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ENGINEERING MANAGEMENT THEORIES AND METHODOLOGIES

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Economic Growth Model Based on Six Basic Factors of Production—Xu Growth Rate Equation

Abstract This paper proposes an economic growth model based on the Six Basic Factors of Production and Xu Growth Rate Equation for the first time, which fills-in the deficits of the New Classical Economic Growth Model based on the Solow Model. The empirical analysis indicates that over the past three decades, the consumption of six basic factors of production had complicated relations with economic growth. In some years, the consumption rate of the basic factors of production was meager, but the economy witnessed relatively rocketing growth rate; in some years, the factors of production consumption rate was very high, but the economy growth rate slowed down. In general, economy grows at the expenses of huge consumption of four factors. There is an obvious characteristic of huge input and low efficiency. The average contribution rate of technological advance peaks in the middle, while it drops down at two ends. Noticeably, since 2004, the technology contribution rate generally shows a downward trend, reasons of which should be explored systematically in aspects like economic policy and industry structure with a view to boost further transformation of the macro-economy scientific growth model.

Keywords: six basic factors of production, economic growth model, Xu Growth Rate Equation

1 Introduction

In the palace of economics, the internal mechanism of economic growth is always the primary concern of the economists. However, economic growth is an awfully complex phenomenon. Although many economists have conducted profound researches, by now, there is no single theory offering an effective enough prescription to the economy of countries. Currently, some countries possess great wealth, but some countries are still stuck in poverty. This is an objective portrait of the dilemma of theory. Therefore, economic growth is still a difficult economic problem to be settled. Every year, a large number of research papers emerge about it. Just like a master once put it: as long as people begin to think about this problem, it's hard for them to think about other issues (Robert, 1988). However, we must keep the warning of Solow in mind: If there are not new ideas proposed, we will have no reason to return to this old problem (Robert, 1991). This article will propose a new economic growth model—economic growth model based on Six Basic Factors of Production, and build a corresponding growth rate equation[①]. This new attempt might uncover a thread and observation.

2 The evolution of the economic growth theory

In essence, to explore economic growth is to answer these questions: how to determine the total output of an economy? Why, in one single economy, the annual total output increases in some years and drops down in other years? How to achieve steady growth of total output in the next period on the basis of the previous period?

Research on this issue is quite interesting but rather difficult. In history, numerous researchers have conducted research on this issue. The researchers include not only great experts like Solow, Robert and Simon Smith Kuznets, but also a lot of unknown scholars. The literature accumulated on growth theory has gone far beyond the life-time reading ability of a person (Domar, 1946). As a result, for the researchers who attempt to make a difference in this field, primarily they must comb through the previous research achievements, and then they can make a new start on the shoulders of giants, otherwise it's hard to make a meaningful

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① The writers of this thesis name it Xu Growth Rate Equation, to reflect the new contribution of six basic production factor theory by Shou-bo Xu, a member of the Chinese Academy of Engineering.

contribution. Of course, reasonable methods should be adopted, which ensures efficient interpretation of the essence of those achievements. Currently, the most commonly used method is classification is based on chronology, and those theories are divided into four classifications: classical growth theory, new classical the economic growth theory, new the economic growth theory and new mechanism the economic growth theory. In this article, the writer will not adopt this common classification. Instead, the problem will be elaborated along with the evolution of a theoretical solution.

The research of the writer indicates that although there are various schools, economic growth theories logically come down in one continuous line. Their themes are to explore the principal factor of real output growth in one country or region, and how to distinguish and measure the contribution and function of different factors in economic growth. As a result, we can classify the problem as follows: for an economy, suppose there are n types of factors of production $x_1,x_2,\ldots,x_n$, which can affect its economic growth; the essence of economic research is to find out the mapping relationship between n types of factors and the output y:

$$y=f(x_1,x_2,\ldots,x_n) \tag{1}$$

Equation (1) indicates relation between n types of production factor mix, and output (also called production function).

In the following part, an analysis will be made on the evolution of the economic growth theory according to the logical indications offered by equation (1).

2.1 "Theory of capital accumulation" and single-factor production function

The earliest research on economic growth originated from the forefather of economics Adam Smith. In the age of Adam Smith, mass production based on social division of labor had just started, and the industrial revolution dominated by the textile industry was on its way. With a keen eye through heavy fog, Adam Smith (1972) seized the significant factors of market and division of labor that shed great influence on economic growth, and proposed the epoch-making Smith's theorem: "the outmost advance in productivity, and more proficiency, skill and judgment in labor, seems to be the result of labor division" (p.1) … "labor division is due to the ability of exchange; therefore, the level of division, is restricted by the ability of exchange; in other words, restricted by the market scale" (p.17). Correspondingly, the growth of wealth derives from labor division, while the degree and specialization of division are determined by the size of the market. Therefore, there are two approaches of national wealth growth: The first is the improvement of productivity by labor division; the second is the increase of labor force in productive labor. However, the improvement of productivity is determined by proficient labor skills, the saving of time, and the adoption of machinery. The increase of productive labor is determined by capital accumulation that boosts this type of labor, so capital accumulation becomes a key factor to determine wealth production. Under the influence of Adam Smith, the classical the economic growth theory emphasizes the role of physical capital, and takes the scale of capital and the speed of capital accumulation as the primary factor that affects economic development.

In the late 1940s', Harold and Domar built the Harrod-Domar model on the basis of the longevity and dynamic analysis of the Keynesianism. The deduction of the model is rather simple: suppose ① production factors are assembled at fixed proportions, namely the technical coefficient is fixed; ② the capital-output ratio is stable; take g as growth rate, take y as the total output, I as the investment, and S as the saving, so:

$$g=\frac{\Delta y}{y}=\frac{\Delta y}{I}\frac{I}{y}$$

Set $s=\frac{S}{y}$, $\sigma=\frac{\Delta y}{I}$, according to the Keynesianism, under the even state $I=S$, the Harrod-Domar Model is :

$$g=s\sigma \tag{2}$$

As the primitive quantitative study achievement of the economic growth theory, after the World War II the Harrod-Domar Model once was widely applied in guiding the economic practice in the developing countries, to deal with the relations between investment, savings, and economic growth. For the developing countries due to the extreme shortage of capital, abundant labor forces are left unused; therefore, it's of great significance to stress the role of capital accumulation in economic growth.

However, the Harrod-Domar Model has obvious defects. First, the Harrod-Domar Model is built on the foundation of the Keynesianism. Although it overcomes the overstress on short-term static analysis of the Keynesianism and elaborates the limitation of economy phenomenon in the angle of demand, prolonging and vitalizing the Keynesianism, it still takes the Keynes equilibrium as foundation, and the savings' complete conversion into investment as the necessary premise of economic growth. In reality, whether savings can be transformed into investment completely is not only affected by the elasticity of interest rate, but also by many complex factors such as the psychological anticipation of the investor and consumer, as well the income division mechanism. Therefore, this premise is not always right. Second, the Harrod-Domar Model assumes that capital output ratio is unchanged, so it requires the technology to remain unchanged in the long run. However, this requirement is obviously unreasonable. Third, since the Harrod-Domar Model assumes that ratio between capital and labor is unchanged, the problem of economic growth becomes searching for the mapping relation between single capital factor and the output, whose key point is to influence the capital accumulation (savings) increase on economic growth rate, so this model can be regarded as a single-factor production function model. Seen from equation (2),s in the model stands for the savings rate, namely the capital accumulation rate; σ stands for the Capital-output coefficients, namely the capital production rate. Since σ is assumed unchanged, s becomes the only factor determining economic growth; the Harrod-Domar Model therefore pushes capital fundamentalism to a peak. Due to the inner theoretical conflict, the Harrod-Domar Model depicts the economic growth as a kind of "growth on the cutting edge", and its explanation of the complex phenomenon in economic growth is, in fact, not convincing.

2.2 New classical the economic growth theory and two-factor production function

In order to overcome the internal defects of the Harrod-Domar Model, since the 1950s, the American economists Solow and Swan, and the British economist Meade proposed the New Classical Economic Growth Model, typically the Solow-Swan model. The New Classical Economic Growth Model obviously differs from the Harrod-Domar Model. First, it contains two factors—capital and labor, and these two factors can replace each other; the capital output ratio can be changeable; it differs from the Harrod-Domar Model because it doesn't require capital/labor ratio and the capital output ratio to be unchangeable. Second, it assumes that capital and labor can be utilized fully at any time—that is, the market is perfectly competitive, while the salary and profit are determined by the marginal productivity of labor and capital; adjusting the portfolio of labor and capital in production by means of the market can realize full employment, and the capital and labor can be fully utilized; Third, it also assumes that there exists technological advances from sources outside the economic system, and the profit scale remains unchanged, with the Hicks neutral nature.

Under the foregoing assumption, the production function can be:

$$Y=A(t)f(K,L) \tag{3}$$

It can be deducted to be:

$$g = u + \alpha\frac{\Delta K}{K} + \beta\frac{\Delta L}{L} \tag{4}$$

Equation (4) frequently is called Solow Growth Rate Equation, in which $g = \frac{\Delta Y}{Y}$ is the economic growth rate; Y stands for the total output; K stands for the total capital; L stands for the total labor; α stands for the output elasticity coefficient of capital; β stands for the output elasticity coefficient of labor; u stands for the contribution rate of technology to the economic growth.

In the development of economic growth theories, the Solow Model is of game-changing significance, and becomes an important method of economic growth research. For this innovative contribution, Solow was awarded the Nobel Prize of Economics in 1987. Obviously, the work of Solow is of great significance in many aspects. First, it innovates the Harrod-Domar Model, which considers only the capital, into a two-factor model considering both capital and labor, and provides more overall and convincing explanation of economic growth. Second, the Solow Model for the first time in history declares the function and role of technological progress. It can be seen from equation (4) that the total of the increment $\alpha\frac{\Delta K}{K}$ resulted from capital increase, and the increment $\beta\frac{\Delta L}{L}$ resulted from labor increase, are not equal to the economic growth rate g; instead there emerges a remainder $u = \frac{\Delta A}{A}$. This remainder is defined by Solow as the contribution of technological progress to economic growth. Solow's contribution also lies in his finding after his sample inspecting American actual statistics:in the US, the contribution of capital and labor to the total growth rate is about 12.5%; the contribution of technological advance to the total growth rate is approximately 87.5%. After that, Denison and other economists' empirical analysis also proves that the economic growth rate of some countries like the United States is much larger than the growth rate of factor input including capital and labor. That is to say, there is always a "remainder". It fully proves that: Economic growth is not only determined by the material factors like capital and labor, but also determined by technological advance, and the factor of technological advance is the principal source of economic growth (Robert, 1991). Thus, the technological determinism joins the group of economic growth theories.

However, just as Abramovitz put it: "remainder" actually is the estimation of human ignorance (Abramovitz, 1993). The Solow Model is like opening a mysterious box, and those who come after should do is to continuously take new factors out of this box and put into the model built by Solow, and this process is hard to stop once started. This phenomenon indicates that the Solow Model is still unperfected (Robison, 1963)①.

2.3 Human resource and three-factor production function

Although the Solow Model incorporates the factor of capital and labor, it ignores the difference of the quality and quantity of factors. In order to reflect the contribution of the labor quality improvement to economic growth, Schults, Lucas and other researchers developed the human capital theory.

① In fact, the Solow Model is under long-term criticism. The British school and the new classical school have debated over it. Just as Robinson once put it: "production function has become a powerful instrument of wrong education. The students are taught to write $Q=F(L,K)$, among which L stands for the quantity of labor; K is the amount of capital; Q is the output rate of product. The students are told to assume all the workers work the same, and the labor quantity is measured by people per hour; he is told about some issues of index statistics while selecting the output measurement unit, but is led quickly to the next question. So he forgets to ask what unit to be used to measure capital. And when he really poses the question, he has become a professor, so such a hotheaded mind is passed on."

After studying the laborers' knowledge and skill accumulation, Thodore W. Schults proposed that capital should be classified into the conventional capital and human capital. The human capital is the capital accumulated to invest in enhancing human strength, intelligence, and skills. Because the rate of return on investment is the core of the economic growth theory, human capital can produce incremental profits, so it is a crucial investment variable deciding economic growth rate. Therefore, only the specialized human capital accumulation is the real source of output growth (Schults, 1990). The human capital has two means of formation; the first is education and training, namely normal school education and off-job training, which is the "internal effect" of human capital; the second is learning while working, namely on-the-job training, apprenticeship or the accumulation of work experience, which can also form human capital. This is the "external effect" of human capital.

Lucas incorporates Schults' concept of human capital, and divides technological advance into ordinary knowledge in production and human capital in the form of labor skill. Human capital is divided into the human capital in ordinary form of knowledge, which is shared by the whole society, and the human capital embodied in the skills of the laborer, and further brings the human capital as an independent factor into the economic growth model, Thus, the concept of technological advance and human capital become clearer, and the quantitative analysis can be applied.

Y stands for the total output of the economy; K_k stands for the total physical capital stock; L stands for the amount of natural the laborer; H stands for total human capital in the system, so the total output function which contains human capital can be: $Y=F(K_k,L,H)$.

Under the new classical assumption, it can be expressed further as follows:

$$Y=A(t)K_k^{\alpha}L^{\beta}H^{\gamma} \tag{5}$$

Obviously, the proposal of human capital theory means an important development of Solow's concept of technological advance, technological advance is embodied in two aspects: the first is the knowledge and skill of the laborer, namely the laborer's knowledge obtained in the means of learning, training, and in-house training etc., it enables the productivity to be improved; the second is the advanced technology embodied in physical products like new equipment and new raw materials etc., which enables the improvement of capital efficiency in production.

2.4 The new economic growth theory and four-factor production function

Although the Solow Model proposed the milestone concept that technological advance has decisive effect on economic growth, it cannot answer the question—where technology originate? It can only bring in technology as an external variable, as if technological advance is a "visitor from the outer space" which is independent from the economy, or "God's blessing". However, when we look back on the economy development of the developed nations since the 20th century, we can find that the technological advance is not only external, but also internal. The economy can function without waiting for the coming of technological advance.

Practices prove that there is an important mechanism between technological advance and economic development which influence each other. Technological advance is the powerful driving force behind sustainable economic development; meanwhile the economic development also boosts sustainable technological advance. Noticeably, if the economic growth theory cannot reflect this point, theory must seek further development. Since 1980s Romer and other researchers built the internal growth theory model with internal technological advance. They proposed that knowledge accumulation is the cause of economic growth, and is also the result of economic growth; these two sides interact with each other and influence mutually. Knowledge can be accumulated in four means—the knowledge accumulation that is materialized into technology, the knowledge accumulation of the labor force (human capital), the knowledge accumulation evolving along with labor division, and the knowledge accumulation incorporated in institutional change. These four means have organic connection with one another. Technological advance relies on human capital; human capital relies on labor division, and labor division relies on institutional change. Therefore, economic growth is an evolving process, with the knowledge accumulation being an approach and the interaction among technological advance, human capital accumulation, labor division evolution and institutional change in it.

The principal representative of the internal growth theory Paul Romer proposed three economic growth models in 1986, 1987 and 1990 respectively. Romer Model I broke through the assumption of New Classical Theory which believes the return scale is unchanged and technology is external, and explore the economic growth with internal knowledge accumulation under the condition of full competition; Romer Model II forged a model to explain economic growth under the specialization and the framework of increasing profits, and believes that increasing profits is the result of specialization upgrading, profit increasing brought by specialization leads to sustainable economic growth; Romer Model III connects specialization with knowledge accumulation, and explores the influence of technology and human capital on economic growth under the condition of monopoly competition (Romer, 1990).

Suppose the economic system includes three departments: department of research, department of intermediary product and department of end product. The research department utilizes the human capital and knowledge stock to produce new knowledge; the intermediary product department utilizes new knowledge to produce durable product; the department of end product utilizes human capital, durable products and labor to produce end products; the total output is the function of four basic factors—technology, human capital, physical capital and labor. If the new knowledge produced by the research department is noted as $\dot{A}$, the human capital input by the research department is noted as H_A, and the knowledge stock is noted as A, Romer Model III can be expressed as follows: $\dot{A}=\theta H_A A$

$$g = \theta H_A = \theta H - \frac{\alpha\gamma}{(1-\alpha-\beta)(\alpha+\beta)} \quad (6)$$

In the formula θ stands for productivity parameter; γ stands for market rate of interest; g stands for the equilibrium rate of growth of economic.

Equation (6) indicates that if the research department inputs more human capital, the equilibrium rate of growth of economic is higher; the higher the total human capital input H, the higher equilibrium rate of growth of the economy; the higher the market rate of interest γ, the lower equilibrium rate of growth of the economy. If the level of human capital is too low, or the human capital of research department is zero, the economy will slide into stagnation. Only when the total human capital in the economy is above a certain level, the economy can achieve sustainable growth. In the Harrod-Domar Model, the economic growth is driven by capital, but the marginal profit of capital is decreasing; influenced by the law of capital marginal revenue decreasing, the total revenue of output necessarily shows a decreasing trend. In the New Classical Growth Model, suppose the capital marginal revenue decreases, but the technological advance leads to revenue increasing, so the revenue scale remains unchanged. In the Romer Model, knowledge, as an independent factor, not only can ensure increasing revenue but also can enable the input of other factors like capital and labor to generate increasing revenue, and then enable the revenue scale of the whole economy to increase. In other words, knowledge is socially external and has a spillover effect. It can lead to the virtuous cycle of knowledge spillover factor of revenue increasing-the knowledge input of the producer-spillover effect expansion; the knowledge accumulation and economic growth abide by the cycling effects of the positive feedback mechanism. This offer guarantees the steady economic growth in long term. Therefore, knowledge accumulation is the new source of economic growth in modern times; the specialized human capital is the principal stimulant of knowledge accumulation growth. In this way, Romer Model goes one step farther than Solow Model. Economic growth is not only determined by technological advance, but also by human capital. This concept is not only proved by the history of developed nations, but also verified widely by the practice of developing nations.

However, the Romer Model also has its internal defects. For example, ① it only analyses the monopoly competition of intermediary market and knowledge market; it still assumes the end product market is a full competitive market. ② It assumes the research department can utilize knowledge for free, and the intermediary product department can purchase new knowledge; for the research department, knowledge is not completely exclusive, while for the intermediary product department, knowledge is completely exclusive. This is a conflict in logic. ③ It owes the economic growth to the revenue scale increase caused by the external nature of knowledge, and ignores the revenue scale increase caused by the internal economy (Meng, 2001).

2.5 Institutional determinism and five-factor production function

In 1968, North pointed out in his thesis Sources of Productivity Change in Ocean Shipping, 1600-1850, that in this period, little changes took place in marine transportation technology, but because the marine transportation became safer, market institution was improved and the cost of marine transportation was reduced sharply; the productivity of marine transportation was increased tremendously. It proved that, when there is no change in technology, productivity can also be improved by institutional revolution, and then boost economic development. So, North pointed out that: the key of economic growth is institution; efficient economic organization is the key of economic growth; and the development of efficient economic organization in west Europe was just the foundation on which the west world rose up (Douglass & Robert, 1989, p. 3).

Neo-institutional Economics believe that, the reason why institutionalization is so significant in economic growth depends in its great influence on the cost of trade. Coase pointed out in his work the problem of social cost: the existence of transaction fee, forces the society to possess proper institution foundation, in order to ensure the achievement of optimal resource allocation. North believes that, since Adam Smith, the economic theory model ignores the transaction fee caused by specialization and labor division. The core of (an) institution is property rights. The most basic function of an exclusive and competitive property rights institution is to cut transaction cost, and then become the incentive and driving force to boost economic growth. Take the property rights of invention as example: "……the expansion of market size and better definition of property rights of inventions, lift the innovation revenue rate , meanwhile the cost of innovation is reduced significantly. It is just these series of changes that pave the way for a real technological revolution which connects science and technology—the second economic revolution". On the contrary, if the result of invention can be applied freely, the inventor's private revenue will be much lower than the social revenue, which will undermine the inventor's enthusiasm, and barrier the generation of invention. Therefore, North believes that the obstacle of economic development lies in the great amount of transaction fees brought by national opportunistic behavior and institutional defects. The nation has double targets. On one hand, it needs to maximize the rulers' rent; on the other hand, it needs to reduce transaction fees in order to maximize the social total output. In practice, these two targets contradict each other. The national opportunistic behavior will result in economic recession. If the economy of one nation or region is sluggish, the basic reason must be the lack of effective incentive to push economic innovation. So, in order to promote sustainable economic growth, a set of proper institutional arrangements is needed, in a view of defining property rights and improving competitive institution, reducing uncertainty in the future, reducing the possibility of opportunistic behavior, and finally stimulating the individual to undertake those activities which can promote economic growth. It's necessary to build and implement the property rights which bring the social revenue rate and the individual revenue rate as close to each other as possible, and replace the inefficient economic organization with an efficient one, and then boost economic growth (Douglass, 1991, p. 180).

Y stands for the total output; $A(t)$ stands for the technological advance; K_k stands for the physical capital stock; L stands for the number of natural labor force; H stands for the human capital of economies; I stands for institutional factor, so the total output function including institutional factor can be expressed as follows:

$$Y=A(t)F(K_k,L,H,I) \tag{7}$$

Equation (7) is the five-factor economic growth model including the institutional factor.

2.6 Basic contemplation on the evolvement of economic growth theories

The foregoing analysis indicates that the evolvement of the economic growth theory in recent decades is in essence based on the Solow Model and mostly goes in two principal directions:

(1) Explain the expansion of the variable. The basic idea is to search out continuously new factors from the black box of "Solow remainder", and then provide new explanatory variables to elaborate the problem of economic growth. The human capital theory will be attached to the knowledge and technology of the laborer and be extracted to be an independent new factor; the new economic growth theory regards the factor of internal technological advance, and extends to the research of technological advance and the mechanism of knowledge finding, which prevents technological advance being a "visitor from the outer space"; the new institutional economics changes the institutional factor into a kind of variable that can be put from the empirical analysis into the model[①], and finally greatly broaden the research of economic growth. Hence it can be seen that to find out a new production factor and explore its mechanism of action has become an important method to develop the economic growth theory.

(2) Explain the expansion of target. The basic idea is to shift from exploring the form of production function to studying the total factor productivity (TFP). Because the core of economic growth research is to explore the mapping relations between factors of production and total output, in early times most of researchers devoted to exploring the form of production function, and successively put forward C-D production function and its refinement (Cobb & Douglass, 1928) distance function (Shephard, 1953), production function including technological advance, production function reflecting technological advance (Solow, 1955–1956; Solow, 1956; Solow, 1957), secondary CES production function (Arrow, 1962, pp. 63–64), VES production function, frontier production function, transcendental logarithmic production function, Generalized Leontief production function, Multiple output translog function, the maximum possible frontier production function and other production functions in various forms, etc. However, people's focus of study has shifted to the discussion of TFP in recent years.

3 The economic growth model of six-factor basic production function

The argument stated in this article is that the two research directions mentioned above have their inborn defects. In the first research direction, an obvious problem is that the continuous expansion trend of a new factor is confusing. We must ask the question: can the factor expand boundlessly? We believe that, a specified explained variable should and must be explained only by the collection of those independent variables which have direct impact on it; those factors which have no direct impact on the explained variables in the model should be treated as sub-level variable. According to their functions, they are classified into secondary variables or even multiple variables. The choice of explaining a variable should comply with the principles of necessity, completeness, and hierarchy. If there is a shortage of scientific hierarchical division, and variables of different levels mix up in use, it will lead to circulation and overlying among variables, which make the analysis unconvincing. In the second research direction, the result of TFP estimation is greatly influenced by the choice of a model explanatory variable and the analysis method; the conclusion of different models will be widely divergent and puzzling[②].

In the Solow Model, only the two material factors—capital and labor—can determine the total output of econo-

① The new institutional economics school with North, Douglass C. as representative actually questions publicly "technology determinism". They argue that institution is the decisive element behind economic growth, and the technological advance is just the embodiment and result of economic growth.

② Currently there are four commonly used methods to analyze TFP: the growth accounting method, index method, distance function method, and the Econometric method. The growth accounting method is the Solow residual value method. It should in advance assume the mode of production function and conduct estimation; index method requires that the equation must satisfy some mathematical expectation properties, distance function method in fact is a kind of DEA analysis; it needs to assume all the industries have the same aggregate production function; The econometric method has the problem of stability in estimation; sometimes it produces unbelievable result.

mies. These two variables are necessary, but they are also not complete. Although three new factors—human capital, knowledge and institution—are introduced respectively into the human capital model, the new growth model and the new institutional economics model, these three factors need to act on economic growth through an intermediary variable; they don't belong to the level of labor and capital. Therefore, whether in the Solow Model or the human capital model, the new growth model or new institutional economics model, the structure of the explanatory variable is of inherent unreasonableness.

Research shows that there are various engineering activities in the economic growth, which are made up of six basic factors, with an aim to efficiently apply scientific technology into the national economy and thus increase the overall welfare. Let us have a look at the energy engineering, which is also made up with six factors, namely factors such as character, quality, quantity and ratio that will lead to different types of engineering such as coal, oil, natural gas, nuclear, hydraulic, wind, solar; capital and technology intensive, labor intensive, mental labor intensive; advanced tech., common tech., backward tech.; intensive and extensive form. Another example is logistics engineering, which is of the single and comprehensive type. Single logistics engineering normally concerns with a certain single commodity, such as coal, oil, electricity, raw materials, equipment, article of daily use; moreover, it also covers transportation, distribution, warehouse, loading and unloading, processing of information and circulation. The comprehensive logistics engineering, instead of being a simple accumulation of the single ones, has its own specific technology. The relationship between the single and comprehensive ones is the same as that of engine parts and overall design in motor manufactures technology. They are both in an irreplaceable position. Auto warehouse engineering is capital and technology intensive, an advanced one; while general warehousing engineering is labor intensive, less advanced, though "suitable". To a certain degree, six factors are replaceable. For example, capital can partly replace labor and nature resource. With the scientific development in logistics, scientific and technological content is increasing, which is decided by the six factor theory.

Then, what variables should be chosen to be the basic explanatory variable of economic growth model? In order to answer this question, the proposal assumes that:

(1) The economic development process is the process in which various factors integrate with one another.

(2) The factors needed in the economic process can be divided into two categories. The first category is the basic production factors, namely the material factors that should be possessed at the same time in the development process of economy and cannot be replaced completely by other factors; the second is how the other non-material factors which have significant influence and impact on the way of material factor combination including: institution, technology, methodology, procedure, process and knowledge and so on.

The functions of all non-material factors on the economic activities must be achieved through the combination of material factors, so the explanatory variables of the first level can only be material factors. All non-material factors belong to the second and even other levels that follow.

Then, in the economic growth model, what basic explanatory variables can satisfy the principles of necessity, completeness, and hierarchy at the same time? The hypothesis is that the basic explanatory variables of the economic growth model are the six basic factors of production, proposed by academician Xu Shoubo.

As the first researcher to make this point, academician Shoubo Xu pointed out in the principle of Six Basic Factors of Production that: the implementation of any labor and production plan must possess six basic conditions at the same time: the laborer, capital, material, natural resource, transportation, and time. These six factors are six most basic factors of production (Xu, 1988). The laborer refers to the human resources that are occupied and consumed in the economic process; capital refers to the material resources such as machinery, equipment, and factory that are occupied and consumed in the economic process; material refers to the raw material, auxiliary material and energy that are occupied and consumed in the economic process; natural resources refer to the natural resources such as land, minerals, biotic resources, air and water resources that are occupied and consumed in the economic process; transportation refers to the stream of people, logistics, and flow of information that are occupied and consumed in the economic process; time refers to the time that are occupied and consumed in the economic development. These six factors of production have the following features: ① All of the factors should possess not only physical form, but also value, but the physical form is primary, and the value is the secondary. This is the real value principle. ② All the factors should possess the nature of being occupied and being consumed. The occupied factors turn up in the form of stock, and the consumed factors turn up in the form of flow. In the process of production, the factors of production that are processed (including physical and chemical processing) are called production factor consumption. In the process of production, the factors that are used without being processed are called production factor occupation. Under normal conditions, in the process of production, there is no production factor that are only occupied without being consumed, or only consumed without being occupied, because the production factors are occupied first by production in the process and then generate consumption. If there is only production factor occupation without production factor consumption, it is the overstock and waste of production factors, which is an abnormal phenomenon. As per the different functions and nature of production factors in the process of production, the production occupation and production consumption can be classified into two categories of factors: production-occupation-dominant factor and production-consumption-dominant factor. Capital and some natural resources belong to production-occupation-dominant factor; human resources, material, transportation, and time belong to production-consumption-dominant factor. Any production factor occupation coexists with production consumption. Production consumption should come after production occupation, and production occupation surely leads to production consumption. The production occupation and consumption of each production factor should have both physical and value forms. This is the six-factor occupation and consumption principle. It is the second objective principle of production. ③ The production process can be push forward and completed after realizing the combination of production factors in time and space. This is the principle of space unity of factors. The important function of transportation lies in that it can integrate various production factors that are located in different places, and the integration is completed at the place where production or service is implemented; therefore it plays a decisive role in the process of production. ④ In the process of economic development, although there exist six independent basic production factors, namely human resources, capital, material, natural resources, transportation, and time, each of them plays a specific role in the process of production, and their roles differ. However, in the process of production, only these six factors function together can carry out and complete the process of production. With the absence of any of the factors, the process of production cannot be pushed forward and completed. This is the principle of six-factor combined action. ⑤ The six factors should develop coordinately, including the coordination of quantity, quality, and between the input and output of the six factors. ⑥ The six basic production factors can replace each other. Any production factor can partially replace other factors, and can be replaced partially by other factors. However they cannot completely replace or be completely replaced by each other.

The economic growth model with the six basic production factors as explanatory variables can be expressed as follows:

$$Y(t)=A(t)f(L,K,P,N,T_f,T) \tag{8}$$

In equation (8), Y stands for the total output of economic institution; $L(t)$ stands for the amount of application of labor(labor force) in period t; $K(t)$ stands for capital in period t; $P(t)$ stands for the material in period t, including raw material, auxiliary raw material and energy; $N(t)$ stands for the natural resources used in period t; $T_f(t)$ stands for transportation used in period t; T stands for the time used by economy; $A(t)$ is the comprehensive factors, which functions on economies, generated by non-material factor, namely general technological advance①.

Derive the two ends of equation (8) and divide by $Y(t)$, it can get:

$$\frac{\dot{Y}}{Y(t)}=\frac{\dot{A}}{A}+\frac{\partial Y(t)}{\partial L(t)}\frac{\dot{L}}{Y(t)}+\frac{\partial Y(t)}{\partial K(t)}\frac{\dot{K}}{Y(t)}+\frac{\partial Y(t)}{\partial P(t)}\frac{\dot{P}}{Y(t)}+\frac{\partial Y(t)}{\partial N(t)}\frac{\dot{N}}{Y(t)}+\frac{\partial Y(t)}{\partial T_f(t)}\frac{\dot{T}_f}{Y(t)}+\frac{\partial Y(t)}{\partial T(t)}\frac{\dot{T}}{Y(t)} \tag{9}$$

set $\alpha=\frac{\partial Y(t)}{\partial L(t)}\frac{L(t)}{Y(t)}$ stand for the human resource elasticity of output, $\beta=\frac{\partial Y(t)}{\partial K(t)}\frac{K(t)}{Y(t)}$ stand for capital elasticity of output, $\gamma=\frac{\partial Y(t)}{\partial P(t)}\frac{P(t)}{Y(t)}$ stand for the material elasticity of output, $\eta=\frac{\partial Y(t)}{\partial N(t)}\frac{N(t)}{Y(t)}$ stand for natural resource elasticity of output, $\lambda=\frac{\partial Y(t)}{\partial T_f(t)}\frac{T_f(t)}{Y(t)}$ stands for transportation elasticity of output, $\mu=\frac{\partial Y(t)}{\partial T(t)}\frac{T(t)}{Y(t)}$ stands for time elasticity of output, $u=\frac{\dot{A}}{A}$, then equation (9) becomes

$$\frac{\mathrm{d}Y(t)}{Y(t)}\frac{1}{\mathrm{d}t}=u+\alpha\frac{\mathrm{d}L(t)}{L(t)}\frac{1}{\mathrm{d}t}+\beta\frac{\mathrm{d}K(t)}{K(t)}\frac{1}{\mathrm{d}t}+\gamma\frac{\mathrm{d}P(t)}{P(t)}\frac{1}{\mathrm{d}t}+\eta\frac{\mathrm{d}N(t)}{N(t)}\frac{1}{\mathrm{d}t}+\lambda\frac{\mathrm{d}T_f(t)}{T_f(t)}\frac{1}{\mathrm{d}t}+\mu\frac{\mathrm{d}T(t)}{T(t)}\frac{1}{\mathrm{d}t} \tag{10}$$

Because the observed statistics are separated, equation (10) needs to be further separated, then it becomes:

$$g=\frac{\Delta Y(t)}{Y(t)}=u+\alpha\frac{\Delta L(t)}{L(t)}+\beta\frac{\Delta K(t)}{K(t)}+\gamma\frac{\Delta P(t)}{P(t)}+\eta\frac{\Delta N(t)}{N(t)}+\lambda\frac{\Delta T_f(t)}{T_f(t)}+\mu\frac{\Delta T(t)}{T(t)} \tag{11}$$

Equation (11) is the economic growth rate equation based on Six Basic Factors Production factor principle. u is the generalized technological advance rate. Seen from (11), the growth rate of the economic institution output is equal to the growth rate generated by the input increase of six factors —labor, capital, material, natural resources, transportation, and time—plus generalized technological advance rate. Because equation (11) is based on the Six Basic Factors of Production principle proposed by academician Xu Shoubo, the founder of technical economics of China, this thesis specially named the equation (11) Xu Growth Rate Equation, with the goal to distinguish it from Solow Growth Rate Equation. The difference between Xu Growth Rate Equation and Solow growth rate equation are as follows. Solow Model includes only two material factors, capital and labor, and its

① Hereby, technological advance is still assumed to be Hicks neutral; that is to say technological advance impacts all physical factors at the same time.

explanatory variable is adequate in completeness. The Solow remainder still contains the contribution of material factors; therefore if the Solow remainder is regarded as the contribution of technological advance, a relatively large systematic deviation is unavoidable. The Xu Growth Rate Equation includes six basic production factors, and explains better the contribution of material factor quantity to the economies, so the remainder of equation (11), u stands better for the contribution of the generalized technological advance.

4 Model parameter estimate

In the following part, the thesis takes the real statistics of China between 1978 and 2009 as sample and conducts empirical analysis on equation (11), and then with the results of analysis inspects theories mentioned above. Because in the past three theories China had achieved great economic growth and accumulated abundant practice experience, and a large amount of statistics, such analysis is of enlightening significance for us to understand deeply the problem of economic growth.

4.1 Variable introduction

(1) Man power L. Man power refers to the human resources occupied and consumed by economic development. The thesis takes the number of social laborers as representative, namely the employees at the end of a year.

(2) Capital K. In the Six Basic Factors of Production theory, capital refers to the physical capital resources, such as machinery, equipment and factory, occupied and consumed by economic development, so it is represented by the total amount of social fixed assets. Since in the economic operation, capital has the nature of being occupied and consumed. At the time of selecting a representative variable for capital, either the total amount of social occupation of capital or the real consumption amount in the process of production can be the choice. As there is a lack of statistics about the capital flow, Xu's thesis represents capital as social physical capital stock (Huang & Gong, 2008).

(3) Material P. Material refers to the physical resources, such as raw material, auxiliary raw material, and energy, which are occupied and consumed in the economic process. The thesis starting from the representativeness, availability and reliability, selects 22 types of principal physical resources, and adopts, as proposed by academician Xu Shoubo, the statistics obtained after the relevant documents are processed in standard treatment as the representative material (Xu, 1997)①.

(4) Natural resources N. Natural resources refer to the natural environmental resources occupied and consumed in the economic process, such as land, minerals, air, water, etc. Due to the availability of the statistics, the thesis takes the amount of water consumed as the representative for natural resources variable.

(5) Transportation T_f. Transportation refers to the transportation resources that are occupied and consumed in the economic process when dealing with people mobility, logistics, and information flow. The variable of transportation in the model is represented by the yearly turnover of freight traffic.

(6) Time T. Time refers to the time occupied and consumed in the economic process. Superficially, the variable of time seems very simple, but when building models it is the most difficult variable to be confirmed and handle. The major reason is that the yearly schedules offer no yearly social workload, and at the same time the value of the time units differ every year. In order to obtain available statistics reflecting the nature and feature of time, this thesis, after repeated analysis, takes the total effective workload of all of employees in China as an index to estimate the total social workload, and takes the unit of time value from previous year, after deflation, as the foundation to calculate its total value to represent the total time consumed in that very year.

4.2 Statistics and samples

The statistics in thesis mainly come from New China Fifty Years Statistical Data Compilation (1999) and China Statistical Yearbook over the years, as well the statistical yearbook of some provinces in some years, and the statistical yearbook of the fixed capital investment, etc. All the samples are the sample statistics of China in 1979-2009. The total output is GDP. Because GDP and capital are both magnitude of value, so GDP over the years and capital statistics are adjusted on the basis of the base of 1978; the statistics used in the analysis are listed in Table 1.

4.3 Model inspection and parameter estimate

In order to eliminate multiple co-linearity, Xu's thesis first adopts principal components analysis to process the statistics. Principal components analysis is a multivariate statistical method observing the relevance among a number of variables. It studies how to explain Variance-covariance structure of variables through some major components (namely the linear combination of original statistics). To be specific, it derives some principal components, preserving as much as possible information about original statistics, and there is no linearity between them. The steps are as follows:

(1) Standard treatment of variables. The dimensions of Six Basic Factors of Production are not exactly the same, so standardization is needed. The indexes with different measurements are transformed into the indexes with the same measurement, which bestows the indexes with comparability.

① Among 22 types of principal raw materials, some materials can replace each other, so they need to go through standardized treatment, such as coal, petrol in the energy, steel, wood, cement of the material etc.. The treatment adopts the standardized method proposed by academician Xu Shoubo, referring to Xu Shoubo: *Comprehensive Energy Engineering*, Jiangsu People's Publishing House, 1997.

Table 1 *The Statistics of Six Basic Factor of Production Observation (1978—2009)*

Year	GDP (billion yuan)	Man power (ten thousand)	Capital (billion yuan)	Material (ten thousand tons)	Natural resources (ten thousand tons)	Transportation (billion tons kilometer)	Time (billion yuan)
1978	3,645.22	40,152	3,837	86,884	438,501	9,829	5,290.38
1979	3,922.26	41,024	4,493.13	90,059	462,066	11,385	5,445.80
1980	4,228.75	42,361	5,152.70	90,492	479,935	12,026	5,183.86
1981	4,450.47	43,725	5,835.43	89,314	518,428	12,143	5,014.06
1982	4,853.54	45,295	6,700.41	93,993	537,290	13,049	4,826.72
1983	5,380.30	46,436	77,94.15	100,292	556,188	14,054	4,699.69
1984	6,196.81	48,197	9,123.90	110,083	612,353	15,694	4,648.89
1985	7,031.29	49,873	10,893.36	120,305	653,427	18,126	4,732.97
1986	7,653.30	51,282	12,877.87	125,189	1,916,119	20,148	4,625.10
1987	8,539.80	52,783	14,889.52	130,864	2,063,356	22,228	4,382.95
1988	9,503.14	54,334	16,957.92	137,293	2,345,634	23,825	4,368.37
1989	9,889.27	55,329	18,430.89	142,779	2,830,377	25,591	4,318.12
1990	10,268.92	63,909	19,783.67	151,149	2,597,906	26,207	4,806.99
1991	11,211.50	64,799	21,428.51	157,686	2,701,161	27,986	4,699.69
1992	12,808.10	65,554	23,813.86	167,874	2,856,051	29,218	4,792.46
1993	14,596.66	66,373	27,064.52	178,360	2,915,384	30,525	4,987.93
1994	16,506.01	67,199	30,770.83	191,934	3,136,099	33,275	4,716.35
1995	18,309.28	67,947	34,712.56	208,638	2,736,256	35,909	4,343.70
1996	20,141.77	68,850	38,966.78	215,800	2,618,145	36,590	4,211.80
1997	22,014.36	69,600	43,547.57	219,192	2,575,176	38,385	4,172.64
1998	23,738.82	69,957	48,916.69	211,985	2,496,452	38,089	4,101.62
1999	25,547.68	70,586	54,518.18	220,117	2,364,756	40,568	4,002.54
2000	27,701.68	71,150	60,400.86	226,816	2,279,239	44,321	3,840.61
2001	30,001.01	73,025	67,044.98	246,900	2,209,878	47,710	3,838.41
2002	32,725.72	73,740	74,964.82	267,318	2,085,609	50,686	3,796.90
2003	36,006.59	74,432	85,305.72	310,366	2,069,345	53,859	3,738.81
2004	39,637.87	75,200	97,579.08	364,806	2,113,633	69,445	3,637.87
2005	44,121.74	75,825	111,784.54	410,709	2,098,008	80,258	3,516.11
2006	49,713.51	76,400	131,806.47	463,943	2,526,259	8,8840	3,456.13
2007	56,756.08	76,990	155,989.53	512,272	1,828,530	101,419	3,328.23
2008	62,223.91	77,480	183,754.46	548,853	1,776,630	110,300	3,218.12
2009	67,892.22	77,995	221,920.93	599,902	1,910,206	122,133	3,014.96

Note. Source of data, excerpt from China Statistical Yearbook from 1979 to 2010

(2) Calculate relevant matrices of coefficients *R*. Suppose R_{ij} is the relevant coefficient between index *i* and index *j* after standard treatment, then:

$$R_{ij} = \frac{COV(x_i, x_j)}{\sqrt{DX_i DX_j}} \quad (12)$$

(3) Calculate relevant eigenvalue *t* of matrix of coefficients and eigenvectors *B*, arrange the eigenvalue obtained in order of size:$t_1 > t_2 > t_1 > \cdots > t_k \geqslant 0$, the corresponding eigenvectors t_i is:

$$B_i = (B_{1i}, B_{2i}, \ldots, B_{ki})^{\mathrm{T}} B_i^{\mathrm{T}} B_i = 1 \quad (13)$$

(4) Build principal component. Solve the linear system of equations and get the principal components of *K*:

$$\begin{cases} Z_1 = XB_1 \\ Z_2 = XB_2 \\ \quad \cdots \\ Z_k = XB_k \end{cases} \quad (14)$$

The contribution rate of principal component Z_i is:

$$H_i = \frac{t_i}{\sum_{l=1}^{k} t_l} \quad (15)$$

(5) Calculate the accumulated contribution rate of principal component from Z_1 to Z_k, select principal component, and build the model.

The results of principal component analysis are illustrated in Table 2 and Table 3.

Table 2 *Eigenvalue and Contribution Rate of Principal Component*

	Initial eigenvalues			Extraction sums of squared loadings		
Component	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %
1	5.1994	88.66	88.66	5.1994	88.66	5.1994
2	0.6844	11.41	98.06	0.6844	11.41	98.06
3	0.0814	1.36	99.42	0.0814	1.36	99.42
4	0.0320	0.53	99.95			
5	0.0017	0.03	99.98	0.0017	0.03	99.98
6	0.0010	0.02	100.000			

Seen from Table 2, the first principal component can represent 88.66% of the information of the original six factors of production. The first 5 principal components can represent 99.98% of the information of the six basic factors of production. Factor loading of the principal components is illustrated in Table 3.

Table 3 *Factor Loading Matrix*

Factor	1	2	3	4	5	6
Ln(L)	–0.4228	–0.2316	0.5273	–0.5895	–0.3761	–0.0259
Ln(K)	–0.4366	0.0907	0.1194	–0.1706	0.8705	–0.0103
Ln(P)	–0.4282	0.2175	0.2207	0.5527	–0.1668	–0.6224
Ln(N)	–0.3128	–0.8344	–0.4122	0.1741	0.0198	–0.0733
Ln(T_f)	–0.4345	0.1323	0.0866	0.4022	–0.1555	0.7747
Ln(T_m)	0.4008	–0.4209	0.6940	0.3547	0.2202	0.0792

The first 5 principal components obtained from the factor loading matrix are as follows:

$$\begin{cases} Z_1 = -0.4228\text{Ln}(L)-0.4366\text{Ln}(K)-0.4282\text{Ln}(P)-0.3128\text{Ln}(N)-0.4345\text{Ln}(T_f)-0.4008\text{Ln}(T_m) \\ Z_2 = -0.2316\text{Ln}(L)+0.0907\text{Ln}(K)+0.2175\text{Ln}(P)-0.8344\text{Ln}(N)+0.1323\text{Ln}(T_f)-0.4209\text{Ln}(T_m) \\ Z_3 = 0.5273\text{Ln}(L)+0.1194\text{Ln}(K)+0.2207\text{Ln}(P)-0.4122\text{Ln}(N)+0.0866\text{Ln}(T_f)+0.6940\text{Ln}(T_m) \\ Z_4 = -0.5895\text{Ln}(L)-0.1706\text{Ln}(K)+0.5527\text{Ln}(P)+0.1741\text{Ln}(N)+0.4022\text{Ln}(T_f)+0.3547\text{Ln}(T_m) \\ Z_5 = -0.3761\text{Ln}(L)+0.8705\text{Ln}(K)-0.1668\text{Ln}(P)+0.0198\text{Ln}(N)-0.1555\text{Ln}(T_f)+0.2202\text{Ln}(T_m) \end{cases} \tag{16}$$

The statistics analysis indicates that there are relatively serious problems with co-linearity and sequence in the sample statistics. After repeating the experiment, finally the principal components composed by Z_1, Z_2, Z_3, Z_5 return to the model, and take the generalized difference method OLS as the parameter to estimate. The estimate result is illustrated in Table 4. Seen from Table 4, the parameters of the model have passed t inspection, and D.W=2.2286, located in section [1.74, 2.26], which proves that all the first-order autocorrelations have been eliminated.

Table 4 *The Estimate Result of Model Parameter*

Variable	Coefficient	Std. error	t-statistic	Prob.
Z_1	–0.360887	0.050495	–7.147048	0.0000
Z_2	0.128691	0.017866	7.203325	0.0000
Z_3	0.106732	0.020388	5.235124	0.0000
Z_5	0.698207	0.116699	5.982978	0.0000
AR(1)	1.702459	0.168373	10.11126	0.0000
AR(2)	–0.730059	0.162012	–4.506200	0.0002
		Durbin-Watsonstat=2.228595		

After the calculation, the Six-Basic-Factor of Production economic growth model is:

$$\mathrm{Ln}(\hat{Y})=-6.24+0.59\mathrm{Ln}(L)+0.202\mathrm{Ln}(K)+0.298\mathrm{Ln}(P)-0.049\mathrm{Ln}(N)+0.215\mathrm{Ln}(T_f)-0.625\mathrm{Ln}(T_m) \quad (17)$$

The growth rate equation based on the Six Basic Factors of Production is:

$$Gu = G-(0.59\frac{dL}{L}+0.202\frac{dK}{K}+0.298\frac{dP}{P}-0.049\frac{dN}{N}+0.215\frac{dT_f}{T_f}-0.625\frac{dT_m}{T_m}) \quad (18)$$

In equation (18), G is the economic growth rate of economies; Gu is the contribution of technological advance to economic growth rate.

5 Conclusion and suggestions

5.1 The output features of six basic factors or production

Seen equation (18), provided that other conditions remain unchanged, when the man power grows by 1% increments, it can drag the economic growth rate up by 0.59%, ranking at the top of six basic factors of production; when the capital grows by 1% increments, it can drag economic growth rate up by 0.2%, ranking the fourth among the six basic factors of production; when the material grows by 1% increments, it can drag economic growth rate up by 0.298%, ranking the second among the six basic factors of production; when the transportation grows by 1% increments, it can drag economic growth rate up by 0.215%, ranking the third among the six basic factors of production. All of these features differ obviously from the conclusion of the like analysis. In previous times, the conclusion of most of the like analysis generally argued that the output elasticity of the capital is the largest. The reasons of this argument may be that the process of economic development in China actually is the process in which labor factors move constantly from low-efficiency industry to high-efficiency industry. The growth of the labor force means that the economic system in China keeps expanding, though there is a problem on the large number of rural working population resulting in constant decrease of a recessive and unemployed population. The output elasticity of capital and material is lower than the labor and transportation. The reason may be that in China there is too much low-efficient investment, frequent investment, and over-investment in the fixed-asset investment, so the problem of inefficient asset resetting is rather serious. China's economic development has features of high consumption and low efficiency, which pull down their output elasticity. Transportation actually stands for the supporting capacity of logistics system being a pillar to China's national economic development in recent years, but now standing in the process of rapid development because its output rate is on the uphill side.

Another obvious feature is that the output elasticity coefficient of natural resources and time are negative. The research shows that the reason behind this problem is that the economic system of China has the serious issues of high consumption, high emission, and low efficiency. When the other factors remain unchanged, the growth of the consumption of these two resources means that the problem of high consumption, high emission, and low efficiency is prevailing.

5.2 The consumption of basic factors and economic growth

In order to further analyze the features of the consumption of six basic production factors in the process of economic process, Xu's thesis calculated the movement of six factors of production consumption from 1979 to 2009, as illustrated in Table 5. It can be seen from the table:

(1) In the past over thirty years, the sustainable fast growth of the economy of China came along with the sustainable fast growth of the consumption of six basic production factors. Particularly the consumption of capital, natural resources, and transportation kept growing at high speed. The average growth rate of three principal factors reached respectively 14.03%, 6.52% and 8.6%; in the same period the average economic growth rate was 9.93%.

(2) Seen from Table 5, the growth of the consumption of three principal factors—capital, material and transportation—was increased quickly. On the contrast, the economic growth rate began to slow down its increase and even deviated from the upward trend from the three principal movements. *Figure 1* shows the growth of six basic production factors consumption and the general movement of economic growth.

Table 5 *The Consumption of Six Basic Product of Factors and Economic Growth* (*1979—2009*)

Year	Growth rate of man power consumption (%)	Growth rate of capital consumption (%)	Growth rate of material consumption (%)	Growth rate of natural resources consumption (%)	Growth rate of transportation consumption (%)	Growth rate of time consumption (%)	Growth rate of GDP (%)
1979	2.17	17.10	3.65	5.37	15.83	2.94	7.60
1980	3.26	14.68	0.48	3.87	5.63	–4.81	7.81
1981	3.22	13.25	–1.30	8.02	0.97	–3.28	5.24
1982	3.59	14.82	5.24	3.64	7.46	–3.74	9.06

cont.

Year	Growth rate of man power consumption (%)	Growth rate of capital consu-mption (%)	Growth rate of material consumption (%)	Growth rate of natural resources consumption (%)	Growth rate of transportation consumption (%)	Growth rate of time consu-mption (%)	Growth rate of GDP (%)
1983	2.52	16.32	6.70	3.52	7.70	–2.63	10.85
1984	3.79	17.06	9.76	10.10	11.67	–1.08	15.18
1985	3.48	19.39	9.29	6.71	15.50	1.81	13.47
1986	2.83	18.22	4.06		11.16	–2.28	8.85
1987	2.93	15.62	4.53	7.68	10.32	–5.24	11.58
1988	2.94	13.89	4.91	13.68	7.18	–0.33	11.28
1989	1.83	8.69	4.00	20.67	7.41	–1.15	4.06
1990	15.51	7.34	5.86	–8.21	2.41	11.32	3.84
1991	1.39	8.31	4.32	3.97	6.79	–2.23	9.18
1992	1.17	11.13	6.46	5.73	4.40	1.97	14.24
1993	1.25	13.65	6.25	2.08	4.47	4.08	13.96
1994	1.24	13.69	7.61	7.57	9.01	–5.44	13.08
1995	1.11	12.81	8.70	–12.75	7.92	–7.90	10.92
1996	1.33	12.26	3.43	–4.32	1.90	–3.04	10.01
1997	1.09	11.76	1.57	–1.64	4.91	–0.93	9.30
1998	0.51	12.33	-3.29	–3.06	–0.77	–1.70	7.83
1999	0.90	11.45	3.84	–5.28	6.51	–2.42	7.62
2000	0.80	10.79	3.04	–3.62	9.25	–4.05	8.43
2001	2.64	11.00	8.85	–3.04	7.65	–0.06	8.30
2002	0.98	11.81	8.27	–5.62	6.24	–1.08	9.08
2003	0.94	13.79	16.10	–0.78	6.26	–1.53	10.03
2004	1.03	14.39	17.54	2.14	28.94	–2.70	10.09
2005	0.83	14.56	12.58	–0.74	15.57	–3.35	11.31
2006	0.76	17.91	12.96	20.41	10.69	–1.71	12.67
2007	0.77	18.35	10.42	–27.62	14.16	–3.70	14.17
2008	0.64	17.80	7.14	–2.84	8.76	–3.31	9.63
2009	0.66	20.77	9.30	7.52	10.73	–6.31	9.11
Average	1.76	14.03	6.52	1.94	8.60	2.94	9.93

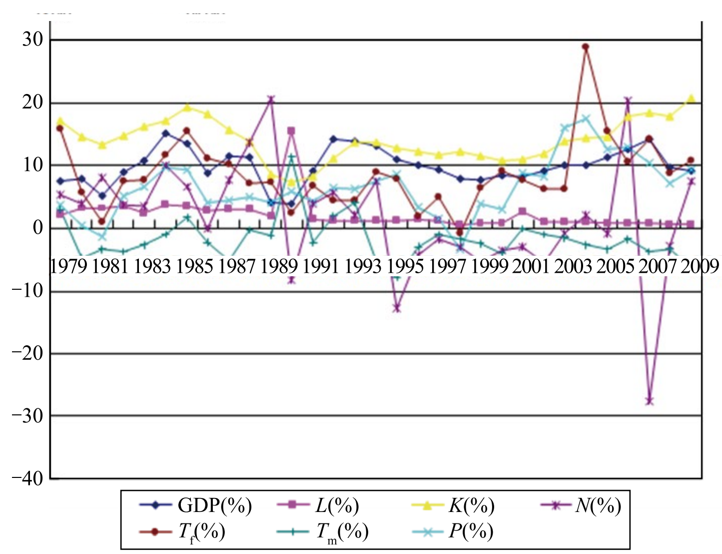

Figure 1. The growth of six basic production factors consumption and the general movement of economic growth. In the graph, L stands for man power; K stands for capital; P stands for material; N stands for natural resources; T_f stands for transportation; T_m stands for time, the same in the following part.

5.3 The role and contribution of technological advance

Seen from Table 5, there is a rather complex relation between the consumption of six basic production factors and economic growth. In some years, the consumption rate of production factors was meager, but the economic growth rate was substantial; in some years, the consumption rate of production factors was very high, but the economic growth rate drops. For example in 1992, the consumption rate of capital, material, and transportation were respectively 11.3%, 6.46%, 4.4%, but the economic growth rate reached 14.24%; while in 2009 the consumption rate of these three principal factors climbed respectively to 20.77%, 9.3% and 10.73%, but the economic growth rate was only 9.11%. It fully proves that, in the process of economic growth, besides the material factors represented by the six basic production factors, some non-material factors also play important roles. We name these factors generalized technology, which are represented by TFP. In order to analyze the role of generalized technology in the economic growth of China, Xu's thesis calculates the contribution rate of six production factors in 1979-2009 and the contribution rate of TFP, as illustrated in table.

Seen from Table 6:

(1) In the past three decades, the factor that made the largest contribution to economic growth was capital. When the other conditions remain unchanged, the average contribution rate of capital in the past 30 years reached 29.67%, while the contribution rate of man power, material, and transportation reached respectively 18.78%, 19.68% and 18.13%. In general, the economic growth of China in the past 30 years is achieved at the expense of high consumption of these four factors, and the feature of high input and low efficiency is quite obvious.

(2) Seen from Table 6, in the past 30 years the average contribution rate of technological advance in China is 8.84%, allocated in three phases. Among them, in the first decade, from 1980 to 1989, the yearly average contribution rate of technological advance is 10.56%; in the second decade, from 1990 to 1999, the yearly average contribution rate of technological advance is 25.32%; in the third decade, from 2000 to 2009, the yearly average contribution rate of technological advance is –9.37%; the curve peaks in the middle and lowers at two ends.

Table 6 *The Contribution of Six Factors and Technology Advance in Economic Growth* (*1979—2009*)

Year	Contribution rate of man power (%)	Contribution rate of capital (%)	Contribution rate of material (%)	Contribution rate of natural resources (%)	Contribution rate of transportation (%)	Contribution rate of time (%)	TFP (%)	Growth rate of GDP (%)
1979	16.97	45.43	14.33	–3.46	44.68	–24.17	6.21	7.60
1980	24.77	37.93	1.83	–2.42	15.46	38.49	–16.06	7.81
1981	36.48	51.02	–7.40	–7.48	3.98	39.06	–15.66	5.24
1982	23.55	33.04	17.24	–1.96	17.67	25.80	–15.35	9.06
1983	13.79	30.37	18.40	–1.58	15.22	15.16	8.63	10.85
1984	14.84	22.70	19.17	–3.25	16.49	4.45	25.58	15.18
1985	15.34	29.08	20.55	–2.44	24.68	–8.40	21.17	13.47
1986	18.97	41.58	13.68	–106.82	27.05	16.11	89.43	8.85
1987	15.01	27.23	11.66	–3.24	19.12	28.26	1.96	11.58
1988	15.47	24.86	12.98	–5.93	13.66	1.84	37.10	11.28
1989	26.77	43.16	29.31	–24.87	39.13	17.70	–31.22	4.06
1980-1989 average	20.5	34.1	13.75	–16.0	19.25	17.85	10.56	
1990	239.94	38.60	45.50	10.46	13.45	–184.40	–63.58	3.84
1991	9.01	18.29	14.04	–2.12	15.86	15.21	29.70	9.18
1992	4.86	15.78	13.52	–1.97	6.63	–8.67	69.83	14.24
1993	5.31	19.74	13.33	–0.73	6.87	–18.26	73.73	13.96
1994	5.65	21.14	17.34	–2.83	14.77	26.03	17.89	13.08
1995	6.05	23.67	23.74	5.71	15.54	45.22	–19.95	10.92
1996	7.89	24.72	10.22	2.11	4.06	18.97	32.02	10.01
1997	6.96	25.53	5.04	0.86	11.32	6.25	44.03	9.30
1998	3.89	31.78	–12.51	1.91	–2.11	13.59	63.47	7.83
1999	7.01	30.34	15.00	3.39	18.32	19.82	6.11	7.62
1990-1999 average	29.66	24.96	14.53	16.79	10.47	–6.62	25.32	

cont.

Year	Contribution rate of man power (%)	Contribution rate of capital (%)	Contribution rate of material (%)	Contribution rate of natural resources (%)	Contribution rate of transportation (%)	Contribution rate of time (%)	TFP (%)	Growth rate of GDP (%)
2000	5.63	25.84	10.76	2.10	23.54	30.00	2.13	8.43
2001	18.86	26.76	31.79	1.79	19.76	0.43	0.59	8.30
2002	6.40	26.26	27.13	3.03	14.73	7.45	14.98	9.08
2003	5.56	27.78	47.87	0.38	13.39	9.54	–4.56	10.03
2004	6.08	28.80	51.83	–1.04	61.55	16.74	–64.00	10.09
2005	4.36	25.98	33.15	0.32	29.52	18.50	–11.86	11.31
2006	3.55	28.53	30.48	–7.88	18.10	8.42	18.78	12.67
2007	3.24	26.15	21.91	9.53	21.44	16.33	1.38	14.17
2008	3.92	37.30	22.09	1.44	19.50	21.47	–5.74	9.63
2009	4.33	46.03	30.43	–4.04	25.26	43.33	–45.37	9.11
2000-2009 average	6.19	29.94	30.76	0.56	24.68	17.22	–9.37	
1979-2009	18.78	29.67	19.68	–4.59	18.13	9.48	8.84	9.93

(3) *Figure 2* shows the comparison of technological advance rate and growth rate of GDP from 1979 to 2009. It can be seen that the generalized technological advance contribution rate is not completely in accord with the movement of economic growth. From 1990 to 2000 the contribution rate of technological advance complies with the movement of economic growth rate; since 2001, although GDP maintains steady growth, the technological advance contribution rate shows a downward trend.

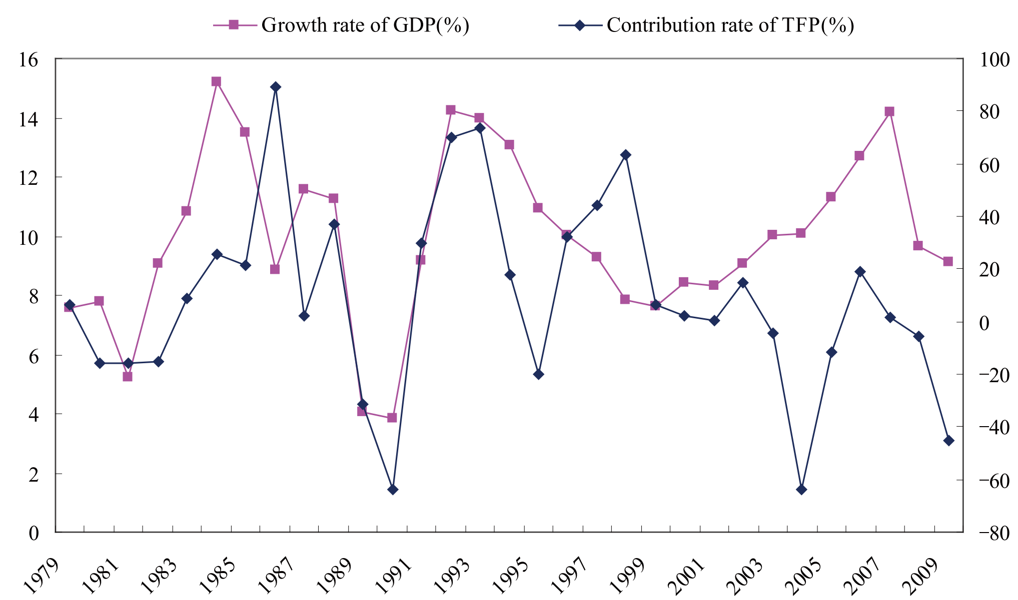

Figure 2. The contribution rate of technology advance in economic growth.

(4) Obviously, in 2004 the contribution rate of TFP dropped sharply from –4.56% of the previous year to –64.34%. Looking back in time we can see that although the growth rate of GDP in this year reached 10.09%, the growth of capital, transportation, and material consumption were larger than the growth of GDP. Also, the contribution rate of technological advance showed a dropping trend since 2004. In 2009 it dropped to –45.37%, which proves that in China there are three main different phases in the economic growth in the past three decades. Maybe it suggests that, since 2004, there are some negative changes in macro-economic operations, industry structures, and growth methods. Therefore, in order to reach regulation and control of the negative elements in current macroeconomic operations, an inspection should be

conducted on the economic policy, industry structures, and methods of economic growth, and a solution should be put into effect from the source of the problem.

References

Abramovitz, M. (1993). The Search for the sources of growth: areas of ignorance, old and new. *The Journal of Economics History*, 2(53), 217-243

Arrow, K. J. (1962). The Economic implications of learning by doing. *The Review of Economic Studies*, 29(3), 155–173

Cobb, C.W., & Douglass, P. H. (1928, March). *A theory of production. Supplement, Papers and Proceedings of the Fortieth annual Meeting of the American Economic Association*. U.S.: American economic Association (18), 139–165

Domar, E. (1946). Capital expansion, rate of growth, and employment. *Econometrica*,14,137–147

Douglass, C.N. & Robert, T. (1989). *The rise of western world* . Beijing: Huaxia Publishing House

Douglass, C.N. (1991). *Structure and change in economic history.* Shanghai: Shanghai Sanlian Bookstore

Huang, Z., & Gong, R. (2008). The comparison and re-estimate of China's physical capital stock estimate methods. *Academic Forum*, 9, 97–103

Meng, X. (2001). *Technical analysis of economic growth*. Tianjin: Tianjin People's Publishing House

Robison, J. (1963). *Essays in the theory of economic growth*. London: Macmillan & Co. Ltd

Robert, L. (1988). On the mechanics of economic development. *Journal of Monetary Economics*,22

Romer, P. (1990). Endogenous technical change. *Journal of Political Economy*, 98

Robert, M. S. (1991). *Analysis of economic growth factors*. Beijing: The Commercial Press

Shephard, R.W. (1953). *Cost and production functions*. Princeton: Princeton University Press

Smith, A. (1972). *An inquiry into the nature and causes of the wealth of nations*. Beijing: The Commercial Press

Solow, R.M. (1955-1956). The production function and the theory of capital. *The Review of Economic Studies*, 23(2), 81–106

Solow, R.M. (1956). A contribution to the theory of economic growth. *The Quarterly Journal of Economics*, 70 (1), 65–94

Solow, R.M. (1957). Technical change and the aggregate production Function. *The Review of Economics and Statistics*, 39 (3), 312–320

Schults, T.W. (1990). *On human resource investment*. Beijing: Press of School of Beijing Economics, 1–18

Xu, S. (1988). *Technical economics*. Nanjing: Jiangsu People's Publishing House

Xu, S. (1997). *Comprehensive energy engineering.* Nanjing: Jiangsu People's Publishing House