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The Impact of Education Quality and Cognitive Ability on Economic Growth Under the Context of China

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Abstract

The study delves into the correlation between cognitive ability, education quality, and economic growth within the Chinese context. Through the analysis of two growth models, it sheds light on the intricate relationship between these factors. The findings suggest that the economic growth rate is contingent upon the interplay between the positive impact stemming from the accumulation of language cognitive ability and educational quality, and the negative effect resulting from investments in cognitive ability. The results indicate that when the level of cognitive ability is low, the positive effect of investing in cognitive ability is outweighed by the negative effect, consequently limiting the influence of cognitive ability enhancement on economic growth. However, as the level of cognitive ability rises, the negative impact of cognitive investment diminishes while the positive effect strengthens, thereby fostering economic growth through the augmentation of cognitive ability. Overall, the study sheds light on the intricate relationship between language cognitive ability, education quality, and economic growth in the Chinese context, showcasing the varying effects of cognitive investment depending on the level of cognitive ability.

Keywords: Cognitive Ability, Education Quality, Economic Development of China

Introduction

China's rapid economic growth and education development since the 21st century can be largely attributed to the significant accumulation of human capital. In 2022, China boasted an

impressive 518,500 schools of various types and levels, catering to the educational needs of a staggering 293 million students. These students were fortunate to be guided by a dedicated workforce of 18,803,600 full-time teachers. It is worth noting that the average number of years of education for the new workforce stands at an impressive 14 years. The statistics reveal the immense strides made in expanding educational opportunities across different levels. By 2022, China's total higher education enrollment is projected to reach 46.55 million, indicating a substantial increase. The gross enrollment rate in higher education has witnessed a remarkable ascent from 30% in 2012 to an impressive 59.6%. Similarly, the gross enrollment rate at the high school level is set to reach an impressive 91.4%, while the junior high school level is expected to achieve universal enrollment at 100%. Furthermore, the enrollment rate in primary schools nationwide is projected to reach a commendable 99.79%. Preschool education, a crucial foundation for future learning, is also making significant strides, with a gross enrollment rate of 89.7% in 2022, representing a 1.6% point increase from the previous year (National Bureau of Statistics of China, 2022).
The above only shows the quantitative progress in human capital. In contrast to the quantitative aspect, the improvement of human linguistic and cognitive skills is more critical to the development of innovative people and the formation of an innovative society, and will influence the growth of our economy over the next 30 years. So, how does language cognitive ability affect economic growth? How should the proportion of investment in cognitive ability be determined at different stages of economic development? This question is of great importance for the development of an innovative society. However, it is essential to recognize that the development of language cognitive abilities is equally critical in cultivating innovative talents and fostering an innovative society. Enhancing language cognitive abilities will directly influence our economy's growth over the next three decades. It is worth emphasizing that the advancement of human language cognitive ability goes beyond mere numbers. By prioritizing the improvement of cognitive skills, China can effectively nurture a generation of individuals equipped with the mental agility and creativity necessary for innovation. This emphasis on cognitive development will serve as a driving force in shaping the country's economic landscape and fueling sustained growth in the coming years.

Literature Review

Studies of the Cognitive Ability and Economic Growth

Hanushek and Woessmann et al. (2010) have argued that factors affecting cognitive ability include teachers' salaries, class size, educational expenditure per student, and the system. These factors reflect the inputs to education, which are ultimately translated through the education system into educational outputs, as expressed in the level of student performance on cognitive ability tests. Their research shows that cognitive ability and education Jones, Hafer, and Hobbs (2011) have studied the role of cognitive ability on economic growth from the perspective of cognitive ability, and their findings suggest that increased cognitive ability can contribute to economic growth. However, these studies were conducted only from the perspective of empirical research and did not reveal the specific mechanisms by which cognitive ability acts on economic growth.
Corbett et. al. (2007) report results for a large prospective birth cohort of the relationship between weight gain in infancy and educational attainment at age 10. Using three large-scale assessments (Rindermann et. al., 2011) calculate cognitive-competence sums for the mean and for upper- and lower-level groups for 90 countries and compared the influence of each group's intellectual ability on gross domestic product. Using three large-scale assessments

(Rindermann et. al., 2011) calculate cognitive-competence sums for the mean and for upper- and lower-level groups for 90 countries and compared the influence of each group's intellectual ability on gross domestic product. The multiple hierarchical regression analysis of a sample of over 60 countries shows that the intellectual class has the greatest impact on economic growth followed by average ability citizens and the non-intellectual class in that order (Burhan et. al., 2014). (Rindermann et. al., 2018) use a data set of national IQ changes ("FLynn effect") from Pietschnig and Voracek (2015). Cognitive aspects are in fact fundamental in making the most of the greater potential of territorial features. Using the concept of territorial capital (Boczy et. al., 2020) investigate this mix between material and cognitive assets in regional planning discourses. (Burhan, 2021) treat happiness as a positive psychological state and intrinsic motivator that encourages labourers to fully utilise their CA and produce higher productivity for the economy. Other influential work includes (Rindermann, 2012), (Stumm, 2012), (Heiner et. al., 2015).
Gui et. al. (2018) investigate longitudinal brain development between birth and term-equivalent age (TEA) by quantitative imaging in a cohort of premature infants born between 26 and 36 weeks gestational age (GA), to provide insight into the relation of brain growth with later neuro developmental outcomes. Cognitive aspects are in fact fundamental in making the most of the greater potential of territorial features. Using the concept of territorial capital (Boczy et. al., 2020) investigate this mix between material and cognitive assets in regional planning discourses. Recent work has suggested that economic activity in midlife can be predicted by the far-reaching effects of early life, such as childhood socio-economic circumstances, cognitive ability and education. (Iveson et. al., 2020) investigate whether these same early-life factors predict the odds of being economically active much later in life, from age 55 to age 75. The subject of (Salahodjaev et. al., 2020) is to extend existing evidence by investigating the link between cognitive skills and income in Tajikistan. (Burhan, 2021) treat happiness as a positive psychological state and intrinsic motivator that encourages labourers to fully utilise their CA and produce higher productivity for the economy. (Tansel et. al., 2021) examine the relationship between wealth and health through prominent growth indicators and cognitive ability. Based on an initial search of 3,766 records (Ozawa et. al., 2021) identify 14 studies, including 8 studies that examined the cognition-education link and 8 studies that assessed cognition-employment returns in LMICs. Kamruzzaman (2022) perform a thorough study selection exercise and a quality assessment to ensure that the present study is valuable to academia and the relevant stakeholders, especially the experts of computer science who can develop the smartest artificial intelligence and cognitive computing tools that can help mitigate those. Other influential work includes Pandey (2021) and Womack et. al. (2021).

Education and Economic Growth
Previous studies have investigated the effect of education human capital on economic growth in. To be specific, Benos et. al., (2013) show that there is substantial publication selection bias towards a positive impact of education on growth. Jalil et. al., (2013) find support for the hypothesis that the investments in education sector may raise the economic growth of the country. Pegkas et. al., (2014) employ cointegration and an error-correction model to test the causal relationship between higher education, physical capital investments and economic growth. Other influential work includes Shackleton (2003) and Glewwe et. al., (2014). Donou-Adonsou (2019) examine whether telecommunications infrastructure promotes economic growth in countries with better access to education compared to those with less access. (Gao et. al., 2019) focus on an empirical study of the role of higher education in building a green

economy. The relationship between higher education and economic development has long been emphasized on economics and education. (Márquez-Ramos et. al., 2019) aim to consider education as a channel for human capital improvement and then for economic growth. Akinwale (2019) study education, openness and economic growth in south africa: empirical evidence from vecm analysis. Education and trade openness have made significant contribution to economic growth in some developed and emerging countries across the globe. Minasyan et. al. (2019) conduct a systematic review and meta-analysis of the empirical literature on the link between gender inequality in education and per capita economic growth. Habibi (2020) aim to examine the contribution of ICT and education to economic growth concerning the Middle East countries in comparison with the Organization for Economic Cooperation and Development (OECD) economies. Through the experience of Jiangsu Province in China Xu et. al., (2020) apply the coupling coordination model to evaluate interactive relationships among the three. (Eyuboglu et. al., 2020) aim to display the potential mechanisms between higher education and CO 2 and expand the environmental economics literature. Tsaurai (2020) investigate two aspects, namely (1) the impact of renewable energy consumption on economic growth in BRICS (Brazil, Russia, India, China, South Africa) and (2) whether education is a channel through which renewable energy consumption affects economic growth in BRICS. Apostu (2022) analyze specific current issues that are representative as influencers of economic growth.
Additionally, Mariana (2015) indicates that education plays a pivotal role in driving economic growth across nations. This study aims to explore the causal relationship between education, particularly higher education, and economic growth in Romania from 1980 to 2013. To investigate the long-term association between education and economic growth, we employ a vector error correction model. Hanushek and Woessmann (2010) argue that the formation of cognitive abilities is related to the government's investment in education. The investment in educational resources can generally be divided into three categories: 1) classroom resources (including teachers' educational background, X teachers' teaching experience, and teacher-student ratio) 2) financial expenditures (including school expenditures per student and teachers' salaries) 3) other resources (administrative costs and related equipment). Their research suggests that investment in cognitive skills will affect the accumulation of physical capital.

Language Ability and Economic Growth

The economics of language is a field of study that examines the impact of language on economic outcomes and public policies1. It explores whether and how language influences human thinking and behavior, and analyzes the effects of linguistic distances on trade, migrations, financial markets, language learning, and its returns1.The quantitative foundations of linguistic diversity, which rely on group identification, linguistic distances as well as fractionalization, polarization, and disenfranchisement indices are discussed in terms of their empirical challenges and uses (Ginsburgh, & Weber, 2018). The study of the economics of language policy evaluation has contributed to the elaboration of language policies, and economists have addressed questions such as "How much does it cost to make a unilingual education system bilingual?"(Grin & Vaillancourt, 2015). The approach is that language skills among immigrants and native-born linguistic minorities are a form of human capital, and there are costs and benefits associated with this characteristic embodied in the person. The analysis focuses on the economic and demographic determinants of destination language proficiency among immigrants, and it also focuses on the labor market consequences (earnings) of proficiency for immigrants and native-born bilinguals (Chiswick, 2008). The study of language economics is significant because it can inform policies that promote linguistic diversity and help individuals and societies reap the benefits of multilingualism. Particularly, the field of Language Economics examines the factors and outcomes associated with individuals' language education quality and language cognitive ability in the language they use in their daily lives. The primary focus lies in understanding the factors that determine proficiency in the dominant language of an economy, particularly in relation to the labor market dynamics of immigrant populations in their destination countries. However, the theoretical framework and research methods can also be extended to non-migrants who are linguistic minorities and native-born bilingual individuals (Chiswick, 2008).

In summary, the gaps are quite evident that there is few research about the correlation of education quality, language cognitive ability and economic growth. So the study attempts to fill the previous research gaps in the investigations of the impact language cognitive ability and education quality on economic growth by constructing two economic growth models that examine the correlation between language cognitive ability and economic growth. The first model assumes that language cognitive ability is an exogenous factor and posits that it impacts economic growth by influencing labor efficiency within the production function. On the other hand, the second model assumes that the accumulation of language cognitive ability necessitates resource investment and suggests that decisions to invest in cognitive ability affect the accumulation of physical capital, thereby influencing economic growth. Additionally, through realistic simulations, this article provides further insights into the intricate relationship between language cognitive ability and economic growth.

Research Methodology and Basic Theoritical Models

Exogenous language cognitive ability model

In a closed economy, we consider a simplified framework comprising a representative consumer and a representative producer. The producer generates a single final product, denoted as Y, with a normalized price of 1. The consumer's immediate utility function, denoted as U(C), captures their level of satisfaction from consumption (the time subscript t will be omitted for simplicity) and C denotes the level of consumption). Within this framework, we make the assumption that the utility function takes a specific form, namely,

$$U(C)=\frac{C^{1-\sigma}-1}{1-\sigma} \quad (1)$$

where σ denotes the relative risk aversion coefficient $\sigma > 0$. Representative consumers have a certain amount of labour L and capital K at the beginning, which they rent out to vendors for wage income w and capital rent R. Let the depreciation rate of capital be 0, the interest rate r = R, and both factor and product markets are perfectly competitive. Assuming no population growth in the model and normalizing L to 1, the supply of both labour and capital is inelastic. The objective of the representative consumer is to maximize lifetime utility. The physical capital accumulation equation can be expressed as:

$$\dot{K} = Y - C \quad (2)$$

Assuming that language cognitive ability enters the production function by influencing labour efficiency, we can set the production technology of a representative manufacturer as:

$$Y = F(K,S,A) = AK^{\alpha}(S)^{1-\alpha}, 0 < \alpha < 1 \quad (3)$$

S represents the stock of language cognitive ability, which accumulates exogenously at a rate determined by the parameter b (b>0). The production function, denoted as F(), is assumed to be continuous, quadratic differentiable, with positive and negative outputs, and exhibits constant returns to scale. Moreover, the production function meet paddy field conditions. The parameter a represents the level of technology, assuming no technological progress is present. The objective of the firm is to maximize profit. By considering the first-order conditions for profit maximization, we can derive the following equations:

$R = r = F'_K = \alpha A K^{\alpha-1} S^{1-\alpha}, w = F'_S = (1-\alpha) A K^{\alpha} S^{-\alpha}$ (4)

The optimization problem of the social planner, which encapsulates the aforementioned economy, can be formulated as follows:

$$\underset{C}{Max} \int_0^{\infty} U(C) e^{-\rho t} dt$$

Subject to: $\dot{K} = A K^{\alpha} S^{1-\alpha} - C$ (5)

Given the initial values of K(0) and S(0), where K(0) is greater than 0 and S(0) is greater than 0, we introduce the parameter $\rho(\rho > 0)$ as the time discount rate.

The cross-cutting conditions are: $\lim_{t \to \infty} K e^{-\rho t} \geq 0$

To establish the equilibrium of the problem, we introduce the present value Hamiltonian function, which incorporates the co-state variables represented by θ:

$H(K, C, \theta, t) = \dfrac{C^{1-\sigma} - 1}{1-\sigma} + \theta(A K^{\alpha} S^{1-\alpha} - C)$ (6)

The first-order conditions are:

$\dfrac{\partial H}{\partial C} = C^{-\sigma} - \theta$ (7)

$\dot{\theta} = -\dfrac{\partial H}{\partial K} + \rho\theta = -\alpha\theta A K^{\alpha-1} S^{1-\alpha} + \rho\theta$ (8)

By utilizing equation (1), we can apply the logarithm function to both sides of the equation and subsequently differentiate it, yielding the following result:

$-\sigma g_C = g_{\theta}$ (9)

g_c denotes the growth rate of consumption and g_{θ} is the growth rate of the co-variate variable θ.

From equations (4) and (5) we have $g_C = \dfrac{\alpha A K^{\alpha-1} S^{1-\alpha} - \rho}{\sigma}$ The cross-cutting condition becomes: $\lim_{t \to \infty} \theta K e^{-\rho t} = 0$. For the positive growth rate and the fulfillment of the cross-sectional condition, it is essential that condition $(1-\sigma) f'(k) < \rho < f'(k)$ is satisfied, $k = \dfrac{K}{S}$.

Proposition 1: In the aforementioned economy with the utility function U(C) and production function F(), under the specified assumptions, there exists a unique equilibrium path such that consumption, capital, and output grow at a rate of $g_K = g_Y = g_S = g_C$, regardless of the initial values of c(0) and k(0). The per capita effective capital and per capita effective consumption at the equilibrium point are given by the following equations:

$f'(k^*) = \rho + \sigma b$ (10)

$A(k^*)^{\alpha} - b k^* = c^*$ (11)

Where $k = \frac{K}{S}, c = \frac{C}{S}$

This model adopts the basic framework of the Ramsey-Cass-Koopman model, and it is evident that a unique saddle-point equilibrium exists. The growth of per capita output, as indicated by $g_K = g_Y = g_S$, depends on the accumulation of language cognitive ability, which in turn promotes economic growth.

The aforementioned model incorporates language cognitive ability into the production function, thereby influencing economic growth through its impact on labor efficiency. However, the model does not provide insights into the generation of language cognitive ability. In general, the formation of cognitive ability requires the investment of resources, and such investments in cognitive ability are likely to reduce the accumulation of physical capital, consequently affecting economic growth. In the following model, we will consider the impact of language cognitive ability investment on economic growth.

Endogenous Language Cognitive Ability Model

The basic economic environment and assumptions are the same as in the previous model. However, the key difference in this model is that language cognitive ability is assumed to be formed through government investment. In our model, we assume that language cognitive ability requires T units of government expenditure, which is acquired through proportional taxation, where T=aY. Here, a represents the tax rate, with 0<a<1. Therefore, the equation for the accumulation of language cognitive ability can be expressed as follows:

$\dot{S} = aY - \delta S$ (12)

δ represents the depreciation rate of language cognitive ability. The accumulation of an individual's physical capital is given by:

$\dot{K} = (1-\alpha)wS + (1-\alpha)rK - C$ (13)

Since language cognitive ability is entirely invested by the government, individuals consider T as given in their decision-making process. The production function of the firm is Y = F(K, S, A) = A, where factor markets and product markets are perfectly competitive. The firm aims to maximize profit. As a result, with

$R = r = F'_K = \alpha A K^{\alpha-1} S^{1-\alpha}, w = F'_S = (1-\alpha) A K^{\alpha} S^{-\alpha}$ (14)

the optimization problem for individuals are as follows:

$$\underset{C}{Max} \int_0^\infty U(C) e^{-\rho t} dt$$

$$\dot{K} = (1-\alpha)wS + (1-\alpha)rK - C$$

$$\dot{S} = aY - \delta S$$

Given K_0、S_0, where ρ is a predetermined value $(\rho > 0)$

The cross-sectional condition is given by: $\lim_{t\to\infty} K e^{-\int_0^t r(s)ds} \geq 0, \lim_{t\to\infty} S e^{-\int_0^t r(s)ds} \geq 0$

To characterize the features of this equilibrium, we establish the present value Hamiltonian function, where the co-state variables are denoted by θ、μ:

$$H(K,C,S,\theta,\mu) = \frac{C^{1-\sigma}-1}{1-\sigma} + \theta\left[(1-\tau)wS + (1-\tau)rK - C\right] + \mu(T-\delta S)$$

The necessary conditions are as follows:

$\frac{\partial H}{\partial C} = C^{-\sigma} - \theta$ (15)

$\dot{\theta} = -\frac{\partial H}{\partial K} + \rho\theta = -(1-\tau)r\theta + \rho\theta$ (16)

$\dot{\mu} = -(1-\tau)w\theta + \mu\delta + \rho\mu$ (17)

From equations (14), (15), and $R = r = F_K' = \alpha A K^{\alpha-1} S^{1-\alpha}$, we can obtain the optimal growth path for consumption as follows:

$g_c = \frac{(1-\tau)r - \rho}{\sigma}$ (18)

The cross-sectional condition is given by: $\lim_{t\to\infty} K e^{-\int_0^t r(s)ds} = 0, \lim_{t\to\infty} S e^{-\int_0^t r(s)ds} = 0$.

To ensure positive growth rate and fulfill the cross-sectional condition, the following must hold:

$(1-\sigma)(1-\tau)r < \rho < (1-\tau)r$ (19)

On the balanced growth path, the growth rate of cognitive ability S is fixed, and the wage rate is given, which implies that τ is necessarily fixed. Given that τ is fixed on the balanced growth path and $r = AK^{\alpha-1}S^{1-\alpha}$ is given, we can deduce from equation (13) that $\frac{C}{K}$ is also fixed on the balanced growth path. Consequently, we have $g_K = g_Y = g_C = g_S$.

For analytical convenience, let's assume that $c = \frac{C}{S}, k = \frac{K}{S}, y = \frac{Y}{S}, y = f(k) = Ak^{\alpha}$.

$\frac{\dot{c}}{c} = \frac{\dot{C}}{C} - \frac{\dot{S}}{S} = \frac{(1-\tau) f_k' - \rho}{\sigma} - \tau f(k) + \sigma$ (20)

$\frac{\dot{k}}{k} = \frac{\dot{K}}{K} - \frac{\dot{S}}{S} = (1-\tau)\frac{f(k)}{k} - \frac{c}{k} - \tau f(k) + \sigma$ (21)

On the balanced growth path, we have the following: $\dot{c} = 0, \dot{k} = 0$

$\frac{(1-\tau) f'(k^*) - \rho}{\sigma} = af(k^*)$ (22)

$c^* = (1-\tau) f(k^*) - \tau k^* f(k^*) - \delta k^*$ (23)

Proposition 2: In the aforementioned economy with preferences U(C) and production function F(), under the given conditions, there exists a unique balanced growth path, where consumption, capital, output, and language cognitive ability all grow. The unique path is determined by the following equations:

$\frac{(1-\tau) f'(k^*) - \rho}{\sigma} = af(k^*)$ (24)

$c^* = (1-\tau) f(k^*) - \tau k^* f(k^*) - \delta k^*$ (25)

Where $k = \frac{K}{S}$.

Proposition 3: In the aforementioned economy with preferences U(C) and production function F(), under the condition $(1-\sigma)(1-\tau)r < \rho < (1-\tau)r$, there exists a unique saddle path equilibrium, where (k, c) converges asymptotically to (k^*, c^*), as given by equation (20), and determined by equation (21). (The detailed proof of this proposition can be found in the appendix.)

From a phase diagram analysis perspective, we can also illustrate this proposition. The dynamics of the model are determined by the condition $\frac{\dot{c}}{c} = \frac{(1-a)f'(k) - \rho}{\sigma} - af(k) + \delta, \frac{\dot{k}}{k} = (1-a)\frac{f(k)}{k} - c - af(k) + \delta$ and the cross-sectional condition $(1-a)f'(k) > \rho > (1-\sigma)(1-a)f'(k)$, along with the initial conditions of k(0) and c(0). From the expression of $\dot{c} = 0, \dot{k} = 0$, we can infer that:

$$\frac{(1-a)f'(k^*) - \rho}{\sigma} = af(k^*) - \delta$$

$$c^* = (1-a)f(k^*) - ak^* + \delta k^*$$

The relationship between $\dot{c} = 0$ and k can be represented by a decreasing curve $\dot{c} = 0$.

The relationship between $\dot{k} = 0$ and c is an increasing curve, and $\frac{d\dot{c}}{dk} = \frac{(1-a)cf''(k)}{\sigma} < 0, \frac{d\dot{k}}{dc} = -k < 0$.

The phase diagram of the aforementioned system is as follows:

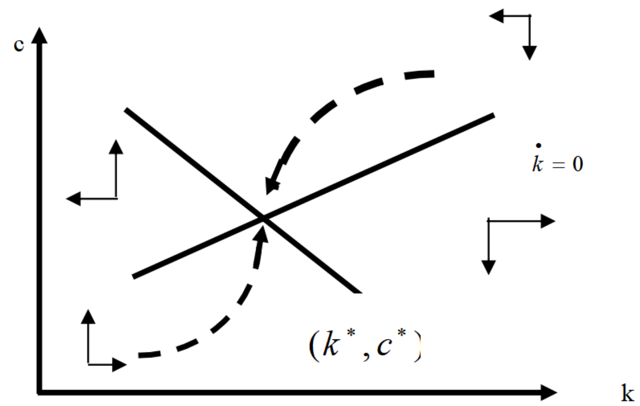

Figure 3.1: Phase Diagram

From the above dynamic system, it can be observed that starting from any point (k(0), c(0)), the economy will eventually converge to the () point, representing a saddle-point equilibrium.

Proposition 4: On the balanced growth path, increasing investment in language cognitive ability will slow down economic growth. The accumulation of language cognitive ability stock, on the other hand, promotes economic growth. Additionally, the marginal effect of cognitive ability on economic growth decreases as a increases. The optimal level of investment in language cognitive ability on the balanced growth path is determined by $[c^*]^{-\sigma}[(1-a-ak^*)f(k^*) - af(k^*) + \delta)\frac{\sigma f(k^*) + f'(k^*)}{(1-a)f'(k^*) - a\sigma f'(k^*)} - f(k^*) - k^* f(k^*)] = 0$.(The proof of this proposition is provided in the Appendix).

Based on the comparative static analysis, it is evident that an increase in the total output allocated to investment in language cognitive ability, as represented by $\frac{\partial g_Y}{\partial \mathrm{a}} = \frac{-\alpha A K^{\alpha-1} S^{1-\alpha}}{\sigma} < 0$, will result in a reduction in the accumulation of physical capital. This, in turn, will have an impact on economic growth.

Indeed, when $\frac{\partial g_Y}{\partial S} = \frac{-\alpha(1-\alpha) A K^{\alpha-1} S^{-\alpha}}{\sigma} < 0$, the increase in language cognitive ability enhances labor efficiency, it can stimulate economic growth. when $\frac{\partial g_Y}{\partial S \partial \mathrm{a}} = \frac{-\alpha(1-\alpha) A K^{\alpha-1} S^{-\alpha}}{\sigma} < 0$, it is essential to set the government's expenditure ratio at a reasonable level. Otherwise, it can affect the role of language cognitive ability in economic growth.

Proposition 5: On the balanced growth path, the economic growth rate depends on the relationship between the positive and negative effects of language cognitive ability investment. In the model without cognitive ability investment, the growth rate obtained is given by:

$$g_{Y_1} = \frac{\mathrm{a} A K^{\alpha-1} S^{1-\alpha} - \rho}{\sigma} > 0,$$

This equation reflects the positive effect of language cognitive ability accumulation on economic growth. In the model with endogenous cognitive ability investment, the economic growth rate is given by:

$$g_{Y_2} = \frac{(1-\mathrm{a})\alpha A K^{\alpha-1} S^{1-\alpha} - \rho}{\sigma} \quad (26)$$

Assuming $g_{Y_3} = g_{Y_1} - g_{Y_2}$, $g_{Y_3} = \frac{-\mathrm{a}\alpha A K^{\alpha-1} S^{1-\alpha}}{\sigma} < 0$ t, his equation reflects the negative effect of cognitive ability investment on economic growth. Consequently, we can decompose g_{Y_2} into two components. On one hand, the accumulation of language cognitive ability can enhance labor efficiency and increase output, which represents a positive effect. On the other hand, language cognitive ability investment reduces the accumulation of physical capital and slows down economic growth, which represents a negative effect. The overall economic growth rate will depend on the relative magnitudes of these two effects. When $g_{Y_3} > g_{Y_1}$, the economic growth rate is negative; When $g_{Y_3} = g_{Y_1}$, the economic growth rate is zero; When $g_{Y_3} < g_{Y_1}$ is present, the economic growth rate is positive.

Simulation and Results

In order to examine the impact of language cognitive ability investment on economic growth, we need to simulate the optimal growth rate $g_Y = \frac{(1-\mathrm{a}) A (\mathrm{k}^*)^{\alpha} - \rho}{\sigma}$ (where k=$\frac{K}{S}$).

The values of parameters A, α, σ, and ρ need to be specified. The setting of capital share, inter-temporal elasticity of substitution (IES) in discounting, can be referred to the estimation model constructed by Gu (2004), which suggests a range of [-5, 5]. In this study, we will use a value of 3. The technological progress coefficient A can be referenced from the estimation by Cui (2002) and set to 0.095.

On the equilibrium growth path $k^* = \left(\frac{\left(\frac{A\alpha}{\sigma} - \frac{aA\alpha}{\sigma}\right)\ \sigma}{\rho}\right)^{\frac{1}{1-\alpha}}$, as the proportion of investment in cognitive ability a is on the (0,1) interval, given the other parameters, we can calculate a range of (100,200) for k. To further explain the conclusions, we need to simulate different values to illustrate the relationship between the proportion of investment in language cognitive ability and economic growth at different stages of economic development, for values of 100, 150 and 200 respectively. Bringing the above simulation values in, the economic growth rate is calculated for different scenarios. The horizontal axis is time t, the vertical axis is the proportion of investment in cognitive ability a. The range of a is (0,1) and the z-axis is the economic growth rate g. The range of time t is [0,30].

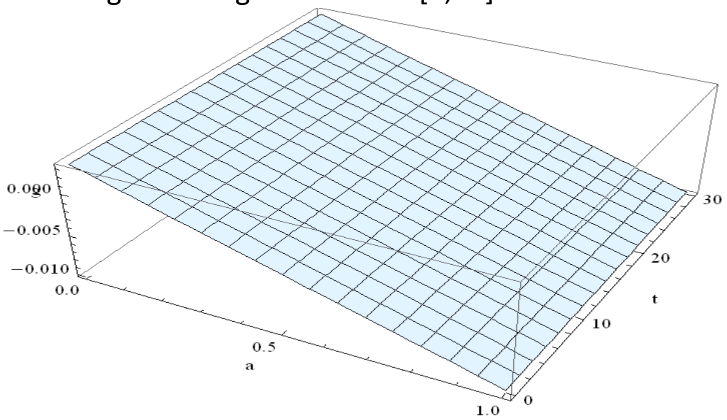

Figure 4.1 The rate of language cognitive ability and economic growth (When K=200)

From the Figure 4.1, it is evident that increasing the investment ratio in language cognitive ability has a decelerating effect on economic growth. Notably, at k=200, cognitive ability investment can potentially lead to negative growth. This indicates that in countries where language cognitive ability is relatively scarce compared to physical capital, the positive growth impact resulting from cognitive ability accumulation is outweighed by the negative growth impact caused by language cognitive ability investment. As a consequence, the proportion of total output allocated to cognitive ability investment decreases. Educational development policies often prioritize quantitative improvements, such as increasing enrollment rates and transition rates. However, concurrently, inadequate investment in cognitive ability stifles its progress. Over the past three decades, China's educational development has gone through the aforementioned stages. Following the Cultural Revolution, there was a pressing need for economic development, prompting substantial investments in physical capital. Although notable strides were made in the education sector, the focus primarily revolved around quantity rather than quality, leading to a lag in educational quality relative to economic development, particularly in terms of nurturing innovative talents. To foster sustainable and well-rounded growth, policymakers need to strike a balance between physical capital accumulation and investments in cognitive ability. This entails not only expanding educational access but also prioritizing the development of language cognitive skills, language proficiency, and language abilities. By concurrently investing in both physical and cognitive capital, countries can enhance their long-term economic growth prospects while cultivating a more innovative and resilient society.

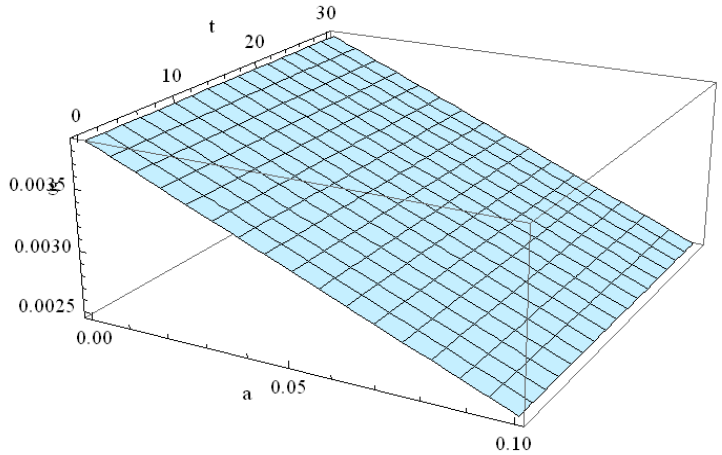

Figure 4.2 The rate of language cognitive ability and economic growth (When K=150)

The Figure 4.2 clearly illustrates that sustained increases in language cognitive ability investment hinder economic growth. However, once a certain phase of language cognitive ability accumulation is reached, the overall level of cognition in society begins to improve. At this point, the positive growth effect resulting from cognitive ability investment outweighs the negative growth effect, as evident from the graph. During this stage, as education develops in our country, the societal level of cognition steadily rises. The enhancement of language cognitive abilities boosts individual labor productivity, leading to increased output that offsets the negative growth caused by cognitive ability investment. Consequently, during this stage, the investment ratio in cognitive ability rises compared to the previous stage.

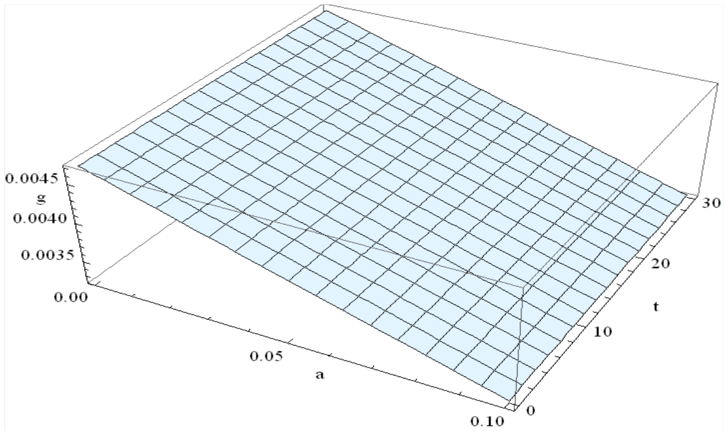

Figure 4.3 The rate of language cognitive ability and economic growth (When K=100)

From the Figure 4.3, it is evident that continuous increases in language cognitive ability investment have a decelerating effect on economic growth. This is observed in the phase where language cognitive ability levels have already reached a high level, and significant physical capital has been accumulated. During this phase, the impact of physical capital investment on economic growth becomes less pronounced, while the positive effects resulting from cognitive ability investment become more prominent. As a result, there is a substantial increase in the investment ratio, with a greater emphasis on the quality of education. This phenomenon can also be observed in developed countries, where the investment ratio in education exceeds 5% and can even reach as high as 6%. In these countries, investment opportunities are relatively limited, and the impact of physical capital investment on economic growth is not as significant as in emerging markets like China. Consequently, the enhancement of labor efficiency plays a more critical role in their economic development, leading to higher investments in education.

In conclusion, the proportion of language cognitive ability investment varies across different stages of economic development. In the early stages, when the level of educational cognitive ability is low, the positive effects of cognitive ability investment may be outweighed by the negative effects, resulting in negative growth outcomes if investment is excessive. However, as the society progresses through a phase of language cognitive ability accumulation, the impact of cognitive ability on labor efficiency becomes more apparent. At this point, the positive effects of language cognitive ability investment may surpass the negative effects, leading to an increase in the investment ratio. In the final stage, when the economy has reached a highly developed state, the contribution of investment-driven growth to the economy diminishes, and the negative effects of cognitive ability investment weaken while the positive effects strengthen. As a result, the proportion of educational cognitive ability investment reaches a higher level. This phenomenon reflects the recognition that in a highly developed economy, the enhancement of language cognitive abilities plays a crucial role in driving sustained growth, making it necessary to allocate significant resources to education and cognitive ability development.

Discussion and Implications

The significant role of cognitive abilities in driving economic growth has attracted considerable attention. This study aims to shed light on the relationship between educational quality, cognitive abilities, and economic growth from a cognitive perspective. The findings reveal that cognitive abilities exert a twofold influence on economic growth. On one hand, they enhance labor efficiency and facilitate economic expansion. On the other hand, there is a crowding-out effect associated with cognitive abilities, which hampers the pace of economic growth. Consequently, the overall economic growth rate is determined by the relative magnitudes of these two effects. Li et al. (2022) also proved that English proficiency plays a crucial role in economic development; however, its impact is entirely mediated by economic policies. Glewwe et al. (2014) indicate that the influence of education on economic growth in Africa is comparatively weaker than in other nations, possibly attributable to lower educational standards. The simulations conducted in Hanushek and Woessmann (2020) study reveal that the previous estimations regarding the influence of knowledge capital on economic growth have significant implications for national economies. Therefore, the findings of this study are consistent with previous research.

Based on the simulation results, when the economy is in an underdeveloped stage, educational cognitive abilities exhibit a strong crowding-out effect. Enhancing cognitive abilities not only fails to stimulate economic growth but actually hampers it. However, after a certain stage of accumulation, the positive effects of educational quality and cognitive abilities on economic growth become evident. Further enhancing cognitive abilities does not impede economic growth. In the developed stage of the economy, the positive effects of cognitive abilities significantly strengthen, and enhancing cognitive abilities becomes instrumental in promoting economic growth. In fact, as the economy continues to evolve, the positive effects of cognitive abilities on economic growth intensify. Consequently, education policies shift from focusing solely on quantity to incorporating both quantity and quality, while economic growth transitions from extensive to sustainable. Therefore, educational quality and cognitive abilities are crucial for the economic transformation and long-term growth.Our findings align with previous research conducted by Glewwe et al. (2014) and Hanushek, & Ludger (2008).

According to the analysis presented in this paper, we propose the following two policy implications: 1) Establish education development goals based on different stages of economic development: As revealed in the preceding analysis, the impact of educational quality and cognitive abilities on economic growth varies across different stages, depending on the levels of physical capital and cognitive abilities. With the rapid growth of our country's economy, the importance of cognitive abilities becomes paramount. This calls for increased investment in education, not only focusing on quantity but also raising cognitive abilities to a level that aligns with economic development. However, it is crucial to be mindful of the crowding-out effect of cognitive abilities and avoid blindly expanding educational investments, which may hinder the accumulation of physical capital. 2) Establish a comprehensive cognitive ability assessment system and improve the education evaluation framework: As demonstrated in this analysis, cognitive abilities are integral components of educational quality. To enhance cognitive abilities, it is necessary to establish a comprehensive cognitive ability assessment system that promptly captures the cognitive abilities of different age groups and educational stages. The establishment of a cognitive ability assessment system relies on continuous exploration by domestic education professionals. Additionally, lessons can be learned from well-developed countries that have existing cognitive ability testing systems, such as TIMSS, PISA, NAEP, among others.

In conclusion, there are two promising directions for future research. Firstly, given China's status as a relatively developed Asian country that participates in international assessments of student performance, further investigation into the quality of education in China and the influence of education quality and language cognitive ability on its economic growth would be valuable. Secondly, there is a need for more microeconomic studies in Asian countries that employ randomized trials and other methodologies to examine the determinants of economic growth. These studies can offer practical recommendations to enhance language skills, cognitive ability, and education quality in these countries.

The study found the relationship among cognitive capacity, educational quality, and economic development in the context of China. It provides insight into the complex interaction between these aspects through the analysis of two growth models. The results imply that the economic growth rate depends on the interaction between the positive effects arising from the accumulation of linguistic cognitive ability and educational quality, as well as the adverse effects resulting from investments in cognitive ability. The findings show that investing in cognitive ability has a positive impact when cognitive ability is high, but a negative impact when cognitive ability is low, which limits the impact of cognitive ability development on economic growth. Therefore, it has significant contribution to among education, cognitive development and economics research areas. Moreover, it filled the gaps among education, cognitive development and economics.

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Mathematical Appendix

Appendix A. Proof of Proposition 2

Proof: If there exists an equilibrium point in the economy, then there exist $\dot{c} = \dot{k} - 0$ and (k^*, c^*) that satisfy the following equations:

$$\frac{(1-\mathrm{a})\ \mathrm{f}'(\mathrm{k}^*) - \rho}{\sigma} = \mathrm{af}\,(\mathrm{k}^*) - \delta \quad (26)$$

$$c^* = (1-\mathrm{a}) - \mathrm{ak}^*\mathrm{f}\,(\mathrm{k}^*) + \delta \mathrm{k}^* \quad (27)$$

By the Inada conditions, there exists a $k^* \in (0,\infty)$ that $\frac{(1-\mathrm{a})\ \mathrm{f}'(\mathrm{k}^*) - \rho}{\sigma} = \mathrm{af}\,(\mathrm{k}^*) - \delta$ holds, and $G(k) = \frac{(1-\mathrm{a})\ \mathrm{f}'(\mathrm{k}^*) - \rho}{\sigma} - \mathrm{af}\,(\mathrm{k}^*) + \delta$ is monotonically decreasing. Therefore, there must exist a unique k^*, and the proposition is proven.

Appendix B. Proof of Proposition 3

Proof: Linearizing $\dot{c}, \dot{k}$ around the equilibrium point (k^*, c^*) yields the following:

$$\begin{bmatrix} \dot{k} \\ \dot{c} \end{bmatrix} = J \begin{pmatrix} \mathrm{k-k}^* \\ \mathrm{c-c}^* \end{pmatrix}$$

$$\frac{d\dot{k}}{dk} = (1-\mathrm{a})\mathrm{f}'(\mathrm{k}) - \mathrm{akf}'(\mathrm{k}) + \delta$$

$$\frac{d\dot{k}}{dc} = -1$$

$$\frac{d\dot{c}}{dk} = \frac{(1-\mathrm{a})\ \mathrm{f}''(\mathrm{k})}{\sigma} - \mathrm{af}'(\mathrm{k})$$

$$\frac{d\dot{c}}{dc} = 0$$

Where

$$J=\begin{pmatrix} \frac{\partial \dot{k}}{\partial k} & \frac{\partial \dot{k}}{\partial c} \\ \frac{\partial \dot{c}}{\partial k} & \frac{\partial \dot{c}}{\partial c} \end{pmatrix} = \begin{pmatrix} (1\text{-a})f''(k) - af(k) - akf''(k)+\delta & -1 \\ \frac{(1-a)f''(k)}{\sigma} - af'(k) & 0 \end{pmatrix}$$

The characteristic equation is given by $\varpi^2 - \varpi\left[(1-a)f'(k) - af(k) - akf'(k) + \delta\right] + \frac{(1-a)f''(k)}{\sigma} - af'(k) = 0$. Since $\varpi_1\varpi_2 = \frac{(1-a)f'(k)}{\sigma} - af'(k) < 0$ and $b^2 - 4ac > 0$, this implies that the differential equation has two real eigenvalues, one positive and one negative. Therefore, the economic system is locally saddle-point stable. Thus, the proposition is proven.

Appendix C. Proof of Proposition 4

Proof: In order to study the optimal investment in cognitive ability along the balanced growth path, let's assume that the economy is on the balanced growth path, and the utility level of the representative consumer is represented by:

$$U^{SS}(a) = \int_0^\infty \frac{(c^*)^{1-\sigma} - 1}{1-\sigma} e^{-\rho t} dt = \frac{(c^*)^{1-\sigma} - 1}{\rho(1-\sigma)} \quad (28)$$

U^{SS} represents the utility level on the balanced growth path, and it can be expressed as a function of a. The optimal value of a is given by the following equation:

$$a^{SS} = \underset{a}{Max} \frac{\left[(1\text{-}a)f(k^*) - ak^*f(k^*) + \delta k^*\right]^{1-\sigma}}{1-\sigma} \quad (29)$$

The first-order necessary condition for this optimization problem is:

$$(c^*)^{-\sigma}\left[((1-a)f'(k^*) - af(k^*) - akf'(k^*) + \delta)\frac{\partial k^*}{\partial a} - f(k^*) - k^*f(k^*)\right] = 0 \quad (30)$$

and also $\frac{(1-a)f'(k^*) - \rho}{\sigma} = af(k^*) - \delta$, Full differentiation of both sides of this equation gives:

$$\frac{\partial k^*}{\partial a} = \frac{\sigma f(k) + f'(k)}{(1-a)f''(k) - a\sigma f'(k)} \quad (31)$$

Substituting this equation into the first-order condition, we obtain:

$$(c^*)^{-\sigma}\left[((1\text{-}a\text{-}ak)f'(k^*) - af(k^*) - akf'(k^*) + \delta)\frac{\sigma f(k^*) + f'(k^*)}{(1-a)f'(k^*) - af'(k^*)} - f(k^*) - k^*f(k^*)\right] = 0$$

(32)

The proposition is proven.