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Appendix to “Forecasting China’s Economic Growth over the Next Two Decades”
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Introduction

Our projection of China’s future economic performance builds on the realities of economic growth during the years 1952-2005. We summarize economic outcomes during this half-century by compiling time series data representing aggregate output, fixed capital stock, and working-age population (ages 16-65) classified according to educational attainment. We use these data to analyze trends in total factor productivity (TFP), which illuminate changes in output per unit of available labor and fixed capital.

Other researchers have undertaken similar efforts, most notably Alwyn Young (2003), who focused on the non-agricultural segment of China’s economy during the period 1978-1998. Other comparable studies include Gregory C. Chow and Anloh Lin (2003).

Main characteristics of the present analysis include:

1. Coverage extends to the entire economy, including the farm sector.
2. On the input side, we focus on labor (number of non-student workers aged 16-65 plus adjustment for educational attainment) and fixed capital, excluding working capital (primarily inventories) and land.
3. We decompose the working-age population (ages 16-65) according to educational attainment.
4. We seek to discern trends in output per unit of available capital and education-enhanced labor. We do not attempt to measure the utilization of labor or fixed assets. Less-than-full employment of either factor will reduce the level and/or growth of these inputs. Note that Young (2003) focuses on employment (whereas we focus on working-age non-student population); his measure of fixed assets parallels ours.
5. This means that our TFP measures are not affected by such changes as the rise (during the 1960s) and fall (during the past decade) of urban female participation

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rates, by the recent trend toward early retirement for urban female employees, or by fluctuations in the utilization of industrial capacity.

The following pages lay out the data, assumptions, and calculations underpinning the time series for GDP, fixed capital, labor force, and educational attainment that we use to derive estimates of productivity growth for the period 1952-2005 and to create projections to 2025.

I. AGGREGATE OUTPUT, 1952-2005

A. Why use official data?

We base our analysis on the most recent GDP data issued by China's National Bureau of Statistics (NBS, formerly known as the State Statistical Bureau). These data are subject to a variety of criticisms, some of which date back to the 1960s. Despite the limitations of official data, we believe that the figures compiled by NBS provide the best available picture of long-term trends in China's economy – the focus of our study. We comment briefly on possible weaknesses of these data.

Economists have been struggling with weaknesses in China's post-1949 published economic data since the first Chinese statistical handbook was published in 1960 (National Bureau of Statistics [1960]) and even before that. One of the first efforts to systematically construct GDP accounts for China was done by T.C. Liu and K.C. Yeh in 1965. They accepted many official data as the starting point for their analysis, but adjusted these figures to eliminate what they believed were distortions due both to weaknesses in the underlying estimates of the production of particular items and to biases introduced by the fact that Chinese prices were not determined by market forces. China stopped the regular publishing of economic data from 1961 through 1979, but that did not stop analyses of the weaknesses and biases in these data as can be seen from a book devoted to the subject edited by Alexander Eckstein in 1980. We will return to a discussion of some of the data issues surrounding the figures published before 1979 as well as after that date later in this essay.

While there was disagreement among specialists on the Chinese economy over the magnitude of some of the biases in the Chinese data from this earlier period, there was something approaching a consensus that, when Chinese statistics reflected poorly on the performance of the Chinese economy, the Chinese government did not typically resort to the publication of massively falsified data except during the 1958-1960 period. Instead the government simply decided not to publish any data at all. Until the National Bureau of Statistics in recent years began to compile retrospective statistical handbooks, the only source of useable data for the 1958-1978 period was information leaked by one Chinese leader or another from time to time, or was derived by compiling trade data from China's trading partners.

For the reform period, many authors have provided evidence suggesting that the official GDP aggregates, and especially the officially-reported figures for industrial output growth, may overstate actual growth. Maddison (1998), Lian Meng and Wang Xiaolu (2000) and Young (2003) are among those who propose downward adjustment of aggregate GDP growth for certain periods. Rawski (2001, 2002, 2005) has suggested that political pressure may have caused official growth figures for 1998-2001 and for 2003 to substantially overstate actual results. Many authors, including W.T. Woo et al (1993), Szirmai and Ren (2000), and Harry X. Wu (2002), have argued that official output data may overstate industrial growth, particularly in the collective/TVE sector. Results from the 1995 industrial census confirmed this suspicion (Jefferson et al 2000, p. 790).

What is the best way of dealing with suspicions, in some cases well-founded, that specific indicators may overstate performance? Some researchers turn to alternate output indicators (e.g. Harry Wu using physical output of industrial products). Others invent data by arbitrarily reducing reported growth rates (as in the Penn World Tables) or applying data from other economies (e.g. Angus Maddison using OECD data on growth of services – see Holz 2006a). Young (2003) accepts the official figures for nominal GDP but replaces the implicit deflators built into the official data with alternate indicators – for example using ex-factory prices of industrial products to deflate nominal value-added for industry.

Some of these procedures seem plausible to us; others less so. Plausible alternatives, such as Young's revision of GDP deflators, have the effect of replacing official series with revised data that researchers regard as more "reasonable" than the original. However the "more reasonable" criterion is rarely subject to verification and possible rejection. Young's (2003) substitution of ex-factory prices for the implicit deflator, for example, assumes that prices of industrial outputs and material inputs move in tandem. But we know that the years 1978-98 covered in his study brought increases in the relative prices of agricultural products, energy and mineral products. Without detailed investigation of the impact of such price changes on the deflator for industrial value-added, it is by no means clear that Young's choice of deflator improves the accuracy of GDP data.

Leaving aside the particulars of various research efforts, proposed alternatives to official measures suffer from two weaknesses:

1. Inattention to possible downward bias in official growth measures.
Two items are of particular importance here:
 - Under-measurement of the level and growth of output in the tertiary sector. Keidel (WB 1994) and Kojima (2002) pointed to big gaps and biases in official measures of service output. Rawski and Mead (1998) and Rawski (2005) showed evidence of under-measurement in commerce and transportation. Although NBS responded to Keidel's findings, prompting the World Bank to agree that further upward adjustment of tertiary output was no longer needed (Xu Xianchun 1999), NBS latest (2005) upward adjustment of

GDP levels and growth during 1993-2004 consists almost entirely of increases in the share and growth of the service sector. It is quite possible that even the 2006 adjustment will not fully eliminate long-standing under-measurement of service output and growth.

- Possible under-measurement of real output growth in manufacturing. Criticism of official data on industry has focused on evidence of upward bias. But what of possible downward bias arising from under-measurement of quality change? Trade outcomes and even casual personal observation make it clear that Chinese industry has attained massive improvements in quality during the past three decades (Brandt, Rawski and Sutton, forthcoming). This improvement has coincided with increases in entry and competition that have replaced the old seller's market with a new buyer's market. The auto industry is one of many that have experienced rising output, big quality upgrades, and falling relative (and in this instance, nominal) prices – trends typical of sectors like computers and semi-conductors in the United States. Under such conditions, is it not possible that standard measures understate the growth of real output? In the United States, where a major effort is made to measure quality improvements, there is an increasingly widespread view that these efforts have not caught all of the improvements in quality that have actually occurred (Boskin, et. al. 1998). The one effort to deal with this problem for China that we are aware of (Klein, et. al. 2006) reaches similar conclusions albeit using a different methodology. At a minimum, these quality improvements make it impossible to use individual industrial output series such as those expressed in tons of steel or the number of refrigerators as substitutes in constructing the growth rate of industrial value added.

2. Neglect of possible inconsistencies between revised data and macroeconomic circumstances. Young (2003) imposes new deflators that reduce measured growth in 1988/89 from +4.1% to -5.6%. Although the combined impact of contractionary macro-policy and the May/June protests and repression made 1988/89 a bad year for China's economy, neither contemporary nor retrospective accounts support the implied conclusion that 1988/89 witnessed the largest single-year GDP decline between 1962 and 2005. Although official data show declining physical output for numerous industrial products, substantial increases in energy use (+4.2%) and ton-kilometers of freight transport (+7.4%) are inconsistent with Young's finding of a steep one-year decline. Young's (2003) revised GDP series also eradicates the policy-induced decline in GDP growth reflected in many Chinese accounts of the mid-1990s. Other efforts to revise official data remain subject to similar criticisms.

We conclude that, given the weak foundations underpinning independent efforts to adjust official Chinese data, the updated NBS series provides the best starting point for analysis of long-term economic trends.

B. Compilation of GDP time series used in this study

Our data come from a succession of publications by China's National Bureau of Statistics. These include,

- 1) A compendium with data for 1952-1995 (GDP1952-1995, published 1997)
- 2) A follow-up volume with data for 1996-2002 (GDP 1996-2002, published 2004), which is now superseded by revisions covering 1993-2004 announced in December 2005 (see the NBS web site www.stats.gov.cn) and published in 2006 (see Abstract 2006 and Yearbook 2006, which also provide GDP data for 2005).

We compile and analyze these figures in an excel file GDP 1952-2005.¹

The difficulty with these results is that they build on relative prices from the early years of the PRC, which are known to assign high values of industrial products relative to agricultural goods and mineral products. Since industry grew much faster than agriculture or mining, the use of early price relatives artificially inflates the measured growth of output. This relative price problem has been recognized by specialists on the Chinese economy going back to the early estimates of GDP by Liu and Yeh (1965), analyses by Perkins (1975, 1980) and Swamy (1973).

Reconstructing China's more recent GDP estimates using later year prices when market forces had become the main determinants of relative prices has been done as early as the 1980s (Perkins 1988) using 1980s prices and later using year 2000 prices (Perkins 2005). Not surprisingly these revisions based on more recent market determined relative prices have a large impact on GDP growth rates prior to 1978 and very little impact from the 1990s on. Thus estimates made by outsiders of China's GDP growth after 1978 are not badly distorted by the fact most ignore this relative price problem. However, by only looking at the post 1978 period, these analyses mostly miss the fundamental change that occurred before and after that date. In our view, understanding these fundamental changes is critical to any analysis of what brought about the acceleration in China's growth during the reform era. Understanding this change is also important for any effort to project China's GDP growth going forward.

To avoid this difficulty, we adopt the following procedure:

1. We calculate the shares of primary, secondary, and tertiary output in nominal GDP for 2000 (as revised by National Bureau of Statistics in 2005).

¹ This and other tables mentioned below are available from the authors: dwright_perkins@harvard.edu or tgrawski@pitt.edu. File **GDP 1952-2005**, Tab **Official GDP Index 1952-2005**: presents the most recent NBS data showing indexes of real growth for real GDP and for its three major components: primary (agriculture, forestry, and fisheries), secondary (mining, manufacturing, utilities, construction), and tertiary (transport and communication, trade and commerce, other services).

Panel A shows GDP and its primary, secondary, and tertiary subdivisions in index-number form, with 1952=100 based on what Chinese sources call "constant prices."

Panel B, beginning at row 67, converts the same data to a 2000 base, so that entries for the year 2000 are taken as 100 for GDP and its sectoral components.

2. We apply the resulting weights to separate NBS indexes of real output growth for the primary, secondary, and tertiary sectors to obtain a revised index of GDP growth as a weighted average of real growth in the primary, secondary, and tertiary sectors using 2000 nominal GDP shares as weights. This method effectively eliminates the impact on GDP growth of the distortions of relative prices between the three major sectors although it does nothing to correct for relative price distortions within each of these three sectors. However, it is the between sector distortions that had by far the greater impact on Chinese GDP growth rates.
3. We use the resulting index of GDP growth over 1952-2005 as the basis for further calculations and projections (See Table A.1 and, for those who want more details, the files referred to in footnotes 1 and 2 which are available from the authors).²

II. FIXED CAPITAL STOCK, 1952-2005

Our objective is to obtain a long-term series of China's fixed capital stock at constant prices. Standard official data do not provide appropriate indicators. The main difficulty arises from the absence of long-term price deflators for spending on fixed capital formation. Official data on fixed assets "at original cost" combine historic and current investment outlays, all valued at current prices. Official data on the "net value" of fixed assets subtract depreciation allowances from these cumulated investment totals. Both

² File **GDP 1952-2005**, Tab **Revised GDP Index 2000 weights**. Panel A displays the shares for the primary, secondary, and tertiary sectors in nominal GDP in 2000. Our calculations use output shares from the revised GDP figures for 2000 announced in late 2005 (see row 12).

Comparing the sectoral shares for the initial and revised GDP totals shows that the recent revisions to official GDP series substantially increased the relative size of China's tertiary sector:

2000 nominal GDP shares		Primary	Secondary	Tertiary
Before NBS revisions	100.00	16.35	50.22	33.42
After NBS revisions	100.00	14.83	45.92	39.25

Panel B shows our revised GDP series, based on 2000 sectoral weights, alongside the official NBS index. As expected, the NBS series grows more rapidly than the revised series, particularly during the early years of the PRC. We compile the difference between the year-to-year growth rates emerging from the two series (columns J-K-L beginning at row 26). For 1953-1965, the NBS series typically grows faster than the revised index, with the difference between the two series averaging 2.5 percentage points. During the reform period, this difference shrinks to 0.2 percentage points for 1978-1985. The gap between the two series is less than or equal to 1 percentage point beginning in 1982 and less than or equal to 0.2 percentage point beginning in 1996.

File **GDP 1952-2005**, Tab **GDP Growth Rates** compiles average annual growth rates over various time periods for both our revised GDP series and the official NBS series. Results confirm the observation that shifting to sectoral weights for 2000 reduces measured growth, particularly during the early years of the pre-reform period. Average annual growth for the revised series amounts to 4.42 percent during 1952-1978 (vs. 6.15 percent for the NBS series) and 9.46 percent during 1978-2005 (vs. 9.62 percent for the NBS series).

sets of data embody mixed price bases. The large price fluctuations that have punctuated Chinese development imply that official capital stock data are not suitable for economic analysis. This is particularly true for the reform period, during which the amplitude of price fluctuations has risen substantially. As a result, independent construction of a time series of fixed capital is unavoidable.

A number of researchers have produced time-series estimates of fixed assets. We focused on studies by Carsten Holz (2006b) and by Zhang Jun et al (2004) which stand out for their careful construction and long-term coverage. Holz (2006b) provides a fully documented analysis of investment and capital stock going back to 1954. His analysis draws on unconventional ideas – for example the notion that depreciation should be deducted only when assets are removed from use. To avoid controversy surrounding these ideas, we decided not to use Holz’ results.

Zhang Jun and co-authors accumulated nearly-complete province-level time series for investment, then used the perpetual inventory method to develop time series for the stock of fixed assets at both the provincial and national level (Zhang and Zhang 2003; Zhang Jun et al 2004). Professor Zhang generously provided the detailed data underlying this research. Upon examining these materials, we found two difficulties:

- i) For 1992/93, Zhang et al (2004) show an investment cost deflator of 5.9 percent, far below the National Bureau of Statistics figure of 26.6 percent. Since NBS figures for 1992/93 show price increases above 22 percent for every province (Fixed Assets 1950-1995), we conclude that the price deflators for 1992/93 in Zhang et al (2004) seem implausible.
- ii) Zhang et al (2004) derive capital stock data for early years of the PRC using a method under which investment in the years prior to 1952 is assumed to parallel investment in subsequent years. The regime change arising from the start of China’s First Five-Year Plan and concomitant arrival of massive Soviet financial and technical support shatters the assumptions required to implement such methods without risking major distortions. The consequences are evident in the results obtained by Zhang et al for the early years of the PRC. These results show fixed assets spread evenly over several regions of China. In reality, fixed assets, like industrial output and electricity production clustered in China’s Northeast and Lower Yangzi regions during the First Five-Year Plan period (1953-1957).

These difficulties persuaded us to put aside the results obtained by Zhang et al and derive our own series for fixed assets using the perpetual inventory method.

To do this, we require four data items:

- A. A time series of nominal outlays on fixed asset investment covering 1952-2005.

- B. A price index for investment costs covering the same period, which will allow us to present flows of fixed investment spending and the resulting stock of fixed assets in real terms.
- C. An initial value for the national stock of fixed assets in 1952.
- D. A depreciation rate.

A. Nominal Outlays on Fixed Assets, 1950-2005

Standard Chinese sources provide consistent long-term time series for gross fixed capital formation in nominal terms.³ Overlapping data from three sources: GDP 1952-1995; Yearbook 2005 and Abstract 2006 are entirely consistent except that the 2005 figure in Abstract 2006 is somewhat larger than the corresponding entry in Yearbook 2005 – a discrepancy that could easily arise during the revision of the initial estimates of 2005 activity. We employ these figures as the starting point for constructing a time series of China’s stock of fixed assets in 2000 prices.

Although these data on the nominal value of gross fixed capital formation are consistent, we should note several drawbacks associated with these figures. Chinese statisticians use several concepts to measure investment spending. In addition to gross fixed capital formation, these include

- i) “Total social investment in fixed assets” (*quanshehui gudingzichan touzi*), which measures “work done to build and purchase fixed assets” but “excludes the values of the building materials that have not yet been used. . . and. . . equipment that. . . has not yet been installed” (Fixed Assets 1950-2000, p.543).
- ii) “Newly increased fixed assets” (*xinzensheng guding zichan*) or “fixed assets transferred for use,” measures the value of newly completed projects that are transferred to normal use (*ibid.*, 554; Ishikawa (1965, p. 135). Holz (2006b, pp. 153, 156-57) applies the term “effective investment” to distinguish the value of completed projects from the (typically larger) total of investment spending.

The latter measure gives rise to the “rate of fixed assets transferred for use,” which is “the ratio of newly increased fixed assets to the amount of investment completed in a certain period” (Fixed Assets 1950-2000, p. 554). Typical data on transfer rates appear in *ibid.*, 191; Holz provides comprehensive estimates of transfer rates (2006b Table 2).

This discussion suggests the following identity:

³ These data appear in Columns B-D, Tab “Fixed Capital Stock” in the file Fixed Capital 1952-2005.112506.

Total social investment in fixed assets * Transfer rate = Newly increased fixed assets [A-1]

Our intent is to measure the time path of productivity by comparing output trends with available resources of capital and labor. From this perspective “total social investment” is a more appropriate vehicle than “newly increased fixed assets” for compiling estimated capital stock. This is because expenditures on incomplete or abandoned projects figure in the former measure but not in the latter.

Although we have not determined the exact correspondence between gross fixed capital formation and the investment measures mentioned above, available data compiled in file **Fixed Capital 1952-2005.083006**, Tab “**Compare Investment Measures**” shows that gross fixed capital formation is typically larger than newly added fixed assets (as anticipated) and, since the mid-1980s, roughly equivalent to “total social investment.”

We conclude that standard measures of nominal gross fixed capital formation provide a plausible foundation for constructing time series measures of China’s fixed capital stock.

B. Price Index of Investment Costs.

Chinese measures of price trends for investment spending begin in 1989/90, when NBS initiated cost indexes for construction and installation, purchase of equipment, tools and instruments, and other segments of investment. The NBS overall investment deflator, “the investment price index for fixed assets is computed by averaging the price indices for the three kinds of investment above with weights” (Fixed Assets 1950-200, p. 542).

We adopt a modified form of the NBS procedure to create an investment deflator covering the entire period 1952-2005.⁴ Our modification is to focus on cost trends for construction/installation and for equipment, and to use the annual shares of construction and equipment costs in total investment spending as weights for separate indexes of construction and equipment costs. Close correspondence between our deflator and the NBS investment price index for 1990-2005 indicates that this procedure is nearly equivalent to the NBS calculations. The small share of “other” spending in total investment outlays is no doubt responsible for the small variation between the new index and the NBS results.⁵

Construction Cost Index

Trends in construction costs are based on the unit construction costs (per square meter) for all structures (1952-1991) and on the NBS index of construction costs (1992-2005).

⁴ Loren Brandt developed this index together with Rawski.

⁵ The Tab “KF Deflator 082906” in file Fixed Capital 1952-2005.083006 lays out our calculations.

Unit construction costs are available for 1957, 1962, 1965, 1978, and 1978-1991. We apply the 1957 cost figure to 1952-1956 and fill remaining gaps by linear interpolation.⁶

Equipment Price Index

The price index for equipment purchases comes from three sources:

- i) for 1990-2005, we use the NBS index for the equipment component of investment spending.
- ii) For 1978-1989, we use the NBS index of ex-factory prices for domestic machinery products.
- iii) For 1952-1977, we use an implicit deflator for output of “heavy industry.”

These appear to provide the best available measures of price trends for equipment used in investment projects. These measures suffer from two weaknesses. First, the indicators used for 1978-1989 and especially for 1952-1977 incorporate many products that are not used in investment projects. Ex-factory prices for domestic machinery products include information about bicycles and home appliances; price trends for “heavy industry” include information about electricity, coal, chemical fertilizer, and lubricants.

Second, and potentially more important, the data underlying our equipment price index for 1952-1989 exclude information about the cost of imported equipment used in investment projects. We do not know whether, and if so, how the NBS index for 1990-2005 treats imported equipment.

Omission of price trends for equipment imports could impart a substantial downward bias to the price index (causing an upward bias in our measure of fixed capital and therefore a downward bias in estimated productivity) during the period 1980-1994 when the official exchange rate of China’s currency declined from RMB1.5 to RMB 8.3 per US dollar, and fell even further with respect to the currencies of Japan and Western Europe, regions that supplied China with large quantities of equipment.

During this period, if domestic prices of imported equipment were set on the basis of the (rising) RMB equivalent of international prices, imported equipment costs would in all likelihood have risen much faster than the modest increases shown in Columns 13-18 of the file Fixed Capital 1952-2005.083006, Tab “KF Deflator,” especially during the period of rapid RMB depreciation. Although this could cause our measures to understate the increase in equipment costs, especially for 1980-1989 (when we use domestic ex-factory prices to gauge cost trends), we are unable to estimate the possible magnitude of the

⁶ The requisite data appear in Columns 1 and 2 of file Fixed Capital 1952-2005.083006, Tab “KF Deflator”; Columns 3-4-5 combine these data to form indexes of construction costs with base 1952, 1978, and 2000.

distortion, or to speculate on the possibility of a comparable distortion in the NBS equipment cost index that begins in 1989/1990.

C. Initial Value for the National Stock of Fixed Assets in 1952

Ishikawa (1965, chapter 3) reviews data on China's fixed asset stock published during the 1950s. Although China's government attempted to evaluate assets of state enterprises in 1951, there is no evidence that this undertaking extended to large-scale private industry (*ibid.*, 108-109). The likelihood of systematic evaluation of assets for large-scale private businesses outside industry seems remote. In addition, except for an estimate of fixed assets in handicrafts for 1955, available data on fixed assets "do not include. . . the unorganized sector." As a result, the published fixed asset total of RMB31.7 billion (*ibid.*, 109) for 1952 is almost certainly too low, in all likelihood by a large margin.

Ishikawa combines available information on national income and fixed assets to derive a capital-output ratio of approximately 1.7 for "the organized material-production sector and. . . urban public utilities" (*ibid.*, 110) – i.e. excluding agriculture, handicrafts, and most of the service sector. Takafusa Nakamura's study of late 19th-century Japan finds higher capital-output ratios for the farm sector than for the economy as a whole. His estimated capital-output ratio for the whole economy falls in the range of 1.8-2.0 during 1885-1900 (1971, p. 12

). Since China's economic structure in 1952 resembled that of late 19th-century Japan, we assume that China's total fixed assets in 1952 amounted to twice the level of annual GDP in that year. We convert this amount to 2000 prices using our investment price deflator. An alternate assumption that the value of fixed assets in 1952 equaled annual GDP in the same year is included to permit sensitivity analysis.

D. Depreciation Rate

Historically, Chinese accountants have set depreciation rates primarily on the basis of the physical lifetime of capital assets. Gao Peirong, apparently summarizing Chinese practice from the 1950s into the early reform years, indicates the following method of calculating annual depreciation (1985, p. 67):

$$\text{Annual Depreciation} = [\text{Original Asset Cost} - \text{Scrap Value} + \text{Disposal Cost}] / \text{Service Life} \quad [\text{A-2}]$$

Gao provides examples using the service lifetimes for various asset types (pp. 70-71) and cautions that enterprises are not permitted to tinker with depreciation rates (p.69), which are either set by or at least approved by upper-level authorities such as the Ministry of Coal or the Ministry of Finance. These methods, which take no account of economic obsolescence, lead to low depreciation allowances. Working with fragmentary information, Field (in Eckstein 1980, p.200) concluded that Chinese depreciation allowances were "too low"; in addition, K.C.Yeh found that actual depreciation allowances fell short of the amounts specified by official regulations, at least during the 1950s (1964, pp. 84, 333).

Subsequent information confirms this diagnosis. Yearbook 1994 (p. 29) provides basic depreciation rates for fixed assets of state enterprises in several sectors for 1983-1992 and for benchmark years during 1952-1980. No rate exceeds 6 percent. The average creeps upward from 2.9 percent (1952) to 3.2 percent (1962-1970), 3.7 percent (1978), 4.7 percent (1985), and 5.5 percent (1991-1992). Standard compilations of China's national accounts reflect these low rates. Economists from Japan's Hitotsubashi University who worked with NBS statisticians to produce materials published in GDP 1952-1995 report that "depreciation of fixed assets for every fiscal year. . . can be calculated, in the case of state enterprises, from financial final accounts" because "there is relatively detailed information on depreciation for state enterprises" (Hitotsubashi 1997, p. 10).

Zhang, Wu and Zhang's study of province-level capital stock data uses information from an earlier study (Huang Yongfeng et al 2002) of service lives for three asset classes: buildings, equipment, and other assets (presumably roads, bridges etc.) to derive an overall depreciation rate of 9.6 percent (2004, p. 39). We apply this rate in constructing our measure of aggregate fixed assets in 2000 prices. We provide an alternate calculation using a 7 percent depreciation rate to facilitate sensitivity analysis. The small difference in results arising from applying these alternate depreciation rates justifies our omission of withdrawals from the capital stock due to scrapping, which Holz (2006b, p. 162 and Table 4) places in the range of zero to one percent for the depreciation-based measure that he sees as "likely to be accurate," at least until 2003 (p.164).

This completes the compilation of information for creating a time series of aggregate fixed assets valued in 2000 prices. With this information, we can apply the perpetual inventory method to derive a time series of fixed assets in 2000 prices using equation A-3:

$$DK(t) = (1-d)*DK(t-1) + DI(t) = (1-d)*DK(t-1) + I(t)/P(t) \quad [A-3]$$

Where K = the year-end stock of fixed assets

d = the rate of depreciation

I = nominal value of gross fixed capital formation

P = the index of investment costs

t indicates time and D indicates inflation-adjusted variables in 2000 prices

Table A.2 summarizes our results; details appear in Tab "Fixed Capital Stock 1952-2005" of the file "Fixed Capital Stock 1952-2005.083006." We present four variants of our series for aggregate fixed capital in 200 prices, corresponding to alternative rates of depreciation (7 percent and 9.6 percent) and alternate figures for the initial capital stock in 1952 (equal to 1952 GDP or to double that value). Examination of the results shows that varying the initial figure has virtually no effect on the long-term outcome. Lowering the depreciation rate from 9.6 percent to 7 percent, illustrated graphically at file Fixed Capital 1952-2005.083006, Tab "Graph Fixed Asset Series," slightly raises the level of the capital stock measure without changing its time profile.

Among these four alternatives, we focus on the version based on 9.6 percent depreciation and an initial 1952 capital stock assumed equal to twice the value of that year's GDP.⁷ This result will occupy the focus of our subsequent calculations.

III. Labor and Human Capital

A. Overview

Our objective is to construct a time series of China's working-age non-student population $L(t)$, classified according to their highest educational attainment, for the period 1952-2005. Together with appropriate weights, this series will allow us to construct an index of China's education-enhanced labor force $H(t)$ with which to conduct our analysis of long-term productivity trends. The ratio $H(t)/L(t)$ measures the degree to which the spread of educational attainment increases the education-enhanced work force beyond the growth in numbers of workers alone. The ratio $H(t)/L(t)$ rises as more workers attain higher levels of education.

As with fixed capital, our indicator will not reflect changes in the utilization of available resources, such as increased participation of urban women in formal employment during the 1960s and 1970s and a reduction in urban female participation rates during the past decade. Changes in the utilization of available resources, or in the effectiveness of resource utilization will emerge from our analysis as increases or reductions in productivity, which we define as GDP per unit of available resources.

To construct a time series of China's education-enhanced work force, we require detailed information on population, education, and wages. Chinese sources provide suitable data on population and education; information on wages comes from survey-based research. Although not without problems, these data do suffice to attain our objective.

Our population data come primarily from standard official sources: results of China's 1982 and 2000 population censuses, and tabulations of annual mortality rates. We supplement these materials with the research results from Chinese and international demographers, particularly in relation to trends in aggregate and age-specific mortality. Standard official sources provide detailed and consistent time-series data on student enrollment and graduation in China's regular education system. China has also developed a rich array of informal, adult, part-time, and short-term education and training programs. Because we cannot evaluate the quality of these widely varying programs, we omit them from our analysis. This imparts a downward bias to our measures of educational attainment among China's populace.

⁷ This result is shown as item 7D in Tab "Fixed Capital Stock 1952-2005," file Fixed Capital 1952-2005.083006 as well as in Table A.2.

Standard sources provide extensive information about the level and trend of wages for workers in different sectors and regions. Since these data rarely distinguish wage payments according to workers' educational attainment, we use the results of survey research to create the weights needed to aggregate separate series of workers with various education levels into a single measure of China's education-enhanced working age population.

To simplify our analysis, we adopt a somewhat idealized picture of China's education system, built on the following assumptions:

1. Children enter primary school at age 7. Primary schools offer a six-year program. Children who complete primary school receive their diplomas at age 12.
2. Middle schools (*chuzhong*) offer a three-year program. Students enter middle school at age 13 and graduate at age 15.
3. Senior high schools (*gaozhong*) offer a three-year program. We classify "specialized secondary schools" (*zhongdeng zhuanke xuexiao*) and "vocational secondary schools" (*zhiye zhongxue*) together with regular senior secondary schools (*gaozhong*) and count graduates of all three types of schools as having attained the high school level of education. We assume that Students enter high school at age 16 and graduate at age 18.
4. Tertiary educational institutions (*putong gaodeng xuexiao*) offer 4-year programs. Students enroll at age 19 and graduate at age 22. Our analysis takes no account of post-graduate education, partly because the number of participants is limited to a tiny fraction of the work force, but mainly because we lack information about the relative wages of postgraduate degree holders.

This model is not entirely realistic. Census data show considerable variation in the ages at which students enter school and receive diplomas. Some primary schools award diplomas after five rather than six years of instruction. Our assumption that all diplomas are awarded to students aged 12, 15, 18, and 22 surely introduces margins for error into specific components of our worksheets: for example, the number of 17 year-olds with high school diplomas and 21 year-olds with college diplomas in 2004 may be larger than the zero figure that our method assumes. These distortions, however, do not significantly affect trends in the educational composition of China's working age population such as the share of workers with middle or high school credentials or the proportion of uneducated persons between the ages of 16-65.

We make two assumptions that do influence long-term trends:

- As noted above, we omit educational qualifications attained outside the regular education system.

- We assume that age-specific mortality rates apply to all persons regardless of educational attainment.

Both assumptions act to limit the growth of educational attainment. They therefore introduce an element of downward bias into the ratio $H(t)/L(t)$.

Omission of educational qualifications outside the regular education system is no small matter. We can combine the results of the 1982 (or 1990) population censuses with information about subsequent numbers of graduates from the regular education system to project the stock of graduates in 1990 (or 2000). Because of intervening deaths, we expect such projections to overstate the numbers reporting specific levels of educational attainment in subsequent censuses. In fact, such projections fall short of reported educational attainments in 1990 (or 2000), often by very large amounts. This unexpected gap arises from two sources: credentials awarded outside the regular education system and fraud.

Available sources make it clear that each factor contributes substantially to the unexpectedly large numbers reporting various educational attainments in the 1990 and 2000 population censuses. A review of cadre training during the 1980s by Hsi-sheng Ch'i's demonstrates that many training programs were weak. Ch'i writes that local leaders often made "exaggerated claims about the accomplishments of their training programs," and that cadres' desire "to participate in 'college-level' programs" imposed "tremendous pressure on many schools to raise artificially their academic status." He concludes that such programs "greatly increased the number of cadres with impressive academic degrees or certificates without meaningful improvement of their educational levels" (1991, pp. 104, 106, 107). A 2003 report cited hundreds of false or suspicious diplomas in Shenzhen and Chengdu and commented that "not all universities consider the issuing of corrupt degrees as being wrong" (Xing Bao 2003).

China has also developed a substantial market for fake credentials. According to *People's Daily*, "Higher education qualifications have become extremely valuable. . . creating a considerable market for fakes. . . . An official with the Ministry of Education said that [recent census results] showed that at least 500,000 people in China held fake qualifications (Fake Diplomas 2002). Cheating on examinations is not uncommon. A 2005 news report described malpractices at national self-study college entrance examinations in Heilongjiang, Jilin, and Beijing (Exam Cheats 2005).

While many informal programs (and all fraudulent claims) provide little human capital and deserve to be excluded from our tabulation, some of the non-standard programs undoubtedly provide knowledge and training that is fully equivalent to standard academic credentials. We cannot speculate on the extent to which unexpected increments in reported educational attainments represent genuine human capital formation. Whatever this amount, our calculations omit this element, and therefore provide an incomplete account of educational attainment among China's working-age population.

Prior to the start of reforms in the late 1970s, Chinese wage structures offered little reward for educational attainment. Indeed, sources speak of negative wage premiums for educated workers, and indicate that major wage reforms specifically excluded pay increases for educated workers. Hou Fengyun reports “large-scale wage reductions for high-level mental workers” in 1957, 1959, and 1961; Hou also notes that “mental workers. . . were mostly excluded” from wage increases in 1959, 1961, 1963 and 1971 (1999, p. 181). Hou argues that returns to education failed to rise during the early reform years; he characterizes the years 1976-1990 as an era of “no payoff to education” (1999, p. 182). Apparently referring to the late 1980s, Hou notes that wages in elementary education and in universities were lower than pay levels in catering, construction, services, and mining; average pay in universities, for example, was RMB57 less than in the food and drink sector (1999, pp. 184-185).

As the reform developed, however, strong demand for educated workers, together with increased flexibility in wage-setting, stimulated the emergence of substantial and growing pay differentials favoring educated workers at all levels (Cai, Park, and Zhao forthcoming summarize relevant literature). Expansion of education-linked financial incentives stoked the demand for many varieties of educational credentials, including genuine as well as fraudulent documentation.

To avoid the difficulties associated with the unexpectedly high level of educational attainment reported in the population censuses of 1990 and 2000, we build our analysis on the education levels reported in China’s 1982 population census, supplemented by standard data on numbers of graduates from the regular education system before and after 1982. An alternative approach would involve compilation of education data from the pre-1949 decades to derive age-specific estimates of education levels in the early years of the People’s Republic, and then using graduation data to extend the spread of educational attainment in subsequent years. Although available sources provide considerable information about numbers of students and of graduates during the decades prior to 1949 (see Education Yearbook 1948), the frequency of data gaps and inconsistencies quickly convinced us to abandon efforts to build our analysis on pre-1949 sources.

Assuming that age-specific mortality operates identically across education cohorts biases our results in the same direction. Contrary to our assumption, we should expect educated persons to outlive less educated citizens in the same education cohort because

- Education is correlated with income and with urban residence, both of which are strongly associated with improved access to health care.
- Education is correlated with work in relatively safe occupations (e.g. teaching and clerical work vs. farming, mining, and construction).
- Education equips graduates with knowledge and information-gathering skills that can extend life expectancy.

We conclude that our measures seem likely to understate the spread of educational attainment among China's labor force, and therefore to understate the ratio $H(t)/L(t)$ of education-enhanced work force to raw labor. We explore the degree of understatement below.

B. Data Sources

Student enrollment. Standard sources provide time series data on enrollment at all levels of China's regular education system.⁸

Graduation data. Standard sources provide time series data showing the annual number of graduates at all levels of China's regular education system.⁹

Demographic and education data for 1982. Our analysis builds on data from China's 1982 population census.¹⁰ Margaret Maurer-Fazio generously provided information on education levels by age cohort from a sample of the 1982 census results. We have applied the proportions of individuals in each age cohort with various educational attainments from the sample to the entire population.

Demographic data for 1990. We use data on the number of persons in each age cohort from China's 1990 population census.¹¹

Mortality and Survival Rates.¹² Since we begin with results from the 1982 population census and project forward and backward to obtain estimates of the size of the work force and the distribution of educational attainments in earlier and later years, we need to account for deaths among persons of working age. Backward projections from 1952 require us to account for deaths among persons up to 95 years of age in 1982 (because persons aged 95 in 1982 were 65 years old and still of working age in 1952). Our calculations require year-by-year estimates of age-specific mortality rates for the entire period 1952-2005.

We begin with aggregate mortality – the average death rate for the entire population. Standard sources provide annual data on aggregate mortality for all years from 1949 to 2005.¹³ Specialists in demography agree that China's official mortality statistics are incomplete, with many deaths going unreported.

⁸ Enrollment data appear in the file "Education Results 1982-2005.090506.xls" at Tab "Student Enrollments."

⁹ See file "Input Data Grads & Survival 1949-2005.090406"

¹⁰ Numbers of persons by age and education level from the 1982 census appears in the file "Education Results 1982-2005.090506.xls" at Tab "1982."

¹¹ These data appear in the file "Education Results 1982-2005.090506.xls" at Tab "1990."

¹² We are particularly grateful for materials and advice from Judith Banister on the measurement of mortality.

¹³ These data appear Column B of the file "Aggregate Mortality 1952-2005.090506.xls,"

Work by Judith Banister, a leading researcher on Chinese mortality, has produced an “adjustment factor” to increase aggregate mortality to more realistic levels.¹⁴ Subsequent work extends the analysis to 2000 (Banister and Hill 2004). Banister and Hill derive separate adjustment factors for male and female mortality covering the periods 1964-1982, 1982-1990, and 1990-2000. We use their results, together with Chinese figures on the share of males in total population, to obtain adjustment factors for aggregate mortality in each of these periods.¹⁵ We apply the aggregate adjustment factor for 1982-90 to the years 1985-1990 and apply the aggregate adjustment factor for 1990-2000 to the years 1990-2005. This gives us a complete time series for the aggregate adjustment factor (Column D of the same file), which we apply to the official data (Column B) to produce a time series of adjusted aggregate mortality covering 1949-2005 (Column C, all in the file “Aggregate Mortality 1952-2005.090506.xls”). We use these results to measure aggregate mortality.

Information on age-specific mortality begins with results from the population censuses conducted in 1982 and 2000. Each census gives aggregate as well as age-specific mortality (e.g. the death rate for persons aged 44 years in 1982 or 2000). Beginning with the 1982 census results, we derive age-specific death rates for the years 1982-1989 as follows:

$P(t, N)$ = probability of death in year t for persons aged N at the beginning of year t =

$$PC(1982, N) * AM(t) / M(1982)$$

Where $t = 1982, \dots, 1989$

$PC(1982, N)$ = 1982 census data: probability of death in 1982 for persons aged N

$AM(t)$ = adjusted aggregate mortality in t ;

$M(t)$ = unadjusted aggregate mortality in t .

This procedure assumes that the age-structure of mortality remains fixed during the period of analysis. We begin with the structure of mortality described in the 1982 census, and simply multiply the column vector of age-specific mortality from the census by an adjustment factor for each year t to obtain a column vector of age-specific mortality rates for that year. The adjustment factor $AM(t)/M(1982)$ simply reflects the ratio of adjusted aggregate mortality (following Banister and Banister-Hill) in the target year to officially reported aggregate mortality in the census year.

Beginning with age-specific mortality results from the 1990 census, we apply the exact same procedure to derive age-specific mortality rates for the years 1990-2005. These procedures result in a complete matrix of age-specific mortality $P(t, N)$ for the period 1982-2005. We use these results to calculate survival ratios needed to complete our labor force projections during the years 1982-2005:

¹⁴ Her results for 1949-1984 appear in Column D of the same file (Banister 1987, p. 353).

¹⁵ See file “Aggregate Mortality 1952-2005.090506.xls,” Row 68ff.

$S(t, N)$ = the probability that a person of age t at the beginning of year t will survive from year N to year $N+1$

As noted above, our analysis for the period 1982-2005 assumes a fixed structure of age-specific mortality rates during 1982-1999 and during 2000-2005. During these periods, we assume that the ratio of mortality rates between any two age cohorts remains fixed. This assumption is not historically accurate. In reality, the structure of age-specific mortality rates has changed considerably over time, with death rates for infants and seniors declining faster than mortality among youths and working-age adults. For example, taking 1953=100, aggregate mortality declined to 30.6 in 1982, but infant mortality dropped to 26.3 (Banister 1987, p. 352). As a result, projections based on an assumption of constant mortality structures can lead to implausible results. Initial efforts to apply the method described above, beginning with the 1982 census data, to extend our estimates backward to 1952 encountered this exact difficulty.

We therefore searched for independent estimates of age-specific mortality covering the decades prior to 1982. Research by the Chinese demographer Zhai Zhengwu (1987) provides mortality rates for persons aged 0, 1-4, 5-9, etc. for two periods, 1953-1964 and 1965-1982.¹⁶ Zhai provides separate mortality information for males and females in each age interval. We combine these separate rates into overall mortality rates for various age intervals using the average of Judith Banister's annual estimates for the sex ratio of China's population during the years 1953-1964 and 1964-1982 (see Tab "Sex Ratio" in the file Mortality & Survival 1952-1981.090706.xls).

With this information, we then construct annual estimates of age-specific mortality for 1952-1963.¹⁷ We assume that Zhai's death rates for specific age intervals (e.g. 1-4, 5-9) apply equally to each age cohort within a particular interval. We also assume that Zhai's results for 1953-1964 apply to the years 1952-1963 and that Zhai's results for 1964-1982 apply to the years 1964-1981.

We derive annual figures for age-specific mortality using the following relationship:

$$P(t, N) = P(b, N) * AM(t) / \Sigma AM(t)$$

Where

$P(t, N)$ is the mortality rate in year t for persons aged N at the start of year t

$P(b, N)$ is the average mortality rate for persons aged N in one of Zhai's two base periods (1953-64 or 1964-82)

$AM(t)$ is adjusted mortality in year t (described above following work by Judith Banister) And the summation in $\Sigma AM(t)$ runs over the years 1952-1963 or 1964-1981.¹⁸

¹⁶ Zhai's mortality results appear in the file Mortality & Survival 1952-1981.090706.xls at Tab "Construct Mortality Rates."

¹⁷ See Tab. "Mortality & Survival 1952-1963) and for 1964-1981 (see Tab "Mortality & Survival 1964-1981".

¹⁸ These calculations appear in Tabs "Mortality & Survival 1952-1963" and "Mortality & Survival 1964-1981."

As before, we use the resulting matrix of age-specific mortality $P(t, N)$ for 1952-1981 to calculate survival ratios.

$S(t, N)$ = the probability that a person of age t at the beginning of year t will survive from year N to year $N+1$

This gives us a complete matrix of survival ratios for all age cohorts covering the entire period of analysis 1952-2005.

Working Age Population by Age Cohort and Educational Attainment.

We now have the data needed to derive figures for China's working-age population (ages 16-65) by age cohort and education level. We begin with the 1982 census results, which provide complete information on numbers of persons and, assuming that sample results are representative of the entire population, educational attainment for each age cohort. Beginning with the 1982 figures, which appear at Tab 1982 in the file "Education Results 1982-2005," we derive results for subsequent years as follows:

To move forward from year t to year $t+1$ requires the following steps:

- The number in each education category aged N in year t is multiplied by the appropriate survival ratio and entered as the total cohort aged $N+1$ in the corresponding education category for year $t+1$.
- Persons who graduated from primary school (assumed to be 12 years old), middle school (15 years old), high school (18 years old), or tertiary education (aged 22) in year $t+1$ are subtracted from the relevant total for their age and former education level and entered at their new, higher education level in year $t+1$.

These calculations are performed in Tabs 1983, 1984, ... 2005 in the file "Education Results 1982-2005."

- We then sum the numbers at each education level for persons aged 16-65 to obtain preliminary results shown in the Tab "Result from Calculation" In file "Education Results 1982-2005." These results include students aged 16 and over, whom we wish to exclude from our final work force measure.
 - After subtracting high school and tertiary students, all of whom are assumed to be at least 16 years of age under our (somewhat artificial) model of China's education system, we obtain our final measure of working-age (16-65) non-student population, divided into five education categories: no diploma, primary, middle school, high school, and tertiary.
-

In shifting from 1999 to 2000, we insert population totals from the 2000 census only for ages 0-9. We avoid the education data from the 2000 census because i) the 2000 census data introduce big inconsistencies because millions of adults reported higher education credentials in 2000 than are implied by earlier data (discussed above) and ii) the 2000 census results appear to classify students as having attained the education level in which they are currently enrolled, rather than recording diploma attainments.

The procedure for moving backward from year t to $t-1$ parallels the mechanics described above. Again, we begin from the 1982 census data, which appear at Tab 1982 in the file “Education Results 1952-1981.”

We then apply the following steps to move backward from year t to $t-1$

- The number in each education category aged N in year t is divided by the appropriate survival ratio and entered as the total for the cohort aged $N-1$ in the corresponding education category for year $t-1$.
- Persons who graduated from primary school (assumed to be 12 years old), middle school (15 years old), high school (18 years old), or tertiary education (aged 22) in year t are subtracted from the relevant total for their age and full education level and entered at their previous, lower education level in year $t-1$.

These calculations are performed in Tabs 1981, 1980, ... 1952 in the file “Education Results 1952-1981.”

- We then sum the numbers at each education level for persons aged 16-65 to obtain preliminary results shown in the Tab “Result from Calculation.” These results include students aged 16 and over, whom we wish to exclude from our final work force measure.
- After subtracting high school and tertiary students, all of whom are assumed to be at least 16 years of age under our (somewhat artificial) model of China’s education system,¹⁹ we obtain our final measure of working-age (16-65) non-student population, divided into five education categories: no diploma, primary, middle school, high school, and tertiary.

These calculations yield a complete time series of China’s working age (16-65) non-student population, decomposed by educational attainment, for the years 1952-2005. We

¹⁹ Technical note: our calculations assume that tertiary graduates receive their degrees at age 22 and immediately enter the labor force. This ignores the reality that some college graduates remain in school to pursue advanced degrees. Our results could be refined by i) removing advanced degree students from the work force, which would reduce H/L; and ii) expanding the analysis of wage differentials by adding a new category for recipients of graduate degrees, who presumably attain higher incomes than undergraduate degree-holders, which would increase H/L. Since the numbers involved are small (graduate enrollment in 2005 was 978,610, of whom 189,728 received graduate degrees in 2005 – see Yearbook 2006, p. 802) and the effects move in opposite directions, we anticipate no substantial consequences from this omission.

summarize results in the File “Education Results 1952-2005.090706,” Tab “Combined Result 1952-2005,” which shows annual totals by education category in each year both in absolute numbers and in percentage terms. This tab also shows annual increments and annual percentage changes for the total and for each education category. The tab “Graph Workforce components” depicts the changing educational composition of China’s work force.

Results follow expectations based on qualitative information. The share of working-age persons with no diploma declines dramatically from 73.9% in 1952 to 15.2 percent in 2005. The share of working-age persons with primary and middle-school credentials rises from 19.6% and 4.8% in 1952 to 32.8% and 33.5% in 2005. The shares of senior high and tertiary graduates rise from 1.4% and 0.4% in 1952 to 15.8% and 2.7% in 2005. These changes occur in a smooth fashion, with discontinuities seemingly consistent with the (rather large) demographic shifts (especially following the 1959-61 famine) and with changes that affected China’s education system during the period of study (especially the Cultural Revolution period 1966-mid-1970s and its immediate aftermath).

Examination of calculations for specific years does reveal implausible results. Not surprisingly, our assumption that every student’s academic career follows a specific timetable generates errors. Our assumption that all primary school graduates are exactly 12 years old leads to negative estimates of numbers of diploma-less 12-year-olds in 1990-93, 1996, and 2000-2002. This outcome could be avoided if we had information about the exact age distribution of primary graduates, which no doubt includes substantial numbers of children aged 11, 13, and 14. These errors, which essentially involve incorrectly assigning certain uneducated children to one age cohort rather than to an adjacent age cohort, will have no meaningful impact on our estimates of long-term changes in the educational composition of China’s working-age population.

An Index of Education-Enhanced Labor Supply

Method. Beginning with these new time series of working age non-student population in different education categories, we now construct a single index of educated-weighted labor supply. To do this, we need a set of weights with which to combine our series of workers with no diploma, and with primary, middle, high school or tertiary education credentials. Ideally, these weights will reflect the actual or potential productivity differentials separating workers who differ only in their educational attainment.

In competitive market economies, wage differentials theoretically reflect variations in the marginal productivity of workers. Beginning with the work of Jacob Mincer, labor economists estimate the scale of education-linked wage differentials by obtaining wage data for large numbers of individuals and controlling for the age, sex, educational attainment, and experience (conventionally treated as being related to age) of each individual.

Mincer coefficients & Focus on 2000 Data. For China, estimates of Mincer coefficients are limited to the reform period. Available studies target samples of rural or urban workers; we have found no studies based on economy-wide samples. This means that using estimated Mincer coefficients to construct the weights needed to combine our education cohorts will require that we separate each education cohort of the working-age population into rural and urban components.

These realities focus our attention on 2000 data as the source of weights for combining our education cohorts. Data from 2000 have the following desirable features:

- Separate studies by Junsen Zhang et al (2005) and deBrauw and Rozelle (2004) respectively use surveys of urban and rural workers to derive Mincer coefficients from wage data pertaining to 2000. The two studies are complementary in that the urban sample used by Zhang et al (2005) excludes migrants from rural areas, while the rural sample developed by deBrauw and Rozelle (2004) includes wage workers who migrated out from their home villages.
- Published results of China's 2000 population census permit us to divide the working-age population into rural and urban components by educational attainment. It is therefore possible to attain a plausible match between education-linked wage differentials and education cohorts of the working age population in 2000.

The development of Chinese labor markets reinforces our focus on the year 2000 as the source of information for combining different education cohorts into a single measure of education-enhanced labor supply. During China's plan era, roughly from 1949 to the late 1970s, official fiat was the chief determinant of wage levels and wage differentials. Chinese sources explain that political preferences rather than productivity potential dominated the practice of wage setting.

To summarize: the availability of suitable data as well as Chinese historical realities contribute to our choice of 2000 as the base year for constructing weights to link various education cohorts within China's working-age population. It is only in recent years that wage differentials bear any relationship to actual or potential productivity gaps among workers of differing educational attainments. In addition, while population census results allow us to decompose each education cohort into rural and urban segments for 1990 and 2000, available data make it increasingly difficult to achieve comparable results prior to 1990. As a result, the best available option for constructing a single index to measure education-enhanced labor supply comes from 2000 data.

To obtain the relevant results, we first use census data to decompose the 2000 education cohorts into rural and urban segments. Next, we obtain separate estimates of education-linked wage differentials for rural and urban areas. We then combine the census decomposition with the rural and urban wage differentials to construct average education-linked pay differentials at the national level. These figures become the weights with

which we can aggregate separate education cohorts into a single index of education-enhanced labor supply to use in our productivity analysis.

Decomposition of 2000 Education Cohorts into Rural and Urban Segments.

Results from China's 2000 population census provide a breakdown reported education levels for the entire population ages 6 years and up and for residents of cities (*shi*) and towns (*zhen*). We tabulate this information in File "Weights for Education Cohorts.091306" Tab "2000 U&RWork Age x Educ Detail." This allows us to determine total numbers of working age persons within each population segment (total, city, town) with different education levels as follows:

Total aged 16-65 = Total aged 6 and up – ages 6-15 – ages 65 and up + age 64

Note the assumption that the numbers of persons with various educational attainments aged 64 and 65 are identical.

We make this calculation at the aggregate (From Row 8), at the city (From Row 20) and the town (from Row 32) levels. We combine results for the city and town levels to obtain totals for the urban population (From Row 44).

This urban total includes migrants and therefore does not match our wage data, which classify migrants' wages in the "rural" category. Fortunately, the census results permit us to identify the numbers and educational attainment of migrants counted in the "urban" totals for the 2000 census, and transfer them to our rural totals.

Information about migrants appears in the same worksheet beginning at Row 61. The data show the numbers of persons, classified by education level, and also the administrative level at which they were registered. We regard migrants registered by the town-level authorities (*zhen de juweihui*) or by street committees as included in the urban component of the census results and remove them from our urban totals.²⁰

Total numbers of such persons appear in Row 82. The revised total of urban working-age persons for 2000, classified by educational attainment, appears in Row 100. We combine education levels to correspond to the education cohorts included in our labor force time series: persons with no schooling or training in literacy classes are classified as having no diploma. The category "high school diploma" includes graduates of regular high schools as well as specialized intermediate schools (*zhongzhuang*). Tertiary graduates include three categories: persons with undergraduate or graduate degrees from colleges and universities, and also graduates of "specialized tertiary programs" (*dazhuanke*). Final totals for the urban working-age population classified by 2000 educational attainment appear at row 109.

²⁰ Kam Wing Chan provided valuable advice on this point.

Parallel results for the rural working age population, including migrants whom the 2000 census registered as residing in urban jurisdictions, are easily derived. Educational attainment of the rural working-age population is the difference between national and urban totals (Row 121). We combine census educational categories as noted above to conform to the education cohorts identified within our labor force time series. Results appear at Row 131.

This allows us to present results showing the distribution of educational attainment among working-age persons in 2000 at the national level (Row 143), for the urban sector (net of migrants; Row 144) and for the rural sector (including out-migrants; Row 145). These totals include high school and college students aged 16 and up, whom we wish to remove from our measure of working-age population.

Separate figures for total high school enrollment and for enrollments in village-level schools allow us to make this correction. In making this adjustment, we i) assign all tertiary students to the urban sector and ii) assign students enrolled in village-level high schools to the rural sector and all other high school students to the urban sector (note that sources give no urban/rural breakdown for specialized technical schools (*zhongzhuan*); our procedure arbitrarily assigns all students in these institutions to the urban sector.

Final results from the 2000 census showing the numbers of urban and rural working-age non-students at each level of educational attainment appear in Rows 153-155 for the national level and for urban and rural components.

We can now derive the distribution of educational attainment in 2000 nationally, within the urban and rural sectors (with migrants classified as rural), and in each cell of a two-way classification combining urban-rural and multiple education levels. This final breakdown, shown in Rows 176 and 177, will be combined with wage data to create weights for aggregating the education cohorts of our long-term time series for China's working-age population.

Our procedure for using 2000 data for constructing weights with which to aggregate numbers of persons in various education cohorts into an index of China's education-enhanced workforce draws on the percentage shares of urban and rural components within each education cohort rather than the actual numbers in each cell of the education x residence classification (see percentage shares at Rows 176-177; absolute numbers in Rows 154-155). The reason is that, as explained above, the reported number of diploma-holders at the junior high and especially at the high school and tertiary levels in the 2000 census include large numbers whose credentials are either non-existent or come from institutions outside the regular education system. In essence, our procedure assumes that the inclusion of diplomas earned (or invented) outside the regular education system in the 2000 census results did not affect the proportion of urban and rural diploma-holders at each level of educational attainment.

Education-linked Rural and Urban Wage Differentials in 2000²¹

As noted above, we use results of survey research by Junsen Zhang et al (2005) and by deBrauw and Rozelle (2004) to establish separate education-linked pay differentials for rural and urban workers in 2000. Next, we link the rural and urban results to create a ladder of education-linked pay differentials that encompasses the entire range of education cohorts for both rural and urban workers.

Urban wage differentials in 2000. Tab “Urban Av Wages x Education” in the file “Weights for Education Cohorts.091306” lays out information on urban wage differentials, average wages for individuals with varying education levels and Mincer coefficients indicating relative pay differences attributable to varying educational attainment.

With wages of primary school graduates taken as 1, different levels of educational attainment are associated with relative wages of 1.16, 1.40, and 2.06 for urban workers with similar demographic characteristics holding junior high, senior high, or tertiary educational credentials. In the absence of Mincer coefficients for workers with no diplomas, we assume that i) such workers had an average of 3 years of schooling and ii) average returns of 3.5 percent for each year of primary schooling (a figure taken from DeBrauw and Rozelle (2004)). These assumptions imply a relative wage figure of 0.90 for urban workers without diplomas (with wages of demographically similar primary school graduates set equal to 1).

Rural wage differentials in 2000. Tab “Rural Av Wages x Education” in the file “Weights for Education Cohorts.091306” lays out information on rural wage differentials, average wages for individuals with varying education levels and Mincer coefficients indicating relative pay differences attributable to varying educational attainment.

With wages of rural primary school graduates taken as 1, different levels of educational attainment are associated with relative wages of 0.81, 1.24, 1.53, and 1.83 for rural workers with similar demographic characteristics holding no diploma, junior high, senior high, or tertiary educational credentials.

Since the majority of Chinese urban workers are employees and wage-earners, generalizing Mincer results obtained from survey research by Junsen Zhang et al (2005) entails little risk. Employment patterns in rural China, however, are quite different, with large numbers working as self-employed farmers or engaging in a succession of short-term jobs, so that regular full-time employment at well-defined wages limited to a modest fraction of the rural work force. Under these circumstances, it is not immediately obvious that Mincerian wage differentials extracted by deBrauw and Rozelle (2004) from a sample of rural wage workers can be taken as representative of education-linked income differentials for the entire rural work force – many of whom do not regularly engage in wage-paying employment.

²¹ Alan de Brauw, Albert Park, Xiaoqing Song, and Yaohui Zhao were particularly helpful in answering multiple queries relating to their studies of education-linked wage differentials.

Despite this possible difficulty, we believe that the mobility associated with massive flows of labor from the farm sector into wage-paying employment in both rural and urban areas – flows that Chinese authors describe as a “tide of workers” (*mingongchao*), ensures that the incomes earned by self-employed rural workers with differing educational attainments will strongly reflect the education-linked pay differentials in the market for wage labor. With the numbers of migrants now estimated to exceed 100 million (or perhaps 200 million), and with administrative obstacles to shifting between self-employment and wage employment rapidly eroding, the expectation that market forces will generate a rough balance between returns to education in self-employment and wage labor strikes us as entirely plausible. We therefore assume that the Mincerian wage relatives identified by deBrau and Rozelle (2004) apply to the entire rural work force, not just to the (much smaller number of) rural wage workers.

National ladder of education-linked wage relatives. We use average nominal wages for urban (RMB 8669.384) and rural (RMB 4066.17) workers in the studies cited above to transform separate sets of urban and rural education-linked pay differentials into a single set of national education-linked pay differentials.²²

Taking the national average pay for primary school graduates as 1, the education-linked pay differentials corresponding to different levels of educational attainment are:

	No diploma	Primary	Middle	Secondary	Tertiary
Relative wage	0.818188	1	1.346137	2.009973	3.277146

Education-enhanced measure of Labor Supply.

We can now construct an education-enhanced labor supply measure (H) which we can compare with the number of working-age non-students (L). In constructing H, we assume that superior human capital endows each middle school graduate with capabilities equivalent to 1.346 primary school graduates, and so on. Results for our labor-education analysis appear in Tables A.3 and A.4 and in the tab listed in the tab “Combined Result 1952-2005.”²³

²² These calculations appear in Tab “National Wage Differential” in the File “Weights for Education Cohorts.091306”

²³ Results for our labor-education analysis appear in the tab “Combined Result 1952-2005” in the file “Education Results 1952-2005.091306.”

Columns A-G contain our previously derived time series for the working age non-student population (ages 16-65) during 1952-2005, divided into education cohorts. Columns K-O show the changing shares of the various education cohorts in the working-age total. We also include annual increments to the total head count and to each education cohort in terms of absolute numbers (Columns A-G, beginning at row 80) and annual percentage changes (Columns A-G, beginning at Row 143).

The 2000 weights shown above appear in Row 70.

We use these weights to construct H, the new index of education-enhanced labor supply, for the period 1952-2005. Results for H appear in Column R; we compare the new index H with the head-count measure L (reproduced in Column Q).

IV. Productivity Analysis

We are now prepared to investigate productivity performance during 1952-2005. Our index of productivity is the quotient of separate indexes of real output, measured by aggregate GDP at 2000 prices, and combined input of labor and fixed capital. Our labor measure is the index H, which measures the growth of China's education-enhanced, working age, non-student population. Our measure of fixed assets is an index of the deflated capital stock $DK(t)/DK(1952)$.

We combine the indexes of labor and capital input using factor income shares from China's national accounts, a standard practice that assumes perfect competition – an assumption that is somewhat plausible for China's markets for products, materials, and labor, but quite unsuited to China's financial markets. Data on factor income shares appear in the file "Factor Shares.070305.xls." We focus on the year 2000, in which labor's income share is 56.7 percent. If we look at the years 1998-2002, labor's income share ranges from 56.7 percent to 57.8 percent. The average figure for the 5 years 1998-2002 is 57.1 percent. We assign weights of 57 percent to labor and 43 percent to fixed capital.

Starting from a 1952 base, we calculate the annual index of economy-wide or total factor productivity as follows:

$$\text{Growth of TFP} = \text{Growth of real GDP} - .57 * \text{Growth of H} - .43 * \text{Growth of DK}$$

Results appear in the file "TFP Calculation 103106" The top panel lays out the basic data: GDP in Column B; four series for of fixed capital in Columns C-F; the series for education-enhanced working-age population (H) in Column G.

The second panel, beginning at Row 66, calculates average annual growth rates during various time periods for output, capital and education-enhanced labor (Columns B-H) and for total factor productivity (TFP) in Columns M-P. There are four measures of TFP, each corresponding to one of the capital stock series. We focus on our preferred measure of capital stock based on assumptions of i) initial capital stock in 1952 assumed to be double that year's GDP; and ii) annual depreciation assumed to be 9.6 percent. The

We calculate the ratio H/L, which measures the annual ratio of education-enhanced labor to the number of workers. This ratio appears in Column S.

H/L = 0.818 means that no workers have primary school diplomas

H/L < 1 means that the average worker has education amounting to less than primary school completion.

H/L = 1 means that the average worker has a primary school diploma

H/L = 1.35 (respectively 2.01 or 3.28) signifies that the average worker possesses a diploma from junior high school (respectively senior high school or tertiary institution).

Our results show the ratio H/L rising from 0.90 in 1952 to 1.0 in 1968, 1.07 at the start of reform in 1978, and 1.31 – meaning that the average worker has nearly attained the junior high school level, in 2005.

series used for our preferred calculation, including this variant 4 of the capital stock measures, appear in **boldface** in the Excel file.

Using these data, we obtain the following average growth rates for TFP:

1952-2005	2.1 percent
1952-1978	0.5 percent
1978-2005	3.8 percent

The bottom panel, beginning at Row 87, shows year-to-year growth for output, inputs, and TFP. These data are presented graphically in Tab “Sources of Growth 1978-2005” which shows annual growth of fixed capital, education-enhanced labor, and TFP (note that annual GDP growth, not shown, equals growth of TFP+ .57*growth of H + .43*growth of DK; the graph is uses our preferred capital stock measure).

One unexpected result: the graph shows a clear slowdown in TFP growth beginning in the late 1990s. Examination of year-to-year changes in results confirms this observation. Average annual TFP growth during 1978-2005 is 3.8 percent. But the TFP series based on our preferred data shows annual TFP growth less than 3.8% for each year beginning with 1997/98. If we consider the TFP results for all four alternate measures of fixed assets, only 2 of 32 observations show annual TFP growth of 3.8% during the years 1997/98 to 2004/05; no observations show TFP growth above 3.8%; 30 of 32 observations show annual TFP growth less than 3.8 percent.

V. Sensitivity Checks for Productivity Results

Three items

1. Possible overstatement of GDP growth during 1997-2002

Another perspective comes from controversy about the veracity of officially announced growth rates for several years beginning in 1997/98. Rawski (2001, 2002, 2005) has proposed alternate real growth rates that are much lower than the official figures, particularly for 1997/98 and 1998/99, as shown in Table A.6.

These suggestions remain controversial. Inserting the alternate GDP figures lowers the average of annual TFP increments during 1997/98 to 2004/05 (using our preferred version of the fixed capital figures) from 3.8 to 2.9 percent. In the alternate results, 2 of 32 annual increments to TFP equal 3.8 percent, none exceed 3.8 percent, and 12 of 32 exceed 2.9 percent.

We conclude that TFP growth appears to have slowed beginning in the late 1990s. This observation applies to calculations based on official output data and also on controversial alternate figures for 1998-2002.

2. Possible Understatement of Human Capital Growth

To check the impact of neglecting non-standard educational credentials, which, as noted above, leads us to understate the spread of education, we examine an alternative procedure that overstates educational attainments. We construct the alternative indicator, which focuses on benchmark years 1982, 1990, 2000, and 2005, as follows:

- begin with census data for 1982.
- For 1990, use results from the 1990 population census showing educational attainment by age cohort
- For 2000, use results from the 2000 population census showing educational attainment by age cohort
- For 2005, derive results by starting with figures from the 2000 population census, adding graduates reported by the regular education system in the intervening years, and adjusting for mortality during 2001-2005.

Because the alternate indicator incorporates self-reported data from China's population censuses of 1990 and 2000 which appear to include considerable amounts of false and inflated credentials, we expect the gap between our measure and the alternative figure to provide an high upper bound for the understatement of educational attainment incorporated into our analysis.

We perform these calculations in the file "Census Educ Data 1990 & 2000.092506 R051907," Tab "Compare LF & Education Results." Table A.7 compares the two measures. In comparison with our preferred results, the alternate measure substantially raises the education profile of working-age Chinese beginning in 1990. The alternate data show considerably higher proportions of working-age Chinese holding diplomas at the junior high (e.g. 40.8% vs. 30.6% in 2000) and tertiary (e.g. 5.15% vs. 1.76% in 2000) levels. Conversely, the alternative data show a much lower share of persons holding no diploma (e.g. 5.1% vs. 15.2% in 2000) than our own results.

Table A.7 also applies the weights derived earlier to create an aggregate measure of education-enhanced labor corresponding to the alternate measure, which is then compared with our own results. Taking our measure of annual H/L as 100, the alternative measure is the same as ours for 1982 (by construction) and then attains levels that are 4.7, 11.1, and 7.4 percent above our measure for 1990, 2000, and 2005 respectively.²⁴

²⁴ Note that our construction of the alternate measure takes no account of non-traditional educational credentials attained after the 2000 census; this explains the narrowing of the gap between the two measures during 2000-2005.

We conclude that, by overlooking the effective component of non-traditional education, our measure of education-enhanced labor may understate the measure H of education-enhanced labor by as much as 11 percent. Because the underlying census data include some credentials that are either fictitious or ineffective, we expect that the actual degree of understatement is considerably smaller than this upper bound.

What is the effect of this error on our productivity results? Recalculating our TFP measures for the period 1982-2005 using the alternate measure of education-enhanced labor reduced the estimated growth of TFP, but the change is very small. Applying the alternate, higher value of H reduces average annual TFP growth during 1982-2005 from 4.4-4.5 to 4.3 percent. This revision also lowers the proportion of GDP growth attributable to increased TFP, but again, the change is small – from 45.2-45.7% using our preferred data to 43.3-43.9 percent using the alternate figures.²⁵ Since the alternate measure certainly exaggerates the spread of education, these small adjustments overstate the impact of possible understatement of educational attainment on our results. We conclude that our preferred results are robust to possible downward bias in our measures of educational attainment arising from our inability to include the beneficial consequences of non-traditional education and training programs on labor quality.

VI. Projections for 2005-2025

Our projection strategy consists of the following steps:

1. Project GDP from 2005 to 2025 by assuming annual real growth of 6 or 9 percent.
2. Project the stock of fixed assets from 2005 to 2025 by assuming that the GDP share of annual investment in fixed assets declines linearly from the 2005 figure of 42.3 percent to a terminal 2025 figure of 35 or 25 percent and applying annual depreciation of 9.6 percent.
3. Project trends in educational attainment by assuming that the growth of enrollment in high school and tertiary education during 2005-2025 in China parallels Japanese experience during 1955-1975.
4. Project trends in the non-student work force aged 16-65 by assuming that the number of births remains at the 2005 level during 2006-2009 and that age-specific mortality remains constant at the 2004 level throughout 2005-2025.

²⁵ Calculations appear in tab “TFP Result Alt-H.012107” in file TFP with Alt H.060707. Results include ranges of possible outcomes because we derive four measures of TFP growth corresponding to four versions of our capital stock series (as shown in Tables A.2 and A.5).

5. Once we have projections for fixed capital stock, labor force, and educational attainment, we can derive the average TFP growth required to sustain GDP growth at the assumed levels of 6 and 9 percent.

Projection for GDP

We project real GDP growth between 2005 and 2055 at assumed annual rates of 6 and 9 percent.²⁶ Results are expressed in terms of 2000 prices.

Projection for Fixed Assets²⁷

We use official data for GDP and gross fixed capital formation (GFKF), both in current prices, to calculate the share of GFKF in GDP. For 2005, the figure is 42.3 percent. We assume that this share declines in linear fashion to a 2025 level of 35% (high investment assumption) or 25% (low investment assumption). The projected annual ratio of GFKF/GDP is derived by linear interpolation between the 2005 value (42.3%) and the assumed 2025 figure of 25 or 35 percent.²⁸

We calculate four alternative series for annual fixed investment²⁹:

V1 high GDP growth (9%) and high investment (terminal GFKF share of 35%)

V2 high GDP growth and low investment (terminal GFKF share 25%)

V3 low GDP growth (6%) and high investment

V4 low GDP growth and low investment

Starting with the estimated 2005 stock of fixed assets (2000 prices, version derived from assumption that fixed assets in 1952 were 2 * GDP in that year using the higher of alternative depreciation rates ($d = .096$)), we then derive projections for the growth of China's fixed asset stock, valued in 2000 prices, during 2006-2025. There are four alternatives, corresponding to V1-V4 noted above.³⁰

Projections for Labor and Educational Attainment

1. Demographic Assumptions

We assume that annual births in 2006-2009 are the same as in 2005. No further assumption about births is needed since persons born during and after 2010 do not enter

²⁶ Calculations appear in tab "GDP Projections" in the file Projection Summary.060707.

²⁷ See Tab "GDP/KF & K Projection" in the file Projection Summary.060707.

²⁸ Results for the projected GDP shares of fixed investment appear in Columns F and G.

²⁹ The four series for annual fixed investment (valued in 2000 prices) appear in Columns M, N, O, and P.

³⁰ Results appear in Columns R, S, T, and U.

the labor force until 2026 or later. We assume that age-specific mortality does not change after 2004. If, as we expect, mortality continues to drift downward, this assumption will introduce a downward bias into our labor force projections, and hence to an overstatement of productivity requirements for attaining benchmark levels of 6% or 9% GDP growth. We anticipate that such errors will be very small and will therefore not discuss them further

2. Method

The approach is to begin with data for 1990-2005 and continue with methods described earlier, building successive annual totals by adding births, adjusting for new graduates, subtracting retirees, and adjusting for mortality year-by-year.

Assumptions About Education

We need to develop additional assumptions about school attendance as we move beyond 2005.³¹

We begin with observations about school graduations in 2005. The annual number of graduates as percentage of relevant age cohort in 2005 is:³²

Primary (ages 7-12) 16.8% - i.e. 1/6 of children aged 7-12 graduated from primary school in 2005

Junior high (ages 13-15) 33.1% – i.e. 1/3 of children aged 13-15 graduated from junior middle school in 2005

High school (ages 16-18) 15.0%

Tertiary education (ages 19-22) 3.8%

These observations indicate universal attendance at both the primary and junior high school (*chuzhong*) levels.

Beginning in 2006, we assume that ALL 12 year olds receive primary diplomas, and that ALL 15 year olds holding primary diplomas receive junior high (*chuzhong*) diplomas.³³

³¹ File Labor and Human K 1995-2025....110306, Tab “Workforce Including Students”.

³² (see Row 13, Columns T-U-V-W).

³³ Technical note: we use these assumptions to compute the annual numbers of graduates at each level for 2006-2025. Results appear in Tab “Input Data (2)” of file “1990_2025...” Beginning in cell BG3 (primary school graduates in 2006). Then copy the data on graduates to the tab “Input Data”. We then use data on annual graduates from tab “Input Data” to modify the annual data for 2006-2025 by shifting new graduates to higher levels of educational attainment at ages 12 (primary school grads), 15, 18, and 22. Do not use data from Input Data (2), which will result in signal of “circular logic”.

This implies that, beginning in 2006, there are no 12-year olds without primary diplomas, and that, beginning in 2009, there are no 15-year olds without primary and junior high school diplomas.

To predict future enrollment trends at the high school and tertiary levels, we look to Japanese experience during the two decades beginning in 1955. Since we see the shift of population and labor from farm to non-farm work and from village to town or city residence as key correlates of increasing school attendance at the secondary and tertiary levels, we choose 1955 as the starting point for this cross-national comparison because the primary sector's share of Japan's labor force in that year was similar to our estimate of China's primary sector labor force share in 2005. The Japan labor force share was 38% in 1955.³⁴ Loren Brandt's calculations based on analysis of household survey data yield an estimate of 39% for China's primary labor force share in 2000 (see his file `alt_employment_5.16.05`; this estimate is considerably smaller than the figures published in standard Chinese sources, which in our view overestimate the primary-sector labor force).

In Japan, high school entry rose from 51.1% to 91.9% of the relevant age cohorts between 1955 and 1975, a rise of 40 percentage points in 20 years. We assume a similar rise of 40 percentage points for China between 2005 and 2025, i.e. we assume that 47% of 18-year olds graduate from high school in 2006, 49% in 2007, 51% in 2008, etc., and $45+40 = 85\%$ in 2025.³⁵

In China, 3.8% of the 4-year age cohort 19-22 graduated from college in 2005, implying attendance rate of $3.8*4 = 15.2\%$. In Japan, college attendance rose from 10.1% to 38.4% between 1955 and 1975.³⁶ We assume a parallel rise of 30 percentage points or 1.5 percentage points each year in college graduation rates for China. Specifically, we assume that 15% of 22 year olds graduate from college in 2006, 16.5% in 2007, 18% in 2008, etc. and finally 43.5% of 22-year olds graduate in 2025.³⁷

Our projections regarding college attendance differ widely from projections offered by Carsten Holz, who anticipates that the share of each cohort attending college levels off quickly before 2010: Holz' projections assume "that the absolute number of new [tertiary undergraduate] enrollment. . . increases by 20% in each year 2005 and 2006, stays constant in 2007-09, and then falls by 5% in each year 2010 and 2011 and by 2% in

³⁴ Data from File Education Projections.052606, Tab "Japan LF Ag share", includes farming, forestry, and fisheries. Data from Historical Statistics of Japan, <http://www.stat.go.jp/english/data/chouki/19.htm>, Accessed 25 May 2006.

³⁵ These assumed graduation rates appear in Row 7 of File Labor and Human K 1995_2025.Redo from1982 base.110306, Tab "Input Data (2)," beginning in Column BG.

³⁶ See Japan Education 1984, p. 193 – data reproduced in File Education Projections.052606, Tab "Japan Educ Progression Rates."

³⁷ These assumed graduation rates appear in Row 8 of the File File Labor and Human K 1995_2025.Redo from1982 base.110306, Tab "Input Data (2)," beginning in Column BG.

each year 2012-19 (parallel to the decrease in the size of the new age cohorts), before leveling out and remaining constant (2005, p. 32). In defense of Holz, a *China Daily* editorial of May 12 2004 p. 4 “Put Brakes on Enrolment” reports approvingly that a State Council conference decided that “expanding enrolment. . . in higher learning institutions needs to be reasonably controlled.” However the conference also decided that the government should “allow universities to determine the number of students. . . in accordance with their handling capacity” – i.e. allow them to pack students in despite faculty complaints of declining student quality and insufficient manpower.

Chinese families place high priority on education. The “one-child policy,” which required most urban households to limit their offspring to a single child, intensified family ambitions for these “little emperors.” With household incomes rising, the demand for tertiary education is intense. Widespread public awareness of rising financial premia attached to educational attainment intensifies the push to attain tertiary credentials. Dongguan (Guangdong), where “an astonishing 58 percent of the residents age 18 to 22 are enrolled in a university,” may represent the leading edge of steep future increases in tertiary enrollment (Kristof 2007). On the supply side, expansion-minded colleges and universities are eager to increase enrollment. If public universities do not expand student slots, private entrepreneurs will fill the gap. As a result, we reject Holz’ expectation of stable enrollments and instead assume rapid expansion of college-level attendance and graduation rates.

Our assumptions about the age groups attending various types of schools imply that all students in high school or tertiary institutions are at least 16 years old. We assume that the number of working age students in each year equals the sum of 3 times the number of that year’s high school graduates + 4 times the number of that year’s college graduates.

4. Results for high school and tertiary graduates and for annual enrollment of students age 16 and up for 2006-2025.

Following these assumptions, we derive results for graduates and for attendance at the high school and tertiary levels during 2006-2025 as follows:

Annual number of graduates: File Labor and Human K 1995_2025.Redo from 1982 base.110406, Tab “Input Data (2),”

High school graduates: cells BG6 to BZ6

Tertiary graduates: cells BG7 to BZ7

Annual enrollments of students age 16 and up. Beginning in 2006, we assume that the number of high school students is 3 times, and the number of tertiary students is 4 times the numbers of annual graduates derived above.

High school student numbers: Tab “Final Labor Result 2005-25,” Column S

Tertiary student numbers: Tab “Final Labor Result 2005-25,” Column T

5. Working age population (16-65 years) by educational attainment.

The resulting projections for working-age non-student population, decomposed by educational attainment, for 2005-2025 appear at Tab “Final Labor Result 2005-25” in File Labor and Human K 1995_2025.Redo from1982 base.110406. These projections show the labor force aged 16-65 rising from 849.6 million in 2005 to a peak of 915.7 million in 2016, followed by a decline to 885.6 million in 2025 – roughly equal to the 2010 figure of 885.3 million.

Projected educational attainment increases substantially, with H/L, which measures the ratio of education-enhanced labor to the number of workers, rising from 1.31 to 1.69 between 2005 and 2025. The projection shows this ratio reaching 1.38 in 2009, indicating that the average worker possesses a junior high school diploma. During 2005-2025, the projections indicate that while junior high graduates continue as the largest contingent (33.6 percent in 2005, 37.0 percent in 2025), the remainder of the distribution swings toward higher levels of education, with the share of workers in the no diploma and primary categories dropping by 9.4 and 12.6 percentage points, while the share with high school and tertiary diplomas increases by 7.5 and 12.0 percentage points.

6. Productivity Implications of Projection Results for 2005-2025.

We are now able to derive the productivity implications of assuming 9% or 6% annual GDP growth during the two decades from 2005-2025. As mentioned above, our two alternative trajectories for capital formation, which portray the GDP share of gross domestic fixed capital formation as declining in linear fashion from the 2005 level of 42.3 percent³⁸ to terminal levels of 35% (respectively 25%) in 2025, yield four separate projections.

We derive the productivity consequences of these four sets of assumptions in Tab “TFP Projections 1952-2005” of the file Projection Summary.060707.xls. Table A.8 shows annual percentage changes in the estimated value of fixed capital stock at 2000 prices, education-enhanced work force, and TFP, over the period 2005/06 to 2024/25. The results for fixed capital and TFP come in four versions representing the possible combinations of high (9%) and low (6%) GDP growth and of high (35%) and low (25%) terminal shares of gross fixed investment in GDP.

³⁸ See File Projection Summary.060707, Tab “GDP KF & K Projection”.

References for DHP & TR Annex

- Abstract. 2006. *Zhongguo tongji zhaiyao 2006*. [China Statistical Abstract 2005]. Beijing: Zhongguo tongji chubanshe.
- Banister, Judith. 1987. *China's Changing Population*. Stanford: Stanford University Press.
- Banister, Judith and Kenneth Hill. 2004. "Mortality in China 1964-2000." *Population Studies* 58: 55-75.
- Boskin, Michael; Ellen Dulberger, Robert Gordon, Zvi Griliches, and Dale Jorgenson. 1998 "Consumer Prices, the Consumer Price Index and the Cost of Living," *Journal of Economic Perspectives*, Vol. 12, No. 1, pp. 3-26.
- Brandt, Loren and Thomas G. Rawski eds. Forthcoming. *China's Great Economic Transformation*, ed. Loren Brandt and Thomas G. Rawski. Cambridge: Cambridge University Press.
- Brandt, Loren, Thomas G. Rawski, and John Sutton. Forthcoming. "China's Industrial Development." Chapter 15 in Brandt and Rawski eds..
- Cai, Fang, Albert Park and Yaohui Zhao. "Labor." Chapter 8 in Brandt and Rawski eds.
- Ch'i, Hsi-sheng. 1991. *Politics of Disillusionment: The Chinese Communist Party under Deng Xiaoping, 1979-1989*. Armonk: M.E. Sharpe.
- Chow, Gregory and Anloh Lin, 2003, "Accounting for Economic Growth in Taiwan and Mainland China." *Journal of Comparative Economics*. 29: 3, pp. [to appear in September 2002].
- deBrauw, Alan and Scott Rozelle. 2004. "Reconciling the Returns to Education in Rural China." Unpublished paper dated March 12, 2004. [Note: this paper is to appear in the *Review of Development Economics*].
- Eckstein, Alexander, ed. 1980. *Quantitative Measures Of China's Economic Output*. Ann Arbor: University of Michigan Press.
- Education Yearbook. 1948. *Dierce Zhongguo jiaoyu nianjian* [The Second China Education Yearbook]. Compiled by Jiaoyu nianjian bianzuan weiyuanhui. 6 volumes.
- Exam Cheats 2005. "Mobile exam cheats caught red handed." Xinhua English, 20 October. Accessed from <http://english.sina.com/china/1/2005/1020/50329.html> 26 October 2005.

- Fake Diplomas. 2002. "China cracks down on fake diplomas." 25 August. Accessed from http://english.people.com.cn/200208/25/eng20020825_102028.shtml 2 October 2005.
- Field, Robert Michael. 1980. "Real Capital Formation in the People's Republic of China, 1952-1973." In Eckstein 1980, pp. 194-245.
- Fixed Assets 1950-1995. *Zhongguo guding zichan touzi tongji nianjian* [Statistical Yearbook On China's Investment In Fixed Assets, 1950-1995]. Beijing: Zhongguo tongji chubanshe, 1997.
- Fixed Assets 1950-2000. *Zhongguo guding zichan touzi tongji shudian, 1950-2000* [Compendium of Data on China's Investment in Fixed Assets, 1950-2000]. Beijing: Zhongguo tongji chubanshe, 2002.
- Gao, Peirong. 1985. *Gongye qiye guding zichan guanli*. [Fixed Asset Management for Industrial Enterprises]. Taiyuan: Shanxi renmin chubanshe.
- GDP 1952-1995. *Zhongguo guonei shengchan zongzhi hesuan lishi ziliao, 1952-1995* [Compendium of China's National Income Statistics, 1952-1995]. Dalian: Dongbei caijing daxue chubanshe, 1997.
- GDP 1996-2002. *Zhongguo guonei shengchan zongzhi hesuan lishi ziliao, 1996-2002*. [Compendium of China's National Income Statistics, 1996-2002]. Beijing: Zhongguo tongji chubanshe, 2004.
- Historical Statistics of Japan, <http://www.stat.go.jp/english/data/chouki/19.htm>, Accessed 25 May 2006.
- Hitotsubashi 1997. China. Guojia tongjiju., and Hitotsubashi Daigaku. Keizai Kenkyujo. *The Historical National Accounts Of The People's Republic Of China, 1952-1995*. Tokyo: Institute of Economic Research Hitotsubashi University.
- Holz, Carsten A. 2005. "The Quantity and Quality of Labor in China 1978-2000-2025." Dated May 2005. Accessed 9 June 2007 from <http://ihome.ust.hk/~socholz/>
- Holz, Carsten A., 2006a. "China's Reform Period Economic Growth: How Reliable Are Angus Maddison's Estimates?" *Review of Income and Wealth*, Blackwell Publishing, vol. 52(1), pages 85-119.
- Holz, Carsten A., 2006b. "New Capital Estimates for China," *China Economic Review*, Elsevier, vol. 17(2), pages 142-185.
- Holz, Carsten A. 2006c. "Response to Gregory C. Chow's 'New Capital Estimates for China: Comments.'" *China Economic Review* 17.2, pp. 193-197.

- Hou Fengyun. 1999. *Zhongguo renliziben xingcheng ji xianzhuang* [Formation and Present Circumstances of Human Capital in China]. Beijing: Jingji kexue chubanshe.
- Huang, Yongfeng, Ruoen Ren, and Xiaosheng Liu. 2002. "Perpetual Inventory Estimate of Capital Stock for Chinese Manufacturing." *Jingjixue (jikan)* [Economics Quarterly] 1 (2).
- Ishikawa, Shigeru. 1965. *National Income And Capital Formation In Mainland China; An Examination Of Official Statistics*. Tokyo,; Institute of Asian Economic Affairs.
- Japan Education. 1984. *Sengo Nihon kyôiku shiryô shûsei - bekkân* (Collection of historical materials on post-war Japanese education; supplementary volume). Compiled by Sengo Nihon Kyôiku Shiryô Shûsei Henshû Inkaï. Tokyo: Sanichi Shobô.
- Jefferson, Gary H., Thomas G. Rawski, Li Wang, and Yuxin Zheng. 2000. "Ownership, Productivity Change, and Financial Performance in Chinese Industry." *Journal of Comparative Economics* 28.4: 786-813.
- Keidel, Albert. 1994. "China: GNP per Capita." Report No. 13580-CHA, December 15, 1994 for County Operations Division, China and Mongolia Department, East Asia and Pacific Regional Office, World Bank.
- Klein, L.R.; Gao, H.; Tao, L.; 2006, *Estimation of China's Inflation Rate* (forthcoming)
- Kleinman, Arthur, and James L. Watson, eds. 2005. *SARS in China : prelude to pandemic?* Stanford, Calif.: Stanford University Press.
- Kojima, Reiitsu, 2002, "On the Reliability of Chinese Economic Statistics with Special Reference to GDP," *Journal of Econometric Study of Northeast Asia*, 4, pp.15-30.
- Kristof, Nicholas D. 2007. "The Educated Giant." *New York Times*. 28 May, A19.
- Liu, Ta-chung and K. C. Yeh. 1965. *The Economy Of The Chinese Mainland : National Income And Economic Development, 1933-1959*. Princeton, N.J.: Princeton University Press.
- Maddison, Angus, 1998, *Chinese Economic Growth in the Long Run*. Paris: Organization of Economic Cooperation and Development.
- Meng Lian and Wang Xiaolu. 2000. "Dui Zhongguo jingji zengzhang tongji shuju kexindu de guji" [An evaluation of the reliability of China's statistics on economic growth]. *Jingji yanjiu* [Economic Research], no. 10, pp. 3-13.

- Nakamura, Takafusa. 1983. *Economic Growth in Prewar Japan*. New Haven: Yale University Press. Trans. Robert A. Feldman. (Original 1971).
- National Bureau of Statistics, 1960, *Weidade shinian* [Ten Great Years] (Beijing: Statistics Press).
- Perkins, Dwight H. 1975, "Growth and Changing Structure of China's Twentieth Century Economy," in Dwight H. Perkins, editor, *China's Modern Economy in Historical Perspective* (Stanford: Stanford University Press) pp. 115-165.
- Perkins, Dwight H., 1980, "Issues in the Estimation of China's National Product," in Alexander Eckstein, editor, *Quantitative Measures of China's Economic Output* (Ann Arbor: University of Michigan Press), pp. 246-273.
- Perkins, Dwight H., 1988, "Reforming China's Economic System," *Journal of Economic Literature*, Volume XXVI, No. 2, June, pp. 601-645.
- Perkins, Dwight H., 2005, "China's Economic Growth in Historical and International Perspective," (in Chinese) *Jingjixue (jikan)* [China Economic Quarterly] Vol. 4, No. 4, pp. 891-912.
- Rawski, Thomas G. 2001. "What Is Happening to China's GDP Statistics?" *China Economic Review* 12.4: pp. 347-354.
- Rawski, Thomas G. 2002. "Measuring China's Recent GDP Growth: Where Do We Stand?" [Chinese-language version in *Jingjixue* (China Economic Quarterly) 2.1: 53-62].
- Rawski, Thomas G. 2005. "SARS and China's Economy." In Kleinman and Watson 2005, pp. 105-121.
- Rawski, Thomas G. and Robert W. Mead "On the Trail of China's Phantom Farmers," *World Development* 26.5 (1998): 767-781.
- Swamy, Subramanian, 1973, *Economic Growth in China and India—A Comparative Appraisal (1952-1970)*, (Chicago: University of Chicago Press)
- Szirmai, Adam and Ruoen Ren. 2000. "Comparative performance in Chinese manufacturing, 1980-1992." *China Economic Review* 11.1: 16-53.
- Woo, Wing Thye, Gang Fan, Wen Hai, Y.B. Jin. 1993. "The Efficiency And Macroeconomic Consequences Of Chinese Enterprise Reform." *China Economic Review*, 4(2), 153-168

- Wu, Harry X. 2002. "How Fast Has Chinese Industry Grown? Measuring The Real Output Of Chinese Industry, 1949-97." *Review of Income and Wealth* 48.2: 179-204.
- Xu Xianchun 1999. "世界银行对中国官方 GDP 数据的调整和重新认可." [The World Bank's Evaluation and Reappraisal of China's Official GDP Data.] *Jingji yanjiu* [Economic Research]. No. 6.
- Xing Bao. 2003. "Unchecked Authority." *Shanghai Star*, 28 August. Accessed from <http://app1.chinadaily.com.cn/star/2003/0828/fo4-1.html> 2 October 2005.
- Yearbook. *Zhongguo tongji nianjian* [China Statistical Yearbook] : Zhongguo tongji chubanshe. Annual.
- Yeh, Kung Chia. 1964. "Capital Formation in Mainland China, 1931-1936 and 1952-1957." Ph.D. thesis, Columbia University.
- Young, Alwyn 2003. "Gold into Base Metals: Productivity Growth in the People's Republic of China during the Reform Period," *Journal of Political Economy*, 111 (December 2003), 1220-1261.
- Zhai Zhengwu 1987. "Estimates for Indicators in Life Tables for China during 1953-1964 and 1964-1982." *Renkou yanjiu* [Population Research] no. 1, pp. 22-29.
- Zhang, Jun, Guiying Wu, and Jipeng Zhang. 2004. "Estimates of Tangible Capital Stock for China's Provinces, 1952-2000." *Jingji yanjiu* [Economics Research] (10):35-44.
- Zhang, Jun, and Yuan Zhang. 2003. "New Estimates for China's Stock of Capital." *Jingji yanjiu* [Economics Research] (7):35-43.
- Zhang, Junsen, Yaohui Zhao, Albert Park, and Xiaoqing Song. 2005. "Economic Returns to Schooling in Urban China, 1988 to 2001." *Journal of Comparative Economics* 33: pp. 688-709.