	5.638	0.004	54.928	27.600	0.591
2014	6.887	2.171	0.400	5.646	2.861	-2.808	5.980	0.000	58.844	29.270	0.071
2015	7.317	2.367	0.412	5.995	2.866	-2.825	6.225	0.005	64.101	29.797	0.722
2016	7.763	2.577	0.433	6.410	2.900	-2.988	6.694	0.004	69.589	31.875	0.662
2017	8.615	2.766	0.448	7.452	3.130	-3.206	7.155	0.022	80.793	35.733	4.034
2018	9.047	2.972	0.468	7.818	3.255	-3.439	7.659	0.019	88.559	40.031	3.712
2019	9.146	3.129	0.476	7.535	3.270	-3.313	8.069	0.000	93.065	42.906	0.067
2020	9.275	3.050	0.484	7.750	3.342	-3.268	8.302	0.000	97.109	44.020	0.059

We turn our attention to the construction of annual rates of return on assets used in production and on measuring capital services. Actual ex post asset inflation rates can be calculated using the asset price information listed in Table A1. As noted in the text, if ex post asset inflation rates are used in a user cost formula, the resulting user costs are too volatile to approximate rental prices. Thus, we used smoothed asset inflation rates in our final user costs.[60] The smoothed asset inflation rates, i_n^t, are listed in Table A7.

Table A7: Smoothed Asset Inflation Rates for Assets 1–16

Year	i_1^t	i_2^t	i_3^t	i_4^t	i_5^t	i_6^t	i_7^t	i_8^t
1970	-0.047	-0.070	-0.014	-0.006	0.002	-0.003	0.018	-0.006
1971	-0.052	-0.066	-0.013	-0.005	0.006	0.001	0.020	-0.004
1972	-0.058	-0.061	-0.012	-0.003	0.009	0.005	0.023	-0.002
1973	-0.063	-0.057	-0.011	-0.002	0.013	0.009	0.025	-0.001
1974	-0.068	-0.053	-0.010	0.000	0.016	0.013	0.028	0.001
1975	-0.072	-0.049	-0.008	0.001	0.020	0.018	0.031	0.002
1976	-0.076	-0.045	-0.007	0.003	0.024	0.022	0.034	0.004
1977	-0.078	-0.041	-0.006	0.005	0.028	0.027	0.037	0.007
1978	-0.081	-0.037	-0.004	0.007	0.032	0.031	0.040	0.009
1979	-0.083	-0.032	-0.002	0.009	0.036	0.036	0.043	0.010
1980	-0.082	-0.026	0.002	0.013	0.043	0.042	0.047	0.013
1981	-0.080	-0.020	0.006	0.018	0.049	0.047	0.052	0.015
1982	-0.076	-0.013	0.011	0.024	0.056	0.054	0.057	0.018
1983	-0.068	-0.006	0.017	0.031	0.063	0.060	0.063	0.021
1984	-0.057	0.002	0.024	0.039	0.072	0.069	0.071	0.025
1985	-0.043	0.011	0.033	0.047	0.082	0.078	0.080	0.030
1986	-0.029	0.021	0.042	0.055	0.092	0.087	0.088	0.035
1987	-0.017	0.029	0.049	0.062	0.100	0.095	0.095	0.041
1988	-0.009	0.035	0.055	0.067	0.106	0.100	0.100	0.046
1989	-0.005	0.037	0.058	0.070	0.108	0.102	0.102	0.048
1990	-0.004	0.036	0.059	0.070	0.107	0.101	0.101	0.046
1991	-0.006	0.033	0.057	0.067	0.102	0.097	0.098	0.042
1992	-0.010	0.027	0.053	0.062	0.097	0.091	0.093	0.037
1993	-0.016	0.019	0.047	0.055	0.090	0.084	0.087	0.031
1994	-0.025	0.010	0.041	0.047	0.084	0.076	0.080	0.026
1995	-0.036	0.000	0.034	0.039	0.077	0.068	0.073	0.022

[60] We used the Lowess smoothing option in Shazam with Smooth=0.4 to smooth the ex post asset inflation rates.

1996	-0.048	-0.011	0.027	0.030	0.070	0.060	0.065	0.021
1997	-0.060	-0.021	0.020	0.021	0.064	0.052	0.057	0.021
1998	-0.070	-0.031	0.013	0.013	0.057	0.044	0.048	0.021
1999	-0.078	-0.040	0.007	0.007	0.051	0.037	0.041	0.020
2000	-0.084	-0.046	0.003	0.002	0.047	0.031	0.036	0.018
2001	-0.088	-0.050	0.001	-0.001	0.045	0.028	0.033	0.016
2002	-0.090	-0.052	0.001	-0.001	0.045	0.028	0.034	0.016
2003	-0.090	-0.052	0.002	0.000	0.047	0.030	0.036	0.019
2004	-0.088	-0.051	0.004	0.001	0.048	0.032	0.038	0.023
2005	-0.086	-0.049	0.006	0.003	0.049	0.034	0.039	0.028
2006	-0.080	-0.046	0.008	0.004	0.048	0.035	0.039	0.033
2007	-0.073	-0.043	0.008	0.004	0.046	0.035	0.038	0.038
2008	-0.065	-0.040	0.009	0.005	0.043	0.033	0.037	0.042
2009	-0.056	-0.037	0.008	0.004	0.039	0.031	0.035	0.046
2010	-0.048	-0.034	0.008	0.004	0.035	0.030	0.033	0.050
2011	-0.041	-0.031	0.007	0.003	0.032	0.029	0.032	0.051
2012	-0.035	-0.028	0.006	0.003	0.032	0.029	0.032	0.048
2013	-0.029	-0.025	0.005	0.003	0.032	0.030	0.033	0.045
2014	-0.024	-0.022	0.004	0.003	0.032	0.030	0.033	0.042
2015	-0.018	-0.018	0.003	0.003	0.032	0.031	0.033	0.039
2016	-0.012	-0.015	0.002	0.002	0.033	0.032	0.033	0.036
2017	-0.006	-0.011	0.001	0.002	0.033	0.033	0.034	0.033
2018	-0.001	-0.008	0.000	0.002	0.034	0.034	0.034	0.029
2019	0.005	-0.004	-0.001	0.002	0.036	0.035	0.035	0.024
2020	0.010	-0.001	-0.002	0.003	0.037	0.037	0.037	0.018

Year	i_9^t	i_{10}^t	i_{11}^t	i_{12}^t	i_{13}^t	i_{14}^t	i_{15}^t	i_{16}^t
1970	0.068	-0.084	0.077	-0.005	0.018	0.089	0.089	0.018
1971	0.065	-0.076	0.073	-0.002	0.023	0.097	0.097	0.023
1972	0.061	-0.068	0.069	0.002	0.028	0.105	0.105	0.028
1973	0.058	-0.061	0.065	0.005	0.033	0.113	0.113	0.033
1974	0.054	-0.053	0.061	0.008	0.039	0.120	0.120	0.039
1975	0.051	-0.046	0.057	0.011	0.044	0.128	0.128	0.044
1976	0.048	-0.039	0.053	0.014	0.050	0.136	0.136	0.050
1977	0.045	-0.032	0.049	0.018	0.055	0.144	0.144	0.055
1978	0.042	-0.024	0.046	0.021	0.060	0.152	0.152	0.060
1979	0.040	-0.016	0.043	0.024	0.065	0.161	0.161	0.065
1980	0.040	-0.007	0.042	0.030	0.071	0.169	0.169	0.071
1981	0.042	0.002	0.043	0.036	0.078	0.177	0.177	0.078
1982	0.045	0.010	0.044	0.042	0.085	0.185	0.184	0.085
1983	0.049	0.017	0.047	0.047	0.092	0.193	0.191	0.092
1984	0.055	0.024	0.052	0.052	0.099	0.202	0.198	0.097
1985	0.063	0.031	0.059	0.056	0.105	0.210	0.206	0.101
1986	0.071	0.038	0.067	0.060	0.111	0.218	0.212	0.106
1987	0.078	0.045	0.074	0.067	0.117	0.223	0.214	0.113
1988	0.083	0.050	0.079	0.074	0.124	0.224	0.213	0.122

1989	0.086	0.053	0.081	0.080	0.130	0.220	0.207	0.133
1990	0.085	0.052	0.081	0.083	0.134	0.211	0.197	0.145
1991	0.082	0.050	0.078	0.083	0.137	0.199	0.186	0.155
1992	0.076	0.045	0.073	0.080	0.137	0.185	0.176	0.163
1993	0.069	0.039	0.066	0.074	0.134	0.172	0.166	0.168
1994	0.061	0.032	0.058	0.067	0.131	0.161	0.157	0.170
1995	0.052	0.025	0.050	0.060	0.127	0.152	0.149	0.171
1996	0.042	0.017	0.041	0.055	0.123	0.144	0.140	0.171
1997	0.034	0.010	0.032	0.050	0.119	0.139	0.131	0.170
1998	0.025	0.002	0.024	0.046	0.116	0.136	0.124	0.168
1999	0.018	-0.005	0.017	0.041	0.112	0.136	0.119	0.166
2000	0.013	-0.011	0.011	0.036	0.110	0.140	0.119	0.162
2001	0.009	-0.014	0.008	0.031	0.108	0.145	0.123	0.158
2002	0.008	-0.016	0.007	0.028	0.108	0.152	0.131	0.153
2003	0.009	-0.016	0.007	0.027	0.111	0.157	0.139	0.150
2004	0.010	-0.015	0.009	0.029	0.115	0.161	0.144	0.148
2005	0.011	-0.015	0.009	0.031	0.121	0.161	0.147	0.149
2006	0.011	-0.015	0.009	0.033	0.126	0.157	0.147	0.151
2007	0.010	-0.015	0.009	0.033	0.129	0.149	0.146	0.154
2008	0.009	-0.015	0.008	0.031	0.130	0.138	0.145	0.157
2009	0.008	-0.016	0.007	0.028	0.129	0.123	0.143	0.159
2010	0.007	-0.016	0.006	0.025	0.126	0.108	0.142	0.159
2011	0.006	-0.016	0.006	0.021	0.122	0.092	0.141	0.155
2012	0.006	-0.015	0.006	0.018	0.116	0.081	0.139	0.144
2013	0.005	-0.013	0.005	0.016	0.110	0.072	0.137	0.133
2014	0.005	-0.012	0.005	0.013	0.104	0.062	0.134	0.122
2015	0.004	-0.011	0.005	0.010	0.098	0.053	0.131	0.111
2016	0.004	-0.009	0.004	0.006	0.092	0.045	0.129	0.100
2017	0.003	-0.008	0.004	0.004	0.085	0.037	0.127	0.089
2018	0.003	-0.006	0.004	0.001	0.079	0.030	0.125	0.077
2019	0.003	-0.004	0.004	-0.002	0.073	0.024	0.123	0.065
2020	0.002	-0.002	0.004	-0.004	0.067	0.018	0.121	0.052

The above smoothed asset inflation rates replaced the actual asset inflation rates in equation (10) and the resulting equations were solved for r^t which is a smoothed version of the ex post rates of return. These smoothed r^t are used as an approximation to the Chinese cost of capital for year t. The resulting user costs U^t for assets 1–16 defined by equation (4) in the main text (but using the smoothed asset inflation rates i_n^t and the smoothed rates of return r^t) are listed in Table A8. All of the smoothed user costs are positive except for 11 negative user costs for industrial land and 9 negative user costs for commercial land. Negative user costs for land components are likely to appear in many countries that experience rapid increases in land prices.

Table A8: Annual Smoothed User Costs for Chinese Assets used in Production

Year	U_1^t	U_2^t	U_3^t	U_4^t	U_5^t	U_6^t	U_7^t	U_8^t
1970	0.513	0.469	0.296	0.264	0.159	0.183	0.125	0.311
1971	0.502	0.441	0.289	0.258	0.156	0.179	0.126	0.286
1972	0.465	0.414	0.284	0.247	0.153	0.172	0.122	0.273
1973	0.410	0.385	0.278	0.252	0.158	0.171	0.121	0.289

1974	0.417	0.344	0.255	0.256	0.150	0.169	0.124	0.261
1975	0.393	0.342	0.282	0.255	0.157	0.178	0.136	0.302
1976	0.416	0.318	0.273	0.244	0.149	0.169	0.128	0.307
1977	0.431	0.311	0.279	0.258	0.164	0.183	0.145	0.341
1978	0.386	0.311	0.291	0.270	0.173	0.192	0.159	0.339
1979	0.349	0.303	0.293	0.279	0.182	0.199	0.167	0.358
1980	0.267	0.279	0.272	0.273	0.182	0.200	0.168	0.330
1981	0.228	0.266	0.271	0.272	0.182	0.206	0.175	0.318
1982	0.209	0.274	0.284	0.285	0.197	0.221	0.194	0.341
1983	0.196	0.274	0.293	0.298	0.229	0.254	0.230	0.340
1984	0.193	0.294	0.312	0.319	0.257	0.284	0.261	0.362
1985	0.191	0.303	0.331	0.330	0.270	0.299	0.272	0.406
1986	0.180	0.275	0.321	0.328	0.265	0.297	0.264	0.402
1987	0.160	0.276	0.319	0.336	0.284	0.314	0.278	0.401
1988	0.153	0.286	0.354	0.379	0.333	0.367	0.328	0.449
1989	0.153	0.274	0.345	0.382	0.323	0.361	0.313	0.470
1990	0.159	0.288	0.362	0.409	0.334	0.375	0.322	0.505
1991	0.166	0.318	0.408	0.477	0.427	0.469	0.418	0.512
1992	0.179	0.364	0.455	0.529	0.497	0.544	0.482	0.536
1993	0.187	0.442	0.560	0.620	0.650	0.701	0.617	0.568
1994	0.197	0.479	0.591	0.684	0.752	0.801	0.712	0.610
1995	0.194	0.509	0.630	0.768	0.876	0.931	0.846	0.684
1996	0.171	0.470	0.649	0.795	0.962	1.022	0.937	0.738
1997	0.157	0.447	0.638	0.784	0.977	1.040	0.955	0.704
1998	0.151	0.398	0.631	0.800	1.013	1.076	1.011	0.620
1999	0.146	0.373	0.608	0.762	0.989	1.056	0.991	0.577
2000	0.147	0.381	0.607	0.765	1.046	1.087	1.068	0.602
2001	0.132	0.356	0.607	0.748	1.035	1.076	1.051	0.647
2002	0.121	0.318	0.604	0.729	1.054	1.073	1.035	0.571
2003	0.101	0.285	0.586	0.707	1.066	1.061	1.026	0.609
2004	0.085	0.267	0.578	0.695	1.106	1.083	1.048	0.648
2005	0.071	0.253	0.577	0.694	1.166	1.110	1.034	0.672
2006	0.065	0.246	0.595	0.721	1.293	1.186	1.090	0.705
2007	0.061	0.236	0.608	0.739	1.460	1.291	1.191	0.691
2008	0.054	0.227	0.622	0.754	1.603	1.368	1.383	0.647
2009	0.046	0.210	0.611	0.727	1.510	1.277	1.275	0.638
2010	0.043	0.195	0.611	0.717	1.554	1.310	1.296	0.689
2011	0.039	0.177	0.587	0.687	1.559	1.348	1.275	0.671
2012	0.036	0.158	0.558	0.648	1.428	1.252	1.147	0.616
2013	0.034	0.150	0.538	0.615	1.353	1.187	1.062	0.650
2014	0.033	0.145	0.511	0.580	1.257	1.101	0.961	0.659
2015	0.033	0.143	0.501	0.567	1.209	1.056	0.924	0.725
2016	0.031	0.140	0.503	0.571	1.214	1.057	0.932	0.887
2017	0.032	0.143	0.530	0.604	1.421	1.220	1.114	0.972
2018	0.031	0.137	0.526	0.600	1.457	1.256	1.136	0.998
2019	0.030	0.130	0.506	0.576	1.364	1.194	1.049	0.969
2020	0.028	0.124	0.492	0.554	1.272	1.114	0.962	0.867

Year	U_9^t	U_{10}^t	U_{11}^t	U_{12}^t	U_{13}^t	U_{14}^t	U_{15}^t	U_{16}^t
1970	0.259	0.587	0.407	0.129	0.106	0.035	0.035	0.106
1971	0.274	0.562	0.432	0.125	0.105	0.029	0.029	0.105
1972	0.289	0.533	0.448	0.121	0.101	0.020	0.020	0.101
1973	0.313	0.496	0.475	0.119	0.100	0.013	0.013	0.100
1974	0.324	0.411	0.484	0.115	0.096	0.001	0.001	0.096
1975	0.362	0.392	0.547	0.121	0.103	0.003	0.003	0.103
1976	0.367	0.372	0.576	0.101	0.078	-0.040	-0.040	0.078
1977	0.429	0.374	0.659	0.126	0.104	-0.006	-0.006	0.104
1978	0.474	0.368	0.745	0.133	0.113	-0.002	-0.002	0.113
1979	0.512	0.377	0.771	0.140	0.123	-0.005	-0.005	0.123
1980	0.512	0.362	0.766	0.139	0.120	-0.047	-0.047	0.120
1981	0.527	0.359	0.788	0.141	0.127	-0.074	-0.074	0.127
1982	0.563	0.370	0.860	0.157	0.155	-0.050	-0.047	0.155
1983	0.586	0.371	0.902	0.180	0.201	0.019	0.030	0.201
1984	0.629	0.388	0.977	0.200	0.246	0.089	0.111	0.249
1985	0.659	0.401	1.050	0.206	0.260	0.064	0.099	0.267
1986	0.670	0.410	1.076	0.200	0.239	-0.101	-0.043	0.250
1987	0.692	0.421	1.121	0.219	0.269	-0.083	0.017	0.280
1988	0.785	0.468	1.237	0.238	0.308	0.043	0.204	0.319
1989	0.820	0.469	1.285	0.236	0.277	-0.121	0.123	0.273
1990	0.904	0.487	1.369	0.230	0.270	-0.082	0.215	0.240
1991	1.043	0.521	1.539	0.276	0.358	0.608	0.884	0.286
1992	1.167	0.535	1.776	0.291	0.394	1.197	1.423	0.274
1993	1.410	0.616	2.178	0.292	0.409	1.583	1.804	0.216
1994	1.546	0.686	2.394	0.341	0.511	2.524	2.772	0.219
1995	1.756	0.750	2.604	0.495	0.778	4.559	4.045	0.431
1996	1.814	0.748	2.640	0.571	0.931	5.375	4.656	0.499
1997	1.849	0.718	2.610	0.599	1.060	5.654	5.144	0.582
1998	1.829	0.694	2.611	0.588	1.115	5.285	5.464	0.624
1999	1.828	0.668	2.569	0.563	1.164	4.903	5.940	0.697
2000	1.899	0.662	2.602	0.590	1.341	5.409	7.232	0.991
2001	1.879	0.647	2.600	0.588	1.312	4.927	7.129	1.010
2002	1.868	0.642	2.610	0.588	1.343	4.871	6.989	1.123
2003	1.837	0.604	2.742	0.559	1.290	4.097	6.074	1.088
2004	1.858	0.598	2.897	0.552	1.246	3.485	5.362	1.088
2005	1.865	0.589	3.025	0.573	1.183	3.404	5.064	1.070
2006	1.955	0.593	3.146	0.616	1.399	6.850	6.947	1.440
2007	2.011	0.597	3.123	0.661	1.676	12.870	9.802	1.849
2008	2.054	0.621	2.960	0.696	1.770	19.214	12.170	1.940
2009	1.959	0.603	2.891	0.744	1.945	26.683	13.826	1.986
2010	1.979	0.589	2.854	0.688	2.054	31.555	14.318	1.921
2011	1.972	0.584	2.766	0.680	1.803	32.900	11.228	1.193
2012	1.871	0.555	2.702	0.648	1.444	31.660	6.984	0.828
2013	1.784	0.516	2.587	0.608	1.387	33.408	4.587	1.103
2014	1.698	0.481	2.485	0.560	1.156	34.397	0.781	1.260
2015	1.652	0.454	2.403	0.561	1.626	39.840	0.942	2.899
2016	1.652	0.440	2.437	0.555	2.342	45.702	2.432	5.630

2017	1.746	0.440	2.508	0.623	4.087	57.201	12.396	11.099
2018	1.761	0.434	2.482	0.641	4.517	59.429	11.152	13.135
2019	1.709	0.417	2.416	0.617	4.480	59.935	3.376	13.842
2020	1.656	0.411	2.384	0.600	4.795	62.596	-2.775	15.499

APPENDIX B: TABLES FOR THE MAIN TEXT

Table B1: Values for Five Capital Stock Components and their Shares in Total Value

Year	V_K^t	V_{KM}^t	V_{KS}^t	V_{KO}^t	V_{KI}^t	V_{KL}^t	s_{KM}^t	s_{KS}^t	s_{KO}^t	s_{KI}^t	s_{KL}^t
1970	0.581	0.092	0.208	0.012	0.048	0.221	0.158	0.359	0.021	0.083	0.380
1971	0.641	0.106	0.230	0.013	0.057	0.235	0.165	0.359	0.021	0.089	0.366
1972	0.694	0.116	0.254	0.015	0.062	0.246	0.168	0.366	0.022	0.090	0.355
1973	0.762	0.129	0.290	0.017	0.067	0.258	0.170	0.381	0.023	0.088	0.339
1974	0.818	0.144	0.315	0.018	0.072	0.270	0.176	0.385	0.022	0.088	0.330
1975	0.875	0.151	0.349	0.021	0.073	0.282	0.173	0.399	0.024	0.083	0.322
1976	0.941	0.167	0.390	0.024	0.070	0.290	0.177	0.415	0.026	0.074	0.308
1977	0.995	0.175	0.428	0.027	0.068	0.297	0.176	0.430	0.027	0.068	0.298
1978	1.078	0.186	0.477	0.028	0.075	0.312	0.172	0.442	0.026	0.070	0.290
1979	1.196	0.202	0.535	0.031	0.088	0.341	0.169	0.447	0.026	0.073	0.285
1980	1.362	0.208	0.633	0.032	0.110	0.380	0.153	0.465	0.024	0.081	0.279
1981	1.518	0.211	0.721	0.034	0.125	0.427	0.139	0.475	0.023	0.082	0.282
1982	1.677	0.208	0.821	0.036	0.133	0.479	0.124	0.490	0.022	0.079	0.286
1983	1.869	0.207	0.950	0.037	0.135	0.540	0.111	0.508	0.020	0.072	0.289
1984	2.121	0.218	1.103	0.041	0.146	0.614	0.103	0.520	0.019	0.069	0.290
1985	2.485	0.248	1.311	0.049	0.183	0.694	0.100	0.528	0.020	0.074	0.279
1986	2.966	0.302	1.579	0.058	0.239	0.788	0.102	0.532	0.020	0.081	0.266
1987	3.469	0.356	1.851	0.066	0.294	0.903	0.103	0.534	0.019	0.085	0.260
1988	4.199	0.464	2.282	0.082	0.329	1.042	0.111	0.543	0.020	0.078	0.248
1989	5.008	0.586	2.674	0.100	0.439	1.210	0.117	0.534	0.020	0.088	0.242
1990	5.798	0.679	3.069	0.116	0.536	1.399	0.117	0.529	0.020	0.092	0.241
1991	6.733	0.755	3.572	0.125	0.626	1.656	0.112	0.531	0.019	0.093	0.246
1992	8.205	0.887	4.440	0.146	0.769	1.964	0.108	0.541	0.018	0.094	0.239
1993	11.007	1.180	6.341	0.182	0.900	2.403	0.107	0.576	0.017	0.082	0.218
1994	13.363	1.518	7.667	0.214	1.077	2.887	0.114	0.574	0.016	0.081	0.216
1995	16.022	1.900	8.837	0.257	1.459	3.569	0.119	0.552	0.016	0.091	0.223
1996	18.800	2.182	10.335	0.296	1.859	4.128	0.116	0.550	0.016	0.099	0.220
1997	21.379	2.442	11.778	0.323	2.159	4.677	0.114	0.551	0.015	0.101	0.219
1998	23.575	2.767	12.981	0.347	2.288	5.192	0.117	0.551	0.015	0.097	0.220
1999	25.738	3.096	14.261	0.373	2.277	5.730	0.120	0.554	0.015	0.089	0.223
2000	28.406	3.460	15.797	0.425	2.348	6.377	0.122	0.556	0.015	0.083	0.225
2001	31.747	3.937	17.601	0.506	2.553	7.150	0.124	0.554	0.016	0.080	0.225
2002	35.474	4.444	19.730	0.547	2.740	8.013	0.125	0.556	0.015	0.077	0.226
2003	40.315	5.065	22.594	0.673	2.894	9.089	0.126	0.560	0.017	0.072	0.225
2004	47.599	6.098	27.000	0.823	3.265	10.414	0.128	0.567	0.017	0.069	0.219
2005	56.066	7.389	31.524	0.982	3.847	12.324	0.132	0.562	0.018	0.069	0.220
2006	65.330	9.128	35.945	1.173	4.217	14.868	0.140	0.550	0.018	0.065	0.228
2007	76.976	11.050	41.827	1.351	4.822	17.926	0.144	0.543	0.018	0.063	0.233
2008	92.734	13.535	49.883	1.568	5.951	21.796	0.146	0.538	0.017	0.064	0.235
2009	104.810	16.095	52.563	1.899	7.184	27.070	0.154	0.502	0.018	0.069	0.258
2010	123.836	19.837	61.705	2.581	7.596	32.117	0.160	0.498	0.021	0.061	0.259
2011	149.449	24.631	75.208	3.394	9.356	36.860	0.165	0.503	0.023	0.063	0.247
2012	171.296	28.368	86.129	4.100	11.181	41.518	0.166	0.503	0.024	0.065	0.242
2013	192.268	32.764	96.234	5.051	12.215	46.004	0.170	0.501	0.026	0.064	0.239
2014	216.569	36.694	108.417	6.077	13.327	52.056	0.169	0.501	0.028	0.062	0.240

2015	238.226	39.719	117.986	7.095	14.138	59.289	0.167	0.495	0.030	0.059	0.249
2016	263.010	42.018	130.661	8.456	14.252	67.623	0.160	0.497	0.032	0.054	0.257
2017	301.390	45.513	155.831	9.576	14.964	75.507	0.151	0.517	0.032	0.050	0.251
2018	347.133	49.941	183.281	10.773	16.581	86.558	0.144	0.528	0.031	0.048	0.249
2019	386.731	54.298	206.256	11.892	17.724	96.560	0.140	0.533	0.031	0.046	0.250
2020	416.497	57.793	224.388	13.111	18.548	102.657	0.139	0.539	0.032	0.045	0.247
2021	467.303	61.147	263.580	14.569	19.384	108.623	0.131	0.564	0.031	0.042	0.232
Mean	77.674	11.438	40.862	2.110	4.343	18.920	0.139	0.506	0.021	0.075	0.260

Table B2: Output and Labour Aggregates, Capital Stock Aggregates, and Capital Output Ratios

Year	P_Y^t	P_I^t	P_L^t	P_K^t	Q_Y^t	Q_I^t	Q_L^t	Q_K^t	V_Y^t	V_I^t	V_L^t	KY^t	VKY^t
1970	1.000	1.000	1.000	1.000	0.236	0.066	0.147	0.581	0.236	0.066	0.147	2.462	2.462
1971	1.024	1.006	1.010	1.027	0.246	0.067	0.155	0.624	0.251	0.068	0.156	2.540	2.548
1972	1.041	1.001	1.062	1.043	0.257	0.070	0.158	0.665	0.268	0.070	0.168	2.586	2.591
1973	1.071	1.028	1.069	1.080	0.265	0.072	0.164	0.705	0.283	0.074	0.175	2.666	2.687
1974	1.092	1.037	1.072	1.098	0.270	0.076	0.170	0.745	0.295	0.079	0.182	2.762	2.779
1975	1.113	1.039	1.084	1.113	0.285	0.086	0.176	0.786	0.317	0.089	0.191	2.763	2.763
1976	1.125	1.049	1.092	1.129	0.286	0.085	0.182	0.833	0.322	0.089	0.198	2.912	2.922
1977	1.154	1.057	1.111	1.143	0.308	0.097	0.187	0.871	0.355	0.103	0.208	2.828	2.802
1978	1.193	1.073	1.185	1.168	0.331	0.112	0.193	0.923	0.395	0.120	0.229	2.786	2.728
1979	1.257	1.102	1.280	1.215	0.353	0.121	0.200	0.985	0.444	0.133	0.255	2.790	2.697
1980	1.323	1.152	1.429	1.296	0.374	0.124	0.208	1.051	0.495	0.143	0.297	2.809	2.752
1981	1.365	1.178	1.446	1.359	0.386	0.120	0.216	1.117	0.526	0.141	0.313	2.896	2.884
1982	1.409	1.208	1.479	1.428	0.412	0.129	0.226	1.175	0.580	0.155	0.334	2.854	2.892
1983	1.454	1.245	1.521	1.509	0.450	0.145	0.232	1.239	0.654	0.181	0.353	2.754	2.859
1984	1.524	1.304	1.741	1.616	0.519	0.191	0.246	1.313	0.792	0.249	0.428	2.528	2.679
1985	1.673	1.395	2.010	1.753	0.562	0.232	0.260	1.418	0.941	0.323	0.523	2.522	2.642
1986	1.772	1.501	2.284	1.919	0.604	0.240	0.272	1.546	1.071	0.360	0.621	2.558	2.770
1987	1.886	1.578	2.485	2.078	0.653	0.248	0.283	1.670	1.231	0.392	0.704	2.558	2.818
1988	2.051	1.771	2.912	2.341	0.746	0.303	0.295	1.794	1.529	0.537	0.858	2.406	2.746
1989	2.260	1.899	3.179	2.573	0.741	0.273	0.300	1.947	1.674	0.519	0.955	2.629	2.993
1990	2.481	2.045	3.464	2.805	0.749	0.251	0.307	2.067	1.858	0.514	1.064	2.761	3.121
1991	2.689	2.205	3.781	3.111	0.834	0.315	0.315	2.165	2.241	0.695	1.193	2.597	3.005
1992	2.915	2.494	4.283	3.577	0.918	0.373	0.327	2.294	2.676	0.931	1.399	2.499	3.066
1993	3.408	3.118	5.207	4.470	1.020	0.450	0.341	2.463	3.476	1.403	1.776	2.415	3.167
1994	3.924	3.431	6.920	5.008	1.165	0.524	0.347	2.668	4.570	1.799	2.402	2.291	2.924
1995	4.537	3.624	8.154	5.524	1.282	0.607	0.357	2.901	5.818	2.200	2.907	2.262	2.754
1996	4.947	3.758	9.048	5.933	1.392	0.666	0.370	3.169	6.885	2.503	3.350	2.276	2.730
1997	5.076	3.808	9.677	6.209	1.508	0.688	0.380	3.443	7.654	2.621	3.673	2.284	2.793
1998	5.074	3.779	9.995	6.336	1.642	0.768	0.384	3.721	8.331	2.904	3.837	2.266	2.830
1999	5.048	3.744	10.419	6.426	1.768	0.822	0.395	4.005	8.926	3.077	4.112	2.265	2.884
2000	5.159	3.743	10.752	6.588	1.940	0.920	0.412	4.312	10.006	3.443	4.432	2.223	2.839
2001	5.289	3.772	11.369	6.823	2.062	1.035	0.426	4.653	10.907	3.905	4.843	2.256	2.911
2002	5.243	3.787	11.959	7.062	2.263	1.195	0.435	5.023	11.867	4.525	5.198	2.219	2.989

2003	5.345	3.860	13.325	7.408	2.483	1.459	0.450	5.442	13.270	5.630	5.995	2.192	3.038
2004	5.667	4.067	15.076	8.003	2.689	1.671	0.464	5.947	15.241	6.795	6.989	2.212	3.123
2005	5.939	4.212	16.587	8.606	2.967	1.845	0.494	6.515	17.624	7.771	8.198	2.195	3.181
2006	6.327	4.342	19.297	9.198	3.313	2.107	0.495	7.102	20.957	9.148	9.545	2.144	3.117
2007	6.702	4.512	23.473	9.935	3.780	2.498	0.485	7.748	25.330	11.269	11.388	2.050	3.039
2008	7.079	4.766	27.709	10.912	4.275	3.035	0.481	8.499	30.263	14.463	13.333	1.988	3.064
2009	7.092	4.682	30.771	11.177	4.722	3.678	0.489	9.377	33.484	17.220	15.044	1.986	3.130
2010	7.419	4.858	32.584	11.826	5.245	4.176	0.536	10.472	38.912	20.284	17.476	1.997	3.183
2011	8.005	5.158	37.848	12.812	5.638	4.524	0.554	11.665	45.132	23.333	20.964	2.069	3.311
2012	8.221	5.194	43.034	13.278	6.041	4.863	0.564	12.901	49.667	25.261	24.262	2.136	3.449
2013	8.387	5.192	47.859	13.585	6.549	5.430	0.576	14.154	54.928	28.191	27.542	2.161	3.500
2014	8.545	5.197	52.664	13.975	6.887	5.646	0.571	15.497	58.844	29.341	30.069	2.250	3.680
2015	8.761	5.091	58.596	14.186	7.317	5.995	0.556	16.793	64.101	30.519	32.566	2.295	3.716
2016	8.965	5.076	61.386	14.540	7.763	6.410	0.557	18.089	69.589	32.537	34.159	2.330	3.780
2017	9.379	5.336	66.109	15.521	8.615	7.452	0.548	19.419	80.793	39.768	36.244	2.254	3.730
2018	9.789	5.595	71.559	16.514	9.047	7.818	0.544	21.021	88.559	43.743	38.958	2.324	3.920
2019	10.176	5.703	78.310	17.072	9.146	7.535	0.533	22.652	93.065	42.972	41.717	2.477	4.156
2020	10.470	5.687	83.210	17.301	9.275	7.750	0.532	24.074	97.109	44.079	44.287	2.596	4.289

Table B3: TFP Growth, Output and Input Aggregates, and Input Shares of Gross Output

Year	TFP_G^t	V_Y^t	V_L^t	V_U^t	s_L^t	s_{UM}^t	s_{US}^t	s_{UO}^t	s_{UI}^t	s_{UL}^t
1970	1.000	0.236	0.147	0.089	0.625	0.104	0.139	0.015	0.026	0.091
1971	0.976	0.251	0.156	0.095	0.622	0.111	0.140	0.015	0.028	0.084
1972	1.002	0.268	0.168	0.099	0.628	0.113	0.140	0.016	0.028	0.076
1973	0.979	0.283	0.175	0.108	0.619	0.118	0.149	0.017	0.028	0.070
1974	0.973	0.295	0.182	0.113	0.618	0.125	0.150	0.017	0.028	0.064
1975	1.005	0.317	0.191	0.126	0.602	0.126	0.161	0.019	0.027	0.064
1976	0.958	0.322	0.198	0.124	0.616	0.132	0.165	0.021	0.022	0.044
1977	1.036	0.355	0.208	0.148	0.584	0.133	0.180	0.022	0.024	0.057
1978	1.028	0.395	0.229	0.167	0.579	0.131	0.187	0.022	0.025	0.056
1979	1.013	0.444	0.255	0.188	0.576	0.129	0.192	0.022	0.027	0.055
1980	1.005	0.495	0.297	0.198	0.600	0.115	0.191	0.020	0.028	0.046
1981	0.981	0.526	0.313	0.213	0.595	0.110	0.203	0.021	0.029	0.044
1982	1.020	0.580	0.334	0.246	0.576	0.102	0.221	0.021	0.030	0.051
1983	1.048	0.654	0.353	0.301	0.540	0.096	0.251	0.020	0.031	0.063
1984	1.086	0.792	0.428	0.364	0.540	0.088	0.255	0.019	0.030	0.067
1985	1.006	0.941	0.523	0.417	0.556	0.085	0.248	0.019	0.032	0.060
1986	1.001	1.071	0.621	0.450	0.580	0.087	0.236	0.019	0.033	0.045
1987	1.012	1.231	0.704	0.527	0.572	0.089	0.239	0.019	0.036	0.046
1988	1.072	1.529	0.858	0.671	0.561	0.096	0.246	0.020	0.033	0.045
1989	0.940	1.674	0.955	0.719	0.571	0.102	0.239	0.021	0.034	0.034
1990	0.969	1.858	1.064	0.794	0.573	0.104	0.239	0.022	0.035	0.028
1991	1.071	2.241	1.193	1.048	0.532	0.104	0.267	0.021	0.038	0.038
1992	1.048	2.676	1.399	1.277	0.523	0.103	0.276	0.020	0.040	0.038
1993	1.041	3.476	1.776	1.700	0.511	0.106	0.299	0.019	0.035	0.030

1994	1.075	4.570	2.402	2.168	0.526	0.107	0.287	0.018	0.033	0.031
1995	1.030	5.818	2.907	2.911	0.500	0.111	0.290	0.018	0.041	0.041
1996	1.009	6.885	3.350	3.535	0.487	0.110	0.301	0.018	0.044	0.041
1997	1.016	7.654	3.673	3.981	0.480	0.111	0.305	0.017	0.047	0.041
1998	1.029	8.331	3.837	4.494	0.461	0.118	0.321	0.017	0.045	0.039
1999	1.011	8.926	4.112	4.814	0.461	0.121	0.322	0.017	0.042	0.038
2000	1.022	10.006	4.432	5.573	0.443	0.124	0.332	0.018	0.041	0.043
2001	0.992	10.907	4.843	6.064	0.444	0.128	0.331	0.019	0.040	0.038
2002	1.029	11.867	5.198	6.669	0.438	0.133	0.334	0.019	0.039	0.037
2003	1.018	13.270	5.995	7.275	0.452	0.135	0.327	0.020	0.035	0.031
2004	1.001	15.241	6.989	8.251	0.459	0.139	0.323	0.021	0.033	0.025
2005	1.003	17.624	8.198	9.427	0.465	0.144	0.316	0.022	0.032	0.021
2006	1.047	20.957	9.545	11.413	0.455	0.151	0.314	0.022	0.031	0.026
2007	1.080	25.330	11.388	13.943	0.450	0.153	0.314	0.022	0.030	0.032
2008	1.062	30.263	13.333	16.931	0.441	0.156	0.319	0.022	0.031	0.033
2009	1.025	33.484	15.044	18.440	0.449	0.163	0.294	0.024	0.033	0.037
2010	0.986	38.912	17.476	21.436	0.449	0.168	0.290	0.027	0.029	0.036
2011	0.981	45.132	20.964	24.168	0.465	0.168	0.281	0.030	0.029	0.028
2012	0.993	49.667	24.262	25.405	0.489	0.166	0.263	0.032	0.028	0.022
2013	1.007	54.928	27.542	27.386	0.501	0.167	0.249	0.035	0.026	0.021
2014	0.996	58.844	30.069	28.775	0.511	0.166	0.240	0.039	0.025	0.019
2015	1.024	64.101	32.566	31.535	0.508	0.163	0.237	0.042	0.024	0.025
2016	1.014	69.589	34.159	35.431	0.491	0.160	0.244	0.047	0.024	0.035
2017	1.068	80.793	36.244	44.549	0.449	0.157	0.272	0.047	0.024	0.051
2018	1.004	88.559	38.958	49.601	0.440	0.154	0.279	0.049	0.024	0.055
2019	0.975	93.065	41.717	51.348	0.448	0.152	0.273	0.050	0.023	0.054
2020	0.975	97.109	44.287	52.822	0.456	0.150	0.264	0.053	0.022	0.055
Mean	1.015	19.505	9.141	10.363	0.520	0.127	0.254	0.024	0.031	0.044

Table B4: Gross Real Income, Real Output Prices, and Real Input Prices

Year	RI^t	p_2^t	p_3^t	p_4^t	p_5^t	w_1^t	w_2^t	w_3^t	w_4^t	w_5^t	w_6^t
1970	0.236	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1971	0.243	0.963	0.971	0.923	0.927	0.975	0.943	0.951	0.950	0.936	0.947
1972	0.252	0.948	0.941	0.903	0.883	0.999	0.882	0.901	0.929	0.882	0.880
1973	0.259	0.943	0.941	0.905	0.831	0.979	0.871	0.899	0.966	0.844	0.839
1974	0.263	0.910	0.925	0.928	0.820	0.957	0.852	0.847	0.916	0.793	0.768
1975	0.275	0.905	0.903	0.882	0.787	0.942	0.836	0.866	1.009	0.815	0.808
1976	0.274	0.859	0.893	0.850	0.771	0.929	0.787	0.805	1.003	0.668	0.554
1977	0.293	0.866	0.873	0.833	0.760	0.917	0.800	0.862	1.110	0.805	0.764
1978	0.316	0.900	0.857	0.850	0.752	0.946	0.811	0.882	1.138	0.820	0.804
1979	0.334	0.905	0.830	0.836	0.711	0.965	0.785	0.872	1.149	0.815	0.827
1980	0.354	0.922	0.824	0.817	0.699	1.022	0.723	0.831	1.059	0.771	0.726
1981	0.362	0.901	0.810	0.798	0.701	0.994	0.692	0.811	1.024	0.749	0.713
1982	0.385	0.898	0.803	0.792	0.690	0.983	0.700	0.850	1.057	0.807	0.881
1983	0.421	0.916	0.801	0.800	0.721	0.978	0.707	0.957	1.049	0.896	1.183
1984	0.489	0.990	0.805	0.852	0.813	1.075	0.725	1.034	1.077	0.958	1.458

1985	0.522	1.018	0.775	0.916	0.881	1.116	0.677	0.975	1.039	0.886	1.385
1986	0.561	1.040	0.787	1.153	1.090	1.197	0.632	0.904	0.988	0.810	1.116
1987	0.597	1.052	0.765	1.180	1.169	1.205	0.594	0.888	0.932	0.823	1.187
1988	0.642	1.055	0.744	0.979	1.380	1.223	0.576	0.903	0.910	0.774	1.262
1989	0.629	1.020	0.714	0.792	1.121	1.195	0.515	0.783	0.849	0.686	0.922
1990	0.657	1.028	0.723	1.008	1.192	1.225	0.516	0.762	0.867	0.631	0.807
1991	0.742	1.068	0.730	1.042	1.193	1.251	0.558	0.910	0.883	0.708	1.212
1992	0.852	1.171	0.794	1.019	1.158	1.363	0.597	1.014	0.919	0.717	1.395
1993	0.983	1.258	0.882	0.817	1.000	1.472	0.627	1.168	0.934	0.639	1.268
1994	1.107	1.367	0.831	1.077	1.319	1.676	0.586	1.152	0.873	0.641	1.439
1995	1.137	1.308	0.709	0.899	1.098	1.594	0.522	1.089	0.791	0.750	1.985
1996	1.206	1.293	0.658	0.751	0.884	1.584	0.480	1.073	0.742	0.774	2.075
1997	1.289	1.310	0.641	0.677	0.808	1.630	0.454	1.050	0.700	0.782	2.218
1998	1.402	1.336	0.636	0.614	0.723	1.682	0.456	1.093	0.656	0.766	2.272
1999	1.489	1.350	0.625	0.613	0.757	1.739	0.432	1.062	0.628	0.728	2.359
2000	1.620	1.353	0.606	0.643	0.792	1.741	0.420	1.087	0.628	0.740	2.872
2001	1.746	1.394	0.604	0.638	0.751	1.820	0.406	1.062	0.633	0.729	2.790
2002	1.995	1.503	0.637	0.687	0.785	2.011	0.414	1.116	0.632	0.765	3.055
2003	2.254	1.623	0.656	0.760	0.858	2.264	0.401	1.125	0.642	0.736	2.834
2004	2.543	1.752	0.679	0.865	0.943	2.515	0.382	1.135	0.647	0.713	2.622
2005	2.938	1.866	0.702	0.934	0.966	2.765	0.375	1.161	0.655	0.739	2.541
2006	3.297	1.994	0.683	0.908	0.917	3.036	0.362	1.183	0.642	0.751	3.458
2007	3.917	2.311	0.698	0.930	0.921	3.630	0.361	1.284	0.637	0.792	4.889
2008	4.502	2.526	0.709	0.918	0.921	4.122	0.350	1.364	0.613	0.801	5.746
2009	5.046	2.699	0.706	0.834	0.800	4.637	0.340	1.289	0.600	0.869	6.900
2010	5.557	2.693	0.694	0.875	0.843	4.653	0.317	1.251	0.577	0.761	7.058
2011	5.907	2.760	0.675	0.819	0.787	4.954	0.278	1.153	0.522	0.689	5.627
2012	6.345	2.891	0.664	0.783	0.741	5.497	0.255	1.030	0.482	0.641	4.628
2013	6.818	2.980	0.644	0.738	0.693	5.940	0.236	0.942	0.451	0.585	4.672
2014	7.001	3.026	0.618	0.668	0.635	6.266	0.215	0.832	0.413	0.516	4.338
2015	7.426	3.140	0.590	0.622	0.550	6.788	0.205	0.778	0.393	0.503	6.010
2016	7.664	3.107	0.559	0.577	0.507	6.760	0.195	0.742	0.380	0.473	8.347
2017	8.502	3.191	0.562	0.575	0.523	6.957	0.197	0.831	0.375	0.507	13.556
2018	9.016	3.304	0.570	0.571	0.528	7.285	0.189	0.825	0.363	0.505	14.575
2019	8.906	3.328	0.546	0.554	0.522	7.494	0.170	0.727	0.329	0.457	13.630
2020	8.869	3.277	0.519	0.532	0.480	7.600	0.157	0.644	0.306	0.424	13.791

Table B5: Gross Real Income Growth, Real Output Price, and Input Growth Contribution Factors

Year	RI_G^t	TFP_G^t	α_2^t	α_3^t	α_4^t	α_5^t	β_1^t	β_2^t	β_3^t	β_4^t	β_5^t	β_6^t
1971	1.028	0.976	0.996	0.992	0.998	1.002	1.031	1.016	1.012	1.002	1.005	1.000
1972	1.038	1.002	0.998	0.992	0.999	1.002	1.014	1.013	1.013	1.002	1.002	1.000
1973	1.031	0.979	1.000	1.000	1.000	1.003	1.022	1.011	1.013	1.001	1.002	1.000
1974	1.013	0.973	0.996	0.995	1.001	1.001	1.021	1.011	1.012	1.001	1.002	1.000
1975	1.047	1.005	0.999	0.993	0.997	1.003	1.023	1.010	1.015	1.001	1.000	1.000
1976	0.996	0.958	0.994	0.997	0.998	1.001	1.019	1.013	1.016	1.002	0.999	1.000

1977	1.070	1.036	1.001	0.994	0.999	1.001	1.017	1.008	1.014	1.001	0.999	1.000
1978	1.077	1.028	1.005	0.995	1.001	1.001	1.019	1.006	1.017	1.001	1.003	1.000
1979	1.059	1.013	1.001	0.990	0.999	1.004	1.020	1.009	1.018	1.001	1.004	1.000
1980	1.060	1.005	1.002	0.998	0.999	1.001	1.025	1.004	1.020	1.001	1.004	1.000
1981	1.021	0.981	0.997	0.995	0.998	1.000	1.024	1.001	1.021	1.001	1.003	1.000
1982	1.065	1.020	1.000	0.998	0.999	1.001	1.025	0.998	1.022	1.001	1.001	1.000
1983	1.092	1.048	1.003	1.000	1.001	0.997	1.015	1.002	1.023	1.001	1.000	1.000
1984	1.162	1.086	1.011	1.002	1.005	0.989	1.031	1.004	1.023	1.002	1.002	1.000
1985	1.069	1.006	1.004	0.988	1.007	0.989	1.033	1.009	1.024	1.002	1.006	1.000
1986	1.074	1.001	1.003	1.005	1.026	0.966	1.025	1.014	1.024	1.002	1.006	1.000
1987	1.063	1.012	1.002	0.991	1.003	0.989	1.024	1.013	1.022	1.002	1.004	1.000
1988	1.076	1.072	1.000	0.991	0.975	0.975	1.023	1.016	1.021	1.002	1.002	1.000
1989	0.979	0.940	0.996	0.987	0.973	1.032	1.011	1.016	1.022	1.002	1.005	1.000
1990	1.044	0.969	1.001	1.004	1.038	0.991	1.013	1.006	1.017	1.001	1.005	1.000
1991	1.129	1.071	1.005	1.003	1.006	1.000	1.015	1.004	1.015	1.001	1.003	1.000
1992	1.149	1.048	1.013	1.028	0.996	1.006	1.019	1.007	1.017	1.002	1.007	1.000
1993	1.154	1.041	1.011	1.040	0.960	1.029	1.023	1.013	1.024	1.002	1.004	1.000
1994	1.126	1.075	1.012	0.977	1.062	0.939	1.009	1.020	1.027	1.002	1.002	1.000
1995	1.027	1.030	0.994	0.940	0.955	1.046	1.014	1.020	1.028	1.002	1.003	1.000
1996	1.060	1.009	0.998	0.973	0.960	1.048	1.019	1.015	1.032	1.002	1.005	1.000
1997	1.069	1.016	1.002	0.991	0.977	1.018	1.012	1.014	1.031	1.002	1.005	1.000
1998	1.087	1.029	1.003	0.997	0.979	1.020	1.005	1.016	1.031	1.002	1.003	1.000
1999	1.063	1.011	1.002	0.994	1.000	0.992	1.013	1.017	1.030	1.002	1.002	1.000
2000	1.088	1.022	1.000	0.990	1.011	0.991	1.020	1.017	1.031	1.002	1.002	1.000
2001	1.078	0.992	1.005	0.999	0.998	1.012	1.015	1.018	1.031	1.003	1.003	1.000
2002	1.143	1.029	1.013	1.020	1.019	0.990	1.009	1.020	1.031	1.003	1.003	1.000
2003	1.130	1.018	1.013	1.012	1.030	0.976	1.016	1.023	1.031	1.003	1.002	1.000
2004	1.128	1.001	1.012	1.015	1.045	0.970	1.014	1.028	1.032	1.003	1.003	1.000
2005	1.155	1.003	1.010	1.015	1.030	0.992	1.030	1.028	1.033	1.003	1.002	1.000
2006	1.122	1.047	1.010	0.988	0.989	1.019	1.000	1.030	1.029	1.004	1.002	1.000
2007	1.188	1.080	1.023	1.009	1.010	0.998	0.991	1.029	1.029	1.004	1.003	1.000
2008	1.149	1.062	1.014	1.008	0.995	1.000	0.996	1.030	1.030	1.004	1.005	1.000
2009	1.121	1.025	1.010	0.998	0.969	1.039	1.007	1.030	1.028	1.005	1.004	1.002
2010	1.101	0.986	1.000	0.991	1.014	0.986	1.043	1.033	1.034	1.007	1.003	1.002
2011	1.063	0.981	1.004	0.986	0.980	1.020	1.015	1.033	1.032	1.007	1.004	1.001
2012	1.074	0.993	1.008	0.991	0.986	1.017	1.009	1.024	1.033	1.007	1.003	1.001
2013	1.075	1.007	1.005	0.985	0.983	1.018	1.010	1.026	1.028	1.008	1.003	1.000
2014	1.027	0.996	1.003	0.979	0.972	1.023	0.996	1.020	1.028	1.008	1.002	1.000
2015	1.061	1.024	1.006	0.977	0.982	1.034	0.986	1.015	1.027	1.008	1.002	1.000
2016	1.032	1.014	0.998	0.975	0.983	1.017	1.001	1.010	1.026	1.007	1.001	1.000
2017	1.109	1.068	1.005	1.002	0.999	0.994	0.993	1.012	1.026	1.006	1.001	1.000
2018	1.061	1.004	1.006	1.007	0.999	0.998	0.997	1.013	1.026	1.006	1.001	1.003
2019	0.988	0.975	1.001	0.980	0.994	1.002	0.990	1.012	1.025	1.006	1.001	1.002
2020	0.996	0.975	0.997	0.978	0.992	1.016	1.000	1.010	1.023	1.006	1.001	1.000
Mean	1.076	1.015	1.004	0.995	0.998	1.003	1.014	1.015	1.024	1.003	1.003	1.000

Table B6: Decomposition for Real Gross Income Growth in China

Year	RI^t/RI^{1970}	TFP^t	A_2^t	A_3^t	A_4^t	A_5^t	B_1^t	B_2^t	B_3^t	B_4^t	B_5^t	B_6^t
1970	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1971	1.028	0.976	0.996	0.992	0.998	1.002	1.031	1.016	1.012	1.002	1.004	1.000
1972	1.066	0.978	0.994	0.984	0.997	1.004	1.045	1.029	1.025	1.003	1.007	1.000
1973	1.099	0.957	0.993	0.984	0.997	1.006	1.069	1.040	1.039	1.004	1.009	1.001
1974	1.113	0.932	0.989	0.979	0.998	1.007	1.091	1.052	1.051	1.005	1.011	1.001
1975	1.166	0.936	0.989	0.973	0.996	1.010	1.116	1.062	1.067	1.007	1.011	1.001
1976	1.161	0.896	0.983	0.970	0.994	1.011	1.137	1.076	1.084	1.008	1.010	1.001
1977	1.242	0.928	0.984	0.964	0.993	1.012	1.157	1.084	1.099	1.009	1.009	1.001
1978	1.337	0.954	0.988	0.958	0.994	1.012	1.179	1.091	1.118	1.010	1.012	1.002
1979	1.416	0.966	0.989	0.949	0.993	1.016	1.202	1.101	1.137	1.011	1.015	1.002
1980	1.500	0.971	0.991	0.947	0.992	1.017	1.232	1.105	1.160	1.012	1.020	1.002
1981	1.532	0.952	0.988	0.942	0.990	1.017	1.261	1.107	1.184	1.014	1.022	1.002
1982	1.632	0.971	0.988	0.940	0.989	1.018	1.293	1.104	1.210	1.014	1.023	1.002
1983	1.782	1.018	0.990	0.940	0.990	1.015	1.312	1.106	1.238	1.016	1.023	1.003
1984	2.071	1.105	1.001	0.941	0.995	1.004	1.354	1.110	1.267	1.017	1.025	1.003
1985	2.214	1.112	1.005	0.929	1.002	0.993	1.398	1.120	1.297	1.019	1.031	1.003
1986	2.378	1.113	1.007	0.934	1.029	0.959	1.432	1.136	1.329	1.022	1.038	1.003
1987	2.529	1.126	1.009	0.926	1.032	0.949	1.466	1.151	1.358	1.024	1.042	1.004
1988	2.722	1.207	1.009	0.917	1.006	0.925	1.500	1.170	1.386	1.026	1.044	1.004
1989	2.665	1.135	1.005	0.905	0.978	0.955	1.516	1.188	1.417	1.029	1.049	1.004
1990	2.783	1.100	1.006	0.908	1.015	0.946	1.535	1.195	1.441	1.030	1.055	1.004
1991	3.142	1.178	1.011	0.910	1.021	0.946	1.558	1.200	1.463	1.031	1.058	1.004
1992	3.608	1.234	1.025	0.936	1.017	0.951	1.587	1.208	1.487	1.033	1.066	1.004
1993	4.164	1.285	1.036	0.974	0.976	0.979	1.623	1.224	1.522	1.035	1.070	1.004
1994	4.690	1.382	1.048	0.951	1.037	0.919	1.638	1.249	1.564	1.037	1.072	1.005
1995	4.819	1.423	1.042	0.894	0.990	0.961	1.660	1.274	1.608	1.039	1.076	1.005
1996	5.108	1.437	1.040	0.870	0.950	1.007	1.692	1.293	1.660	1.041	1.081	1.005
1997	5.462	1.460	1.042	0.862	0.929	1.025	1.712	1.311	1.712	1.043	1.086	1.005
1998	5.939	1.502	1.045	0.860	0.909	1.046	1.721	1.333	1.764	1.045	1.089	1.005
1999	6.311	1.519	1.047	0.854	0.908	1.037	1.744	1.355	1.818	1.047	1.091	1.005
2000	6.863	1.552	1.047	0.845	0.918	1.027	1.778	1.377	1.873	1.050	1.093	1.005
2001	7.399	1.541	1.052	0.844	0.917	1.040	1.804	1.403	1.932	1.052	1.096	1.005
2002	8.454	1.584	1.066	0.861	0.934	1.029	1.820	1.431	1.993	1.055	1.099	1.006
2003	9.551	1.613	1.079	0.871	0.962	1.004	1.848	1.464	2.055	1.058	1.102	1.006
2004	10.773	1.614	1.092	0.884	1.005	0.974	1.874	1.504	2.121	1.062	1.105	1.006
2005	12.447	1.619	1.103	0.898	1.035	0.966	1.930	1.546	2.191	1.065	1.108	1.006
2006	13.969	1.695	1.114	0.887	1.024	0.983	1.931	1.593	2.255	1.069	1.109	1.007
2007	16.595	1.831	1.140	0.895	1.034	0.982	1.914	1.639	2.320	1.073	1.113	1.007
2008	19.075	1.943	1.156	0.902	1.028	0.982	1.907	1.688	2.388	1.077	1.118	1.007
2009	21.380	1.991	1.168	0.900	0.997	1.020	1.921	1.738	2.455	1.083	1.122	1.009
2010	23.545	1.963	1.167	0.892	1.011	1.007	2.002	1.796	2.538	1.090	1.126	1.011
2011	25.027	1.926	1.172	0.880	0.990	1.027	2.032	1.856	2.618	1.098	1.130	1.012
2012	26.882	1.913	1.181	0.872	0.977	1.044	2.049	1.901	2.705	1.106	1.134	1.013
2013	28.886	1.926	1.187	0.859	0.960	1.063	2.070	1.950	2.781	1.114	1.137	1.013
2014	29.663	1.919	1.190	0.841	0.934	1.088	2.062	1.989	2.859	1.123	1.139	1.014

2015	31.465	1.964	1.198	0.822	0.917	1.124	2.034	2.018	2.937	1.132	1.142	1.014
2016	32.471	1.991	1.196	0.801	0.901	1.143	2.035	2.038	3.014	1.140	1.143	1.014
2017	36.022	2.126	1.201	0.803	0.900	1.136	2.021	2.062	3.092	1.147	1.145	1.014
2018	38.202	2.135	1.208	0.809	0.899	1.134	2.014	2.089	3.172	1.154	1.146	1.017
2019	37.732	2.081	1.210	0.793	0.894	1.136	1.995	2.114	3.251	1.161	1.147	1.020
2020	37.578	2.029	1.207	0.775	0.886	1.154	1.994	2.135	3.327	1.168	1.148	1.020

Table B7: Nonparametric Decomposition of Real GDP Growth Relative to the 1970 Level

Year	RI^t/RI^{1970}	A^t	B^t	C^t	E^t	T^t	$NTFP^t$
1970	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1971	1.028	0.988	1.066	1.000	0.976	1.000	0.976
1972	1.066	0.979	1.114	0.999	0.979	1.000	0.977
1973	1.099	0.981	1.171	0.999	0.958	1.000	0.958
1974	1.114	0.974	1.227	0.999	0.933	1.000	0.932
1975	1.166	0.967	1.288	0.999	0.937	1.000	0.936
1976	1.161	0.959	1.353	1.001	0.894	1.000	0.895
1977	1.242	0.954	1.406	1.000	0.926	1.000	0.926
1978	1.337	0.954	1.472	0.999	0.954	1.000	0.953
1979	1.416	0.948	1.549	0.995	0.970	1.000	0.965
1980	1.501	0.948	1.633	0.987	0.982	1.000	0.969
1981	1.532	0.941	1.717	0.986	0.962	1.000	0.949
1982	1.632	0.939	1.797	0.985	0.982	1.000	0.967
1983	1.782	0.939	1.872	0.986	1.000	1.028	1.013
1984	2.071	0.945	1.991	0.986	1.000	1.117	1.101
1985	2.214	0.934	2.142	0.986	1.000	1.123	1.107
1986	2.378	0.935	2.301	0.985	1.000	1.123	1.105
1987	2.529	0.922	2.455	0.984	1.000	1.135	1.117
1988	2.722	0.869	2.616	0.984	1.000	1.217	1.198
1989	2.665	0.856	2.765	0.983	0.941	1.217	1.126
1990	2.783	0.879	2.884	0.982	0.918	1.217	1.098
1991	3.142	0.890	2.998	0.985	0.983	1.217	1.178
1992	3.608	0.928	3.152	0.984	1.000	1.253	1.234
1993	4.164	0.964	3.364	0.984	1.000	1.304	1.284
1994	4.690	0.950	3.572	0.984	1.000	1.404	1.382
1995	4.819	0.887	3.817	0.984	1.000	1.447	1.424
1996	5.109	0.866	4.106	0.984	1.000	1.460	1.437
1997	5.462	0.855	4.377	0.984	1.000	1.484	1.460
1998	5.939	0.853	4.633	0.984	1.000	1.526	1.502
1999	6.311	0.842	4.933	0.984	1.000	1.543	1.519
2000	6.863	0.835	5.294	0.984	1.000	1.578	1.553
2001	7.400	0.846	5.672	0.984	0.993	1.578	1.542
2002	8.454	0.881	6.053	0.983	1.000	1.613	1.586
2003	9.551	0.907	6.522	0.983	1.000	1.642	1.614
2004	10.773	0.945	7.059	0.983	1.000	1.644	1.615
2005	12.447	0.989	7.766	0.983	1.000	1.649	1.620
2006	13.969	0.995	8.282	0.983	1.000	1.726	1.696
2007	16.595	1.036	8.750	0.983	1.000	1.864	1.832

2008	19.075	1.052	9.323	0.983	1.000	1.978	1.944
2009	21.380	1.068	10.049	0.983	1.000	2.027	1.992
2010	23.545	1.059	11.324	0.982	0.986	2.027	1.963
2011	25.027	1.047	12.405	0.978	0.973	2.027	1.928
2012	26.882	1.048	13.386	0.968	0.977	2.027	1.917
2013	28.886	1.037	14.410	0.956	0.997	2.027	1.932
2014	29.663	1.013	15.210	0.951	0.999	2.027	1.925
2015	31.465	1.011	15.786	0.951	1.000	2.074	1.971
2016	32.471	0.984	16.524	0.951	1.000	2.102	1.998
2017	36.023	0.983	17.171	0.951	1.000	2.245	2.134
2018	38.202	0.993	17.957	0.951	1.000	2.254	2.143
2019	37.732	0.970	18.622	0.949	0.977	2.254	2.090
2020	37.578	0.952	19.376	0.945	0.956	2.254	2.037

Table B8: Net Real Income, Real Net Output Prices, and Real Net Input Prices

Year	RI^{t*}	p_2^{t*}	p_3^{t*}	p_4^{t*}	p_5^{t*}	w_1^{t*}	w_2^{t*}	w_3^{t*}	w_4^{t*}	w_5^{t*}	w_6^{t*}
1970	0.220	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1971	0.227	0.963	1.029	0.923	0.927	0.975	0.952	0.972	0.951	0.961	1.014
1972	0.238	0.948	1.062	0.903	0.883	0.999	0.897	0.941	0.935	0.933	1.020
1973	0.246	0.943	1.124	0.905	0.831	0.979	0.897	0.963	0.982	0.918	1.049
1974	0.252	0.910	1.175	0.928	0.820	0.957	0.883	0.933	0.925	0.891	1.059
1975	0.266	0.905	1.221	0.882	0.787	0.942	0.900	0.989	1.059	0.937	1.155
1976	0.262	0.859	1.279	0.850	0.771	0.929	0.774	0.864	0.977	0.806	1.023
1977	0.289	0.866	1.322	0.833	0.760	0.917	0.924	1.047	1.234	0.971	1.251
1978	0.315	0.900	1.367	0.850	0.752	0.947	0.968	1.101	1.302	1.003	1.360
1979	0.338	0.905	1.392	0.836	0.711	0.965	0.972	1.115	1.342	1.013	1.462
1980	0.367	0.922	1.500	0.817	0.699	1.022	0.907	1.111	1.235	1.012	1.514
1981	0.383	0.901	1.605	0.798	0.701	0.994	0.892	1.114	1.221	1.031	1.663
1982	0.420	0.898	1.732	0.792	0.690	0.983	0.957	1.224	1.331	1.134	1.981
1983	0.470	0.916	1.887	0.800	0.721	0.979	1.030	1.413	1.400	1.258	2.443
1984	0.555	0.990	2.048	0.852	0.813	1.075	1.103	1.580	1.508	1.349	2.915
1985	0.602	1.018	2.096	0.916	0.881	1.117	1.045	1.562	1.486	1.276	2.997
1986	0.660	1.040	2.268	1.153	1.090	1.197	0.981	1.534	1.412	1.234	3.043
1987	0.720	1.052	2.363	1.180	1.170	1.205	0.961	1.593	1.387	1.289	3.354
1988	0.775	1.055	2.380	0.979	1.380	1.223	0.957	1.625	1.396	1.243	3.514
1989	0.774	1.020	2.383	0.792	1.121	1.195	0.868	1.459	1.297	1.194	3.412
1990	0.813	1.028	2.446	1.008	1.192	1.225	0.864	1.421	1.305	1.143	3.574
1991	0.906	1.068	2.507	1.042	1.193	1.251	0.929	1.569	1.350	1.227	4.241
1992	1.042	1.171	2.693	1.019	1.158	1.363	0.983	1.758	1.399	1.216	4.805
1993	1.177	1.258	2.889	0.817	1.000	1.472	0.975	1.952	1.369	1.073	4.931
1994	1.276	1.367	2.660	1.077	1.319	1.676	0.886	1.825	1.240	1.018	5.007
1995	1.287	1.308	2.265	0.899	1.098	1.594	0.804	1.651	1.148	1.101	5.304
1996	1.332	1.293	2.088	0.751	0.884	1.584	0.714	1.533	1.055	1.104	5.400
1997	1.417	1.310	2.012	0.677	0.808	1.630	0.665	1.487	0.976	1.086	5.743
1998	1.496	1.336	1.964	0.614	0.723	1.682	0.634	1.438	0.890	1.045	6.138
1999	1.584	1.350	1.901	0.613	0.757	1.739	0.596	1.393	0.835	0.965	6.531
2000	1.705	1.353	1.834	0.643	0.793	1.741	0.582	1.403	0.839	0.941	7.228

2001	1.821	1.394	1.847	0.638	0.751	1.820	0.548	1.349	0.827	0.907	7.665
2002	2.079	1.503	2.008	0.687	0.785	2.011	0.555	1.423	0.805	0.936	8.849
2003	2.342	1.623	2.146	0.760	0.858	2.264	0.525	1.435	0.810	0.903	9.595
2004	2.652	1.752	2.300	0.865	0.943	2.515	0.502	1.479	0.813	0.890	10.352
2005	3.070	1.866	2.489	0.934	0.966	2.765	0.491	1.520	0.818	0.948	11.797
2006	3.447	1.994	2.520	0.908	0.917	3.036	0.488	1.550	0.827	0.966	13.774
2007	4.083	2.311	2.656	0.930	0.921	3.630	0.495	1.670	0.833	1.012	16.698
2008	4.640	2.526	2.776	0.918	0.921	4.122	0.474	1.720	0.776	1.018	19.240
2009	5.284	2.699	2.864	0.834	0.800	4.637	0.468	1.665	0.755	1.095	22.881
2010	5.720	2.693	2.826	0.875	0.843	4.653	0.426	1.579	0.716	0.938	23.637
2011	5.991	2.760	2.752	0.819	0.787	4.954	0.361	1.439	0.621	0.840	22.105
2012	6.368	2.891	2.742	0.783	0.741	5.497	0.314	1.283	0.535	0.780	21.649
2013	6.758	2.980	2.682	0.739	0.693	5.940	0.284	1.172	0.489	0.704	21.729
2014	6.886	3.026	2.596	0.668	0.635	6.266	0.247	1.036	0.430	0.612	21.455
2015	7.283	3.140	2.511	0.622	0.550	6.789	0.237	0.973	0.416	0.581	23.397
2016	7.472	3.107	2.401	0.577	0.507	6.760	0.225	0.926	0.415	0.530	25.144
2017	8.285	3.191	2.427	0.575	0.523	6.957	0.239	1.053	0.444	0.554	29.047
2018	8.760	3.304	2.476	0.571	0.528	7.286	0.226	1.053	0.421	0.541	29.287
2019	8.574	3.328	2.377	0.554	0.522	7.494	0.194	0.930	0.359	0.478	26.833
2020	8.485	3.277	2.262	0.532	0.480	7.600	0.174	0.835	0.320	0.435	25.608

Table B9: Net Real Income Growth and Real Output Price and Input Growth Contribution Factors

Year	RI_G^{t*}	TFP_G^{t*}	α_2^{t*}	α_3^{t*}	α_4^{t*}	α_5^{t*}	β_1^{t*}	β_2^{t*}	β_3^{t*}	β_4^{t*}	β_5^{t*}	β_6^{t*}
1971	1.034	0.976	0.995	1.006	0.998	1.003	1.033	1.008	1.010	1.001	1.005	1.000
1972	1.046	1.003	0.998	1.007	0.999	1.002	1.015	1.007	1.012	1.001	1.002	1.000
1973	1.037	0.978	0.999	1.013	1.000	1.003	1.024	1.005	1.012	1.001	1.002	1.000
1974	1.021	0.972	0.996	1.010	1.001	1.001	1.022	1.006	1.011	1.001	1.002	1.000
1975	1.057	1.004	0.999	1.009	0.997	1.003	1.024	1.005	1.014	1.001	1.000	1.001
1976	0.984	0.940	0.994	1.012	0.998	1.001	1.020	1.007	1.015	1.001	0.999	1.000
1977	1.105	1.058	1.001	1.009	0.999	1.001	1.018	1.004	1.013	1.000	0.999	1.000
1978	1.089	1.027	1.005	1.010	1.001	1.001	1.019	1.003	1.017	1.000	1.003	1.000
1979	1.073	1.015	1.001	1.006	0.999	1.004	1.020	1.005	1.018	1.001	1.004	1.001
1980	1.086	1.006	1.002	1.023	0.999	1.001	1.024	1.002	1.020	1.001	1.005	1.000
1981	1.045	0.979	0.997	1.021	0.998	1.000	1.023	1.001	1.022	1.001	1.003	1.000
1982	1.096	1.021	1.000	1.025	1.000	1.001	1.023	0.999	1.023	1.000	1.001	1.001
1983	1.118	1.043	1.002	1.030	1.001	0.997	1.014	1.001	1.024	1.001	1.000	1.001
1984	1.181	1.077	1.009	1.031	1.005	0.991	1.028	1.002	1.025	1.001	1.002	1.001
1985	1.085	1.004	1.003	1.010	1.006	0.991	1.028	1.005	1.026	1.001	1.007	1.001
1986	1.096	0.997	1.003	1.035	1.023	0.971	1.021	1.008	1.027	1.001	1.008	1.001
1987	1.091	1.015	1.001	1.018	1.003	0.991	1.020	1.008	1.025	1.001	1.005	1.001
1988	1.077	1.057	1.000	1.003	0.979	0.979	1.019	1.010	1.025	1.001	1.002	1.001
1989	0.998	0.947	0.996	1.001	0.977	1.026	1.009	1.009	1.026	1.001	1.007	1.001
1990	1.051	0.974	1.001	1.011	1.030	0.992	1.010	1.004	1.020	1.001	1.007	1.001
1991	1.114	1.052	1.004	1.011	1.005	1.000	1.012	1.003	1.017	1.001	1.005	1.001
1992	1.151	1.050	1.011	1.033	0.996	1.005	1.015	1.004	1.019	1.001	1.009	1.001
1993	1.130	1.030	1.009	1.035	0.967	1.024	1.019	1.008	1.026	1.001	1.006	1.001
1994	1.084	1.062	1.011	0.960	1.053	0.948	1.008	1.011	1.030	1.001	1.003	1.001

1995	1.008	1.031	0.995	0.929	0.961	1.040	1.012	1.011	1.030	1.001	1.004	1.001
1996	1.035	1.001	0.999	0.965	0.964	1.043	1.017	1.009	1.034	1.001	1.006	1.000
1997	1.064	1.024	1.002	0.985	0.979	1.016	1.011	1.008	1.032	1.001	1.006	1.000
1998	1.056	1.014	1.003	0.991	0.980	1.019	1.005	1.009	1.030	1.001	1.004	1.000
1999	1.059	1.023	1.002	0.988	1.000	0.992	1.012	1.010	1.030	1.001	1.002	1.000
2000	1.076	1.025	1.000	0.986	1.010	0.991	1.019	1.009	1.030	1.001	1.003	1.000
2001	1.068	0.991	1.005	1.003	0.998	1.012	1.014	1.010	1.030	1.001	1.003	1.000
2002	1.142	1.027	1.012	1.034	1.018	0.990	1.009	1.010	1.030	1.001	1.003	1.000
2003	1.126	1.013	1.012	1.029	1.029	0.977	1.015	1.011	1.030	1.002	1.002	1.002
2004	1.133	1.005	1.012	1.032	1.044	0.971	1.013	1.013	1.031	1.001	1.003	1.001
2005	1.158	1.001	1.009	1.038	1.029	0.992	1.029	1.014	1.032	1.001	1.003	1.001
2006	1.123	1.046	1.010	1.006	0.989	1.018	1.000	1.015	1.029	1.001	1.002	1.002
2007	1.185	1.077	1.022	1.025	1.009	0.998	0.992	1.015	1.028	1.002	1.004	1.002
2008	1.136	1.051	1.013	1.022	0.995	1.000	0.997	1.016	1.029	1.002	1.005	1.001
2009	1.139	1.035	1.010	1.016	0.970	1.038	1.007	1.016	1.027	1.002	1.004	1.007
2010	1.082	0.984	1.000	0.993	1.014	0.987	1.041	1.018	1.032	1.003	1.004	1.006
2011	1.048	0.984	1.004	0.986	0.980	1.019	1.015	1.017	1.031	1.003	1.005	1.004
2012	1.063	0.991	1.008	0.998	0.987	1.017	1.008	1.012	1.032	1.002	1.004	1.003
2013	1.061	1.009	1.005	0.989	0.983	1.018	1.010	1.012	1.028	1.003	1.003	1.001
2014	1.019	0.998	1.003	0.984	0.972	1.023	0.996	1.010	1.028	1.002	1.003	1.002
2015	1.058	1.026	1.007	0.984	0.982	1.035	0.986	1.007	1.027	1.002	1.002	1.000
2016	1.026	1.012	0.998	0.980	0.983	1.017	1.001	1.005	1.026	1.002	1.002	1.002
2017	1.109	1.074	1.005	1.005	0.999	0.994	0.993	1.006	1.026	1.002	1.002	1.001
2018	1.057	1.004	1.006	1.010	0.999	0.998	0.997	1.006	1.027	1.002	1.001	1.007
2019	0.979	0.970	1.001	0.981	0.994	1.002	0.990	1.006	1.026	1.002	1.001	1.006
2020	0.990	0.975	0.997	0.979	0.991	1.016	1.000	1.005	1.025	1.002	1.001	1.000
Mean	1.077	1.014	1.004	1.005	0.998	1.003	1.013	1.008	1.025	1.001	1.003	1.001

Table B10: Nonparametric Decomposition of Real NDP Growth Relative to the 1970 Level

Year	RI^{t*}/RI^{1970*}	A^{t*}	B^{t*}	C^{t*}	E^{t*}	T^{t*}	$NTFP^{t*}$
1970	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1971	1.034	1.003	1.058	1.000	0.975	1.000	0.975
1972	1.081	1.009	1.097	0.999	0.978	1.000	0.977
1973	1.121	1.025	1.146	0.999	0.956	1.000	0.955
1974	1.145	1.033	1.193	0.998	0.930	1.000	0.928
1975	1.211	1.043	1.246	0.999	0.933	1.000	0.932
1976	1.191	1.050	1.298	0.995	0.878	1.000	0.874
1977	1.315	1.061	1.343	1.001	0.922	1.000	0.923
1978	1.433	1.075	1.402	1.000	0.950	1.000	0.950
1979	1.537	1.083	1.470	0.997	0.969	1.000	0.966
1980	1.669	1.108	1.548	0.990	0.983	1.000	0.973
1981	1.745	1.129	1.625	0.986	0.965	1.000	0.951
1982	1.912	1.157	1.702	0.985	0.986	1.000	0.971
1983	2.138	1.193	1.771	0.985	1.000	1.028	1.013
1984	2.526	1.235	1.876	0.985	1.000	1.107	1.090
1985	2.742	1.247	2.008	0.985	1.000	1.112	1.095

1986	3.005	1.285	2.144	0.984	0.998	1.112	1.091
1987	3.277	1.302	2.275	0.983	1.000	1.125	1.106
1988	3.529	1.253	2.408	0.983	1.000	1.190	1.170
1989	3.522	1.253	2.537	0.982	0.948	1.190	1.108
1990	3.703	1.291	2.647	0.981	0.928	1.190	1.084
1991	4.123	1.316	2.748	0.981	0.977	1.190	1.140
1992	4.745	1.375	2.884	0.981	1.000	1.220	1.197
1993	5.359	1.421	3.059	0.981	1.000	1.257	1.233
1994	5.810	1.375	3.223	0.981	1.000	1.337	1.311
1995	5.857	1.269	3.416	0.981	1.000	1.379	1.352
1996	6.063	1.228	3.649	0.980	1.000	1.380	1.353
1997	6.451	1.205	3.865	0.980	1.000	1.413	1.385
1998	6.809	1.195	4.059	0.980	1.000	1.432	1.404
1999	7.209	1.172	4.282	0.980	1.000	1.465	1.436
2000	7.760	1.158	4.551	0.980	1.000	1.502	1.472
2001	8.289	1.178	4.822	0.980	0.992	1.502	1.460
2002	9.463	1.242	5.082	0.979	1.000	1.532	1.500
2003	10.659	1.300	5.399	0.979	1.000	1.552	1.519
2004	12.071	1.375	5.751	0.979	1.000	1.560	1.527
2005	13.973	1.469	6.223	0.979	1.000	1.562	1.529
2006	15.690	1.502	6.533	0.979	1.000	1.634	1.599
2007	18.585	1.586	6.804	0.979	1.000	1.760	1.723
2008	21.119	1.633	7.146	0.979	1.000	1.849	1.809
2009	24.053	1.688	7.609	0.979	1.000	1.914	1.873
2010	26.035	1.676	8.429	0.978	0.985	1.914	1.843
2011	27.270	1.656	9.072	0.975	0.973	1.914	1.816
2012	28.985	1.668	9.643	0.966	0.975	1.914	1.803
2013	30.764	1.656	10.200	0.956	0.996	1.914	1.822
2014	31.345	1.624	10.612	0.950	1.000	1.915	1.819
2015	33.150	1.633	10.871	0.950	1.000	1.965	1.868
2016	34.012	1.596	11.276	0.950	1.000	1.989	1.890
2017	37.711	1.600	11.610	0.950	1.000	2.137	2.031
2018	39.874	1.620	12.081	0.950	1.000	2.145	2.038
2019	39.029	1.584	12.452	0.949	0.973	2.145	1.979
2020	38.625	1.557	12.851	0.945	0.953	2.145	1.931