

Economic Analysis of Law Review

Study on Impacting Mechanism of Institutional Quality for Economic Growth of China during Economic Transition Period

Estudo sobre Mecanismos que Impactam na qualidade institucional para o crescimento econômico da China durante o período de transição econômica

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RESUMO

Este trabalho é uma extensão do modelo de crescimento endógeno multi-setores incluindo o capital com base no modelo de Aghion e Howitt (1999). Ele define a instituição, o capital humano endógeno e inovação tecnológica em um quadro de análise unificada, e testa os efeitos da instituição, a acumulação de capital e inovação tecnológica para o crescimento econômico de longo prazo. Os resultados mostram que o crescimento econômico de longo prazo, não só depende da qualidade institucional e da inovação técnica, mas também depende da acumulação de capital e preferências do agregado familiar. O equilíbrio estável de longo prazo da taxa de crescimento positiva só ocorre quando a qualidade institucional atinge um determinado nível, e a melhoria da qualidade institucional irá melhorar a taxa de crescimento econômico de longo prazo, quando o equilíbrio existe. Além disso, a política de subsídios fiscais do governo também pode afetar o crescimento econômico de longo prazo. Este trabalho tem como objetivo fornecer apoio e sugestões políticas teóricas para o renascimento da reforma da China.

Palavras-chave: Qualidade Institucional; Acumulação de Capital; Inovação Tecnológica; Crescimento Econômico.

JEL: O1, O3, O5, C00

ABSTRACT

This paper is an extension of the multi-sectors endogenous growth model including capital based on the model of Aghion and Howitt (1999). It sets the institution, endogenous human capital and technological innovation into a unified analysis framework, and tests the effects of the institution, capital accumulation and technological innovation on long-run economic growth. The results show that long-run economic growth not only depends on the institutional quality and the technical innovation, but also depends on the capital accumulation and household's preferences. The long-run stable equilibrium of positive growth rate only occur when the institutional quality reaches a certain level, and the improvement of the institutional quality will improve the long-run economic growth rate when the equilibrium existing. In addition, government tax and subsidy policy can also affect the long-run economic growth. This paper aims to provide theoretical support and policy suggestions for the revival of China's reform.

Keywords: Institutional Quality; Capital Accumulation; Technological Innovation; Economic Growth.

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1. Introduction

Since China adopted the opening-up and reform policy, its economic growth had attracted worldwide attention, nowadays China has become one of the economic entities enjoying the rapidest economic development and the mostly vigorous growth in the world. However, various conflicts hid by the extensive growth pattern and the high-speed growth dominated by government, as well as covered by the short-term performances become more and more intensive. If the institutional barriers can't be broken as soon as possible and economic growth pattern is not changed, it is inevitable to result in economic and social disaster someday in future (Wu Jinglian, 2013). According to the Third Plenary Session of the 18th Central Committee of the Chinese Communist Party, the job to deepen the reform is the focus of current economic institution reform; therefore it is very urgent to kick off a new round reform so as to seek a new dynamic energy for Chinese economy for realizing its healthy and sustainable development. However, how to seek the continuous dynamic energy for Chinese economy? Why institutional quality improvement is vital to economic growth of China during the economic transition period? What is the theoretic mechanism? All of these problems are worthy of our profound thinking over.

For a long term, economists have been always seeking and exploring the economic growth sources. According to the neoclassical growth theory, economic growth is the result of capital, labor force and exogenous technical progress, then endogenous growth theory find that the endogenous human capital and the technical progress are of great importance, and according to the new institutional economics, the institution is the authentic reason of economic growth. China is now undergoing institutional transition, where the institutional change will play an assignable role in economic growth, so the establishment of the high-quality institution is vital to the development of China by becoming into a high-income country from a medium-income country (Tran, 2013). Currently a consensus on the importance of the institution has been reached in the academic circles. However most of studies from the perspective of historical analysis or the individual case analysis could not provide a thorough analysis on the action mechanism of institution impacts on economic growth. It is worth noting that the technical innovation is the byproduct of the capital accumulation (Arrow, 1962), the technical accumulation and the technical innovation can't be regarded as two different driving factors in growth process, but as two aspects of a same process, it is insignificant to divide both of them (Ding and Knight, 2011), therefore it is rather important to incorporate the capital accumulation and the technical innovation into an uniform framework when exploring economic growth source (Zeng Jinli, 1997; Aghion and Howitt, 1998).

In line with the purpose, this paper, on the basis of the Aghion and Howitt (1999) model and by introducing the institutional variables, tries to incorporate the institution, capital and technical innovation into an uniform analysis framework so as to discuss the action mechanism of the institution, capital and technical innovation in long-run economic growth. The study under the paper is a useful exploration for integrating new institutional economics theory with endogenous growth theory, but also a rational expansion for the fact that the endogenous growth theory applies to developing countries, therefore the study under the paper has important theoretical and practical significance.

2. Literature review

The endogenous growth theory is usually researched by two methods, i.e.: the capital accumulation model and the innovative model. For such two methods, the former focuses on the spillover effect of the capital accumulation, and regards the endogenous physical capital and the human capital accumulation as economic growth sources (Lucas, 1988; Rebelo, 1991), however according to the latter, the endogenous technical progress resulted from the R&D innovation is regarded as economic growth source (Romer, 1990; Aghion and Howitt, 1992). However the physical capital accumulation and human capital accumulation are the basic input elements, technical progress resulted from innovation activities may also irritate more physical and human capital investment, therefore the capital accumulation and technical innovation are two aspects of the same process, both of them can't be separated from each other (Aghion and Howitt, 1998). Aghion and Howitt (1999) integrated the physical capital accumulation with the Aghion and Howitt (1992) creative destruction model, made the expansion for the Schumpeter Growth Model on the basis of Jones criticism (1995), and then established capital-comprising multi-departmental endogenous growth model, the results indicated that long-run economic growth rate is jointly affected by the R&D incentives and capital accumulation incentives, and government-related policies have long-run effect. Zeng Jinli (2003) made a further endogenous-based treatment for human capital in the Aghion and Howitt (1999) model, and then re-verified the relations between the technical innovation and capital accumulation. According to the result, the long-run growth of a country depends on the technical innovation, capital accumulation and preference, and governmental tax revenue and subsidy policy can affect such long-run growth. According to the researches related to the ones above, the human capital accumulation and technical innovation were incorporated into an uniform formwork so as to explain the mechanism that the human capital accumulation and technical innovation boost economic growth and expand endogenous growth model (Blackburn et al., 2000; Yang Liyan and Wang Xinli, 2004).

However what it is a pity that the existing studies regard institution as the portion under a natural status, and thence omit such portion, or regard institution as the given one, and presumes that it has no business with the economic growth. However, the institutions are vital to economic growth (North, 1994). To be specific, the institutional environment affects the capital investment, accumulation and activation, the capacity that capital input turns into output is not only the function of technical progress, but also the function of the institution (Zhang Fengxi et al., 2012), the high-quality institution can guarantee private yield rate coming from individual economic effort approach to social yield rate, improve the effort degree of human's production activity, and then impact economic performance (Rodrik, 2000; Gwartney et al., 2004), moreover, the institution may affect the technical innovation, the institutional arrangement and technical innovation are two dynamic factors important and indispensable to long-run economic growth, and the technical innovation and institution must depend each other, and it is a must to make analysis in a continuously interactional logic (North, 1994; Ruttan, 1994; Pan Shiyuan and Shi Jinchuan, 2002; Khan, 2004; Pi Jiancai, 2006). Especially for the developing countries, the institutional quality may directly affect capital input efficiency (Barzel, 1989; He Jun et al., 2006; Zhang Chao, 2007; Xiong Hui Bing et al., 2007), and institutional environment badness may even cause capital go into non-productive rent-

seeking departments, which may hinder economic growth instead (Pritchett, 2001; Wu Jinglian, 2010; Hall et al., 2010). So the institution, capital accumulation and technical innovation are important aspects of long-run economic growth, all of them support each and are indispensable.

In recent years, the study on the action mechanism of the institution, capital accumulation and technical innovation for long-run economic growth on the macroscopic level has attracted the attention of scholars gradually. Wang Jinying (2004) established the human capital externality model, the human capital enhancement-type institutional change model and the physical capital enhancement-type institutional change model so as to separate the functions of institutional elements from the total-factor productivity and analyze the actions of the institutional change for the physical capital and human capital in the economic growth. Through the studies, it is found that human capital of China contributes 14% approximately to the economic growth, but substance capital accumulation is still the main contribution factor of the economic growth, the existing institution in China are mainly innovated by encircling physical capita; Pan Huifeng and Yang Liyan (2006) adopted the frame of the endogenous growth theory and discussed the impacting mechanism of institution for the economic growth on the basis of the decreasing institutional marginal income, institutional innovation and technical innovation matching hypothesis. The result showed that the physical capital, human capital and resource endowment are only the required conditions of economic growth, if the continuous institutional change are not available, the economy can't grow continuously, whereas the government can expedite institutional change by offering subsidy and allowance to human capital of institutional departments, and then affect the economic growth; Dawson (1998) incorporated the institution into neoclassical growth model firstly and utilized multinational panel data to study the channels institution affects long-run economic growth via the empirical study. The result showed that economic freedom can't only improve the total factor productivity directly, but also affects long-run economic growth indirectly by stimulating investment, besides; economic freedom and the civil liberty can also impact human capital investment and then further the economic growth.

The follow-up scholars tried also to introduce institution into the mainstream economic growth model as a variable, however it is only limited to the basic frame of the neoclassical growth model, or the interactions of institution, capital accumulation and technical innovation in long-run economic growth were not considered comprehensively (Pi Jiancai, 2006; Hall et al., 2010; Yang Youcai, 2010; Yang Ming et al., 2013). This paper, on the basis of the studies made by Zeng Jinli (2003), introduced institutional variables to the capital-comprising multi-departmental endogenous growth theory of Aghion and Howitt (1999) considered comprehensively the action mechanism of the institution, capital and technical innovation in long-run economic growth, which has the great theoretic innovation.

3. The model

We assume that the model economy is populated with identical households. The size of population L is constant. The basic framework is due to Zeng Jinli (2003), both physical and human capital accumulation are determined by intertemporal utility maximization of a representative household. The production technologies and household's preferences are described below.

3.1. Technologies

There are six types of production activities in this economy: final good production, intermediate good production, vertical and horizontal innovations, and physical and human capital accumulation. It is assumed that perfect competition prevails in all sectors except the intermediate good sectors where there exists temporary monopoly power.

3.1.1. Technologies

The final good production uses a continuum of intermediate goods and a fixed factor as its inputs subject to a constant-returns-to-scale technology with the Cobb-Douglas form

$$Y_t = X^{1-\alpha} \int_0^{Q_t} A_{it} x_{it}^\alpha di \quad 0 < \alpha < 1 \quad (1)$$

Where Y_t is final output; X is the quantity of the fixed factor; Q_t is the measure intermediate goods; x_{it} is the flow of intermediate good i ($i \in [0, Q_t]$) and t represents time. The parameter α measures the contribution of an intermediate good to the final good production and inversely measures the intermediate monopolist's market power. The parameter A_{it} is the productivity parameter of intermediate good i . For simplicity, the quantity of the fixed factor is normalized to equal unity ($X=1$). As a result, the final good production function can be simplified to

$$Y_t = \int_0^{Q_t} A_{it} x_{it}^\alpha di \quad 0 < \alpha < 1 \quad (2)$$

The competitive final good sector yields the inverse demand function for intermediate good i

$$p_{it} = \alpha A_{it} x_{it}^{\alpha-1} \quad \forall i \in [0, Q_t] \quad (3)$$

Where p_{it} is the price of intermediate good i in terms of the final good. Note that the final good is used as the numeraire for all prices.

3.1.2. Intermediate good production

Each intermediate good i is produced using physical and human capital K_{it} and H_{it} , and are constrained by the institution condition, by reference to Hall et al. (2010) distinguished the institutional quality on capital efficiency from the production function, we have

$$x_{it} = \left(\frac{K_{it}}{A_{it}}\right)^{\gamma+Xk\Delta It} \left(\frac{H_{it}}{A_{it}}\right)^{1-\gamma+Xh\Delta It}, 0 < \gamma < 1, 0 < Xk < 1, 0 < Xh < 1 \quad (4)$$

Where $\gamma, 1 - \gamma$ measure the contribution of physical capital and human capital to the intermediate good production separately without considering the institutional factors situation, Xk, Xh measure the effect of institutional quality to physical capital and human capital productivity, $\Delta It = It - I^*$, where I^* represents the optimal institutional quality, It represents current institutional quality, so ΔI reflects the institutional quality gap between current time t and the optimal institutional quality, $\Delta It \leq 0$, $|\Delta It|$ more close to 0, suggesting that existing higher institutional quality.

The two inputs are deflated by the productivity parameter A_{it} to capture the fact that as technology advances; better intermediate goods are more difficult to produce. Given the wage rate w_t , the interest rate r_t , and the final sector's demand for intermediate goods given by the inverse demand function (3), each intermediate good producer chooses a monopolistic price p_{it} to maximize its profit π_{it} :

$$\pi_{it} = p_{it} x_{it} - w_t H_{it} - r_t K_{it} = \alpha A_{it} x_{it}^\alpha - w_t H_{it} - r_t K_{it} \quad (5)$$

The solution to the maximization problem of Eqs. (5) yields the intermediate good sector i 's demand for physical and human capital K_{it} and H_{it} . Substituting the values of K_{it} and H_{it} into (4) gives the optimal output of intermediate sector i :

$$x_{it} = x_i = [\alpha^{2(1+\Delta I_t)} (\gamma + \chi_k \Delta I_t)^{\gamma+\chi_k \Delta I_t} (1-\gamma)^{1-\gamma+\chi_h \Delta I_t} r_t^{-(\gamma+\chi_k \Delta I_t)} w_t^{-[(1-\gamma)+\chi_h \Delta I_t]}]^{-\frac{1}{1-\alpha(1+\Delta I_t)}} \quad (6)$$

From the solution to the maximization problem along with the factor market equilibrium conditions

$$\int_0^{Q_t} H_{it} di = (1 - v_t) \bar{Z}_t L \text{ and } \int_0^{Q_t} K_{it} di = K_t$$

we calculate the intermediate producer i's profit flow:

$$\pi_{it} = A_{it} \alpha [1 - \alpha(1 + \Delta I_t)] \Gamma y_t \quad (7)$$

where

$$y_t = \frac{Y_t}{A_t^{\max} Q_t}, \quad \Gamma^{-1} = \int_0^1 a \left(\frac{1}{\sigma} a^{1/\sigma-1} \right) da = \frac{1}{1+\sigma}^2$$

and

$$A_t^{\max} = \max \{A_{it}, i \in [0, Q_t]\}$$

where σ is a parameter measuring the impact of each vertical innovation on the stock of public knowledge².

Considering the steady-state equilibrium conditions, we know that the interest rate r_t and the wage rate w_t are constant in equilibrium. Therefore, the profit of flow at date s for an intermediate good producer who use a technology of vintage t :

$$\pi_{ts} = A_t^{\max} \alpha [1 - \alpha(1 + \Delta I_t)] \Gamma y_s \quad (8)$$

Where the productivity-adjusted output is given by:

$$y_s = Y_s / (Q_s A_s^{\max})$$

3.1.3. Vertical innovation

A successful vertical innovation improves an existing intermediate product, and replaces the existing one in the final good production. The successful innovator becomes the temporary monopolist until the arrival of the next successful innovation in that sector. Assume that vertical innovations follow a Poisson process, with a common arrival rate given by:

² See Appendix A, Aghion and Howitt (1999).

$$\phi_t = \lambda n_t \quad n_t = N_{vt} / (Q_t A_t^{\max}) \quad \lambda > 0 \quad (9)$$

Where λ is the productivity parameter of vertical R&D, N_{vt} is the expenditures on vertical R&D (measured in units of the final good), and n_t is the productivity adjusted expenditure on vertical R&D in each sector. Deflating vertical R&D expenditures by the leading-edge productivity parameter is based on the assumption that the complexity of innovation increases proportional to the technology progress. As Aghion and Howitt (1999), we assume that the government subsidizes both vertical and horizontal R&D expenditures at proportional rate s_n in order to encourage investment in R&D. A vertical R&D firm chooses its R&D expenditure N_{vt}/Q_t to maximize its profit

$$\{ \phi_t V_{vt} - (1 - s_n) N_{vt} / Q_t \}$$

where V_{vt} is the expected value of a vertical innovation. The expected value of a vertical innovation is given by

$$V_{vt} = \int_t^\infty \exp[-\int_t^s (r_\tau + \phi_\tau) d\tau] \pi_{ts} ds$$

Substituting (8) and the steady-state equilibrium conditions $r_t = r$, $n_t = n$, and $y_t = y$ into the value function gives

$$V_{vt} = \frac{A_t^{\max} \alpha [1 - \alpha(1 + \Delta I_t)] \Gamma y}{r + \phi} \quad (10)$$

Since we will consider equilibria with $n_t > 0$ only, along with (9), the first-order condition for a vertical innovator's maximization problem is

$$\lambda V_{vt} / A_t^{\max} = 1 - s_n \quad (11)$$

Equation (11) says that the expected marginal benefit of vertical R&D (the left-hand side) equals the after-subsidy marginal cost of vertical R&D (the right-hand side).

3.1.4. Horizontal innovation

A horizontal innovation aims at a new intermediate product. A successful innovator becomes the monopolist of his newly created product until the product is improved by a vertical innovation.

Assume that the rate of new product innovation is

$$\dot{Q}_t = \psi(N_{ht}, Y_t) / A_t^{\max} \quad (12)$$

Where a dot on the top of a variable represents the time change rate of that variable, N_{ht} is the expenditures on the horizontal R&D (measured in units of the final good), and Ψ is a concave, constant-returns production function with positive marginal product. Eq. (12) implies that the average product Q/N is a decreasing function of the fraction $ht = N_{ht} / Y_t$ of final output allocated to horizontal R&D.

Also assume that the productivity of a newly created intermediate good is drawn randomly from the productivity distribution of existing intermediate goods. It follows from this assumption that the expected value of a horizontal innovation is

$$V_{ht} = E(A_{it} / A_t^{\max}) V_{vt} \quad (13)$$

Where E is an expectation operator. Similar to vertical R&D firms, a horizontal R&D firm chooses its R&D expenditure N_{ht} to maximize its profits

$$\psi'(h_t) V_{ht} / A_t^{\max} = 1 - s_n \quad (14)$$

Where the function

$$\psi(h_t) = \psi(h_t, 1)$$

is assumed to have the following properties:

$$\psi'(h_t) > 0, \quad \psi''(h_t) < 0$$

and

$$\psi'(0) > \lambda\Gamma$$

And there exists³

$$\hat{h}_t \in (0, +\infty)$$

³ These properties are needed to ensure the existence and uniqueness of the steady state.

such that

$$\psi'(\hat{h}_t) < \lambda\Gamma$$

Eq.(14) states that the expected marginal benefit of horizontal R&D (the left-hand side) equals the after-subsidy marginal cost of horizontal R&D (the right-hand side).

3.1.5. Knowledge spillovers

Following Caballero and Jaffe (1993) and Aghion and Howitt (1999), we assume that growth in the leading-edge productivity A_t^{max} comes from knowledge spillovers of vertical innovations. Specifically,

$$g_{A_t} = \dot{A}_t^{max} / A_t^{max} = \sigma \lambda n_t \quad \sigma > 0 \quad (15)$$

Where g is the growth rate of the productivity of the leading-edge technology and, as mentioned above, σ is a parameter that measures the impact of each vertical innovation on the stock of public knowledge. Since the productivity of a newly created intermediate good is randomly draw from the distribution of the existing intermediate goods, the productivity distribution of new intermediate goods is identical to the productivity distribution of existing intermediate goods. As a result, the distribution of relative productivity $a_{it} = A_{it}/A_{it}^{max}$ converges to the invariant distribution $Prob\{a_{it} \leq a\} = F(a) = a^{1/\sigma}$, where $0 < a \leq 1$. As shown in Aghion and Howitt(1999), in the long run, $E(A_{it}/A_t^{max}) = \Gamma^{-1}$.

3.1.6. Physical and human capital accumulation

We assume that each unit of consumption good forgone can produce one unit of physical capital and there is no depreciation. Since final output is allocated among vertical R&D expenditures N_{vt} , horizontal R&D expenditures N_{ht} , consumption C_t , investment in human capital D_t , and investment in physical capital K_t , the stock of physical capital evolves according to

$$\dot{K}_t = Y_t - N_{vt} - N_{ht} - C_t - D_t \quad (16)$$

Eq.(16) is also the final good market clearing condition. For human capital accumulation, we assume that growth of human capital depends on the amount of time devoted to education and physical investment in education. Specifically, the human capital accumulation technology is given by (Rebelo, 1991; Jones et al., 1993; Stokey and Rebelo, 1995; Jinli Zeng, 2003):

$$\dot{\bar{Z}}_t = \delta (v_t \bar{Z}_t)^\beta \bar{D}_t^{1-\beta} \quad \delta > 0, 0 < \beta < 1 \quad (17)$$

Where Z_t is the total human capital stock; a bar on the top of a variable represents the per capital value of that variable, so $\bar{Z}$ is per capital human capital stock and $\bar{D}$ is per capital physical investment in education (foregone output), v_t is the amount of time devoted to education, δ is the productivity parameter of human capital accumulation, and $\beta, 1 - \beta$ measure the contribution of human capital and physical capital investment on human capital contribution respectively⁴.

3.2. Preferences

We assume that the representative household is endowed with one unit flow of time which is inelastically allocated between human capital accumulation v_t and production $1 - v_t$. We also assume that the representative household's preferences are given by

$$\int_0^\infty e^{-\rho t} \left(\frac{\bar{C}_t^{1-\epsilon}}{1-\epsilon} \right) dt \quad \epsilon > 0 \quad (18)$$

Where C is per capital consumption, ρ is the constant rate of time preference, and ϵ is the elasticity of marginal utility.

Suppose that, in addition to subsidizing R&D, the government also subsidizes investments in physical and human capital at rates s_k and s_d respectively and the government's expenditures are financed by a lump-sum tax T_t (per capita), a physical capital income tax τ_k , and a human capital income tax τ_z , the representative household's budget constraint is

$$\dot{\bar{C}}_t = (1 - \tau_z)w_t(1 - v_t)\bar{Z}_t + r_t(1 - \tau_k)\bar{K}_t - \bar{T}_t - (1 - s_k)\dot{\bar{K}}_t - (1 - s_d)\dot{\bar{D}}_t \quad (19)$$

Where K is per capita physical capital asset.

The representative household chooses consumption C , investment in education D and time allocation v_t to maximize its life-time utility (18) subject to the human capital accumulation technology (17) and the budget constraint (19). The current-value Hamiltonian function and the first-order conditions for the representative household's utility maximization problem are given by:

$$\bar{C}_t^{-\epsilon} = \theta_t / (1 - s_k) \quad (20)$$

⁴ Note that without considering institution factors, if $\beta = 1$, then human capital is the only input in human capital production. This is the specification of the human capital accumulation technology used in Lucas ((1988), Arnold(1998) and Blackburn et al.(2000).

$$\mu_t \delta v_t^{\beta-1} \bar{Z}_t^\beta \bar{D}_t^{1-\beta} = \theta_t (1 - \tau_z) w_t \bar{Z}_t / (1 - s_k) \quad (21)$$

$$\mu_t \delta (1 - \beta) (v_t \bar{Z}_t)^\beta \bar{D}_t^{1-\beta} = \theta_t (1 - s_d) / (1 - s_k) \quad (22)$$

$$\theta_t r_t (1 - \tau_k) / (1 - s_k) = \rho \theta_t - \dot{\theta}_t \quad (23)$$

$$\mu_t \delta v_t^\beta \bar{Z}_t^{\beta-1} \bar{D}_t^{1-\beta} + \theta_t (1 - \tau_z) w_t (1 - v_t) / (1 - s_k) = \rho \mu_t - \dot{\mu}_t \quad (24)$$

$$\lim_{t \rightarrow \infty} e^{-\rho t} \theta_t \bar{K}_t = 0 \quad (25)$$

$$\lim_{t \rightarrow \infty} e^{-\rho t} \mu_t \bar{Z}_t = 0 \quad (26)$$

Where θ_t and μ_t are the costate variables. Eq. (20) (respectively, (21), (22)) equalizes the marginal benefit and the marginal cost of consumption respectively, time and human capital devoted to education, physical investment in education). Eqs. (23) and (25) (respectively, (24) and (26)) are the optimal dynamic conditions for physical (respectively, human) capital accumulation.

Solving the above first-order conditions gives the conditions that determine the optimal time path of per capita consumption, physical investment in education and time allocation:

$$\dot{\bar{C}}_t / \bar{C}_t = (\eta_k r_t - \rho) / \epsilon \quad (27)$$

$$\bar{D}_t / v_t = (1 - \beta) \eta_z w_t \bar{Z}_t / \beta \quad (28)$$

$$v_t = \beta g_{zt} / (\eta_k r_t) \quad (29)$$

where

$$\eta_k = (1 - \tau_k) / (1 - s_k), \quad \eta_z = (1 - \tau_z) / (1 - s_d)$$

and

$$g_z = \dot{\bar{Z}}_t / \bar{Z}_t$$

Eqs. (27)-(29) are the equilibrium conditions from the household side.

3.3. Government budget constraint

Assume that the government's budget is balanced at each point in time, then we have

$$\tau_k r_t K_t + \tau_z w_t (1 - v_t) \bar{Z}_t L + \bar{T}_t L = s_n (N_{vt} + N_{ht}) + s_d D_t + s_k \dot{K}_t \quad (30)$$

4. Steady-state equilibrium and results

We consider only steady-state balanced growth equilibria. In a steady-state balanced growth equilibrium, stationary is imposed on the allocation of time v_t , and on the ratios of output, consumption, and capital stock to productivity in terms of $Q_t A_t^{max}$ such as $y_t, c_t = C_t / Q_t A_t^{max}$ and $k_t = K_t / Q_t A_t^{max}$. Stationary is also imposed on the amount of vertical R&D expenditure per product n_t , the fraction of final output allocated to horizontal R&D h_t , the interest rate r_t and the wage rate w_t . In addition, the number of intermediate goods Q_t , the leading-edge productivity A_t^{max} and human capital Z_t grow at constant rates g_o, g_A and g_Z , respectively. To simplify our analysis, we reduce the equilibrium equation system to the following three conditions that determine the fraction of final good allocated to horizontal R&D h , productivity-adjusted output y , and per capital output growth g :

Horizontal R&D condition:

$$\psi'(h) = \lambda \Gamma \quad (H)$$

Vertical R&D condition:

$$g = \frac{\{[\lambda \Gamma \alpha [1 - \alpha(1 + \Delta I_t)] / (1 - s_n) + \psi(h) / \sigma\} / y - \rho / \eta_k}{\epsilon / \eta_k + 1 / \sigma} \quad (V)$$

Human capital accumulation condition:

(Z)

$$g = \frac{1}{\epsilon} \left\{ \left[\delta \eta_k \frac{(\gamma + \chi_k \Delta I_t)(1-\beta)}{1-\gamma + \chi_h \Delta I_t} \beta^\beta ((1-\beta)\eta_z)^{1-\beta} (\alpha^{2(1+\Delta I_t)} (\gamma + \chi_k \Delta I_t)^{\gamma + \chi_k \Delta I_t} \right. \right. \\ \left. \left. (1-\gamma)^{1-\gamma + \chi_h \Delta I_t} \right)^{\frac{1-\beta}{1-\gamma + \chi_h \Delta I_t}} (\Gamma y)^{\frac{(1-\alpha(1+\Delta I_t)(\beta-1))}{\alpha(1-\gamma + \chi_h \Delta I_t)}} \right]^{\frac{1-\gamma + \chi_h \Delta I_t}{(1-\gamma + \chi_h \Delta I_t) - (\beta-1)(\gamma + \chi_k \Delta I_t)}} - \rho \right\}$$

From (H), we can see that the fraction of final output allocated to horizontal R&D h is independent of the productivity-adjusted output y and the steady-state growth rate g , so Eq.(H) independently determines the fraction of final output allocated to horizontal R&D. Given the technology and policy parameters, there always exists a unique value of h satisfying

$$(H): h = \psi'^{-1}(\lambda \Gamma)$$

By substituting

$$h = \psi'^{-1}(\lambda \Gamma)$$

into (V), we reduce the three equilibrium conditions to two Eqs. (V) and (Z) that determine the steady-state productivity-adjusted output y and the steady-state growth rate g . Now we examine the properties of the steady-state equilibria.

First, we look at the properties of the two equilibrium conditions (V) and (Z) and the condition under which a steady-state equilibrium with positive growth exists. From (V), we have

$$\partial g / \partial y > 0$$

from (Z), we find that when

$$\gamma + \lambda_k \Delta I_t \geq 0$$

and

$$1 - \gamma + \lambda_h \Delta I_t \geq 0$$

namely when

$$\Delta I_t \geq \max \left\{ -\frac{\gamma}{\lambda_k}, \frac{\gamma-1}{\lambda_h} \right\}, \partial g / \partial y < 0$$

That is, the vertical R&D curve (V) is upward-sloping because a higher (productivity-adjusted) output level raises the flow of profits to successful vertical innovators, leading to more investment in vertical R&D and thus a higher steady-state growth rate; the human capital accumulation curve (Z) is downward-sloping because a higher steady-state growth rate (resulting from more investment in vertical R&D) increases the interest rate, and a higher interest rate reduces the demand for human capital and thus the productivity-adjusted output (see Fig.1).

In addition, the vertical R&D curve (V) intersects the y-axis at

$$y = y_1 > 0$$

and the human capital accumulation curve (Z) cuts the y-axis at

$$y = y_2 > 0$$

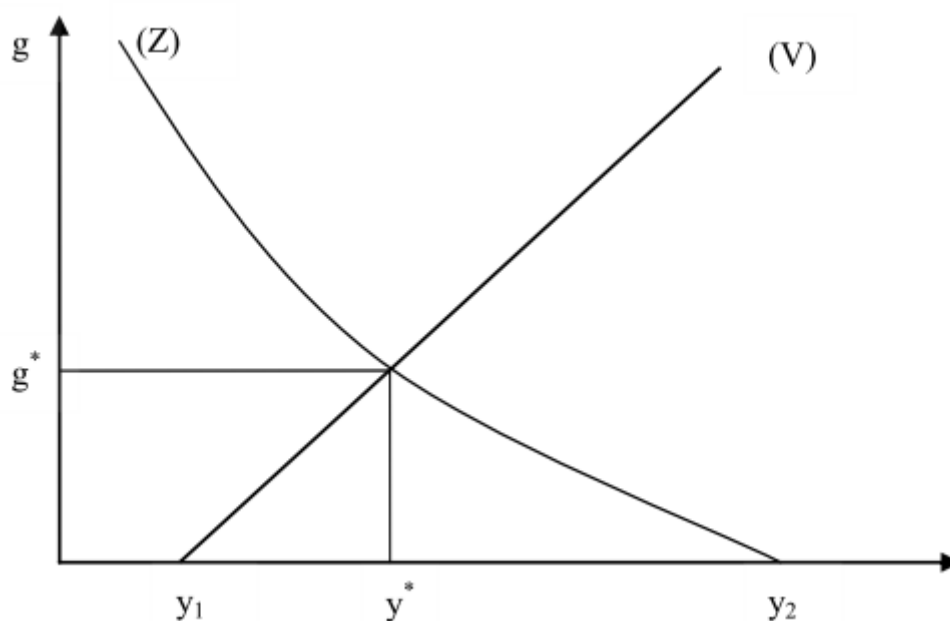
where

$$y_1 = \frac{\rho / \eta_k}{\lambda \Gamma \alpha [1 - \alpha(1 + \Delta I_t)] / (1 - s_n) + \psi(h) / \sigma}$$

and

$$y_2 = \frac{1}{\Gamma} \left\{ \left[\delta \eta_k \frac{(\gamma + \chi_k \Delta I_t)^{(1-\beta)}}{1-\gamma + \chi_h \Delta I_t} \beta^\beta (1-\beta) \eta_z^{1-\beta} (\alpha^{2(1+\Delta I_t)} (\gamma + \chi_k \Delta I_t)^{\gamma + \chi_k \Delta I_t} \right. \right. \\ \left. \left. (1-\gamma)^{1-\gamma + \chi_h \Delta I_t} \right)^{\frac{1-\beta}{1-\gamma + \chi_h \Delta I_t}} \rho^{\frac{(\beta-1)(\gamma + \chi_k \Delta I_t) - (1-\gamma + \chi_h \Delta I_t)}{1-\gamma + \chi_h \Delta I_t}} \right]^{\frac{\alpha(1-\gamma + \chi_h \Delta I_t)}{(1-\alpha)(1+\Delta I_t)(1-\beta)}} \right\}$$

Figure 1: Existence of ready-state equilibrium



These properties guarantee the following proposition:

Proposition 1. When the institutional quality reach a certain level, namely

$$\Delta I_t \geq \max \left\{ -\frac{\gamma}{\lambda_k}, \frac{\gamma-1}{\lambda_h} \right\}, \text{ if } y_1 < y_2$$

then there always exists a unique steady-state equilibrium with a positive growth rate per capita output.

The intuitions behind this proposition can be easily be verifying that the condition

$$y_1 < y_2$$

is equivalent to the condition

$$\lambda V_{vt} / A_t^{\max} > 1 - s_n$$

(at the point $n=0$). That is, if the condition

$$y_1 < y_2$$

holds, then when investment in vertical R&D is greater than the marginal cost of vertical R&D. Under this condition, investment in vertical R&D is profitable, therefore it is optimal for profit-maximizing R&D firms to invest in vertical R&D until the expected marginal benefit and the marginal cost of vertical R&D are equalized

$$(\lambda V_{vt} / A_t^{\max} = 1 - s_n)$$

This condition can be guaranteed by various sufficient conditions concerning the values of the technology, preferences and policy parameters such as a sufficiently low subjective discount rate (low ρ), a sufficiently productive human capital accumulation technology (large δ) and a sufficiently large subsidy to vertical R&D (large s_n). However, if

$$y_1 \geq y_2$$

then investment in vertical R&D is not profitable and thus no R&D firms invest in vertical R&D. As a result, there is no growth in per capita output.

By using the graphs, we firstly made a comparative static-state analysis on the steady-state equilibrium so as to obtain the long-run economic growth effect of all parameters, such as preference, physical capital, human capital investment technology, horizontal innovation and vertical innovation activity⁵. For instance, the improvement of the subjective discount rate ρ can cause the vertical innovation curve (V) and the human capital accumulation curve (Z) to move downwards, and thence reduces the long-run economic growth rate [(Fig.2 (a))].

Similarly, the improvement of the human capital accumulation productivity δ can cause the human capital accumulation curve (Z) to move upwards, and thence improves long-run economic growth rate [(Fig.2 (b))]. What it is worth noting that the quality level of the institution affects long-

⁵ The other parameters are presumed to keep unchanged when considering the impact of the change in a certain parameter on the long-term economic growth.

run economic growth rate too, when the institutional quality reaches a certain level and there is the steady-state equilibrium, the institutional quality improvement

($|\Delta I_t|$ more approaching to 0)

can improve the expected revenue of the vertical innovation activity, and improve the human capital accumulation efficiency meanwhile, *i.e.*: the vertical innovation curve (V) and the human capital accumulation curve (Z) can move upwards [(Fig.2 (c))], and hence improve long-run economic growth rate. Hereafter we shall present a proposition 2.

Figure 2(a): Growth effect when the subjective discount rate is improved

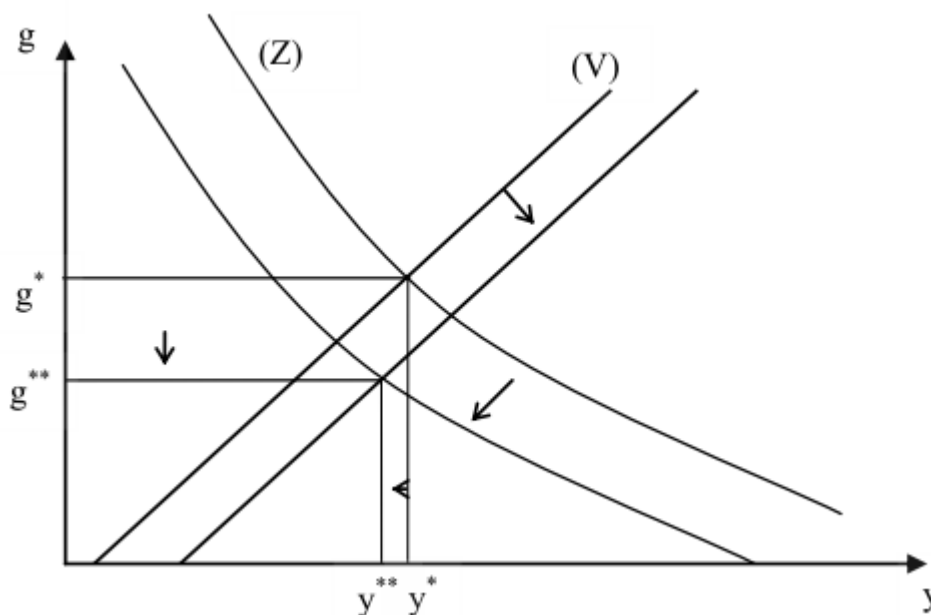
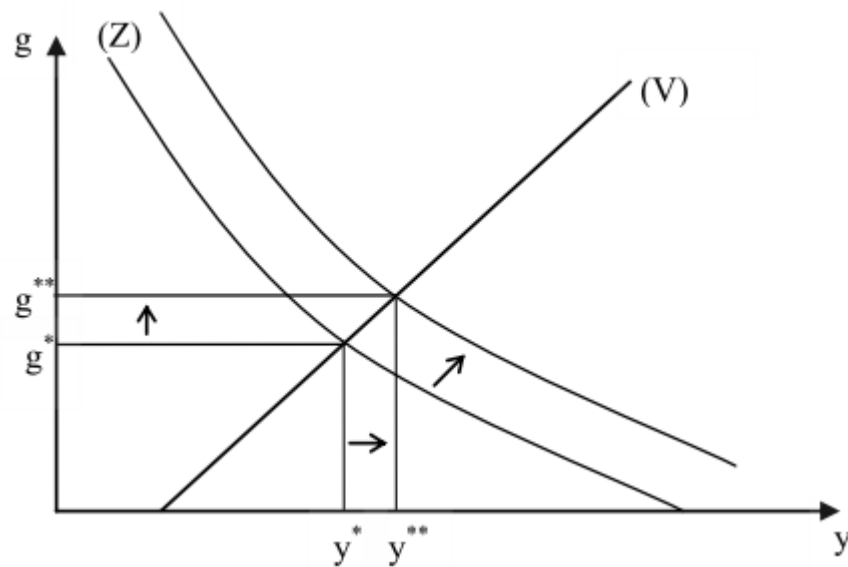
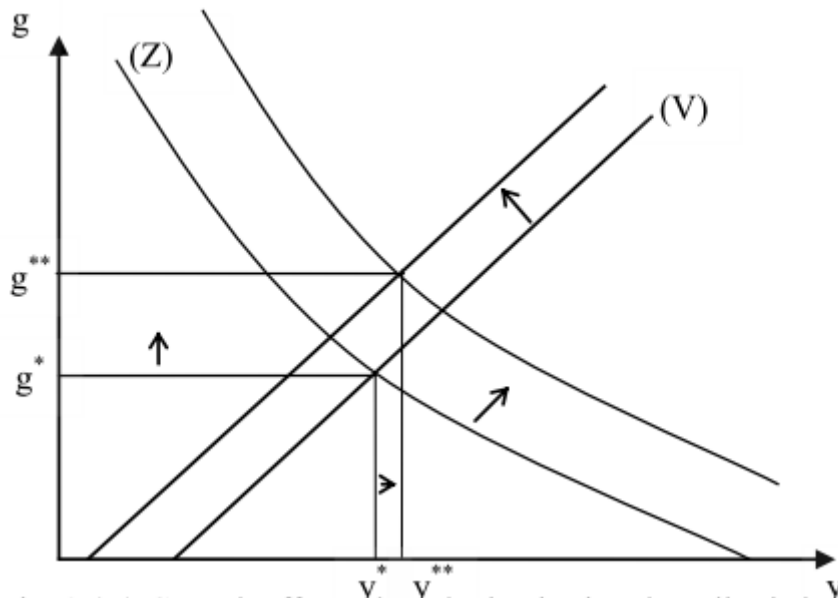


Figure 2(b): Growth effect when the human capital accumulation is improved**Figure 2(c): Growth effect when the institutional quality is improved**

Proposition 2: The long-run economic growth depends on the institutional quality and technical innovation, but also the capital accumulation and household's preference. When positively increased steady-state equilibrium exists, the improvement of institutional quality can improve the human capital accumulation efficiency and the expected revenue of the vertical innovation activity, make the vertical innovation curve (V) and the human capital accumulation curve (Z) move upwards, and thence improve long-run economic growth rate.

From the sole steady-state equilibrium, it can also be seen that the physical capital accumulation and the human capital accumulation are the required conditions of long-run economic growth,

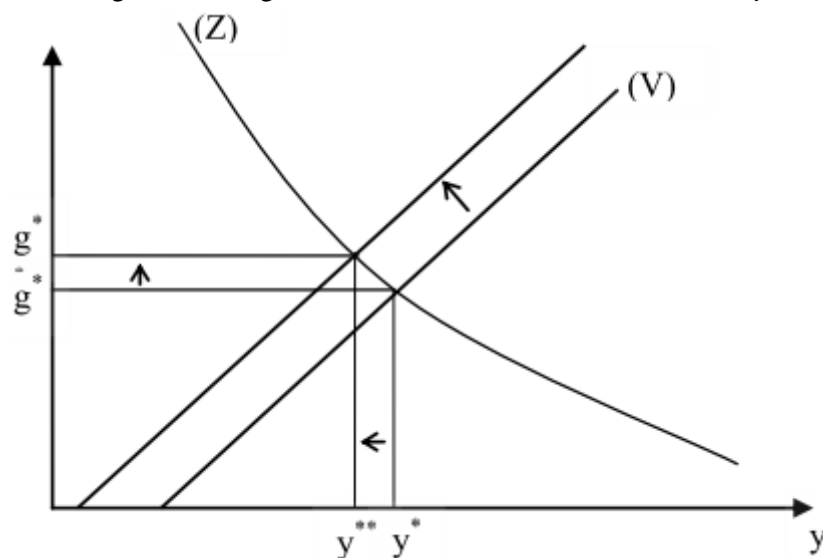
and the government-related policies have long-run effect. We can also use the graphs to analyze the impacts of the governmental policies on long-run economic growth.

In this paper, we consider mainly the five policy parameters, i.e.: physical capital, human capital tax τ_k and τ_z , allowance to innovation, physical capital and human capital investment (s_n , s_k and s_d). Herein we shall respectively the changes in the above five parameters. Firstly the reduction of the physical capital income tax τ_k or the improvement of the physical capital investment subsidy s_k can make the vertical innovation curve (V) and the human capital accumulation curve (Z) move upwards, finally, the government-related policies can make the expected revenue of the vertical innovation activity improve, which can stimulate the investment of the vertical innovation department and thence improve long-run economic growth rate [for the curve variation, please see Fig. 2(c)].

Second, the reduction of the human capital income tax τ_z or the improvement of the human capital accumulation subsidy s_d can make the human capital curve (Z) move upwards, which can similarly improve the expected revenue of the vertical innovation department and improve the long-run economic growth rate [for the curve variation, please see Fig. 2(b)]. Finally, the increase to the subsidy s_n of the vertical or the horizontal innovation department can make the vertical innovation curve (V) move upwards, reduce the marginal costs of the vertical innovation investment, and thence stimulate more R&D investment and improve long-run economic growth rate (Fig. 3).

We present proposition 3:

Figure 3: Long-run effect of R&D innovation subsidy



Proposition 3: If the human capital production needs the human capital and the physical capita ($0 < \beta < 1$), the subsidy offered to physical capital and human capital or the subsidy offered to the innovation department investment can also improve long-run economic growth rate per capita yield, however the tax collection of physical capital and human capital can reduce long-run economic growth rate.

5. Conclusions

From the perspectives of the paper, the existing endogenous growth theory omits the impacts of the institutional factors to long-run economic growth, however for the developing country China, the institutional quality affects not only the substance capital and the human capital investment efficiency of China, but also affects the technical innovation of China, therefore the existing endogenous growth theory does not fit to explain the economic growth of the developing countries.

Meanwhile, the interactions of the physical capital, human capital accumulation, technical innovation and institution in long-run economic growth should be studied under an uniform analysis frame. In line with the purpose, this paper, on the basis of the Aghion and Howitt (1999) model and by introducing the institutional variables to the endogenous growth model, tries to discuss the actions of the institutional quality, capital accumulation and technical innovation in long-run economic growth. Its results show long-run economic growth depends on the institutional quality and technical innovation, as well as capital accumulation and household's preference.

The long-run steady-state equilibrium with the positive growth rate can only appear when the institutional quality reaches to a certain level, and when the equilibrium exists, the improvement on the institutional quality can improve long-run economic growth rate by improving the human capital accumulation efficiency and the expected revenue of the vertical innovation activity. Additionally, if the human capital production needs the human capital and the physical capital, the governmental tax collection policy and subsidy policy will also affect long-run economic growth. To be specific, the subsidy offered to the physical capital and human capital investment or the subsidy offered to the R&D and innovation department investment can improve long-run economic growth rate per capita output, the tax collection of the physical capital and the human capital revenue can reduce long-run economic growth rate.

The research conclusions under the paper disclose the urgency and importance of further deepening reform, especially the institutional innovation is vital to the successful economic transmission of China. To be specific, it is preferred to transform the function of the government, simplify the examination and approval procedures, transform the economic management functions of the government to various principal services on market, establish and improve the institution, policy and legal environment fitting to the market economy, further improve the market system, give full play of the role of the market for configuring resources, and finally improve the marketization degree of China. Meanwhile, the improvement of human capital and the technical innovation have the function for long-run sustainable economic growth of China, and such function can't be ignored, the government should take advantage of tax collection, subsidy and other financial policies to enhance the incentives to education and R&D departments. Besides, we must be aware of the importance of the physical capital input in the human capital production process, for instance the importance of enhancing the education infrastructures and other hardware investments.

All in all, as long as there is available a high-quality institutional environment, the capital conditions and the technical conditions co-work each other, the efficiency of capital investment can be improved, the productivity level of China can be improved, and the long-run sustainable economic development of China can be finally realized.

6. References

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