Writing Sample

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This chapter was excerpted from my master's dissertation in the Faculty of Education at Beijing Normal University, titled *A China Perspective on the Role of Education in Economic Growth*. The original text was written in Chinese.

The chapter examines the unique situation China faced after the Reform and Opening Up, where the economy could be divided into two sectors: traditional agriculture with a large number of accumulated laborers and modern industry. What was unique was the recognition of human capital's importance at that time, along with the wider technological gap between the two sectors compared to that of the Industrial Revolution. Therefore, education became a threshold to get into the modern industry sector.

Initially, the chapter develops a model to represent this scenario. Subsequently, it empirically validates the marginal condition inferred from the model using data from China spanning 1996 to 2014. Finally, the chapter offers policy implications based on the findings.

1 A two-sector model with education threshold

1.1 Model Setting

Suppose that there are two sectors in the economy, namely traditional agriculture and modern industry. The traditional agriculture has two inputs, land, and labor, and is unaffected by technological progress. The modern industry inputs two factors, material capital, and human capital, and is affected by technological progress. Hence, the production functions for the two sectors are

$$Y_1 = \mathrm{G}(L_1)$$
$$Y_2 = A\mathrm{F}(K, H_2)$$

where Y_1 and Y_2 represent the output of agriculture and industry, respectively; L_1 represents the amount of labor input in the agriculture; A symbolizes the technology level; and K denotes the stock of material capital. H_2 represents the amount of human capital input in the modern industry, defined as the product of skill level h (to be defined later) and the amount of labor invested in the modern industry L_2. L_2 satisfies $L_1 + L_2 = L$, where L is the total population. G and F are production functions that exhibit diminishing marginal returns.

In today's modern agricultural production, heavy machinery and intelligent control systems are employed. Therefore, caution is warranted, similar to Lewis' s approach: no economy can be unequivocally divided into two sectors; the term "traditional" is used here to denote a less developed industry. The final goods symbol Y is used in both sectors, meaning the outputs of both sectors are completely substituted. When a specific agricultural unit improves its technology and capital use, it is thought to break away from the traditional production and enter the modern industry. This assumption can be troublesome when using aggregated real-world data since it is impossible to separate the advanced and backward parts effectively. However, in the theoretical model, this setting is feasible.

Li and Jin (2003)[12] pointed out in a study of traditional agriculture in China that the efficiency improvement of traditional agriculture in China reached its peak in the Tang Dynasty, followed by a decline, and the technology used remained at the personal experience level. Hu (2014) [1] pointed out that after the founding of the PRC, the application of irrigation technology has improved agricultural productivity to a certain extent, but there has been some negative growth after 1957. After the reform and opening up, Li Xiannian, Vice Premier of the State Council, mentioned that China's per capita grain share was only slightly higher than that in 1957. It is thus reasonable to assume that in the traditional agriculture, production efficiency has reached extreme value. Therefore, in the traditional agriculture, the efficiency factor can be absorbed by the production function G as a constant.

The reason for not considering human capital in agriculture is apparent. Excess skill levels are useless. In a typical traditional agricultural scenario, workers provide primarily manual labor, and the knowledge they need comes from word of mouth, known as "personal experience technology". A report in China Education News [9], citing data from the National Bureau of Statistics, pointed out that in 2016, only 1.2% of agricultural production and operation personnel had a junior college degree or above, the highest proportion had a junior high school degree or below. Only 4.93% of rural residents had basic scientific quality in 2018, far below the national average of 8.47%.

As for the use of material capital, research [5] by the Rural Research Department of the State Council shows that before the founding of the PRC, real estate accounted for 75% of the average total assets of farmers, while the means of production mainly included livestock and agricultural tools, accounting for only about 2% of the total assets, and another 15% of the asset existed in monetary form. A study by Jiao and Dong (2018) [13] pointed out that the development of agricultural mechanization in China has achieved preliminary developments after the founding of the PRC, but after the reform and opening up, it has experienced an impact, the level has declined, and the growth rate is slow. Therefore, it is reasonable to assume that K accounts for a relatively low and constant proportion in the traditional agriculture.

Land is generally considered unchanged in traditional economic analysis and thus omitted. Combined with Li (1999) [11], China's natural resources statistics and the World Bank's agricultural land area data, since the 1996 National Land Survey with the highest credibility, China's cultivated land area stock is in the order of one billion mu, and the annual increase and decrease of cultivated land is in the order of one million mu. Therefore, it can be considered that the input of land is unchanged.

Placed in A are all the efficiency improvements, such as competition brought by the reform of the market and the management knowledge absorbed from the outside after China's entry into WTO. However, for the analysis convenience, A is considered exogenous as a constant here.

The external effect of human capital is not considered. The main reason is that during the Reform and Opening Up in China, production is still largely driven by factors. The external effect is also unrelated to the main issue of labor migration.

It is natural to consider human capital rather than labor in F. This paper is a study of the educational economy. In the previous discussion, it has been shown that the complexity of industrial production faced by China after the Reform and Opening Up has required the intervention of human capital. A study by Zhang et al. (2011) [7] based on provincial panel data from 1978 to 2018 in China shows that human capital has a significant positive correlation with industry and service but not with agriculture.

Assuming that individuals are born in the traditional agriculture without additional skills, they must pay a certain education fee to acquire skills h. The concept is the same as Lucas's setting [3], where a worker with a skill level of $2h$ working one hour is equivalent to two workers with a skill level of h working one hour or one worker with a skill level of h working two hours. Therefore, h can also be directly used to measure effective labor.

Assuming that the education fee E is related to and non-decreasing in the skill level h:

$$\partial E/\partial h \geq 0$$

It is obvious that higher skill levels require more education. For simplicity, assuming that there are homogeneous individuals and education in the economy, that is, all individuals pay the same education cost E and obtain the same human capital h.

Individuals with human capital migrate to the modern industry. Although this situation does not necessarily hold in reality, for example, where illiteracy may also find jobs in industrial firms, it is important to note that the "modern industry" referred to here is an abstract sector that inputs human capital and compensates its wage. An individual who is engaged in simple labor and receives payment for it, even if employed by a nominal industrial firm, is still classified under the traditional agriculture. For a rational economic man, paying the cost of education is bound to enter the modern industry because its education cost will not be compensated in the traditional agriculture. Correspondingly, wages are higher in the modern industry, so individuals have the incentive to pay a certain education fee for higher wages, which the Mincer earnings function can prove. Cheung's [6] chapter *The Initial Opening of China* in the book *The New Orange Seller's Speech* contains a vivid example: in the 1980s, the chores done in the county's idle time paid less than 40 yuan, and shoe mending business in big cities was very profitable. The mayor of Huangyan County devised a good idea to teach children to mend shoes and let them leave their hometown to make money in big cities. It took a year for an average child to learn to mend shoes, but when they obtained the skill and went out, they could send home nearly 100 yuan a month, excluding their expenses.

The education choices of rural individuals are elucidated in the micro-level study of Liu (2007) [4], who noted that (at that time) in rural households, the money saved was typically used to allow some children to attend school first. This was partly due to the limited educational resources within families and the competition among siblings for these resources. Therefore, the number of rural individuals receiving education at each instant is set as the ratio of unconsumed income of rural households to the cost of education.

The accumulation process of material capital is consistent with the settings of other classical economic models. Thus, the law of motion can be written as:

$$\dot{L}_{1,t} = -\frac{Y_{1,t} + T_t - C_{1,t}}{E}$$

$$\dot{K}_t = Y_{2,t} + I - C_{2,t} - T_t$$

where C_1 is the consumption in the traditional agriculture, C_2 is the consumption in the modern industry, and T is the flow of income between the two sectors. As assumed earlier, the final goods are completely substituted, so there is no reason to stop the flow of income between the two sectors. In the story of shoe mending youth [6], many new houses in Huangyan county were funded by the money they sent back. T_t changes the budgets of both sectors, thus affecting the consumption decisions. I stands for the foreign direct investment minus net export. Assuming all the investments come from the unconsumed income of the modern industry implies that the economy is closed, but one of the most prominent features of the Reform and Opening Up is openness. While many net exports became foreign exchange reserves, another large amount of foreign direct investment has dramatically increased the capital stock. For simplicity, I is assumed to be exogenous and, for the existence of a solution, finite.

The total population L is also assumed to be constant and depreciation to be zero for simplicity.

Given the absence of externalities, a social planner problem can be solved:

$$\max \int_0^\infty e^{-\rho t} \mathrm{U}(C_{1,t} + C_{2,t}) \mathrm{d}t$$

where U is the utility function, and ρ the discount factor. The direct addition of C_1 and C_2 corresponds to the T mentioned above, which indicates that decision-making in both sectors takes into account the aggregate level of consumption.

1.2 Model Solving

To sum up, the following problem determines the path of the economy:

$$\begin{aligned}
&\max \int_0^\infty e^{-\rho t} \mathrm{U}(C_{1,t} + C_{2,t}) \mathrm{d}t \\
&\text{s.t. } \dot{L}_{1,t} = -\frac{Y_{1,t} + T_t - C_{1,t}}{E} \\
&\qquad \dot{K}_t = Y_{2,t} + I - C_{2,t} - T_t \\
&\qquad Y_{1,t} = \mathrm{G}(L_{1,t}) \\
&\qquad Y_{2,t} = A\mathrm{F}(K_t, H_{2,t}) \\
&\qquad H_{2,t} = h(L - L_{1,t})
\end{aligned}$$

where t represents time, T, C_1, C_2 are control variables and L_1, K are state variables.

With λ_1, λ_2 being co-state variables, the Hamiltonian is given by:

$$\begin{aligned}
\mathcal{H}(t; L_1, K; T, C_1, C_2; \lambda_1, \lambda_2) = e^{-\rho t} \mathrm{U}(C_{1,t} + C_{2,t}) + \lambda_{1,t} \left(-\frac{\mathrm{G}(L_{1,t}) + T_t - C_{1,t}}{E} \right) \\
+ \lambda_{2,t} \left(A\mathrm{F}\left(K_t, h(L - L_{1,t})\right) + I - C_{2,t} - T_t \right)
\end{aligned}$$

According to Pontryagin's Maximum Principle, the first-order conditions and transversality conditions can be derived:

$$
\begin{aligned}
0 &= \frac{\partial \mathcal{H}}{\partial T_t} = -\frac{\lambda_{1,t}}{E} - \lambda_{2,t} && (1)\\
0 &= \frac{\partial \mathcal{H}}{\partial C_{1,t}} = e^{-\rho t}\mathrm{U}'(C_{1,t} + C_{2,t}) + \frac{\lambda_{1,t}}{E} && (2)\\
0 &= \frac{\partial \mathcal{H}}{\partial C_{2,t}} = e^{-\rho t}\mathrm{U}'(C_{1,t} + C_{2,t}) - \lambda_{2,t} && (3)\\
\dot{\lambda}_{1,t} &= -\frac{\partial \mathcal{H}}{\partial L_{1,t}} = \frac{\lambda_{1,t}}{E}\frac{\partial Y_{1,t}}{\partial L_{1,t}} - \lambda_{2,t}\frac{\partial Y_{2,t}}{\partial L_{1,t}} && (4)\\
\dot{\lambda}_{2,t} &= -\frac{\partial \mathcal{H}}{\partial K_t} = -\lambda_{2,t}\frac{\partial Y_{2,t}}{\partial K_t} && (5)\\
&\lim_{t\to\infty} \lambda_{1,t}L_{1,t} = 0 && \text{(TVC1)}\\
&\lim_{t\to\infty} \lambda_{1,t}K_t = 0 && \text{(TVC2)}
\end{aligned}
$$

From (1)(2)(3) there are:

$$
\begin{aligned}
\lambda_{1,t} &= -Ee^{-\rho t}\mathrm{U}'(C_{1,t} + C_{2,t}) && (1')\\
\lambda_{2,t} &= e^{-\rho t}\mathrm{U}'(C_{1,t} + C_{2,t}) && (2')
\end{aligned}
$$

It shows that T_t is not necessary, as considering the sum of C_1 and C_2 in the utility function implicitly assumes that there is a transfer between the two sectors. However, it is explicitly specified here, as it reflects real-world scenarios.

Substituting (1')(2') into (4)(5) yields the instantaneous changes of co-state variables:

$$
\begin{aligned}
\dot{\lambda}_{1,t} &= -e^{-\rho t}\mathrm{U}'(C_{1,t} + C_{2,t})\left(\frac{\partial Y_{1,t}}{\partial L_{1,t}} + \frac{\partial Y_{2,t}}{\partial L_{1,t}}\right) && (4')\\
\dot{\lambda}_{2,t} &= -e^{-\rho t}\mathrm{U}'(C_{1,t} + C_{2,t})\frac{\partial Y_{2,t}}{\partial K_t} && (5')
\end{aligned}
$$

The instantaneous changes of co-state variables can be derived from (1')(2'):

$$
\begin{aligned}
\dot{\lambda}_{1,t} &= Ee^{-\rho t}\left[\rho \mathrm{U}'(C_{1,t} + C_{2,t}) - \mathrm{U}''(C_{1,t} + C_{2,t})(\dot{C}_{1,t} + \dot{C}_{2,t})\right] && (6)\\
\dot{\lambda}_{2,t} &= -e^{-\rho t}\left[\rho \mathrm{U}'(C_{1,t} + C_{2,t}) - \mathrm{U}''(C_{1,t} + C_{2,t})(\dot{C}_{1,t} + \dot{C}_{2,t})\right] && (7)
\end{aligned}
$$

Combining (4')(5') and (6)(7) to obtain:

$$
\begin{aligned}
\frac{\mathrm{U}''(C_{1,t} + C_{2,t})}{\mathrm{U}'(C_{1,t} + C_{2,t})}(\dot{C}_{1,t} + \dot{C}_{2,t}) &= \rho + \frac{1}{E}\left(\frac{\partial Y_{1,t}}{\partial L_{1,t}} + \frac{\partial Y_{2,t}}{\partial L_{1,t}}\right) && (8)\\
\frac{\mathrm{U}''(C_{1,t} + C_{2,t})}{\mathrm{U}'(C_{1,t} + C_{2,t})}(\dot{C}_{1,t} + \dot{C}_{2,t}) &= \rho - \frac{\partial Y_{2,t}}{\partial K_t} && (9)
\end{aligned}
$$

Therefore, the terms involving the derivatives of the utility function cancel each other out when using (8)(9):

$$
\frac{\partial Y_{1,t}}{\partial L_{1,t}} + \frac{\partial Y_{2,t}}{\partial L_{1,t}} = -E\frac{\partial Y_{2,t}}{\partial K_t} \tag{10}
$$

Note that $\partial Y_{2,t}/\partial L_{1,t} = -\partial Y_{2,t}/\partial L_{2,t}$. Let $\mathrm{MPL}_{1,t}$ denote $\partial Y_{1,t}/\partial L_{1,t}$, $\mathrm{MPL}_{2,t}$ denote $\partial Y_{2,t}/\partial L_{2,t}$, and $\mathrm{MPK}_{2,t}$ denote $\partial Y_{2,t}/\partial K_t$. Then (10) can be written as:

$$\mathrm{MPL}_{2,t} - \mathrm{MPL}_{1,t} = E \times \mathrm{MPK}_{2,t} \tag{11}$$

The direct economic implication of this equation is that the cost of education creates a discrepancy between the marginal products of labor in the two sectors. At every instant along the optimal growth path, the difference equals the product of the cost of education and the marginal product of material capital in the modern industry.

1.3 Stationary State and Comparative Statics

A stationary state is anticipated because A and L are constant. At the stationary state, where $\dot{C}_{1,t} + \dot{C}_{2,t} = 0$, setting the right-hand side of (9) to zero yields the material capital stock at the stationary state $\bar{K}$.

The marginal product of material capital remains constant as K does, halting migration between the two sectors as indicated by (11). By setting the rate of change of $L_{1,t}$ to be zero, there is:

$$Y_{1,t} + T_t = C_{1,t} \tag{12}$$

By setting $\dot{K}_t$ to zero in the capital accumulation equation, there is:

$$Y_{2,t} + I = C_{2,t} + T_t \tag{13}$$

Add (12) and (13) to get:

$$Y_{1,t} + Y_{2,t} + I = C_{1,t} + C_{2,t} \tag{14}$$

Again, it shows that T_t is not necessary. As the population allocation and the stock of material capital remain unchanged, (14) can be written as:

$$\bar{Y} + I = \bar{C} \tag{14'}$$

where $\bar{Y}$ stands for the stationary total output, and $\bar{C}$ stands for the stationary total consumption. That is to say, the economy accepts money from the outside world but consumes it instead of investing it. The model tells us that foreign investment accelerates China's urbanization, but it does not change the eventual outcome if there is no technological progress.

The education fee does change the stationary state as it affects the population allocation. By setting the right hand side of (9) to zero, there is:

$$\mathrm{MPL}_{2,t} - \mathrm{MPL}_{1,t} = \rho E$$

Without the loss of generality, a graphical approach is employed to analyze the effect of a shock to E at the stationary state.

The graph of MPL_1 is easy to plot, and it can be assumed to go down to zero eventually, as Lewis (1954) [2] proposed. It is also easy to plot MPL_2 as an analog of scaled-up horizontal mirror image of MPL_1.[1] MPL_1 and MPL_2 may not necessarily intersect, but the scenario where they do intersect will first be analyzed (Figure 1). The stationary

[1] To draw the graph of MPL_2 on the same axis, MPL_2 can be considered as some function $H(h, L - L_1) = \partial(A\mathrm{F})(h(L - L_1))/\partial L_1$, thus its graph is stretched to make its L-coordinates correspond with those of MPL_1.

allocation is determined by finding the L_1, which makes the distance between the two curves $\overline{BC}$ exact ρE.

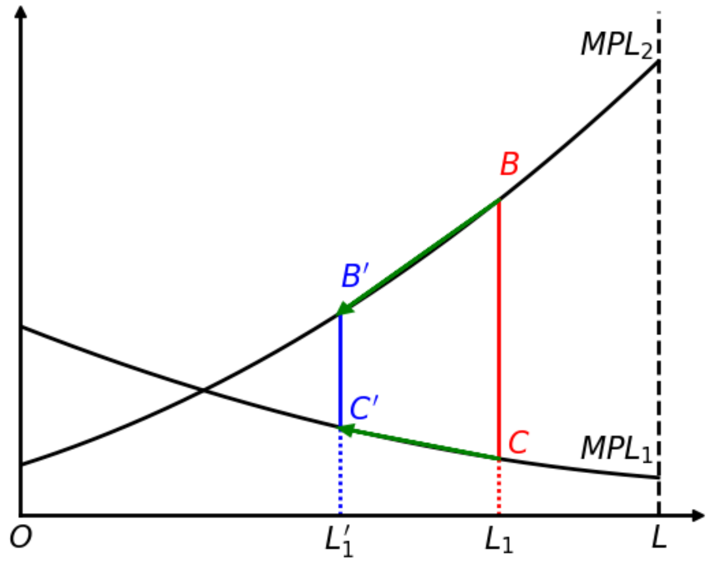

Figure 1: Graphs of intersected MPL_1 and MPL_2

There are two ways to improve education. The first way is to reduce the education fee E without changing other conditions, which will shrink the distance required. The vertical line $\overline{BC}$ in Figure 1 moves to the left $\overline{B'C'}$, which means that more laborers become human capital in the modern industry. The work of Li (2017) [10] provides evidence to support this conclusion by comparing the eastern region with the central region of China. The latter requires relatively more investment to achieve the same level of education, which inhibits the accumulation of human capital in the region.

The second way is to improve the skill level h provided by education. Given the relation $\text{MPL}_2 = h\text{AF}_{H_2}(K, h(L-L_1))$, an increase in h leads to an expansion of the MPL_2 curve. Moreover, the expansion rate of the MPL_2 curve exceeds that of h. Consider that $\overline{NP}$ expands to $\overline{NQ}$ and $\overline{MP}$ expands to $\overline{MR}$ in Figure 2. As the relationship between h and E is ambiguous, the change in the stationary state is unpredictable. When h is linear with E, $\overline{NQ}/\overline{NP} - 1 < \overline{MR}/\overline{MP} - 1$, thus $\overline{PQ} < \overline{PR}$, $\overline{NP}$ moves left to $\overline{N'Q'}$. When h shows increasing marginal cost in E, the expansion rate of the required distance may be greater than that of the MPL_2 curve, which leads to the right shift of the stationary state. Conversely, a decreasing marginal cost in E leads to a lower expansion rate of the vertical line than in the linear case, causing a leftward movement.

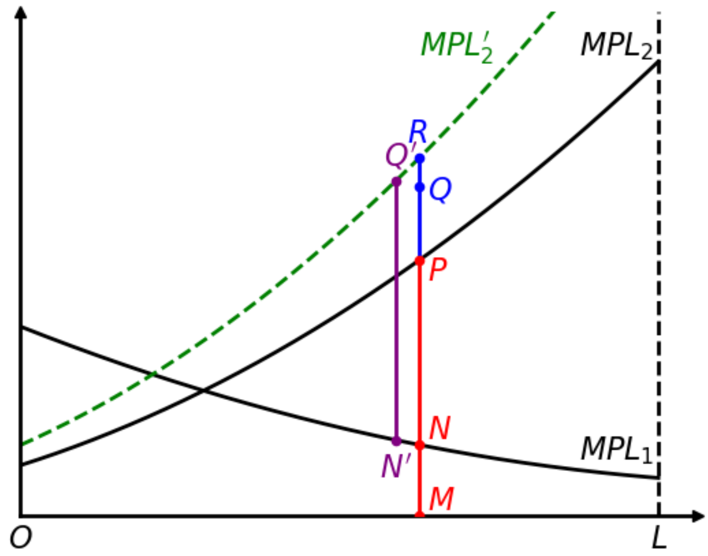

Figure 2: Movement of the stationary state when h is linear with E

It can also be imagined that in a scenario where the technology level of the modern industry is so high that even the entire population migrates to it, the difference in the marginal product of labor is larger than ρE. In this case, all laborers are in the modern industry in the stationary state. (Figure 3)

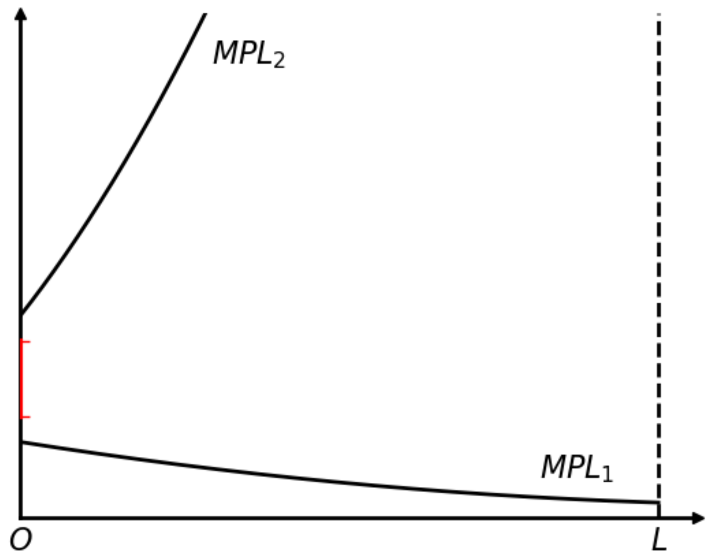

Figure 3: A scenario where A is too high

Generally speaking, education development can promote the accumulation of human capital and the migration of the population to modern industry. However, it should also be recognized that the progress of education has a limit. Even if E is reduced to 0, the population allocation is limited to the same marginal output of labor in the two sectors (the intersection of the two curves in Figure 1). For an economy to transcend its stationary state and fully realize industrialization, it must not solely rely on education and population allocation. Advancements in technology and a transition to a neoclassical growth framework are imperative.

1.4 Empirical Validation

The econometric model is built upon the marginal condition of the optimal path, as expressed in Equation (11). This condition is tested using the following equation:

$$\text{empk2} = \beta_0 + \beta_1 \text{mpl1} + \beta_2 \text{mpl2} + \mathbf{Z}\boldsymbol{\gamma} + \varepsilon \tag{15}$$

where mpl1 and mpl2 are variables of interest and $\mathbf{Z}$ are control variables. It is expected that β_1 will be negative and β_2 will be positive, with their absolute values similar.

All data used in this section comes from official sources. The data on "Educational Tuition Fees of Various Schools", "National Financial Educational Expenditure", "Per Capita Disposable Income of Urban Residents", "Per Capita Disposable Income of Rural Residents", and "Trade Balance" are sourced from the National Bureau of Statistics of China. The data on "Primary Industry Added Value", "Secondary Industry Added Value", "Tertiary Industry Added Value", "Agricultural Population", "Non-agricultural Population", "Urban Fixed Asset Investment" and "Number of Students Enrolled" are obtained from the CNKI Big Data Research Platform, with their original data being derived from the official China Statistical Yearbooks. "Lending Interest Rate" is from the World Bank Open Data, as any relevant variable cannot be found in the other two databases. All data in monetary units are fixed to 1996 prices using the "GDP index" from the National Bureau of Statistics of China.

Consider that in the case of a perfectly competitive market, the marginal output of labor is equal to the income earned by workers. "Per Capita Disposable Income of Rural Residents" and "Per Capita Disposable Income of Urban Residents" serve as the proxy variables for MPL_1 and MPL_2, respectively. Similarly, "Lending Interest Rate" approximates MPK_2. The quotient of "Educational Tuition Fees of Various Schools" divided by the "Number of Students Enrolled" is used as the estimate of individual education fees. Then, the product of the marginal product of material capital and the individual education fee becomes the dependent variable.

The economic agents not endogenously modeled are foreigners and governments, so the following two possible confounding factors are considered: the first is international trade, which has greatly promoted the marginal output of labor and capital after the reform and opening up; the second is government subsidies for education, which reduce the burden of individual tuition, improve the actual level of education and push up the marginal output of labor. Therefore, the following two control variables are considered: the first is the dependence on foreign trade, which is calculated as the percentage of net exports to total output, in which net exports are represented by the "Trade Balance", and total output is the sum of added value of all industries; the second is the proportion of fiscal education expenditure to GDP, which is calculated by dividing "National Financial Educational Expenditure" by total output.

Robustness is tested by replacing variables. It is natural to use the quotient of the first-order difference of the series of the output divided by that of the input to estimate the marginal product. However, from the final result, using the average output of labor as the proxy variable of MPL_1 is found to be more accurate. Because agriculture, in reality, has actually introduced the progress of material capital and improved labor efficiency, its output still increased in the case of labor migration, and the marginal output of labor calculated by the above method is negative, which cannot reflect the fact. Besides, the average output per labor in agriculture has practical economic significance: in modern industry, workers are not the owners of material capital, so their income is the marginal output of the labor they provide; however, in agriculture, farmers are also the owners of land and material capital, and they have the total income, so the average output per laborer can more accurately reflect the decision-making factor. The output of the traditional agriculture is represented by "Primary Industry Added Value", while the output of the modern industry is represented by the sum of "Secondary Industry Added Value" and "Tertiary Industry Added Value". The labor in the traditional agriculture is represented by "Agricultural Population", and the labor in the modern industry is represented by "Non-agricultural Population". The change of physical capital in the modern industry is represented by "Urban Fixed Asset Investment". The education fee remains the same.

Table 1: Definition and units of variables

Variable Name	Definition	Unit
avgincome1	Per Capita Disposable Income of Rural Residents	Yuan
avgincome2	Per Capita Disposable Income of Urban Residents	Yuan
e	Individual Education Fee	Yuan/Person
r	Lending Interest Rate	%
er	Explained Variable	Yuan/Person
edufundrate	The Proportion of Fiscal Education Expenditure to GDP	%
nxrate	Foreign Trade Dependence	%
apl1	Alternative Average Estimate of MPL_1	Yuan/Person
dpl2	Alternative Differential Estimate of MPL_1	Yuan/Person
dpk2	Alternative Differential Estimate of MPK_2	%
edpk2	Alternative Explained Variable	Yuan/Person

The study period starts in 1996, based on the availability of data. The end year of the study period is selected by the "Lewis Turning Point", which describes the rural-urban labor migration – before the second Lewis turning point, economies are in the phase of labor migration between the two sectors. A review by Yi (2020) [8] points out that the mainstream view is that China's first Lewis turning point occurred at some point before 2016. According to the results of Wang and Zhang (2014) [14], as of 2012, China had not crossed the second Lewis turning point. Xue's (2016) [15] study suggests that by 2014, the second Lewis turning point had begun to manifest, albeit not thoroughly. Hence, this section selects the study period to end in 2014.

The names and descriptive statistics of the key variables are shown in Table 2.

Table 2: Descriptive statistics of variables

Variable Name	Observations	Mean	Standard Deviation	Minimum	Maximum
avgincome1	19	1748.13	195.29	1506	2146.29
avgincome2	19	5013.96	440.56	4552.15	5902.14
e	19	194.39	63.13	85.86	261.53
r	19	6.24	1.23	5.31	10.08
er	19	1176.40	356.60	630.40	1824.00
edufundrate	19	3.09	0.64	2.33	4.3
nxrate	19	3.39	1.82	1.42	7.53
apl1	19	1231.22	132.05	1037.77	1535.09
dpl2	19	33931.21	31423.17	324.06	107050.10
dpk2	19	8.82	6.10	0.10	19.54
edpk2	19	1698.89	1299.64	9.61	4772.43

The estimates are reported in Table 3. All the coefficients in columns (1)-(3) are statistically significant at the significance level of 10% or better. Column (1), with the constant term omitted, replicates the theoretical specification as Equation (11). This model achieves an R-squared of 0.970, indicating a high explanatory power. The estimated coefficients with similar magnitudes exhibit the anticipated signs, while the absolute values are not very closely aligned. Column (2) includes the constant term in the model. Though with a decrease of R-squared to 0.807, the values of the coefficients are close to our theoretical prediction. The introduction of control variables in Column (3) results in coefficient values that more accurately reflect our theoretical model, approximating -1 and $+1$, respectively. Our model receives partial corroboration through the observed results.

Table 3: OLS estimation results

VARIABLES	(1) er	(2) er	(3) er	(4) edpk2	(5) edpk2	(6) edpk2	(7) e	(8) r
avgincome1	-1.275***	-1.137***	-1.090**				-0.238***	0.000206***
	(0.372)	(0.278)	(0.423)				(0.0291)	(5.67e-05)
avgincome2	0.682***	0.979***	1.023*				0.135***	-0.000173**
	(0.130)	(0.123)	(0.507)				(0.0349)	(6.80e-05)
apl1				0.331	-3.665***	-3.615***		
				(0.213)	(0.991)	(0.949)		
dpl2				0.0365***	0.0365***	0.0380***		
				(0.00577)	(0.00416)	(0.00450)		
Constant		-1,743***	-1,981*		4,973***	6,054***	-179.8**	0.317*
		(451.1)	(1,104)		(1,218)	(1,345)	(75.97)	(0.148)
Control Variables	No	No	Yes	No	No	Yes	Yes	Yes
Observations	19	19	19	19	19	19	19	19
R-squared	0.970	0.807	0.825	0.884	0.840	0.875	0.974	0.551

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Columns (4)-(6) serve as robustness tests, employing alternative dependent and independent variables while maintaining the same specifications as in columns (1)-(3). Except for the coefficient of apl1 in column (4), all the coefficients are statistically significant at the significance level of 1%. The estimated coefficients display the anticipated signs, though their magnitudes differ. However, the significant figures are closely aligned. From Table 2, it can be noticed that the range and standard deviation of alternative variables are substantially larger than those of the original variables. It can be attributed to the coarse granularity of estimation. The marginal products of the two sectors differ by a factor of one hundred, a magnitude mirrored in the difference between the estimated coefficients. Conversely, the original variables exhibit similarity in their magnitudes. Owing to the linearity of the OLS method, it is reasonable to expect that coefficients will closely align when the magnitudes of the data are similar.

Only the dependent variable is changed in columns (7) and (8) to ensure that the alignment in the absolute values of the coefficients results only from the combination of “e” and “r”. It can be observed that compared to columns (1)-(3), the magnitudes and absolute values of the significant figures vary notably. Consequently, it is reasonable to infer that the coefficients behave as expected only when the dependent variable is the product of “e” and “r”, which is predicted by our theoretical model.

A constrained regression is also conducted, setting β_2 and β_1 to be inverses, effectively regressing “er” on the difference “avgincome2 - avgincome1”. Despite these constraints, the linear model demonstrated a significant relationship between the variables, as illustrated in Figure 4. The estimated regression coefficient for the predictor is 0.949, with an R^2 value of 0.800, both of which suggest a strong linear association.

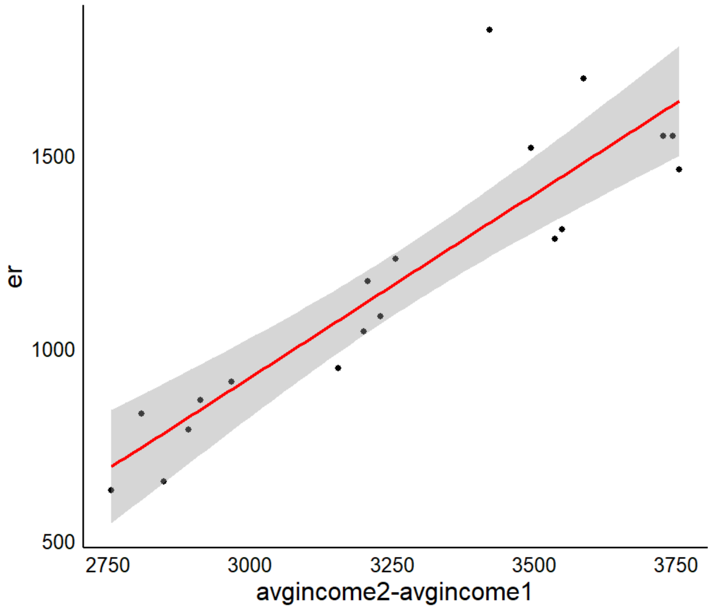

Figure 4: Scatter and regression line plot of constrained regression

As all the variables are time series data, it is essential to ensure no spurious regressions. Unit root tests are first applied to the residual series of the model (1)-(3). The results presented in Table 4 confirm that at the significance level of 5%, all the residual series are stationary.

Table 4: Dickey-Fuller Test results

Model	H0	Test Statistic	Dickey-Fuller Critical Value			p-value
			1%	5%	10%	
(1)	Random walk with or without drift	-3.432	-4.38	-3.6	-3.24	0.0473
(2)	Random walk without drift, d = 0	-4.010	-3.75	-3	-2.63	0.0014
(3)	Random walk without drift, d = 0	-4.414	-3.75	-3	-2.63	0.0003

Furthermore, Johansen tests for cointegration with constant trend and two lags are also conducted on the key variables (“er”, “avgincome1”, “avgincome2”) to show that the null hypothesis of no cointegration is rejected (Table 5). This outcome significantly mitigates the risk of spurious regression in our models.

Table 5: Johansen tests for cointegration result

Maximum Rank	Params	LL	Eigenvalue	Trace Statistic	Critical Value 5%
0	12	-284.40771	.	41.1786	29.68
1	17	-268.51738	0.84579	9.3980*	15.41
2	20	-263.95514	0.41535	0.2735	3.76
3	21	-263.8184	0.01596		

* selected rank

1.5 Chapter Summary

The chapter develops a model including two sectors: the agriculture inputs only labor, and the industry, which is affected by technology, inputs human capital and material capital. Laborers are initially in the agriculture without skills. Education is the sole pathway for laborers to acquire human capital, allowing them to cross the threshold into the modern industry. The model's solution is derived using optimal control, which yields a marginal condition on the optimal path that the difference between the marginal product of labor in the two sectors is equal to the product of the cost of education and the marginal output of material capital in the modern industry.

The analysis of the stationary state demonstrates that advancements in education can positively influence the rate of industrialization within the economy. However, the extent of this enhancement is limited. For sustained economic growth, the introduction of exogenous or endogenous technological progress is essential.

Following the theoretical framework, the chapter employs official Chinese data from 1996 to 2014 to validate the model's predictions. OLS estimations corroborate the relationships posited by the model, demonstrating their applicability in real-world scenarios. To further ensure the reliability of this analysis, both robustness checks and cointegration tests are performed.

Two policy implications can be derived from the insights of the model. Firstly, at the primary stage of the dual-sector economy, prioritizing the reduction of education costs is crucial, as its positive impact on labor migration is clear, whereas the benefits of enhancing education quality remain uncertain. The reduction in education fees can also accelerate consumption growth, as demonstrated in Equation (8). In the long run, however, education quality should also be improved as it leads to the leftward shift of the intersect in Figure 2, which increases the potential industrialization rate achieved by lowered education fees. Secondly, viewing education merely as a means to improve human capital input in production results in a stationary state. To sustain economic growth, education should be recognized not just as a way to increase human capital for production but also as a key driver of technological progress.

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