Economic growth and optimal transportation structure

[1, 2]Yi Tang

[1]Chang'an University, Xi'an710064, Shaanxi, China
[2]Chang Sha University, Chang Sha410022, Hunan, China

Jianwei Wang

Chang'an University, Xi'an710064, Shaanxi, China

Abstract
This paper makes a systematic theoretical analysis of the problem of the optimal transportation structure from the aspects of the evolution in specialized division of transportation and economic growth, by using the method of new classical economic theory and the infra-marginal analysis. It reveals the dynamic mechanism of the evolution of the optimal transportation structure. The Study has shown that the adjustment of transport structure should be based on economic development level which affects the rate of progress of transport structure adjustment, i. e. the transport modes adapting to economic development stage, its development level and proportion relation. The summation of all the relations of transport structure constitutes optimal traffic transportation structure. The optimal transportation structure of economic development should adapt to the demand of economy industrial structure for transportation service in the corresponding stage, in order to effectively fulfill the basic function of transportation system, and promote the growth of economy.
Key words: SPECIALIZED DIVISION OF LABOR, OPTIMAL TRANSPORTATI-ON STRUCTURE,NEW CLASSICAL ECONOMICS

Introduction

Since the reform and opening up, economy in China has developed rapidly, and a remarkable achievement has been made, but at the same time, China's economy has entered a critical stage for transformation and upgrading of industrial structure. A series of researches about economic growth have become one of the hot issues in today's theoretical circle, however the optimal transportation structure and internal mechanism of economic growth have not been involved in current studies.

In classical economic theory, Smith pointed out that division of labor is one of the most important driving forces of economic growth. However, it is restricted with the range of market. Transportation development enlarges market, therefore, he pointed out "traffic improvement is the most efficient one in all reform"[1]. However, in neoclassical economic model, represented by Debreu's general equilibrium model, in order to deal with economic issues in a mathematical way, the researcher constructed a utility maximization model with no spatial dimension through redefining goods [2]. Taking its base into no consideration makes neoclassical economics lose the extensive explanation for modern economic phenomenon. The new trade theory and institutional theory have improved the flaws of neoclassical economics. Through the study how people make choices between different forms of increasing returns and different types of transport

costs, Krugman suggested that transport costs determine the size and spatial distribution of economic activities by affecting centripetal force and centrifugal force of the accumulation [3]. New institutional economists, represented by Coase make the transaction cost as tool to analyze. During the analysis, North explained the effects of institutional change on economic development by applying the change of transaction cost and ownership structure [4]. The circulation of goods or products between production and consumption includes the “transaction” of ownership and “transport” in spatial place. Most of institutional economists and new trade economists regard transportation as a skill, which excludes transportation cost from transaction cost and economic growth depends on the exogenous technical progress of transport. However, the paradigm of new institutional economics provides a reference for transportation included into economic system. It is the breakthroughs mentioned above that enhance the theoretical level of study about the relationship between transport and economic growth.

Mainstream economic theory abstracts transportation system as the external factors of economic agglomeration, and treats the transportation cost as exogenous variable under a regular transportation production condition, ignoring the value structure and the flow discipline of the transportation system. In the process of transportation development, in order to solve the economic problems of transportation at that time, a number of transportation economic theories studying the transportation phenomena and transportation disciplines were developed. Button elaborates the rules of transformation of transportation structure in the perspectives of the scale economy, scope economy and density economy and analyzes the impact of transport demand elastic changes in different types and modes of transport on transport demand [5]. Transport economics initially focused on the economic problems in the transport system, and then further developed into the study of transportation problems in economy. Aggregated model and disaggregated model forecast traffic transportation demand by analyzing the relationship between land use and transportation. Through applying the typical engineering methods and collecting cross section data, Lowry and Wilson analyzed the relation between traffic volume and population location to explore the spatial distribution of human travel [6, 7]. McFadden established Logit model based on random utility theory and explained its characteristics, basically forming disaggregated model theory system [8]. Lerman and Manski applied Probit model into transport demand forecast [9]. Based on the analysis of the historical data of the changes of community transportation structure in German, Zhao Yiping and Hu Anzhou discusses the influence of the factors of economic evolution stage on transportation structure change. They believe that transportation structure in a certain period of time should be suitable to the stage of economic development and the technical level [10]. Relative to the transportation structure in a certain period of China, its development should fit in economic development level and stage in that period. So the study of transportation economy should not only focus on the problems in transport system, but should closely be combined with the stage of country's economic development, the transformation of industrial structure, the process of urbanization and other major strategic issues. Measurement empirical literatures on the relationship between transportation and economic development at home and abroad are relatively abundant, and with experiential value, but they did not further explore the internal logic relationship between transportation industry evolution and economic growth.

New classical mode disposes production and consumption separately, namely the producers only produce goods but do not consume them, and consumers only consumer goods but do not produce them.[11] When using exogenous variables, iceberg transaction cost, to indicate the link between production and consumption, iceberg transaction cost ignores the characteristics of the transportation cost, which rules the transportation system out of the economic system. This paper, by using the new classical economics mode, unifies the dual identity of producers and consumers, and regards the transportation service as a special product which must be co-produced in the commodity trading, and thus brings the transportation system into the economic system effectively. By introducing the new classical economic framework and iniframarginal analysis in the transportation industry’s specialized production, and exploring the coupling mechanism of transport structure and economic development, this paper reveals the dynamic mechanism of the optimal transportation structure evolution.

Methods and Results

General equilibrium mode for improved division of labor based on specialization

(1)The establishment of the mode and its explanation

Supposing there are M consumers-producers in the economy and they need consume products x and y. To achieve the purpose of the consuming two products, x and y, each consumer-producer can choose two kinds of products which are produced by themselves, namely self-sufficiency; They can also choose specialized production mode, namely, producing a product, x, specially, and at the same time they sell product, x, and purchase product, y. Or they can choose specially produced product, y, and at the same time they sell the product, y, and purchase product, x. The production functions of x and y are shown respectively:

$$x^p = x + x^s = \max\{l_x - \alpha, 0\} \quad (1)$$

$$y^p = y + y^s = \max\{l_y - \alpha, 0\} \quad (2)$$

In the functions, x^p, x and x^s are the amount, self-consumption and sale of x respectively; y^p, y and y^s are the amount, self-consumption and sale of y respectively; $l_x \in (0,1)$ is the personal labor input in the process of producing x; $l_y \in (0,1)$ is the personal labor input in the process of producing y; and $\alpha \in (0,1)$ is the fixed learning parameter.

Specialized production can bring the growth of productivity, but it causes market division, which means trade comes into being, as a result, there is transaction cost. If transaction cost is only the necessary product transportation cost which is used to overcome the space barrier for trade, when the increased earning made by the division of labor exceeds the transportation cost due to trading, the specialized production is profitable. But when the increased earning made by the division of labor is less than the transportation cost due to trading, self-sufficiency mode is a better choice. In order to establish the transportation system in the process of economic development, this article will regard the transport service for overcoming the space barrier in trading as a product, which is transport product. In the economic system, self-sufficient mode does not produce transport product, and transport product will be the necessary product only in specialized production mode, and the number of transport products is equal to the number of products in trade. According to the theorem, in the specialized production mode, there are two ways to produce transport product, one is provided by the manufacturer himself, that is, the manufacturer produces product x (or y), sells x (or y), buys y (or x), and transport service of the purchased product y (or x) in self- sufficiency, namely half specialized mode (or part division structure). Another is to outsource the transportation service to professional transportation provider, that is, the manufacturer only specially produces product x (or y), which means he sells x (or y), and purchases product y (or x) and transport service for product y (or x). Professional transportation provider only provides the transport service for one kind of product x (or y), namely to sell transportation service, t_x (or t_y) ,of the product x (or y) and purchase product x (or y) and product y (or x) and their transportation services, t_y (or t_x). The production function of transportation service is:

$$t_x^p = t_x + t_x^s = \max\{l_{tx} - \beta, 0\} \quad (3)$$

$$t_y^p = t_y + t_y^s = \max\{l_{ty} - \beta, 0\} \quad (4)$$

Here, t_x^p and t_y^p are the amounts of transportation service for product x and y respectively, $l_{tx} \in [0,1]$ and $l_{ty} \in [0,1]$ are the labor inputs for transport product x and y respectively; t_x^p, t_x and t_x^s are the total transport volume of product x, volume for self-use and sale volume of product x in transport service respectively. t_x^p, t_x and t_x^s are the total transport volume of product y, volume for self-use and sale volume of product y in transport service respectively. $\beta \in (0,1)$ is fixed learning cost parameter for transport service. Endowment constraints and budget constraints of each consumer-producer' working time are as follows:

$$l_x + l_y + l_{tx} + l_{ty} = 1 \quad (5)$$

$$p_x x^s + p_y y^s + p_{tx} t_x^s + p_{ty} t_y^s = p_x x^d + p_y y^d + m_x s_x p_{tx} x^d + m_y s_y p_{ty} y^d \quad (6)$$

Here, $l_x, l_y, l_{tx}, l_{ty} \in [0,1]$ are labor shares of four kinds of activities respectively, namely the corresponding specialized levels, p_x and p_y are trading prices of product x and y respectively, p_{tx} and p_{ty} are transport service prices of product x and y in unit weight and unit

distance respectively, m_x and m_y are weights of product x and y respectively, s_x and s_x are transport distances of product x and y respectively.

Every producer- consumer's utility function is:

$$U = (x + x^d)(y + y^d) \quad (7)$$

The optimal resources allocation of given specialization level

According to the theorem, each producer-consumer does not buy and sell the similar product at the same time, is not self-sufficient and buys similar goods at the same time, but sells a kind of goods at most. This means that there are seven kinds of modes in the process of the evolution of transportation system. Mode A (self-sufficiency) means the number of all self-sufficiency products is positive, and the number of all goods for trade is zero, so it doesn't have any product transportation service; Part division of labor structure (x/y) means that product, x is produced professionally, and x is sold, y is bought, and transportation service t_y of the purchased product, y, is self-sufficient at the same time. Here, the transportation volume of products, y, equals to the number of purchased products, y. Part division of labor structure (y/x) means product y is produced professionally, and y is sold, x is bought, and transportation service t_x of the purchased product x is self-sufficient at the same time. Here, the transportation volume of products x equals to the number of purchased products x; Specialized structure (x/yt_y) means product x is produced professionally, and x is sold, y is bought, and transportation service t_y of product y is bought at the same time. Here, the transportation volume of products y equals to the number of purchased products y. Specialized structure (y/xt_x) means product y is produced professionally, and y is sold, x is bought, and transportation service t_x of product x is bought at the same time. Here, the transportation volume of products x equals to the number of purchased products x. Specialized structure (t_x/xyt_y) means providing transport service t_x of product x professionally, selling t_x to buy x, y and transport service t_y. Here the mount of self-sufficiency of x's transport service equals to the number of purchased products x, and the mount for purchased transport service of product y equals to the number of purchased products y. Specialized structure (t_y/xyt_x) means providing transport service t_y of product y professionally, selling t_y to buy x, y and transport service t_x. Here the mount of self-sufficiency of y's transport service equals to the number of purchased products y; and the mount for purchased transport service of product x equals to the number of purchased products x.

In using the mode showed in formula(1)-(7) to analyze the decision-making problem above, the utility function can maximize the effectiveness of this mode, in a given mode using marginal analysis of the effective allocation of labor between product production and product transportation. Optimal decision in a given mode is to maximize the utility through allocating labour share in product x and y, and their transport under effective compromise. Therefore, with the marginal analysis method, we can find out corner solutions for 7 modes, as shown in table 1.

Table 1. The corner solutions of seven modes

Mode	Number of self-sufficiency	Level of specialization
A	$x = y = \frac{1}{2} - \alpha$	$l_x = l_y = \frac{1}{2}$
x/y	$x = \frac{1-\alpha-\beta}{2}$	$l_x = 1-\beta-\frac{1-\alpha-\beta}{2} Ч \frac{m_y s_y k_y p_x}{m_y s_y k_y p_x + p_y}$
y/x	$y = \frac{1-\alpha-\beta}{2}$	$l_y = 1-\beta-\frac{1-\alpha-\beta}{2} Ч \frac{m_x s_x k_x p_y}{m_x s_x k_x p_y + p_x}$

x/yt_y	$x=\frac{1-\alpha}{2}$	$l_x=1$	
y/xt_x	$y=\frac{1-\alpha}{2}$	$l_y=1$	
t_x/xyt_y	$t_x=\frac{1-\beta}{2}ц\frac{m_x s_x k_x p_{tx}}{m_x s_x k_x p_{tx}+p_x}$	$l_{tx}=1$	
t_y/xyt_x	$t_y=\frac{1-\beta}{2}ц\frac{m_y s_y k_y p_{ty}}{m_y s_y k_y p_{ty}+p_y}$	$l_{ty}=1$	
Mode	Supply	Demand	Indirect utility function
A	-	-	$(\frac{1}{2}-\alpha)^2$
x/y	$x^s=\frac{1-\alpha-\beta}{2}ц\frac{p_y}{m_y s_y k_y p_x+p_y}$	$y^d=\frac{1-\alpha-\beta}{2}ц\frac{p_x}{m_y s_y k_y p_x+p_y}$	$\left(\frac{1-\alpha-\beta}{2}\right)^2 ц\frac{p_x}{m_y s_y k_y p_x+p_y}$
y/x	$y^s=\frac{1-\alpha-\beta}{2}ц\frac{p_x}{m_x s_x k_x p_y+p_x}$	$x^d=\frac{1-\alpha-\beta}{2}ц\frac{p_y}{m_x s_x k_x p_y+p_x}$	$\left(\frac{1-\alpha-\beta}{2}\right)^2 ц\frac{p_y}{m_x s_x k_x p_y+p_x}$
x/yt_y	$x^s=\frac{1-\alpha}{2}$	$y^d=\frac{1-\alpha}{2}ц\frac{p_x}{m_y s_y k_y p_{ty}+p_y}$	$\left(\frac{1-\alpha}{2}\right)^2 ц\frac{p_x}{m_y s_y k_y p_{ty}+p_y}$
y/xt_x	$y^s=\frac{1-\alpha}{2}$	$x^d=\frac{1-\alpha}{2}ц\frac{p_y}{m_x s_x k_x p_{tx}+p_x}$	$\left(\frac{1-\alpha}{2}\right)^2 ц\frac{p_y}{m_x s_x k_x p_{tx}+p_x}$
t_x/xyt_y	$t_x^s=\frac{1-\beta}{2}ц\left(1+\frac{p_x}{m_x s_x k_x p_{tx}+p_x}\right)$	$y^d=\frac{1-\beta}{2}ц\frac{p_{tx}}{m_y s_y k_y p_{ty}+p_y}$ $x^d=\frac{1-\beta}{2}ц\frac{p_{tx}}{m_x s_x k_x p_{tx}+p_x}$	$\left(\frac{1-\beta}{2}\right)^2 ц\frac{(p_{tx})^2}{(m_y s_y k_y p_{ty}+p_y)(m_x s_x k_x p_{tx}+p_x)}$
t_y/xyt_x	$t_y^s=\frac{1-\beta}{2}ц\left(1+\frac{p_y}{m_y s_y k_y p_{ty}+p_y}\right)$	$y^d=\frac{1-\beta}{2}ц\frac{p_{ty}}{m_y s_y k_y p_{ty}+p_y}$ $x^d=\frac{1-\beta}{2}ц\frac{p_{ty}}{m_x s_x k_x p_{tx}+p_x}$	$\left(\frac{1-\beta}{2}\right)^2 ц\frac{(p_{ty})^2}{(m_y s_y k_y p_{ty}+p_y)(m_x s_x k_x p_{tx}+p_x)}$

The resources allocation of the optimal specialization

Marginal analysis can deduce the maximum utility of each producer-consumer, due to effective resources allocation for each mode. But there is difference between the maximum utilities for different modes, producer-consumer will finally choose the optimal mode on the basis of total revenue-cost analysis of the corner solution of each mode and adopt resources allocation of the maximum utility in this mode. Table 1 lists the corner solutions of seven modes. Various combinations of the seven modes lead to three organization structures. If all people choose mode A, that is, self-sufficiency, then there is one structure in which there is no market, price and transportation and there are no mutual contacts and interactions between individuals. M people's division of labor between mode (x/y) and mode (y/x) generates a part division structure, noted as p. In this structure, there are two kinds of commodity markets and two kinds of specialists who sell different products and transport the goods they have purchased independently. The number of people who choose (x/y) is noted as M_x while the number of people who choose (y/x) is noted as M_y. M people's division of labor between mode (x/yt_y), (y/xt_x), (t_x/xyt_y) and (t_y/xyt_x) generates a complete division structure, noted as D. In this structure, there are four kinds of commodity markets and two kinds of specialists who sell different products and the other two

specialists sell the transportation service for two commodities respectively. The number of people who choose (x/yt_y) is noted as M_x, while the number of people who choose (y/xt_x) as M_y, the number of people who choose (t_y/xyt_x) as M_{ty}, the number of people who choose (t_x/xyt_y) as M_{tx}. In the part or complete division structure, the division of labor can only be formed as long as all kinds of modes are chosen. If producer-consumer can freely enter or exit from different professions, the utility equilibrium of two professional modes must be established in balance. According to utility equilibrium and the market clearing based on Walras mechanism, the corner equilibrium of three structures can be determined by adopting the infra-marginal analysis of new classical economics, shown in Table 2. The real per-capita income is the corner equilibrium value of the indirect utility function of a structure while the indirect utility function is the maximum utility value of a mode. See appendix for the specific derivation process.

Table 2 The corner equilibrium of three structures

Structure	Relative price	Number of people who sell different goods	Real per-capita income
Self-sufficiency	-	-	$(\frac{1}{2}-\alpha)^2$
Part division	$\frac{p_x}{p_y}=\frac{m_y s_y k_y - m_x s_x k_x}{2}+\sqrt{\left(\frac{m_y s_y k_y - m_x s_x k_x}{2}\right)^2+}$	$\frac{M_x}{M_y}=\frac{m_y s_y k_y p_x + p_y}{m_x s_x k_x p_y + p_x}$	$\left(\frac{1-\alpha-\beta}{2}\right)^2 \times \frac{1}{\frac{m_y s_y k_y + m_x s_x k_x}{2}+\sqrt{\left(\frac{m_y s_y k_y - m_x s_x k_x}{2}\right)^2}+1}$
Complete division	$\frac{p_{tx}}{p_{ty}}=1$ $\frac{p_x}{p_{tx}}=\sqrt{\left(\frac{m_x s_x k_x}{2}\right)^2+\left(\frac{1-\beta}{1-\alpha}\right)^2}-\frac{m_x s_x k_x}{2}$ $\frac{p_y}{p_{ty}}=\sqrt{\left(\frac{m_y s_y k_y}{2}\right)^2+\left(\frac{1-\beta}{1-\alpha}\right)^2}-\frac{m_y s_y k_y}{2}$ $\frac{p_x}{p_y}=\frac{\sqrt{\left(\frac{m_y s_y k_y}{2}\right)^2+\left(\frac{1-\beta}{1-\alpha}\right)^2}+\frac{m_y s_y k_y}{2}}{\sqrt{\left(\frac{m_x s_x k_x}{2}\right)^2+\left(\frac{1-\beta}{1-\alpha}\right)^2}+\frac{m_x s_x k_x}{2}}$	$M_{tx}=M_{ty}$ $\frac{M_x}{M_y}=\frac{m_y s_y k_y p_{ty}+2p_y}{m_x s_x k_x p_{tx}+2p_x}$ $\frac{M_y}{M_{ty}}=\frac{1-\beta}{1-\alpha}\times\frac{2p_x}{m_x s_x k_x p_y}$ $\frac{M_x}{M_{tx}}=\frac{1-\beta}{1-\alpha}\times\frac{2p_y}{m_y s_y k_y p_x}$	$\left(\frac{1-\alpha}{2}\right)^2 \frac{\sqrt{\left(\frac{m_x s_x k_x}{2}\right)^2+\left(\frac{1-\beta}{1-\alpha}\right)^2}-\frac{m_x s_x k_x}{2}}{\sqrt{\left(\frac{m_y s_y k_y}{2}\right)^2+\left(\frac{1-\beta}{1-\alpha}\right)^2}+\frac{m_y s_y k_y}{2}}$

Discussion: The optimal transportation structure in economic growth

The factors influencing the transport industry structure

After determining the corner equilibrium of three structures, the general equilibrium and its comparative static analytical results can be obtained from the comparison of per capita real income of the structures A, P, and D. From table 2, it's known that when $\alpha<\beta$ (the fixed learning cost of product transportation is lower than that of product production), $u_P<u_A$ and the general equilibrium is A; when $\alpha>\beta$ (the fixed learning cost of product transportation is higher than that of product production), any of self-sufficiency, regional division of labor , and complete division of labor possibly becomes the general equilibrium structure. *Matlab* is used to analyze the per capita real income function of three structures. It's concluded that when there are only self-sufficiency and regional division of labor structure, the equilibrium structure is shown as in Figure 1.

With the economic development, when three structures (A , P , and D) coexist, equilibrium structure is presented by two cases as follows in figure 2:

1) when $\alpha < \beta$, $u_P < u_A$ and $u_D < u_A$;

2) when $\alpha > \beta$ and $T_x T_y - \gamma(T_x + T_y) + \gamma^2 < 1$, $u_P < u_A$; When $\alpha > \beta$ and $T_x T_y - \gamma(T_x + T_y) + \gamma^2 > 1$, $u_D > u_P > u_A$; In which $T_x = m_x s_x k_x$, $T_y = m_y s_y k_y$, $\gamma = \left(\frac{1-\alpha-\beta}{1-2\alpha}\right)^2$。

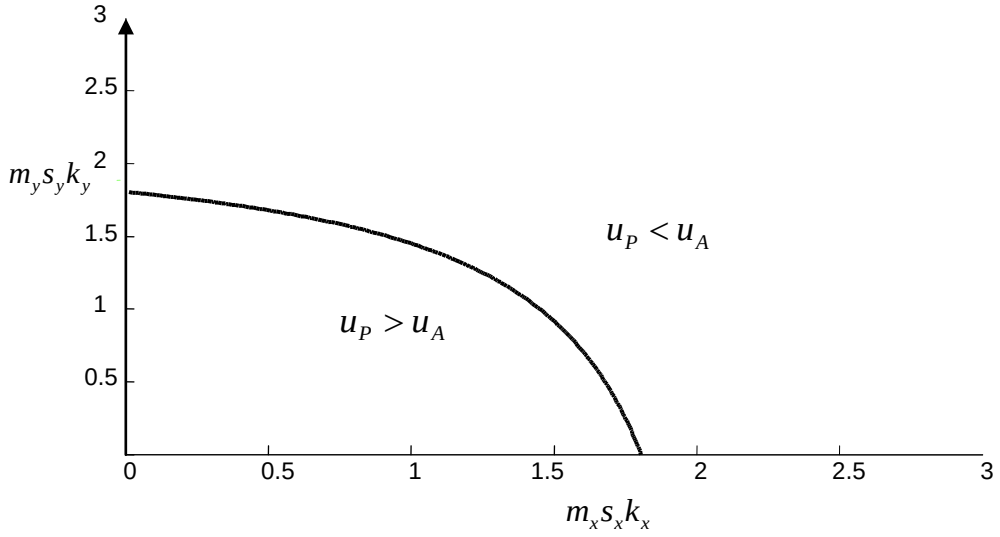

Figure 1. The equilibrium structure distribution of regional division of labor

Through analyzing the model above, it's known that the basic factors influencing transportation industrial structure are mainly fixed learning cost, transport distance, transportation technology, and transport object and so on.

(1). Fixed learning cost

In new classical economics, fixed learning cost includes: training cost in search of the best approach of product production, fixed labor for starting production and fixed cost relevant to product production getting into barrier. There are two implications in table 2 and figure 2.

One is that fixed learning cost of transportation service has an effect on equilibrium structure. Analysis of table 2 reveals that if the fixed learning cost of transportation service β is higher than the fixed learning cost of product production α , equilibrium structure will be self-sufficiency. To put it simply, if the producer is specialized in the production of certain product and outsources transport service to professional transport contractor, and if the fixed learning cost of transport service is too high, per capita real income of self-sufficiency structure is more than that of regional division of labor structure and complete division of labor structure, i. e. the benefits of specialized production are not enough to offset the loss of high transport cost, self-sufficiency structure will be the general equilibrium. Therefore, it shows that in fishing, hunting and gathering Age and the Agrarian Age, except some indispensable life necessities like grain, salt which needed professional transportation, the production and consumption of other products were limited in a very small range, and the products in most parts were self-sufficient. Thus it can be seen that higher fixed learning cost of transport service encourages individuals to allocate considerable sources for self-sufficient production and consumption, and restrains the purchase of specialized production products in market. Lower specialization level which is caused by higher fixed learning cost of transportation service will lead to lower productivity.

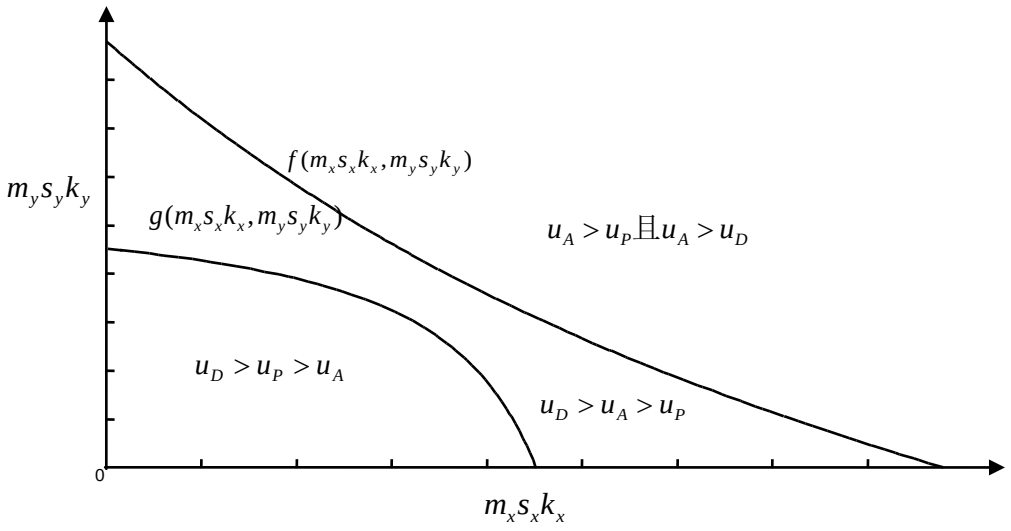

Figure 2. The equilibrium structure distribution of complete division of labor

The other is that specialized production of products can save fixed learning cost of product production and increase transport cost. When relative fixed learning cost of transportation service is lower, the benefits of specialized economics are enough to offset the loss caused by transport cost. *Matlab* is used to analyze the changes of equilibrium structure above. The results show that when $\alpha > \beta$, curve $f(m_x s_x k_x, m_y s_y k_y)$ and $g(m_x s_x k_x, m_y s_y k_y)$ both move to the right as fixed learning cost α, β decrease. Under the circumstances that product transportation service is lower than fixed learning cost of product production, fixed learning cost of transportation service will decrease, and the range of self-sufficiency will narrow down, i. e. the product types of professional transport increase and the range of product sales market expands. For example, in the early stage of transportation development, people used traffic infrastructure with less fixed investment such as natural roads and water channels and applied natural power with less investment such as man power, animal power, wind power, water power, tidal power and so on for the locomotion of people and goods. Together with some measures like toll exemption, China has constructed a low-doorsill transportation network of fresh agricultural products, which has promoted the circulation of fresh agricultural products. From the analysis above its concluded that:

Proposition 1: compared with fixed cost of products, it's not helpful for specialized product production if the fixed cost of product transport is too high; with the development of transportation industry and the decrease of fixed learning cost of transportation service, the range of specialized production will be enlarged, the productivity of each industry will be improved, and the optimization and upgrading of industrial structure and economic development will be promoted.

(2). Transport distance

In complete division of labor, per capita real income is

$$u_D = \left(\frac{1-\alpha}{2}\right)^2 \frac{\sqrt{\left(\frac{m_x s_x k_x}{2}\right)^2 + \left(\frac{1-\beta}{1-\alpha}\right)^2} - \frac{m_x s_x k_x}{2}}{\sqrt{\left(\frac{m_y s_y k_y}{2}\right)^2 + \left(\frac{1-\beta}{1-\alpha}\right)^2} + \frac{m_y s_y k_y}{2}}$$

$$= \left(\frac{1-\beta}{2}\right)^2 \frac{1}{\left(\sqrt{\left(\frac{m_y s_y k_y}{2}\right)^2 + \left(\frac{1-\beta}{1-\alpha}\right)^2} + \frac{m_y s_y k_y}{2}\right)\left(\sqrt{\left(\frac{m_x s_x k_x}{2}\right)^2 + \left(\frac{1-\beta}{1-\alpha}\right)^2} + \frac{m_x s_x k_x}{2}\right)} \quad (8)$$

Per capita real income is the intersection equilibrium value of indirect utility function of a structure. The equation above shows that when transport range s_x, s_y expands, transport costs increase and per capita real income in complete division of labor structure decrease. According to analyses of figure 2, it's known that there is a critical value in the range of specialized production, within which general equilibrium structure is complete division of work, and beyond which general equilibrium structure is self-sufficiency since the benefits brought by specialized production cannot offset the increase of transport costs.

Division of labor is the important basis to improve economic efficiency. The maximum efficiency of metropolitan area caused by intercity division of labor is the decisive factor of a metropolitan area formation and development. The transport costs produced by overcoming the space distance are one of the fundamental factors to affect the formation and development of intercity division of labor. Different regions and positions in metropolitan area make the difference in transport costs, which makes specialization degree deepen from perimeter to central area, and helps form different economic structures and traffic structures. The viewpoints and phenomenon above reveal Krugman's insights. Judging the changes of transport costs in terms of transport distance determines the strength of centripetal force and centrifugal force, and becomes one of the basic elements to influence the dynamic evolution of economic activities in spatial agglomeration and diffusion. Thus it can be concluded that:

Preposition 2: the distance parameter in transport costs is one of the basic factors to determine the difference between economic space structure and transport space structure. Using transport distance as the standard to measure the changes of transport costs has a great significance for the formation of cities and metropolitan area.

(3). The characteristics of transport object

Equation (8) reveals that, their transport cost will increase and per capita real income will decrease as the weight of transport object (m_x, m_y) increases. It's known from table 2 that there is a critical value in the range of product weight in specialized production, within which general equilibrium structure is complete division of work and beyond which general equilibrium structure is self-sufficiency since the benefits brought by specialized production are not enough to offset the increase of transport cost.

Only if transport cost occupies major proportion in total production cost or there is great difference in the transport cost between potential areas, the decrease of transport cost will have an important significance. Nevertheless, the transport cost of major finished products only occupies tiny proportion in total production cost so that the change of transport price has a limited effect on the demand. Consequently, according to the proportion of transport cost in total production cost, transport objects can be divided into non-bulk products with high additional value and bulk stuff with low additional value, between which there is great difference due to the influence of transport cost. Non-bulk finished products with high additional value receives limited influence of transport cost, has strong ability to bear direct transport cost, and have great demands for transport quality such as transport time, frequency, punctuality, convenience and so on, that is, non-bulk finished products have little transport price elasticity of demand and transport quality has great influence on transport demand. Most stuff and primary products have lower technology due to its low additional value, and are not strong enough to bear transport price despite they are the products which must be transported. If their transport price is raised, it will cause the price of serious products rising, which will be against national economic development.

(4). Traffic transport technology

k_x, k_y in equation (8) represent the consumed labor share of transporting unit product in unit distance and unit weight (not including the labor which may produce fixed learning cost). Equation (8) shows that as k_x, k_y increase (i. e. the labor productivity of product transport decreases), product transport cost increases and per capita real income in complete division of labor structure decreases. It's known from table 2 that transport labor productivity of specialized production has a critical value, beyond which general equilibrium structure is complete division of labor and within which general equilibrium structure is self-sufficiency since the benefits brought by specialization are not enough to offset the increase of transport cost.

The factors affecting social productivity mainly include: ① the average proficiency of laborer, ② the development degree of science and technology, ③ the organization and management of production process, ④ the scale and efficiency of production means (it's primarily in surplus transport capacity and decrease of actual load rate).

Because k_x, k_y in equation (8) refer to the consumed labor share of transporting unit product in unit distance and unit weight (not including the labor which may produce fixed learning cost), the transport labor productivity represented by k_x, k_y is determined by the technological development degree of transport basic facility and equipment, the organization and management of transport process and so on. Meanwhile, natural environment also has an effect on transport labor productivity. Based on the analysis of the model above, the technological progress of transport facility and basic equipment , the technological innovation of transport management decrease the cost that people need to overcome the space obstacle, which helps deepen specialized division of labor, and promote the optimization and upgrading of transport structure.

Preposition 3: the shortening of transport distance, the decrease of transport weight and the progress of transport technology will lead to the decrease of transport cost, and will produce more extensive and prominent positive effect of division of labor network.

Optimal transport structure in economic growth

As was mentioned above, factor endowment conditions and industrial structure of an economic entity determine the change of transport structure. Therefore, in order to realize the basic functions of traffic transport system and promote economic development, economic entity in certain development stage should own optimal transport structure which is appropriate to its industrial structure and factor endowment conditions, i. e. in an economic entity, the proportions of all kinds of transport modes in its integrated transport system and their interrelation should match the transport fixed cost and traffic technology level, which are determined by factor endowment conditions, and the transport distance and transport objects, which are determined by industrial structure. From the point of view of longitudinal comparison, the optimal transport structure of an economic entity develops dynamically as factor endowment and entity economic industrial structure change, which may lead to the evolution of its optimal transport structure. While from the point of view of horizontal comparison, factor endowment conditions and industrial structure both have some difference in different regions, so optimal transport structure also differs.

The analysis of the model above reveals that table 1 provides product demand and supply in different patterns, and table 2 provides the proportion of the producers-consumers of each product in different structures under general equilibrium. The analysis of figure 2 shows that general equilibrium only includes self-sufficiency structure and complete division of labor structure. And in self-sufficiency structure there is no deal and transport demand between the regions. Suppose in complete division of labor structure the total number of people participating in specialized production is M , and then:

$$M_x + M_y + M_{tx} + M_{ty} = M \tag{9}$$

From the proportion of the people selling different products in complete division of labor in table 2, it's known that:

$$M_{tx} = \frac{1-\alpha}{2(1-\beta)\left(\frac{p_x}{m_x s_x k_x p_y} + \frac{p_y}{m_y s_y k_y p_x} + 1\right)} M \tag{10}$$

The transport demand in complete division of labor structure can be got by the demand of product x and product y multiplying their corresponding number of people. Thus the transport demand of product x and product y can be obtained, which are:

$$L_x = \frac{m_x s_x k_x}{2(m_x s_x k_x p_{tx} + p_x)}\left[(1-\alpha)M_y p_y + (1-\beta)(M_{tx} p_{tx} + M_{ty} p_{ty})\right] = (1-\beta)M_{tx} \tag{11}$$

$$L_y = \frac{m_y s_y k_y}{2(m_y s_y k_y p_{ty} + p_y)}\left[(1-\alpha)M_x p_x + (1-\beta)(M_{tx} p_{tx} + M_{ty} p_{ty})\right] = (1-\beta)M_{tx} \tag{12}$$

According to equation (10), (11), and (12), the total transport volume L can be deduced, which is:

$$L = 2(1-\beta)M_{tx} = \frac{1-\alpha}{\frac{p_x}{m_x s_x k_x p_y} + \frac{p_y}{m_y s_y k_y p_x} + 1} M \tag{13}$$

in which p_x / p_y can be deduced with relative price equation of complete division of labor in table 2:

$$\frac{p_x}{p_y}=\frac{\sqrt{\left(\frac{m_y s_y k_y}{2}\right)^2+\left(\frac{1-\beta}{1-\alpha}\right)^2}+\frac{m_y s_y k_y}{2}}{\sqrt{\left(\frac{m_x s_x k_x}{2}\right)^2+\left(\frac{1-\beta}{1-\alpha}\right)^2}+\frac{m_x s_x k_x}{2}} \quad (14)$$

It can be concluded from equation (13) and (14) that transport demand is determined by the total scale of the number of people who participate in specialized division of labor in two regions, the quality of transport goods (weight), transport distance and transport productivity. The more the total number of people is, the greater the transport demand will be, and the larger the weight of transport goods is, the farther the transport distance is, and the lower the productivity is, the greater the transport demand will be.

Transport demand is the logic starting point of the planning, constructing, operating and managing of traffic transport system. The adjustment of transport structure reflects the adaption to the change of transport demand. The root of change of transport demand quantity, quality and structure lies in the change of industrial structure which is necessarily related to traffic transport structure. The adjustment of industrial structure will necessarily lead to the change of product structure and transport object in space distribution so that transport cargo structure and transport range will also change. Different transport modes have difference in their technological economic characteristics, which will decide their labor productivities, adapted objects and advantage ranges. Meantime, the advance of transport technology makes the comparative advantages of different transport modes changing. Consequently, with the change of traffic transport technology, transport range and cargo structure, every transport mode will influence their development speed, which results in the change of traffic transport structure. In different stages of industrial structure and different industrial structures' regions, social production and resident consumption have different requirements to cargo transportation in quantity and quality. The development of cargo transportation should start from satisfying quantity demand, and then gradually adapt to other transport demands such as high-speed, convenience, safety, thrift package and so on. The general tendency is that transport demand will be diverse, and the proportion of high-quality demand will become greater. Industrial structures in different periods require the corresponding transport structures so as to achieve best social economic benefits. Obviously, there is a general mechanism of transportation system development in a region which has a resource endowment advantage of different elements and industrial structures, which is that specialized division of labor between regions causes the motivation of trade and transport between these regions, and the greater the specialization degree is and the more people will participate in specialized production, the stronger the motivation will be and the more obvious the advantage of logistic position will be. Meantime, this kind of motivation may be influenced by the difference of industrial structures in different regions, and there is a great difference between different regions in industrial structure features, social productions and the demands of residents on cargo transportation in quantity and quality. Because of such a difference in the demands of cargo transportation in quantity and quality, regional optimal transportation system with different structure features is to be formed.

Conclusion

Based on new classical economic theories, this paper utilizes revised general equilibrium analytical frame of transportation specialized division of labor and inframarginal analytical method, introduces traffic transportation system into main stream economic theories so as to explore coupling mechanism of transport structure and economic development, and construct general equilibrium model of transportation specialized division of labor. The conclusion shows that the reduction of transport distance, the decrease of transport weight and the advance of transport technology will lead to the decrease of transport cost and produce extensive and prominent positive effect on division of labor network. The adjustment of industrial structure brings about the change of transport cargo structure and transport range, making the industrial structures in different periods and different regions require the corresponding transportation structures so as to obtain the best social economic benefits. Therefore, the adjustment of transport structure should be based on economic development level which affects the rate of progress of transport structure adjustment, i. e. the transport modes adapting to economic development stage, its development level and proportion relation. The summation of all the relations of transport structure constitutes optimal traffic transportation structure. The development of transportation should emphasize the economic development level as the center, making and transportation and economic development should step forward synergistically as a resultant force

instead of lack of coordination or the decentralization of acting force.

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