Regional Integration in China:
Incentive, Pattern, and Growth

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Abstract

We analyze the incentive, effects of regional integration (or local protection) in current China in the dynamic context by using an R&D-based endogenous growth model. Given specific assumptions on the endogenous growth model refined from Chinese characteristics, we show that economic integration always makes both regions better off. Even with completely local protection for commodities flow but having technology flow, the new balanced growth rate for two regions under integration are still higher than that under autarky. However, in the poor region with assumed low level of technology its R&D sector will diminish eventually, and its human capital in the R&D sector will move to the R&D sector in the rich region or the manufacturing sectors, in this case. Under completely economic integration with free commodities and technology flow, the new balanced growth rate is higher and the human capital in the R&D sector in both regions will be same as before integration. That is the incentive for close economic integration. The interesting thing we show is the possibility to have a worst situation that both regions have the same level of technology and there is completely local protection. Then the balanced growth rate will be lower than that under autarky.

Key Words: Inter-regional Integration, Economic Growth, Chinese Economy

JEL Classification Numbers: O53, O57, O41, O11, O31
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1. Introduction

The China’s economic reform has been proceeded more than twenty years. In some extent, this reform can be viewed as the process of decentralization and/or the redistribution of power between the central government and local governments. While this process brings some incentive to local governments to promote local economic growth and development, it also results in some negative effects, such as the local protectionism, increased regional income differences, and consequently, reduction of investment on local high education and research and development (R&D), etc. Therefore, there raises a new question for the continuous China’s economic reform: how to eliminate the negative effects without hurting the local government interest/incentive for regional economic growth.

The original aim of such proposed re-allocation of administrative rights is, of course, to promote nationally economic growth through giving the local government enough incentive to stimulate regionally economic growth. The modern history of China shows that, however, such adjustment of administration rights has been carried on several times since 1949, but the results are ambiguous. Such facts imply that there are some deeper reasons beyond such administrative adjustment. Moreover, we observe there is significantly local protectionism causing fragmented
markets with limited economic integration and widening gaps among different regions (say, GDP gaps). On the other hand, the theory of trade indicates that the free trade will increase the welfare for both sides of trade. Within a unified nation, this conclusion can be confirmed further intuitively, since the all surpluses are transferred within the nation. Then in the point of view of the central government, the local protectionism should must be prohibited.

However, it does not means that every region can be guaranteed to be better off after “opening” its door to others. That is the key of the problem: what is the incentive for local government to open its door? Does it really benefit from it? In the circumstance that local governments focus on their own economic growth, say, GDP growth, to request or enforce one region (government) to suffer its loss from inter-regional integration is very difficult for the central government, perhaps is impossible, in the reality. That is also the reason that different kinds of local protectionism can exist. Moreover, even the central government can force the local government to conduct some activities, which are significantly harmful for its own region but benefit for most of other regions, the final result could be still uncertain since the local government has enough motivation to do something to reduce its own loss from such activities. This is a typical example of “principle-agent” problem since the final situation is not stable. So, what we attempt to do here is to find out what one region can get from economic integration, and to find the solution for every part on a steady state -- it is not only a Nash Equilibrium, but also a Pareto Efficiency. To solve the potential interest conflict and find out its Nash Equilibrium solution are our primary motivation for this paper.

Current dispute on the degree of such protectionism and its trend in China provides the other motivation for this paper. Given existence of local protections in China, Young (1996, 2000) thinks that the local protectionism has been increased with declining of regional specification. He uses the evidence that increased transportation capacity with reduced transportation intensity in China to
support his conclusions: different regions will become more similar than before. On the other hand, Naughton (1999) argues that his data, which is from input-output tables among Chinese provinces covered from 1987 to 1992, shows that the increasing regional specification with increased inter-provincial trade. That is a puzzle in the empirical study for Chinese regional development, since they hold different data sets and no one can argue their empirical results based on their data. In this paper, we attempt to find a kind of explanation for it, since the theoretical analysis for inter-regional integration can explore some deeper reasons for local incentive for such integration.

Historically, people believe that the larger economy (i.e. larger domestic market in size) will bring the higher rate of economic growth. Then the economic integration should increase the growth rate for the new unified economy from such integration. Moreover, the other opinion that any kind of restrictions to the flow of consumption goods, capital and knowledge will cause the growth rate diminish permanently is also popularly accepted by most economists. Due to technical difficulties, a rigorous model of growth cannot be given to describe and justify people's belief precisely. We know, however, some most important components in growth models, therefore we are able to build some general models to examine such believe and approach our concerns. From the mid 1980’s the endogenous growth models represent the latest development in the field of economic growth, and Paul Romer is the founder for this development. More significantly, Romer and Rivera-Batiz successfully separate the flow of knowledge from the flow of goods and from the flow of human capital (Romer, 1990; Rivera-Batiz and Romer, 1991a, 1991b) (RRR, thereafter), which allows people to analyze the impact of each factor on the growth. This special structure of RRR’s model sheds some lights on solving our problem. Romer and Rivera-Batiz have analyzed the effects of international economic integration, and find effects of economic integration on the growth depending on the R&D process for different scenarios of the flow of technological information and
goods between countries. Devereux and Lapham (1993, 1994) (henceforth DL) first introduce the
dynamic analysis into the RRR model. Now, we attempt to explore the dynamic effect of some key
conditions change and local protection on regional economic growth and to find a stable growth
solution for every region during inter-regional economic integration. The special characteristics of
current China formed on our assumptions should enhance the rationality and feasibility of our
results.

There are some restrictions or specific characteristics in China economy. They are crucial in
setting up our theoretical assumptions. Moreover, theoretically, for the benefit of large or integrated
economy, there are still some uncertainty on large economy growth which is conditional growth. For
example, Grossman and Helpman (1992) pointed out that the larger size of economy will bring faster
growth if all factors supply increases at same ratio, or if elasticities of substitutes between factors
in all manufacturing industries are greater one. It is very difficult for whether fragmented or unified
market in China, because of severe restrictions on resources, for example, electricity.

Precisely, total market system, and the supply of inputs and outputs in China are changed
dramatically over last twenty years. The national goods market was divided by provinces, even
smaller areas practically, and could be still divided implicitly at different extents by local
protectionism for various considerations. For the factor market, the unskilled labour and human
capital were strictly restricted to flow from one region to the other because of the existence of
"Household Register System" (Hu-ji-zhi), and are now allowed to flow practically. But cross-
regional investment is still strictly restricted, while foreign investment, especially foreign direct
investment (FDI) are unrestricted, and encouraged in any region in China. Although current
economic development makes it change gradually, in most areas, except in some "Special Economic
Zones" (SEZ, thereafter) and several "Coastal Opening Cities" (COC, thereafter), the requirement
of completely free flows of physical capitals is not achieved. This situation above allows us to modify some theoretical assumptions and models from international integration.

In general, all we inquire here is to find the incentives, the conditions, and the effects of regionally economic integration on the long-run economic growth and their changes within fragmented and/or unified markets. We wish that this paper would provide a useful approach to think about the regional incentive to decrease the local protectionism with national welfare increase. We also hope our theoretical analysis can provide some possible policy implications for governments.

My paper is designed as follows. Section 2 will review the related theoretical literature, which includes the RRR model, the balanced growth paths, their results for economic integration, and derived transitional dynamic analysis. Section 3 will use the detailed specific characteristics of current China to set up/refine our basic assumptions and models. Section 4 will show the derived static and dynamic results and, discuss the reasons and policy implications in China under various scenarios. Section 5 will conclude our results, policy implication, and furthermore, some potential further researches.

2. Theoretical Literature Review

There are plenty of literature discussing economic growth, economic integration and trade, including Grossman and Helpman’s results (1992) mentioned before. However, we attempt to focus on RRR model here, since we will adopt their framework later.

1 We may define the national welfare as the long-run economic growth with non-expended regional income differences.
Romer (1990) and Rivera-Batiz and Romer (1991a) set a simple three-sector and four-factor model for endogenously economic growth. Although there are three sectors in the economy, they focus on two of them: the manufacturing and the research and development (i.e. R&D) sector. The intermediate goods (i.e. capital goods) sector obtains the new technology from the R&D sector and produces the capital goods for the manufacturing sector for the production of the final goods. It is only determined by the other two sectors in terms of primary inputs (i.e. factors) supply and demand of the final goods. Four inputs are labour, human capital, capital goods, and knowledge\(^2\). The human capital is defined as the well-educated people who possess the ability to create, invent, and innovate the technology and management system using theoretical and empirical knowledge, and use such knowledge effectively in any sector. In the meantime, the return brought from such human capital is absolutely increasing.

The knowledge, as the key concept in this paper, is defined as technology, which is a “non-rival, partially excludable good”, in Romer's paper in 1990. Practically, it can be thought as a set of new designs, or the stock of technology, while the technical progress is expressed as the invention of new capital goods.

In RRR model there are two types of activities: production of consumption goods and physical capital goods in the manufacturing sector. But these two activities were described in same production function: Cobb-Douglas function, with fixed prices of all goods.

\[ Y = H^\alpha L^\beta \int_0^1 x^{1-\alpha-\beta} (i)di \]  

(2-1)

where: \(Y\) is the output, \(i\) is the index and a continuous variable, \(L\) is the labour used,

\(^2\) In this paper, we will not distinguish the difference among knowledge, knowledge capital, technology.
K is the aggregate capital goods, H is the human capital,

x (i) is the set of capital goods of type i used,

A is the index of the most recently invented goods, so, x (i) = 0 for all i>A.

In the R&D sector, there are two different models to represent the knowledge increasing based on the different thoughts for the change of knowledge. The first model is called as "knowledge-driven specification of R&D" (Rivera-Batiz and Romer, p.536, 1991) (KD model, thereafter):

\[ \dot{A} = \delta HA, \]

(2-2)

where: A is a measure of knowledge including general theoretical knowledge and practical skill accumulated; \( \delta \) is a positive constant.

This model indicates that the relative importance of human capital and knowledge. In the other word, the physical capital and unskilled labor are relative less important in the R&D process.

The second model is considered as "lab-equipment specification of R&D" (Rivera-Batiz and Romer, p.537, 1991) (LE model, thereafter):

\[ \dot{A} = B^\alpha H^\alpha L^\beta \int_0^A x(i)^{1-\alpha-\beta} di, \quad \text{where: } B>1. \]

(2-3)

This model shows that R&D needs all inputs which used in the manufacturing sector, but the knowledge has not productive value, except the knowledge works as a capital good when all capital technological knowledge, and idea. We assume they are same in our discussion.
goods are homogenous, i.e., \( x(1) = x(2) = \ldots = x(i) = A \).

Consumers hold CRRA preferences with an RRA coefficient \( \sigma \) and rate of time preference \( \rho \). Households choose consumption and patent having to maximize their own utility, while firms choose human capital, physical capital, and labour to maximize their own profits. The representative consumer's utility function is:

\[
U(C,H) = \int_0^\infty \frac{(C(t))^{1-\sigma}}{1-\sigma} e^{-\rho t} dt,
\]

where \( 0 < \sigma < 1 \) \hspace{1cm} (2-4)

Devereux and Lapham (1994) derived the RRR’s balanced growth rate for an isolated economy itself in the KD model as follows:

\[
g = (\delta H - \Lambda \rho) / (\Lambda \sigma + 1), \quad \text{where} \quad \Lambda = \alpha (\alpha + \beta)^{-1} (1 - \alpha - \beta)^{-1}
\]

\hspace{1cm} (2-5)

The capital good, which is assumed as symmetry between any pair of capital goods, then is:

\[
x = \left[ (1 - \alpha - \beta)^2 \phi^\alpha + \sigma \delta \phi \right] / \left[ \rho + \sigma \delta H \right]^{(1-\alpha)/(\alpha+\beta)}
\]

where: \( \phi = \left[ (\alpha(1 - \alpha - \beta)) / (\delta(\alpha + \beta)) \right]^{1/(1-\alpha)} \hspace{1cm} (2-6)

Similarly, we derive this RRR’s the growth rate of both sectors and the capital good under the equilibrium of both sectors in the LE model.

RRR also discusses the static effects of patterns of economic integration on growth rates for three patterns of integration: trade with goods flows alone, trade with knowledge flows alone, and
trade with knowledge and goods flows. Moreover, they use scale effects to explain why closer economic integration can incur the faster balanced growth rate. Since the production functions for the R&D sector have the increasing returns to scale, the increasing of scale will bring the growth effect consequently. Since the scale effects from endogenous growth theory, however, is still in debt empirically (Kohe, 1994; xxxx; 2 japoneses, 2002), we donot want to focus on this issue, and will not discuss in our paper further.

Here is Devereux and Lapham’s (1993, 1994) (henceforth DL) contribution, which introduces one of RRR’s results into dynamic analysis. That result is that if the flow of technological information is restricted, then only one country will invest on the R&D with human capital increasing (?), free trade between two identical countries has no improvement on the world economic growth rate. This surprising conclusion was examined by Devereux and Lapham (1993, 1994) DL thereafter). Theoretically, DL only release one assumption from RRR assumptions: they allow the initial level of knowledge to be different. Then they find that the conclusion of RRR only holds on knife-edge case, and they also find that under the RRR's conditions, the slight difference between two countries on initial level of R&D will result in the corner solution of R&D in these two countries, with the increasing of the world economic growth rate. This result show the great difference between static and dynamic analyses.

3. The Basic Assumptions and Models

We set up and/or refine our basic assumptions and models in this section based on the empirical evidences from China. That ensures our theoretical results applicable to analyze China’s facts and
provide a rational base for policy implications. We discuss our basic models first.

3.1 Basic Models

We will justify our theoretical model by calibrating the reality of China step by step.

Inter-regional integration is not same as inter-regional trade, even the latter could plays a very important role in the former. However, for China, we need to examine all possible channels for such integration: regional co-operation for some national projects, inter-regional investment, inter-regional trade. The first one becomes very limited because of the transition of central-planning system. Inter-regional investment is also limited given the current restrictions on cross-regional investment for China's firms (see Boyreau-Debray and Wei, 2002)3. That is why we focus on the inter-regional trade on the topic of inter-regional integration. Current empirical evidence supports our above conclusion. Barry Naughton (1999) shows that the inter-provincial trade not only is most important for provincial GDP (both inflow and outflow take 70% of each provincial GDP aggregately for twenty-five provinces in China), but also is significantly more important than the international trade for all of provinces (the ratios of inter-provincial trade to its GDP is about 2.5 to 3.5 times over those of international trade to its GDP) (see Table 1). Therefore, we can assume inter-regional trade is all we consider for the inter-regional integration in this paper.

Furthermore, for the inter-regional trade, there is still two issues needed to be distinguished. First, the inter-regional trade means goods trade concerning the local industries, their competition and their location. So, precisely, we should explore the relationship between industries in both

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3 This kind of investment, however, will not be restricted by any local protectionists in capital inflow regions since it will increase employment and boom the local economy.
regions, say, two provinces. Generally, whatever local protectionism or local induction for external investment, industry relation should be the core of regional integration since as the industries in the region have been changed for some reasons, the circumstances of inter-regional trade, and relevant policies designed to protect the local firms will be consequently changed. It seems to be a blind point for most researches on China, and perhaps on most regional development papers.

Second, inter-regional trade includes both inter-industry and intra-industry trade. If the former is more important than the latter, we prefer to use a trade model for such integration. If the latter is more important than the former, we prefer to deal with an endogenous growth model with massive trade for intermediate goods (inputs). For China, Barry Naughton (1999) shows his empirical finding that intra-industry trade is significant higher than inter-industry trade which goods traded are used as the final goods (see Table 2). Therefore, in this paper, we adopt an endogenous growth model with economic integration between autarky economies to describe the inter-regional integration study in China.

The theory of trade already finds that if significant differences exist in both trading sides, the both sides can gain from trade. Furthermore, Nancy Stokey found that "if a small open economy is either very advanced or very backward relative to the rest of the world, its rate of investment on human capital is lower under free trade than under autarky" (1991), when she set up a growth model with investment of human capital on individuals. All her conclusions can be inferred that when two sides with large difference on technology have trade, the both sides can gain from lower rate of investment on human capital with constant rate of growth. In this paper, however, we will focus on the growth problem which two sides of economic integration are similar, not significant differences.

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4 Actually, both new trade model and endogenous growth model have involved both trade and growth (Krugman, 1979, 1989; Grossman and Helpman, 1989a,b,c,d; Romer, 1986, 1990; Lucas, 1988; Rivera-Batiz and Romer, 1991, 1993). Here we just want to distinguish the relative advantage each model deals better with.
In fact, if two regions are great different, the local protectionism is less possible since there are weak substitution between their goods. But it does not means our conclusions are invalid for the case of economic integration between great different regions Stokey discussed above. Our dynamic approach will show the generality of our results.

The knowledge (or technology)5 advance is the engine of economic growth, as most economists agree. However, as Hu, Jefferson and Qian (2003) distinguished, there are three possible different channels to promote Chinese technology upgrade as whole. There are: (1) Foreign Direct Investment (FDI) and its possible knowledge spillover; (2) technology transfer; (3) domestic R&D. For one channel of technology advance, there should be a specific model to match it. Hu, Jefferson and Qian (2003)’s empirical results indicate that within Chinese industry the contributions from these three channels are great different, based on the annual survey of Large and Medium Size Enterprises (LME) conducted by China’s National Bureau of Statistics (NBS), which “spans a period of five years from 1995 to 1999 and includes data for 29 two-digit manufacturing industries and over four-digit industries” (Hu, Jefferson, and Qian, 2003). The technology transfer, whatever from domestic and from foreign ones, can affect the productivity only through domestic R&D. The FDI does not show its usefulness for the adoption of foreign technology transfer6. Moreover, the patentable knowledge is exclusively from domestic R&D. Although our paper discusses the technology upgrade within a region, which is totally in a country and does not concern any international issue, the Hu, Jefferson and Qian (2003)’s results are still very useful for us to understand technology advance in Chinese industry. Therefore, we can simple assume the R&D is the only source for knowledge (technology) creation.

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5 We do not want to distinguish the difference between knowledge and technology. We assume they are same in our paper.
Now we need to overview all theoretical R&D models and choose one for our study that is suitable for current China. There are several options for the R&D modelling. The RRR model has two specifications: the first one is the KD model: \[ \dot{A} = \delta HA. \]

This means that Romer and Rivera-Batiz thought that the increasing of knowledge comes from the work of well-educated intelligent people with all existing knowledge. Therefore, if there are smart people with knowledge, then the new knowledge will be produced continuously without significant inputs of unskilled labour and physical capital goods.

The second is the LE model: \[ \dot{A} = B^\alpha H^\beta L^\gamma \int_0^A x(i)^{1-\gamma} \, di, \]

where: \( B > 1. \)

This model shows that R&D needs all inputs which used in the manufacturing sector, but the knowledge has not directly productive value, except the knowledge works as a capital good when all capital goods are homogenous, i.e., \( x(1) = x(2) = \ldots = x(i) = A. \)

When we, theoretically, examine the rationality of these two specifications in the R&D sector in the RRR framework and justify them, we should think about the relationship between the knowledge and other factors. The LE model looks quite general for the production of the knowledge, but it shows the relative importance of unskilled labor comparing with other factors. It is not popular in the R&D sector, whatever in the past or in the current time, since many people think the importance of unskilled labor is small enough to be ignored. Moreover, when we recognized that the R&D production is also different from the intermediate inputs production, while the former only concerns the “ideas” creation, the LE model seems to be inappropriate.

To simplify the R&D process, the KD model is also reasonable because people just attempt to catch the key factors in the production of the knowledge. The human capital plays, of course, the

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6 It could be because of the quality of FDI in China. We will find more about this issue when we discussed the
key role in such production, comparing to the unskilled labour in technological progress. It also makes sense for us when the KD model expresses the difference between the production of knowledge and that of manufacturing durable, since we use the general Cobb-Douglas model to format the manufacturing sector that include all important inputs. However, when considering the current technological development, we can see that the modern scientific progress is great different from the past technological progress a hundred years ago. The past inventors, such as Thomas Alva Edison (1847-1931), who used a very little equipment and many published documents, plus a very smart brain, to invent plenty of important designs. In the modern society, this situation is almost impossible. Any scientific progress, even quite small, always depends on the quite large quantity of physical capital (or capital goods), as well as human capital as inputs.

However, the KD model has some empirical support. Xu (2002) that in many developing countries the domestic R&D is the main source of their economic growth. Therefore, when we agree that the KD model shows some facts in current economies, especially in developing countries, we also attempt to find the other more reasonable model in the current R&D sector.

There is the third model we called as "Knowledge-Capital-driven specification of R&D", or the KC model.

\[ \dot{A} = \xi H^{\eta} \int_{0}^{A} x(i)^{1-\eta} \, di \]  

(3-1)

When assuming that the symmetry between any pair of capital goods \( x(i) \), we have the following equivalent formula:

relationship between labor and FDI later in this section.
\[ \dot{A} = \zeta H^\eta (A \chi^{1-\eta}) \] (3-1a)

As the matter of fact, if we examine all these LE, KD, KC models, we can find the following relationships among these three models:

If \( \eta = 1 \), the KC model becomes the KD model;

If \( \beta = 0 \), the LE model will be the new KC model.

Since \( \alpha \) cannot be zero, and should be a positive number, we find that the LE model can be a special case of the KC model. Similarly, the KC and the KD model can be converted to each other. This finding improves our understanding for the growth models in the R&D sector.

Given all above theoretical R&D models, our task becomes to identify which specification for the R&D sector is suitable for China. First of all, let us see the R&D in the Chinese industries. Considering the role of China’s 22,000 large and medium-size enterprises (LMEs) most of which belonging to the State-owned enterprises (SOEs) they are accounted for a small proportion of China’s nearly 8 million industrial enterprises and contribute one-third of China’s total industrial output. The other findings from Jefferson and et. (2002) show the R&D is mostly conducted by SOEs comparing to all other enterprises. Then the R&D conducted by LMEs should represent the major part of the R&D in Chinese industries.

There are some interesting phenomena in empirical studies for China. On the one hand, Gary Jefferson, etc.(2002) tested their “knowledge production function” with some empirical models to examine the R&D performance in Chinese industries that they assumed R&D expenditures include expenditures on labor, capital, and intermediate inputs (their “labor” should be interpreted as human
capital in our framework). So the capital should be a very important factor for the R&D production. From the point of view of ownership types, they find that “R&D performers are more concentrated among SOEs and shareholding companies and least concentrated among foreign and overseas enterprises”. Here SOEs indicates the LMEs above. Since the most of FDI in mainland China is conducted by Hong Kong, Taiwan and Marco enterprises (HKT), their performance occupies the main part of foreign companies'. The contribution to the R&D from HKT enterprises is limited. It can be revealed by the different results from Gao (2002) and Cheng and Kwan (2000)’s papers. Cheng and Kwan (2000) find that there is little evidence to show the relationship between labor quality and the FDI in China using the data from 1985 when HKT can be viewed as a representative of the foreign enterprises from any aspect, since the other foreign firms from developed economies did not enter China massively. For these HKT, the technology they used is not advanced generally. The capacity and incentive conducting the R&D are not high as well. This is why Cheng and Kwan’s results (2000) are different from Gao’s (2002) which shows the clear relationship between labor and FDI. Some FDI from some developed countries could conduct the significant FDI in the future and gradually change the current situation, which is Gao (2002) emphases. But currently, we could still assume the SOEs, especially LMEs is the main force to conduct the R&D in Chinese industries.

On the other hand, Gary Jefferson, etc.(2002) find that the SOEs show the lowest efficiency in the knowledge production. However, “once they acquire new knowledge, SOEs appear to be able to use the innovations as effectively, or sometimes more so, than enterprises of other ownership forms” (Gary Jefferson, etc., 2002). This fact reveals some difficulty in transition of knowledge production. Human capital could be one problem, but we will discuss the effects of different initial levels of the R&D and human capital on the economic growth. Then, the capital could be the key
problem for the knowledge production. The fact that SOEs, especially LMEs have incurred financial
difficulty is not the surprising news. The problem Boyreau-Debray and Wei (2002) revealed, which
inter-regional capital flow is very difficult and it is not like a unified nation but similar to the capital
flow within OECD nations, shows the SOEs are difficult to finance the R&D activities. This fact
could explain why Chinese industries in general are at the low level of technology and lack of
capacities to conduct the R&D activities. The problems for Chinese production and Chinese firms’
effort to expand overseas market in color TV sets, refrigerators and other electronics can be good
examples. In this circumstance, we assume the suitable model for the R&D sector in current China
is the KD model above.

There is another reason to choose the KD model to represent the R&D activity in China. As a
result of the application of the central-planning model for development, most of R&D activities
concentrate in universities and research academies belonged to the central and provincial
governments. The civil, independent research institutes and professional institutes belonged to
commercial institutions are very few. With the current institution reform in governments, the
research institutes attached to governments will be reduced sharply in size and in number. In the
meantime, the emerging enterprises and the limited foreign firms can not establish their own
research institutes in recent future due to their view, financial capacity, and political situation.
Therefore, universities will still be the centre of the R&D sector in the near future. In this way, the
change of investment and initial level of R&D activities on higher education can be considered as
the change of investment and initial level of knowledge on the R&D sector. For universities that
focus more on scientific research, the existing knowledge and human capital are much more
important than others.

For the manufacturing sector, we still follow the general assumption of production most people
including RRR (1990, 1991a) used: the Cobb-Douglas production function with fixed prices of all goods. Therefore, the relationships can be expressed in following functions.

\[
Y = C + K \quad \text{(3-2)}
\]

\[
Y = H^\alpha L^\beta \int_0^A x^{1-\alpha-\beta} (i) di \quad \text{(3-3)}
\]

\[
K = \int_0^A x(i) di \quad \text{(3-4)}
\]

where: \( Y \) is the output, \( C \) is the aggregate consumption goods, \( H \) is the human capital, \( K \) is the aggregate capital goods, \( L \) is the labour used, \( i \) is the index and a continuous variable, \( x(i) \) is the set of capital goods of type \( i \) used, \( A \) is the index of the most recently invented goods, so, \( x(i) = 0 \) for all \( i > A \),

For the intermediate goods sector, however, we still keep RRR’s assumption that there is monopoly in the short run due to latest knowledge protection and unique capital goods. On the household side, there is also a general utility function. Specifically, we can assume a basic utility function in the infinite horizon is as follows:

\[
U(C, A) = \int_0^\infty e^{-\rho t} u(C(t), A(t)) dt \quad \text{where } 0 < \rho < 1, \quad \text{(3-5)}
\]

where: \( C \) is the consumption, \( A \) is the knowledge or knowledge capital.

In the following basic model we will discuss, we adopt the utility function with the assumed CRRA preference as we mentioned in Section 2:
\[ U(C, H) = \int_0^\infty \frac{(C(t))^{1-\sigma}}{1-\sigma} e^{-\sigma t} dt, \quad \text{where } 0 < \sigma < 1 \] (2-4)

In the dynamic environment, we assume both regions supposed to be integrated economically have the KD model for both R&D sectors. Therefore, we will explore the dynamic result from the R&D integration in the form of KD – KD in the next section, which also meets our previous assumption confined in the integration between similar regions.

### 3.2 Basic Assumptions

We follow most of assumptions RRR assumed. Except assumptions mentioned already in models, we should add the specific assumption for the R&D activities in China. In the past, Chinese governments have invested much on their research academies and universities for long times. The impacts for such long-run policies are still significant. Generally, this kind of investment to government-sponsored research academies and universities are much more than those industries obtained in terms of R&D activities. Now we discuss the potential change of such investment on R&D from the two sides.

In research academies and universities, since the current investment for higher education comes from the central government budget directly, we have a reasonable forecast for the future change of such investment on higher education. Currently, the rich regions have most universities and most of them are famous and outstanding. On the other hand, the relative poor regions have fewer universities and those qualities are relative lower and the funding from governments' investment is
relative less. In the future, reasonable saying, when the local governments gain more power on their own business including managing universities in their region, the universities within rich regions will be expected to gain at least as much financial support from governments' and, perhaps, enterprises as that they obtain currently. On the other hand, the universities in the related poor regions will be expected to obtain less research fund comparing to the financial support obtained before and other universities in rich regions. This forecast is reasonable not only because the investment from the central government is continuously decreasing and the process of transferring the power to manage universities from the central government to local governments is also continuing, but also because the local development and growth will depend on the R&D in these universities, and the universities have contributed more and more to the local economic development.

Among Chinese industries, the situation is very similar. We can see that many large firms are concentrated in rich regions, which are much more than those in poor regions. As Gary Jefferson, etc. (2002) show, “R&D performers are more concentrated among capital-intensive firms with large sale volumes”, which is defined as “large enterprises” by China’s National Bureau of Statistics (NBS). Therefore the conclusion for the distribution of R&D in China from university side is still same as that from industry side. Moreover, with the different initial levels of R&D (and human capital and knowledge) among regions, such differences have some trend to be expanded. This fact becomes one of our assumptions in the following analysis: there are the different initial levels of R&D among regions. As the matter of fact, one of our purposes in this paper is to discuss the dynamic effect of the R&D conditions (such as, the initial levels) on the regional and national economic growth in long run, given such assumptions.

The labor mobility in current China may be thought as the free flow in the reality, whatever for
unskilled labor or for skilled labor that could be treated as human capital in some cases. There is a dispute about the relationship between labor quality and FDI, when Gao (2002) finds the positive relationship between labor quality and FDI and Cheng and Kwan (2000) did not. Fortunately, this dispute will not affect the labor and human capital supply for the production. So we do not need to add some assumption on labor and human capital.

Capital is always an important factor in manufacturing, and probably in the R&D productions. Fortunately, in our model, since we adopt the KD model for the R&D sector, capital will not directly involve the knowledge production. However, the restriction on capital mobility is still a potential problem. Boyreau-Debray and Wei (2002) show that in China the capital mobility among regions is significantly restricted from their two empirical tests. They found that the situation about capital mobility in China is not like a unified nation such as the United States, and is similar to the situation of the relationships among OECD countries. However, the entrepreneurs, whether in the manufacturing or in the R&D sector, can set up their new companies in other regions which can avoid the problem resulted from the restrictions on inter-regional capital flow. Actually, many Chinese companies always do this kind of “investment”. Therefore, we assume that the manufacturing production for each region is kept in its region at the beginning of inter-regional integration. Diminishing the local protectionism only means the goods flow can be free.

We also assume that each region, regardless its richness, is viewed as a “small open economy” within China, so the interest rate is assumed to be same (actually, according to the fact of significant restrictions on inter-regional capital flow, the interest rate should not be same. However, since the People’s Bank of China is powerful at setting the interest rate in the past, our assumption could be reasonable).
4. The Transitionally Dynamic Effects of Chinese Regional Integration on Growth

Since the model we assumed is in form of R&D integration: KD-KD for the R&D sector, then we have the following analysis for different integration patterns. The first pattern we discussed is the completely local protection, which set up trade barrier to block all the goods flow, while knowledge flow still free.

4.1 Pattern 1 : Integration with Completely Local Protection for Goods Trade

4.1.1 The Existence and Stability of the Growth Effect

We keep all DL’s assumptions (1993, 1994), that is, keep all RRR’s assumptions except allowing the different levels of knowledge in different regions. Then the production function in the manufacturing sector is:

\[ Y = H^a \int_0^x L^\beta x^{1-\alpha-\beta} (i) di \]  

(4-1)

Here, we hold L fixed, then L=1 in this section. H, H_y, and H_A are the employed human capital in one region, in manufacturing sector, and in R&D sector, respectively. The definitions for A, x, and i are same as before in the RRR model and DL model. Therefore, \( K = \int_0^x x(i) di \) is the total physical capital stock in a region.
The K-D model gives the production function for R&D sector.

\[ \dot{A} = \delta H_A A = \delta (H - H_y) A \quad (4-2) \]

The RRR's balanced growth rate for an isolated economy itself as follows:

\[ g = (\delta H - \Lambda \rho) / (\Lambda \sigma + 1), \quad \text{where } \Lambda = \alpha(\alpha + \beta)^{-1}(1 - \alpha - \beta)^{-1} \]

The capital good, which is assumed as symmetry between any pair of capital goods, is:

\[ x = \left[ \left( (1 - \alpha - \beta)^2 \phi^\alpha + \sigma \delta \phi \right) / [\rho + \sigma \delta H] \right]^{(1-\alpha)/(\alpha+\beta)}, \quad \text{where: } \phi = \left[ (\alpha(1 - \alpha - \beta)) / (\delta(\alpha + \beta)) \right]^{1/(1-\alpha)} \]

In these two assumed identical regions, autarky levels of g and x for each region are the same, but their stock of technological knowledge are different since the technological knowledge is region-specific, according to DL.

Thus we adopt DL’s assumptions that assume the share of one region’s knowledge in the two-region total knowledge stock is:

\[ \theta = A / (A + A’), \quad (4-3) \]

where A is the knowledge stock in one region as defined before,

* indicates the other region’s variables.
\[ H_y = \psi P_A \left( \frac{1}{(1-\alpha)\theta} \right) \frac{1}{(1-\alpha)} X \] (4-4)

\[ H_y = \psi P_A \left( \frac{1}{1-\alpha} (1-\theta) \right) \frac{1}{(1-\alpha)} X \] (4-5)

where \( P_A \), as the value of new patent for patent holder, is common across two countries.

When \( \theta = 1/2 \), since the national market clearing and no depreciation on physical capital are assumed, we have the solution of \( g \) for our symmetric balanced growth path (i.e. SBGP in DL model):

\[ \dot{g} = \frac{\delta H - 2^{1-\alpha}}{2^{\frac{1-\alpha}{\Lambda}} \Lambda \rho} \], where \( \Lambda = \alpha(\alpha + \beta)^{-1}(1-\alpha - \beta)^{-1} \) (4-6)

The capital good \( x \) for our SBGP path:

\[ \dot{x} = \frac{2^{1-\alpha}(1-\alpha - \beta)^2 \phi^\alpha + 2^{\frac{1}{\alpha}} \Lambda \sigma \phi}{\Lambda \sigma H} \] (4-7)

where: \( \phi = [(\alpha(1-\alpha - \beta))/(\delta(\alpha + \beta))]^{1/(1-\alpha)} \)

So, we can find that under the new situation, both \( g \) and \( x \) are changed. Assuming \( \rho<1, \sigma<1, \Lambda>1, \delta>>1, H>>1 \), we can see that the new \( g \) will fall down slightly if \( \alpha>1/2 \), and \( g \) will go up slightly if \( \alpha<1/2 \). Since we can not narrow the range of the value of \( \alpha \), even we know the general case such that \( 0<\alpha<1 \). Therefore we can think that new \( g \) from (4-6) does not change significantly.
The new \( x \) from (4-7) increases and is greater than the \( x \) from (4-4) in the complete closed economy, without technology and goods flow, for the home region, but less than the corresponding \( x \) from the DL results under the case of goods flow only. It shows that opening the communication with technological knowledge will increase the output of capital goods. However, the effect of opening the communication with technological knowledge alone on the output of \( x \) is less significant than that of opening flow of goods alone, while both of DL’s goods flow alone and our Pattern 1 (i.e. completely local protection) are as the different situations of partially inter-regional economic integration.

Moreover, we can show that all of these results based on the condition of \( \theta=1/2 \) could NOT be held when \( \theta \neq 1/2 \). Precisely, when \( \theta \neq 1/2 \), we can see from (4-4) and (4-5) that when \( A^*<A \), that is, \( \theta<1/2 \), we have \( H^*<H_y \). This result is opposite to DL's result under opposite situation. This means that for common values of \( P_A \) and same amount of \( x \), when the other region has more stock of technological knowledge, its wage will has higher than that in one region (as the home region). It happens since the wage is equal to the marginal value of product of labor in same sector, and opening flow of technological knowledge allows the same marginal value of product of labor in R&D sector in each region, which leads the same marginal value of product of labor in manufacturing sector in each region. It is not the end of story. The dynamic analysis gives us the following propositions for it.

**PROPOSITION 1.** For the situation of complete local protection for commodities in two-region Chinese economy (i.e. free flow of ideas without commodities flow in China), the proposed SBGP is not achieved when \( \theta \neq 1/2 \). Especially, when \( \theta <1/2 \), \( \theta \) approaches to 0; when \( \theta >1/2 \), \( \theta \) approaches to 1.
Proof: see Appendix.

These conclusions tell us that in China assumed as a two-region-economy, if the home region's initial stock of technological knowledge is less than the foreign's, the home region with lower initial level of technology will lose its share of R&D in both regions (or the integrated economy) gradually, and theoretically, its output in R&D sector will reduce to zero, while all new technologies will come from the other region eventually. However, it does not mean that the home region will produce all of manufacturing products in both regions (or the integrated economy), since the other region will still produce some capital goods with all of new designs.

This result occurs not only in the current situation that no commodities flow with free technological knowledge flow, but also in the opposite situation with free goods flow and no flow on knowledge (see Devereux and Lapham, 1994). But, we can see that our result from PROPOSITION 1 for current situation is different from DL's prediction (Devereux and Lapham, p.305, 1994).

4.1.2 Comparative Analysis for the Growth Effects in Complete Closed Region

Since under Pattern 1, the SBGP is unstable when $\theta \neq 1/2$, and we never know the result of real balanced growth rate under such situation, comparing with that under the situation of complete closed region (i.e. without both technology and goods flows). We will discuss this situation as follows.
**PROPOSITION 2.** The real balanced growth rate when \( \theta < 1/2 \) or \( \theta > 1/2 \) will exceed that in a complete closed region without any flow of ideas and commodities with the other region.

*Proof:* see Appendix.

From the foregoing proof, we know not only that the real balanced growth rate in Pattern 1 is greater than that under in autarky, but also that the real output of capital goods in Pattern 1 will be higher than that in autarky. This result could be more important than human capital flow for each region.

4.2 Pattern 2: Complete Integration with Free Flow of Knowledge and Commodities

4.2.1 The Existence and Stability of the Growth Effect

We still in the circumstance of K-D model, thus the basic assumptions such that (4-1) and (4-2) are still held. The results from the RRR model like (4-3) and (4-4) are also kept for this section. However, the change of conditions concerning regionally economic integration causes the change on the equations of "equal wages":

\[
\alpha H^{-1}_{Y} \left[ \int_{0}^{4} x(i)^{1-\alpha-\beta} di + \int_{0}^{4} x(i^*)^{1-\alpha-\beta} di^* \right] = P_A (A + A^*)\delta \tag{4-8}
\]

\[
\alpha H^{*a-1}_{Y} \left[ \int_{0}^{4} x^*(i)^{1-\alpha-\beta} di^* + \int_{0}^{4} x(i^*)^{1-\alpha-\beta} di^* \right] = P_A (A + A^*)\delta \tag{4-9}
\]

We get the new expressions for the human capital in both regions:
\[
H_y = 2^{-(1-\alpha-\beta)} \psi P_A^{1-(1-\alpha)} x^{(1-\alpha)} (4-10)
\]
\[
H_y^* = 2^{-(1-\alpha-\beta)} \psi P_A^{1-(1-\alpha)} x^{(1-\alpha)} (4-11)
\]

where \( P_A \), as the value of new patent for patent holder, is still common across two countries.

Then we have the following proposition:

**PROPOSITION 3.** Regardless of the relative proportion of \( A \) and \( A^* \) in total stock of the integrated region’s technological knowledge, the equation \( H = H^* \) is always held.

**Proof:** Follow (4-10) and (4-11) directly.

The conclusion from this proposition is different from those under DL’s work and Pattern 1 above.

That means that in the situation of complete regionally economic integration, because of the free flows of capital goods and knowledge, the stock of human capital in the R&D sector in each region will be the same during economic integration. The possible different stocks of technological knowledge in each region will have negligible effect on the human capitals on the R&D sector in each region.

Since we obtain the following result for the change of \( \theta \):

\[
\frac{\dot{\theta}}{\theta} = \delta(1-\theta)(H_y - H_y^*) = 0 (4-12)
\]

Then we have the following proposition.
**PROPOSITION 4.** $\theta = 0$ in (4-12) is independent of rest of the parameters of the dynamic System. Therefore the SBGP is globally stable regardless of the initial value of $\theta$ is.

*Proof:* Follow (4-12) directly.

This result sounds surprising in some way. But it is reasonable, if we see the fact that the human capital in the R&D sector in each region is always equivalent, or we consider it further that the fully free flows on goods and technological knowledge make the relative knowledge in each region keep unchanged, especially under our assumptions of wages in all sectors in this two-region Chinese economy are the same (see (4-8)-(4-9)).

As we did before, we assume that after economic integration, the SBGP allows $\theta = 1/2$. Under this condition, we obtain the solutions for such SBGP:

\[
\dot{g} = \frac{\delta H - \Lambda \rho}{1 + 2^{-\alpha} (1 - \alpha - \beta)^{-1}} \Lambda \sigma, \quad \text{where } \Lambda = \alpha(\alpha + \beta)^{-1}(1 - \alpha - \beta)^{-1} \tag{4-13}
\]

\[
\dot{x} = \left[2^{-\alpha} (1 - \alpha - \beta)^{-1} \phi^a + 2^{-\alpha} (1 - \alpha - \beta)^{-1} \sigma \delta \phi\right]^{1 - \alpha} \tag{4-14}
\]

where: $\phi = [(\alpha(1 - \alpha - \beta))/((\delta(\alpha + \beta))]^{1/(1-\alpha)}$

Since we adopt the DL model, we use their dynamic method to examine the stability of the SBGP. Thus we can find that the result of $\theta = 0$ in (4-12) is independent of rest of the parameters of the dynamic system, i.e., $\theta = 0$ has not been affected by the values of $x$, $P_A$, $\theta$, and $c$ and their possible changes. Therefore, we can say that the SBGP is globally stable, since the value of $\theta$ will be
unchanged over time, as Devereux and Lapham predicted before (Devereux and Lapham, p.305, 1994). It should be an additional good news for each region that their human capital will not flow out.

4.2.2 Comparative Analysis for the Growth Effects between Complete Open and Closed Economy

In the circumstance of complete integration between two regions (i.e. Pattern 2), the SBGP is globally stable whatever the initial value of $\theta$ is. Here we will compare these solutions from the SBGP with those under each complete closed economy (i.e. without any flow of technological knowledge and commodities in each region) as follows.

We have known the values of the balanced growth rate $g$ and the output of each capital goods $x$ in (4-3) and (4-4), and the corresponding values under Pattern 2 in (4-13) and (4-14). Comparing these growth rates, we obtain the other proposition.

**Proposition 5.** The new balanced growth rate in the circumstance of complete integration between two regions will exceed that in a complete closed region (i.e. without any flow of technological knowledge and commodities in each region). The output of each capital goods becomes also higher in the circumstance of complete integration between two regions.

*Proof:* see (4-3) and (4-4), and (4-13) and (4-14).
5. Concluding Remarks and Further Researches

If regional economies in China, say, two regions, integrate when their R&D sectors are in the form of K-D model, we can have the following conclusions.

With completely local protection that suppose to no goods flow and have ideas flow between these two regions, if the home region is the relatively poor region in the technology level (i.e. the assumed lower level of technology), it can take the rich partner’s advantage to obtain more technological knowledge. However, as the result, all human capital in the home region will move to the other region, the rich one. Then its R&D section will diminish eventually. That is, since both partners’ technology levels are not same, it will cause each partner focus on its comparative advantage.

But it does not means the home region will grow slower. As the matter of fact, both regions will have a higher balanced growth rate, which is higher than the rate of each region having before integration. It could explain the fact that each region has higher growth rate comparing to the growth rate before even some of them have significantly local protection trend.

However, it does not mean the integration is always good for both sides. We can see that in the situation with local protectionism, if two regions have the same stock of technology, it is the worst situation: balanced growth rate is lower than that of close economy. In this special case, the integration could be a bad decision for both regions.

Without local protectionism, there is a sustainable growth rate for both regions, which is higher than that in the closed economy for each region, and could be higher than that without local protectionism discussed before.

There are some good things for both regions, especially for the poor region that has the strong
incentive to protect its own firms and industries. In the circumstance of complete integration without any protection, the human capital in one region will not move to the other region whatever the initial level of technological knowledge for each region is. Moreover the new balanced growth rate will be higher as mentioned above. That could be the important incentive for each region to give up their local protection. All conclusions above should have some interesting policy implications.

There are some suggestions for further potential research. First of all, the specified R&D model for each region should be examined by empirical testing. The author does not find directly testing for each region, even Jefferson (1999, 2000, 2002) did significant work on China’s R&D sector. Secondly, some restrictions on factor flow in the reality should be modified and analyzed in the theoretical research. Domestic capital flow restriction and its interaction with international capital flow in China (i.e. FDI and its relocation in regions and industries in China) should also be analyzed theoretically. Thirdly, since China's policies and business environment change vastly over time, some assumptions used here could be refined again in the future. Therefore the dynamic analysis only gives an indicator given the environment or conditions do not change so much (or so quickly). We hope the readers to particularly mention this point. Finally, there is a policy suggestion. If there exists the loss for the specific region due to some sectors declining or the growth rate decreasing, for the incentive and sustainable development, the central government could think about the reasonable compensation for it.
Table 1: Domestic and Foreign Trade Ratios, 1992  
(Percent of Provincial GDP, 25 Provinces)

<table>
<thead>
<tr>
<th></th>
<th>Domestic</th>
<th>Final Use</th>
<th>National Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Outflows/GDP</td>
<td>70%</td>
<td>8.5%</td>
<td>34.1%</td>
</tr>
<tr>
<td>Domestic Outflows/GDP</td>
<td>49%</td>
<td>43.9%</td>
<td>33.2%</td>
</tr>
<tr>
<td>Exports/GDP</td>
<td>20%</td>
<td>7.2%</td>
<td>29.8%</td>
</tr>
<tr>
<td>Adjusted</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Inflows/GDP</td>
<td>68%</td>
<td>36.3%</td>
<td>60.1%</td>
</tr>
<tr>
<td>Domestic Inflows/GDP</td>
<td>53%</td>
<td>41.8%</td>
<td>42.1%</td>
</tr>
<tr>
<td>Imports/GDP</td>
<td>15%</td>
<td>16.6%</td>
<td>19.5%</td>
</tr>
</tbody>
</table>

Table 2: Characteristics of Goods in Interprovincial Trade

<table>
<thead>
<tr>
<th></th>
<th>Share of Total Domestic Outflows</th>
<th>Intra-Industry Trade Share</th>
<th>Percent Final Use</th>
<th>Domestic Outflows from 25 Provinces/National Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemicals, Rubber, Plastic</td>
<td>12.7%</td>
<td>70.3%</td>
<td>8.5%</td>
<td>34.1%</td>
</tr>
<tr>
<td>Machinery</td>
<td>9.8%</td>
<td>63.4%</td>
<td>43.9%</td>
<td>33.2%</td>
</tr>
<tr>
<td>Food Products</td>
<td>9.4%</td>
<td>67.5%</td>
<td>63.1%</td>
<td>31.1%</td>
</tr>
<tr>
<td>Agriculture</td>
<td>8.9%</td>
<td>56.2%</td>
<td>42.5%</td>
<td>11.3%</td>
</tr>
<tr>
<td>Textiles</td>
<td>8.7%</td>
<td>62.8%</td>
<td>7.2%</td>
<td>29.8%</td>
</tr>
<tr>
<td>Transport Machinery</td>
<td>8.4%</td>
<td>56.2%</td>
<td>36.3%</td>
<td>60.1%</td>
</tr>
<tr>
<td>Metallurgy</td>
<td>8.3%</td>
<td>55.4%</td>
<td>0.8%</td>
<td>31.4%</td>
</tr>
<tr>
<td>Building Materials</td>
<td>5.0%</td>
<td>49.0%</td>
<td>10.9%</td>
<td>28.2%</td>
</tr>
<tr>
<td>Electric Machinery</td>
<td>4.7%</td>
<td>39.8%</td>
<td>23.5%</td>
<td>39.2%</td>
</tr>
<tr>
<td>Electronics</td>
<td>3.6%</td>
<td>50.4%</td>
<td>41.8%</td>
<td>42.1%</td>
</tr>
<tr>
<td>Metal Products</td>
<td>3.2%</td>
<td>50.1%</td>
<td>12.7%</td>
<td>32.6%</td>
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<tr>
<td>Coal Mining</td>
<td>3.2%</td>
<td>33.5%</td>
<td>11.6%</td>
<td>52.0%</td>
</tr>
<tr>
<td>Garments</td>
<td>3.0%</td>
<td>50.4%</td>
<td>66.2%</td>
<td>27.0%</td>
</tr>
<tr>
<td>Paper, Toys, Handicrafts</td>
<td>2.9%</td>
<td>59.2%</td>
<td>16.9%</td>
<td>22.2%</td>
</tr>
<tr>
<td>Petroleum Refining</td>
<td>1.6%</td>
<td>36.7%</td>
<td>3.7%</td>
<td>19.5%</td>
</tr>
<tr>
<td>Petroleum</td>
<td>1.5%</td>
<td>35.2%</td>
<td>0.0%</td>
<td>27.9%</td>
</tr>
<tr>
<td>Other Industry</td>
<td>1.4%</td>
<td>44.0%</td>
<td>5.4%</td>
<td>40.6%</td>
</tr>
<tr>
<td>Mineral Mining</td>
<td>0.9%</td>
<td>37.0%</td>
<td>9.8%</td>
<td>19.5%</td>
</tr>
<tr>
<td>Ferrous Mining</td>
<td>0.8%</td>
<td>36.7%</td>
<td>0.0%</td>
<td>44.1%</td>
</tr>
<tr>
<td>Instruments</td>
<td>0.8%</td>
<td>61.8%</td>
<td>18.0%</td>
<td>46.8%</td>
</tr>
<tr>
<td>Coking &amp; Coal Gas</td>
<td>0.5%</td>
<td>35.9%</td>
<td>35.2%</td>
<td>45.9%</td>
</tr>
<tr>
<td>Lumber &amp; Furniture</td>
<td>0.4%</td>
<td>32.0%</td>
<td>28.3%</td>
<td>11.6%</td>
</tr>
<tr>
<td>Electricity</td>
<td>0.3%</td>
<td>15.4%</td>
<td>16.6%</td>
<td>3.9%</td>
</tr>
</tbody>
</table>

Notes: “Table 1” and “Table 2” are cited from Barry Naughton’s paper (1999).
Appendix

1. Proof for Proposition 1:

Substituting (4-4) and (4-5) into (4-2), we have the growth of output of knowledge:

\[
\frac{\dot{A} + \dot{A}^*}{A + A^*} = \delta H - \delta \left[ \psi P_A - \frac{1}{1-\alpha} \frac{1-\alpha}{1-\alpha} \frac{\alpha}{(1-\theta)(1-\alpha)} \right].
\]

From the definition of \( \dot{A} \), (4-2), and (4-a), we can obtain the equation for the rate of change of the share of knowledge produced in the home region (\( \dot{\theta} \)):

\[
\frac{\dot{\theta}}{\theta} = \frac{A}{A} - \frac{\overline{A}}{\overline{A}} = \delta (1-\theta) [H^*_y - H^*_y], \text{ where } \overline{A} = A + A^*.
\]

Combining (4-4), (4-5), and (4-b), we obtain the following function:

\[
\frac{\dot{\theta}}{\theta} = \delta (1-\theta) \psi P_A \frac{1}{1-\alpha} \frac{1-\alpha}{1-\alpha} \frac{\alpha}{(1-\theta)(1-\alpha)} \frac{1}{1-\theta}.
\]

On the right-hand side of (4-b'), the part outside the square brackets is positive. Therefore, we have the following results:

\[
(i) \quad \theta > \frac{1}{2}, \quad \dot{\theta} < 0; \quad (ii) \quad \theta = \frac{1}{2}, \quad \dot{\theta} = 0; \quad (iii) \quad \theta < \frac{1}{2}, \quad \dot{\theta} > 0.
\]

These results are independent of all other parts of the dynamic system, \( x, P_A, \), and the ratio of the aggregate C and the aggregate K are parameters in the dynamic system, as DL described in their paper (Devereux and Lapham, 1994, p.302), or other parameters in our models above. Since there are only corner solutions available for the case of \( \theta = 1/2 \), therefore, the dynamic system cannot have a saddle point stability along SBGP path.

Q.E.D.
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38


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