Resource Trade and the Spillover Effect between Two Regions

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Abstract: Multi-regional spillover and sustainable development subject to resources constraint are two important problems of regional growth study. Many models were developed in these 2 fields. But the impacts of resources constraint on multi-regional spillover are few discussed, and it is lack of consideration about sustainable development in a multilateral world. In this article a 2-regional growth model is brought forward with regional spillover, resources development and resources trade. In the model, one of the 2 regions sells part of its resource. The parameters of the model are altered to analyze the regional output. It is found that a region will achieve more income by inputting its resources to production than by selling them when it has strong region-internal knowledge spillove. It is also found that the 2 regions can both get positive spillover through resource trade if the ratio is set properly. Regional spillover and the sustainable development problem in growth study are reviewed in the first part of the article. Models are given in the second part. In the third section the impacts of parameters alteration on both regions are studied in detail. Discussions and conclusions are in the fourth part.

Keywords: growth theory; resources constraint; growth spillover; two-region

1 Introduction

In recent years, the mutual effects of multi-regional growth have become a most important problem in growth study. The regional growth effects, which are the result of regional economic integration, have brought about the question that in a multi-region system, the growth of one region will lead to the growth of another. Traditional integration theories pay much attention to the mutual benefits brought by regional integration[1], but take almost no notice of the problem of the extent of the mutual effects in regional integration. Recent research has associated such mutual effects with growth spillover. Growth spillover gained recognition in as early as the 1950s, yet didn't come to prominence till the 1990s, when the Mundell-Flemming Model with 2-nation under open economy was constructed by Mckibbin, Sachs[2]. Then the development of new growth theories brought about further progress in actual growth spillover calculation, with such examples as the study of the multi-region growth effects of trade under the condition of knowledge spillover by Ben-David[3], and the complete framework based on Solow residual for analyzing growth spillover by Conley and Ligon[4].

However, growth spillover analyses fail to address the question of sustainable development in regional integration. As any economic growth has to be fueled by resources consumption, resources trade is inevitable wherever the distribution of resources is unequal. Thus raises the question of what is the optimal growth under the constraints of resources. This issue has become popular in recent years. Barbier studied the relationship between internal economic growth and natural resource scarcity[5]. He first established a Romer-Stiglitz internal growth model of resource scarcity and population growth to analyze the optimal balanced growth route, then extended the original model by considering the restrictions of resources availability on technological innovation. Krutilia, Reuveny[6] investigated Ramsey's renewable resources model, in order to find out whether higher resource extraction costs would cause growth complexity in a system. Wirl[7] developed a complete dynamic model that integrates economic growth into constraint dynamics of resource and environment. All these models are characterized by their focus on the growth activity of a single economy and paying scant attention to the question of resource constraints on multi-economy growth.

To address the above two problems, we raise a new question, that is, within the constraints of resources, what are the mutual effects of the 2-region growth? As there has been no research report on this topic to our knowledge so far, we present this article as one of the first attempts to fill in this gap.

2 Model

Bretschger considered negative spillover that occurs in

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capital utilization[8]. Such spillover suggests that capital accumulation harms the environment, which in turn leads to reduction in production. Thus there are the following production function and relationship between capital and resources:

$$Y = K^{\eta} K^{\alpha} N^{1-\alpha} \quad (1)$$

$$N = N^{*} K^{-\psi} \quad (2)$$

where K is capital and N is natural resources. According to Bretschger, technological advances outstrip the learning effects of investment in physical capital[8]. Hence technological advances are expressed as the equation $A = K^{\eta}$, where η is the level of technological advance, which is related to the region-internal knowledge spillover. And ψ is the parameter for the impact of capital on resource renewal, the value of which is less than 1, as the environment is somewhat self-recoverable. Formula (2) suggests that the increase in capital input means the expansion of production scale, which in turn aggravates the environmental damage. As the environment is to some degree self-recoverable, the parameter is less than one. It is especially the case for renewable resources. N^{*} in equation (2) actually is a proxy for the original amount of renewable resources. As K increases, the renewal speed of natural resources will be impeded by pollution, and the useable resources available will become N. Then we have

$$Y = K^{\eta} K^{\alpha} \left[N^{*} K^{-\psi}\right]^{1-\alpha} \quad (3)$$

So far, according to Brestchger's model[8], natural resources are another form of capital input that affects production. And the negative effect of capital accumulation on natural resources will ultimately result in reduction in economic welfare. Nevertheless, Brestchger's model[8,9] is a single region model that doesn't touch upon the mutual effects across regions. To address this question, we attempt to further develop the relationship of capital and resources in Brestchger's theory and establish a 2-region spillover growth model subject to resource limit. Since a spillover of this type is a sub-growth effect generated by resource transfer, we call it resource spillover. Some researchers tend to think that the spillover is a free lunch, and there exists trade in resource transfer. But it is just not the case. As Grossman and Helpman[10] pointed out, there exist spillovers in trade. We see a spillover as a sub- economic production effect of one economy's activities upon another economy. Thus assume that there are 2 economies, region 1 and region 2. Both possess certain types of natural resources, and at a certain point, the useable amounts of resources are respectively N_1 and N_2. When there is no resource trade between the 2 regions, the production function for both regions is formula (1), and the relationship between amount of useable resources and capital is showed in formula (2).

For Region 1, if it sells part of its resources by ratio b at price P, which of course will bring direct income (production) to Region 1, and input the rest of its resources into production, its production function will be as follows:

$$Y_1 = K_1^{\eta_1} K_1^{\alpha_1} \left[N_1(1-b)\right]^{(1-\alpha_1)} + PN_1 b \quad (4)$$

where b is the ratio of the resources sold out of region 1 to the region's overall useable resources. And the second summed term in formula （4） represents income obtained from selling resources, with P being unit price for resources. All the other variables and parameters have a subscript 1, indicating they are variables for Region 1. Substituting equation （2） in formula (4）, we obtain:

$$Y_1 = K_1^{\eta_1+\alpha_1} (N_1^{*} K_1^{-\psi_1})^{(1-\alpha_1)} (1-b)^{(1-\alpha_1)} + P(N_1^{*} K_1^{-\psi_1}) b \quad (5)$$

To see clearly the respective incomes (productions) the region gains when it sells its resources and when it does not, we now rewrite the production function of the region when it does not sell resources as follows:

$$Y_1^{'} = K_1^{\eta_1+\alpha_1} (N_1^{*} K_1^{-\psi_1})^{(1-\alpha_1)} \quad (6)$$

By comparing equations（5）and (6）, we can see whether resource trade has brought in more income for Region 1. We thus define the spillover of resource trade as follows:

$$\Delta Y_1 = Y_1 - Y_1^{'} = K_1^{\eta_1+\alpha_1} (N_1^{*} K_1^{-\psi_1})^{(1-\alpha_1)} [(1-b)^{(1-\alpha_1)} - 1] + P(N_1^{*} K_1^{-\psi_1}) b \quad (7)$$

It's obvious that if $\Delta Y_1 > 0$, region 1 will get higher income by trading resources and the spillover is positive. Contrariwise, it will lose part of the income and the spillover is negative.

For Region 2, if it purchases all the resources sold by Region 1, which is $N_1 b$, it will have to spend part of its capital in buying resources, and its production function will be as follows:

$$Y_2 = (K_2 - N_1 bP)^{\eta_2+\alpha_2} (N_2 + N_1 b)^{1-\alpha_2} \quad (8)$$

Substituting the N-K equation into (8), we obtain:

$$Y_2 = (K_2 - N_1^{*} K_1^{-\psi_1} Pb)^{\eta_2+\alpha_2} (N_2^{*} K_2^{-\psi_2} + N_1^{*} K_1^{-\psi_1} b)^{1-\alpha_2} \quad (9)$$

Expression $K_2 - N_1^{*} K_1^{-\psi_1} Pb$ indicates that in the case of region 2, capital investment in production will decrease as part of the capital is used to buy resources. This item should always be positive, as investment in resources should not exceed the overall capital. To compare the functions for the region when there is resource trade and when there is not, we substitute the equation of *N-K* into（1）and mark the variables with subscript 2, and thus we get:

$$Y_2^{'} = K_2^{\eta_2+\alpha_2}(N_2^{*}K_2^{-\psi_2})^{(1-\alpha_2)} \quad (10)$$

Hence, the spillover of resource trade for Region 2 can be defined as:

$$\Delta Y_2 = Y_2 - Y_2^{'} \quad (11)$$

Now compare the productions of Region 2 in both cases. If the region yields a higher production when it buys resources than when it does not, the resource spillover will be positive; contrarily, if production is lower, the region will get a negative spillover and obviously in a free market it will not make the purchase. If the production remain the same whether there is resource trade or not, there will be no spillover.

As $\Delta Y_1 = 0$ indicates that the resource trade does not yield any spillover, we defined the point when $\Delta Y_1 = 0$ as zero point for spillover. First we divide both sides of equation（7）by $K_1^{\eta_1+\alpha_1}(N_1^{*}K_1^{-\psi_1})^{(1-\alpha_1)}$:

$$\frac{\Delta Y_1}{K_1^{\eta_1+\alpha_1}(N_1^{*}K_1^{-\psi_1})^{(1-\alpha_1)}} = [(1-b)^{(1-\alpha_1)} - 1] + P(N_1^{*})^{\alpha}\frac{K_1^{-\psi_1\alpha_1}}{K_1^{\eta+\alpha}}b \quad (12)$$

Equation（12）shows first, $[(1-b)^{(1-\alpha_1)} - 1] < 0$, as $0 < b \le 1, 0 < \alpha_1 < 1$; 2nd, as $\psi_1\alpha_1 > 0$, the larger the value of K_1, the smaller the value of $P(N_1^{*})^{\alpha_1}K_1^{-\psi_1\alpha_1}b / K_1^{\eta_1+\alpha_1}$. So that selling resources will not be to the region's profit when K_1 is sufficiently large. And similiarly, the higher the value of P, the larger the value of $P(N_1^{*})^{\alpha_1}K_1^{-\psi_1\alpha_1}b / K_1^{\eta_1+\alpha_1}$. The increase in P will spur the trade of resources in a linear pattern.

3 simulation results

3.1 case of Region 1

To further analyze the problem, we simulate the interactive process between the 2 regions. First of all we assign an initial value to each parameter, and then alter the value of each parameter separately to investigate the respective change in ΔY_1 caused by the variation in K_1; then, we tune each parameter at around the point of zero spillover, and investigate the respective change in ΔY_1 against the variation in each parameter. The initial values of the parameters are as in table 1.

Table 1 Initial Values of Parameters for Region 1

Parameter	Definition	Initial value
b	Ratio of sold resources to overall resources	0.1
α_1	Capital elasticity	0.6
P	Resource price	10
N_1	Total amount of renewable resources	10000
η_1	Region-internal knowledge spillover coefficient	0.3
ψ_1	Resource spillover coefficient	0.2
K_1	Capital ,Assignable value range	0~50000

Firstly, we consider the impact of the value of ψ_1 on regional resource spillover. Due to the negative effect brought about by capital accumulation, the amount of useable resources decreases as capital accumulates. The larger ψ_1 is, the stronger the impact of capital upon resource renewal, and the more serious the problem of resource reduction caused by capital increase. Thus it is predictable that the other parameters being the same, the increase in ψ_1 will result in earlier arrival of the zero spillover point. Figure 1 shows the respective spillover curves when ψ_1 =0.1，0.2，0.3. As ψ_1 goes up, the curve reaches the zero point at a faster speed and shifts from the area of positive spillover to the area of negative spillover, where region 1 start to lose instead of gaining benefits in the resource trade. In other words, in regional trade, the weaker the resource's renewable ability is, the vulnerable the resource-exporting region will be, as is commonly recognized. However, contrary to common assumption, our simulation shows that the impact of renewable ability in this case is not linear, and improvement in the renewable ability of resources will result in a significantly larger area of positive spillover.

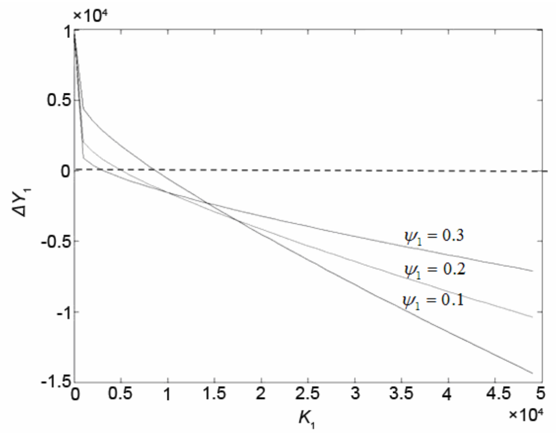

Figure 1 Impact of different values of ψ on Spillover

Next we investigate the impact of region-internal technological advance upon. Figure 2 illustrates the respective curves when $\eta_1 = 0.2, 0.3, 0.4$. The higher the value of η_1, the greater the internal technological advance, and the larger the multiple effect of K_1 upon N. That is, the region will gain a higher income if it retains part of the resources to be sold and input them into production. Therefore, the higher the value of η_1 is, the smaller the amount of K_1 will become when the region reaches the zero spillover point.

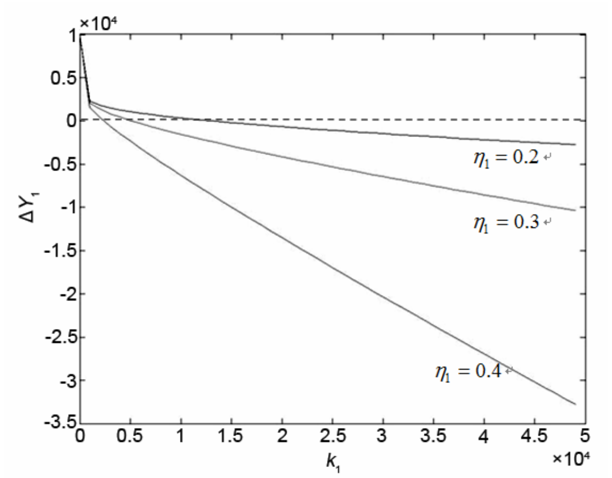

Figure 2 Impact of different values of η on Spillover

3.2 case of Region 2

Now let's discuss the spillover for region 2, the region that purchases resources. In our simulation, the parameters in region 1 will retain their assigned initial values. In the case of Region 2, however, considering that in the realistic world the region that imports resources tends to feature a relatively more developed economic system and a stronger internal technological advance, we assign the initial values for the parameters in Region 2 as in table 2.

Table 2 Initial Values for Parameters in Region 2

Parameter	Definition	Initial value
α_2	Capital elasticity	0.8
N_2	Total amount of renewable resources	5000
η_2	Regional technological advance coefficient	0.6
ψ_2	Resource spillover coefficient	0.2
K_1	Capital K_1, assignable value range	0~100000
K_2	Capital K_2, assignable value range	0~100000

Figure 3 shows that when K_2 is fairly large and K_1 is much smaller, Region 2 will obtain a large positive spillover.

This is because a large K_2 implies a sharp decrease in the amount of useable resources available in region 2, and therefore a large import of resources to meet the need in the production, whereas a small K_1 indicates plenty of resources available in region 1 and thus a large positive spillover through resource export. This is not unlike the status of trade between the South and the North. With the countries or regions in the South in the primary stage of economy and the countries or regions in the North in the advanced economic level, when the South sell their resources and the North buy them, both parties will gain significant positive spillover in the resource trade and it is thus a win-win situation. However, if K_2 remains at a high level and K_1 keeps going up, there will be a dramatic drop in the positive resource spillover gained by region 1 and meanwhile a material fall in the positive spillover for region 2. This is because the rise in K_1 leads to the reduction in useable resources in region 1, which in turn results in decrease in the amount of resource export, even though the ratio remains the same. When K_2 is at a low level, then no matter K_1 is big or small, region 2 will not get positive spillover in resource trade, as is shown in the dark black part (the downward bulge) in Figure 3, therefore there should be no trade. Or in other words, trade does not occur until the accumulation of regional capital has reached a certain level.

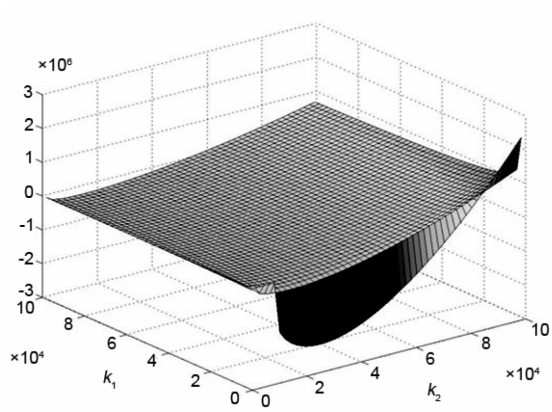

Figure 3 Spillovers for Region 2 at Different Capital Value K_1 and K_2

3.3 case of 2 regions

Under what conditions will resource trade occur when the economic systems of the 2 regions in question are of different economic status? We take a closer look at this by changing the value of b and assuming that all the other parameters remain unchanged. We make such an inquiry because region 1 and region 2 could achieve a win-win solution by adjusting the amount of trade, given the price of the resources. A particular case is shown in Figure 4.

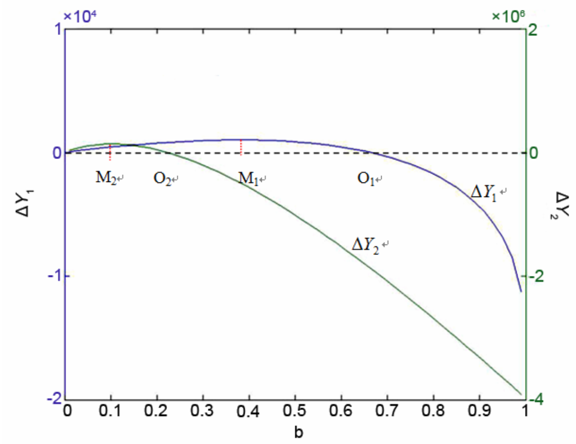

Figure 4 Impact of Resource Trade Ratio on 2-regions

The 2 curves in Figure 4 respectively represent the changes in ΔY_1 and ΔY_2 caused by the changes in b, with O_1 and O_2 being the respective points of ΔY_1 and ΔY_2 where the spillover turns from positive to negative. When the ratio $b < O_2$, both regions will profit from the resource trade; when $O_2 \le b < O_1$, resource trade will benefit region 1 but not region 2; when $b \ge O_1$, resource trade will be to neither side's benefit. Therefore, resource trade will take place only when $b < O_2$. It can also be seen from the diagram that the maximum resource spillovers for both regions occur at 2 different points, with the maximum spillover in region 1 occurring at the point when $b = M_1$, while the maximum gain for region 2 at $b = M_2$. It's obvious that both regions expect to gain larger spillover in resource trade. When $b = M_1$, there will not be any resource trade as the point is beyond O_2; when $b < M_2$, the spillover for region 2 is not maximum, and meanwhile the spillover for region 1 is quite small, therefore resource trade in this case will be mutual beneficial, but not optimal for either party; when $M_2 < b < O_2$, rise in b will lead to increase in spillover for region 1, and decrease in spillover for region 2, therefore, there exists a win-win spillover in the space in question, which therefore is where resource trade is most likely to occur.

4 conclusion

While mutual effects of multi-region economic growth is a prominent economic question, spillover of natural resources represents a relatively weak link in current spillover studies. In our attempt to bridge the gap, we have constructed a 2-region natural resources spillover model, and inquired into the mutual effects of regional economic growth via numeric simulation. (We have reached the following conclusions:

We find, through simulation, that a region that features strong internal knowledge spillover will achieve more income by inputting its resources to production than by selling them. Therefore, for regions abounding in natural resources but short in capital, the internal spillover of knowledge is a crucial element.

And in the policy making of one particular region, the ratio of the resources to be sold to the resources overall can be adjusted, just the same way as OPEC sets its output according to the oil price. For a given resources price, both regions could gain by adjusting the volume of resources trade.

For the relationship between the capital K and the usable amount of natural resources N, there are a number of possibilities, according to Brestchger（1999a. We have discussed only one of them. Yet the basic premise remains the same, that is, the accumulation of capital will not lead to any improvement in the environment, but always to its deterioration and reduction in usable resources. Not all economists agree on this though. They think there may exist the Environmental Kuznets Curve（EKC）. But the validity of EKC is questionable, for the ergodic hypothesis does not hold true owing to the finiteness of the earth. To sum up in other words, the function of usable resources and capital is still subject to modification, and this we believe is one direction to follow in further discussion of this model.

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