Genuine output and genuine productivity of China's provinces : a multiregional input-output analysis

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Keywords: Genuine savings method, Total factor productivity, Multiregional input–output method, China

JEL classification: D24, D57, O47, Q01

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Genuine Output and Genuine Productivity of China's Provinces: A Multiregional Input–Output Analysis

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Abstract This paper recalculates value added, capital formation, capital stock, and related multifactor productivity for China's provinces by expanding on the genuine savings method proposed by the World Bank. Specifically, we construct China's time-series multiregional input–output tables to account for the natural resource depletion and environmental damage that affect genuine output when considering inter-provincial trade. The results show that although the loss of natural capital in China's provinces in terms of value added and investment has declined, the impact on productivity during the past decades is still significant and has even increased during the past decades.

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During the past 30 years, China has been one of the world's fastest growing economies, with one of the highest rates of gross domestic savings (GDS) and gross domestic investment as a percentage of GDP. According to World Bank (2000a) statistics, average GDP growth rates in the 1980s and 1990s in China were 10.1% and 10.7%, respectively, ranking the second among 206 countries and regions worldwide, after Botswana, an African country rich in natural resources. In 1999, the GDS and GDI in China were the highest in the world at 42% and 40%, respectively. This was 20% higher than the world average at that time. However, according to the recently published World Bank Database, the loss of natural capital in China is also shockingly high. To a great extent, this counteracts the nominal GDS and GDI.

1. China's Genuine GDP and Genuine Productivity

The current national economic accounts system, which is based on nominal GDP, has serious flaws. It does not take into account the loss of natural capital even as it accounts for the value of overexploited resources and energy, especially non-renewable resources, into GDP as additional value. This will exaggerate economic income while causing rapid consumption or depletion of natural resources and severe deterioration of the natural environment, inevitably leading to a large reduction in real national welfare. It is therefore necessary to amend the current national accounts system according to Kunte et al. (1998) and Hamilton and Clemens (1998). Starting in 1995, the World Bank began to redefine and remeasure national wealth using genuine national accounting, which was based on the early research of Dasgupta and Heal (1974, 1981), Dasgupta (1982), Dasgupta and Maler (1990), and Maler (1991).

The World Bank (1997) first proposed the concept and calculation method of genuine domestic savings, or the real savings rate of a country, after the depletion of natural resources (especially non-renewable resources) and the loss of environment through pollution are deducted.

The formal model of the genuine savings is given by Hamilton and Clemens (1998),

$$G = GNP - C - \delta K - n(R - g) - \sigma(e\text{-}d) + m \quad (1)$$

Here, $GNP - C$ is traditional gross savings, which includes foreign savings; GNP is gross national product; and C is consumption. With δK as the depreciation rate of produced assets, $GNP - C - \delta K$ is traditional net savings. Further, $-n(R - g)$ is resource depletion and $S = -(R - g)$ expresses the case where resource stocks S grow by an amount g, are depleted by extraction R and are assumed to be costless to produce, and n is the net marginal resource rental rate. $-\sigma(e - d)$ is pollution emission costs, with $X = -(e - d)$ the growth of pollutants that accumulate in a stock X where d is the quantity of pollutant that would naturally dissipate from the stock, and σ is the marginal social cost of pollution; m is investment in human capital (current education expenditures), which does not depreciate (and can be considered as a form of disembodied knowledge).

Natural resource depletion is measured by the rent gained through the exploitation and procurement of natural resources. The rent is the difference between the producing price (calculated by the international price) and total production costs. The costs include the depreciation of fixed capital and return of capital. Note that while the rational exploitation of natural resources is necessary for economic growth, if the resource rent is too low, it will induce over-exploitation. If the resources rent is not reinvested (e.g. investment in human resources) but rather put into consumption, it is also “irrational.” Pollution loss mostly refers to CO_2 pollution. This is calculated by the global margin loss caused by the emission of one ton of CO_2, which Fankhauser (1995) suggested was 20 US dollars.

The World Bank has estimated the losses of various natural resources in many countries since 1970 (Table 1) China’s loss of natural capital as a percentage of GDP is shockingly high, although the magnitude of this loss has varied over the years. During the early 1970s, the loss accounted for 3% of GDP. Between the late 1970s and 1980s, the economic loss reached its peak of 17.5% of GDP. It began to drop in the late 1980s, reaching about 10%. However, the expense is actually much more costly than the estimate made at the time. In the 1990s, the percentage lost fell further. By 1995 it had decreased by half to 5.51%. During the late 1990s, this trend was quite distinct, with the loss reaching a low of 4.44% in 2000 before rising again to 9.77% in 2008. The genuine domestic savings rate is greatly discounted because of the loss of natural resources. This is reflected in the trend of the genuine domestic savings rate, which rises gradually after a sharp fall. After accounting for natural capital loss, the net domestic savings rate appears to rise after the 1990s, and the two curves tend to converge.

Table 1 Natural Capital and Genuine Domestic Savings Rate in China (Unit: % of GDP)

	1970	1980	1990	1995	2000	2005	2010	2013
Domestic Savings	27.36	33.39	39.22	42.12	36.83	47.96	52.23	51.28
Net Domestic Savings	18.89	23.15	29.39	31.22	23.86	33.35	35.46	33.17
Natural Capital Loss	−1.91	−19.41	−8.67	−4.72	−3.94	−6.52	−7.65	−5.33
Energy Depletion	−0.12	−15.27	−4.39	−1.50	−1.88	−3.95	−4.51	−2.74
Mineral Depletion	−0.11	−0.26	−0.26	−0.13	−0.04	−0.42	−1.77	−1.39
Net Forest Depletion	−0.55	−1.62	−0.61	−0.40	−0.08	−0.06	−0.07	−0.05
CO_2 Damage	−1.13	−2.27	−3.41	−2.70	−1.93	−2.08	−1.31	−1.16
Education Expenditure	1.40	1.70	1.57	1.67	1.78	1.79	1.79	1.79
Genuine Domestic Savings	18.38	5.44	22.29	28.17	21.69	28.62	29.60	29.62

Resource: World Bank, World Development Indicator Database.

According to the World Bank's adjustment to the saving rate, we can calculate the relevant genuine gross domestic product (GGDP) from the GDP by using the expenditure approach, in which we deduct the energy, mineral, and net forest depletion and CO_2 damage from GDP and add human resource expenditure. Here we do not count consumption of fixed capital (CFC) because it is a part of value added included in GDP in addition to not being listed in the national accounts of China's statistics. In addition, the CFC of China in the World Development Indicator (WDI) database is not comparable between 1993 and 1994.

In the measurement of productivity, the different measures of capital formation greatly influence the measured capital stock constructed with the perpetual inventory method. We can define the green capital stock using the method of Hamilton, Ruta, and Tajibaeva (2005):

$$K'_t = K'_{t-1}(1 - \delta_t) + I' \quad (2)$$

where δ_t it is the depreciation ratio. (Time subscripts are omitted below.) Our depreciation rate increases along a linear trend from 4% in 1952 to 6% in 2004. I' is the genuine fixed capital formation (FCF). According to formula 1, we can define the genuine FCF as follows:

$$I_t' = I_t - n_t(R_t - g_t) - \sigma_t(e_t - d_t) + m_t \quad (3)$$

where I_t is the traditional gross capital formation, $n_t(R_t - g_t) - \sigma_t(e_t - d_t)$ is the natural capital lost, and m_t is the education expenditure.

As shown in Table 2, compared with traditional GDP, the GGDP was about 0.55% higher on average in terms of TFP growth rates in the 1978-2004 period, with lower TFP growth in the 1992-2004 period. The TFP growth rate of traditional GDP is more stable and has the opposite trend. This means that China's growth has varied between episodes of extensive and intensive growth. Economic growth in the 1980s was intensive growth—higher TFP growth compensated for the diminishing contribution of natural resources, that is, of "natural capital." During the 1990s, as a result of the comparative decline of its natural resource consumption, China's capital stock began to increase rapidly and its growth became more extensive, especially with respect to capital.

Table 2 Genuine GDP and Genuine Productivity of China

	1978-1992		1992-2004		2004-2013		1978-2013	
GDP	9.02	(100.0)	10.12	9.61		(100.0)	9.61	(100.0)
K	7.74	(34.3)	11.27	9.56			9.56	(39.8)
L	2.96	(9.8)	1.07	2.44			2.44	(7.6)
H	2.25	(7.5)	1.90	2.02			2.02	(6.3)
TFP	4.36	(48.3)	4.72	4.45			4.45	(46.3)
GGDP	9.87	(100.0)	11.06	10.51		(100.0)	10.51	(100.0)
K'	5.95	(24.1)	15.88	10.42			10.42	(39.7)
L	2.96	(9.0)	1.07	2.44			2.44	(7.0)
H	2.25	(6.8)	1.90	2.02			2.02	(5.8)
TFP'	5.93	(60.1)	3.82	5.00			5.00	(47.6)

Notes: GDP here is real GDP in 1978 prices; GGDP is the genuine GDP. K denotes capital services input, L denotes labor input, H denotes inputs of education. TFP denotes total factor productivity. The shares of capital, labor, and human resources are 0.4, 0.3, and 0.3, respectively. Numbers in parentheses are the contribution ratio of each factor.
Source: Zheng, Hu, and Bigsten (2009).

2. Provincial Natural Capital Loss Accounting

When we turn to the natural capital of China's provinces, the estimation of the rental rate for natural resources in each province will become difficult because of a lack of price data. To simplify the accounting, we assume that the total production costs (including the depreciation of fixed capital and return of capital) per unit of a natural resource are equal in all provinces during the given year. This assumption leads to a result in which the rental rate of a unit of a natural resource is also equal in all provinces because the production price (the international price) is the same. The energy depletion is defined as "the product of unit resource rents and the physical quantities of energy extracted." This allows us to calculate the energy depletion of province *i*:

$$D_i^E = n_i E_i^E = nE_i^E = \frac{D^E}{E^E} E_i^E = D^E \frac{E_i^E}{E^E} \qquad (n_i = n_j = n) \tag{4}$$

This shows how the share of the provincial energy depletion in China's total is actually weighted by its energy extraction share. Here D^E refers to the energy depletion of China, which is taken from the WDI database, and E^E refers to the energy extracted (consumption) of China, which can be found in the China Statistics Yearbooks. The energy extracted in each province E_i^E is taken from the *China Compendium of Statistics 1949-2008* (NBS, 2010) and *China Energy Statistical Yearbook* (NBS and NDRC, various years).

When we pull the data for China directly from the WDI database as the average instead of the algebraic average we find that the trend of the enveloped surface of provincial energy depletion is quite synchronous. With the exception of Shanxi, the most energy-intensive province of China, all other provinces varied between half and double the average. Shanxi shows an astonishing share of total energy depletion in GDP at its peak in the early 1980s, when it rose from 15.% in 1978 to 27.4% in 1981, followed by a sharp drop back to 15.% in 1983Figure 1).

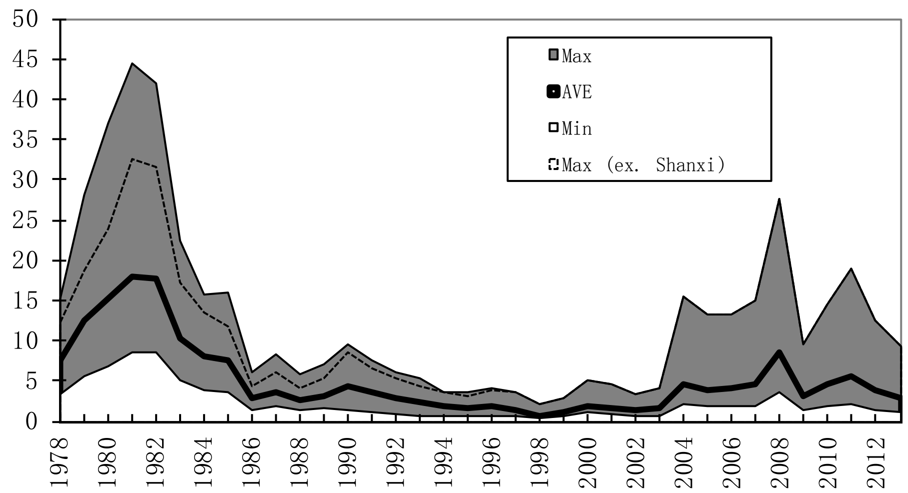


Figure 1 Energy Depletion as a Percentage of GDP

The estimation of mineral depletion is more complicated. It is defined here as “the product of unit resource rents and the physical quantities of minerals extracted” (referring to bauxite, copper, iron, lead, nickel, phosphate, tin, zinc, gold, and silver). Here we choose only two of these minerals: the widely used metal resource iron, which is reflected in crude steel production, and the widely used non-metal resource phosphate, which is mainly used to produce fertilizer. The assumption of one price in total production costs is also used here and we can therefore write the mineral depletion of the province *i* as follows:

$$D_i^M = n_i E_i^M = n_i^I E_i^I + n_i^P E_i^P = n^I E_i^I + n^P E_i^P = n^M (\frac{n^I}{n^M} E_i^I + \frac{n^P}{n^M} E_i^P)$$

$$= \frac{D^M}{E^M} (\frac{n^I}{n^M} E_i^I + \frac{n^P}{n^M} E_i^P) = D^M \frac{w_1 E_i^I + w_2 E_i^P}{w_1 E^I + w_2 E^P} \quad (w_1 = \frac{n^I}{n^M}, w_2 = \frac{n^P}{n^M}) \tag{5}$$

Here n^M and E^M refer to the rental rate and extraction of minerals and the letter *I* and *P* are for those factors for iron and phosphate. We use only the international price, the *World Bank Commodity Price Data*, as the weights of the two kinds of mineral resources because of a lack of domestic prices. The highly synchronous trend between the enveloped surface and China's average level shows that our assumption of the weights is acceptable. Before the second valley in 1997, Liaoning always has the largest mineral depletion share in its GDP with a peak of 2.2% in 1988. Hebei had the largest share, ahead of Qinghai, after 2003 as the new steel production base of China, whose mineral depletion reached nearly 6% of its GDP.

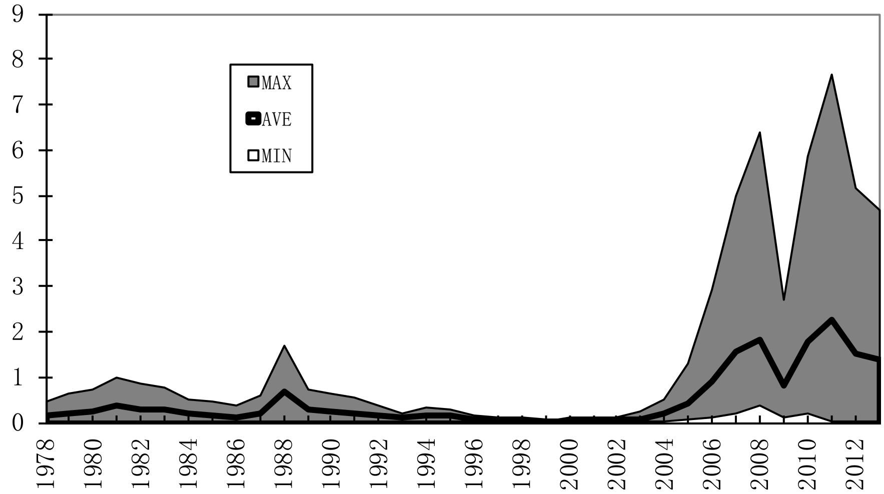


Figure 2 Mineral depletion as Share of GDP (%)

The difficulty in estimating the CO_2 damage comes from the lack of CO_2 emission data in any of the environmental statistics and materials of China. Because CO_2

emission is of great importance and highly correlated with energy consumption, we estimate the volume of provincial CO_2 emission ourselves. The estimation of CO_2 emission based on energy consumption is calculated according to the following formula:

CO_2 Emission = Consumption of Fossil Fuel[2] × Carbon Emission Factor × Fraction of Carbon Oxidized + Production of Cement × Processing Emission Factor

Fraction of Carbon Oxidized refers to the ratio of the quantity of CO_2 that produces one ton of carbon after complete gasification, which is a constant 3.67 (44:12). The most important coefficient here is the Carbon Emission Factor, which refers to the equivalent carbon emission in the consumption of fossil fuel. The three most commonly used factors are the following: that of the Energy Research Institute of China's National Development and Reform Committee, which is 0.67; that of the Carbon Dioxide Information Analysis Center of the US Department of Energy, which is 0.68; and that of the Institute of Energy Economy of Japan, which is 0.69. We use the first factor in this paper. In addition, the production of cement will emit more CO_2 than the consumption of fossil fuel because of the calcination of limestone, and will on average emit 0.365 tons of CO_2 when producing one ton of cement (China Cement Net, 2007).

In this paper, data on energy consumption structures, total energy consumption from 1978-1994, and cement production are from the *China Compendium of Statistics 1949-2008* (NBS, 2010), while data on provincial aggregate energy consumption for 1995-2008 are from *China Energy Statistical Yearbook* (NBS and NDRC, various years). Because data on the energy consumption structures of Shanxi and Shanghai are terminal energy consumption data, they cannot be used directly. We instead use "Energy Production Structure" as an alternative with some missing values replaced by linearly interpolated data.

2 More accurate calculation should exclude the carbon stored. We here use the approximate amount because of the limit of data.

Carbon dioxide damage is estimated to be $20 per ton of carbon (the unit damage in 1995 US dollars) times the number of tons of carbon emitted. The damage by province also follows the trend of the Chinese average and has a similar variety of energy depletion, except in the case of Shanxi, which maintains a level above 7% of GDP until 1994, followed by Ningxia with a new peak of 5.3% in 2004.

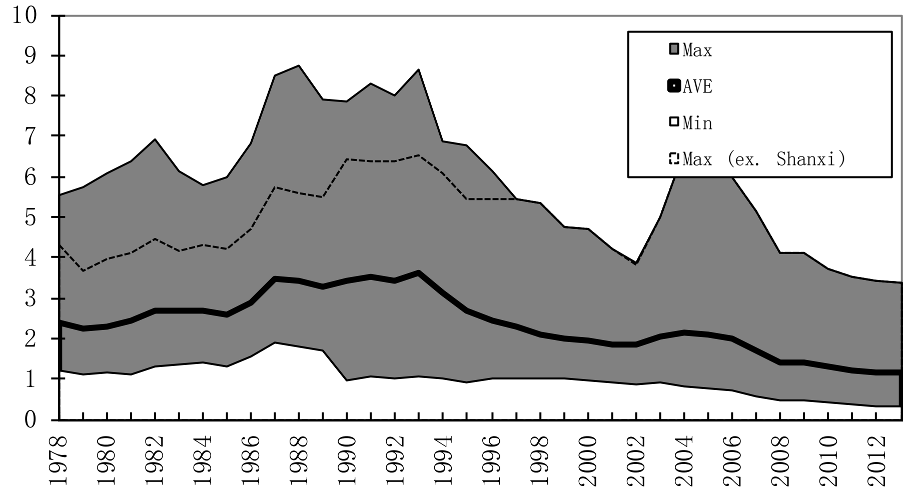


Figure 3 CO_2 Depletion as Share of GDP (%)

Net forest depletion is defined as “the product of unit resource rents and the excess of round wood harvest over natural growth.” Here we use the production of timber in each province from the *China Compendium of Statistics 1949-2008* (NBS, 2010) as the “consumption” of forest resources. The share of net forest depletion of each province is therefore the same as their production using the same estimation method of energy depletion.

Heilongjiang has always had the largest net forest depletion during the past 27 years with a peak of 2.3% of its GDP in 1987, followed by Inner Mongolia, Jilin, and Fujian, which are all areas with abundant forest resources. Forest resources have shown the smallest depletion in natural capital loss as the net forest depletion of all provinces dropped to a very small share of GDP after the “Returning Farmland to Forest” policy of 1998.

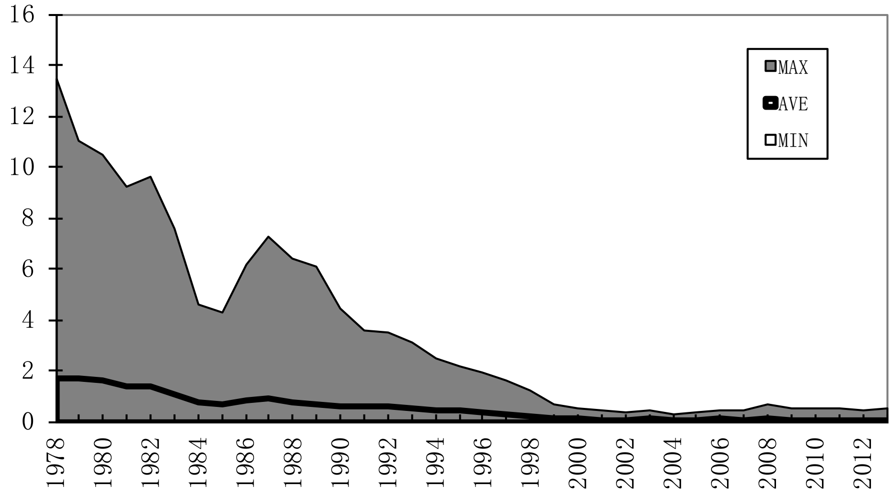


Figure 4 Net forest depletion as Share of GDP (%)

By summing the four depletions, we can calculate the natural capital loss of all provinces. The trend of natural capital lost is quite similar to the trend in energy depletion, which makes up its largest part. With the exception of Shanxi, which always had the highest value before 1997, the natural capital loss of the province with the second highest value makes up more than 30% of its GDP during the peak time of 1981-1982. After the lowest point in 1999, the trend reversed and rose to about %. In contrast, the lowest provinces, Shanghai and Guangdong, show natural capital loss of only 10% of GDP during the peak, falling to less than 2% after 1998 and maintaining this level until 2004.

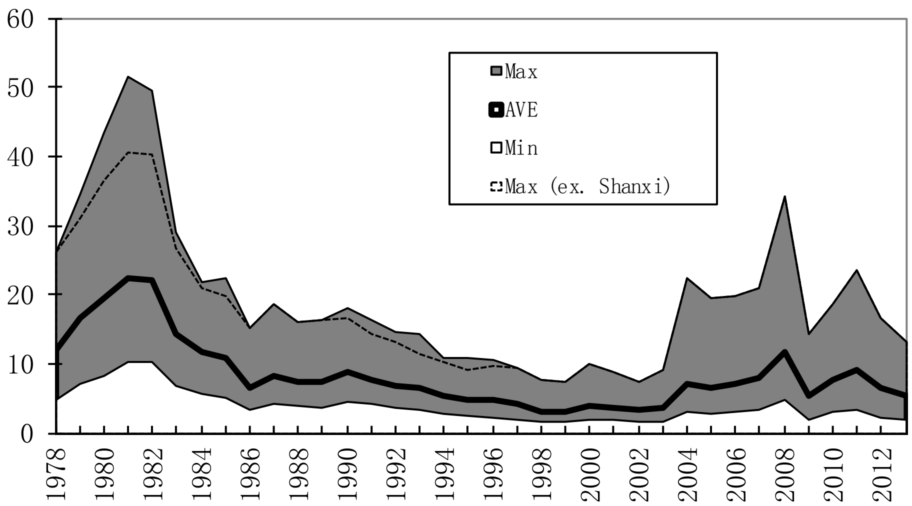


Figure 5 Natural Capital Lost as Share of GDP (%)

3. Provincial Genuine GDP, Investment, and Capital Stock

(1) Provincial Genuine GDP

Provincial GGDP is calculated using the same method as that used for the national level. However, estimation of education expenditure is limited by a lack of data, with the only traceable data available being the share of Operating Expenses for Culture, Education Science & Health Care in the budgetary expenditure of provincial output. However, these items all reflect the investment in human resources and show trends similar to the Chinese average from WDI. This share remained stable while the greatest fluctuation was seen in the provinces of Qinghai, Ningxia, Xinjiang, and later Guizhou. Shanghai had the lowest investment in human capital before 1987, leading to lower compensation for its natural capital lost.

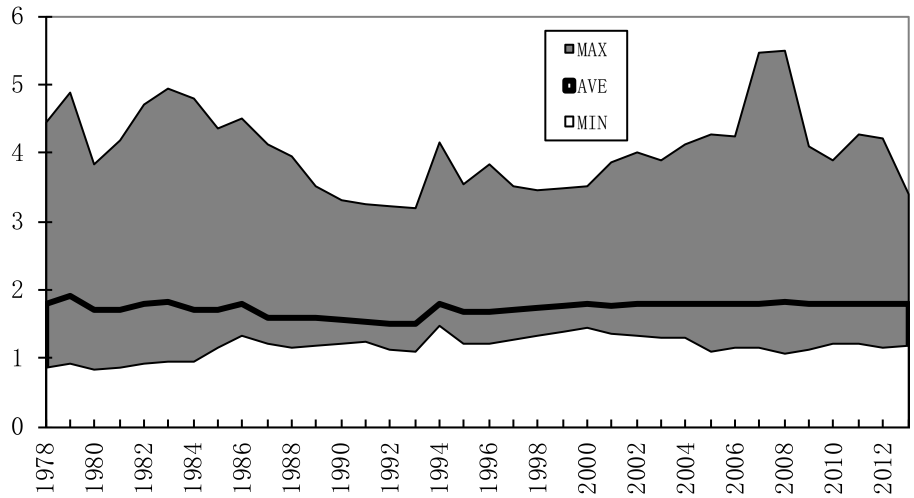


Figure 6 Education Expenditure as Share of GDP (%)

With the exception of Shanxi, the province with the lowest GGDP share had a share of 57% of traditional GDP in 1981, increasing to 80% in the late 1980s. Before 1996, Shanxi's GGDP was always lower than that of other provinces, especially in the early 1980s when it fell to only 11.13% of its GDP. This is mainly because of its high energy depletion and comparatively low GDP in the early 1980s.

The province with the highest GGDP (usually Guangdong and Shanghai) maintained a level of more than 90% of its traditional GDP. This trend reversed after 1998 when Guizhou and Ningxia became the provinces with the lowest share at around 80%. The ratio dropped from 92.4% to 83.4% in 2004 and to 74.7% in 2008.

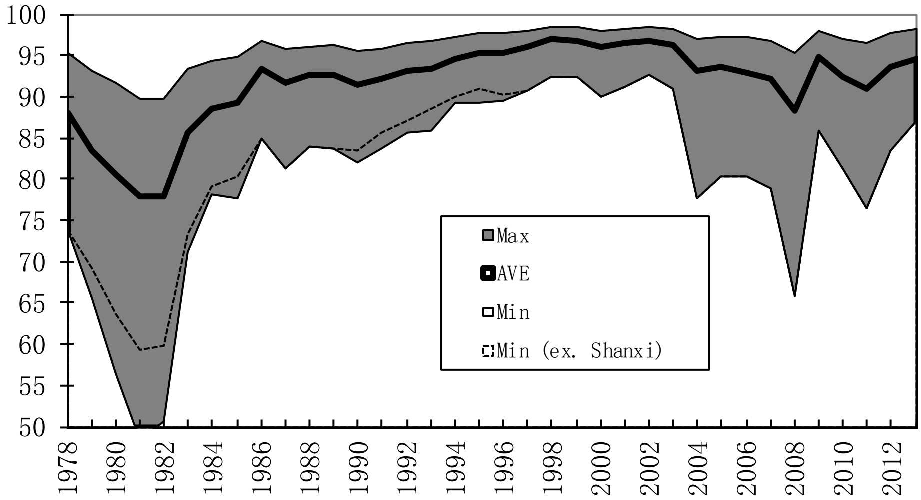


Figure 7 Genuine GDP as Share of GDP (%)

(2) Provincial Genuine Investment

According to formula (1) we can define the genuine investment of province *i*:

$$I'_t = I_t - n_i(R_t - g_i) - \sigma_t(e_t - d_t) + m_i \quad (6)$$

I_{it} is the traditional investment, $n_{it}(R_{it} - g_{it}) - \sigma_{it}(e_{it} - d_{it})$ is the natural capital lost, and m_{it} is education expenditure. Data on investment are from the FCF figures found in *Data of Gross Domestic Product of China 1952-2004* (NBS, 2007) and *China Compendium of Statistics 1949-2008* (NBS, 2010). We deflate the FCF according to the given indices using the methodology of Zhang (2008).

The traditional FCF ratio of China shows a very stable trend, rising from 30% to 42%. The province with the lowest value, usually Sichuan, also saw a gradual increase from 10% to 30% while the provinces with the highest values, Ningxia and Qinghai, saw an increase from 40% in the early 1980s to more than 80% in 2005. Under this traditional approach, most provinces have experienced a process of capital deepening which is also the result of a general applied extensive growth mode.

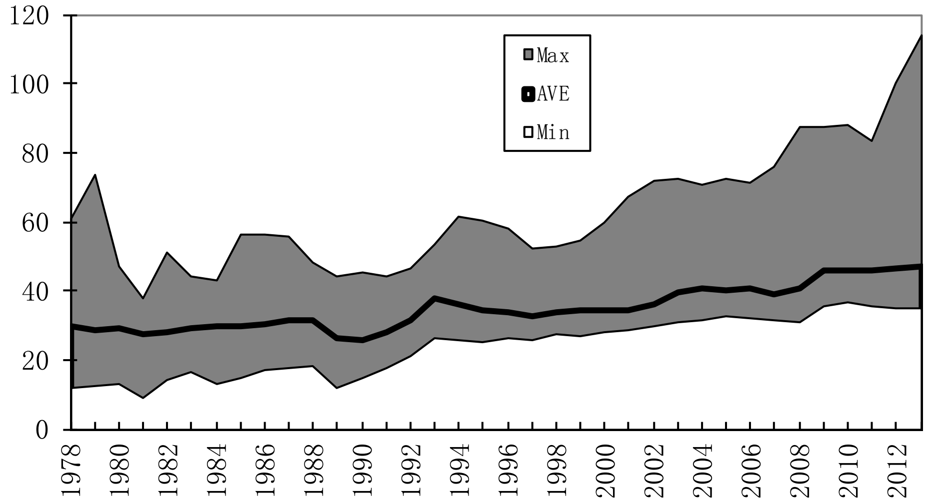


Figure 8 Fixed Capital Formation Ratio (%)

When we examine the genuine FCF ratio, an obvious “V” curve appears with a turning point in 1981, along with the overall negative ratio for the whole of China. The province with the highest ratio, Guangdong, had a decrease to only 17.8% of its GDP, while Shanxi reached its lowest point of −12% of its GDP. After this, a similar stable trend is seen in the provinces as the genuine FCF ratio rises from 25% to 79% of GDP. This curve is in fact the source of the trend in GGDP for the expenditure approach mentioned above.

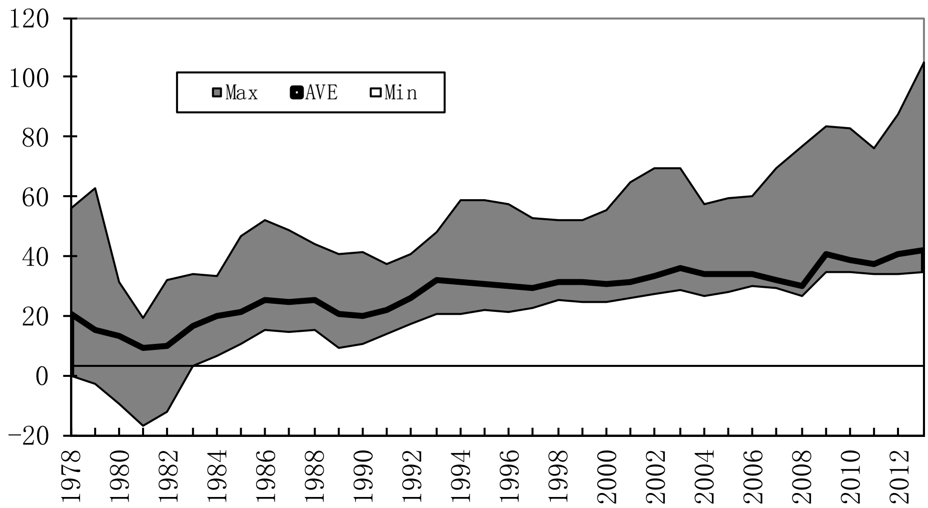


Figure 9 Genuine Fixed Capital Formation Ratio (%)

(3) Provincial Genuine Capital Stock

In the measurement of productivity, the difference in capital formation greatly influences the capital stock in the perpetual inventory method. We can define the genuine capital stock as the following:

$$K'_{it} = K'_{it-1}(1 - \delta_{it}) + I'_{it} \quad (7)$$

Where δ_{it} refers to the depreciation ratio calculated using the estimation method of Wu (2008), while I'_{it} is the genuine FCF. The capital stock in 1952 of each province is assumed to be ten times its FCF of 1952. Data for genuine capital stock dates from 1978 because of the limits of genuine FCF. Much as with the level of China's average, most provinces' genuine capital stock all experienced a period of stability in their traditional capital stock from the mid-1980s to the early 1990s, after which their share gradually rises to the level of the late 1970s. However, some provinces, such as Shanxi, Liaoning, and Yunan, all follow a deep "V" curve as their genuine FCF experienced a long period of negative levels.

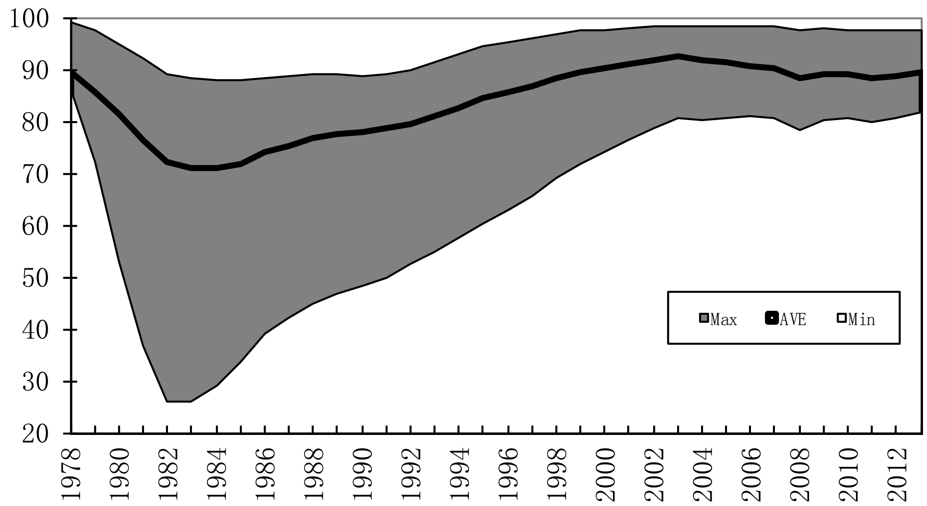


Figure 10 Genuine Capital Stock as a Share of Traditional Capital Stock

4. Indirect Decomposition of Provincial

The decomposition of natural capital lost D therefore occurs on only the block of intermediate inputs and final use in the input–output table. The intermediate "use" of the natural capital lost will be decomposed and re-combined into the real "use" for the first step as follows:

$$D_{out} = A^T D + CD = (A^T + C)D \tag{8}$$

Here D is a $1 \times n$ vector of the natural capital lost in the sector. A^T is the transposition of the direct input coefficient matrix, while C is a diagonal matrix of the ratio of final use in the total of intermediate inputs and final use.

$$C = diag(1 - \sum_i a_{ji}) \tag{9}$$

As these are total input coefficients in the general input–output models, here they must also incorporate the indirect loss of natural capital through the cycling of intermediate goods. Therefore, the final decomposition of the initial natural capital loss is similar to the derivatives of the Leontief inverse and should be written as follows:

$$D'_{\mathrm{out}} = CD + CA^T D + CA^T A^T D + \cdots = C(I - A^T)^{-1} D \tag{10}$$

In the calculation of the data for this paper, the decomposition of the natural capital loss in a sector must first add up the totals for each of the multiregional input–output (MRIO) tables by sector according to the classification of the input–output tables and then be divided again after transformation. Therefore, to calculate the natural capital loss of all sectors for all provinces this decomposition needs time series MRIO tables.

The construction of time series MRIO tables is based on the structure of the intermediate use table of the base year tables (Table 3) and control vector data using the standard RAS method. The column sum control vector of non-base year MRIO tables were sector-level total intermediate inputs of all provinces, which is the gap between total input and value added. Gross output and value added data before 2008 of the industrial sectors come from the China Industry Statistics Yearbook while value added was calculated by a linear interpolation and extrapolation of the value added ratio in the base year MRIO tables. In contrast, the value added of the agricultural sector and all service sectors comes from the annual database of China's National Bureau of Statistics and also the value added ratio in the base year MRIO tables for the corresponding sectors for all provinces.

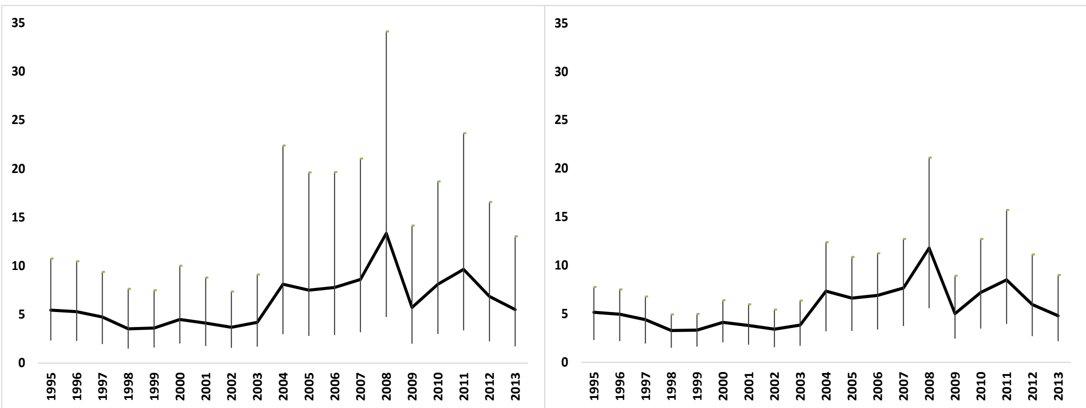
The row sum control vector were the gaps between total output and value added by the expenditure approach, which is the sum of final consumption, FCF, and net export of goods and service. The main items of provincial GDP, final consumption, FCF, and net export of goods and service were announced in the China Statistics Yearbooks every year. The sectoral structure of these items for non-base years is also taken from the base year MRIO tables.

Table 3 Years Covered in Multiregional Input–Output Tables

Based input–output table	Number of sectors	Number of regions	Year covered
1997 multiregional input–output table	17	8	1995、1996、1997、1998、1999
2002 multiregional input–output table	17	8	2000、2001、2002、2003、2004
2007 multiregional input–output table	17	8	2005、2006、2007、2008、2009
2012 multiregional input–output table	58	31	2010、2011、2012、2013、2014

Notes: The 2012 MIRO table comes from Gao, Li, and Hu (2017)
Source: Author's design.

Although most energy depletion and all mineral depletion were counted in the consumption of industrial sectors, this decomposition shows that around half of the natural capital loss was finally used by other non-industrial sectors such as construction and transportation. Compared with the unadjusted natural capital lost, the ratio of adjusted loss to gross value added was about 3% to 8% lower, showing a more stable proportion to the total value added of all industrial sectors.



Direct measure Indirect measure

Figure 11 Range of Provincial Natural Capital Depletion

When comparing the change of the provincial natural capital depletion under two different measures, we can identify those provinces with higher indirect than direct measures, or "importers" versus "exporters." Typically, China's largest coal producer, Shanxi Province, and its largest steel producer, Hebei Province, are the two top exporters while the three coastal importer provinces of Zhejian, Shandong, and Guangdong serve as the manufacturing centers of China. This new measure adjusted the distorted nature of natural capital lost, recasting it as consumption based, which means that final consumers, not producers, should be responsible for the loss.

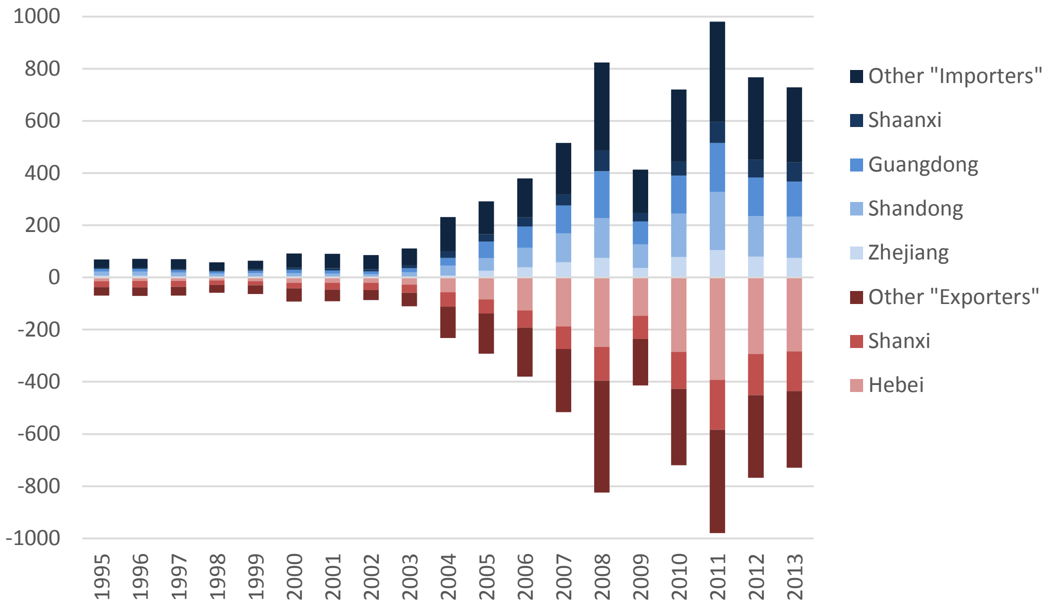
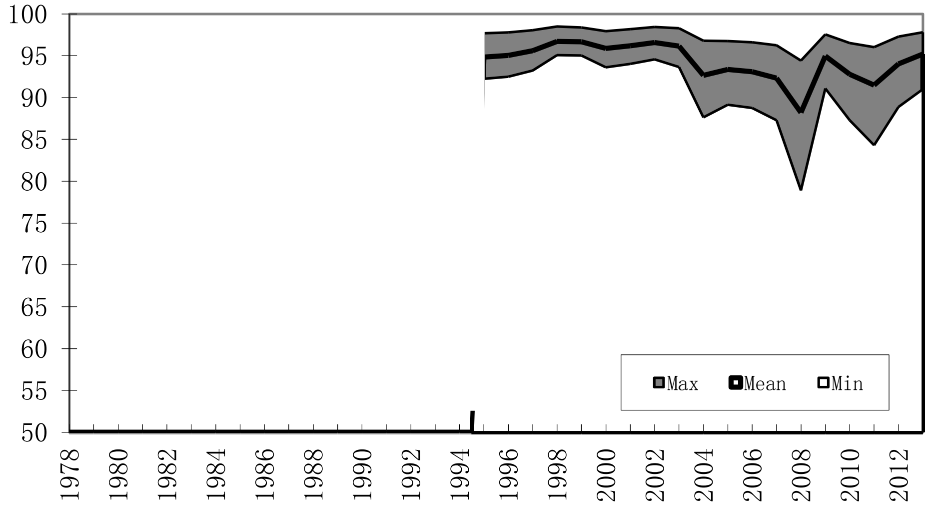
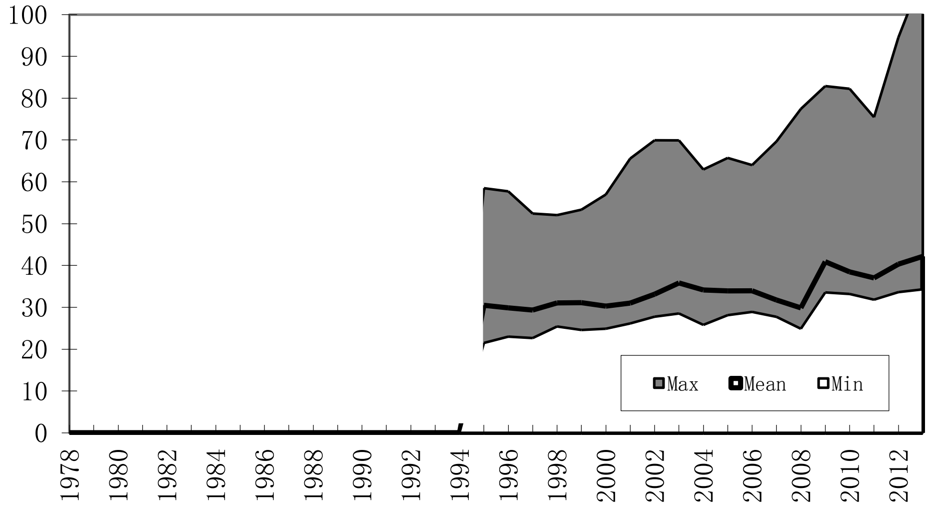


Figure 12 Regional Redistribution of Natural Capital Depletion

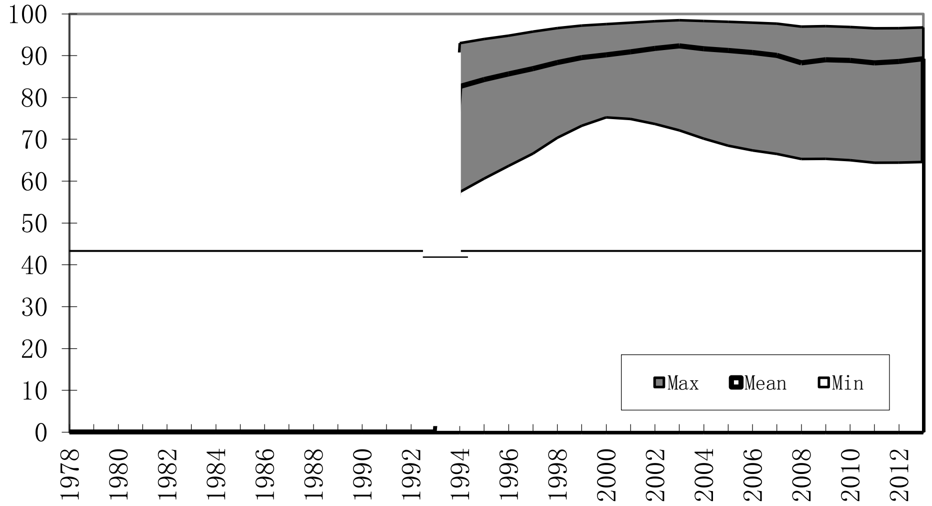
Compared with the direct measure of decomposition, the indirect measure leads to a relative higher average provincial GGDP level. The lowest level is now 80% in 2008, much higher than 65% under the direct measure. Correspondingly, the provincial genuine capital formation and genuine capital stock would also be relatively higher than the direct measure, especially during the 1990s. This will make the impact of all depletions more balanced between the producers and consumers, which is very important when calculating the "correct" growth rate of genuine capital stock and later the productivity for the resource-intense provinces such as the top two "importers," Hebei and Shanxi.



(a) Indirect Measure of Genuine Provincial GDP



(b) Indirect Measure of Genuine Capital Formation Ratio



(c) Indirect Measure of Genuine Capital Stock

Figure 13 Indirect Measure of Genuine GDP, Capital Formation and Stock

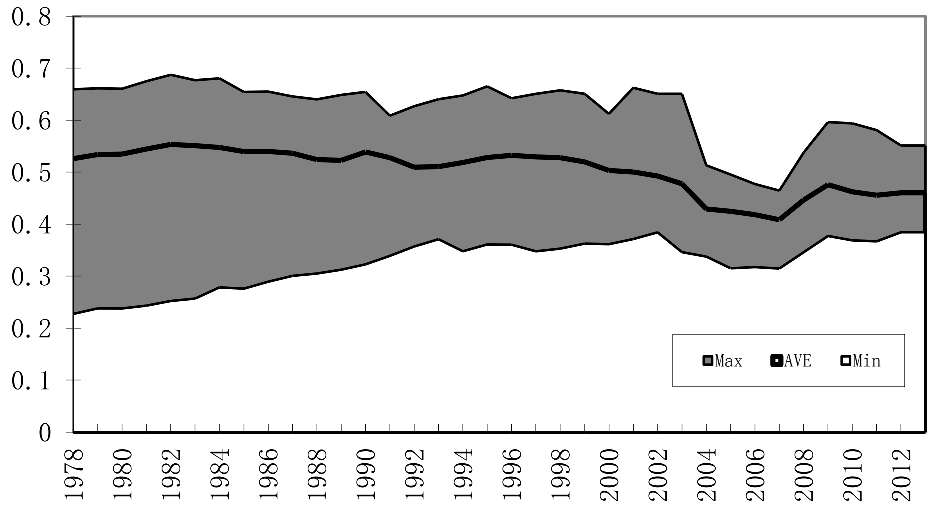
5. Accounting Genuine Productivity

Growth accounting is considered to be the classic method of productivity analysis. Assuming constant returns to scale, we can decompose GDP growth into factor contribution and productivity contribution. The coefficients of capital growth and labor growth, or their elasticity to output, were shown to be their proportion of GDP under the income approach. The new World Input–Output Database also provides a complete series of industry-level capital/labor share. The adjustment on the value added will affect the operating surplus portion of capital compensation and therefore change the capital output elasticity:

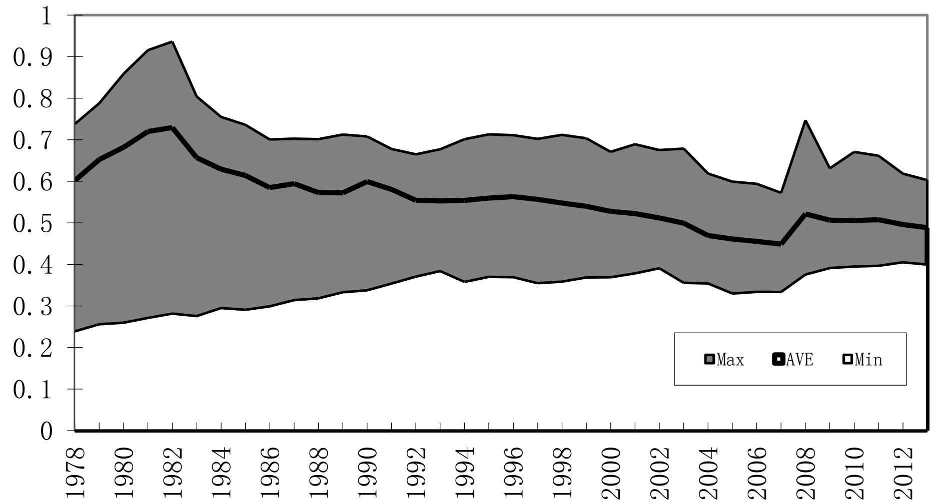
$$\alpha' = (\alpha - \rho)/(1 - \rho) \tag{11}$$

where α is the original capital output elasticity and ρ is the proportion of natural resource depletion and environmental damage in original value added.

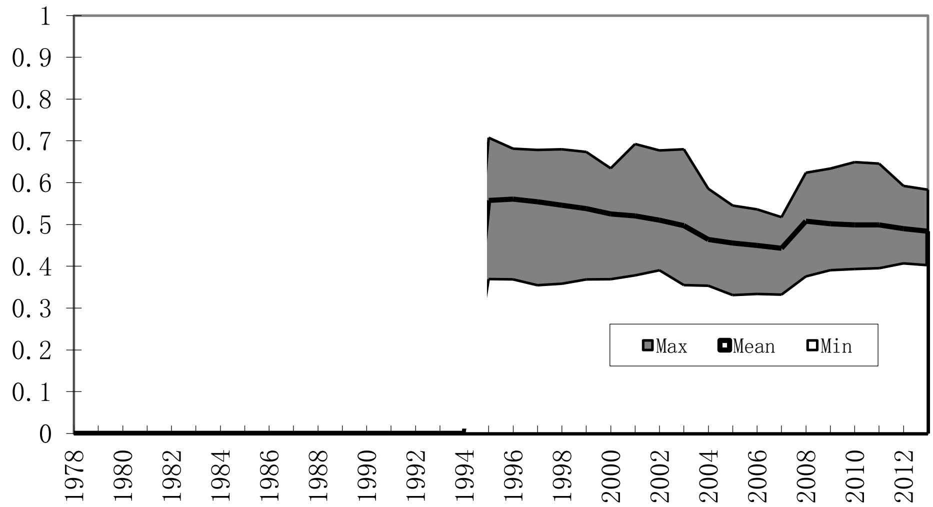
With the decline in overall labor share, the gap between the traditional and genuine labor share narrowed from 0.06 to 0.02. This indicates a rise in the share of capital and a catching up in the genuine capital share. This gap is due to a loss of capital compensation from resource depletion and environmental damage, while the decrease in natural capital loss was the driving force behind this convergence.



(a) Traditional Measure of Provincial Labor Share



(b) Direct Measure of Genuine Labor Share



(c) Indirect Measure of Genuine Labor Share

Figure 14 Different Measure of Labor Share

Assuming constant returns to scale where the sum of labor output elasticity and capital output elasticity is equal to 1, the growth rate of genuine total factor productivity can be expressed in the widely used Divisia Productivity Index (Jorgenson and Griliches, 1971; Star and Hall, 1976) recommended by the OECD Productivity Handbook as follows:

$$\dot{A}' = \dot{Y}' - \alpha' \dot{L} - (1 - \alpha') \dot{K}' \tag{12}$$

where *A'* is the genuine total factor productivity, *Y'* is the genuine value added, *K'* is the genuine capital stock, and *α'* is the adjusted labor share.

While keeping input factors and output measures in constant price, we see that the contribution of the growth of input factors to the output growth is the key measure in estimating different patterns of productivity. Although the level of the direct measure of provincial GGDP was lower than the traditional measure, the narrowing gap made the growth rate of the former higher than the latter on average most of the time. The growth rate difference was just 0.4% during the first period between 1978 and 1995. This difference narrowed to 0.3% between 1995 and 2003. The sharp drop of provincial GGDP growth in 2008 makes the difference −0.7% after 2003. However, for the indirect genuine measure, the provincial GDP growth kept at higher growth rate which is 1% on average between 1995 and 2013.

The traditional measure of the level of capital stock was much higher than the genuine measure while the expanding accumulation effect of natural resource depletion and environmental damage seriously lowers the growth rate of capital stock in the genuine measure. This effect led to an average 0.8% slowdown of genuine capital stock growth between 1978 and 1995. The shrinking ratio of natural capital lost to GDP narrowed this gap to −0.8% for direct measure and even −1% for indirect measure during the following decade but its expansion made the traditional measure higher again after 2003. This indicates that the traditional measure overestimates the contribution of capital stock in the total growth of China's provinces when natural capital lost was relatively rising (between 1995 and 2003) while it underestimates the contribution when it was declining (between 2003 and 2013).

The most important part of growth accounting is total factor productivity. Between 1995 and 2003 the growth rate of TFP was 2% lower under the direct measure of genuine productivity and its contribution to provincial GDP growth is 15% lower even considering that the provincial GDP growth was slightly higher. However, it is 1.3%

higher than the growth rate of TFP under the traditional measure after 2003 and the contribution to GDP growth is also 14% higher. There is also a gap in the growth rate of total factor productivity of 2% between the two periods, making a gap of 16% in their contribution to provincial GDP growth.

In contrast, the total factor productivity growth rates between the two periods under the indirect genuine measure are quite close to the traditional measure and have a gap of only 1.1%. This emphasizes that its contribution to average provincial GDP growth between 1995 and 2003 which is 14% higher than the average contribution of the period between 2003 and 2013. However, this intensive growth model was replaced by a more extensive one during the second period. Here total factor productivity growth contributes only around a quarter of the GGDP growth, and there is no obvious difference from the traditional measure.

This is the reason that the indirect measure of genuine productivity was much closer to the traditional measure not only on the aggregate level but also on the provincial level. Although the traditional TFP growth rate were all higher than 2%, the range of the direct measure of genuine productivity growth varied between 0.24% and 5.77%. In contrast, the indirect measure of provincial genuine productivity growth was highly correlated with the traditional ones. This means that the indirect measure captures the basic pattern of provincial productivity with proper adjustments for natural resource depletion and environmental damage, typically for Guangxi, Shanxi, and Heilongjiang.

Table 4 Provincial GDP and Productivity Growth (Median, %)

		Traditional		Genuine (Direct)		Genuine (Indirect)	
1978-1995	**GDP**	**11.10**		**11.91**			
	Capital	**11.59**	} **(61.85)**	**10.75**	} **(67.72)**		
	Labor	**1.90**		**1.90**			
	TFP	**4.23**	**(38.15)**	**3.85**	**(32.28)**		
1995-2013	**GDP**	**9.80**		**9.46**		**10.88**	
	Capital	**12.91**	} **(65.95)**	**12.89**	} **(66.95)**	**13.18**	} **(68.79)**
	Labor	**2.72**		**2.72**		**2.72**	
	TFP	**3.34**	**(34.05)**	**3.13**	**(33.05)**	**3.40**	**(31.21)**
1995-2003	GDP	8.30		8.40		10.14	
	Capital	11.90	} (51.22)	12.74	} (76.15)	12.86	} (60.50)
	Labor	0.81		0.81		0.81	
	TFP	4.05	(48.78)	2.00	(23.85)	4.01	(39.50)
2003-2013	GDP	11.01		10.33		11.47	
	Capital	13.72	} (74.84)	13.01	} (60.91)	13.43	} (74.65)
	Labor	4.28		4.28		4.28	
	TFP	2.77	(25.16)	4.04	(39.09)	2.91	(25.35)

Notes: Numbers in brackets are the percentage of growth contribution.

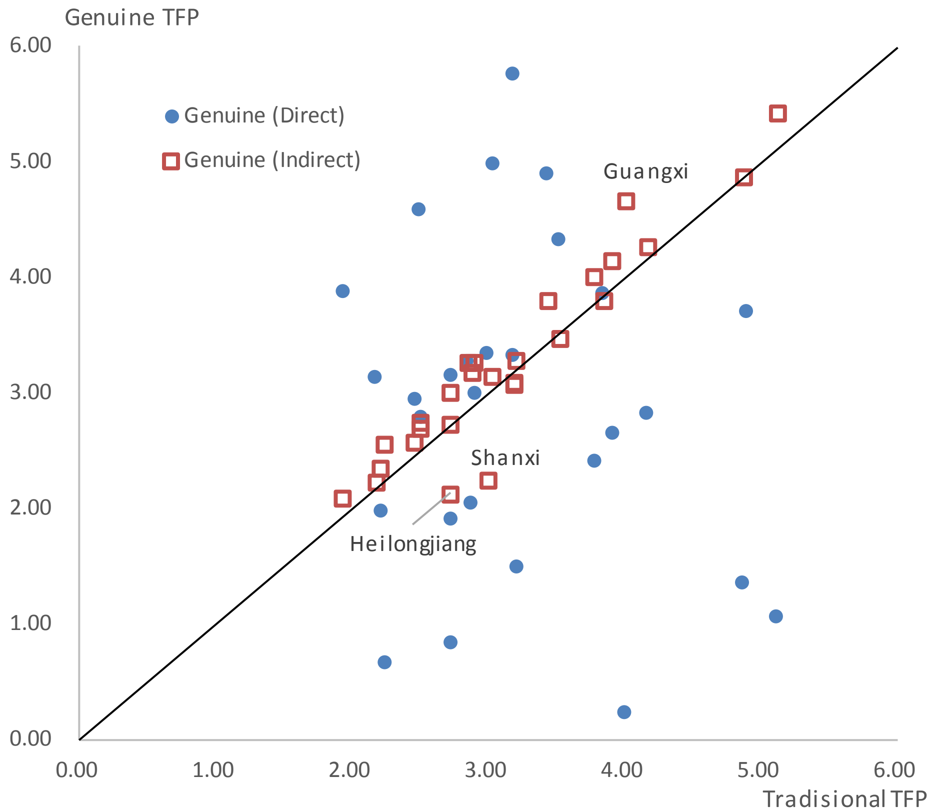


Figure 15 Provincial TFP Growth (1995-2013)

6. Conclusions

The over-consumption of natural resources and the related pollution will greatly discount the GDP growth and capital stock of provincial economies. The costs of natural resource depletion and carbon damage vary between 5% and 20% of China's provincial GDP and up to 20% of capital stock on average. The greater the natural capital loss, the lower the GGDP share of traditional GDP; the greater the expenditure of human resources, the greater the share of GGDP. At the same time, the greater the natural capital loss, the lower the accumulation of genuine capital stock; the more intensive the use of natural capital intensively used, the faster the genuine capital stock growth.

The economic growth of the provinces in the 1980s was a process that utilized high TFP growth to compensate for the loss of natural capital and to enable higher growth. After the 1990s, the comparative natural capital lost decreased and turned to more intensive consumption. However, physical capital stock increased rapidly and China's provincial economic growth turned to a more extensive mode. This also led to a slowdown in productivity growth under the direct approach by the early 2000s while a consistent pattern using the indirect approach has recently emerged. Transfer of national capital lost between resource suppliers and advanced coastal provinces is quite obvious under the multiregional input–output method.

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