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Abstract

We discuss the sustainability of Chinese high growth relative to growth experience elsewhere, and specifically Soviet Russia in the 1950s to the 1960s by asking if the aggregate technology can eventually similarly constrain high growth performance in the Chinese case as argued by Weitzman in a paper in 1970 discussing the Soviet case. We note in the Chinese case, in contrast to Russia, the declining labor share in GDP over time, which suggests a substitution elasticity above rather than below one. We use time series data on labor's share in GDP to estimate a substitution elasticity for China, finding that the substitution elasticity is greater than one. We then discuss how sub aggregate high growth can occur when there are three sectors, and large outflows of labor occurring from rural to urban areas over time with implications for the role of factor substitution in future Chinese growth. We argue that high growth in China can be supported in such a framework by a rural to urban labor outflows even if the substitution elasticities in both the urban and rural sectors are less than one. We estimate these two production functions using share data and these indicate substitution elasticities less than one. As such we suggest that aggregate substitution elasticities do not necessarily provide a clear guide as to the sustainability of high Chinese growth.

JEL-Code: O400.

Keywords: China, growth, sustainability, substitution elasticity.

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1. Introduction

Over the last 10 years there has been much discussion in the literature of the future sustainability of China's high growth rate. In the three years before the 2008 financial crisis growth rates averaged 11% per year, and over the three decades between 1978 and 2008 the average growth rate was nearly 10%. This was despite low population growth following China's adoption of the one child per family policy.

Commentators have provided a long list of reasons as to why this growth performance may not persist into the future.[1] These include China exhausting export markets if trade continues to grow at 30% per year; problems of non-performing loans in the banking system potentially intensified by bad housing loans following a prospective downturn in apartment prices; growing environment problems and stagnant to declining agricultural yields; and growing inequality and associated social problems. But no discussion to our knowledge of sustainability of high Chinese growth has focused on the structure of aggregate technology, and whether or not this facilitates or constrains high growth.

Our point of departure is growth accounting literature following Solow (1957) and Dennison (1967), and its application to Soviet growth performance by Weitzman (1970). In the Soviet case Weitzman noted progressively slowing Soviet growth from the 1950's through to the late 1960's in the face of continued high rates of capital accumulation and low labor force growth. He suggested that under Solow growth

[1] See for example "Beware the middle income trap: China's roaring growth cannot last indefinitely" (The Economist, June 23, 2011), "Waiting for the great fall: Some hedge funds continue to short the China dream" (The Economist, Jan 20, 2011), and "Panda bears: Betting against China is in vogue" (The Economist, Oct 8, 2011). All these articles highlight the various concerns about China's growth potential that we list above.

accounting, there would over time be a progressive shift in weights away from the fast growing capital input and towards the much slower growing labor input if the elasticity of substitution in an aggregate CES production function was less than one. He then directly estimated the Soviet substitution elasticity (not using first order conditions as in econometric literature on market economies) and found the elasticity of substitution was around 0.4. This low elasticity of substitution fully explained falling Soviet growth rates as more and more capital accumulation served to ever further depress the marginal product of the faster growing factor and lower the factor share used in one sector growth accounting.

We evaluate the sustainability of Chinese high growth in light of this Soviet discussion by asking if the aggregate technology can eventually similarly constrain high growth performance in the Chinese case. We note in the Chinese case the declining labor share in GDP over time which suggests a substitution elasticity above rather than below one. We use time series data on labor's share in GDP to estimate the substitution elasticity, finding, unlike in the Soviet case, that the substitution elasticity is greater than one which for a one sector growth accounting exercise implies continual and even accelerating growth for the Chinese case.

We then discuss the sub aggregate growth accounting case where there is an urban and rural sector, and large outflows of labor occur from rural to urban areas over time. We show how high growth in China can be supported in such a framework by a rural to urban labor outflow even if the substitution elasticities in both the urban and rural sectors are less than one. We estimate these two production functions using share data and these indicate substitution elasticities less than one.

Simple one sector growth accounting applied to China seemingly points to the necessity of the aggregate substitution elasticity being above one, and with it factor shares (and weights in growth accounting) over time increasing for faster growing capital. This view is consistent with declining labor share data. Existing growth accounting literature for China (Chow (1987, 1998), Hsieh (2005)) uses Cobb-Douglas functions with implicitly fixed weights for factor input growth and does not address the issue of the aggregate elasticity. With an elasticity above one high GDP growth can be sustained and can even accelerate under continued high rates of capital accumulation. On the other hand, if a sub aggregate structure is used in the growth accounting exercise then substitution elasticities at urban and rural level can both be less than one if sufficient labor mobility between sectors occurs.

The paper proceeds as follows. Section 2 reviews literature. Section 3 presents model specification. Section 4 to 5 present data and empirical results. Section 6 to 7 discuss implications of our results. Section 8 concludes.

2. Literature review

Growth accounting analysis usually proceeds using Cobb-Douglas production functions, assuming the elasticity of substitution between capital and labor is one. However, the constancy of labor's share (and accordingly a unit elasticity of substitution) has been questioned in a number of studies. Solow (1957) notes that the wage share in the US for the period 1929-1954 was not stable. Kravis (1959) reports evidence that in the first half of the 20th century there was a long run increase in labor share in US, while Arrow *et al.* (1961) use cross country data and find the elasticity of substitution between capital and labor for most industries is lower than one. More recently, Antras (2004) estimates aggregate production functions for the US and finds the elasticity of substitution is significantly lower than one.

The magnitude of capital-labor substitution has major implications for the sustainability of economic growth, especially in situations where capital grows much faster than labor. If the elasticity of substitution is greater than one, output per worker becomes infinitely large as the capital-labor ratio increases (Arrow et al., 1961, page 230). But if it is less than one, diminishing returns will make it progressively more difficult for output to grow by largely accumulating one factor.

Weitzman (1970) notes that the former Soviet Union experienced increases in the implicit labor share while capital deepening was occurring. He suggested that if the aggregate elasticity of factor substitution was less than one, the weights on the more rapidly growing factor, capital, would fall and with it aggregate growth. His estimate of the elasticity of substitution between capital and labor for the Soviet economy was significantly lower than one, and he reached the conclusion that the Soviet Union's then high rate of economic growth was not sustainable by accumulating only capital. This raises the issue of whether the aggregate technology and specially the factor substitution elasticity can eventually play a similar role in the Chinese case and act to lower achievable growth rates.

Capital accumulation has played a major role in China's economic growth since the late 1970's. Chow (1993) constructed capital stock data from 1952 to 1985 for China and estimated a production functions for both the aggregate economy and five sectors. He found that 75% of the increase in income between 1952 and 1985 could be attributed to capital accumulation, and that technological change made almost no contribution to China's growth during the period. In a subsequent study Chow and Li (2002) found that China's TFP increased by 2.6% annually between 1978 and 1998, but capital accumulation was still the major contributor to growth. Both studies assumed a unit elasticity of substitution and estimation was also of Cobb-Douglas production functions.[2]

During this same period China's labor share in GDP decreased gradually (Bai and Qian, 2009; Benjamin, *et al.*, 2008), which is inconsistent with the assumption of a unit elasticity of factor substitution, which implies constancy of labor's share. Several studies have tried to explain this including by globalization (Shao and Huang, 2010), economic structural change, bargaining power (Li *et al.*, 2009), market

[2] Other researchers have also investigated the role of human capital (Whalley and Zhao, 2010; Wang and Yao, 2001; Bosworth and Collins, 2008), resource reallocation (Hsieh and Klenow, 2009; Brandt and Zhu, 2010; Song *et al.*, 2011), and other factors that can constrain China's growth. There is no discussion, however, of the aggregate substitution elasticity between capital and labor.

structure (Bai and Qian, 2009), and other variables in econometric work. None seems to have focused on the capital-labor substitution elasticity.

3. China's Aggregate Production Function and The Factor Substitution Elasticity

Following Arrow *et al.* (1961), Berndt (1976) and Antras (2004), we assume China's aggregate production function takes a CES form with constant returns to scale.

$$Y_t = \left[\delta \left(A_t^K K_t \right)^{\frac{\sigma-1}{\sigma}} + (1-\delta)\left(A_t^L L_t \right)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}} \quad (1)$$

where Y_t is output in real terms, K_t and L_t are the flows of services from capital and labor. A_t^K and A_t^L are indices of capital-augmenting and labor-augmenting efficiency, σ is the elasticity of substitution between capital and labor, the central parameter in this paper. When $\sigma = 1$, the production function asymptotically approaches a Cobb-Douglas production function, as shown by Arrow et al. (1961) using l'Hôpital's Rule.

If the output price is P_{Yt}, the rental price of capital is R_t, and the price of labor (wage) is W_t. First order conditions for profit maximization yield:

$$\frac{R_t}{W_t} = \frac{\delta}{1-\delta} \left(\frac{A_t^K}{A_t^L} \right)^{\frac{\sigma-1}{\sigma}} \left(\frac{K_t}{L_t} \right)^{-\frac{1}{\sigma}} \quad (2)$$

Taking logs on both sides gives:

$$\ln\left(\frac{R_t}{W_t} \right) = \ln\left(\frac{\delta}{1-\delta} \right) + \frac{\sigma-1}{\sigma} \ln\left(\frac{A_t^K}{A_t^L} \right) - \frac{1}{\sigma} \ln\left(\frac{K_t}{L_t} \right) \quad (3)$$

After some simple manipulation and with an assumption of constant growth rates of factor augmenting of technical change $A_t^i = A_0^i \exp\left(\lambda_i t \right)$ (i=K, L), the following can be obtained:

$$\ln\left(\frac{L_t W_t}{K_t R_t}\right) = \ln\left(\frac{1-\delta}{\delta}\right) + \frac{1-\sigma}{\sigma}\ln\left(\frac{A_0^K}{A_0^L}\right) + \frac{1-\sigma}{\sigma}\ln\left(\frac{K_t}{L_t}\right) + \frac{1-\sigma}{\sigma}\left(\lambda_K - \lambda_L\right)t \qquad (4)$$

The dependent variable is the log of the ratio of labor and capital shares. When the elasticity of substitution between capital and labor equals one, the labor share will be constant and there will be no variation in the dependent variable. If the elasticity of substitution does not equal one, (relative) factor shares will change when capital and labor have different growth rates and/or when technological change is biased $\lambda_K \neq \lambda_L$. For this model to be identified, it is important that capital and labor have different growth rates.

In this paper we use variations both in relative factor shares and in the capital-labor ratio to identify the elasticity of substitution between capital and labor. In particular, we estimate the following for the aggregate economy:

$$\ln\left(lshare_t / \left(1 - lshare_t\right)\right) = \alpha + \beta \ln\left(k_t\right) + \delta t + \varepsilon_t \qquad (5)$$

where $lshare_t$ refers to labor share, k_t refers to capital per labor. We use estimates of β to infer the elasticity of substitution between capital and labor, $\sigma = 1/\left(1+\beta\right)$. When β is below zero and larger than -1, the elasticity of substitution would be larger than one. To estimate the same parameter by sector, we use the same specification as (5).

Different first order conditions from profit maximization can be used for a CES production technology to estimate the elasticity of substitution. However, it matters which first order condition is used in the estimation (see Berndt, 1976; Antras, 2004). The first order condition (4) we use is equivalent to specification (6') in Antras

(2004).[3] We use this first order condition rather than others for the estimation because it helps link the factor shares to the elasticity of substitution.[4] For the same reason, we do not use Weitzman's (1970) procedure since he estimates the production function directly using a non-linear regression program given the absence of competitive markets in central planned Soviet Russia. Weitzman (1970), instead of using factor shares to infer production parameters, calculates the implicit factor shares using the estimated production function parameters.

[3] It is also equivalent to specification (6) in Berndt (1976) if biased technological change is not considered.
[4] In the later section, we use another first order condition to estimate the parameter for a robustness check.

4. Data Sources

For the estimation of equation (5) we need relative factor shares and the capital-labor ratio over time. With labor share data being available, the data requirements are much less demanding than the specifications in Berndt (1976) and Antras (2004). The construction of time series for wages, rental price of capital, and output price is unnecessary.

a) The labor share

The labor share is calculated as the share of labor remuneration in GDP. As the labor remuneration is only available at the provincial level, the aggregate labor remuneration is the sum of all provinces. We divide it by GDP to get the aggregate labor share. The data for periods 1978-1992, 1993-2004, and 2005-2007 is collected from Hsueh and Li (1995), NBS (2007), and CSY (2006, 07, 08), respectively.

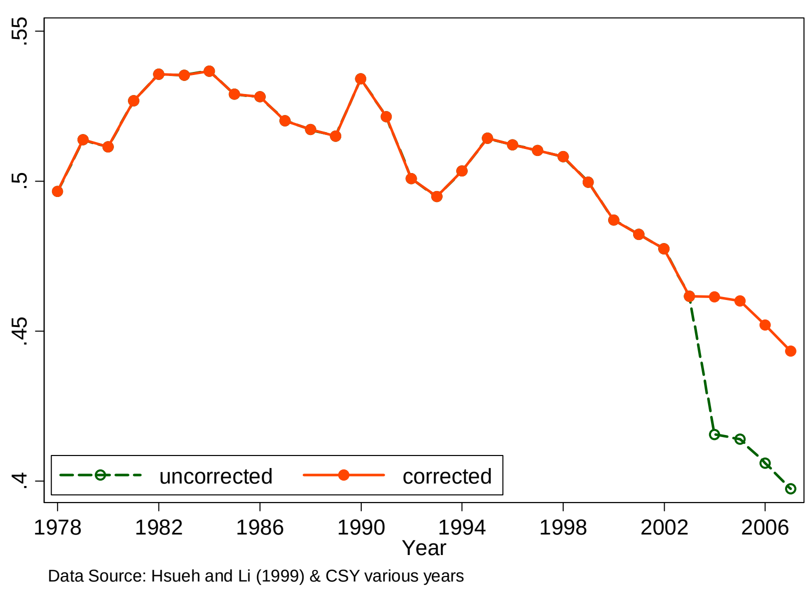

Figure 1 The Labor Share, China, 1978-2007

Figure 1 shows the labor share between 1978 and 2007. In the late 1970s and early 1980s, the labor share increased slightly. From 1985 on the figure shows a decreasing trend. After some volatility in late 1980s and 1990s it fell gradually. By 2007 the labor share had reached 0.397. Before 2004 the income for self-employed was all classified as labor income, from 2004 on that part of the income is calculated as capital income. According to Bai and Qian (2009) the sharp decline in the labor share from 2003 to 2004 was largely due to this *statistical* reason. To get a consistent time series of the labor share, we adjust the data by adding 0.046 (the difference between 2004 and 2003) to the labor shares for 2004 and after. The labor share still decreased by 7 percentage points after 2003.

b) Capital Stock and Labor

The way we construct Chinese capital stock data is similar to Whalley and Zhao (2010) who use a perpetual inventory approach. The initial value of the capital stock, 1,411.2 billion Yuan is taken from Chow and Li (2002, table 1 in page 250). Given real investment of I_t in year t, the capital stock can be calculated recursively:

$$K_t = (1-\lambda)K_{t-1} + I_t \tag{6}$$

where λ is the depreciation rate. To get I_t, we use gross fixed capital formation from CSY (2009) and deflate it using an investment deflator. The investment deflator for 1978 to 1995 is from Hsueh and Li (1995), and for 1978-1995 from CSY (2009). Finally we set the depreciation rate to 5% following Perkins (1988), Wang and Yao (2003), and Whalley and Zhao (2010).

The solid line in Figure 2 shows the time trend of the real capital stock between 1978 and 2007. Growing at an annual rate of 9% over the last three decades it increased dramatically. In the last decade the average growth rate reached nearly 13%.

Our employment data is from CSY (2009) and Holz (2006). CSY have data for 1952-2008, but it is not consistent before and after 1990 because of revisions after the 1990 population census. Holz (2006) provides adjusted data but it only covers 1952-2005 (appendix 14, page 238-9). We use the employment data from CSY (2009) for 1990 to 2007, and then use data from Holz (2006) to calculate the employment growth rate between 1978 and 1990. This growth rate is then applied to the CSY employment data for 1990 to retrieve employment data for 1978-1989.

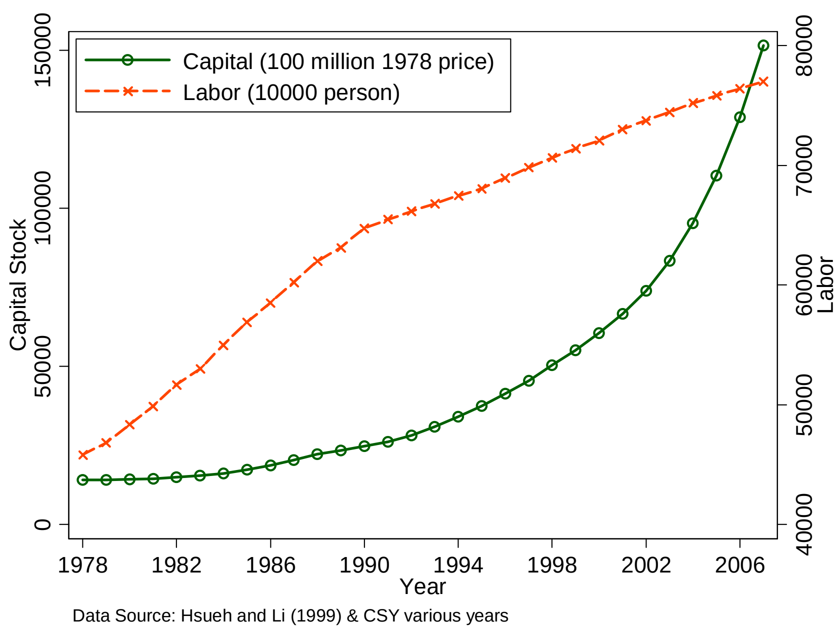

Figure 2 Capital Stock and Labor, China, 1978-2007

The dotted line in Figure 2 reports employment between 1978 and 2007. Employment increased gradually, but the growth rate was much lower than that of capital. The capital-labor ratio increased accordingly. With the labor share declining and the capital-labor ratio increasing, an elasticity of substitution between capital and labor greater than one is more suitable to describe aggregate production.

5. Elasticity of Substitution between Capital and Labor

5.1 Evidence at the Aggregate Level

Table 1 reports the results of our estimation. We first estimate model (5) without controlling for a time trend. As expected the coefficient for the capital-labor ratio is -0.163, significantly negative (column 1). Using the formula $\sigma=1/(1+\beta)$, we have the elasticity of substitution between capital and labor being equal to 1.2, significantly greater than one. Allowing for technological change (column 2) gives an even greater elasticity of substitution between capital and labor, 1.44. The coefficient of time is 0.01 (significant at the 5% level), suggesting that labor augmenting technological change was faster than that of capital. Table 1 also reports results using data for 1978-2003 and for 1978-1998. The estimates are similar.

Table 1 Estimates of the Aggregate Elasticity of Substitution

	Dependent variable = Log (Labor Share / Capital Share)					
	1978-2007		1978-2003		1978-1998	
	(1)	(2)	(3)	(4)	(5)	(6)
Ln(*k*)	-0.163	-0.304	-0.142	-0.320	-0.091	-0.262
	(0.014)	(0.040)	(0.021)	(0.060)	(0.035)	(0.090)
t		0.010		0.011		0.009
		(0.003)		(0.003)		(0.004)
Constant	-0.089	-19.942	-0.069	-21.489	-0.016	-17.376
	(0.012)	(5.418)	(0.019)	(6.982)	(0.035)	(8.520)
Imputed σ	*1.195*	*1.437*	*1.166*	*1.471*	*1.100*	*1.355*
Test: σ=1	0.0000	0.0000	0.0000	0.0015	0.0289	0.0460
λK -λL		-0.033		-0.034		-0.034
Adj-R2	0.828	0.881	0.647	0.738	0.223	0.334
N	30	30	26	26	21	21

Note: Standard errors are in parenthesis.

The relationship between the labor share and the capital-labor ratio is presented in Figure 3. The *x* axis is the log of the capital-labor ratio and the *y* axis is the log of labor's relative share. We first run regressions to de-trend these two variables, the residuals are then used to draw the plot. The negative relationship between them is clear.

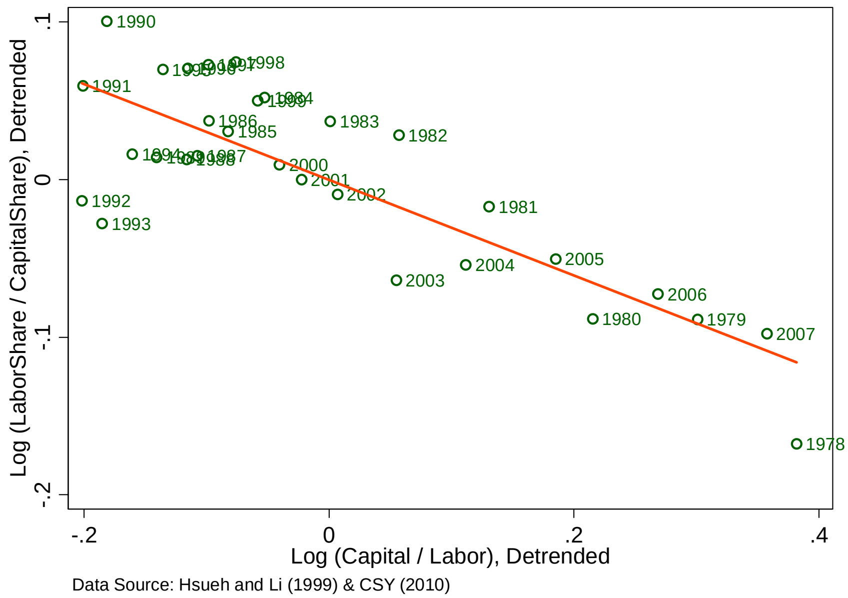

Figure 3 Relationship between Labor Share and Capital-Labor Ratio

5.2 An Alternative Model Specification

Previous studies show that different model specifications often produce different estimates for the substitution parameter (Arrow et al., 1961; Berndt, 1976; Antras, 2004). A thorough investigation of the specification issue is not the purpose of this paper, however we have tried one other specification, which give similar results. We note that equation (4) is equivalent to the following equation (7):

$$\ln\left(\frac{K_t}{L_t}\right) = -\sigma \ln\left(\frac{1-\delta}{\delta}\right) - (1-\sigma)\ln\left(\frac{A_0^K}{A_0^L}\right) + \sigma \ln\left(\frac{W_t}{R_t}\right) - (1-\sigma)(\lambda_K - \lambda_L)t \qquad (7)$$

However, when estimating the equations, due to measurement error, equation (7) and (4) will not give identical results. We obtain the time series data for $\ln(W_t/R_t)$

by using $\ln\left(L_t W_t / K_t R_t\right)$ minus $\ln\left(L_t / K_t\right)$. The coefficients for $\ln\left(W_t / R_t\right)$ will be the estimates for the substitution elasticity. The results are reported in Table 2, which still give substitution elasticity greater than one. Compared to those in Table 1 however, the elasticity was smaller in magnitude.

Table 2 Estimates of the Aggregate Elasticity of Substitution

	Dependent Variable: *ln(K/L)*					
	1978-2007		1978-2003		1978-1998	
	(1)	(2)	(3)	(4)	(5)	(6)
Ln(W/R)	1.186	1.319	1.150	1.244	1.070	1.068
	(0.020)	(0.076)	(0.028)	(0.111)	(0.041)	(0.131)
t		-0.008		-0.005		0.000
		(0.004)		(0.006)		(0.006)
Constant	0.101	15.663	0.069	9.752	-0.008	-0.205
	(0.015)	(8.628)	(0.023)	(11.030)	(0.038)	(11.374)
Adj-R2	0.992	0.993	0.985	0.985	0.971	0.97
N	30	30	26	26	21	21

Note: Standard errors are in parenthesis.

5.3 An Alternative Measure of Employment: Human Capital

Ideally we should use the amount of labor in efficiency unit, instead of the amount in man-years. One major component that should be taken into consideration is human capital due to its important role in the growth accounting literature. Whalley and Zhao (2010) find human capital increased at an annual growth rate of 7.6% between 1978 and 2008 if it is constructed in the way they suggest.

To assess the robustness of our results, we substitute human capital data from Whalley and Zhao (2010) for our earlier employment data and re-estimate the elasticity of substitution. The results are reported in Table 3. The coefficients for the log of the capital-labor (human capital) ratio are significantly negative, and their absolute values are larger in comparison to those in Table 1. When the data for 1978-2007 is used, the imputed elasticity parameter is 1.8 if a time trend is not controlled for. With time controls, the elasticity became 1.5. The results in columns 3 to 6 suggest that the elasticity is smaller in the earlier period.

Table 3 Estimates of the Aggregate Elasticity of Substitution Using Human Capital

	Dependent variable = Log (Labor Share / Capital Share)					
	1978-2007		1978-2003		1978-1998	
	(1)	(2)	(3)	(4)	(5)	(6)
Ln(*k*)	-0.448	-0.354	-0.390	-0.312	-0.269	-0.254
	(0.035)	(0.048)	(0.050)	(0.057)	(0.072)	(0.071)
t		-0.003		-0.003		-0.002
		(0.001)		(0.001)		(0.001)
Constant	4.217	9.579	3.679	8.748	2.565	6.615
	(0.326)	(2.062)	(0.469)	(2.208)	(0.667)	(2.798)
Imputed σ	*1.812*	*1.548*	*1.639*	*1.453*	*1.368*	*1.340*
Test: σ=1	0.0000	0.0001	0.0001	0.0010	0.0132	0.0132
Adj-R2	0.851	0.877	0.703	0.749	0.394	0.430
N	30	30	26	26	21	21

Note: Standard errors are in parenthesis. Human capital data is from Whalley and Zhao (2010).

The reason for obtaining higher estimates of the elasticity of substitution when using human capital instead of employment data can be seen in equation (4). With a higher growth rate in human capital, the change in log(K/L) will become smaller (but still positive as long as physical capital increases faster than human capital). For a given decline in relative shares (log(labor share/capital share)), the coefficient ($\frac{1-\sigma}{\sigma}$) must be negative and relatively larger in absolute value, implying a larger elasticity of substitution.

5.4 Evidence by Economic Sector

Holz (2006) provides labor shares in different sectors, which are reported in

Figure 4. The primary sector had the highest labor share ranging from 80% to 90%, while the secondary and tertiary sectors had much lower shares ranging from 40% to 50%. Figure 4 gives a different picture from Figure 1: between 1978 and 2002, only the labor share in primary sector fell gradually. For the secondary sector, the labor share increased gradually between 1978 and 1997, and after that it decreased due to the ownership restructuring and more adverse conditions facing urban workers. The labor share in the tertiary sector was largely flat between 1978 and the early 1990s, and it began increasing after the early 1990s. Beginning from 1996 the labor share in the tertiary sector became larger than that in the secondary sector.

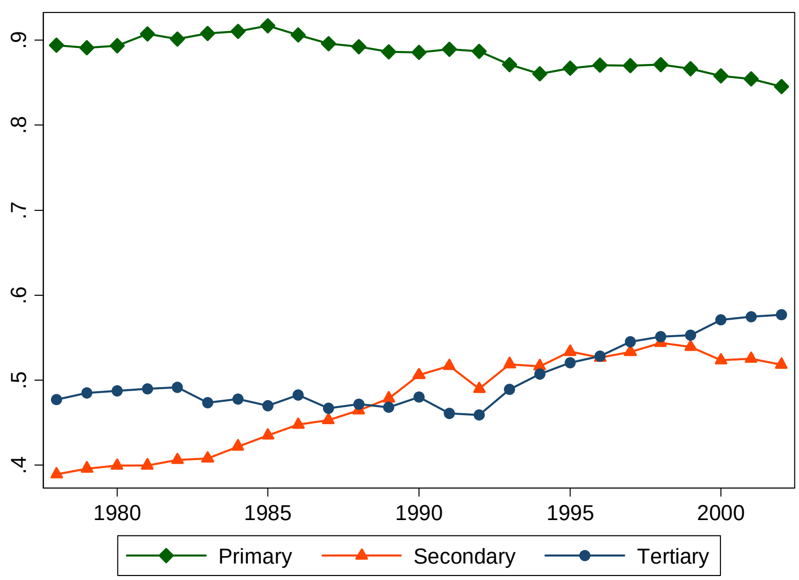

Figure 4 Labor Shares in Different Sectors, China, 1978-2002.

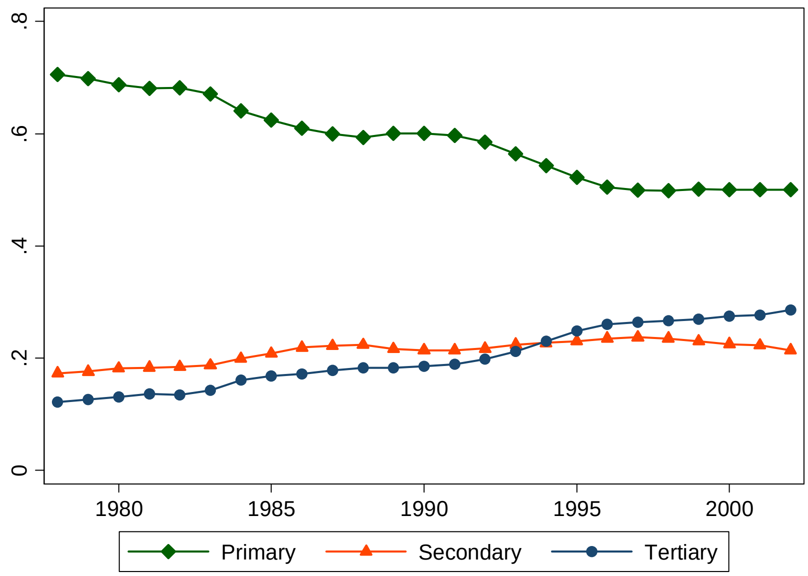

Figure 5 Shares of Employment in Different Sectors, China, 1978-2002.

The employment shares in different sectors also changed during the same period. The share of the labor force in the primary sector decreased from over 70% in 1978 to around 50% in 2002. In contrast the share of the labor force in the tertiary sector increased from nearly 12% in 1978 to 28% in 2002. The share of secondary sector employment also increased but to a lesser extent especially after 1997.

Table 4 reports our estimates of the elasticity of substitution for each sector. The elasticity of substitution for each sector depends on whether we control for a time trend. When time is not controlled for, the elasticities of substitution in the three sectors are 1.4, 0.77, and 0.83, respectively. The two increasingly important sectors (secondary and tertiary) have significantly lower than unit elasticities. Controlling for a time trend changes the results, but the pattern remains. The primary sector has an elasticity of substitution greater than one (=1.2), and the other two sectors have an elasticity of substitution either close to or below one (1.0 and 0.7 for secondary and tertiary sectors, respectively).

Table 4 Estimates of the Elasticity of Substitution by Sector

	Dependent variable = Log (Labor Share / Capital Share)					
	primary sector		secondary sector		tertiary sector	
Ln(k)	-0.290	-0.153	0.307	-0.020	0.200	0.434
	(0.037)	(0.198)	(0.028)	(0.097)	(0.031)	(0.225)
year		-0.011		0.030		-0.020
		(0.015)		(0.009)		(0.019)
Calculated σ	*1.408*	*1.181*	*0.765*	*1.020*	*0.833*	*0.697*
Constant	0.813	11.332	-0.172	-97.336	0.041	26.333
	(0.148)	(21.466)	(0.025)	(12.314)	(0.014)	(9.267)
Adj-R2	0.744	0.735	0.727	0.925	0.815	0.858
N	25	25	25	25	25	25

Note: Standard errors are in parenthesis.

Different sectors having different factor substitution has implications for factor allocation when income increases (Arrow et al. 1961). This can be clearly seen using the following equation (ignoring technological change for simplicity):

$$\ln\left(\frac{K}{L}\right) = \sigma \ln\left(\frac{\delta}{1-\delta}\right) + \sigma \ln\left(\frac{W}{R}\right) \quad (8)$$

As we noted earlier, rising income has been associated with a declining share in the primary sector and an increasing share in the tertiary sector. The primary sector having an above unit elasticity implies the decline of employment share should have been larger than for the output share. On the contrary, the tertiary sector having a less than unit elasticity means employment should increase by more than its output share.

6 Implications for Productivity Growth

6.1 One-sector Results

Given a constant return to scale (CRS) production function, $Y_t = F\left(A_t^K K_t, A_t^L L_t\right)$, the growth in output ($g_Y$) can be decomposed into four parts:

$$g_Y = s_K g_{A^K} + s_L g_{A^L} + s_K g_K + s_L g_L \tag{9}$$

where g_K and g_L are growth rates of capital and labor, s_K and s_L are factor shares of capital and labor. Given g_Y, g_K, g_L, s_K, and s_L, the growth rate of capital-augmenting and the labor-augmenting efficiency terms, g_{A^K} and g_{A^L} are not identified. Assuming $g_{A^K} = g_{A^L} = g_A$, we can calculate the efficiency growth rates $g_A = g_Y - s_K g_K - s_L g_L$. In this paper, we first use the actual factor shares to calculate g_A. For comparison, we then also calculate g_A, assuming constant factor shares.

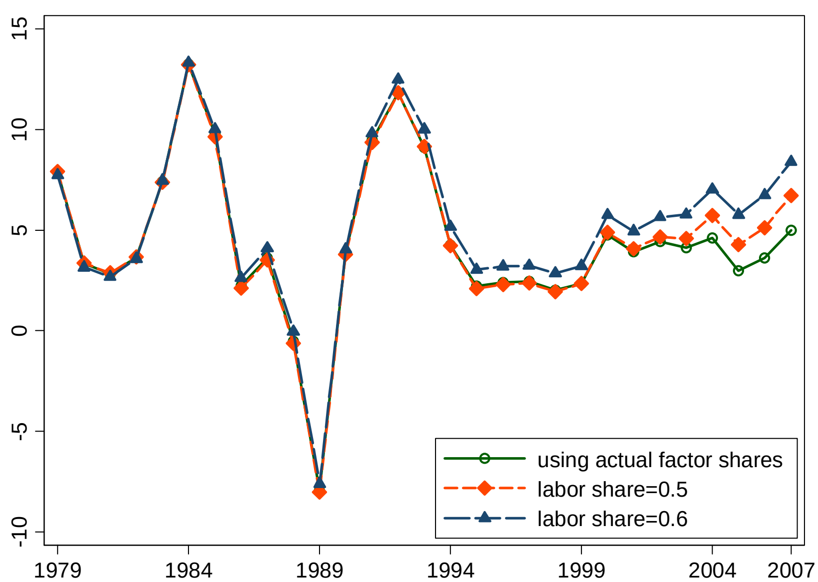

Figure 6 TFP Growth Rates, China, 1978-2007.

The results are reported in Figure 6 and Table 5. The aggregate productivity growth rates were more volatile in the 1980s and early 1990s. In the mid to late 1990s, aggregate productivity grew at an annual rate of around 4%. Entering the 21st century, aggregate productivity grew at a slightly higher rate. Considering the whole period 1979 to 2007, however, it is hard to say the productivity growth rate is not constant.

We also calculate the productivity growth rate under an assumption of constant factor shares. Factor shares are first assumed at an average level between 1979 and 2007, with both the capital and labor shares being around 50%. We also experiment using factor shares of 40% and 60% for capital and labor, respectively. It turns out that using different factor shares has major implications for productivity growth especially in the later period of time, when labor's share declined significantly. Taking 2007 as an example, the productivity growth rate was 5% when actual factor shares are used, and it becomes 6.7% and 8.4% when the labor share is set to 50% and 60%.

The difference in g_A under different assumptions is not hard to understand. Because labor increased at a relatively lower growth rate, assuming a constant share of 50% or 60% gives labor growth a weight greater than its actual level, and more output growth must be attributed to productivity growth. In economic terms, when constant factor shares and unit elasticity of substitution are assumed, the marginal product of capital decreased to a larger extent than when an elasticity of substitution greater than one is assumed, and the contribution of rapid physical accumulation will be underestimated while the contribution of productivity growth will be overestimated.

Table 5 Calculations of TFP growth, China, 1979-2007.

Year	Growth rate (%)			Factor Share (%)		TFP growth (%)[a]			Labor efficiency growth [b]		
	GDP	Capital	Labor	Capital	Labor	Assumed labor share=			Assumed labor share=		
						Actual	0.5	0.6	Actual	0.5	0.6
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1979	9.26	0.55	2.17	48.60	51.40	7.88	7.91	7.74	9.49	9.56	9.06
1980	5.56	1.13	3.26	48.90	51.10	3.34	3.36	3.15	4.95	5.01	4.47
1981	5.09	1.21	3.22	47.30	52.70	2.82	2.87	2.67	4.38	4.52	3.99
1982	6.80	2.65	3.59	46.40	53.60	3.64	3.68	3.58	5.18	5.33	4.90
1983	10.35	3.43	2.52	46.50	53.50	7.41	7.38	7.47	8.94	9.03	8.79
1984	17.59	4.96	3.79	46.30	53.70	13.26	13.22	13.33	14.79	14.87	14.65
1985	14.97	7.15	3.48	47.10	52.90	9.76	9.65	10.02	11.31	11.30	11.34
1986	7.51	7.99	2.82	47.20	52.80	2.25	2.11	2.62	3.81	3.76	3.94
1987	9.37	8.79	2.93	48.00	52.00	3.63	3.51	4.10	5.21	5.16	5.42
1988	5.27	8.86	2.94	48.30	51.70	-0.53	-0.63	-0.04	1.07	1.02	1.28
1989	-4.11	6.01	1.83	48.50	51.50	-7.96	-8.03	-7.61	-6.36	-6.38	-6.29
1990	7.60	5.06	2.55	46.60	53.40	3.88	3.79	4.05	5.42	5.44	5.37
1991	12.84	5.80	1.15	47.80	52.20	9.47	9.37	9.83	11.05	11.02	11.15
1992	16.17	7.70	1.01	49.90	50.10	11.82	11.82	12.49	13.47	13.47	13.81
1993	14.42	9.53	0.99	50.50	49.50	9.11	9.16	10.01	10.78	10.81	11.33
1994	9.92	10.42	0.97	49.70	50.30	4.25	4.22	5.17	5.89	5.87	6.49
1995	7.71	10.36	0.90	48.60	51.40	2.22	2.08	3.03	3.82	3.73	4.35
1996	8.11	10.31	1.30	48.80	51.20	2.41	2.30	3.20	4.02	3.95	4.52
1997	7.93	9.86	1.26	49.00	51.00	2.46	2.37	3.23	4.08	4.02	4.55
1998	7.74	10.44	1.17	49.20	50.80	2.01	1.93	2.86	3.63	3.58	4.18
1999	7.76	9.75	1.07	50.00	50.00	2.35	2.35	3.22	4.00	4.00	4.54
2000	10.19	9.66	0.97	51.30	48.70	4.77	4.88	5.75	6.46	6.53	7.07
2001	9.75	10.05	1.30	51.80	48.20	3.92	4.08	4.95	5.63	5.73	6.27
2002	10.62	10.95	0.98	52.20	47.80	4.43	4.66	5.65	6.16	6.31	6.97
2003	11.53	12.97	0.94	53.80	46.20	4.12	4.58	5.78	5.89	6.23	7.10
2004	13.29	14.11	1.03	58.40	41.60	4.62	5.72	7.03	6.55	7.37	8.35
2005	12.57	15.76	0.83	58.60	41.40	2.99	4.28	5.77	4.93	5.93	7.09
2006	13.96	16.89	0.76	59.40	40.60	3.62	5.13	6.75	5.58	6.78	8.07
2007	15.85	17.50	0.77	60.30	39.70	5.00	6.72	8.39	6.99	8.37	9.71

Note: a, columns 7-9 are calculated under the assumption of Hicksian-neutral technological change. b, columns 10-12 are calculated assuming labor augmenting efficiency grew faster than capital augmenting efficiency by 3.3%.

We can make other assumptions regarding the growth of factor augmenting efficiencies. In Table 1, where we assume both capital augmenting and labor augmenting efficiency grow exponentially, the capital-augmenting efficiency term grows more slowly than the labor-augmenting efficiency term by 3.3%. Next, we assume $g_{A^K} = g_{A^L} - 0.033$. We can then calculate the efficiency growth rates of labor as: $g_{A^L} = g_Y + 0.033 * s_K - s_K g_K - s_L g_L$. The growth rates g_{A^L} are reported in columns 10 to 12 of Table 5. Obviously, labor augmenting efficiency grew at a higher rate under this assumption than those under the assumption of Hicksian neutral technological change. Correspondingly, the capital augmenting efficiency term grew at a relatively lower rate. It remains true that assuming constant factor shares produces a larger productivity growth in the later period when labor's share declined significantly. There is no evidence suggesting any trend for the productivity growth rates.

6.2 Three-sector Results

Using a similar formula to (9), we can also calculate the TFP growth for each sector. For simplicity we do not consider the biased technological change in this subsection. The results are reported in Table 6. On average the TFP growth rates in the three sectors are 4.7%, 2.2%, and 2.1%, respectively. The significantly higher productivity growth is a result of the high labor share for this sector. Mechanically with a large labor share and low employment growth, the high growth in the primary sector comes from productivity growth as long as capital growth is high.

Given these TFP growth rates for each sector, we can again calculate GDP growth in each sector by assuming the same employment growth rate. We assume away the inter-sector labor reallocation by assuming that employment in each sector grew at the same rate, i.e. the growth rate of total employment. We use the actual factor shares in each sector to calculate the counterfactual sector GDP growth. As shown in the last three columns of Table 6, the predicted growth rates for the secondary and tertiary sectors are lower than the actual growth rates, meaning that the inter-sector labor allocation has played an important role in China's growth process. Taking the tertiary sector for example, if employment grew at the average rate, the average growth rate between 1978 and 2002 would have been 9.9%, rather than the actual 12%.

Table 6 TFP Growth and GDP Growth by Sector, China, 1979-2002

	Real GDP Growth (%)			TFP Growth (%)			Predicted Growth Assuming Same Employment Growth (%)		
Year	Prim.	Sec.	Ter.	Prim.	Sec.	Ter.	Prim.	Sec.	Ter.
1979	21.2	7.5	-1.2	18.9	2.1	-10.6	22.1	6.8	-3.0
1980	1.9	8.1	5.4	-0.2	3.2	-3.0	3.3	6.6	3.7
1981	11.0	0.5	7.1	8.3	-3.7	-2.7	11.9	0.2	5.0
1982	11.9	3.7	6.0	8.2	0.2	-0.2	11.8	3.4	6.6
1983	9.7	9.4	13.4	7.7	3.4	2.4	11.1	8.8	10.5
1984	13.9	14.2	29.9	15.2	5.1	14.7	18.1	11.4	23.5
1985	1.8	14.4	33.0	0.8	5.6	20.9	4.2	12.3	30.9
1986	2.6	9.6	9.3	1.4	-1.4	-2.0	4.8	7.3	8.0
1987	8.0	8.9	11.3	5.2	-2.5	-1.2	9.5	8.2	9.5
1988	0.9	5.8	8.4	-1.8	-6.0	-3.4	1.9	5.5	7.1
1989	-6.3	-6.2	0.8	-10.6	-14.5	-10.2	-7.4	-4.6	0.7
1990	16.2	3.9	5.9	13.9	-3.6	-4.3	16.1	4.4	5.3
1991	2.1	14.1	20.5	1.1	5.5	10.6	2.7	14.1	19.5
1992	3.2	20.8	19.9	3.9	14.6	12.4	5.0	20.1	17.7
1993	3.5	22.6	11.0	4.9	15.2	2.3	6.6	20.9	7.5
1994	10.8	9.9	9.4	11.8	3.6	-1.5	14.0	9.2	5.1
1995	8.3	9.1	5.4	8.6	-1.0	-10.1	11.6	8.4	1.3
1996	6.6	8.9	7.8	6.5	-2.2	-6.3	9.5	7.8	5.2
1997	0.2	7.9	12.5	-1.6	-3.1	0.5	1.3	7.5	11.7
1998	3.4	4.7	14.2	2.3	-0.6	6.5	3.6	5.2	13.6
1999	1.1	6.7	12.3	-0.4	4.1	6.1	0.6	7.9	11.9
2000	0.8	10.6	13.8	0.9	11.3	9.9	1.0	11.7	12.5
2001	4.9	7.9	13.8	3.9	6.4	9.8	4.9	8.4	13.4

2002	5.6	9.7	13.4	5.0	10.2	8.7	5.6	11.8	11.5
Average	6.0	8.9	11.8	4.7	2.2	2.1	7.2	8.5	9.9

7 Is Chinese High Growth Sustainable?

In the previous sections we first obtained an aggregate elasticity of substitution greater than one, which seems to imply an optimistic future for Chinese economic growth: With an above unit elasticity, output per worker can increase infinitely as long as capital keeps growing, and China's economic growth would not experience a downturn. However, the sub-aggregate evidence suggests China's not being immune to a downturn. The discrepancy between the aggregate and sub-aggregate elasticities also suggests a major role for labor reallocation between sectors in recent growth experience.

Our results are consistent with the growth accounting literature that stresses the role of capital accumulation and labor deepening, in particular labor reallocation from agriculture. According to Young's (2003) research, labor deepening was the key to the Chinese high growth rate, while other researchers (Chow, 1993, 2002 for example) identify capital deepening as the key force. Our results in this paper, however, suggest that both could be important factors behind China's extraordinary growth performance: with a capital accumulation rate much higher than the labor growth rate, not to face a downturn in growth quickly, there must be some labor reallocation among sectors. In similar vein, recent research by Dekle and Vandenbroucke (2009) emphasizes the role of labor reallocation from agriculture. They build a two sector general equilibrium model to account for China's growth, but do not discuss the elasticity of substitution between factors.

Following this line of argument, China's growth potential lies in the amount of "surplus" labor in the agricultural sector. This concern justifies the heated debate regarding whether China has entered an era of labor "shortage." No consensus has been reached yet. While some regard recent wage growth in rural areas and the difficulties in recruiting facing some firms as the evidence of labor shortage (Zhang et al. 2010), others point to institutional factors that impede labor migration across regions and among sectors (Meng, 2010).

While our results indicate the significant roles played by labor reallocation and capital accumulation, they do not necessarily rule out other sources of economic growth. Agriculture productivity grew substantially in the early reform period. McMillan et al. (1989) find that over three quarters of the productivity growth during 1978-84 was due to the decollectivization reform. Lin (1991) also identified a major role played by the adoption of the household responsibility system in place of a communal production system. Agricultural growth slowed after 1984. According to Dekle and Vandenbroucke (2009), however, TFP growth for the agricultural sector was 4.4% in the period 1978-03, significantly higher than for the non-agricultural sector.

Within the non-agricultural sector, factor reallocation from low efficiency SOEs or the government sector to the private sector also played an important role. But its relative importance for China's growth accounting is still debated. Brandt and Zhu (2010) identify rising TFP in the non-state non-agricultural sector as the key contributor to China's growth. Song et al. (2011) use financial imperfections and the reallocation of resources from the SOEs to the private sector to explain both China's growth performance and some prominent features in the growth process. Both researchers emphasize resource misallocation within the non-agriculture sector and the growth potential when resources are reallocated to the more efficient sector. Based on this argument, China’s growth potential lies in reform in the non-agriculture sector.

8 Comparisons with Other Countries and Implications for China's Future Economic Growth

Unlike many other countries China experienced a continuously declining labor share, which is at odds with the Kaldor stylized facts of growth. Based on capital deepening and the decreased labor share, we generate an estimate of the aggregate elasticity of substitution between capital and labor, which is bigger than one. This suggests China is a different case from former Soviet Union in the 1950s and 60s when the former Soviet Union maintained high economic growth through capital accumulation. The elasticity of substitution being less than one also means that it would eventually face a low marginal product of capital. It was thus impossible for the former Soviet Union to keep high economic growth simply by capital accumulation.

It seems that China can keep growing by capital accumulation as long as there is a declining labor share. However, after breaking down the aggregate economy into different sectors and estimating the elasticity of substitution by sector, the elasticity turns out to be either less than one or insignificantly different from one. The decline in labor's share mainly come from the labor being allocated from the high labor-share sector to the low labor-share sector. This result has major implications which are different from those of the aggregate results: namely that it is difficult for China to maintain its high economic growth simply by accumulating capital. Future growth potential must come from either from labor reallocation from agriculture or from efficiency increases within different sectors.

9 Conclusion

We use the variation in the labor share of China to infer the elasticity of substitution between capital and labor both at an aggregate level and by economic sector. A Cobb-Douglas production function (elasticity of substitution being one) seems to be a poor approximation for the aggregate economy, but may be appropriate for production by individual economic sectors. The declining labor share at the aggregate level is mainly the result of labor being reallocated from high labor share sector to low labor share sector. Its implications for China's economic growth are discussed.

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