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Human Capital Externality, Knowledge Spillover, and Sustainable Economic Growth*

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We attempt to introduce human capital externality and endogenous labor-leisure decision into the analytical framework constructed by Uzawa (1965) and Lucas (1988) simultaneously, so as to explore the internal relationship among endogenous labor supply, human capital externality and sustainable economic growth as well as the choice problem of government's education policy. The main conclusions of this thesis are as follows: 1. The sound degree of household's time endowment allocation and the magnitude of human capital externality will work on the height of the steady state's growth rate on the balanced growth path. 2. The larger the subjective time preference and the stronger the leisure awareness is, the lower the steady state's growth rate of the country will be; the larger the output elasticity and education investment expenditure elasticity of knowledge spillover becomes, the higher the steady state's growth rate of the country will be; and vice versa. 3. The government can choose from carrying out lump-sum output taxation or education subsidy to stimulate the adjustment of private labor supply and human capital investment, such that the decentralized economy could be induced to the sustainable optimal growth state. We employ China's province level panel data to analyze empirically, all the main conclusions are supported by the empirical research; meanwhile, we also observed some puzzles which are different from the existing conclusions.

Key Words: Human capital externality; Knowledge spillover; Sustainable economic growth; Education policy; Panel data model.

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1. INTRODUCTION

"The consequences for human welfare involved in questions like these are simply staggering: Once one starts to think about them, it is hard to think about anything else."[1], just as Robert E. Lucas, Jr. pointed out, economic growth is an attractive and exciting research field. It has been verified theoretically and empirically that human capital plays a vital role in the process of economic growth, and it is also a fundamental element to promote long-term economic growth. In 1988, Lucas made one explanation to human capital externality[2], he divided the effect of human capital into internal effect and external effect, where the former means that individual's human capital can enhance its own productivity and revenue while the latter indicates that the increase of average human capital can promote the productivity of all production factors. Because little attention has been paid to the latter effect when households make their decisions about human capital investment, it is recognized as the human capital externality. Lucas employ an externality parameter ε to measure the degree of external effect that average human capital makes on the productivity of each enterprise[3], however, in our analysis we follow the route taken by Grossman (1972) while he analyzed the health human capital[4]. We think that human capital externality not only can enhance production factor's productivity,

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[1]Refer to Robert E. Lucas. Jr. On the Mechanics of Economic Development [J] , Journal of Monetary Economics ,1988 ,(22):3 - 42.

[2]See also Robert E. Lucas. Jr. On the Mechanics of Economic Development [J] , Journal of Monetary Economics ,1988 , (22):3-42.

[3]Robert. J. Barro and Xavier Sala-i-Martin, Economic Growth, Beijing, China Social Sciences Press, 2000, 1st edition, p196-197.

[4]Grossman, M. The demand for health: a theoretical and empirical investigation, NBER, Occasional paper119, Columbia University Press.

but also can improve household's utility level $z(t)$ through increasing the society's average knowledge level. In other words, we assume that the average knowledge level which represents human capital externality enters household's utility function, thus we can study the effect that human capital makes on sustainable economic growth through the general equilibrium framework.

New-classical economists investigate leisure thoroughly through considering it as a normal good which has positive marginal effect, however, in the early studies of economic growth, such as Uzawa (1965) and Lucas (1988), leisure was neglected (Qing Qianlong, 2005). Actually, leisure is a key element in contemporary economic fluctuation theory, just as Finn Kydland (1995) pointed out, in business cycle, almost 2/3 output fluctuation was attributed to the variation of working hours and leisure. Following Ryder Stafford and Stephan (1976), Ladron. de. Guevara, Ortigueira and Santos (1995), Stokey and Rebelo (1995), we introduce leisure represented by e into household's utility function, in order to investigate how household's decisions on leisure and labor supply affect economy's steady growth as well as its effects on human capital externality and education.

The structure of this paper is as follows: Section 2 is literature review, we will tease and comment the existing related literature, so as to deduce the problem discussed in this paper and our novelties. Section 3 is the basic framework of our model, we postulate the economy's consumption and preference, production and technology as well as the flow of knowledge spillover, meanwhile, we simultaneously introduce consumption, leisure and average knowledge level into household's utility function. In section 4, based on endogenous growth theory, we conduct social optimal analysis and comparative static analysis through studying social planner's problem, at the same time, we also study the effect that endogenous labor supply and leisure decisions make on economy's balanced growth path and further investigate the result which variations of all kinds of parameters makes on steady growth rate. In the following section 5, we concentrate on the equilibrium of decentralized economy and government's problem on the choice of education policy, in order to investigate the effect that endogenous transformation of human capital externality makes on economy's steady state. In section 6, we employ China's province level panel data to make empirical tests on the main propositions that we have already made in our theoretical analysis from the static and dynamic angle of view. The final part is our conclusions.

2. LITERATURE RETROSPECTION

In 1776, Adam Smith already took manpower as capital to commence studies (Zhang Xianji and Zhan Lianfu, 2005; Gao Bei and Hou Xiaohui,

2007), however, as a concept, human capital was firstly proposed in 1935 (J. R. Walsh, 1935). Under the endeavor of Theodore W. Schultz, Gale. Johnson, Kenneth J. Arrow et al, human capital gradually constituted a systematic theory till the late 1950s and early 1960s. As for the discussion of the relationship between human capital and economic growth, we can trace back to the development of economic growth theory itself. K. J. Arrow (1962) proposes the learning by doing model, thus he introduces the process of obtaining knowledge while individuals participating production into endogenous model. Paul. M. Romer (1986) makes modifications to the production function by introducing externality, he investigates the external effect that knowledge spillover which related to technique made on production, and this is the earliest research concerning the discussion of the relationship between human capital externality and economic growth. Robert E. Lucas, Jr. (1988) uses an external parameter ε to measure the degree of external effect that average human capital makes on the productivity of each enterprise, and constructs an endogenous growth model which put human capital externality in center, what's more, human capital reveals increasing returns to scale and thus made economic growth sustainable, henceforth, human capital became the key element of economic growth. After that, Paul. M. Romer (1990), Gene. M. Grossman and Elhana Helpman (1991), Rebelo. S (1991), Philipe Aghion and Peter Howitt (1992) continue to develop endogenous growth theory separately following those two directions of endogenous research & development (R&D) and endogenous human capital, they think that either human capital or research & development (R&D) could stimulate growth through influencing output. But just as Johannes Hers (1998) pointed out "however, the relative importance of human capital in stimulating economic growth and the mechanism through which human capital stimulates growth remain unclear."[5] Hence, we try to introduce labor-leisure decision and knowledge spillover into utility function, from the perspective that human capital externality affects household's utility, we study the relationship among human capital externality, knowledge spillover and sustainable economic growth, and this is a new research method which differentiates our paper to the existing literature.

Different from the earlier endogenous economic growth theory, Jones (1995), Redding (1996), Sjogren (1998), Keller (1996) and Arnold (1998), Funke and Strulik (2000) attempt to introduce human capital investment and research & development (R&D) into a unique framework, they try to make meaningful considerations from a complementary view of angle. Klenow. Peter J. (1998), Cannon and Edmund (2000), Teles. Vladimir K

[5]Johannes Hers. Human capital and economic growth: a survey of the literature, cpb report, 1998, 02.

(2005), Mengistae. Taye (2006) study the application situation of the endogenous growth theory. Robert. Barro (1991) investigates the relationship between education, human capital and economic growth, and verified the capability to explain economic phenomenon of endogenous growth models; what's more, Barro (2000), Chu and others (1995), Tanzi and Chu (1998) also make studies on these aspects, although these research has paid much attention to the combination of human capital externality and research & development (R&D), however, no research has already made a very good integration of the measurement of human capital externality and research & development (R&D). We employ the level of knowledge spillover $z(t)$ to measure human capital externality, and try to unify human capital externality and knowledge spillover into an unique framework, which is also one of the novelties of our research.

As for the aspects of government education expenditure, human capital and economic growth, Cronovich (1997, 1998) explore the theoretical possibility of effects that government expenditure made on endogenous technological improvement and economic growth. Ross. Capolupos (2000) constructs an endogenous model whose human capital was accumulated through government public education expenditure, and explores the relationship between education taxation, human capital accumulation and economic growth. The research conducted by Gupta and Verhoeven (2001), Gupta, Verhoeven and Tiongson (1999) reveals that the scale and efficiency of government education investment play a very important role in the process of promoting society's economic performance. Shuanglin Lin (2001) studies the effect that different kinds of taxation made on human capital accumulation and economic growth. Although these literature recognized that government expenditure indeed made contributions to economic growth, little attention has been paid to the functioning mechanisms between government education investment and economic growth. Therefore, following the ideas expressed by Gradus and Smulders (1993), Smulders and Gradus (1996) and Chen, Lai and Shieh (2003) in their models, we combine knowledge spillover level $Z(t)$, education investment expenditure $G(t)$ and economic output $Y(t)$ together via employing an equation which measures the flow of knowledge spillover, thus we can analyze the interaction mechanisms between them, which also constitutes one of the novelties in our research.

Furthermore, some literature explores the relationship between income distribution, equality, human capital and economic growth, such as Glomm and Ravikumar, 1992; Zhang, 1996,2003; Bovenberg and Jacobs, 2005. Besides, some paper studies the relationship between institution and economic growth, for example, Daron Acemoglu, 2007. However, these work has little connection with the focus of our research. Literature relating to the empirical studies on the relationship between human capital externality, labor

supply decisions as well as leisure and economic growth is relatively scarce. However, empirical literature about the interactions between education investment, human capital accumulation and economic growth is relatively abundant, Rob A. Wilson and Geoff Briscoe (2004) made a very comprehensive and elaborate review[6]. Thereafter, Keller (2006) investigates how education affects economic growth in developed countries, and reveals that the lagged 10 years' enrollment rate of high school and university education have obvious effect on per capita growth. Jamison and Hanushek (2006) make use of data from more countries and find out that the quantity and quality of education both have important effect on per capita growth rate. Obviously, these empirical literature studies the short-run relationship between education, human capital accumulation and economic growth, but ignores to analyze the long-term dynamic effect. Therefore, in this paper, we will employ vector auto-regression model to inquire the inner dynamic relationship between them and we will also apply panel data model to make comparisons, which compose the empirical innovations in our research.

3. THE BASIC FRAMEWORK OF THE MODEL

In this paper, at first, we assume that the whole economy is composed of a government and a representative family. Secondly, we suppose that the economy's representative household not only is the commodity's consumer, but also is the producer of our economy[7], and the family just produce one homogenous commodity[8], this commodity can be either used for consumption or paying for government taxation, as well as education expenditure investment. Thirdly, without the loss of generality, we assume the time endowment of the household is 1 in this paper, where $m(t)$ is used for working, $e(t)$ is set aside for leisure and the residual time $\nu(t)$ is used for accumulating human capital. Finally, as for population growth, we follow the method taken by Barro and Sala-i-Martin (1995), we standardize the population at time 0 to 1, then the population at time t is $L(t) = e^{nt}$, of

[6]See Rob A. Wilson and Geoff Briscoe. The impact of human capital on economic growth: a review, Third report on vocational training research in Europe: background report. Luxembourg: Office for Official Publications of the European Communities, 2004, Cedefop Reference series, 54.

[7]Barro and Sala-i-Martin (1995) proved that, an economy which segregates the household sector and the production sector, also named enterprise sector, is equivalent to a economy whose theoretical framework is that household directly participate in production, refer to Barro and Sala-i-Martin, Economic Growth, Beijing, China Social Sciences Press, 2000, 1st edition; there is another advanced textbook written by professor Liutang Gong, Advanced Macroeconomics, Wuhan, Wuhan University Press, 2005. 4.

[8]Here homogeneous commodity means that the commodity can easily transfer from capital goods to consumption goods, and vice versa, this is the hypothesis often used by growth literature, refer to Barro and Sala-i-Martin, 1995.

which n is the growth rate of population, if $C(t)$ is the total consumption at time t, then $c(t) = C(t)/L(t)$ is the per capita consumption of each household.

3.1. Consumption and Preference

Differentiating from the study method employed by Uzawa (1965) and Lucas (1988), we assume that at time t the average knowledge level $z(t)$ affects the representative household's utility; furthermore, the average knowledge level $z(t)$ is affected by average output $y(t)$ and per capita government education expenditure $g(t)$, in order to study human capital externality. Therefore, the representative household's utility not only comes from per capita consumption $c(t)$ and leisure $e(t)$, but also comes from the economy's average knowledge level $z(t)$ at time t, which reflects the economic activity participant's ability and can enhance household's capability to engage in production activities, hence, it can bring positive utilities to the household[9], the representative household want to maximize the following total utility[10]:

$$\max \int_0^{\infty} u[c(t), e(t), z(t)] \cdot \exp(nt) \cdot \exp(-\rho t) dt \tag{1}$$

Equation (1) assumes that the household wants to achieve maximization on the sum of discount values about all the instantaneous utility functions $u[c(t), e(t), z(t)]$, where ρ is the subjective time preference, $u[c(t), e(t), z(t)]$ is the instantaneous utility function, and $u_c > 0$, $u_{cc} < 0$, $u_e > 0$, $u_{ee} < 0$, $u_z > 0$, $u_{zz} < 0$, $u_{ce} > 0$, $u_{cz} > 0$, $u_{ez} > 0$ were satisfied. Furthermore, the following Inada conditions were also held: $\lim_{c\to 0} u_c \to \infty$; $\lim_{c\to\infty} u_c \to 0$; $\lim_{e\to 0} u_e \to \infty$; $\lim_{e\to\infty} u_e \to 0$; $\lim_{z\to 0} u_z \to \infty$; $\lim_{z\to\infty} u_z \to 0$. To guarantee that equation (1) can be solved, we adopt the assumption that $\rho > n$ as Barro and Sala-i-Martin (1995). For simplicity of our model and analytical process, we set the instantaneous utility function as the following logarithm linear form[11]:

$$u[c(t), e(t), z(t)] = \ln c(t) + \varepsilon \ln e(t) + \omega \ln z(t) \tag{2}$$

[9]Here we treat this positive utility resulted from the positive human capital externality, so we can call $z(t)$ knowledge spillover level, which measures the magnitude of externality.

[10]In order to show the clear relationship between each variable and time t, we don't omit t here; however, for convenience to express, without loss of clearness, time t can be omitted.

[11]Actually, for a more general form of the widely used Cobb—Douglas utility function: $u(c(t), e(t), z(t)) = \frac{(c(t)e(t)^{\varepsilon} z(t)^{\omega})^{1-\theta} - 1}{1-\theta}$, although the model in our paper may become more complex, the main conclusions will be still correct and robust.

In the above equation, the parameters ε and ω are positive constants, and each measures the effect degree that leisure and average knowledge level made on consumer's utility.

3.2. Production and Technology

We assume that the household in the economy only needs one input of element to produce: effective human capital, which is the adjusted labor supply through human capital, according to the study conducted by Duffy and Papageorgiou (2000). From the previous assumption, we know that this production not only can be used to consume and pay for the taxation levied by the government, but also can be spent on education investment. Based on the method taken by Lucas (1988), we don't take physical capital into consideration, and assume the form of the production function as the following:

$$Y(t) = m(t) \cdot h(t) \cdot L(t) = u(t) \cdot h(t) \cdot \exp(nt) \tag{3}$$

Where $Y(t)$ is the total output, $h(t)$ is the average human capital level.

The purpose of human capital investment for a household is to accumulate human capital, or broadly speaking, it is to accumulate technological capital or knowledge. As the existence of human capital externality, the accumulation of human capital such as full-time school education and on the job training is non-convex. We make modifications to the postulate about human capital accumulation made by Uzawa (1965) and Lucas (1988), and we take the effect of depreciation factor made on human capital accumulation, that is the variation of human capital equals the multiplication of the time devoted into study and the existing human capital level minus the depreciation of human capital, then we have[12]:

$$\dot{h}(t) = B \cdot \nu(t) \cdot h(t) - d \cdot h(t) = [B(1 - e(t) - m(t)) - d] \cdot h(t) \quad B > 0 \tag{4}$$

Of which, $\dot{h}(t)$ is the increment of human capital, and indicates the outcome of human capital accumulation, B is the parameter which measures the human capital efficiency and reflects the productivity of the education sector, d indicates the depreciation speed of human capital.

3.3. Knowledge Spillover Level

Based on the idea of modeling externality by Uzawa (1965), Lucas (1988), Romer (1986, 1989), Barro (1995, 1996), Zhang and Lee et al. (2003), Tamura (2006), we assume that the knowledge level in economy is a function of output plane and education expenditure amount. The reasons are

[12]In this paper, we treat human capital like physical capital that they will discount while time elapses, therefore, we introduce the discount term $d \cdot h(t)$, and this makes our human capital accumulation function different from the form given by Lucas (1988), which makes this paper's economic intuition more dominant.

as follows: on the one hand, output $Y(t)$ is the main source of income, which determines the development level of education and accumulation plane of knowledge; on the other, education expenditure $G(t)$ supplied by the government can promote the development of education via enhancing the knowledge amount. As a result, the flow equation of knowledge spillover level is assumed as follows[13]:

$$Z(t) = Y(t)^{\alpha} G(t)^{\beta} \tag{5}$$

In the above equation, parameters α and β are positive constants, and satisfy $\alpha + \beta = 1$, α and β represents the elasticity of knowledge spillover level $Z(t)$ to output amount $Y(t)$ and the elasticity of knowledge spillover level $Z(t)$ to education expenditure $G(t)$.

4. EQUILIBRIUM ANALYSIS OF SOCIAL PLANNER'S ECONOMY

In section 3, we have already constructed the analytical framework of this paper through assuming preference, technology and externality. In the following part, we will analyze the social planner's decision problem, in order to study the inner relationship between endogenous labor supply, knowledge spillover and economic growth as well as when the economy is in the steady state, how the variation of each kinds of parameters affect consumption, government and economic growth.

4.1. Social Planner's Decision Problem

Assume there is a social planner in the economy[14], what he considers is the welfare of the whole society. As what we employs in this paper is the representative household, hence, the social planner's welfare maximization can be given by the following optimal problem[15][16]:

$$\max_{m,e,g} \int_0^{\infty} (\ln c(t) + \varepsilon \ln e(t) + \omega \ln z(t)) \cdot \exp(nt) \cdot \exp(-\rho t) dt \tag{6}$$

[13]This equation enables us to measure the magnitude of human capital externality by employing the flow of knowledge level, which differentiates our analysis with Lucas (1988), who made use of the output elasticity parameter of human capital to measure externality, and this is one of the novelties of our paper.

[14]Social planner, which is also named as central planner, please refer to Robert J Barro and Sala-i-Martin (1995), Economic Growth, Beijing, China Social Sciences Press, 2000, 1st edition.

[15]As $C(t) = m \cdot h(t) \cdot e^{nt} - G(t)$, indicates that total consumption is equal to total output minus the part spent on education expenditure, divide both sides of this equation by e^{nt} and we can get the per capita variable expression.

[16]Based on equation (5), we can get: $Z(t) = Y(t)^{\alpha} G(t)^{\beta}$, as $\alpha + \beta = 1$, so divide both sides simultaneously by e^{nt} so we can get $z(t) = (mh)^{\alpha} g^{\beta}$.

s.t. $c(t) = m(t)h(t) - g(t)$

$$\dot{h} = [B(1 - e(t) - m(t)) - d] \cdot h(t)$$

$$z(t) = (m(t)h(t))^{\alpha} g(t)^{\beta}$$

According to dynamic optimization theory, we define the Current-value Hamilton function[17] as follows:

$$H_c = [\ln(mh - g) + \varepsilon \ln e + \omega \ln((mh)^{\alpha} g^{\beta})] + \lambda[B(1 - m - e) - d]h \quad (7)$$

there are three control variables m, e, g and one state variable h in this optimal control problem, in equation (7), $\lambda(t)$ is the co-state variable, and it indicates the shadow price of state variable $h(t)$ at time t, based on the modified maximum value theory, we can get the first order conditions and transversality conditions which maximizes (7) as follows:

$$\frac{\partial H_c}{\partial m} = \frac{h}{c} + \frac{\omega\alpha}{m} - \lambda B h = 0 \quad (8)$$

$$\frac{\partial H_c}{\partial e} = \frac{\varepsilon}{e} - \lambda B h = 0 \quad (9)$$

$$\frac{\partial H_c}{\partial g} = -\frac{1}{c} + \frac{\omega\beta}{g} = 0 \quad (10)$$

$$\dot{\lambda} = -\frac{\partial H_c}{\partial h} + (\rho - n)\lambda$$

$$= -\frac{m}{c} - \frac{\omega\alpha}{h} - \lambda[B(1 - m - e) - d] + (\rho - n)\lambda \quad (11)$$

$$\lim_{t \to +\infty} \lambda h(t) \exp[-(\rho - n)t] = 0 \quad (12)$$

Equations (7) $\sim$ (12) together depicts the dynamic system that we studies, when social welfare maximizes, the economy is in its steady state, each variable $\{y, c, h, g, \lambda\}$ is on their balanced growth path respectively, to study the characters of the steady state, solve this system and we can get proposition 1:

PROPOSITION 1. *When social welfare maximizes, the economy is in its steady state and each variable is on their balanced growth path respectively, the following two properties hold:*

[17] As for the contents of dynamic optimization and Present value Hamilton function, please refer to Alpha C. Chiang, Elements of Dynamic Optimization, McGraw-Hill Publishing Co., 1992, Chapter 8; M. L. Kamien and N. L. Schwartz, Dynamic Optimization: The Calculus of Variations and Optimal Control in Economics and Management, Second Edition, North-Holland (Advanced Textbooks in Economics), Amsterdam and New York, 1991.

(1) household's optimal allocation of time is

$$m = \frac{\rho - n}{B} \tag{13}$$

$$e = \frac{\varepsilon(\rho - n)}{B(1+\omega)} \tag{14}$$

$$\nu = \frac{(1+\omega)(B-\rho+n) - \varepsilon(\rho-n)}{B(1+\omega)} \tag{15}$$

(2) the steady state growth rate for each variable of the economy is

$$g_h = g_y = g_c = g_g = \frac{(1+\omega)(B-\rho+n) - \varepsilon(\rho-n)}{1+\omega} - d \tag{16}$$

$$g_Y = g_C = g_G = g_Z = \frac{(1+\omega)(B-\rho+n) - \varepsilon(\rho-n)}{1+\omega} - d + n \tag{17}$$

The proof process is omitted here, please contact us for details if you are interested in it.

Proposition 1 reveals that, the representative family's optimal allocation on time endowment is determined by subjective time preference ρ, population growth rate n, human capital accumulation efficiency B and the importance of society's average knowledge level to the family ω. As we assume that the representative family's time endowment is 1, hence it requires that $0 < m < 1$, $0 < e < 1$, $0 < \nu < 1$, however, based on equations (13) $\sim$ (15) as soon as $\rho - n < B$ and $\varepsilon < 1 + \omega$ simultaneously hold[18], the former three conditions will be satisfied, that is to say, household's subjective time preference minus population growth rate must be smaller than human capital accumulation efficiency, meanwhile, the important degree of leisure to consumer must be less than that of knowledge plus 1, this is the conditions for representative families to achieve optimal allocation of resources. Moreover, the discount rate d of human capital is also very important to the steady state growth rate of each variable in the economy, in the steady state, when $\rho - n < B$ and $\varepsilon < 1 + \omega$ holds, output, consumption and knowledge spillover could achieve sustainable economic growth.

4.2. Comparative Static Analysis

We will make comparative static analysis in the following discussion, so as to study how the variation of parameters which represent preference, technology and knowledge spillover affects household's decision on how to allocate time and the economy's long-term growth rate.

[18]According to $m + e + \nu = 1$, as soon as $0 < m < 1$, $0 < e < 1$, then $0 < \nu < 1$ naturally holds, so, based on equations (13) and (14) we can deduce that $\rho - n < B$ and $\varepsilon < 1 + \omega$ hold.

4.2.1. Effect of The Variation of Time Preference Parameter

According to equations (13) $\sim$ (17), we make partial derivative to the time preference parameter, and we can get:

$$\frac{\partial m}{\partial \rho} = \frac{1}{B} > 0, \quad \frac{\partial e}{\partial \rho} = \frac{\varepsilon}{B(1+\omega)} > 0 \tag{18}$$

$$\frac{\partial \nu}{\partial \rho} = \frac{-(1+\omega)-\varepsilon}{B(1+\omega)} < 0, \quad \frac{\partial g_Y}{\partial \rho} = -\frac{1+\omega+\varepsilon}{1+\omega} < 0 \tag{19}$$

According to in-equations (18) $\sim$ (19), we know that, if the consumer's subjective time preference ρ is larger, which means that the consumer is more shortsightedness: the current consumption and leisure can bring more utility to him than the future's, in other words, the marginal utility of future consumption and leisure is decreasing, under this case, the representative family will increase the current time spent on working and leisure to attain higher utility: On the one hand, the increase of leisure time e indicates the decrease of labor supply, time ν devoted to study will also decrease, meanwhile this will make the variation rate of human capital lower[19] and reduce the accumulation rate of human capital, this is detrimental to the long-run growth of output[20], what's more, it makes the long-term growth rate of consumption, education investment expenditure decrease. On the other hand, the increase of working hours will enhance the current output and consumption, so as to promote the education investment level G and knowledge spillover level Z, which will be beneficial to short-run economic growth and the improvement of education level, thus, we can get the following proposition 2:

PROPOSITION 2. *If the subjective time preference ρ of the consumer in the economy is bigger, the household will pay more attention to the present consumption and leisure, although this may stimulate output growth and improvement of education level in the short run, it will be detrimental for the accumulation of human capital and sustainable economic growth, and can simultaneously low the growth rate of education expenditure in the long run.*

[19] According to equation (4) we have: $\dot{h}(t) = B \cdot \nu(t) \cdot h(t) - d \cdot h(t) = [B(1-e-m) - d] \cdot h(t)$, when $\nu(t)$ becomes smaller, $\dot{h}(t)$ will certainly decrease.

[20] Based on equation (5), we know: $Y(t) = m(t) \cdot h(t) \cdot L(t) = m(t) \cdot h(t) \cdot \exp(nt)$, as effective human capital $h(t)$ is the only element that affect output, therefore, if the accumulation rate of human capital decreases, in the long-run, the output $Y(t)$ will also decrease, and this will be detrimental to economic growth.

4.2.2. Effect of The Variation of Utility Parameter

Make partial derivative to the utility parameter in equations (13) $\sim$ (17), we can get:

$$\begin{aligned}
\frac{\partial m}{\partial \varepsilon} &= 0, \quad \frac{\partial e}{\partial \varepsilon} = \frac{\rho - n}{B(1+\omega)} > 0, \\
\frac{\partial \nu}{\partial \varepsilon} &= -\frac{\rho - n}{B(1+\omega)} < 0, \quad \frac{\partial g_Y}{\partial \varepsilon} = -\frac{\rho - n}{1+\omega} < 0 \qquad (20) \\
\frac{\partial m}{\partial \omega} &= 0, \quad \frac{\partial e}{\partial \omega} = \frac{-\varepsilon(\rho - n)}{B(1+\omega)^2} < 0, \\
\frac{\partial \nu}{\partial \omega} &= \frac{\varepsilon(\rho - n)}{B(1+\omega)^2} > 0, \quad \frac{\partial g_Y}{\partial \omega} = \frac{B - \rho + n}{(1+\omega)^2} > 0 \qquad (21)
\end{aligned}$$

According to in-equations (20) $\sim$ (21), if the representative household pays more attention to the utility brought by leisure, that is to say, the parameter ε will become larger, this will degrade the marginal utility brought by future leisure, and cause the family to increase the demand for the present leisure. Although the household will not adjust the time it devoted to working[21], the increase of leisure will reduce labor supply and learning time spent on accumulating human capital as well as education expenditure, which will engender negative impact on sustainable economic growth and human capital accumulation.

If the representative family thinks much of knowledge, knowledge spillover level $z(t)$ will bring more utility to the family, which means that the parameter ω will become larger, and this will promote the marginal utility of future leisure and the family must reduce current leisure[22], meanwhile the family will increase the time spent on accumulating human capital, this will increase the marginal return of human capital. At the same time, the larger the parameter ω is, the higher the education investment growth rate will be and the same to the steady state growth rate, hence, this will generate positive impact on education's long term development and economy's sustainable economic growth. Thus we get proposition 3 and 4:

[21] Based on equation (20), we can get: $\frac{\partial m}{\partial \varepsilon} = 0$, which indicates that the variation of ε will not affect working hours; meanwhile, as $\frac{\partial e}{\partial \varepsilon} = \frac{\rho - n}{B(1+\omega)} > 0$, so the representative family will increase the time spent on leisure and decrease that spent on education.

[22] According to equation (21), we have: $\frac{\partial e}{\partial \omega} = \frac{-\varepsilon(\rho - n)}{B(1+\omega)^2} < 0$, if ω increases, then e will decrease, hence the household will decrease time devoted to leisure, and this enhance future leisure's utility and decrease that of the present leisure.

PROPOSITION 3. *If the representative household in the economy pays more attention to leisure, which means a larger ε, then the family will set aside more time for current leisure and less time on accumulating human capital, this will promote consumption and output growth in the short run, however, it will lower output growth rate and education expenditure growth rate in the long run, and cause negative effect on human capital accumulation and sustainable economic growth.*

PROPOSITION 4. *If the importance of knowledge to the representative household in the economy is larger, which means a bigger ω, the family will reduce leisure and increase time spent on accumulating human capital conditional on not reducing labor supply, this will enhance output growth rate in the long-run and education investment's steady state growth rate, and will be beneficial for the development of long run education and sustainable economic growth.*

4.2.3. Effect of The Variation of Technology Parameter

Make partial derivative to the technology parameter in equations (13) $\sim$ (17), and we get:

$$\frac{\partial m}{\partial B} = -\frac{\rho - n}{B^2} < 0, \quad \frac{\partial e}{\partial B} = -\frac{\rho - n}{B^2(1+\omega)} < 0 \tag{22}$$

$$\frac{\partial \nu}{\partial B} = \frac{(\rho - n)(1+\omega+\varepsilon)}{B^2(1+\omega)} > 0, \quad \frac{\partial g_Y}{\partial B} = 1 > 0 \tag{23}$$

The increase on technological parameter B of human capital accumulation efficiency indicates that if the marginal return to human capital increases, the representative family will decrease time spent on current work m and leisure e, and increase the learning time ν spent on accumulating human capital, this will make the labor supply in the economy rise and enhance the steady state growth rate of each variable in economy and government's education investment growth rate, therefore, the household's decision can promote sustainable economic growth and continual improvement of education level, then we have proposition 5:

PROPOSITION 5. *To enhance the technological parameter B of human capital accumulation will make the representative family reduce time spent on working and leisure, and increase time spent on accumulating human*

capital, which is positive to promote long term economic growth rate, knowledge spillover growth rate and government education investment growth rate, and ultimately cause the improvement of social welfare and education level.

In this section, we have studied the representative household's time endowment allocation and each variable's steady state growth rate through solving social planner's problem, and we also have discussed the effect of the variation of every kind of parameters made on the representative household's time endowment allocation and each variable's steady state growth rate via comparative static analysis, in the following section 5, we will further study the equilibrium under decentralized economy and government's policy choice problems on education.

5. EQUILIBRIUM UNDER DECENTRALIZED ECONOMY AND GOVERNMENT'S POLICY CHOICE PROBLEMS ON EDUCATION

In this section, we will further study the equilibrium under decentralized economy and discuss government's policy choice problem. At present, some scholars take education investment as public investment to study the relationship between education investment and economic growth, such as Glomm and Ravikumar (1992), Eckstein and Zilcha (1994), Glomm and Ravikumar (2003), Zilcha (2003), Blankenau and Simpson (2004); meanwhile, other researchers treat education as a private investment good to investigate the function mechanism between subsidy to education and economic growth, such as Zhang (1996, 2003), Bovenberg and Jacobs (2005), Blankenau (2005). Based on these existing research methods, we first treat government education investment as a public good that was provided by the government, so as to study the relationship between one lump-sun taxation, government education investment and economic growth; next we take education investment as a private investment good, in order to investigate the effect that government education subsidy makes on economic growth.

5.1. Government's Education Investment and Output Taxation

At first, we mainly analyze how government's education expenditure affect long-term economic growth and knowledge spillover level, assuming that the government levies one lump-sum taxation from output Y according to the tax rate τ_Y so as to satisfy the need of education investment, under the condition that government accomplishes budget equilibrium con-

straint, we have:

$$R = G = \tau_Y \cdot Y \tag{24}$$

In equation (24), R is the lump-sum taxation, which equals government's education investment G, in this case, the representative family's budget constraint is $C = Y - G$. In a decentralized economy, we assume that the representative family is just a very small part of the economy so that it can't affect the operation manner of the whole economy. As knowledge spillover level $Z(t)$ is the function of output Y and education investment $G(t)$, so they treat the average knowledge spillover level $z(t)$ in the economy as constant $\overline{z}(t)$, thus the representative household can enjoy the benefit of education investment and can avoid extra investment. In the decentralized economy, the decision agent is not the social planner but the representative household, then the optimal problem for the representative family is:

$$\max_{m,e} \int_0^\infty (\ln c(t) + \varepsilon \ln e(t) + \omega \ln \overline{z}(t)) \cdot \exp(nt) \cdot \exp(-\rho t) dt \tag{25}$$

s.t. $c = mh - \tau_Y y$[23]

$\dot{h} = B \cdot \nu \cdot h(t) - d \cdot h(t) = [B(1 - e - m) - d] \cdot h(t)$

We define the Current-value Hamilton function as:

$$H_c = [\ln(1 - \tau_Y) mh + \varepsilon \ln e + \omega \ln \overline{z}(t)] + \lambda[B(1 - m - e) - d]h \tag{26}$$

there are two control variables m, e and one state variable h in this optimal control problem, in equation (26), $\lambda(t)$ is the co-state variable, and it indicates the shadow price of state variable $h(t)$ at time t, based on the modified maximum value theory, we can get the first order conditions which maximize (26) as follows:

$$\frac{\partial H_c}{\partial m} = \frac{1}{(1 - \tau_Y)u} - \lambda B h = 0 \tag{27}$$

$$\frac{\partial H_c}{\partial e} = \frac{\varepsilon}{e} - \lambda B h = 0 \tag{28}$$

$$\begin{aligned} \dot{\lambda} &= -\frac{\partial H_c}{\partial h} + (\rho - n)\lambda \\ &= -\frac{1}{(1 - \tau_Y)h} - \lambda[B(1 - m - e) - d] + (\rho - n)\lambda \end{aligned} \tag{29}$$

[23]As $C(t) = m \cdot h(t) \cdot e^{nt} - \tau_Y Y$, this indicates that total consumption minus one lump sum taxation, we divide the two sides by e^{nt} thus we can get per capita expression $c = mh - \tau_Y y$.

equations (26) $\sim$ (29) together depicts the dynamic system that we studies, through solving the representative family's optimal problem we can obtain the conditions that household, government and each variable satisfies in the decentralized economy when it is in its steady state, we can get proposition 6:

PROPOSITION 6. *In the decentralized economy, the two following characters will hold in the steady state which we get through the representative household's optimal behavior:*

(1) household's optimal allocation of time is

$$m = \frac{\rho - n}{B} \tag{30}$$

$$e = \frac{\varepsilon(1-\tau_Y)(\rho - n)}{B} \tag{31}$$

(2) the steady state growth rate of each variable in the economy is:

$$\begin{aligned} g_Y &= g_Z = g_C = g_G = g_h \\ &= B - (\rho - n) - \varepsilon(1-\tau_Y)(\rho - n) - d + n \end{aligned} \tag{32}$$

$$\begin{aligned} g_y &= g_z = g_c = g_g \\ &= B - (\rho - n) - \varepsilon(1-\tau_Y)(\rho - n) - d \end{aligned} \tag{33}$$

The proof process is omitted here, please contact us for details if you are interested in it.

Through comparing proposition 6 with proposition 1 we know that, in the decentralized economy, the growth rate of each variable in the steady state is all smaller than that of the social optimal level, from the perspective of economics, as there is strong externality in education investment and human capital accumulation, the private return of human capital investment is less than the social return of that, the household in the decentralized economy doesn't want to invest in education themselves and make other people become "free riders", hence, the magnitude of human capital investment in the decentralized economy is less than that for the social optimal level, which resulted that in steady state the growth rate generated by the representative family's decision is smaller than the optimal growth rate; however, the government can induce sustainable economic growth for the decentralized economy via adjusting output tax rate, as well as achieving

social optimal state, we can prove that[24], the government's optimal tax rate is:

$$\tau_Y^* = \frac{\omega}{1+\omega} \tag{34}$$

From proposition 6 we found that, the government can not only affect steady state growth rate, but also can adjust the allocation of household's time endowment via monitoring taxation rate, through simple comparative analysis we can find:

$$\frac{\partial e}{\partial \tau_Y} = -\frac{\varepsilon(\rho - n)}{B} < 0, \quad \frac{\partial \nu}{\partial \tau_Y} = \frac{\varepsilon(\rho - n)}{B} > 0, \quad \frac{\partial g_Y}{\partial \tau_Y} = \varepsilon(\rho - n) > 0$$

So, we have the following proposition 7 and proposition 8:

PROPOSITION 7. *If $\varepsilon \neq 0$, the government imposes output tax whose rate is τ_Y can reduce household's demand to leisure e and increase learning time ν spent on accumulating human capital while not affecting the labor supply m, so as to promote the society's knowledge level, which is beneficial to the economy's sustainable economic growth; if $\varepsilon = 0$, the resource allocation in the economy is not elastic anymore, then government's taxation policy to stimulate growth will not function.*

PROPOSITION 8. *In the decentralized economy, government can impose a lump-sum taxation whose optimal rate is $\tau_Y^* = \frac{\omega}{1+\omega}$, that is imposing public education investment policy, so as to enhance the household's time ν spent on accumulating human capital, this can promote education's development and induce the decentralized economy to society's optimal sustainable growth state.*

Through the above analysis, we have studied the decentralized economy's equilibrium problem and we also have made comparisons and modifications with the society's optimal level, which reveals the relationship existing between government's one lump-sum taxation, education investment and economic growth. In the following analysis, we will study education investment from another point of view, in order to investigate the effect that

[24]Here the optimal tax rate is not the rate which maximizes the government's tax income, it is rather the one which makes the growth rate of each variable in the decentralized economy's balanced growth path equal that for the social optimal balanced growth path, according to equations (17) and (32) we can have: $\tau_Y^* = \frac{\omega}{1+\omega}$.

government's education subsidy makes on household behavior and economy equilibrium.

5.2. Household Education Investment and Government Education Taxation or Subsidy

If the education investment $G(t)$ which affects knowledge spillover is provided by the household sector, as the public goods character of human capital externality and knowledge spillover, education's private return is smaller than social return, which can't be compensated by pure market mechanism. Without government intervention, for example, imposing taxation or enforcing education subsidy, the private education investment must be very small or even zero, so this requires government intervention. We assume that government can stimulate individual's education investment through imposing education tax whose rate is τ_Z, government's budget constraint is:

$$\tau_Z Z = TR \tag{35}$$

Where TR is the one time government transfer payment to household, hence the family's budget constraint becomes: $C = Y - G - \tau_Z Z + TR$, given τ_Z and TR, household not only considers how to allocate time endowment, but also thinks about how much to invest, then the representative household's optimal decision problem is:

$$\max_{m,e,g} \int_0^\infty (\ln c(t) + \varepsilon \ln e(t) + \omega \ln \overline{z}(t)) \cdot \exp(nt) \cdot \exp(-\rho t) dt \tag{36}$$

$$s.t. \quad c = mh - g - \tau_Z (mh)^\alpha g^\beta + tr$$

$$\dot{h}(t) = [B(1 - e - m) - d] \cdot h(t) \tag{37}$$

We define the Current-value Hamilton function as:

$$H_c = [\ln[mh - g - \tau_Z (mh)^\alpha g^\beta + tr] + \varepsilon \ln e + \omega \ln \overline{z}(t)] + \lambda[B(1 - m - e) - d]h \tag{38}$$

there are three control variables m, e, g and one state variable h in this optimal control problem, in equation (38), $\lambda(t)$ is the co-state variable, then the first order conditions and transversality conditions which maximizes

(38) are as follows:

$$\frac{\partial H_c}{\partial m} = \frac{h - \tau_Z \alpha Z/m}{c} - \lambda B h = 0 \tag{39}$$

$$\frac{\partial H_c}{\partial e} = \frac{\varepsilon}{e} - \lambda B h = 0 \tag{40}$$

$$\frac{\partial H_c}{\partial g} = -\frac{1 + \tau_Z \beta Z/g}{c} = 0 \tag{41}$$

$$\begin{aligned} \dot{\lambda} &= -\frac{\partial H_c}{\partial h} + (\rho - n)\lambda \\ &= -\frac{m - \tau_Z \alpha Z/h}{c} - \lambda[B(1 - m - e) - d] + (\rho - n)\lambda \end{aligned} \tag{42}$$

$$\lim_{t \to +\infty} \lambda h(t) \exp[-(\rho - n)t] = 0 \tag{43}$$

Through comparing the first order conditions (39) $\sim$ (43) for decentralized economies with that (8) $\sim$ (12) for social optimal solutions, we can find that government can obtain optimal growth rate in a decentralized economy equilibrium framework via imposing education tax or subsidy, which resulted the optimal tax rate:

$$\tau_Z^* = -\frac{g}{\beta Z} = -\frac{g^\alpha}{\beta (mh)^\alpha} = -\frac{\{\beta[c(1 + \omega) - y]\}^\alpha}{\alpha^\alpha \beta y^\alpha} \tag{44}$$

from the expression for optimal tax rate, we can see that, in order to keep public education investment continually growing and education sustainable developing, government must give subsidies to the household according to (43) under the background of everlasting economic growth, which is consistent with our intuition, because of the existence of human capital externality, the private return of education investment is smaller that social return, so the economy requires government intervention to induce household's investment so as to achieve social optimal level, such we get the following proposition 9:

PROPOSITION 9. *The government can enforce education policy, such as education subsidy, whose optimal subsidy rate is given by equation (44), to stimulate individual enhancing education investment, so as to make the human capital externality endogenous in the economy, and induce a decentralized economy to attain sustainable economic growth state.*

Through analyzing equilibrium under decentralized economy, we have studied the effect that government's output tax makes on economic growth,

because of the existence of human capital externality and knowledge spillover, the dispersion decision equilibrium of education investment must be lower than that of the social optimal level, therefore, government can choose appropriate education policy to induce decentralized economy to achieve the optimal state of sustainable economic growth.

6. EMPIRICAL ANALYSIS—RESEARCH BASED ON CHINA'S PROVINCE-LEVEL PANEL DATA

In the above theoretical analysis, we introduce human capital externality, knowledge spillover and labor-leisure decision into the framework constructed by Uzawa (1965) and Lucas (1988), in order to study the short run effect and long term relationship that among representative family's labor-leisure decision, knowledge spillover level, preference parameter and technological parameter variation, government education policy adjustment and steady state economic growth rate. In this section, based on China's province-level panel data, we first employ panel data model to make static analysis, in order to analyze the short run effect and static relationship between them; then we use vector auto-regression model to make dynamic analysis, so as to study the further long term and dynamic relationship between them.

6.1. Data Source and Empirical Design

The data we employed in this paper is province-level panel data from 29 provinces[25] between 1989 and 2005, which is 17 years in total, and the data comes from the database of National Bureau of Statistics (NBS) and that of China Economic Information Net (CEIN). At first, we use each province's resident consumption price index to adjust the regional gross domestic product (gdp), resident consumption level (cns), worker's revenue (lin), total value of fixed asset investment (inv), government income (gin) into its corresponding real value. After that, based on the theory content and availability of real data for each variable, we employ each province's labor income lin as the proxy variable of household's labor supply in the process of empirical studies, and we use resident's consumption plane cns

[25] Because of data availability, we use 29 provinces which include: 13 eastern provinces, such as Beijing, Tianjin, Liaoning, Heilongjiang, Jilin, Hebei, Shandong, Shanghai, Jiangsu, Fujian, Zhejiang, Guangdong, Hainan; 6 middle provinces, for example, Anhui, Shanxi, Henan, Hubei, Hunan, Jiangxi; 10 western provinces, including Qinghai, Xinjiang, Inner Mongolia, Guangxi, Sichuan, Xizang, Gansu, Yunnan, Guizhou, Shanxi, as Chongqing was separated from Sichuan at 1997, so Chongqing's data after 1998 are integrated with Sichuan's, we are grateful to professor Zhao Xiliang for helpful suggestions here.

to measure household's leisure level[26], we make use of average number of university graduate students as the proxy variable for society's average knowledge level; as tax is the main source of government's finance income, we use each province's finance income as the substitute variable for taxation. Finally, following the method dealing with health human capital investment taken by Wang Dihai, Gong Liutang and Li Hongyi (2008), we employ the number of universities in each province to measure human capital level, thus we choose data for the 8 variables from 29 provinces between 1989 and 2005, so the sample used in our paper includes 3944 data.

Based on the former theoretical study, the empirical part of our paper is divided into two sections: The first one deals with the static relationship existing between each variables, which is mainly accomplished through panel data model, and we also investigate the various performance of these relations in different regions of China. The other section mainly focuses on the dynamic relationships through constructing VAR model and making use of the impulse response function as well as the variance decomposition techniques.

6.2. Short Term Effect and Static Relationship Analysis—Research Based on Panel Data Model

Here we focus on the static and short run effect between each variable and *gdp*, in order to make more elaborate studies on the various performances of the relationship in different areas, we make use of the traditional method to divide areas of China taken by Cai Fang and Du Yang (2000); Lin Yifu and Liu Mingxing (2003); Teng Jianzhou and Liang Qi (2006), and divide our country into three regions consisting eastern, western and middle areas, we attempt to compare the coefficients of different areas so as to investigate the economic principles behind it. We first study the summary statistic character of the variables, and then make assumptions and regressions on the specified model.

6.2.1. The Summary Statistic Characters of Our Variable

Employing software Stata 10.0, we get the basic statistic characters of *gdp*, *cns*, *lin*, *gin*, *hsn*, *atn*, *inv* and *pgr*, the table 1 below reveals some basic statistic characters of the variables and we will further give the Pear-

[26]We employ resident's consumption expenditure to substitute household's leisure level not only because of the unavailability of leisure data, but also because that it is closely related with household's leisure level, from economic intuition, gene rally speaking, the area whose resident's consumption level is high always has very high leisure level.

son correlation coefficient between the 8 main variables in table 2. Based on the outcome of table 2, *gdp* is dominant positively related with labor supply *lin* and household leisure *cns*, this is consistent with our theoretical analysis; *gdp* is also positively related with society's average level *atn* and human capital investment level *hsn*, which reveals that human capital investment and knowledge level can promote economic growth. As for population growth rate *pgr*, it is negatively related with *gdp*, which indicates that excessive population growth is not good for growth; however, *gdp* is positively related with government taxation *gin*, this is controversial with our theory and intuition, we will further study this relation in the following analysis.

TABLE 1.

Statistical Characters of *gdp*, *cns*, *lin*, *gin*, *hsn*, *atn*, *inv* and *pgr*

variables	mean	Standard Error	Min.	Max.	Number of observations
gdp	830.0471	840.4445	38.00364	6140.420	493
cns	340.4758	303.1089	18.95809	2468.000	493
lin	402.7029	362.7755	18.14112	2424.772	493
hsn	40.6714	21.09978	4.000000	114.0000	493
atn	5.401546	5.668336	1.529680	34.16943	493
gin	396.1003	376.4117	13.77630	3298.865	493
inv	291.3858	328.2466	11.50186	2600.650	493
pgr	8.576146	4.638269	−1.90000	20.75000	493

Sources of table 1: (1) we calculate to get it via using Stata 10.0; (2) in the above, the unit of *gdp*, *cns*, *lin*, *gin*, *inv* is a hundred billion yuan; the unit of *atn* is in number; and the unit of *pgr* is in percent.

6.2.2. The Postulate and Regression Result of The Model

In the process of econometric analysis, we consider fixed effect model and stochastic effect model simultaneously. For fixed effect model, we report the F statistic to test whether fixed effect parameter is predominant or not; and for stochastic models, we mainly judge whether there exists stochastic effect or not through Hausman Test. Via statistics test and econometrics test, our econometric outcome reveals that, almost all the Hausman Tests for stochastic effect model consistently reject to accept stochastic effect model, even in the case of not rejecting, its regression results are almost the same as that under the fixed model. Therefore, in the following analysis, we will mainly report the outcome of fixed effect model; meanwhile, in order to study the differences among various regions in China, we postulate and

regress the model according to the three regions of eastern, western and middle areas. We assume the regression equation of One-way fixed-effect model that only contains regional effect as follows:

$$\begin{aligned} gdp_{it} &= a_0 + a_1 cns_{it} + a_2 lin_{it} + a_3 atn_{it} + a_4 hsn_{it} + a_5 gin_{it} + a_6 inv_{it} \\ &\quad + a_7 pgr_{it} + \sum_{j=8}^{8+w} a_j D_j + u_{it} \end{aligned} \tag{45}$$

To meet the needs of empirical analysis, following the method taken by Lin (1992), Yao and Shen (2006), we simultaneously study the Two-way fixed-effect model which contains time effect and regional effect:

$$\begin{aligned} gdp_{it} &= b_0 + b_1 cns_{it} + b_2 lin_{it} + b_3 atn_{it} + b_4 hsn_{it} + b_5 gin_{it} + b_6 inv_{it} \\ &\quad + b_7 pgr_{it} + \sum_{j=8}^{8+w} b_j D_j + \sum_{j=8+w+1}^{8+w+17} b_j T_j + \varepsilon_{it} \end{aligned} \tag{46}$$

where $i = 1, 2, 3, \cdots, 29$ indicates provinces, $T = 1, 2, 3, \cdots, 17$ delegates time, and u_{it}, ε_{it} represents stochastic disturbance term, in equation (45) and (46), $\sum_{j=8}^{8+w} a_j D_j$ and $\sum_{j=8}^{8+w} b_j D_j$ respectively represent the effect of regional dummy variables; in equation (46), $\sum_{j=8+w+1}^{8+w+17} b_j T_j$ indicates the effect of time dummy variables, here w is the number of provinces included in eastern, middle and western areas, when it indicates the eastern area, $w = 13$; while it comes to the middle, $w = 6$; as for the western areas, $w = 10$. Employing data from China's 13 eastern provinces, 6 middle provinces and 10 western provinces between 1989 and 2005, we regress equations (45) and (46), in the process of regressing, besides traditional OLS, we also make use of maximum-likelihood estimator method in order to make comparisons, the specific outcome for the three regions is in the following table 3 and table 4.

The regression results of table 3 and table 4 reveal that: Firstly, from the value of $\overline{R}^2$, $LogLi.$ and $Pr1 > F^a$, the fitting effect of equations (45) and (46) to data is very good, and the fixed effect is statistically significant. Secondly, based on the results of z statistic and $Pr1 > F^b$ reported by Stata, all the variables are significant at the 5% significant level. Thirdly, consider the sign of each variable, in the regression result of one-way and two-way fixed effect model, the signs of lin, atn, inv are all positive, which

TABLE 2.

The Pearson correlation coefficient for *gdp*, *cns*, *lin*, *gin*, *hsn*, *atn*, *inv* and *pgr* ($N = 493$)

	gdp	*cns*	*lin*	*gin*	*hsn*	*atn*	*inv*	*pgr*
gdp	1							
	(0.000)							
cns	0.9553	1						
	(0.000)	(0.000)						
lin	0.9776	0.9340	1					
	(0.000)	(0.000)	(0.000)					
gin	0.9009	0.9038	0.8526	1				
	(0.000)	(0.000)	(0.000)	(0.000)				
hsn	0.7291	0.7271	0.7401	0.6963	1			
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)			
atn	0.0402	−0.0223	−0.0375	0.1803	0.3282	1		
	(0.373)	(0.621)	(0.406)	(0.000)	(0.000)	(0.000)		
inv	0.9402	0.9082	0.9165	0.8428	0.7051	0.1170	1	
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.009)	(0.000)	
pgr	−0.4508	−0.4090	−0.4321	−0.4204	−0.5454	−0.5197	−0.4783	1
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

Sources of table 2: (1) we calculate to get it through Stata 10.0; (2)the numbers in brackets is the p value of the dominant test to correlation coefficient.

indicate that the effect of labor supply, average knowledge level and physical capital investment made on economic growth is positive, while negative signs of *gin* and *pgr* indicate that the effect of government tax and population growth made on growth is negative, and this is consistent with our theoretical analysis. Fourthly, no matter the regression results of one-way or two-way fixed effect, they all reveal that the coefficient of *hsn* in the middle and western areas are negative, which is controversial to our theory, this indicates that in our sample, the human capital investment level generated negative effect on economic growth. One possible explanation is that because the migration and flow of educated individuals between regions, many educated from the middle and western regions migrate to the east, thus causing detrimental effect to the economic growth of the source region, therefore, the sign of *hsn* for these two regions is negative, this is one of the new phenomena that discovered in our study.

In the process of estimating, we choose both the GLS Fixed-effects estimator and the Maximum-likelihood Random-effects estimator. From the regression results of one-way fixed effect models, the coefficients for the regression results of MLE estimate are almost the same to that for the FE

TABLE 3.

Regression Results I: the explained variable is the growth rate of *gdp*

Explanatory variables	One-way fixed-effects						Robustness Test
	FE Estimator			MLE Estimator			
	east	middle	west	east	middle	west	
cns	1.27697	1.66778	1.00819	1.27697	1.66778	1.00819	RT
	(0.091)	(0.154)	(0.081)	(0.087)	(0.143)	(0.077)	
lin	0.63292	0.12723	0.21499	0.63292	0.12723	0.21499	RT
	(0.071)	(0.079)	(0.076)	(0.068)	(0.074)	(0.072)	
atn	0.72040	6.28520	3.36752	0.72040	6.28520	3.36752	RT
	(0.359)	(0.743)	(0.446)	(0.204)	(0.694)	(0.421)	
hsn	4.16449	−3.4271	−0.7103	4.16449	−3.4271	−0.7103	RT
	(0.981)	(1.022)	(0.056)	(0.935)	(0.955)	(0.053)	
gin	−0.0805	−0.2205	−0.2266	−0.0805	−0.2205	−0.2266	RT
	(0.036)	(0.081)	(0.050)	(0.034)	(0.075)	(0.047)	
inv	0.59515	0.76605	0.74082	0.59515	0.76605	0.74082	RT
	(0.037)	(0.095)	(0.058)	(0.035)	(0.089)	(0.055)	
pgr	−4.9923	1.22082	−1.3903	−4.9923	1.22082	−1.3903	RT
	(0.849)	(0.172)	(1.203)	(0.763)	(0.161)	(1.141)	
Regional dummy	yes	yes	yes	yes	yes	yes	RT
Time dummy							
$\overline{R}^2$	0.9907	0.9862	0.9889				
LogLi.				1210.64	512.281	781.797	
$Pr1 > F^a$	0.0000	0.0000	0.0001	0.0000	0.0000	0.0001	
$Pr1 > F^b$	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	

estimate, but its standard errors are small than that of the RE estimate, so from the estimate accuracy, MLE estimate is superior to FE estimate; what's more, the regression results of two-way effect model also indicates the superiority of MLE estimate. At the same time, from the regression results of one-way and two-way fixed effect models, the signs of *atn* and *hsn* both generated a slightly variation, this indicates that the unobservable time effect made effects to these two variables simultaneously in our sample period, actually, one possible reason is that as time elapsed, that the time trend for the number of students graduated and total universities is obvious resulted in this outcome, therefore, the estimate effect of one-way fixed effect is superior to that of the two-way fixed effect model, the standard error of MLE estimate is smaller than that of FE estimate.

TABLE 4.

Regression Results II: the explained variable is the growth rate of *gdp*

Explanatory variables	Two-way fixed-effects						Robustness Test
	FE Estimator			MLE Estimator			
	east	middle	west	east	middle	west	
cns	1.24549	1.33669	0.88011	1.24549	1.33669	0.88011	RT
	(0.098)	(0.183)	(0.085)	(0.083)	(0.178)	(0.076)	
lin	0.64265	0.29430	0.25465	0.64265	0.29430	0.25465	RT
	(0.079)	(0.108)	(0.080)	(0.072)	(0.102)	(0.071)	
atn	−2.1825	1.63537	0.86626	−2.1825	1.63537	0.86626	NO
	(0.380)	(0.123)	(0.588)	(0.298)	(0.113)	(0.528)	
hsn	5.56596	−4.7336	−0.1671	5.56596	−4.7336	−0.1671	NO
	(0.109)	(0.143)	(0.605)	(0.098)	(0.138)	(0.543)	
gin	−0.0767	−0.5526	−0.3714	−0.0767	−0.5526	−0.3714	RT
	(0.043)	(0.141)	(0.059)	(0.036)	(0.126)	(0.053)	
inv	0.57849	0.69996	0.72041	0.57849	0.69996	0.72041	RT
	(0.041)	(0.133)	(0.060)	(0.040)	(0.095)	(0.054)	
pgr	−6.1013	5.45099	−4.5972	−6.1013	5.45099	−4.5972	RT
	(0.300)	(0.356)	(0.177)	(0.283)	(0.338)	(0.159)	
Regional dummy	yes	yes	yes	yes	yes	yes	RT
Time dummy	yes	yes	yes	yes	yes	yes	RT
$\overline{R}^2$	0.9897	0.9928	0.9683				
LogLi.				1086.39	476.825	765.856	
$Pr1 > F^a$	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
$Pr1 > F^b$	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	

Notes: (1) table 3 and table 4 are calculated through software Stata 10.0; (2) the original data is the panel data from 29 Chinese provinces from 1989 to 2005; (3) the value in brackets are the standard error of regression coefficients; (4) following Lin (1992), as these 29 regional dummy variable and 17 time dummy variables all can pass the test, so we won't give the related regression coefficient and standard error; (5) $\overline{R}^2$ is the adjusted fitting accuracy, and *LogLi.* is the index to judge the accuracy of MLE estimation; (6) $Pr1 > F^a$ is the p value of the F statistic used to test the fixed effect model, and $Pr1 > F^b$ is the p value of the F statistic used to test the joint significance of explanatory variables; (7) RT indicates that the robustness test is satisfied.

As for regional differences, first of all, in fixed effect model, except the signs of *pgr* is different among regions, the other factors' functioning direction are the same among different regions, although the magnitude is a little different, however, in the model of two-way fixed effect models, the signs of *pgr*, *atn* and *hsn* all presents a little difference among regions, one proper explanation is that while time passes, the high educated individuals always flow among regions. Secondly, no matter one-way or two-way

fixed models, the short run effect of leisure decision *cns* made on economic growth is more higher in the middle area than western and eastern areas, perhaps this is resulted from the fact that there is very little leisure in the middle area so the marginal utility is very high. Thirdly, the effect generated by labor supply *lin* and human capital investment *hsn* for the eastern area is the highest, one possible reason is that there are more work opportunity and the flow of educated workers in the east of China. Fourthly, the effect of physical capital investment for the middle and western areas are higher than that for the east, perhaps this can be attributed to the scarce of physical capital in those areas, just because of this, the functions of taxation is more obvious in middle and west than in east, which is also supported empirically by our study.

6.2.3. The Robustness Test to The Regression Results

In the above we have analyzed the regression results, then we will wonder whether the econometric results have robustness or not? Here, we will make robustness test to this problem, the purpose of the robustness test is to see whether the regression results are sensible to the new added explanatory variables. If the regression results turned to reverse when the new added explanatory variables emerges, then we can say that there is no robustness in the previous regression results; or else, there will be robustness. The method by which we employ to test robustness is established by Levine and Renelt (1992), we conduct this through introducing this new variable government expenditure *gep* to test the robustness of equations (45) and (46), for the test outcome please refer to the last column in table 3 and table 4. As the signs of *atn* and *hsn* vary in the two-way effect model, hence the results reveal that the one-way fixed effect model is more robust than the two-way fixed effect model.

Through the analysis of panel data model, we have already studied the short run and static relationship existing among the variables, then we will consider how their long term and dynamic relationship would be. In the next section, we will further our study on this problem via employing VAR model, impulse response function and variance decomposition principles.

6.3. Long Term and Dynamic Relationship Discussion—Analysis Based on VAR Model

Based on the above theoretical analysis, we have known that the effects generated by household's labor supply decision *lin*, leisure decision *cns*, human capital investment level *hsn* in the short run and long run are different. In the previous empirical analysis, we have already studied the

short run effects and static relations, hence, next, we will focus on their dynamic relations and long run effects via employing VAR technology as well as impulse response functions.

6.3.1. Unit Root Test

We made Augmented Dickey-Fuller Test to labor supply lin, leisure decision csn, human capital investment level hsn and output gdp, and found that they were all non-stationary time series, then we made ADF test to their log values, please see table 5 for the results.

From table 5 we can find that, the absolute values of the t-statistic for ADF test of $\ln(gdp)$, $\ln(lin)$, $\ln(cns)$, $\ln(hsn)$ are all smaller than that of the absolute values of the ADF statistic test critical values at 5% significance level, which indicate that they are all non-stationary time series. However, the absolute values of the t-statistic for the one order difference of $\triangle \ln(cns)$, $\triangle \ln(gin)$, $\triangle \ln(hsn)$'s ADF test are all larger than that of the absolute values of the ADF statistic test critical values at 5% significance level, $\triangle \ln(gdp)$'s is larger than that of the 10% significance level, so they are one order integration series. As $\ln(gdp)$, $\ln(lin)$, $\ln(cns)$, $\ln(hsn)$ themselves are not stationary series, but they are stationary after one order difference. If we directly make regressions on them, there will be false regression phenomena, therefore it is necessary to make co-integration test between them.

TABLE 5.

The Augmented Dickey-Fuller Test for Related Variables

Variable sign	Variable name	Test type (e, T, d)	t-statistic	Critical value	Prob.
$\ln(gdp)$	Log output	$(e, 0, 1)$	-2.572537	-2.627420	0.1219
$\ln(cns)$	Log leisure	$(e, 0, 1)$	-3.135327	-3.587527	0.0770
$\ln(lin)$	Log wage	$(e, 0, 1)$	-2.317449	-2.976263	0.0640
$\ln(hsn)$	Log human capital investment	$(e, 0, 1)$	-3.157108	-3.587527	0.0550
$\triangle \ln(gdp)$	Difference of $\ln(gdp)$	$(e, 0, 0)$	-2.872537	-2.627420^*	0.0619^*
$\triangle \ln(cns)$	Difference of $\ln(cns)$	$(e, 0, 0)$	-3.735327	-3.587527	0.0370
$\triangle \ln(lin)$	Difference of $\ln(lin)$	$(e, 0, 0)$	-3.317449	-2.976263	0.0240
$\triangle \ln(hsn)$	Difference of $\ln(hsn)$	$(e, 0, 0)$	-4.157108	-3.587527	0.0150

Note: e and T respectively represent the test with constant term and trend term, d indicates the order we employed, * means the critical value is calculated under 10% significance level, others are obtained under 5% significance level.

6.3.2. Co-Integration Test

We make use of the Trace Test of Characteristic Roots and Maximum Eigenvalue Test simultaneously, and employ Johansen co-integration test to the values of $\ln(gdp)$, $\ln(lin)$, $\ln(cns)$, $\ln(hsn)$ after one order difference, the "Deterministic trend assumption of test. Assume no deterministic trend in" in this paper is "intercept(no trend) in CE and test", based on the choice criteria of choosing lag intervals, we choose 1 order log, the regression results are reported in table 6 and table 7.

The two test methods of table 6 and table 7 both reveal that, no matter the Trace Test of Characteristic Roots or Maximum Eigenvalue Test, their corresponding null hypothesis—None, which indicate that there is no co-integration relationship, its test statistic values are both larger than the critical values under 5% significance level. This means that we can reject the hypothesis that there is no co-integration relationships under the confidence level of 95%, and there exists co-integration relationships between the four variables $\ln(gdp)$, $\ln(lin)$, $\ln(cns)$, $\ln(hsn)$ after taking logarithm. The value for the test statistic of corresponding null hypothesis "At most 1" which indicates there is at most one co-integration vector is smaller than the critical value under 5% significance level, which means that we can't reject the original hypothesis that there is at most one co-integration vector. Therefore, there exists co-integration relationships between $\ln(gdp)$, $\ln(lin)$, $\ln(cns)$, $\ln(hsn)$ these four variables, what's more, there is only one co-integration vector, which indicates that there is long term equilibrium relationship among these four variables $\ln(gdp)$, $\ln(lin)$, $\ln(cns)$, $\ln(hsn)$, that is to say, the relationship between our country's output, labor supply, leisure, human capital investment does exist and it should be stable, so the regression that we makes on them is not false regression, hence the study on the dynamic relations between output, labor supply, leisure, human capital investment is meaningful.

TABLE 6.

Rank Test Results of Characteristic Roots

Hypothesized		Trace	0.05	
No. of CE(s)	Eigenvalue	Statistic	Critical Value	Prob.**
None *	0.861992	66.50718	47.85613	0.0004
At most 1	0.697264	26.80049	29.79707	0.1663
At most 2	0.511714	8.87708	15.49471	0.3749
At most 3	0.418194	1.124274	3.841466	0.2044

Note: * indicates rejecting the null hypothesis under 5% significance level;
** means the p value of Mackinnon-Haug-Michelis (1999).

TABLE 7.

Maximum Eigenvalue Test Results

Hypothesized		Max-Eigen	0.05	
No. of CE(s)	Eigenvalue	Statistic	Critical Value	Prob. **
None *	0.861992	29.70669	27.58434	0.0263
At most 1	0.697264	17.92342	21.13162	0.1327
At most 2	0.511714	10.75280	14.26460	0.1670
At most 3	0.418194	1.124274	3.841466	0.5644

Note: * indicates rejecting the null hypothesis under 5% significance level; ** means the p value of Mackinnon-Haug-Michelis (1999).

TABLE 8.

The Choosing Criteria of the Lag Period for the VAR Model

Lag	LogL	LR	FPE	AIC	SC	HQ
0	−409.2502	NA	4.54e+18	54.15627	55.31516	54.21562
1	−352.3406	42.68219*	5.56e+16	49.04257*	50.97405*	49.14148*
2	−330.7012	41.33067	4.34e+16*	50.08373	53.67608	50.36021

Note: * indicates the lag period is chosen under this rule.

6.3.3. The Construction of VAR Model

Based on the previous analysis, we choose output $\ln(gdp)$, labor supply $\ln(lin)$, leisure $\ln(cns)$, human capital investment $\ln(hsn)$ to construct a four dimension vector auto-regression model, the test results of the lag structure for the model is reported in table 8:

Judging from the results of table 8, four of the five assessing indices indicate that we should construct $VAR(1)$, hence we choose the lag period of our VAR model is 1, it has the following form:

$$y_t = \Gamma_0 + \Gamma_1 y_{t-1} + \varepsilon_t, \quad t = 1, 2, \ldots, T \tag{47}$$

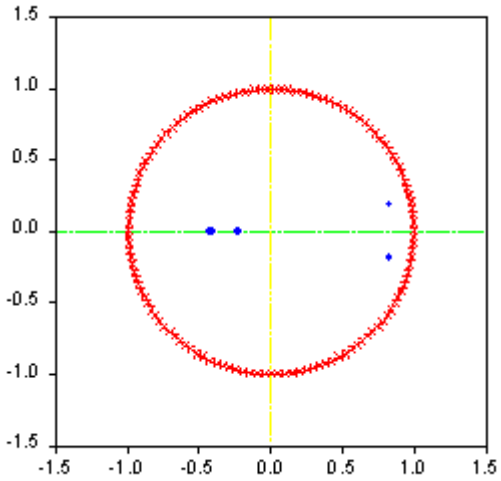
Where $y_t = (\ln(gdp)_t, \ln(cns)_t, \ln(lin)_t, \ln(hsn)_t)^T$ is a 4 dimension endogenous variable vector, Γ is the parameter matrix to be estimated, ε is the 4 dimension stochastic disturbance term, and model (47) is the basis of our following analysis.

Employing added up China's province level panel data between 1989 and 2005 to regress, the outcome reveals that[27], the model's total fitting accuracy R^2 is 0.999860, Adj. R-squared is 0.999650. By observing the residual series of each equation we found that the residual is all white noise

[27] As the regression results of the vector auto-regression model will not be used in the following analysis, we don't report it in this paper, those who are interested in it may contact us for details.

series, and the inverse roots of the characteristic polynomial are all in the unit round, as figure 1 demonstrates, so the model is stable, therefore the model can be further used to analyze their dynamic relationships.

FIG. 1. The figure of inverse roots for the characteristic polynomial



6.3.4. Impulse Response Function Analysis

Impulse response function analysis is used to measure the effect made by the impulse of one standard error from stochastic disturbance term on other endogenous variables' current and future values, it is the effect of the impulse that one endogenous variable made on other endogenous variables, generally we employ impulse response function to assess the contents of VAR model.

It is required that the endogenous variable series must be stationary while imposing impulse response analysis[28], however, our endogenous variables in the VAR model $\ln(gdp)$, $\ln(cns)$, $\ln(lin)$, $\ln(hsn)$ are all one order integration. So we need to take one order difference to them, so as to make them become stationary series $\triangle \ln(gdp)$, $\triangle \ln(cns)$, $\triangle \ln(lin)$, $\triangle \ln(hsn)$, and then we will make impulse response analysis. What's more, as we know that the order of variable postulate will affect the analytical result, based

[28]If the endogenous variable series are not stationary, the figure of the impulse response function will appear to be the trend of dispersing, as for the theoretical analysis, refer to James D. Hamilton: Time Series Analysis, Beijing, China Social Science Press, 1999.

on our research purpose, we postulate the order of our variable is: economic growth, leisure, labor supply and human capital investment. According to the above estimated VAR model, we can get the following figures on impulse response functions, see figures 2 to 17, where, the horizontal axis represents the functioning period of the impulse generated by one unit of Cholesky standard innovation, and its unit is year, the vertical axis represents the corresponding variable, the solid line delegates impulse response function's curve, and the dashed line represents the deviation band of the two times positive an negative standard error.

From figure 2 we can see that, the effect generated by the variation of current economic growth on itself is positive in the first three period, and it becomes negative from the fourth period. One possible explanation is that China's economic growth consumes a lot of resources, to achieve sustainable economic growth, we have to make effective use of the economic resources. From figure 3 and 4, we can see that present time leisure $\triangle \ln(cns)$ and labor supply $\triangle \ln(lin)$ make similar variation trend to economic growth, in the first two period, they constrain economic growth, and from the third period on, they promote economic growth, which indicates that household's labor-leisure decisions in the micro-level may generate different effect to economic growth both in the long run and short run. The response values of economic growth to leisure and labor supply are respectively attaining the maximum value of 47.54773 and 173.48000, after that, they gradually decreases to 0, and this provides evidence that proposition 3 can be held. Figure 5 reveals that, when human capital was hit by one unit Cholesky innovation in the positive direction, its effect to economic growth is always positive, and reaches its peak value at 320.9155, then the response value of economic growth to human capital investment gradually decreases to 0, which testifies the conclusions given by proposition 4.

FIG. 2. The impulse of economic growth to itself

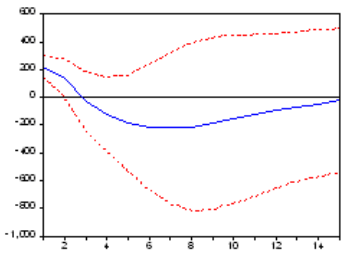


FIG. 3. The impulse of leisure to economic growth

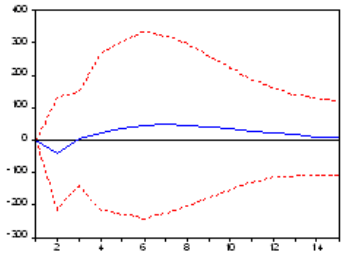


FIG. 4. The impulse of labor supply to economic growth

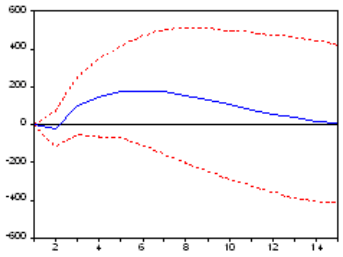


FIG. 5. The impulse of human capital to growth

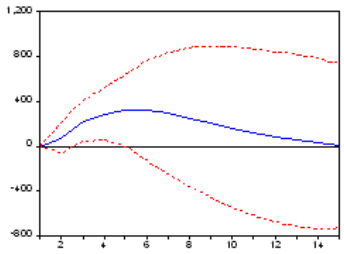


FIG. 6. The impulse of economic growth to leisure

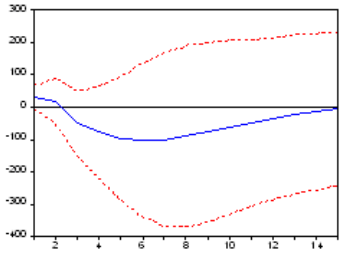


FIG. 7. The impulse of leisure to itself

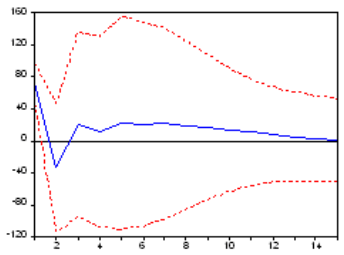


FIG. 8. The impulse of labor supply to leisure

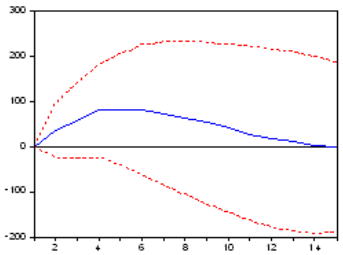


FIG. 9. The impulse of human capital to growth

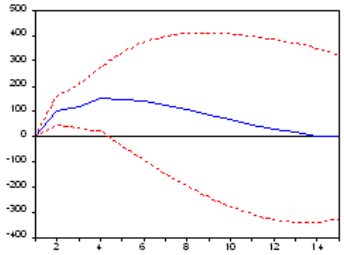


Figure 6 reveals that, the impulse of economic growth to leisure in the first two period is positive, then it becomes negative continually, one possible explanation is that our economic growth depends more on labor input. Figure 7 indicates that, the impulse trend of leisure to itself is ambiguous in the beginning period, however, after the second period, the impulse is always positive, and the response value achieve its maximum value of 22.381. Figure 8 and Figure 9 demonstrate that the impulses of labor supply and

human capital to leisure are always positive, as time elapsed, the deviation band of standard error appears to be increasing, which indicates that the uncertainty is rising, this provides empirical experience for proposition 5.

Figure 10 indicates that, the impulse of economic growth to labor supply in the first three periods is always changing, but overall, it appears to be dominated by negative impulses, which proves the conclusion that our economic growth is promoted through high labor inputs once again. Figure 11 tells us that, the effect that leisure made on labor supply is a little weak, but it appears to be increasing in all, one possible reason is that leisure raises the working activity and production efficiency of the labor force. Figures 12 and 13 indicate that there is some kind of inertia in labor supply, which is consistent with the actual case of our labor market, what's more, human capital investment promotes labor supply, and this is mainly because it can enhance the production efficiency for each unit of labor.

FIG. 10. The impulse of economic growth to labor supply

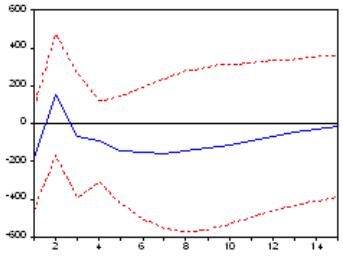


FIG. 11. The impulse of leisure to labor supply

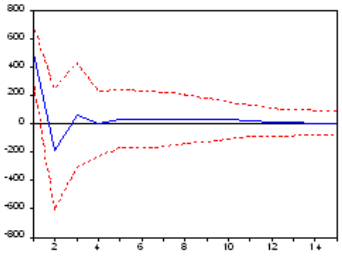


FIG. 12. The impulse of labor supply to itself

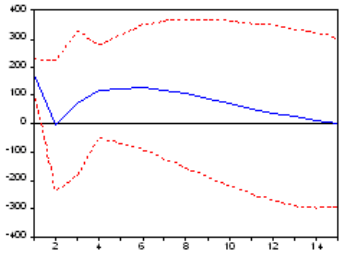


FIG. 13. The impulse of human capital to labor supply

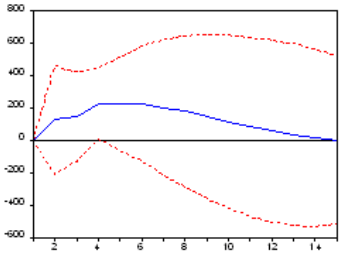


Figure 14 reveals that, the impulse of economic growth to human capital investment at its early period is negative, after the fifth period, it turns out to be positive, this is mainly because in the beginning of economic growth,

FIG. 14. The impulse of economic growth to human capital

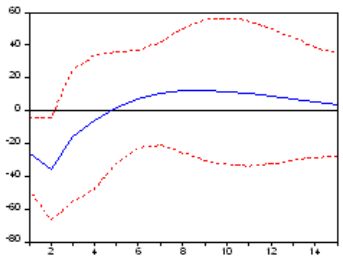
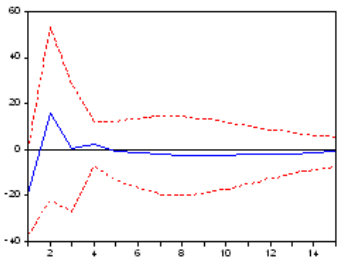


FIG. 15. The impulse of leisure to human capital



as the limited capital amount, economic growth consumes most of the capital which may be used to human capital investment otherwise, however, as the economic develops, the total capital increases in the economy, and thus provides more money for human capital investment, this testifies the conclusions of proposition 5. Figure 15 indicates that, the effect of leisure to human capital is uncertain in the short run, but it will make weak negative effect in the medium and long run, this is consistent with some conclusions in proposition 3 and proposition 4.

FIG. 16. The impulse of labor supply to human capital

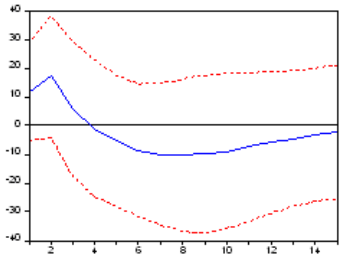


FIG. 17. The impulse of human capital to itself

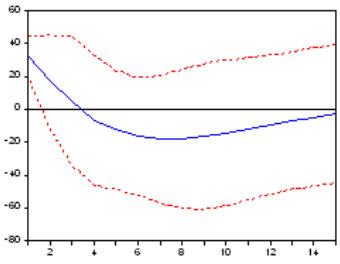


Figure 16 and figure 17 show that the variation trend of the effect that labor supply and human capital made on human capital appears to be similar, i.e., that the short run effect is positive while the medium and long run effects are negative. Which indicates that these two factors don't generate perpetual impulses to human capital, and the conclusion is consistent with proposition 5. Meanwhile, we found that, the impulse of economic growth to human capital investment is smaller than that of human capital to economic growth, one proper explanation is that Chinese parents always pay attention to the education of their children, no matter what the economic

and other conditions are, the relative money they spent on education will never vary a lot, and this is also one of the new discoveries in our research.

6.3.5. Variance Decomposition Analysis

Similarly, based on the estimated VAR model we can get the following variance decomposition figures, see figures 18 to 33. Where, the horizontal axis represents the lag periods of functioning impulses, whose unit is year, and the vertical axis indicates the contribution rate of all variable to the studied variable, the solid line delegates the curve of the contribution function.

FIG. 18. The contribution of economic growth to itself

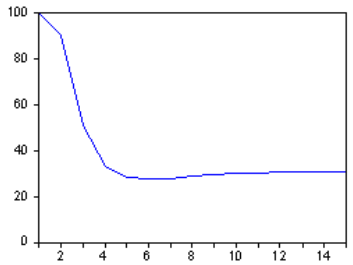


FIG. 19. The contribution of leisure to growth

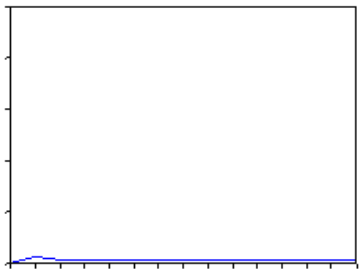


FIG. 20. The contribution of labor supply to growth

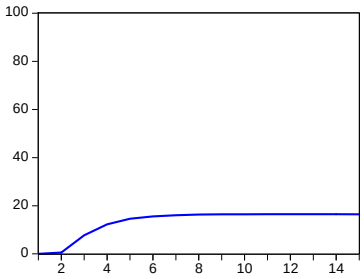
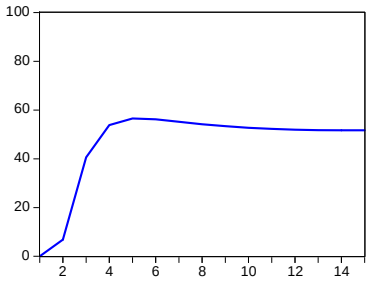


FIG. 21. The contribution of human capital to growth



From figure 18 to figure 21, we can see that in the contribution rate of economic growth, the contribution of economic growth itself is the largest, but its contribution is decreasing, in the 15th period, it is 30.60565. The second and third contributors are human capital investment and labor supply, in the 15th period, their contribution rates are respectively 51.66549 and 16.44745, this fully demonstrates that in the long run, the effect of human capital and labor supply to economic growth is increasing. What's

more, the contribution of leisure to economic growth is small, but the trends for the contribution of the latter three are all increasing.

FIG. 22. The contribution of economic growth to leisure

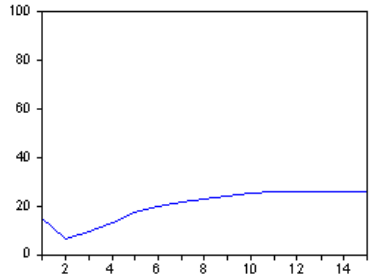


FIG. 23. The contribution of leisure to itself

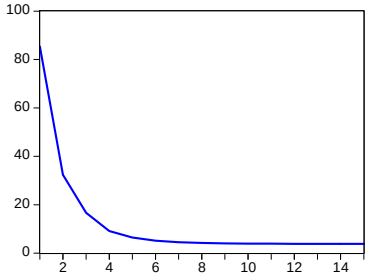


FIG. 24. The contribution of labor supply to leisure

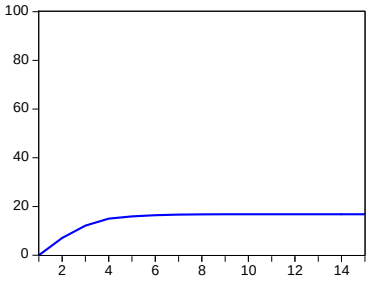
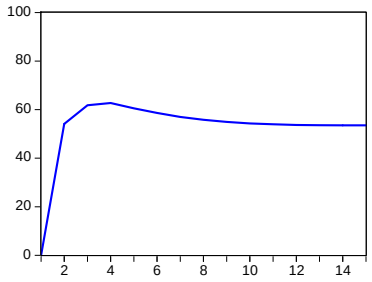


FIG. 25. The contribution of human capital to leisure



From figure 22 to figure 25, in the variation contribution rate of leisure, the contribution of human capital is the largest, but it appears to be decreasing, in the 15th period, it is 53.50823. The ones following that are economic growth and labor supply, in the 15th period their contribution rate are respectively 25.85818 and 16.77376, of which, the contribution rate of economic growth to leisure is increasing and that of labor supply is decreasing. Furthermore, the contribution of leisure to itself is minimum and decreasing, this reveals that leisure is an endogenous variable that was determined by other economic variables, its inertia is relatively small. Which indicates that there is a little difference between leisure and consumption habit, this is also a new conclusion that we found out in our research different from the existing studies.

Figures 26 to 29 reveal that, in the contribution rate to the variation of labor supply, the contribution of leisure is the largest and it appears the trend of decreasing, in the 15th period it is 32.14079. The factors

FIG. 26. The contribution of growth to labor supply

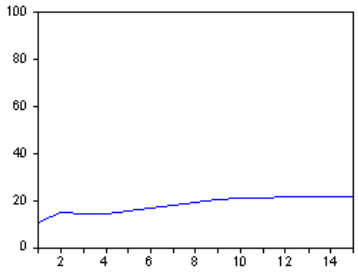


FIG. 27. The contribution of leisure to labor supply

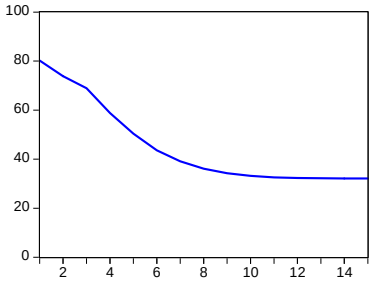


FIG. 28. The contribution of labor supply to itself

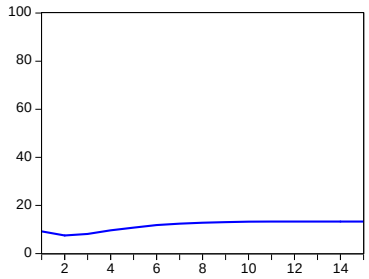
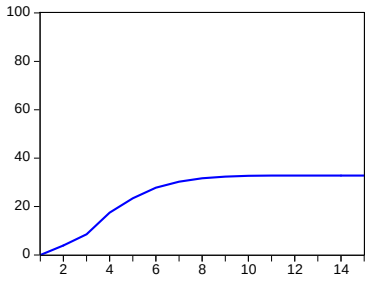


FIG. 29. The contribution of human capital to labor supply



following that are economic growth and human capital investment, in the 15th period, their contribution rates are 21.75544 and 32.77845 respectively, what's more, the contributions of the two are all increasing. Finally, the contribution of labor to itself is the smallest and decreasing, this indicates that there is a little inertia in china's labor supply, which is consistent with our theory analysis and impulse response analysis.

From figures 30 to 33 we can see that, in the contribution rate of the variation of human capital investment, the contribution of economic growth and that of human capital investment are relatively larger, in the 15th period their contribution rates are respectively 38.37621 and 40.64931. What's more, the contribution rate of labor supply to human capital is relatively high and increasing, in the 15th period its contribution rate is 13.11611. Finally, the contribution rate of leisure to human capital is the smallest and decreasing, in the 15th period it is 7.858368, which indicates that China's human capital investment is mainly affected by economic growth and the existing human capital stock, the effect of leisure and labor supply contribute quite a little to our country's human capital investment, how-

ever, in the long run, labor supply may contribute a lot to human capital investment, this can be seen from the variance decomposition table.

FIG. 30. The contribution of growth to human capital

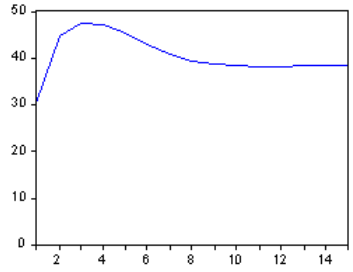


FIG. 31. The contribution of leisure to human capital

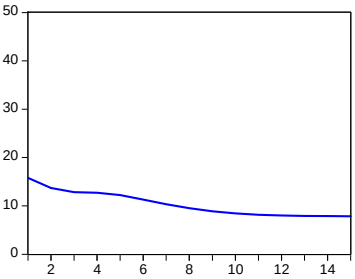


FIG. 32. The contribution of labor supply to human capital

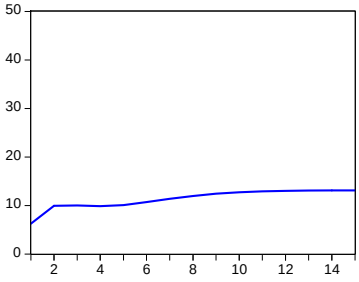
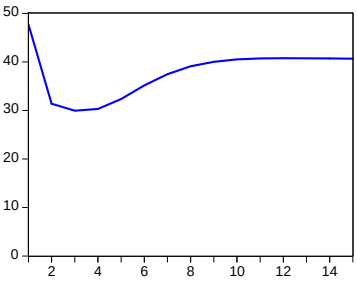


FIG. 33. The contribution of human capital to itself



In summary, the outcome of the impulse response functions reveals that, the short run effects and long term impulses of leisure, labor supply and human capital to economic growth are different, and this testified the theoretical analysis conclusions of endogenous labor-leisure decisions from the empirical level. The results of variance decomposition reveal that the main contributors for the variation of different variables are different, and as time elapsed, the relative significance of different economic variables are also changing, which provides theoretical and empirical reflections on studying the relative importance of each concerned element.

7. CONCLUSIONS

In this paper, we have studied the inner relationship of endogenous labor supply, human capital externality, knowledge spillover and sustainable economic growth as well as government's choice problem of education policy

and their effect on the growth rate of balanced growth path via simultaneously introducing human capital externality, knowledge spillover and endogenous labor- leisure decision into the framework constructed by Uzawa (1965) and Lucas (1988).

The results of the theory analysis indicate that, firstly, the allocation behavior of household in the micro-level will affect the country's growth rate of macro-economy. Secondly, the magnitude of human capital externality, knowledge spillover level will also affect the growth rate of a country's macro economy. Thirdly, through comparative static analysis we found that the variation of different kinds of parameters will generate different effect on the economy's growth rate in the long run and short term, the increase of preference parameters will enhance the growth rate of the economy, but it will low the long term growth rate; however, the variation of knowledge spillover parameter and technological parameter will promote economic growth in the long run and the development of education. Fourthly, as the existence of human capital externality, the equilibrium of the decentralized economy can't achieve social optimal state, government can impose a lump-sum output taxation, education taxation or subsidy to induce the decentralized economy to achieve society's optimal state.

We also make empirical studies on the relationships existing among our country's province level economic growth and its determinants through employing panel data from 29 provinces between 1989 and 2005. We make use of panel data model to study their static relationship and short term effect while we employ VAR technology, impulse response function and variance decomposition principle to investigate their dynamic relationship and long term effect.

The research of employing panel data model reveals that, for our inter-provincial panel data: First of all, *gdp* growth is positively related with leisure decision *cns*, labor supply *lin*, average knowledge level *atn*, but it is negatively related to population growth rate *pgr*, government taxation *gin*, and these results are all consistent with our theoretical analysis. Secondly, no matter the regression results of one-way or two-way fixed effect, they all reveal that the relationship between *hsn* and *gdp* growth rate is negative for the middle and western areas, this is controversial to our theoretical analysis. One possible explanation is that in the range of our sample, as the migration and flow of educated individuals between regions, the human capital investment generates detrimental effect to the middle and western regions. The corresponding policy implication is that government should give some subsidy or policy support to develop education in these regions. Thirdly, the short run effect that leisure decision *cns* made on economic

growth is much higher in the middle area than western and eastern areas, which may be resulted from the fact that there is very little leisure in the middle area so the marginal utility is very high. Fourthly, the effect generated by labor supply *lin* and human capital investment *hsn* for the eastern area is the highest, our explanation is that there are more work opportunities and the flow of educated workers in the east of China. Fifthly, the effects of physical capital investment for the middle and western areas are higher than that for the east, which can be attributed to the scarce of physical capital in those areas. Finally, the results of robustness test prove the effectiveness of our outcome as well as the robustness of our model.

The dynamic analytical results of VAR model reveal that, the short run relationships and long term effects between labor supply *lin*, leisure decision *cns*, human capital investment *hsn* and economic growth are different, what's more, the effects that labor supply *lin* and human capital investment *hsn* made on economic output *gdp* are positive, and its long term effects are greater than its short run effect. Meanwhile, we found that the response of human capital investment to output is relatively small, one possible reason is that Chinese residents always pay more attention to education. Additionally, the contributions of human capital and labor supply to the other variables are most dominant. In our analysis, because of the problem of data availability, in dynamic analysis we don't take taxation and other factors into consideration. Furthermore, the main data we employed in this paper belongs to the macro level, the applicability of our theory to micro data still needs to be tested, we will further study these problems in our future work.

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