AN EMPIRICAL ANALYSIS OF THE LEWIS-RANIS-FEI THEORY OF DUALISTIC ECONOMIC DEVELOPMENT FOR CHINA*

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Abstract

We employ the Lewis-Ranis-Fei theory of dualistic economic development as a framework to investigate China's rapid growth over 1965-2002. We find that China's economic growth is mainly attributable to the development of the non-agricultural (industrial and service) sector, driven by rapid labour migration and capital accumulation. Our estimates of the sectoral marginal productivity of labour indicate that China's 1978 Economic Reform coincided with moving from phase one to phase two growth, as defined in the Lewis-Ranis-Fei model. This implies that phase three growth could be achieved by the commercialisation of the Chinese agricultural labour market. (95 words)

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JEL classification: O14, O15, O18, O41, O47, O53.

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1 Introduction

Lewis (1954) proposed a seminal theory of dualistic economic development for over-populated and under-developed economies with vast amounts of surplus agricultural labour[1] for which he was later to be awarded the 1979 Nobel Prize in Economics. Economic growth in such an economy can be achieved by rapid capital accumulation in the non-agricultural (industrial and service) sector, facilitated by drawing surplus labour in the agricultural sector. In the Lewis theory, an economy transits from the first, labour-surplus "stage" to the second, labour-scarce "stage" of development.

Later, Ranis and Fei (1961) formalised the Lewis theory and defined three "phases" of dualistic economic development by sub-dividing the first stage in the Lewis model into two phases. Thus, the second labour-scarce stage of the Lewis model corresponds to phase three of the Ranis-Fei model. These three phases, illustrated in Diagram 1 below, are distinguished by the marginal productivity of agricultural labour. The entry into each phase is marked three turning points:

- The *breakout point* leads to phase one growth with redundant agricultural labour.
- The *shortage point* leads to phase two growth with disguised agricultural unemployment.
- The *commercialisation point* leads to phase three of self-sustaining economic growth with the commercialisation of the agricultural sector.

The Lewis-Ranis-Fei theory of dualistic economic development therefore provides a suitable theoretical framework for studying the growth path of labour-surplus developing economies such as China.

China's 1.3 billion inhabitants account for a fifth of the world's population. Over 50 percent of the Chinese population is engaged in the rural agricultural sector. China's

[1] Throughout the paper we refer to the two sectors as agricultural and non-agricultural. Various authors have used different terms interchangeably for these two sectors. Lewis (1954) originally named the two sectors as the subsistence and the capitalistic sectors and later on in Lewis (1979) referred to them as the traditional and modern sectors. Jorgenson (1967, p.291) elaborates further on the distinction between the two sectors and narrows this down to the stylised fact that the two sectors do not share the same production technology, particularly when it comes to capital accumulation.

agricultural labour productivity is very low due to the presence of surplus labour relative to other scarce resources. The agricultural wage rate is lower than the non-agricultural one. The 1978 Economic Reform propelled the Chinese economy into a path of rapid economic growth, at the rate of approximately eight percent per annum. This remarkable economic growth, particularly in the urban non-agricultural sector, requires a great inflow of labour (Knight, 2007). The gradual relaxation of the stringent Hukou registration system has further facilitated the temporary rural to urban migration of over 100 million workers.

There are very few recent studies discussing China's economic growth and labour reallocation within the framework of the Lewis theory. Both Cai (2007) and Knight (2007), focus more on examining the Lewis turning point than testing the Lewis theory. In this paper, we are the first to systematically assess the Lewis (1954) theory and its formalization by Ranis and Fei (1961) for China. We address the three core questions:

(1) Is the main source of economic growth non-agricultural capital accumulation?

(2) What is the net effect of agricultural to non-agricultural labour reallocation?

(3) What phase of economic development is the Chinese economy in? In other words, has China passed the commercialisation point signified by the exhaustion of surplus labour, as discussed by Cai (2007) and Knight (2007)?

To answer these questions we estimate Cobb-Douglas production functions for China's agricultural and non-agricultural sectors, using time-series national-level data over 1965-2002. Our results show that China's overall economic growth is driven by the rapid development of the non-agricultural sector, which results from the fast accumulation of non-agricultural capital. As capital accumulates, employment expands and contributes almost as much as capital to economic growth in the non-agricultural sector. This confirms the answer to our first question that capital accumulation is the main source of economic growth in the non-agricultural sector.

Secondly, we evaluate the effect of labour reallocation away from agriculture to non-agriculture by comparing the labour productivities of the two sectors. In addition, we repeat the exercise by applying the Labour Reallocation Effects (LRE) equation specified by the World Bank (1996). Both approaches suggest that labour reallocation has a positive impact on China's economic growth, accounting for 1 to 2 percent per annum of GDP growth. We find the effect of labour reallocation has declined since the mid-1990s because of less absorption of the surplus rural labour in the non-agricultural sector, particularly in industry. Our result coincides with the findings of Kuijs and Wang (2005), Woo (1998), and World Bank (1996).

Thirdly, we identify the phase of China's economic development by examining the evolution of labour productivities over time as indicated in the Lewis-Ranis-Fei model. We find that the Chinese economy has fully absorbed the redundant agricultural labour, as shown by the rising marginal productivity of labour since the 1978 Economic Reform, but has not yet completely reallocated the disguised unemployment, as shown by the marginal labour productivity being still lower than the institutional wage defined by the initial low average productivity of labour. All this indicates that, following the 1978 Economic Reform, China entered phase two of economic development defined in the Lewis-Ranis-Fei model. However, it has not reached phase three marked by the exhaustion of the disguised agricultural unemployment. Furthermore, we find that the gap of labour productivities between the two sectors is widening, which is at odds with the theoretical expectation. This reflects the effects of market imperfections and government intervention. A "critical minimum effort" is required for China to release the remaining disguised agricultural unemployment and enter phase three of economic development.

The paper proceeds as follows. Section 2 reviews the Lewis theory, the Ranis-Fei model and the related literature. Section 3 discusses China's dual-sector economic development and rural-urban labour migration. Section 4 presents the model specifications for estimating the production functions, decomposing dual-sectoral economic growth rates, and evaluating the effect of labour reallocation away from agriculture toward non-agriculture. Section 5 explains the data in relation to China's employment, capital stock, labour migration and technological progress. Section 6 presents our estimation results. Section 7 provides detailed analyses regarding the three crucial questions regarding the Lewis-Ranis-Fei model in the Chinese case. A final section concludes and makes tentative policy recommendations.

2 Literature survey

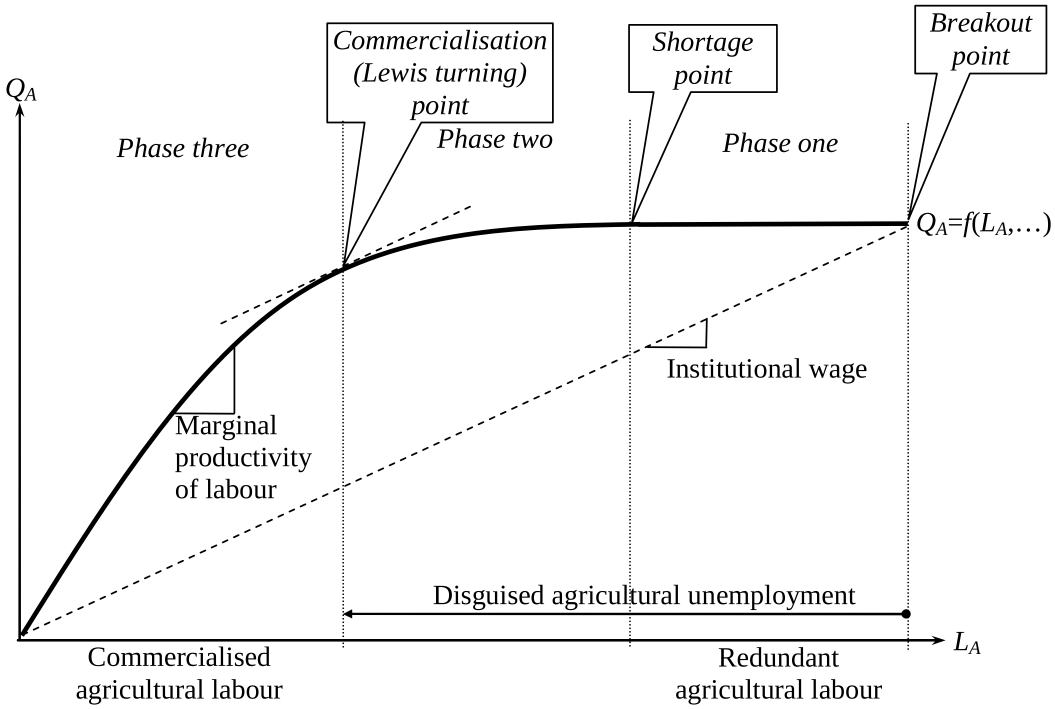
2.1 The Lewis-Ranis-Fei model

The Lewis (1954) theory of dualistic economic development provides the seminal contribution to theories of economic development particularly for labour-surplus and resource-poor developing countries. In the Lewis theory, the economy is assumed to comprise the agricultural and non-agricultural sectors. The agricultural sector is assumed to have vast amounts of surplus labour that result in an extremely low, close to zero, marginal productivity of labour. The agricultural wage rate is presumed to follow the sharing rule and be equal to average productivity, which is also known as the institutional wage. The non-agricultural sector has an abundance capital and resources relative to labour. It pursues profit and employs labour at a wage rate higher than the agricultural institutional wage by approximately 30 percent (Lewis, 1954, p.150). The non-agricultural sector accumulates capital by drawing surplus labour out of the agricultural sector. The expansion of the non-agricultural sector takes advantage of the infinitely elastic supply of labour from the agricultural sector due to its labour surplus. When the surplus labour is exhausted, the labour supply curve in the non-agricultural sector becomes upward-sloping.

Ranis and Fei (1961) formalised Lewis's theory by combining it with Rostow's (1956) three "linear-stages-of-growth" theory. They disassembled Lewis's two-stage economic development into three phases, defined by the marginal productivity of agricultural labour. They assume the economy to be stagnant in its pre-conditioning stage. The breakout point marks the creation of an infant non-agricultural sector and the entry into phase one. Agricultural labour starts to be reallocated to the non-agricultural sector. Due to the abundance of surplus agricultural labour, its marginal productivity is extremely low and average labour productivity defines the agricultural institutional wage. When the redundant agricultural labour force has been reallocated, the agricultural marginal productivity of labour starts to rise but is still lower than the institutional wage. This marks the shortage point at which the economy enters phase two of development. During phase two the remaining agricultural unemployment is gradually absorbed. At the end of this process the economy reaches the commercialisation point and enters phase three where the agricultural labour market is fully commercialised. Diagram 1 below illustrates the three phases defined by Ranis-Fei (1961, diagram 1.3):

Diagram 1. Agricultural output (QA), labour input (LA) and

Lewis-Rains-Fei phases of economic development



2.2 Relevant empirical studies

Empirical studies of the Lewis theory have met with varying degrees of success. Minami (1967b) and Ohkawa (1965) studied the effect of agricultural labour migration on Japanese economic growth. They found that Japan's sectoral labour migration made a significant contribution to its economic growth in 1921-1962. Fei and Ranis (1973) analysed the economic development of Taiwan in 1965-1975 and Korea in 1966-1980 by comparing descriptive statistics and their results also supported the Lewis theory. However, Ho (1972) tested the Lewis theory on Taiwan for the period 1951-1965 and found that technological progress played a far more important role on economic growth than sectoral labour migration.

Minami (1967a) compared several approaches to identifying the agricultural commercialisation of the Japanese economy. He pointed out that a necessary condition for the existence of surplus labour is that the marginal productivity of agricultural labour is, albeit rising, lower than the institutional (subsistence) wage. Nevertheless, a sustained increase in the marginal productivity may indicate that the agricultural commercialisation has been reached. Minami also suggested other approaches for detecting the coming of commercialisation. For example, a rising agricultural real wage rate, a higher correlation between the agricultural real wage and marginal productivity of labour, an infinity-to-zero elasticity of non-agricultural labour supply with respect to the subsistence wage, and large sustained decreases in the agricultural labour force. However, he points out that these approaches using the agricultural real wage face the same problem:

> "… when there is a rising trend in the real wage, we can not ascertain straightforwardly whether that increase comes from a change in the marginal productivity of labour or from an increase in the subsistence level itself." (Minami, 1967, p.384).

Hence, changes in real wages often lead to erroneous identification of agricultural commercialisation. Nonetheless, falls in the agricultural labour force can not help differentiate the exhaustion of the redundant labour from that of the entire disguised unemployment. They can only be taken as a complimentary approach. In sum, changes in the agricultural marginal productivity of labour relative to the subsistence level appear to be the most appropriate approach to identify the turning points. In this paper, we thereby adopt this approach to identify the turning points in the process of the Chinese economic development.

There have been few studies of the Lewis theory with respect to China. Recently Cai (2007) has argued that the demographic transition, marked by a substantial decline in population growth rates, has accelerated the onset of agricultural commercialisation. The noticeable increase in rural migrants' wage rate also indicates the exhaustion of China's surplus agricultural labour. The forthcoming labour-scarcity has been warned by the phenomenon of "migrant rural labour-scarcity"[2] occurred in the Zhujiang triangle coastal area in 2003. Soon after that, the entire Chinese economy will confront with labour scarcity. However, Knight (2007) casts doubt on Cai's claim. He argues that the rapid growth of real wages may not necessarily be the result of growing labour scarcity. Moreover, there is still much surplus labour in the rural areas, particularly in inland provinces. Knight thereby contends that the Chinese economy has not yet progressed to the second, labour-scarce stage of the Lewis model but is moving towards it. For continuing the remarkable economic growth, China should gradually absorb its remaining labour surplus in agriculture. However, both studies focus more on examining the Lewis turning point than testing the Lewis theory in the Chinese economy.

In summary, the empirical evidence of the Lewis theory is mixed and varies from country to country. Moreover, it is rare to see any systematic empirical test of the Lewis theory on the Chinese economy. In this paper, we redress this shortcoming by testing the Lewis (1954) theory and its formalisation by Ranis and Fei (1961) on the Chinese economy, investigating the sources of dual-sectoral economic growth, quantifying the contribution of sectoral labour reallocation to economic growth, and identifying the phases of economic development.

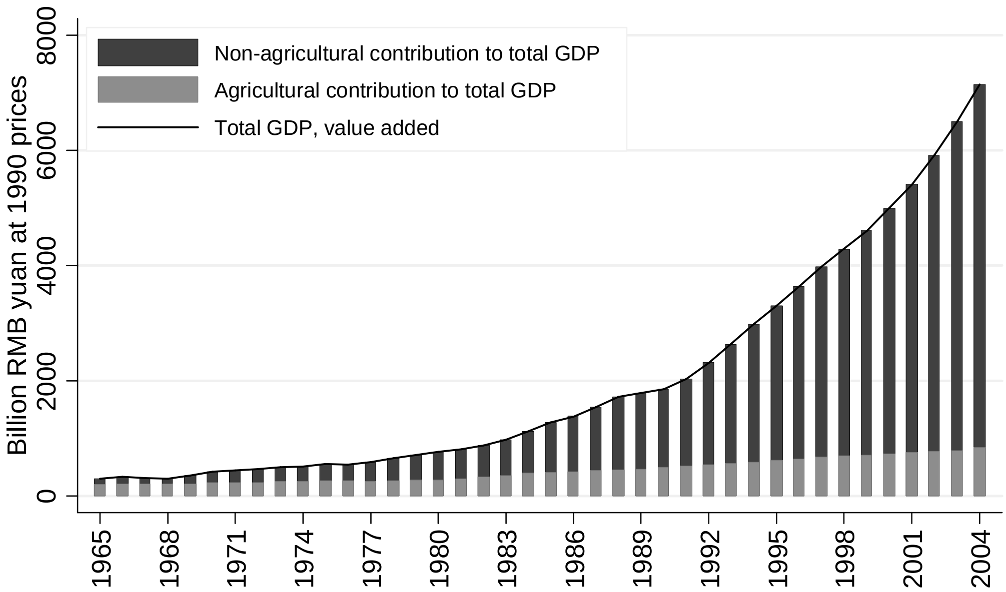
[2] According to some newspapers (e.g., China Net, May 11, 2007), in 2003, many enterprises in the Zhujiang triangle coastal area had difficulty in employing rural migrants. On the one hand, there are fewer rural migrants to employ than before; while on the other hand, migrants turn to ask for higher wage payment for working.

3 The Chinese experience

3.1 China's dualistic economic development

China has had a long history of dualistic economic development. According to Putterman (1992), prior to the 1978 Economic Reform, the rural agricultural sector was run using collective farms and wages were set by the government. In the urban industrial sector, the pursuit of profit was allowed. The 1978 Economic Reform has not brought this dualistic structure to an end. Instead it has allowed the urban sector to develop further by creating an expanding service sector and a new class of town-village enterprises.

Figure 1: Development of the Chinese two-sector economy



Source: World Development Indicators (World Bank, 2005).

Thus, the dualistic structure involves the agricultural sector in rural areas and the non-agricultural sector mainly concentrated in urban areas. Specifically, the agricultural[3] sector includes farming, animal husbandry, forestry and fishery. The non-agricultural sector includes construction, industry (i.e. manufacturing, mining and quarrying, electricity, gas and water supply), transport, post and telecommunication

[3] In the China Statistical Yearbooks, published by the NBS, the agricultural sector is referred to the primary sector, while the non-agricultural sector is composed of the secondary and tertiary sectors.

services, wholesale and retail trade and catering services. The output of town-village owned enterprises[4] is included in the non-agricultural sector, though they are in semi-urban locations. As shown in Figure 1, economic growth in China is largely driven by the non-agricultural sector and less so by that of the agricultural sector.

3.2 China's sectoral labour reallocation

China is a labour-surplus economy and most of this surplus is engaged in the agricultural sector. Before the 1978 Economic Reform, labour mobility was controlled by the government through the "Hukou system". According to Zhao (2000), the average annual rural-urban migration rate was only 0.24 percent in 1949-1985, much lower than the world average rate of 1.84 percent in 1950-1990. Since the early 1980s, the restrictions on labour mobility have been relaxed to accommodate labour demand in the non-agricultural sector. However, the one-child policy introduced in the 1970s has been imposed more stringently, particularly in urban areas. This has substantially slowed down the growth of the urban-born labour force and aggravated the labour shortage in the non-agricultural sector (Knight, 2007). Gradually the restrictions on labour mobility have been relaxed and increasing numbers of rural labourers have migrated to the towns and cities. As a result, relative employment in the agricultural sector illustrated in Figure 2 dropped from 70.1 percent in 1978 to less than 50 percent after 1994. Correspondingly, employment in the non-agricultural sector rose rapidly and reached 50 percent of total employment. Note that even with the relaxation of restrictions on labour mobility, most of the migrants are only allowed into the cities on a temporary basis.

The data for China's labour migration are only available in a few population censuses at eight to ten-year intervals, or in surveys covering a few provinces. Many studies (e.g. Wu, 1994; Zhang and Song, 2003) apply the residual method suggested by the United Nations (1970) to derive a consistent time-series for China's rural-urban labour migration. This method assumes that without international labour migration, the increase in urban population is attributable to the natural growth of the urban population

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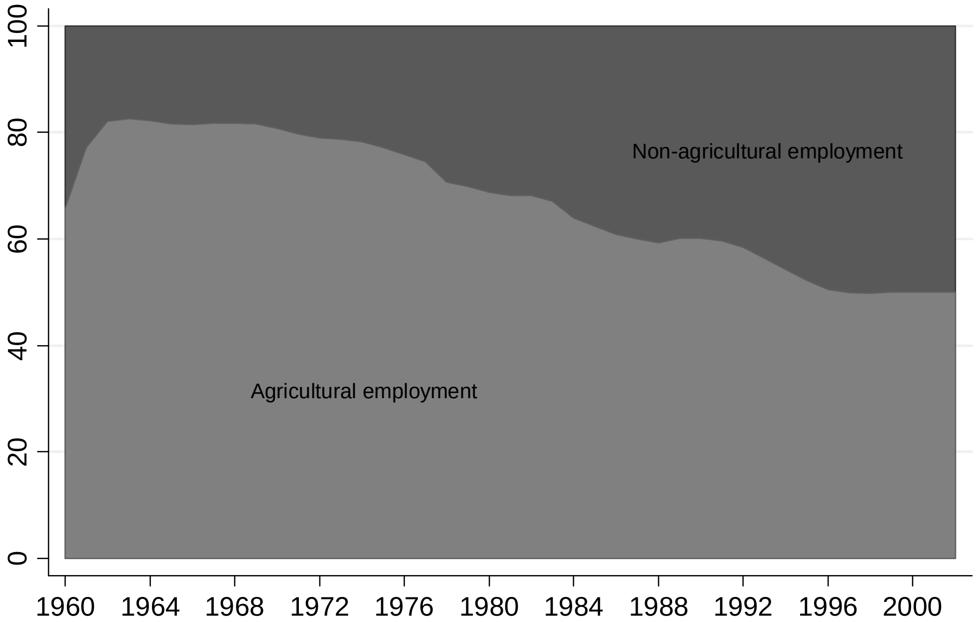
[4] Town-village owned enterprises were first instituted in the early 1980s and their output was formally accounted in the Statistical Yearbooks starting in 1984.

and net rural-to-urban migration. Thus, net labour migration can be derived by deducting the natural population growth from the aggregate population increase in urban areas. Zhang and Song[5] (2003, Table 1, p.388) apply this method and compute the series for rural-urban labour migration in 1978-1999, illustrated in Figure 3. The abrupt drop in labour migration during 1989-1991 may be due to events following the Tiananmen Square incident. Similar patterns of the rural-urban labour migration are observed in the data generated by Wu (1994, Figure 4, p.694).

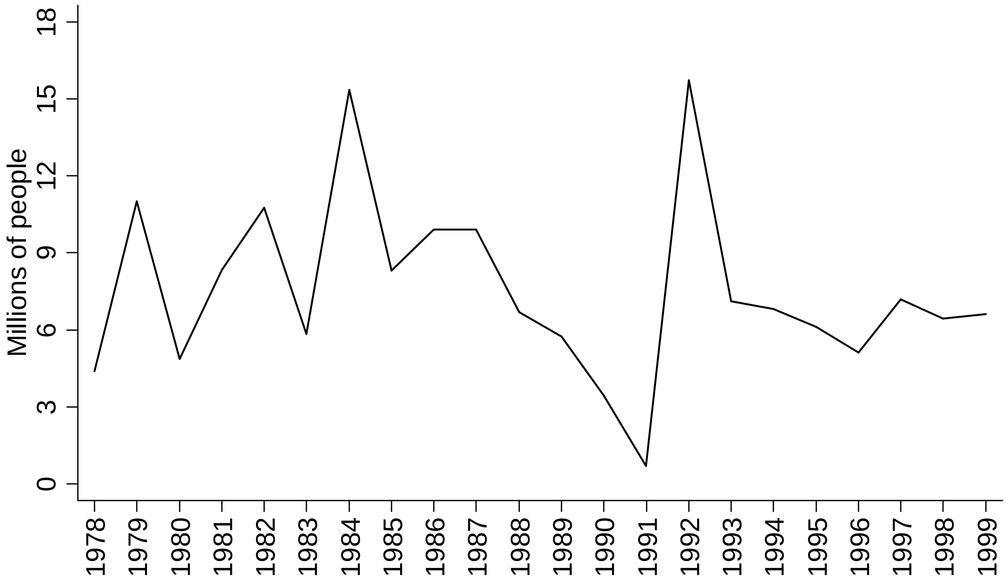
Figure 2: Employment in the two-sectors



Source: China Statistical Yearbook (NBS, 2004).

[5] Zhang and Song (2003) compute the natural growth of urban population as the product of the total urban population and the natural urban population growth rate, which is proxied by the official "natural city growth rates". The data for the natural city growth rates in 1978-1982 and 1988-1999 are sourced from the NBS Statistical Yearbook (2000). For the missing data in 1982-1988, they use a combination of correlations with city growth and projections from the available years.

Figure 3: China's net rural-urban labour migration



Source: Zhang and Song (2003, Table 1, p.388).

4 Model specification

In this section we introduce the specification for the production functions of the two sectors, equations for growth decomposition, and equations for computing the effect of labour reallocation away from agriculture.

4.1 The production functions and growth decompositions

We assume a dualistic economic framework with the agricultural and non-agricultural sectors representing the traditional and modern sectors in the Lewis theory. Accordingly, agricultural output (Q_A) is a function of cultivated hectares (H_A), labour input (L_A) and agricultural capital (K_A). Output of the non-agricultural sector (Q_N) depends on employed labour (L_N) and capital stock (K_N). Both production functions feature Hicks neutral technological progress ($f_A(T)$, $f_N(T)$) where T denotes time; the exact functional form of these contains trends that reflect socio-economic events and possibly dummies for structural shifts. The resulting Cobb-Douglas production functions for the agricultural and non-agricultural sectors are:

$$Q_A = f(L_A, K_A, H_A, T_A) = \alpha_0 e^{f_A(T)} L_A^{\alpha_L} \ H_A^{\alpha_H} \ K_A^{\alpha_K} \quad (1)$$

$$Q_N = g(L_N, K_N, T_N) = \beta_0 \, e^{f_N(T)} L_N^{\beta_L} \ K_N^{\beta_K} \quad (2)$$

By taking logarithms, we derive the log-linear forms in equations (3) and (4). The parameters with a hat "^" are those to be estimated:

$$\ln Q_A = \ln \hat{\alpha}_0 + f_A(T) + \hat{\alpha}_L \ln L_A + \hat{\alpha}_H \ln H_A + \hat{\alpha}_K \ln K_A + e_A \quad (3)$$

$$\ln Q_N = \ln \hat{\beta}_0 + f_B(T) + \hat{\beta}_L \ln L_N + \hat{\beta}_K \ln K_N + e_N \quad (4)$$

We test for, but do not impose, constant returns to scale in each sector by the conditions $\alpha_L + \alpha_H + \alpha_K = 1$ and $\beta_L + \beta_K = 1$. We differentiate functions (3) and (4) with respect to time and obtain the following equations for decomposing sectoral economic growth rates:

$$g_{Q_A} = \tfrac{\partial f_A(T)}{\partial t} + \hat{\alpha}_L \ g_{L_A} + \hat{\alpha}_H \ g_{H_A} + \hat{\alpha}_K \ g_{K_A} \quad (5)$$

$$g_{Q_N} = \tfrac{\partial f_N(T)}{\partial t} + \hat{\beta}_L \ g_{L_N} + \hat{\beta}_K \ g_{K_N} \quad (6)$$

where the exponential growth rates for each factor X is calculated by either the instantaneous percentage growth rate in continuous time, $g_X = \frac{d \log X}{dt} \cdot 100 = \frac{(\log X_{2002} - \log X_{1965})}{(2002-1965)} \cdot 100$, or the true annual (compounded) percentage growth rate in discrete time, $AGR = (\exp g_X - 1) \cdot 100$. In empirical studies, AGR is normally used for representing the exponential growth rate; however, growth theory is usually expressed in continuous time and uses g_X. When growth rates are low, these are close to each other. The time-derivatives with respect to the Hicks-neutral technological chance ($f_A(T)$, $f_N(T)$) are the appropriate time-trend and time-dummy parameters in the estimated models.

4.2 The labour reallocation effect

We apply two approaches to account for the effect of labour reallocation away from the agricultural sector. The first approach is intuitive and closely related to the Lewis-Ranis-Fei model. Theoretically, a net impact of the sectoral labour reallocation is expected due to the relatively low productivity in the agricultural sector and the high productivity in the non-agricultural sector. This indicates that the labour reallocation effect (LRE) may be represented by the product of the difference of labour productivity of the two sectors and the number of migrating labourers. To see its contribution to total output, we divide it by real GDP. Using the average productivities of labour (APL) to proxy for labour productivity, we derive the effect of labour reallocation as:

$$LRE_{APL} = \frac{M}{Y}(APL_N - APL_A) \qquad (7)$$

where M represents the net number of migrating labourers and Y denotes real GDP at 1990 prices.

Within the first approach we can, alternatively, compute the effect of labour migration using the marginal productivity of labour (MPL), which is defined as derivative of output to labour input, i.e. $MPL = \frac{dQ}{dL}$. Hence the MPL in the agricultural and non-agricultural sectors are:

$$MPL_A = \frac{dQ_A}{dL_A} = \hat{\alpha}_L \frac{Q_A}{L_A} = \hat{\alpha}_L \ APL_A \qquad (8)$$

$$MPL_N = \frac{dQ_N}{dL_N} = \hat{\beta}_L \frac{Q_N}{L_N} = \hat{\beta}_L \ APL_N \qquad (9)$$

where $\hat{\alpha}_L$ and $\hat{\beta}_L$ are the estimated parameters in Equations (3) and (4). Thus, the effect of labour reallocation is derived as:

$$LRE_{MPL} = \frac{M}{Y} (MPL_N - MPL_A) \qquad (10)$$

Note that the *LRE* may be slightly underestimated by using *MPL* which represents the slope of production function with respect to labour at the margin, while it may be overestimated using *APL*. Thus, the *LRE* estimates using *MPL* and *APL* provide a reasonable range for the true value of the net impact of labour reallocation.

The second approach is proposed by the World Bank (1996) specifically accounting for the labour reallocation effect. As well as being valid for calculating the effect of labour reallocation away from the agricultural to non-agricultural sector, this approach is also valid for computing the effect of labour reallocation from the state to non-state sector. According to the World Bank, the agricultural labour reallocation effect is defined as following:

$$LRE_{WB} = \frac{L}{Y} (MPL_N - MPL_A)\, g_{l_N}\, l_N \ , \qquad where\ l_N = \frac{L_N}{L} . \qquad (11)$$

This equation shows that a reallocation of labour away from agriculture will have a positive net effect on growth so long as the value of the marginal productivity of labour in the non-agricultural sector exceeds that in the agricultural sector. The size of this effect depends on how much more productive the non-agricultural sector is and on how large the share of labour (l_N) in the non-agricultural sector is (World Bank, 1996, pp.67-68).

In summary, the first approach provides a reasonable band for the true value of the labour reallocation effect. The second approach, independent of the actual number of migrants, is able to give a relatively accurate account for the contribution of sectoral labour reallocation to growth. Both approaches are essentially based on the differences in the labour productivities of the two sectors.

5 The data

Our data are mainly from the World Bank's World Development Indicators (WDI). Data on China's sectoral employment are from China Statistical Yearbooks (2001, 2003, 2004) by China's National Bureau of Statistics (NBS) and the Labour Statistical Yearbook 1998 by China's Ministry of Labour and Social Security (MOLSS). The data span 1965-2002. We cannot start the sample before 1965 because earlier WDI data on fixed gross capital formation are not available. We cannot extend the data beyond 2002 because, even at the time of writing, more recent MOLSS data for "sum of sectoral employment" are not available. Output and capital stock values are in real RMB deflated to 1990 prices. Appendix 1 provides summary statistics and variable descriptions.

Agricultural and non-agricultural outputs are derived from the multiplication of the relative sectoral shares value added in GDP by the real values of GDP. The data for China's employment create a spurious jump in 1990 due to statistical adjustments. To avoid this spurious jump, we source the data for total employment during 1978-2002 from the column entitled the "sum of sectoral employment" in the NBS statistical Yearbook (2001, 2004). The total employment data before 1978 is sourced from the MOLSS Labour Statistical Yearbook (1998). Thus, sectoral employment series are derived by multiplying the total employment data by the sectoral employment shares. Agricultural capital is represented by the number of tractors, which is consistently available for a long time period. Capital stock in the non-agricultural sector is obtained by applying the conventional Perpetual Inventory Method (PIM). Detailed explanation about the data for sectoral employment and capital stock are in Appendix 2.

The data for rural-urban labour migration is taken from Zhang and Song (2003, Table 1, p.388). Note that due to the absence of data for "natural city growth rates" in the NBS Statistical Yearbook after 2000, we can not extend this measure beyond 1999. The unavailability of continuous authoritative data also hampers the forecast that we could make on rural-urban labour migration in China.

Following the work of Ash (1988) we model technological progress in the agricultural sector by two segmented deterministic time trends. The first trend covers 1979 to 1984 and captures the decentralization of farming. The second trend covers 1985 onwards and indicates the introduction of the market system to the rural economy. No technological trend is included before 1979, it is well established that agricultural technological progress was negligible due to destabilising socio-economic events, see Chow (1993). Technological progress in the non-agricultural sector is modelled by a shift dummy for 1965-6 and a time trend from 1982 onwards. Political events surrounding the Cultural Revolution and the Tiananmen Square incident would justify several year dummies for the non-agricultural sector in 1967-1969, 1976 and 1990-1991. However, this would remove almost all dynamics from the model and would necessitate a substantial number of dummies. We therefore opt for the far more parsimonious application of just one structural shift dummy that equals one in 1965-6. In the non-agricultural sector, experimental reform on state-owned enterprises began in August 1980 and this translated into general technological reforms starting in January 1982.

6 Estimates of the production functions

6.1 Stationarity tests

Before estimating the production functions, we test the stationarity of variables using ADF (Dickey and Fuller 1979, 1981) and KPSS (Kwiatkowski et al. 1992) tests. The Augmented Dickey-Fuller (ADF) tests are for the null hypothesis that the series are non-stationary, the KPSS tests are for the null hypothesis that the series are stationary. The results of these tests are reported in Table 1 and they suggest, at the 5 percent significance level, that all the variables are non-stationary and integrated of order one I(1). The one exception is the log of agricultural capital that is borderline integrated of order one or two, $\ln K_A$ ~ I(1/2), but it seems that this ambiguity may be due more to the long cycle in the data rather than it being I(2). Aware of the non-stationarity in the data we take steps to address it in the estimation of the models.

Table 1: Stationarity tests on variables

Var.s	ADF on level	ADF on difference	ADF result	KPSS on level	lag	KPSS on difference	lag	KPSS result
$\ln Q_A$	0.433	-4.877	I(1)	0.734	5	0.160	0	I(1)
$\ln L_A$	-2.377	-3.015	I(1)	0.622	5	0.367	4	I(1)
$\ln K_A$	-1.352	-2.471	I(2)	0.622	5	0.655	4	I(1)/I(2)
$\ln H_A$	-1.219	-4.397	I(1)	0.538	4	0.239	1	I(1)
$\ln Q_N$	0.721	-4.357	I(1)	0.740	5	0.321	6	I(1)
$\ln L_N$	-1.758	-3.214	I(1)	0.727	5	0.376	4	I(1)
$\ln K_N$	-0.033	-4.009	I(1)	0.751	5	0.326	4	I(1)

Notes:

ADF(n): Augmented Dickey-Fuller test with n autoregressive lags. Reported value is t-statistic on lagged levels variable. Null hypothesis is that the variable contains a unit root (is non-stationary). Critical values are: -3.67 at 1%, -2.969 at 5%, -2.617 at 10%.

KPSS: Kwiatkowski et. al. test. Null hypothesis is that the variable does not contain a unit root (is stationary). Optimal lag-length is chosen by the Newey-West (1994) automatic bandwidth selector applied by Hobijn et al. (1998). Critical values are 0.347 at 10%, 0.463 at 5%, 0.739 at 1%.

6.2 Results estimates of the production functions

We run regressions on the data described above to estimate the log-linear production functions in equations (3) and (4). We estimate these production functions[6] by OLS, GLS and Maximum Likelihood (ML) with robust t-tests based White (1984) heteroscedasticity-consistent standard errors. We also estimate the production functions by the Johansen method to address the issue of non-stationarity. Regression results are reported in Tables 2 and 3.

The OLS production function estimates are reported in columns (1) in Tables 2 and 3, and they represent our initial base-cases. The estimated elasticity parameters seem reasonable as do the technological trend parameters. The parameter on agricultural labour, is borderline statistically different from zero. This is exactly as predicted by the Lewis-Ranis-Fei theory insofar as the marginal productivity of labour is close to zero if its elasticity of supply is low, see equation (8). F-tests suggest the both sectors exhibit constant returns to scale. The diagnostics on the residuals highlight two problems not uncommon to time-series regressions. The first is the large degree of residual serial correlation in both sectors and the second is the heteroscedasticity in the non-agricultural production function. The heteroscedasticity has already been accounted for by using the White (1984) heteroscedasticity-consistent standard errors for the t-tests and F-tests. The autocorrelation is accounted for in the GLS and ML estimates that follow.

The GLS and ML estimates reported in columns (2) and (3) respectively of Tables 2 and 3 are for models that accommodate first order autoregression, AR(1), in the structural residuals. Equations (12) and (13) below illustrate how AR(1) in the structural residuals is accommodated by adding a second equation to the production function:

$$\ln Q_t = \hat{\phi}_L \ln L_t + \hat{\phi}_K \ln K_t + ... + u_t \tag{12}$$

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[6] Note that we did estimate the production function in the agricultural sector by involving fertilizer consumption and irrigation but the results suffered from severe multi-collinearity problems. We therefore settled on the parsimonious parameterisation reported in Table 2. Note also that although it has been suggested that the panel estimates could have been carried out using provincial-level data, the data for some variables, for example, agricultural machinery, are not available before 1978 across provinces. In that case, the sample period would not be long enough to test the Lewis theory, nor would it be long enough to identify the stages of economic development in China.

$$u_t = \hat{\rho} u_{t-1} + e_t \qquad (13)$$

where u_t are the structural residuals and et are the non-structural residuals. These equations are valid for both the agricultural and non-agricultural production functions in equations (3) and (4). The GLS estimator is based on the Cochraine-Orcutt (1949) iterative procedure with the Prais-Winstern (1954) transformation to retain the first observation. The ML estimator is based on a unified log-likelihood equation that incorporates equations (12) and (13) into one. The parameter estimates in the GLS and ML estimates are very similar to one another. This indicates that the estimates are robust to the estimation method. We expect that the GLS and ML parameter estimates are slightly better defined than the OLS ones. The only substantial change is an increase in the statistical significance of the dummy for 1965-6 ($D_{1965\text{-}6}$). The structural residuals have significant autoregressive parameters of magnitude 0.492 and 0.482 in agriculture, and 0.467 and 0.455 in non-agriculture. The diagnostics now pass the Breusch-Godfrey AR(1) test suggesting the non-structural residuals are, apart for the heteroscedasticity, white noise. There is evidence of non-normality in the residuals of the non-agricultural production function but this is due to large negative socio-economic shocks associated with 1968, 1976 and 1990.

The presence of non-stationary variables also leads us to test for the presence of cointegration in the estimated production functions. In the spirit of the Engle-Granger (1987) two-step procedure we test, and confirm, the stationarity of the residuals using the ADF test. This therefore confirms that both sets of estimated parameters represent cointegrating vectors. In the second Engle-Granger step we estimate error correction models by using the lagged residuals as error correction terms. The estimated parameters in the error correction terms are -0.832 and -0.877, these indicate relatively fast adjustment speeds in any one year to any disequilibrium in both sectors. For completeness we also run the error correction models, by OLS, on the structural residuals of these equations. The speeds of adjustment are -0.921 and -0.917 in the agricultural sector and -0.877 in the non-agricultural sector, again, suggesting very fast annual speeds of adjustment.

Furthermore, we also estimate the production functions using the Johansen (1991, 1995) cointegration methodology. We normalise the parameters on the logarithm of output (ln*Q*) to equal one[7] so that we can compare the cointegration estimates to those in OLS, GLS and ML. We also restrict the adjustment coefficients on the technological trends to zero[8] so that these trends are not interpreted as dependent variables in the error correction equations. Note that the sample period in the non-agricultural sector has been restricted to 1969-2002 in order to avoid the large structural shift in 1965-6, this is why the sample size in column (4) in Table 3 is only 34 years. In both sectors two cointegrating vectors are identified at the five percent significance level but we restrict the estimates to one cointegrating vector in each case to maintain comparability with the previous estimates. From columns (4) in Table 2 and Table 3 we see that the parameter estimates are similar to those under OLS, GLS and ML. Both tests strongly reject the null hypotheses of constant returns to scale, setting them apart from the tests under OLS, GLS and ML. The diagnostics on the non-structural residuals for the error correction equation with respect to changes in the log of output (ln*Q*) in both sectors seem to suggest no autocorrelation, homoscedasticity and normality. The one exception is the presence of further autocorrelation in the agricultural sector with a LM test statistic of 54.03. The estimated annual speeds of adjustment in both sectors are still quite fast at -0.967 and -0.912 in the agricultural and non-agricultural sectors respectively.

All these results are consistent with each other within each sector. All estimates seem reasonable with most diagnostic tests being passed. The only potentially problematic case is the test for residual autocorrelation in the Johansen estimates for the agricultural sector. Given all the structural parameter estimates are so similar, within each sector, the growth decomposition analysis and other analyses could equally well be carried out with any set of parameter estimates. We therefore opt to use the ML estimates for the analyses that follow, as these estimates represent the most parsimonious model estimates that satisfy all the diagnostic tests.

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[7] Technically, this restriction is defined as β (1,1) = 1 in the standard Johansen notation.

[8] Technically, these restrictions are defined as α (5,1)=0 and α (6,1)=0 in the agricultural estimates and as α (4,1)=0 in the non-agricultural estimates.

Table 2: Agricultural production function estimates

Dependent variable: lnQ_A	(1)	(2)	(3)	(4)
Estimation method:	OLS	GLS	ML	Johansen
Variables:		AR(1)	AR(1)	(lags 1)
lnL_A	0.191	0.188	0.189	0.133
	(1.35)	(0.91)	(0.90)	(1.09)
lnK_A	0.078**	0.080**	0.080**	0.096**
	(5.10)	(3.55)	(3.65)	(9.91)
lnH_A	0.661**	0.551**	0.554**	0.455**
	(5.18)	(4.30)	(2.78)	(2.88)
$T_{1979-84}$	0.064**	0.064**	0.064**	0.086**
	(15.93)	(9.19)	(9.47)	(18.79)
T_{1985}	0.043**	0.043**	0.043**	0.041**
	(39.30)	(24.54)	(25.59)	(46.46)
Constant	9.384**	11.410**	11.340*	13.972
	(2.78)	(2.75)	(2.33)	n.a.
AR(1)		0.492**	0.482**	
		(3.34)	(3.22)	
Observations	38	38	38	36
R^2	0.9960	0.9997		
Constant returns to scale test	F = 0.17	F = 0.73	$\chi2$ = 0.49	$\chi2$ = 48.60
	[0.69]	[0.40]	[0.48]	[0.00]
Non-structural residual (et) diagnostics:				
Breusch-Godfrey LM $\chi2$ test	8.77	1.45	1.53	54.03
	[0.00]	[0.23]	[0.22]	[0.03]
White heteroscedasticity $\chi2$ test	13.82	8.16	8.44	16.96
	[0.18]	[0.61]	[0.59]	[0.15]
Jarque-Bera normality $\chi2$ test	1.14	3.79	3.46	1.93
	[0.57]	[0.15]	[0.18]	[0.38]
Ramsey Reset F test	0.50	0.28	0.28	
	[0.49]	[0.60]	[0.60]	
Structural residual (ut) diagnostics:				
ADF [5% critical value is -3.17]	-4.026	-3.887	-3.893	
Error Correction Term (ut-1)	-0.832**	-0.921**	-0.917**	-0.967**
	(-3.74)	(-4.08)	(-4.07)	(-6.50)

Notes:

(Parentheses) around t statistics, * significant at 5%; ** significant at 1%. OLS, GLS and ML estimates of t statistics are based on the White (1984) robust covariance estimator.

[Square] brackets represent densities in the tail of each distribution for rejection of the respective null hypotheses.

Johansen estimates are restricted to one cointegrating vector although rank tests suggest two cointegrating vectors are present: for maximum rank 2, parameters are 62, trace statistic is 39.06, 5% critical value is 47.21.

Table 3: Non-agricultural production function estimates

Dependent variable: lnQ_N	(1)	(2)	(3)	(4)
Estimation method:	OLS	GLS	ML	Johansen
Variables:		AR(1)	AR(1)	(lags 1)
lnL_N	0.679**	0.704**	0.703**	0.766**
	(11.79)	(9.32)	(10.07)	(10.78)
lnK_N	0.324**	0.314**	0.314**	0.231**
	(5.32)	(4.91)	(5.87)	(5.11)
T_{1982}	0.048**	0.048**	0.048**	0.053**
	(10.78)	(10.03)	(10.74)	(21.06)
D_{1965-6}	0.112	0.131*	0.131*	
	(1.91)	(2.58)	(2.40)	
Constant	5.200**	5.018**	5.025**	6.142
	(5.62)	(4.80)	(4.69)	n.a.
AR(1)		0.467**	0.455**	
		(3.13)	(2.11)	
Observations	38	38	38	34
R^2	0.9985	0.9991		
Constant Returns to Scale test	F = 0.01	F = 0.16	$\chi 2$ = 0.12	$\chi 2$ = 13.64
	[0.92]	[0.69]	[0.73]	[0.00]
Non-structural residual (et) diagnostics:				
Breusch-Godfrey LM $\chi 2$ test	7.51	0.75	0.94	16.51
	[0.01]	[0.38]	[0.33]	[0.42]
White heteroscedasticity $\chi 2$ test	15.43	16.09	16.41	91.11
	[0.03]	[0.02]	[0.02]	[0.45]
Jarque-Bera normality $\chi 2$ test	17.27	12.93	14.35	7.01
	[0.00]	[0.00]	[0.00]	[0.63]
Ramsey Reset F test	0.04	0.04	0.04	
	[0.85]	[0.85]	[0.85]	
Structural residual (ut) diagnostics:				
ADF [5% critical value is -3.17]	-4.178	-3.827	-3.840	
Error Correction Term (ut-1)	-0.877**	-0.877**	-0.877**	-0.912**
	(-4.56)	(-4.55)	(-4.55)	(-5.34)

Notes are the same as for Table 2.

Johansen estimates are restricted to one cointegrating vector although rank tests suggest two cointegrating vectors are present: for maximum rank 2, parameters are 32, trace statistic is 12.22, 5% critical value is 15.41.

7 Empirical analysis on sectoral growth

7.1 Sources of China's dual-sector economic growth

We apply equations (5) and (6)[9] to decompose China's sectoral economic growth and display the results in Table 4. We find that the 4.86 percent exponential annual growth rate of labour in the non-agricultural sector is much higher than the 0.84 percent rate of the agricultural labour. Capital inputs in both sectors rise rapidly, 10.81 percent in the non-agricultural sector and 8.12 percent in the agricultural sector. Agricultural land, however, remains relatively constant, shrinking by an annual mean of just 0.31 percent during 1965-2002. Additionally, the 6.859 or 7.132 percent annual economic growth in the non-agricultural sector is over nine times larger than that of the agricultural sector at 0.744 when measured by instantaneous growth rates, or 0.770 percent when measured by annually compounded growth rates. This implies that economic growth is mainly driven by the expansion of the non-agricultural sector, as suggested by the Lewis theory. Moreover, we find that growth in the non-agricultural sector is predominated by capital accumulation at 49.49 to 50.26 percent, while labour contributes nearly as much as capital does. In both sectors, technological progress, despite being statistically significant in the estimation, only accounts for a relatively small share of economic growth. This finding is in contrast with that by Ho (1972), who finds that agricultural growth in Taiwan depended mainly on fast technical change during 1951-1965. In summary, consistent with the Lewis-Ranis-Fei theory, China's economic growth is driven by the rapid expansion of the non-agricultural sector, which is mainly affected by capital accumulation as well as employment growth fuelled by sectoral labour reallocation.

[9] In the literature, growth accounting is often applied to decompose economic growth. However, it is well established that growth accounting has many drawbacks. For example, it treats the contribution other than that by factor input as the total factor productivity. It thereby can not distinguish the pure effect of technological progress on growth. In addition, the result is subject to the input shares assigned. In this paper, we carefully estimate the input elasticity and decompose economic growth by factor contributions. Chow and Li (2002) and Ho (1972) have used this approach to decompose economic growth in their studies.

Table 4: Dual-sector growth decomposition (1965-2002)

	Parameter estimates	Instantaneous annual growth rate* [or AGR**]	Product of parameter and growth	Contribution to sectoral growth
	(1)	(2)	(3)	(4)
Agricultural sector:				
Labour	0.189	0.84% [0.84%]	0.159 [0.159]	21.35% [20.65%]
Capital	0.080	8.12% [8.45%]	0.650 [0.676]	87.36% [87.79%]
Land	0.554	-0.31% [-0.31%]	-0.172 [-0.172]	-23.10% [-22.34%]
$T_{1979\text{-}1984}$	0.064		0.064	8.61% [8.31%]
T_{1985}	0.043		0.043	5.78% [5.58%]
Total			0.744 [0.770]	100%
Non-Agricultural sector:				
Labour	0.703	4.86% [4.98%]	3.417 [3.500]	49.81% [49.07%]
Capital	0.314	10.81% [11.42%]	3.394 [3.584]	49.49% [50.26%]
T_{1982}	0.048		0.048	0.70% [0.70%]
Total			6.859 [7.132]	100%

Column notes: (1) The coefficients are from the estimated results by the ML method for both sectors and are taken from column (3) in Tables 2 and 3.

(2):*Instantaneous annual growth rates in column (2) are derived by $gX = [(\ln X_{2002}-\ln X_{1965})/(2002-1965)]*100$.

**AGR, annual compound growth rate, derived by AGR=(exp g_X -1)*100, values given in square brackets.

(3) The value is simply the product of the value in columns (1) and (2).

(4) The contribution to sectoral growth calculated as the corresponding value in column (3) divided by the respective Total for column (3) in each sector.

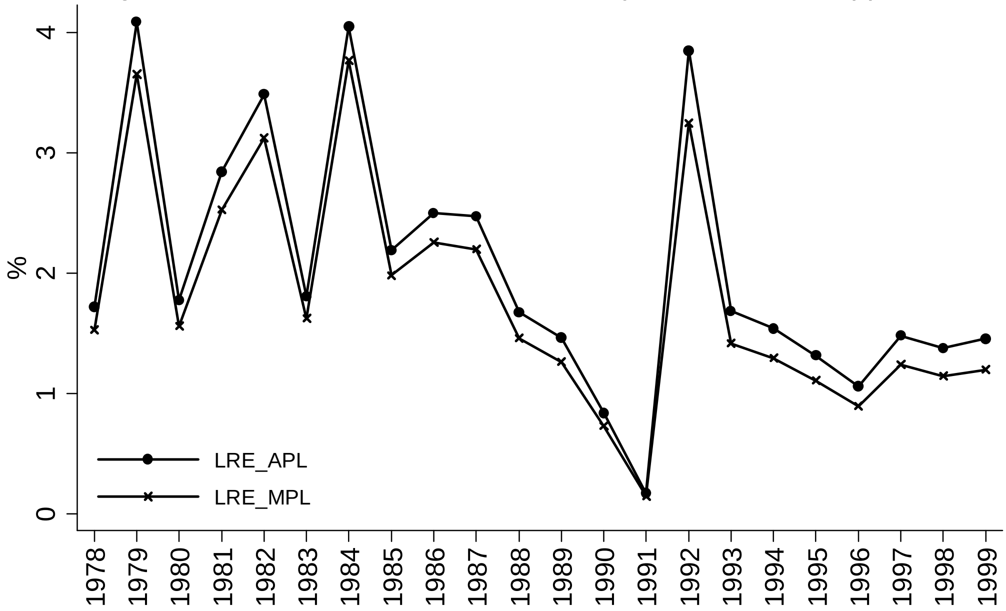
7.2 The contribution of sectoral labour reallocation

To calculate the contribution of agricultural to non-agricultural labour reallocation we firstly apply equations (7) and (10) to calculate the effect. As illustrated in Figure 4, the estimates by the APL (LREAPL) and MPL (LREMPL) methods comprise a range of the labour reallocation effect. By taking averages, we find that sectoral labour reallocation has accounted for 1.78-2.03 percent of economic growth, amounting to approximately 30-35 billion RMB Yuan to China's real GDP in 1978-1999.

We then apply equation (11) to account for the sectoral labour reallocation effect (LREWB) suggested by the World Bank (1996) approach. This approach is independent of the data for migrant labourers and able to show the contribution of sectoral labour reallocation over a longer time period. As shown in Figure 5, the reallocation of labour away from agriculture has positively affected China's economic growth during 1965-2002, except for a few years like 1967-1968 and 1989-1990 due to the disturbance of some social-economic events. The computed effect of sectoral labour reallocation contributes to economic growth by 1.23 percent on average in the period 1965-2002. This finding is consistent with many studies. For example, the World Bank (1996) found that the effect of labour reallocation away from agriculture accounted for 1 percent of China's rapid economic growth during 1985-1994. Cai and Wang (1999) reported the 1.62 percent contribution of sectoral labour reallocation to growth in 1982-1997, while Woo (1998) suggested the 1.3 percent contribution to growth in 1985-1993.

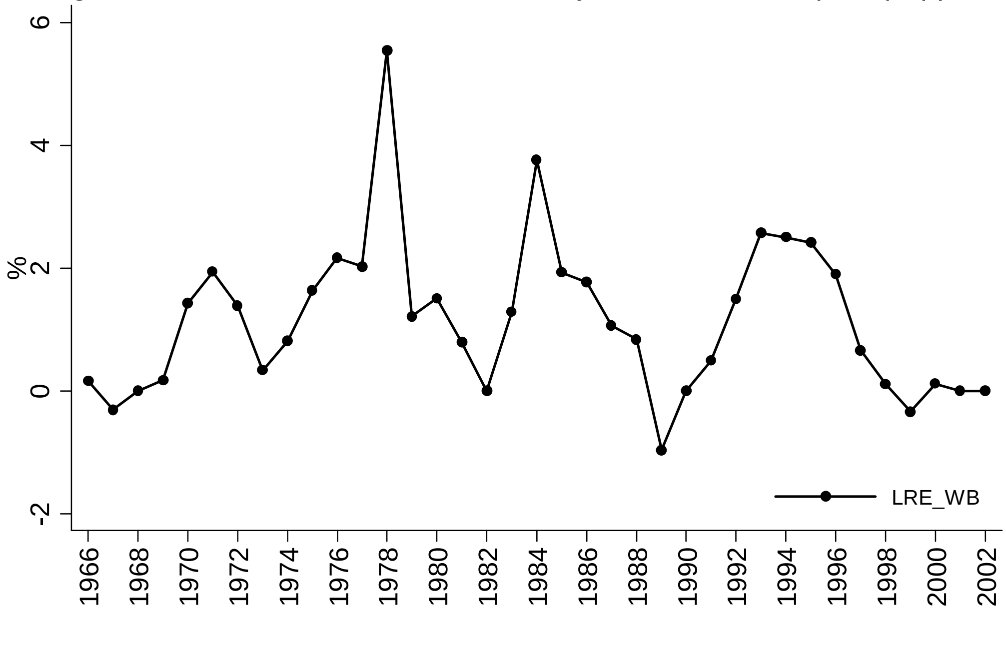
Additionally, in Figures 4 and 5, we also find that the contribution of sectoral labour reallocation achieved its highest value, around 2.01 percent, during 1978-1984. This is closely associated with the boom of the town-village enterprises which has effectively absorbed large amounts of rural surplus labourers (Knight, 2007). However, since 1993, the effect of labour reallocation has declined significantly to approximately 0.82 percent. This implies that the absorption of rural labour in the non-agriculture sector has fallen. This finding is supported by Kuijs and Wang (2005), who also detected the slow-down of the sectoral labour reallocation in the mid-1990s. They argue that the growth of urban employment has declined to 2.9 percent in 1993-2004 from 5.2 percent in 1978-1993. This is attributable to the demise of town-village enterprises and the fairly stable share of industry employment in that period. As a result, the slow-down of labour reallocation away from agriculture has largely hampered improvement in agricultural productivity. To conclude, we find that the reallocation of labour away from agriculture has made a great contribution to China's economic growth. This finding too accords with the core of the Lewis-Ranis-Fei theory.

Figure 4: The labour reallocation effect by APL and MPL approaches



Source: Author's calculations.

Figure 5: The labour reallocation effect by the World Bank (1996) approach

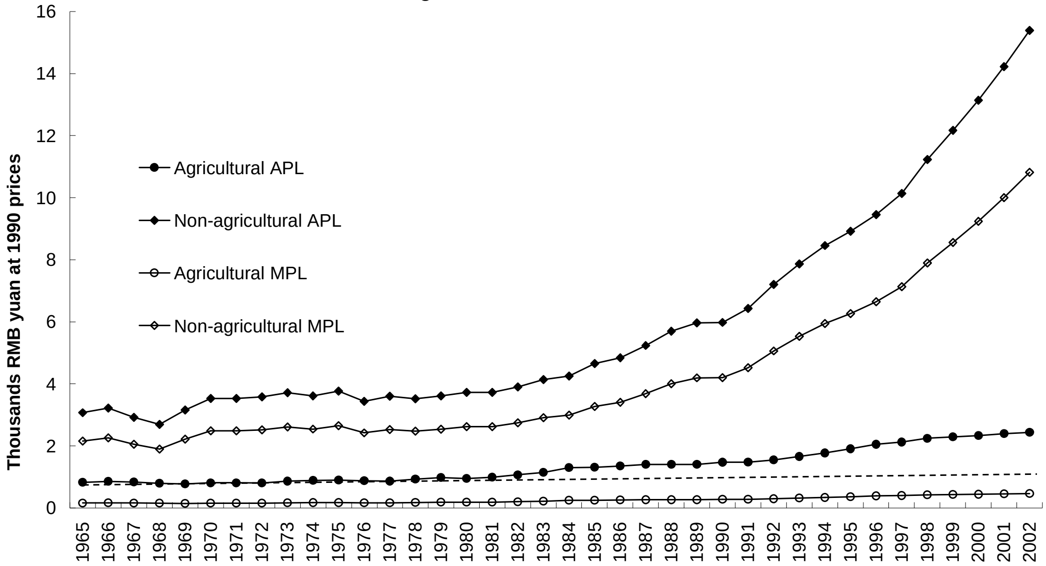


Source: Author's calculations.

7.3 Phases in China's economic development and the turning points

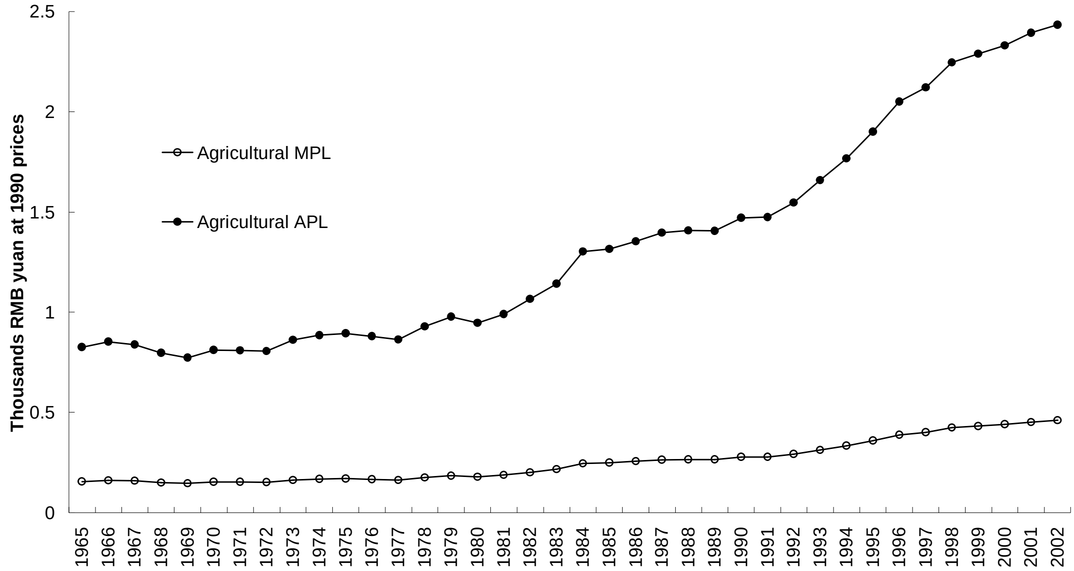
Based on the estimated elasticities of output to labour, we compute the marginal productivities of labour (MPL) in the agricultural and non-agricultural sectors respectively using equations (8) and (9). The series for MPL and APL are illustrated in Figure 6. Figure 7 shows the values for MPL in APL for the agricultural sector on its own. It is obvious that in both sectors, both the marginal and average productivities of labour are stagnant before the 1978 Economic Reform and then rise rapidly, particularly in the non-agricultural sector.

Figure 6: APLs and MPLs



Source: Author's calculations.
Note: the dashed line shows the initial low agricultural average productivity of labour.

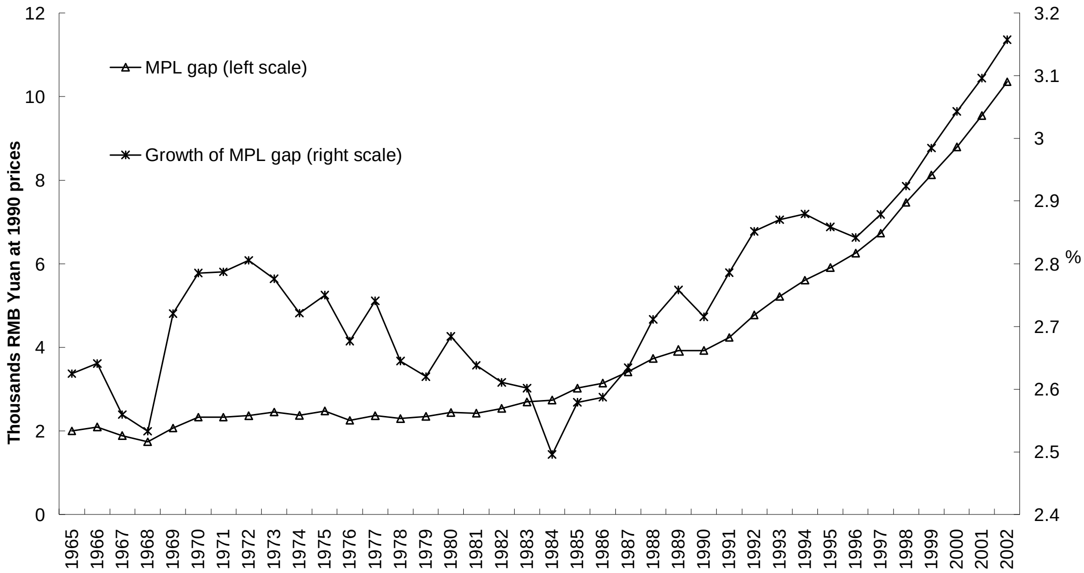
Figure 7: Agricultural MPL and APL



Source: Author's calculations.

We identify the phases in China's economic development using the marginal productivity of labour in the agricultural sector, as suggested by Minami (1967a). In the Ranis-Fei model, an economy is regarded as entering phase two of economic development if the agricultural MPL starts to increase but is still lower than the institutional wage represented by the initial low agricultural APL. As revealed in Figure 7, the agricultural MPL is very low before 1978 but begins to rise rapidly after the 1978 Economic Reform. The rising trend in agricultural MPL indicates that the redundant labour has been reallocated away from agriculture. On the other hand, the rising agricultural MPL is found to be still lower than the initial low agricultural APL before the Reform, denoted by the dashed line in Figure 6. This implies that the disguised agricultural unemployment has not been completely reallocated. Neither has the agricultural labour market been commercialised. Thus we conclude that, since the 1978 Economic Reform, the Chinese economy has passed the shortage point (see Diagram 1) and progressed into phase two of economic growth. Nonetheless, China has not completed its take-off yet because the surplus labour still exists.

Figure 8: The MPL gap



Source: Author's calculations.

Furthermore, we find that the productivity gap between the agricultural and non-agricultural sectors, for example in terms of MPL displayed in Figure 8, is high and increasing since the mid-1990s. This finding is confirmed by Kuijs and Wang (2005), who argue that the increasing productivity gap is attributable to two possible reasons. Firstly, the growth of agricultural productivity is hindered by the slower reallocation of labour away from agriculture in the mid-1990s. Secondly, during 1993-2004, industry productivity grew very rapidly. This rapid growth is driven by the substantial increase in capital investment rather than employment growth.

8 Conclusion and policy recommendations

Having tested the Lewis-Ranis-Fei theory for the Chinese economy over 1965-2002 we have found that China's economic growth is mainly attributable to the development of the non-agricultural sector. This is driven by rapid capital accumulation as well as employment growth. The reallocation of labour away from agriculture has made a positive net contribution to China's rapid economic growth by around 1.23 percent. The rise in the marginal productivity of agricultural labour indicates the absorption of redundant agricultural labour since the 1978 Economic Reform. However, the marginal productivity of agricultural labour is still lower than the initial low average productivity of agricultural labour. This implies the continued existence of disguised agricultural unemployment. This suggests that the Chinese economy has entered the Lewis-Ranis-Fei phase two of development but has not yet achieved phase three. The continuing widening productivity gap between the two sectors calls for the removal of market restrictions and government interventions so as to allow the continued absorption of surplus labour.

Several policy recommendations are tentatively suggested. First and foremost, more effort should be made in promoting employment to effectively absorb the remaining labour surplus and promote China's economic development. This can be achieved by further relaxing the Hukou restrictions on migration, increasing labour market flexibility and improving the allocative efficiency of labour. It can also be achieved by encouraging the development of private enterprise to create more employment opportunities. Second, China's government should continue implementing the Sunshine Policy, initiated in 2003, designed to provide rudimentary job training, recruitment information and information about conditions in the destination cities to rural migrants. This will not only help facilitate employment of rural migrants but also satisfy the increasing demand for skilled labour in the growing non-agricultural sector. Third, agriculture could be promoted by tax breaks, direct subsidies and most importantly, by removing price controls on agricultural products. Agriculture could thus be commercialised and the economy would enter phase three of economic development.

Appendix 1: Summary statistics

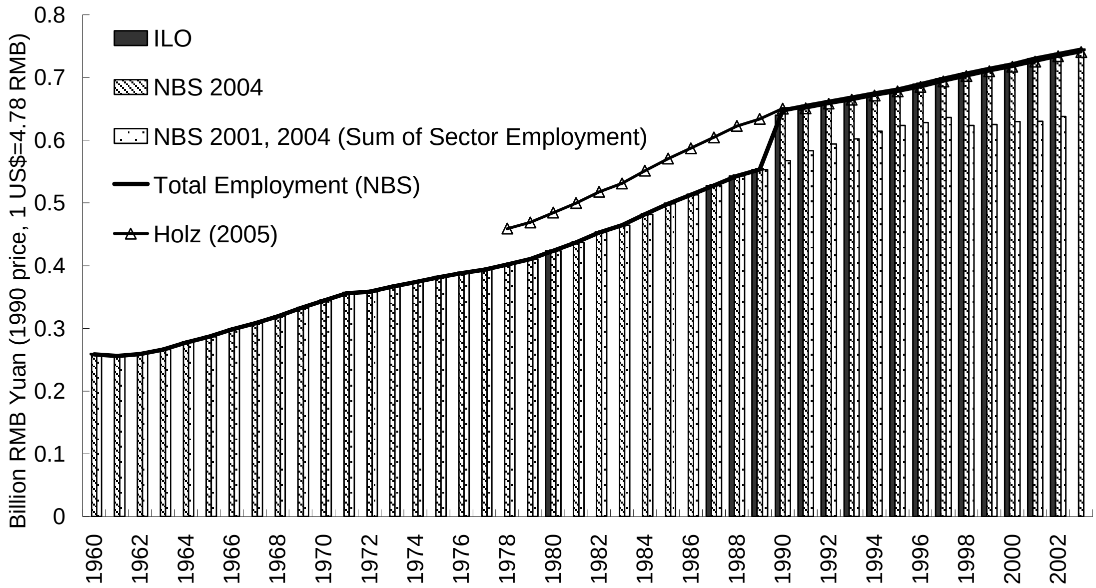
Variables	Mean	Min	Max	Description:
Q_A	4.14×10^{11}	1.93×10^{11}	7.76×10^{11}	Agricultural output: in RMB Yuan at constant 1990 prices.
L_A	3.02×10^{8}	2.34×10^{8}	3.48×10^{8}	Agricultural labour: total workers.
K_A	586648	45929	926031	Agricultural capital: total number of tractors.
H_A	9.24×10^{7}	8.18×10^{7}	9.86×10^{7}	Agricultural land: hectares under cereal production.
$T_{1979\text{-}84}$	3.39	0	6	Agricultural technological trend: trend starts in 1979 and stops increasing in 1984, equals zero before 1979.
T_{1985}	4.5	0	18	Agricultural technological trend: trend starts in 1985, equals zero before 1985
Q_N	1.35×10^{12}	1.58×10^{11}	4.91×10^{12}	Non-agricultural output: in RMB Yuan at constant 1990 prices.
L_N	1.77×10^{8}	5.28×10^{7}	3.19×10^{8}	Non-agricultural labour: total workers.
K_N	2.71×10^{12}	1.91×10^{11}	1.04×10^{13}	Non-agricultural capital: calculated by the perpetual inventory method, 1990 prices.
$D_{1965\text{-}6}$	0.05	0	1	Pre-Cultural Revolution dummy: equals one in 1965 and 1966, zero otherwise.
T_{1982}	6.08	0	21	Non-agricultural technological trend: trend starts in 1982, equals zero before 1982.

Appendix 2: China's sectoral employment and capital stock

A. China's sectoral employment

There are no direct data for China's sectoral employment in the WDI as it only provides percentages for China's sectoral employment in 1980 and 1987-2000. Though data for sectoral and total employment are available in the Statistical Yearbooks of the NBS and MOLSS, we notice an unrealistic jump in 1990 as illustrated in Figure 6. This jump is also observed in the WDI, whose data are based on the ILO. When investigating this jump, we found the following paragraph in the Population paper of the 2003 NBS Statistical Yearbook Instructions: "Data before 1982 were taken from the annual reports of the Ministry of Public Security. Data in 1982-1989 were adjusted on the basis of the 1990 national population censuses. Data in 1990-2000 were adjusted on the basis of the estimated on the basis of the 2000 national population censuses. Data in 2001 and 2002 have been estimated on the basis of the annual national sample surveys on population changes."

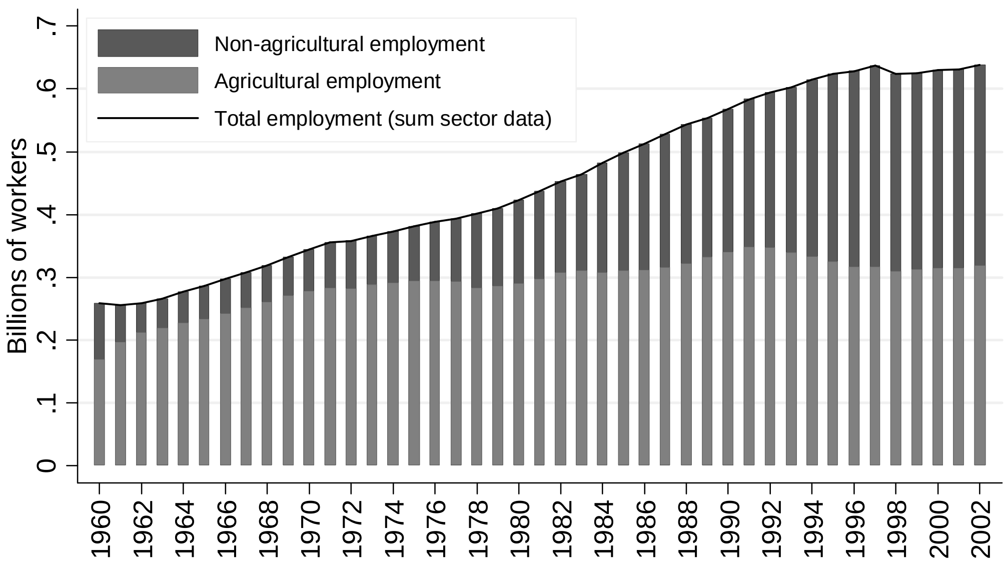
Figure A1: Total employment, various sources



We therefore suspect that the data for total employment in 1990-2000 are adjusted on the basis of population statistics. This is confirmed by Chow (2006) who attributes the jump to possible revisions in data collection methods, especially the change in the component of primary industry in China. This adjustment in total employment is also reflected in the sectoral employment and it would create the occurrence of a spurious structural break in estimated models. Holz (2005a) resolved this spurious jump in total employment by comparing various datasets for 1978-2003. These include total employment data in the Statistical Yearbooks (2001, 2004), four population censuses, three surveys and "sum sector employment" data. Holz computed a new data set known as the "final mid-year series" on the basis of these comparisons. Holz's new data, also illustrated in Figure A1, is smoother but displays much higher values than other data sets. We therefore build on Holz's approach but go on to derive our own data.

We derive China's sectoral employment data by multiplying the "sum of sectoral employment" by the percentages of sectoral employment. The data for the "sum of sectoral employment" during 1978-2002 displayed by Holz (2005a, Table 7) are taken from the paper version of the NBS Statistical Yearbook (2001, 2004) without the presence of the spurious jump in 1990. The data before 1978 are taken from the MOLSS Labour Statistical Yearbook (1998). The percentages of sectoral employment are from the NBS Statistical Yearbook (2003). Figure A2 illustrates the data we compute for sectoral employment. Despite the restriction on our time span due to this derivation, the spurious jump in 1990 does not occur using this approach.

Figure A2: China's dual-sector employment

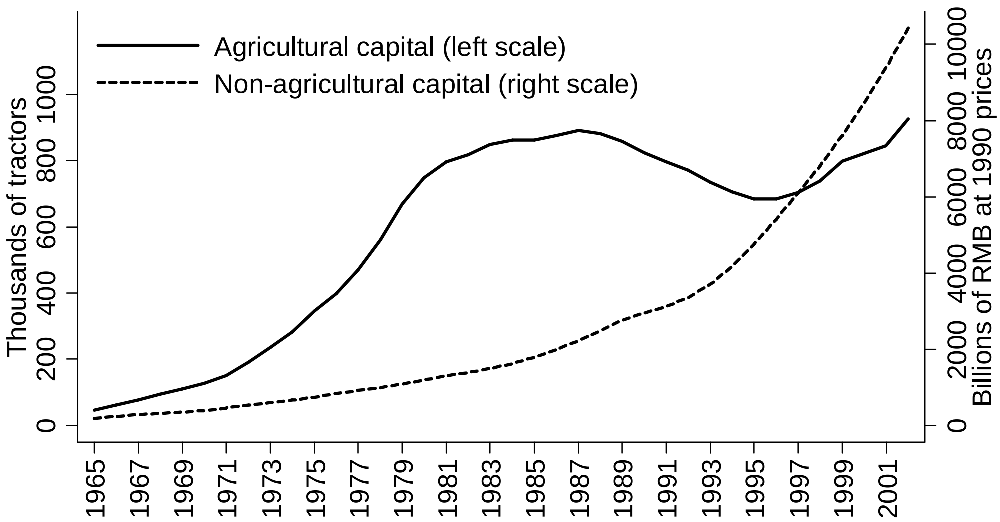


Source: Author's calculations based on the data from China Statistical Yearbooks (NBS, 2001, 2003, 2004); Labour Statistical Yearbook (MOLSS, 1998).

B. China's capital stock

To generate China's agricultural capital stock series we use data on the number of tractors. These values are taken from the World Bank's WDI and are illustrated in Figure B1. The original data has two abrupt jumps that occur in 1970 and 2000 when the measure is re-defined. We create a smoothed series purely by removing these two artificial jumps and not by smoothing the other observations in order not to induce additional serial correlation. Agricultural capital could also have been represented by fixed investment in monetary values. However, the data for fixed investment in agricultural sector is only available since 1985 in the NBS Statistical Yearbook 1996. An additional problem with this measure is that it includes the value of inventories in the agricultural sector. We therefore opt to use the number of tractors to proxy agricultural capital; this allows us to trace consistent data for a relatively long time period starting in 1965.

Figure B1: Capital stock



Source: Agricultural capital is from World Development Indicators (World Bank, 2005). Non-agricultural capital is author's calculation, based on World Development Indicators (World Bank, 2005), Holz (2006), and Penn World Tables 6.1 (Heston et al., 2002).

To generate China's non-agricultural capital stock series we use data on the investment share of GDP from the Penn World Tables (PWT) 6.1 (Heston et al., 2002). There are no authoritative capital stock data for China and many economists generate their own series. For example, Chow (1993) estimates the series of capital stock for five sectors in 1952-1985 by accumulating "net capital of fixed and circulating assets in three types of enterprises" recorded in China Statistical Yearbooks. Despite the long time span, the capital stock calculated by this accumulation method has been criticized for the inclusion of inventories and depreciated capital. Chow and Li (2002) estimate the capital stock for 1952-1998 by aggregating net investment to an initial capital stock of 221,300 million in 1952, which is derived in Chow's (1993) paper. They calculate the capital stock to be 1,411,200 million RMB Yuan in 1978. They then apply the Perpetual Inventory Method (PIM) to calculate capital stock after 1978 with an assumed depreciation rate of 5.4 percent. The capital stock series in Chow and Li (2002) has also been criticized for the inclusion of inventories. Holz's (2005b) series for China's capital stock has been criticized for using scrap rates instead of capital depreciation rates.

Felipe and Fan (2008) construct a capital stock series for 1978-2003 by applying the PIM method with a 5 percent depreciation rate. In our view this 5 percent depreciation rate is probably too low for China, especially compared to the 7 percent world average depreciation rate. Our supposition is confirmed by Holz (2006, Table 2) who finds that China's depreciation rates were very high and varied between 9.6 and 15.9 percent during 1978-2003.

We borrow ideas from all of the above and construct our capital stock series by the PIM method but with a specifically computed value of initial capital stock using the method of King and Levine (1994). This method is widely cited and applied by many economists like Liman and Miller (2004). The corresponding formulae for calculating initial capital stock are as follows:

$$K_0 = \kappa Y_0 \qquad \text{(B1)}$$

$$\kappa = \frac{i}{\delta + \underline{\gamma_j}}, \text{ where } i = \frac{I}{Y} \qquad \text{(B2)}$$

$$\underline{\gamma_j} = \lambda\, \gamma_j + (1-\lambda)\, \gamma_w \qquad \text{(B3)}$$

where κ is the capital-output ratio assumed to be constant over time, *i* is the investment share of output, $\underline{\gamma_j}$ is the weighted average growth rate of a country j, γ_w is the world growth rate over the last thirty years which is approximately 4 percent according to King and Levine (1994), γ_j is the growth rate of country j, λ is a weight parameter which equals 0.25 according to Easterly et al. (1993). Considering the aforementioned high depreciation ratios of the capital stock in China found by Holz (2006), we assign 10 percent to the depreciation rate δ. China's growth rate γ_j in the 1960s is taken from the WDI and averaged to $\gamma_j = 13.255\%$. The value of investment share in 1965 is unavailable from the WDI but available from the PWT at $i = 10.22\%$. By substituting the corresponding values into equations (B2) and (B3), we compute the capital-output ratio for China to be $\kappa = 0.639$. Multiplying the capital-output ratio by the GDP value of China in 1965 obtained from the WDI, we set the initial value of the capital stock in

1965 to be 19,0916,213,235.342 RMB Yuan at 1990 prices, accounting for 63.9 percent of GDP. Given the computed initial value of capital stock, it is easy to generate a series of capital stock in 1965-2004 by the PIM formula $K_t = I_{t-1} + (1-\delta)\,K_{t-1}$. In this formula, investment It is represented by gross fixed capital formation available in the WDI, which excludes the values of inventories. Therefore our series of capital stock addresses previous criticisms on the depreciation ratio, initial capital stock and the computation method. Figure B1 provides an illustration of the resulting capital stock series.

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