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« Total Factor Productivity Growth in

Chinese Industry: 1952-2005 »

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Total Factor Productivity Growth in Chinese Industry: 1952-2005[*]

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ABSTRACT

This paper presents a timely assessment of Chinese industrial productivity performances over the period 1952-2005. The total factor productivity (TFP) growth analysis is based on a Cobb-Douglas specification with aggregated annual data set. This study tackles some theoretical and methodological issues raised by critics of previous studies. First of all, the use of economic tools allows us to relax some restrictive hypothesis of the neoclassical growth framework such as competitive market behaviour, constant returns to scale production technology and Hicks neutral technological change. In addition, our TFP growth estimates are adjusted for business fluctuations. The paper also deals with the autocorrelation issue prevailing in most previous studies.

Our major findings are: (*i*) In Chinese industry, between 1952 and 2005 capital accumulation has been the main engine of economic takeoff. (*ii*) During the post-reform period, TFP growth contributed significantly to economic growth. (*iii*) TFP gains have exhibited a sharply increasing pattern since the late 1980's, along with the accelerated integration of China into the world economy.

Key words: Total factor productivity; Production function estimations; Capital stock; Transition economies.

JEL classification: O47, P27, L60.

I. INTRODUCTION

China has undergone a continuous and spectacular economic growth since the beginning of the economic reform policy, in the early 1980's. Along with the rapid economic takeoff, Chinese economy has experienced a progressive transition from a centrally planned to a market based economy. The structural transformation of Chinese economy over the past two decades is striking: Prior to 1978 China was, above all, an autarkic country isolated from the global economy. Since 1978, it emerged progressively in the global economy as a major trading partner. Besides, China's opening up to the world boosted inward foreign direct investment (FDI). Starting from the late 1990's, China has become the first recipient of FDI among developing countries.

The economic reform program implemented in the early 1980's was built, by and large, on the promotion of industry at the expense of agriculture. Over the past two decades, the rapid industrialization of China was mainly marked by the surge of small-scale enterprises in rural areas which absorbed huge amounts of surplus labour in agriculture. As a consequence, during the reform era, substantial efficiency gains have been reaped from the reallocation of resources to higher productivity sectors (Maddison, 1998; Wu, 2004; World Bank, 1997[1]).

Investigating on major sources of Chinese economic growth became a particular concern between economists. Since the last decade, with improved data availability, assessment of the contribution of productivity gains to economic growth aroused great interests among researchers. Most growth accounting studies on the East Asian newly industrialized countries (NICs) (Kim and Lau, 1994; Young 1992, 1995) inferred that the great success of the East Asian "tigers" has been largely driven by massive factor accumulation, rather than innovative activities and technological progress. In this way, Krugman (1994) reached the conclusion that, the input driven economic growth in the NICs would not be sustainable in the long run. However, unlike the NICs, most studies on China (Chow, 1993; Borensztein and Ostry, 1996; Hu and Khan, 1998; Chow and Li, 2002; OECD, 2005) infer a significant contribution of TFP to economic growth during the reform period.

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[1] According to the World Bank (1997), labour reallocation from agriculture to industry contributed about a percentage point to China's overall output growth.

The purpose of this paper is to analyse the main sources of economic growth in Chinese industry between 1952 and 2005. Using annual aggregate data, the paper investigates empirically to what extend factor accumulation and TFP growth have contributed to output growth in Chinese industrial sector. The study period (1952-2005), which covers both centrally planned and reform periods, enables us to explore the impact of economic reforms and the open-door policy on productivity performances in Chinese industry.

This paper discusses extensively some crucial data issues prevailing in most previous studies. In the production function estimates we rely principally on the official national data provided by the National Bureau of Statistics (NBS). Besides, we compute a new aggregate capital stock data set for Chinese industrial sector for the period 1952-2005. The use of the parametric approach in the production function estimates allows us to relax some restrictive, if somewhat unrealistic, hypothesis of the neoclassical growth theory. In this way, our productivity analysis incorporates non-competitive pricing behaviour of firms, variable returns to scale production technology and both Hicks neutral and factor-augmenting technological progress. The impact of capacity utilisation through business cycles is also taken into account into TFP growth estimates. Moreover, this study deals with important econometric issues such as heteroscedasticity and autocorrelation. In addition, it tests for the intertemporal stability of the production function parameters over the pre-reform and post-reform eras.

The paper is organised as follows: Section 2 contains an extensive discussion of underlying data series used in the empirical analysis. Section 3 provides an account of the estimation procedure of production function parameters. Section 4 describes estimation results and discusses empirical findings. Section 5 provides some concluding remarks.

II. DATA ISSUES

Some of the major obstacles standing against an accurate analysis of China's industrial productivity are, undoubtedly, the accuracy and availability of official Chinese statistics. China's Statistical System is originally inherited from the Soviet Material Product System. Since the last two decades, along with the gradual alignment with the international System of National Accounts (SNA), the sectoral coverage of Chinese data has been subject to several changes. China's National Bureau of Statistics (NBS) formerly the State Statistics Bureau (SSB) made significant revisions in 1984 and in 1994 to make Chinese data more in line with the international standards of international classification (ISIC). Besides, during the pre-

reform period, the political upheaval introduced by the Great Leap Forward Movement (1958-1960) and Cultural Revolution (1966-1976)[2] gave rise to serious inconsistencies in official Chinese statistics.

The productivity analysis performed in this study requires constant price measures of GDP and investment data. Yet, in China, price indexes prior to 1978 have only became available very recently. Thus, some previous studies (Chow, 1993; Chow and Li, 2002; JRZ, 1992) consider that under the centrally planned economy, changes in prices were negligible despite high inflation figures in the early 60's. A detailed discussion about the construction of data series used in the growth accounting analysis is provided below.

2.1. Output

In this study, for accuracy and data availability considerations, industrial output is represented by gross domestic product (GDP) rather than net output. Thereby, in the production function, only primary factor inputs, namely capital and labour, are taken into account. For the period between 1952 and 1995, industrial value added data are originated from "GDP 1952-95", while value added figures from 1978 to 2005 come from the various issues of "China Statistical Yearbook" (CSY). It should be stated that between 1978 and 1995, both "GDP 1952-95" and "China Statistical Yearbook" report identical values.

China's official GDP statistics are far from being flawless and may present some inconsistencies. In 1994, the Chinese national income accounting system changed in order to be in line with the international standards of National Income and Product Accounts (NIPA). Compared with the former "National Income" data, the new GDP series include a broader coverage of economic activities[3]. Moreover, China's system of industrial classification changed three times in the reform period (Holz, 2006a).

In the literature, it is generally asserted that official Chinese statistics underestimate inflation and overstate real output growth (Maddison, 1998[4]; Young, 2000). In fact, China's official statistics are mainly based on the reports of local officials. Especially in rural areas, many collective enterprises are believed to report equal rates for both nominal and real changes in output (Woo, 2000). Besides, it is often claimed that political pressure to meet central policy growth targets might push local governments into exaggerating output

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[2] In their productivity analysis in China, Chow (1993), Chow and Li (2002) exclude the years 1958-1969 from aggregate production function estimates due to the data inconsistencies.
[3] Up to 1994, "National Income Available" equalled to consumption + accumulation. Since 1994, "Gross Domestic Product" corresponds to final consumption expenditure + gross capital formation + net exports.
[4] Maddison (1998) proceed to a downward adjustment of GDP and reduces China's (official) average growth rate from 9, 88 percent to 7,49 percent.

performances (Chow and Li, 2002). Moreover, a potential downward bias on Chinese official statistics due to the exclusion of the underground economy should also be taken into consideration. However, it is very hard to say to what extend these two opposite biases cancel each other out. According to Chow (2006) and Holz (2006b) despite some accuracy problems, which are common in developing and transitional countries, the official Chinese statistics remain mostly reliable and useful for drawing economic conclusions.

In the literature, the implicit GDP deflator[5] is commonly used to obtain output data in real terms. Some previous studies (Woo, 2000; Young, 2000[6]) suspected that the implicit price deflator systematically understates the underlying inflation rate. Yet, a possible upward bias in the output data could induce a bias in growth accounting exercises by exaggerating the TFP growth. In this study, the retail price index (1952-1977) and the ex-factory price index[7] (1978-2005) are used to convert industrial value added to constant price values. It should be noted that, the ex-factory price index indicates substantially higher inflation rates when compared with other deflators, namely the implicit GDP deflator and the retail price index. Consequently, we expect that the use of the ex-factory price index will lower the overall rate of industrial growth in the reform period and cancel out a potential upward bias.

2.2. Labour Input

The OECD (2001) highly recommends the use of the total number of hours worked to measure the contribution of labour force to output[8]. However, given the data limitations, in this study labour is measured in terms of number of workers rather than hours worked. The year-end values of number of employed persons are derived from the "Labour Yearbook 1996" and "China Statistical Yearbook 2006". Employment series for industry are obtained by subtracting labour force in construction sector from secondary sector total employment figures.

The official Chinese employment data has several shortcomings: Firstly, a potential underestimation of labour share due to non-reported incomes should be considered. Secondly, starting from the year 1998, official annual employment data exhibit some discontinuities.

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[5] The implicit GDP deflator refers to the ratio of nominal to real GDP.
[6] Young (2000) infers that the official real GDP growth is overestimated by about a 2 percentage points.
[7] In China, the ex-factory price is only available for the period after 1978.
[8] The use of "total number of hours worked" statistics enables to isolate the effect of evolution of part time jobs and double jobs as well as shifts in normal hours. For further discussion see OECD Manual "Measuring Productivity" (2001, pp. 39).

Prior to 1998, employment data included "staff and workers" who were *de facto* laid off[9]. In addition, the official employment statistics reported in the CSY were revised in 1997 in order to be in line with the results of the annual Survey of Population Change.

Previous studies based on number of workers statistics assume systematically a fixed work week. By doing so, they ignore the regulations that reduced the work week in Chinese industry for the "staff and workers[10]" sub-category. In fact, in China, the work week was shortened from a 48-hour-week to a 44-hour-week in March 1994 and to a 40-hour-week in May 1995. In this study, we attempt to compute a consistent employment series by taking into consideration the shortened work week. In this regard, starting from March 1994, we build the 48-hour-week equivalent series for the "staff and workers" sub-category by deducting the effect of typical work week declines on annual employment figures[11].

2.3. Capital Input

Data issues for China become more problematic when capital input is in question. First of all, China's official statistics do not report capital stock estimates which satisfy international national accounting standards. As a result, most researchers are led to derivate their own capital stock series following different methods. Capital stock estimates are extremely sensitive to the functional form of depreciation, choice of deflators, aggregation level, capacity utilisation adjustments and contents of the investment data (inclusion of land, inventories, residential buildings, etc.). Hence, it is hardly surprising that in the literature, Chinese capital stock estimates exhibit, in many cases, seriously different patterns.

In this study, we compute a new net capital stock[12] data set following the perpetual inventory method (PIM) introduced by Goldsmith (1951). In sum, the PIM consist of adding the net investment data of the current year to an assumed base year of capital stock. The capital stock series for Chinese industry are computed following Equation I, where K is capital stock, I is net investment, δ is the depreciation rate and t denotes time.

$$K_t = (1-\delta)K_{t-1} + I_t \tag{I}$$

The amount of the initial capital stock in 1952 is originated from Chow's (1993) estimates of 15,8b yuan RMB (in 1952 constant prices) for Chinese industrial sector. In the

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[9] In China, especially in state-owned enterprises (SOEs), it should be considered that some workers could be furloughed or take long absences and still remain on the payroll for some political reason (JRZ, 1996).

[10] « Staff and workers » is a sub-category of total employment which refers to formal employment, particularly, in urban sectors.

[11] For further information see JRZ (2000, pp. 809).

[12] Due to the lack of data, the contribution of capital input to output is approximated by the "capital stock" data instead of the "flows on capital services" as recommended by the OECD (2001).

previous literature (Hu and Khan, 1997; Young, 2000), the measurements of investment expenses are usually based on Gross Fixed Capital Formation (GFCF) or Investment in Fixed Assets (IFA) statistics. However, it should be noted that, not all investment increases lead to increases in fixed assets. Put differently, in a centrally planned economy, as the Chinese one, some IFA projects may not immediately produce results that meet the standards for fixed assets or some of them could even be wasted[13]. In this study, we use the economy-wide "newly increased value of fixed assets through investment" (effective investment) data obtained from Holz (2006a[14]). Effective investment refers exclusively to a fraction of the GFCF or IFA expenditures that have been turned into new fixed assets. Hence, we consider that it is more in accordance with the SNA concept of investment. In China, the investment price index has only been available since 1990. Hence, to derive inflation free investment series, the implicit GFCF deflator is used for the period prior to 1990 and the investment price index, for the years 1990-2005.

The official Chinese statistics do not provide information on the sectoral distribution of the GFCF. Thereby, in the existing literature, national investment statistics for industrial sector are usually obtained by summing up provincial data. However, in many cases, these estimates display serious discrepancies when compared with national aggregated figures. In this study, to obtain investment series for industrial sector, national investment data are weighted by the share of industry in Newly Increased Fixes Assets (NIFA) statistics of each year[15].

As long as a fixed asset gets older, both its efficiency and price go down. The concept of depreciation refers to changes in the value of assets along with aging and obsolescence. In order to compute net capital stock series, capital goods should be disaggregated into the relevant categories and depreciated separately for each type of asset. This requires information on average service life, retirement pattern, age-efficiency and age-price profiles of each type of fixed assets. However, to our knowledge, data on depreciation patterns are not available for Chinese industrial sector over the study period. Moreover, official depreciation statistics in national accounts are based on historical costs and the underlying depreciation methodology remains generally unclear. In addition, official depreciation rates range from 4,1

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[13] For further discussion see Chow (1993, pp. 816).

[14] Holz (2006a, pp. 263) indicates that the economy-wide (total) effective investment data (1981-2005) originated from "Investment 1950-2000 " (2002, pp.77); "Investment Yearbook " (2003, pp.3); (2004, pp.27) and "Statistical Abstract" (2006, pp.52).

[15] Due to the data limitations, for the period 1952-1985 the weight of the year 1985 (0, 42) is used to compute investment data for industry. The weight of 0,42 is also consistent with the industrial share of the NIFA in SOEs, available starting from the year 1952 (CSY, 1997).

to 4,6 percent which are far below international standards for transitional economies (Chen and al., 1988).

Some previous studies adopted systematically the official depreciation method without any empirical justification (Chen and al. 1988; Chow 1993; Hu and Khan, 1997). In this study, in the same manner as Wu (2004), Young (2000), Bosworth and Collins (2007), we set the depreciation rate with arbitrary assumptions. Thereby, we assume a geometric depreciation pattern suggesting that the efficiency of assets decays at a constant rate over time. Accordingly, we consider that the depreciation rate covers both the loss of efficiency of fixed assets due to aging and retirement from service (scrapping)[16]. The annual constant depreciation rate is set to 7 percent[17]. This is also in line with most previous studies (JRZ, 1996; Wu, 2004; OECD, 2005; Bosworth and Collins, 2007). The comparison of our capital stock estimates with those of some other authors is summarised below in Table 1.

Table 1 Insert here

III. ESTIMATION METHODOLOGY OF THE PRODUCTION FUNCTION FOR CHINESE ECONOMY

China's aggregate industrial output is represented in the Cobb-Douglas production functional form in Equation II. Where, Y is industrial value added, K and L are respectively capital and labour inputs, t indicates time, α and β denote output elasticities with respect to capital and labour. A corresponds to Solow residual which is, in general, assimilated to technological change. All variables are expressed in 1952 base year pricing.

$$Y_t = A_t K_t^{\alpha} L_t^{\beta} \qquad\qquad (II)$$

By taking the logarithm on both sides we obtain the estimation equation below, where ε denotes a stochastic error term that is assumed to be a white noise.

$$\ln Y_t = \ln A_t + \alpha \ln K_t + \beta \ln L_t + \varepsilon_t \qquad\qquad (III)$$

In the empirical literature, productivity analyses are mainly based on two different approaches: On one hand, the parametric approach applies econometric techniques to estimate

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[16] In China, there is little information about scraping rates. Hence, most studies (Chen et al., 1988; Wu, 2004; Li et al, 1993) disregard scrapping issues in capital stock estimates.

[17] We also generated five different capital stock series using the constant depreciation rates of 5, 6, 7, 8 and 10 percent. On the outcome of several regressions, we found out that production function parameters are not veritably sensitive to the choice of depreciation rate.

parameters of production function. On the other hand, the non-parametric approach approximates factor elasticities by means of index numbers techniques.

The non-parametric approach assumes firms to operate in distortion-free perfectly competitive markets. It should be noted that the perfect competition hypothesis implies that firms are profit maximisers and factors are paid to their marginal product. In this manner, output elasticities of factors equal to their respective shares of payment in national income. However, in transitional and centrally planned markets, like the Chinese one, assuming perfect competition and profit maximisation could not correspond to the reality. In China, particularly, during the pre-reform period, prices were highly controlled by political authorities. In the case of distorted prices, the use of factor shares as output elasticities may be inappropriate and could result in some biased parameter estimates.

In this study, the parametric approach is adopted to estimate the production function parameters. By applying econometric tools, we avoid postulating a relationship between income shares and factor elasticities. In this way, we also relax some restrictive hypothesis of the neoclassical growth framework such as perfect competition, constant returns to scale (CRS) production technology and Hicks neutral technological progress.

Most of the previous productivity analyses in the literature impose CRS restriction to production function estimates. In this study, we do not assume, *a priori,* CRS of production technology. The relaxation of CRS hypothesis implies that factor elasticities do not necessary have to add up to unity ($\alpha+\beta\neq1$).

Growth accounting literature assumes systematically technological change to be Hicks-neutral[18]. Thus, TFP growth is usually captured by the inclusion of an exponential time trend to the regression analysis (Chow and Li, 2002; Chow 1993; Wu, 2004). In the production function estimates, we relax Hicks neutral technological change assumption and allow for factor augmenting technological progress. Thereby, the constant term in the regression analysis captures any form of technological change, namely both Hicks-neutral and factor-augmenting (capital-augmenting and labour-augmenting).

Table 2 summarizes the OLS estimates in levels of the Cobb-Douglas production function. We preferred to estimate in levels since the first difference operator could remove some information about the long-run relationship between factor inputs and output, and also emphasise the short-run fluctuations. According to Table 2, most of the coefficients of the model variables are statistically significant at the 1 percent level. The Adjusted R-squares of

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[18] Hicks-neutral technological change hypothesis implies that technological progress increases the marginal productivity of both capital and labour to the same extent.

both regressions are highly close to one, indicating a very good fit of the model. In addition, the F-Statistics presented below, illustrate that all regressions are globally significant at the 1 percent level.

Variable returns to scale (VRS) estimates are presented on the left side of Table 2. In the non-restricted OLS specification we can observe that the sum of the coefficients is slightly lower than one, supporting the assumption of decreasing returns to scale production technology. To determine whether this outcome is statistically significant, we perform the Wald coefficient restriction test. The associated F-statistics of the Wald test show that the null hypothesis of CRS can not be rejected even at the 5 percent level. In addition, the ARMA (1,1) specifications illustrated in columns (3) and (5) yield almost the same output elasticities, which sum to unity, whether or not the CRS restriction is imposed. These results give strong evidence on the existence of CRS production technology in Chinese industry over the period 1952-2005.

To detect a likely heteroscedasticity of the error terms, the White heteroscedasticity test is performed. The associated *p*-values of the F-Statistics give evidence about the existence of heteroscedasticity in the OLS estimations. Whereas, the White test results indicate that the null hypothesis of homoscedasticity of residuals can not be rejected at the 5 percent level in the ARMA (1,1) estimations.

The major shortcoming prevailing in most previous studies is, undoubtedly, the serial correlation of errors. According to Table 2, in the OLS specifications, the associated Durbin-Watson Statistics reveal a significant positive serial correlation. This outcome is also confirmed by the Breusch-Goldfrey Lagrange (LM) test performed with 4 lags. In order to correct for the autocorrelation issue, we proceed to an ARMA specification under both VRS and CRS hypothesis (columns 3 and 5). Eventually, the D-W statistics of residuals for ARMA (1,1) regressions reveal no remaining autocorrelation. In addition, the F-statistics associated to LM test also confirm the absence of serial autocorrelation of residuals.

Table 2 Insert here

The use of an aggregate production function assumes factor elasticities to be constant across the entire period observed. However, alongside the reform policies, Chinese industry underwent substantial structural changes that may have had an effect on production technologies. Hence, before validating the ARMA specification, it is crucial to investigate empirically on the intertemporal stability of production function parameters. Thereby, we

perform the Chow forecast test with different time breaks in the years 1978, 1979, 1980 which correspond to the introduction of reform policies. For those three breakpoint years, the F-statistics of the Chow forecast test indicate that the null hypothesis of no structural change in the production function parameters could not be rejected at the 5% confidence level. Consequently, we consider that in Chinese industry, production function elasticities remained constant between 1952 and 2005.

In view of these outcomes, the CRS restricted ARMA (1,1) specification turns out to produce the best statistical results. Furthermore, the ARMA (1,1) specification yields almost identical coefficient estimates (which add up to unity) whether or not the CRS restriction is imposed[19]. Accordingly, the output elasticities of 0,78 with respect to capital and 0,22 with respect to labour are used in the growth accounting analysis below. It can be observed that the capital elasticity of 0,78 is slightly higher than those in the literature[20]. However, we consider that these results are in accordance with the reality: Low labour elasticity as well as high capital elasticity are major characteristics of transitional economies where labour is abundant whereas capital is scarce.

IV. PRODUCTIVITY PERFORMANCES OF CHINESE INDUSTRY

Industrialisation of the Chinese economy began in the early 1950's, just after the foundation of the People's Republic of China in 1949, by Mao Zedong. Besides, physical capital accumulation speeded up in the reform period due to the high level of both investment and domestic savings. Investment in Chinese industry indicates a significantly changing pattern between 1952 and 2005. Under the centrally planned economy, investment was fully funded by government and particularly concentrated in heavy industries. In contrast, since the introduction of reform policies, a growing part of investment has been financed by household savings and oriented towards labour-intensive manufacturing industries. It is obvious from Figure 1 that the capital per worker ratio exhibited an increasing trend in the course of the reform period. Moreover, Figure 1 also highlights that the capital intensity shifted strikingly starting from the early 1990's. The substantial increase in capital per labour ratio expresses the changes in the allocation of productive factors, for instance substitution of capital for labour and ongoing capital deepening. Undoubtedly, the elimination of redundant workers in

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[19] We also tried several auto-regressive and moving-average specifications with different time lags. To save place, only the OLS and ARMA(1,1) estimation results are reported in table 2. The MA(1) and AR(1) regression results are available on request from the author.

[20] The output elasticity of capital in Chinese industry is estimated to 0,75 in Chow (1993) over the period 1952-1985 and to 0,72 in Xu and Wu (2001) over the period 1979-1997.

SOEs has also contributed to enhance capital intensity in the industrial sector. Furthermore, China's rapid exposure to foreign trade and FDI inflows has accelerated capital formation since the last decade. In this section, extended overviews of both multifactor and single factor productivity performances for the period from 1952 to 2005 are presented.

Figure1 Insert here

4.1. TFP Growth

In the neoclassical growth framework, TFP growth is calculated as a residual term, by subtracting the contribution of capital and labour inputs from output growth. In other words, TFP growth corresponds to the portion of growth left unaccounted by increases in factor inputs. We derive the year-to-year estimates of TFP growth following Equation IV.

$$\frac{\partial \ln TFP}{\partial t} = \frac{\ln GDP}{\partial t} - \alpha \frac{\partial \ln K}{\partial t} - \beta \frac{\partial \ln L}{\partial t} \qquad \text{(IV)}$$

Since the use of inputs is subject to cyclical factors, economic activities tend to fluctuate over the business cycle. As a consequence, TFP estimates exhibit procyclical behaviour and need to be adjusted for capacity utilisation (Hulten, 2000). For instance, downturn periods in demand are characterized by excess capacity whereas during upturn periods production capacities are fully utilised. Hence, TFP estimates could be biased if capacity utilisation is overlooked in productivity analysis. In addition, procyclical fluctuations of TFP growth are likely to occult some information about the movements in the long-run components and conceal some significant breaks in the time trend (Hulten, 2000).

In the literature, capital stock statistics are usually adjusted for capacity utilisation by means of inventory data, unemployment statistics or power utilisation rates (Jorgenson and Griliches, 1997). However, in China, there is no direct measure of capacity utilisation available over the period 1952-2005. Hence, we obtain smoothed TFP series by applying the widely used Hodrick-Prescott (H-P) filter. In summary, the H-P is a linear filter suggested by Hodrick and Prescott (1997) which removes the cyclical components of the long run path of the residual. It proceeds by decomposing the original series (y_t) into two components: long term trend component (g_t) and cyclical component (c_t)), that is:

$$y_t = g_t + c_t \qquad \text{(V)}$$

Solving the following minimisation problem allows to determine the growth component:

$$Min_{\{g_t\}_{t=1}^{T}} \sum_{t=1}^{T} (y_t - g_t)^2 + \lambda \sum_{t=2}^{T-1} [(g_{t+1} - g_t) - (g_t - g_{t-1})]^2 \qquad (VI)$$

The first term is the sum of the squared deviations from trend whereas the second term is the multiple λ of the sum of squares of the trend component's second differences. The parameter λ[21] penalises variability in the growth component. The H-P filter consists of a trade-off between the cost of incorporating fluctuations in the growth series (i.e. good fit) and the prescribed smoothness of the trend component. In this study, the smoothing parameter λ is set to 100 following the suggestion of Hodrick and Prescott (1997) for annual data.

In the last decade, some critical literature pointing out several shortcomings of the H-P filter has blossomed (Cogley and Nason, 1995; Harvey and Jaeger, 1993). Critics of the H-P filter mainly focus on the likelihood of spurious cycles estimates, particularly while filtering difference stationary data series. Some likely autocorrelation issues related to H-P filtered time series are also addressed in the recent literature. However, presenting a detailed discussion about the drawbacks and shortcomings of the H-P filter is beyond the scope of this paper.

Figure 2 Insert here

The Chinese economy has been challenging a process of technological development and institutional change, since the beginning of the reform period. In a centrally planned economy, allocation of resources and investment decisions are not determined through market mechanism but by the government's budget allocation policy. In addition, industrial prices and wages are highly regulated by the central authority. As a consequence, Chinese industry has suffered severely from the inefficient allocation of factor inputs in the central planning period. Alongside the extended reforms policies, significant efforts have been made to establish a capitalist market economy.

The H-P smoothed TFP growth series between 1952 and 2005 are illustrated above. It is obvious from Figure 4 that political turmoil introduced by the Great Leap Forward Movement (1958-1960) and the Cultural Revolution (1966-1976) undermined dramatically

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[21] Note that while λ approaches to 0, the trend component becomes equivalent to the original series, i.e. $y_t = g_t$. While λ goes to infinity the growth component converges to the OLS estimates of y_t's linear time trend.

the TFP outcomes of Chinese industry. According to Figure 2, in the central planning period, TFP growth recorded negative figures. The outcome of negative TFP growth during the pre-reform era is also consistent with previous studies which infer the absence of technological progress in the pre-reform period (Chow, 1993; Chow and Li, 2002). Besides, Figure 2 continues to display negative TFP growth estimates until the late 1980's. This finding is also in line with some previous studies which detect a productivity decrease in Chinese industry in the middle of the 1980's (JRZ, 1992; Wu, 2004; Wu and Xu, 2001). Weak productivity performances during the first decade of the reform period could be attributed to several factors: First of all, in the beginning of the reform era, in Chinese industry, TFP gains were hampered by the sluggish economic performances of the state sector. Given soft budget constraints, in state-owned enterprises (SOEs), there were very few incentives to enhance productivity. As a consequence, during this period, the Chinese state sector was mainly characterised by overstaffing, excess investment in fixed capital and poor management. In the mid 1980's a series of industrial reforms was conducted in order to restructure the economic system and introduce a market based economy. However, the implementation of those reform policies turned out to be very complicated and needed more time to produce results (Wu, 2004). Under the dual-track system, productivity performances of Chinese industry were impeded. Moreover, owing to some political reasons, resources were globally allocated into loss-making SOEs rather than into the growing private sector. Consequently, bank debts and non performing loans to support SOEs also undermined productivity performances of Chinese industry. In addition, poor TFP performances until the late 1980's could well be related to the overstatement of capital and labour inputs due to their inefficient utilisation, especially in the state sector. In fact, a possible overstatement of factor inputs could also lead to an underestimation of the residual over this period.

The reform period in Chinese industry is largely marked by the huge expansion in industrial activity outside state sector. Along with the structural transformation of Chinese industry, the relative importance of the state sector has declined continuously. In the 1980's, township and village small-scale enterprises emerged in rural areas. Furthermore, by the early 1990's, foreign-invested enterprises gained important market shares in industrial sector.

According to Figure 2, since 1988, with a gradual adoption of a distortion-free market economy, TFP in Chinese industry started to exhibit positive growth figures. During this period, institutional reforms carried out in the state sector as well as in the banking sector began progressively to bear fruit. The reallocation of the labour force out of SOEs gave substantial opportunities for achieving efficiency gains. Furthermore, by the early 1990's, the

government had undertaken some comprehensive reforms to open-up China to the world economy. In this regard, significant efforts have been made to reduce barriers to foreign trade and investment. China's rapid integration into the world economy resulted in a massive inflow of FDI flows and the expansion of foreign trade. Thereby, starting from the late 1990's, China has become the first recipient of FDI between developing countries. It also joined the World Trade Organization (WTO), in December 2001. In China's industrial sector, the growing share of foreign-owned enterprises (FOEs) is likely to involve spillover effects. In fact, a reinforced competition on domestic markets may increase overall productivity by constraining local enterprises to upgrade their efficiency and competitiveness. Furthermore, substantial improvements in human capital, recorded since the last decade, are prone to propel TFP gains in the industrial sector.

4.2. Single Factor Productivity

Under the centrally planned economy, labour movements between sectors had been tightly restricted through the *hukou* (household registration) system. Consequently, in the pre-reform era, a massive labour surplus in rural areas developed due to technological improvements and democratic increase. Alongside the market-oriented reform policies, barriers to labour migration between urban and rural sectors have been lowered. The expansion of small-scale enterprises in rural areas contributed to improve labour productivity in Chinese industry. Figure 3 illustrates the positive long-term trend of labour productivity in industrial sector during the reform era. In addition, since the early 1990's, the output per worker ratio has shown an impressive accelerating growth pattern. This could largely be attributed to the high rate of capital formation, substitution of capital for labour and to a better resource allocation across sectors. Moreover, the elimination of redundant workers in SOEs has, doubtlessly, contributed to reap labour productivity gains in Chinese industry.

Figure 3 Insert here

In contrast to increases in output per worker, Figure 3 depicts a globally declining trend in output per unit of fixed assets, particularly in the second half of 1980's. The capital productivity slowdown during this period could stem from the excess investment and inefficient capital allocation, especially in SOEs. Since the last decade, capital productivity pictures a slightly accelerating pattern which could be related to the rapidly growing share of private enterprises in low-capital intensive industries.

4.3. TFP Debate

Since the initiation of the neoclassical growth theory, conceptual problems about the TFP have been the subject of a heated debate between economists. Hence, we consider that it is vital to clearly define the concept of TFP before interpreting empirical results. An extended discussion about the contents and definition of the TFP residual is presented below.

The TFP concept takes its origin from the pioneering works of Tinbergen (1942) and Solow (1957). According to Solow's growth framework, the residual refers to the part of output growth that could not be explained by the growth in inputs. In this way, TFP is interpreted as a shift of the production function over time, whereas the growth in factor inputs refers to movements along a production function. In the neoclassical growth theory, the residual is viewed as an exogenous technological change that takes place like "manna from heaven". Consequently, its occurrence is completely independent of other components of the economy such as investment and capital accumulation. Abromovitz (1956) call the residual "measure of our ignorance", since it does not only contain technological change but a mix of unwanted components, namely measurement errors, aggregation biases, omitted variables, business fluctuations, model misspecification, etc. However, according to Jorgerson and Griliches (1967) the TFP residual is nothing else than a result of mis-measurement. Hence, it should disappear if factor inputs were measured correctly.

Under the neo-classical assumptions, the residual is confined to exogenous, disembodied and Hicks-neutral technological progress (Chen, 1997). Whereas, in this study, we proceed to a wider interpretation of the residual: In our analysis, TFP involves all kinds of disembodied technological changes (new managerial and organizational methods, R&D and innovation activities, etc.) which improve production efficiency. Besides, the residual captures a mix of factors that enhance economic growth (scale economics, spillover effect, improvements in resource allocation, institutional and political factors) and measurement errors.

According to the embodiment hypothesis, a significant part of technological change could be embodied in factor inputs. As for capital input, this refers to advances in the design and quality of new vintages (OECD, 2001). On that account, fixed asset series should be deflated by price deflators which take into consideration quality changes in capital stock by type, model and vintage. As regards labour input, improvements in labour force skills could lead to substantial efficiency gains. Hence, employment series should be adjusted for changes

in quality, in accordance with the age-sex composition and level of educational attainment of labour force.

In the case of quality adjusted factor input series, factor contribution estimates capture both the effect of changes in input qualities and quantities on output growth. The magnitude of the residual depends deeply on the extent of quality adjustments. Put differently, if quality improvements in input factors are overlooked, the residual term should be expected to be higher since it shows up the effects of changes in the quality of capital inputs and improvements in human capital[22]. In this study, given that factor input measurements do not include quality improvements, TFP estimates are expected to capture technological change both embodied and disembodied.

4.4. Growth Accounting for Chinese Industry 1952-2005

Neoclassical growth accounting framework identifies two major sources of economic growth, namely factor accumulation and TFP growth. Given that capital accumulation is subject to the law of decreasing returns, theoretically, an input-driven economic growth could not be sustainable. Hence, in the long run, growth should be generated by advances in knowledge or technology, through better policies and improved management. In other words, a sustainable long term economic growth should essentially lie on TFP growth.

In order to inquire into the main sources of economic growth in Chinese industry, we perform the conventional growth accounting analysis[23]. A summary of the average growth rates of output and primary factor inputs are presented in Table 3. From Table 3 we observe that industrial output in China recorded a steady rate of growth of about 10 percent between 1952 and 2005. However, following a sharp rise from 1966 to 1978, the growth rate of employment has been continuously declining during the post-reform period. Moreover, employment growth figures continued to decrease dramatically in the early 1990's. This phenomenon could be attributed to the replacement of laid-off state workers by the labour force reallocated from farming to industry (OECD, 2005).

Chinese industry has been marked by a rapid capital formation since the early 1950's. During the pre-reform period, capital accumulation growth rate exceeded the overall GDP growth and ranged around 12 percent per annum. Since the early 90's, the physical capital

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[22] Young (2000) estimates the contribution of human capital improvement to output growth about 1,1 percentage points per year for the period 1978-1998.
[23] In the growth accounting exercise the weights assigned to capital and labour inputs are respectively 0,78 and 0,22. However, in most previous studies output elasticity with respect to capital is usually set about 0,6. Consequently, in this study, the use of greater output elasticity for capital input is expected to reduce TFP estimates.

accumulation rate has fallen slightly behind the GDP growth rate. However, since the last few years, excess investment in Chinese industry has become an issue of great concern for some scholars and government authorities.

Table 3 Insert here

The average contributions of input factors and TFP to economic growth are summarized in Table 4. At a first glance, we observe that during the whole study period, capital accumulation has been the main growth engine of Chinese industry and accounted for 88 percent of output growth. Besides, TFP growth has shown a globally accelerating trend and contributed positively to economic growth at a pace of 1,9 percent. According to Table 4, in Chinese industry, growth in labour input explains 10 percent of output growth between 1952 and 2005.

Table 4 Insert Here

In contrast to some previous studies, Table 4 gives evidence about the absence of TFP gains under the centrally planned economy. It also illustrates that TFP growth figures remained positive in the overall reform period despite a slight decline from 1979 to 1992. Furthermore, Chinese industry recorded the best TFP performances starting from the early 1990's. Since 1993, TFP has grown at a rate of 3,8 percentage, supporting China's ability to sustain these high rates of economic growth in the near future.

V. CONCLUDING REMARKS

This study investigates empirically on the driving forces of economic growth in Chinese industry through a parametric approach. The use of econometric tools in production function estimates enables us to relax some behavioural assumptions of the neoclassical growth theory, such as constant returns to scale, Hicks neutral technological change and perfectly competitive markets.

The major outcome of this paper is that massive capital accumulation has been the driving force of the spectacular economic performances in Chinese industry, between 1952 and 2005. Besides, TFP gains contributed positively to economic takeoff during both pre-reform and post-reform periods. Our empirical results yield no support for the concern of TFP

slowdown as expressed in some recent studies. Besides, our TFP estimates exhibit an accelerating growth pattern since the early 1990's, giving consistent evidence about the sustainability of economic growth in the near future.

In this study, we proceed to a broader interpretation of the conventional Solow residual: Our TFP estimates include both embodied and disembodied technological change, effects of resource allocation between sectors, scale economics, institutional and political factors that effect growth and measurement errors.

Issues of data availability are of a great concern in Chinese studies. Likewise, some data accuracy problems are likely to threaten the robustness of our results. In the literature, it is often asserted   that China's official GDP statistics may display some upward bias. Thereby, understatement of the real inflation rate may exaggerate the measured growth rate of output and lead TFP to overstate the truth. Furthermore, careful interpretation should be made of employment statistics: The employment data only cover formal economy, although the proportion of labour force in the informal sector is estimated to be very high.

Data accuracy issues become more problematic as far as capital input is concerned. Chinese Statistical authorities do not yield capital stock estimates that satisfy international standards. Moreover, official depreciation rates are generally ambiguous and range far below international standards. Yet, an overstatement of capital stock due to under-depreciation could reduce the TFP residual. In this study, we compute a new data set for capital input which may have some shortcomings. Due to the lack of data availability, investment data are not decomposed into their major components and deflated separately for each major asset type. Yet, the application of a single deflator to heterogeneous investment goods could be, somehow, problematic and may induce an aggregation bias (Jorgenson and Griliches, 1967). In addition, capital and labour input measurements overlook the value of the underutilisation of production factors, especially in SOEs. However, a possible overestimation of factor inputs is likely to understate the TFP residual estimates. Finally, it is very hard to predict the net effect of measurement errors in input and output statistics on productivity estimates.

The TFP analysis presented in this study consists of isolating the Solow residual using an improved data set and robust econometric tools. Our findings direct attention to several opportunities for further research. In the neoclassical growth framework, innovation is considered as exogenous to the economic system. In the 1980's, the introduction of new growth theories give scope to separate investigation on the contribution to economic growth of human capital, R&D activities, improvement in allocation efficiency and technology transfer. In addition, our empirical findings show that the TFP growth in Chinese industry has

increased dramatically since the last decade. These findings give room to further scrutiny on spillover effects resulting from China's accelerated integration to the world economy through FDI and foreign trade.

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Table 1 : Average Growth Rates of China's Capital Stock

Source	Period	Growth Rate (%)
Industrial		
This study	1952-1978	12,2
	1979-2005	9,6
Chow (1993)	1952-1985	12,6
Jefferson and al. (1996)	1980-1992	7,4
National		
Borensztein and Ostry (1996)	1979-1994	9,9
Hu and Khan (1997)	1979-1994	7,7
Maddison (1998)	1952-1978	7,6
	1978-1995	8,8
Wu (2004)	1979-1997	9,6

Table 2 : Regression Results for the Aggregate Production Function of Chinese Industry: 1952-2005

Independent to Scale Variable: GDP ARMA(1,1)	Variable Returns to Scale		Constant Returns to Scale	
	OLS	ARMA(1,1)	ARMA(1,1)	OLS
Constant	-0,21 (-1,38)	-0,43 (-1,08)	-0,31*** (-3,98)	-0,41*** (-3,16)
Ln K	0,76*** (1,40)	0,79*** (19,06)	-	-
Ln L	0,19 (9,95)	0,21** (1,89)	-	-
lnK/L	-	-	0,73*** (18,51)	0,78*** (11,06)
AR(1)	-	0,67*** (4,69)	-	0,67*** (3,85)
MA(1)	-	0,67*** (4,02)	-	0,67*** (3,78)
Adjusted R²	0,98	0,99	0,91	0,98
Number of observation	54	53	54	53
Residual Sum of Square	1,89	0,57	1,90	0,47
Model F-Statistic	1320 [0,00]	2358 [0,00]	555 [0,00]	710 [0,00]
Akaike Info Criterion	-0,40	-1,53	0,43	-1,72
White test	3,10 [0,02]	1,56 [0,19]	5,97 [0,00]	2,16 [0,12]
Durbin-Watson Statistics	0,38	1,99	0,36	1,99
Serial Correlation LM Test	61,61 [0,00]	0,10 [0,89]	60,04 [0,00]	0,07 [0,92]
Test for CRS restriction	-	-	F(1,51)=0,35 [0,55]	F(1,48)=0,00 [0,96]

Notes: *** denotes significance at 1% level, all numbers in parentheses are White heteroscedasticity-consistent t-statistics while figures in squared blankets are *p*-values.

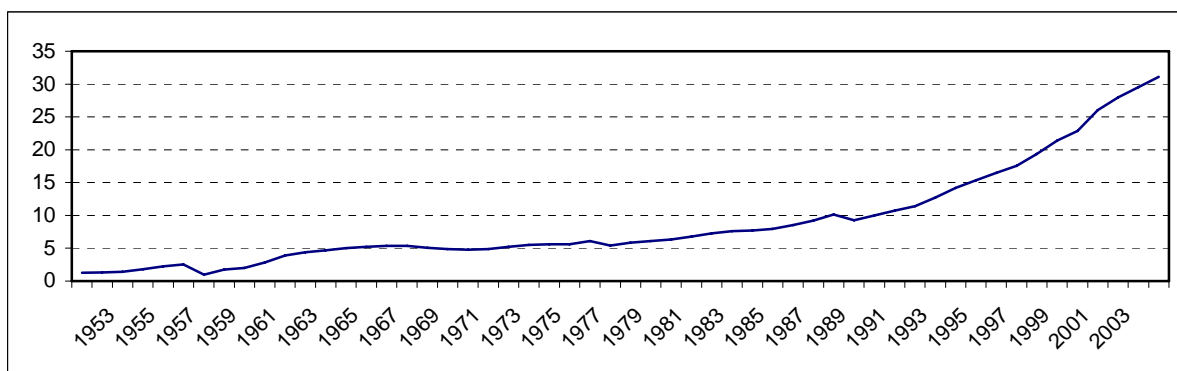**Figure 1 : Capital intensity in Chinese Industry**

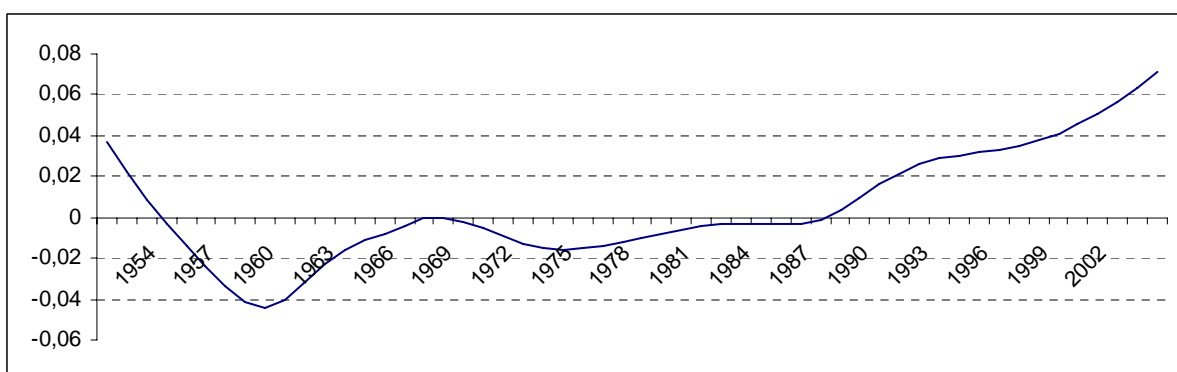**Figure 2: The HP Filtered Total Factor Productivity Growth Estimates**

Figure 3: Single Factor Productivity: Output per worker and output per capital
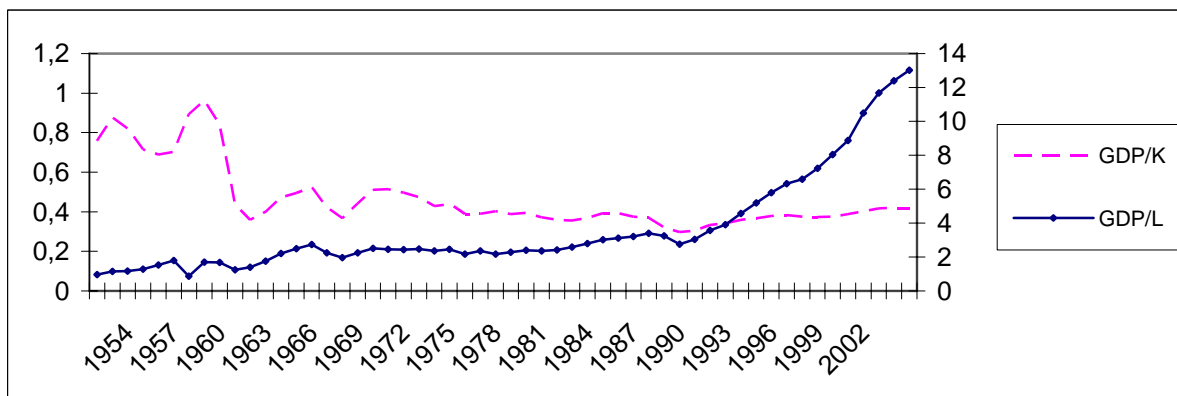
Table 3: Average Annual Growth Rate (%)

Period	Output	Capital	Labour
1952-2005	**9,78**	**11,02**	**4,52**
1952-1965	10,80	14,49	2,99
1966-1978	7,72	10,11	9,84
1952-1978	**9,67**	**12,37**	**6,29**
1979-1992	8,56	9,86	4,88
1993-2005	11,36	9,49	0,71
1979-2005	**9,95**	**9,64**	**2,82**

Source: Author's calculates.

Table 4 : Average contributions of input factors and TFP to economic growth in Chinese Industry : 1952-2005

Period	Output Growth	TFP Growth	Capital contribution	Labour Contribution	TFP Contribution
1952-2005	**9,78**	0,19	88%	10%	2%
1952-1965	10,8	-1,16	105%	6%	-11%
1966-1978	7,72	-2,33	102%	28%	-30%
1952-1978	**9,67**	**-1,36**	100%	14%	-14%
1979-1992	8,56	-0,20	90%	13%	-2%
1993-2005	11,36	3,80	65%	1%	33%
1979-2005	**9,95**	1,81	76%	6%	18%

Source: Author's calculates.

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