Cross-border Transport Infrastructure and Aid Policies*

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Abstract

We investigated resource allocation concerning the provision of cross-border transport infrastructure, which is used for trade of goods between two neighboring countries. Since the level of infrastructure is sub-optimal under the circumstances that two governments choose the levels of infrastructure independently, we focus on the role of foreign aid to improve the efficiency of infrastructure provision. In this paper, we examine the welfare effects of aid policies, and show that aid can make both countries better off, i.e., Pareto improvement. Furthermore, Pareto improvement is more likely if the stage of development in recipient country is very low or sufficiently high.

1 Introduction

This paper deals with issues related to cross-border transport infrastructure between two neighboring countries. Transport infrastructure plays an important role in trade between two countries. Investment in infrastructure reduces the transport cost, which expands the volume and scope of traded goods, and countries enjoy larger gains from trade. However, cross-border transport infrastructure raises the

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problem of resource allocation as follows. Each country is responsible for the construction of infrastructure within its territory, and chooses the level of investment independently taking into account the welfare of its own citizens. Note that investment in transport infrastructure on one side reduces the transport costs of both import and export goods, thus bringing benefits to both of the trade partners. This implies that independent decision-making leads to an inefficient outcome.

The problem is more serious in developing countries. Extremely high transport cost due to lack of infrastructure is a significant impediment for trade (for evidence, see Limao and Venables (2002)), which restricts economic development in such countries. Governments in developing countries have limited funds for investment in infrastructure. We focus on the role of foreign aid as an instrument to improve efficiency. Aid from neighboring countries promotes improvement of infrastructure, which may benefit not only the recipient but also the donor as a user of the infrastructure. If this benefit for the donor exceeds the financial burden for aid, aid policy could be Pareto-improving, which may raise public support for providing aid.

Such policy responses are widely observed in reality; in several instances of economic integrations, the processes involve coordination and aid transfer for infrastructure development. The European Union proposes TEN-T (Trans-European Transport Network), TINA (Transport Infrastructure Needs Assessment), and sets up programs to reconstruct transport networks in response to enlargement of the union to the east, such as Phare, ISPA. These programs include financial assistance by grant aid and loans. South Korea is providing funding and materials not only for reconnection of the North-South railroad but also for infrastructure improvement in North Korea. These policies may have a major impact on the trade patterns and welfare of residents, although the primary reason for foreign aid is not only for economic benefit, but also for political or security reasons, etc. Formal economic analysis of this problem is useful for evaluating whether the policies are effective. This may also help the design of aid policies.

We developed a simple two-country model of international trade where the transport cost between two countries is endogenously determined by the decision-making on infrastructure provision by two governments. Traditionally, international economists have paid relatively little attention to transportation cost, despite its quantitative importance (for a survey, see Casas (1983)). Transport cost plays a more important role in the trade theories based on the New Economic Geography framework (Fujita, Krugman, Venables (1999)), nevertheless most models treat transport cost as an exogenously given parameter. It is only recently that economists have begun to construct trade models using endogenous transport cost. There are two approaches to this problem; scale economy in transportation, and decisions on infrastructure. Mori and Nishikimi (2002), and Takahashi (2005) are examples of the former approach.[1] Our paper is based on the second approach, which focuses on the transport cost determination by infrastructure development. Martin and Rogers

[1] Mori and Nishikimi constructed a three region model in which transport cost on a link of the network decreases with the volume of traffic, and investigate the industrial location patterns in which hub and spoke type route choices are possible. Takahashi (2005) assumes that the modern transport technology is adopted if the volume of trade is sufficiently large. He shows that the spatial distribution of economic activities among regions is a significant determinant of transport technology adoption.

(1995) constructed a two-country model, to investigate how industrial location patterns are affected by differences in the levels of transport infrastructure between two countries. However the levels of infrastructure are exogenously given parameters. Bougheas, Demetriades, Morgenroth (1999) examine the effects of geography and endowments on the infrastructure levels and trade volumes in the model of two symmetric countries. The study by Bond (2000) is probably the most closely related to our paper. He investigated the consequences of independent decision-making by governments concerning infrastructure investment, and examined the effects of trade liberalization on the incentive to invest. Fukuyama (2005) also discusses a similar problem based on numerical simulations. Our paper further extends the analysis by investigating the effect of foreign aid policies on the incentive to invest, and economic welfare[2].

The effects of foreign aid on the terms of trade and welfare have been extensively studied in the literature of international economics. Samuelson (1954) shows that introducing the transport cost affects the results concerning the neutrality of income transfer on the terms of trade. Other works treating aid policies include Kemp and Kojima (1985), Hatzipanayotou and Michael (1995), Chao and Yu (1999). To our knowledge, however, there have been no studies that discuss the effects of foreign aid on the transport cost through the decisions of infrastructure investments.

The rest of the paper is organized as follows. Section 2 describes the model and characterizes the equilibrium and the optimum. Section 3 investigates the effects of foreign aid on infrastructure levels and economic welfare. Section 4 presents the analysis with the specific form of the utility function, to derive explicitly the condition that foreign aid is Pareto improving. Section 5 extends the analysis so that the level of foreign aid is endogenously determined. Section 6 summarizes the results and discusses future extensions.

2 The Model

2.1 The setting

Consider an economy that consists of two countries, indexed by i ($i = 1, 2$). There are l_i households in country i. All households in the same country have identical preferences and labor skills. Two countries may be different in income levels and country size.

In the economy, three types of consumption goods are produced; goods 1, 2, and z. We assume that the productions of goods 1 and 2 are completely specialized; countries 1 and 2 produce goods 1 and 2, respectively. Since each household in both countries consumes all types of goods, country 1 exports good 1 and imports good 2. On the other hand, good z is produced in both countries, and is set as

[2]The structure of the problem is similar to those in the literature on the voluntary provision of public good, in which the relations between income transfer and public good provision are discussed. See, e. g., Cornes (1993), Nakagawa (2004). Fujimura (2004) associates the cross-border transport infrastructure with weaker-link public good.

the numeraire. Labor is only input for production. Goods and factor markets are perfectly competitive.

Transport costs are incurred when goods 1 and 2 are traded, while good z is transported without cost. Transport costs depend on the levels of transport infrastructure in these countries.

The government of each country seeks to maximize the utility level of its citizens. It determines the level of transport infrastructure and collects tax to finance the expenditure.

2.2 Households

Each household consumes three goods, 1, 2, z. The utility function is defined as

$$u_i\left(x_i^i, x_i^j, z_i\right)$$

where x_i^i and x_i^j are respectively the consumption of goods i and j by a household in country i, z_i is the household's consumption of good z. Each household is endowed with one unit of labor. The budget constraint is

$$w_i^g = z_i + p_i^i x_i^i + p_i^j x_i^j,$$

where w_i^g represents the household's disposable income (wage net of tax), p_i^i and p_i^j represent the prices of goods i and j in country i. We suppose that goods 1 and 2 are normal goods.

Solving the utility maximization problem yields the household's demand functions,

$$x_i^i\left(p_i^i, p_i^j, w_i^g\right), x_i^j\left(p_i^i, p_i^j, w_i^g\right), z_i\left(p_i^i, p_i^j, w_i^g\right).$$

and the indirect utility function,

$$v_i\left(p_i^i, p_i^j, w_i^g\right).$$

2.3 Firms

The production of each good abides by a linear production technology. Thus the following relations should hold,

$$p_i^i = w_i a_i^i, \text{ for } i = 1, 2, \tag{1}$$

where w_i is the wage rate in country i and a_i^i is the amount of labor required to produce one unit of good i in country i.

Since the price of good z in each country is equal to unity, the following relations should hold,

$$1 = w_i a_i^z, \text{ for } i = 1, 2.$$

where a_i^z is the amount of labor required to produce one unit of good z in country i. Without loss of generality, we assume that

$$a_1^z < a_2^z.$$

Consequently the wage rate in country 1 is higher than that in country 2, namely,

$$w_1 > w_2.$$

2.4 Transportation and trade

Trade between countries 1 and 2 involve transportation across two countries. We suppose that the production and consumption in each country take place in a single location, which is defined as market. In other words, goods are transported between markets in two countries. The input for production of transportation service is labor. Trading firms employ labor in country i to transport goods between the market of country i and the border. Labor required for transportation in country i is described as a function $t_i(k_i)$, where k_i is the level of country i's transport infrastructure. We assume that $t_i' \equiv \frac{dt_i}{dk_i} < 0$, $t_i'' \equiv \frac{d^2 t_i}{dk_i^2} > 0$. This formulation is appropriate in that improvement of transport infrastructure affects speed, thereby saving labor. Transport cost between 1 and 2 is equal to $w_1 t_1(k_1) + w_2 t_2(k_2)$. We assume perfect competition among trading firms, which eliminates the positive profits. According to the assumed pattern of specialization, the following relations hold,

$$p_i^j = p_j^j + w_1 t_1(k_1) + w_2 t_2(k_2), \text{ for } i, j = 1, 2, j \neq i. \tag{2}$$

2.5 Government

Each government chooses the level of transport infrastructure within its territory and collects tax to cover the expenditure.

We assume that the transport infrastructure is produced from good z with constant returns to scale technology. Let p_i^k represent the amount of good z to produce one unit of transport infrastructure in country i, which is also interpreted as the unit cost of infrastructure.

The government of each country seeks to maximize the welfare of its citizens, subject to budget constraint. For country i the problem to solve is,

$$\max_{k_i} v_i \left(p_i^i, p_j^j + w_i t_i(k_i) + w_j t_j(k_j), \frac{I_i - p_i^k k_i}{l_i} \right), \quad j \neq i,$$

where I_i represents country i's aggregate income that is independent of policy variable, k_i. $I_i = l_i w_i$ in the absence of aid policy, and $v_i\left(p_i^i, p_i^j, w_i^g\right)$ is assumed to be concave with respect to k_i. We assume that the government makes decisions taking the other county's transport infrastructure as given. Following the optimality condition of the above problem, the government determines its level of transport infrastructure so that

$$-l_i x_i^j w_i t_i' = p_i^k, \quad i, j = 1, 2, \quad i \neq j. \tag{3}$$

The LHS of the above equation is the quantity of import good multiplied by marginal change in transport cost, which represents the benefit of travel cost saving by improvement of transport infrastructure. This condition is consistent with the conventional cost-benefit rule when the government is interested in the welfare of its citizens. The solution to the above equation is written as

$$k_i = K_i\left[I_i, p_i^k, k_j\right], \quad i, j = 1, 2, \quad i \neq j$$

where $K_i\left[I_i, p_i^k, k_j\right]$ is considered as a reaction function of the other country's decision variable, k_j, and is called hereafter *the transport infrastructure supply function.* As shown in the Appendix, the transport infrastructure supply function has the following properties

$$\frac{\partial K_i}{\partial I_i} > 0, \frac{\partial K_i}{\partial p_i^k} < 0, \quad \frac{\partial K_i}{\partial k_j} > 0, \quad \text{for } i, j = 1, 2 \text{ and } \ j \neq i, \tag{4}$$

$\frac{\partial K_i}{\partial k_j} > 0$ implies that the supply of transport infrastructure is a strategic complement.

We assume that equilibrium is unique and stable. The condition of stability is $\frac{\partial K_i}{\partial k_j}\frac{\partial K_j}{\partial k_i} < 1$.

2.6 The first-best optimum

In this paper, the optimum allocation is characterized as the solution to the following global welfare maximization problem:

$$\max_{w_1^g, w_2^g, k_1, k_2} W\left(v_1, v_2\right)$$

subject to

$$\begin{aligned} l_1 w_1 + l_2 w_2 &= l_1 w_1^g + l_2 w_2^g + p_1^k k_1 + p_2^k k_2, \\ v_i &= v_i\left(p_i^i, p_i^j, w_i^g\right), \ i, j = 1, 2, \ j \neq i, \end{aligned}$$

where $W\left(u_1, u_2\right)$ is a function that is strictly increasing in v_i and quasi-concave with respect to policy variables. The optimality conditions with respect to the infrastructure levels are

$$-l_i x_i^j w_i t_i' - l_j x_j^i w_i t_i' = p_i^k \text{ for } i, j = 1, 2, j \neq i. \tag{5}$$

The second term on the LHS of (5) is the benefit of citizens in the other country, which does not appear in (3), the optimality condition for the problem of national government. This implies that independent decision-making by each national government does not attain optimal allocation because it ignores the benefit of citizens in the other country. In the next section, we look at the role of foreign aid to improve the efficiency.

3 Foreign Aid and Transport Infrastructure

We suppose that aid is provided from country 1 to 2, as we assumed that the income level of country 1 is higher. Two types of aid policy are considered: a lump-sum transfer, s, and a matching grant, which subsidizes the $100m\%$ of country 2's expenditure for transport infrastructure. Then, the budget constraints of the governments in country 1 and 2 are respectively rewritten as

$$l_1 w_1 - s - m p_2^k k_2 = l_1 w_1^g + p_1^k k_1 \tag{6}$$

$$l_2 w_2 + s = l_2 w_2^g + (1 - m) p_2^k k_2. \tag{7}$$

The equilibrium levels of transport infrastructure with foreign aid are obtained as the solution to the system of equations as follows,

$$k_1 = K_1\left[I_1, p_1^k, k_2\right], \tag{8}$$

$$k_2 = K_2\left[I_2, (1-m)\,p_2^k, k_1\right], \tag{9}$$

where $I_1 = l_1 w_1 - s - m p_2^k k_2, I_2 = l_2 w_2 + s$.

3.1 The effect on transport infrastructure

We evaluate the changes from the initial equilibrium, in which neither a lump-sum transfer nor a matching grant is adopted, that is, $s = m = 0$. Totally differentiating (8) and (9), and rearranging yield

$$\begin{bmatrix} 1 & -\frac{\partial K_1}{\partial k_2} \\ -\frac{\partial K_2}{\partial k_1} & 1 \end{bmatrix} \begin{pmatrix} dk_1 \\ dk_2 \end{pmatrix} = \begin{bmatrix} -\left(\frac{\partial K_1}{\partial I_1}\right) ds - p_2^k k_2 \left(\frac{\partial K_1}{\partial I_1}\right) dm \\ \left(\frac{\partial K_2}{\partial I_2}\right) ds - p_2^k \left(\frac{\partial K_2}{\partial p_2^k}\right) dm \end{bmatrix}. \tag{10}$$

Let us denote the determinant of the matrix on the LHS by D, which is obtained as follows

$$D = 1 - \frac{\partial K_1}{\partial k_2}\frac{\partial K_2}{\partial k_1},$$

where $D > 0$, from the condition of the local stability.

Solving (10), we have the following formulas to evaluate the effects of aid policies on the equilibrium levels of transport infrastructure

$$Ddk_1 = \left(-\frac{\partial K_1}{\partial I_1} + \frac{\partial K_1}{\partial k_2}\frac{\partial K_2}{\partial I_2}\right) ds + \left(-\frac{\partial K_1}{\partial I_1} - \frac{1}{k_2}\frac{\partial K_1}{\partial k_2}\frac{\partial K_2}{\partial p_2^k}\right) p_2^k k_2 dm, \tag{11}$$

$$Ddk_2 = \left(-\frac{\partial K_2}{\partial k_1}\frac{\partial K_1}{\partial I_1} + \frac{\partial K_2}{\partial I_2}\right) ds + \left(-\frac{\partial K_2}{\partial k_1}\frac{\partial K_1}{\partial I_1} - \frac{1}{k_2}\frac{\partial K_2}{\partial p_2^k}\right) p_2^k k_2 dm. \tag{12}$$

We compare below the effects of two types of policies: lump-sum transfer and matching grant. Let us suppose that only one of two policies is exclusively implemented: $ds = 0$ if $dm > 0$, $dm = 0$ if $ds > 0$. Thus $\frac{dk_i}{dm}$ and $\frac{dk_i}{ds}$ represent the separate effects of matching grant and lump-sum transfer, respectively. Comparing two bracketed terms in each of (11) and (12), the following relation is derived

$$\frac{1}{p_2^k k_2}\frac{dk_i}{dm} \gtreqless \frac{dk_i}{ds} \Longleftrightarrow -\frac{1}{k_2}\left(\frac{\partial K_2}{\partial p_2^k}\right) \gtreqless \frac{\partial K_2}{\partial I_2}, \text{ for } i, j = 1, 2, j \neq i.$$

As shown in the Appendix, it is true that

$$-\frac{1}{k_2}\left(\frac{\partial K_2}{\partial p_2^k}\right) > \frac{\partial K_2}{\partial I_2}.$$

Thus we have

$$\frac{1}{p_2^k k_2}\frac{dk_i}{dm} > \frac{dk_i}{ds}.$$

The above inequality implies that, when the same amount of money is spent, $ds = p_2^k k_2 dm$, the matching grant increases the transport infrastructure more than the lump-sum transfer.[3]

3.2 The effect on welfare

Totally differentiating the indirect utility function and budget constraint of country 1 yields

$$dv_1 = \left(\frac{\partial v_1}{\partial p_1^2}\right)(-w_1 t_1' dk_1 - w_2 t_2' dk_2) + \left(\frac{\partial v_1}{\partial w_1^g}\right) dw_1^g, \tag{13}$$

$$l_1 dw_1^g + p_1^k dk_1 = -ds - p_2^k k_2 dm. \tag{14}$$

Substituting (14) to (13) and incorporating the first order condition of country 1, we have

$$l_1 dv_1 = \left(\frac{\partial v_1}{\partial w_1^g}\right)\left[-l_1 x_1^2 w_2 t_2' dk_2 - p_2^k k_2 dm - ds\right]. \tag{15}$$

The first term in the bracket on the RHS represents the benefit from improvement of the infrastructure in the recipient country in response to aid, the second and third terms are increase in expenditure for matching grant and lump-sum transfer, respectively.

As in the Section 3.1, $\frac{dv_i}{dm}$ $\left(\frac{dv_i}{ds}\right)$ represents the effect of the matching grant (lump-sum transfer) when $ds = 0$ ($dm = 0$). Since $\frac{1}{p_2^k k_2}\frac{dk_2}{dm} > \frac{dk_2}{ds}$ is shown earlier, we have

$$\frac{1}{p_2^k k_2}\frac{dv_1}{dm} > \frac{dv_1}{ds}$$

Applying the same procedure to country 2, we have

$$l_2 dv_2 = \left(\frac{\partial v_2}{\partial w_2^g}\right)\left[-l_2 x_2^1 w_1 t_1' dk_1 + p_2^k k_2 dm + ds\right], \tag{16}$$

which means that

$$\frac{1}{p_2^k k_2}\frac{dv_2}{dm} > \frac{dv_2}{ds}.$$

Thus the matching grant performs better than the lump-sum transfer in terms of the economic welfare of both countries. This also implies that the matching grant is more likely to attain Pareto-improvement.

[3] In general, the signs of dk_i/dm, dk_i/ds are ambiguous: they can be negative if the income effect of consumption in the donor country is sufficiently large. Since this paper deals with aid as an instrument to facilitate infrastructure development, we suppose that the signs are positive. This is true, in the discussion based on a specific utility function in the next section.

4 Analysis with Specific Functional Form

4.1 Equilibrium

To obtain explicit solutions, we specify the form of the utility function of a household as

$$u_i\left(x_i^i, x_i^j, z_i\right) = z_i - \frac{x_i^i}{\alpha_e}\left[\ln\left(\frac{x_i^i}{\alpha_e}\right) - 1\right] - \frac{x_i^j}{\alpha_m}\left[\ln\left(\frac{x_i^j}{\alpha_m}\right) - 1\right], \text{for } i, j = 1, 2, j \neq i, \tag{17}$$

where α_e and α_m are parameters representing the preferences for export and import goods, respectively. The demand of the household for the import goods are given by

$$x_i^j = \alpha_m e^{-\alpha_m p_i^j}, \quad \text{for } i, j = 1, 2, \ j \neq i. \tag{18}$$

The above demand function is restrictive in that there is no income effect. However, wage rate affects consumption demand through production and transport costs. The use of the demand function without income effect will illuminate the role of wages as the determinant of prices. Note that the wage rate is determined by production technology. So we treat hereafter the wage rate as the factor representing the stage of development, rather than the income level. The indirect utility function of the household in country i is given by

$$v_i\left(p_i^i, p_i^j, w_i^g\right) = w_i^g + \exp\left(-\alpha_e p_i^i\right) + \exp\left(-\alpha_m p_i^j\right) \quad \text{for } i, j = 1, 2, \ j \neq i.$$

We specify the form of the function describing the transport technology as

$$t_i\left(k_i\right) = -\beta \ln \frac{k_i}{\bar{k}}, \tag{19}$$

where $\bar{k}$ is the upper limit of the level of transport infrastructure. By choosing the unit of infrastructure appropriately, we set $\bar{k} = 1$.

In this setting, the infrastructure supply functions, (8) and (9), are written as

$$K_1\left[I_1, p_1^k, k_2\right] = \left(k_2\right)^{\frac{\alpha_m \beta w_2}{1-\alpha_m \beta w_1}}\left[\frac{\beta w_1 \Gamma_1}{p_1^k}\right]^{\frac{1}{1-\alpha_m \beta w_1}}, \tag{20}$$

$$K_2\left[I_2, (1-m)\, p_2^k, k_1\right] = \left(k_1\right)^{\frac{\alpha_m \beta w_1}{1-\alpha_m \beta w_2}}\left[\frac{\beta w_2 \Gamma_2}{(1-m)\, p_2^k}\right]^{\frac{1}{1-\alpha_m \beta w_2}}, \tag{21}$$

where $\Gamma_i \equiv l_i \alpha_m \exp\left(-\alpha_m p_j^j\right)$. Γ_i represents the quantity of good j that meets the aggregate demand for good j in country i when the transport cost equals zero. The stability condition is

$$1 - \frac{\partial K_1}{\partial k_2}\frac{\partial K_2}{\partial k_1} = \frac{1 - \alpha_m \beta\left(w_1 + w_2\right)}{\left(1 - \alpha_m \beta w_1\right)\left(1 - \alpha_m \beta w_2\right)} > 0. \tag{22}$$

Solving the system of equations (8) and (9), we obtain the equilibrium levels of transport infrastructure as

$$k_1 = \left[\frac{\beta w_1 \Gamma_1}{p_1^k}\right]^{\frac{1-\alpha_m \beta w_2}{1-\alpha_m \beta (w_1+w_2)}} \left[\frac{\beta w_2 \Gamma_2}{(1-m)\, p_2^k}\right]^{\frac{\alpha_m \beta w_2}{1-\alpha_m \beta (w_1+w_2)}}, \tag{23}$$

$$k_2 = \left[\frac{\beta w_1 \Gamma_1}{p_1^k}\right]^{\frac{\alpha_m \beta w_1}{1-\alpha_m \beta (w_1+w_2)}} \left[\frac{\beta w_2 \Gamma_2}{(1-m)\, p_2^k}\right]^{\frac{1-\alpha_m \beta w_1}{1-\alpha_m \beta (w_1+w_2)}}. \tag{24}$$

4.2 The first-best optimum

The optimal levels of transport infrastructure in the two-country economy as a whole are obtained by solving the system of equations (5), to which (18) is substituted. The solution, k_i^* is obtained as

$$k_i^* = \left[\frac{\beta w_i (\Gamma_1+\Gamma_2)}{p_i^k}\right]^{\frac{1-\alpha_m \beta w_j}{1-\alpha_m \beta (w_1+w_2)}} \left[\frac{\beta w_j (\Gamma_1+\Gamma_2)}{p_j^k}\right]^{\frac{\alpha_m \beta w_j}{1-\alpha_m \beta (w_1+w_2)}} \quad \text{for } i,j=1,2,\ j\neq i. \tag{25}$$

We compare the first-best levels of transport infrastructure with the initial equilibrium levels. From (23), (24), and (25), it follows that

$$\frac{k_i}{k_i^*} = \left(\frac{\Gamma_i}{\Gamma_1+\Gamma_2}\right)^{\frac{1-\alpha_m \beta w_j}{1-\alpha_m \beta (w_1+w_2)}} \left(\frac{\Gamma_j}{\Gamma_1+\Gamma_2}\right)^{\frac{\alpha_m \beta w_j}{1-\alpha_m \beta (w_1+w_2)}} < 1, \text{ for } i,j=1,2,\ j\neq i.$$

This inequality states that the transport infrastructure in both countries is under provided in the case of independent decision-making.

4.3 The effect of foreign aid

In view of (23) and (24), we immediately see that a lump-sum transfer between countries has no effect on the levels of transport infrastructure. This is because the demand for goods 1 and 2 has no income effect under the specified utility function. The effects of the matching grant on infrastructure levels, k_1 and k_2,are evaluated by differentiating (23) and (24) with respect to m, as follows

$$\frac{1}{k_1}\frac{dk_1}{dm} = \frac{\alpha_m \beta w_2}{[1-\alpha_m \beta (w_1+w_2)]} > 0,$$

$$\frac{1}{k_2}\frac{dk_2}{dm} = \frac{1-\alpha_m \beta w_1}{(1-m)[1-\alpha_m \beta (w_1+w_2)]} > 0. \tag{26}$$

The above inequalities suggest that the matching grant increases not only the level of infrastructure in the recipient country but also that in the donor country. This is due to the strategic complementarity; as the infrastructure in the recipient country is increased by the aid, the donor responds by increasing its infrastructure.

Substituting (23), (24) into (15) and (16) yields

$$l_1 dv_1 = -ds + E_1^m p_2^k k_2 dm, \tag{27}$$

$$l_2 dv_2 = ds + E_2^m p_2^k k_2 dm, \tag{28}$$

where

$$
\begin{aligned}
E_1^m &= -l_1 x_1^2 w_2 t_2' \frac{1}{p_2^k k_2} \frac{dk_2}{dm} - 1 \\
&= \frac{l_1 x_1^2}{l_2 x_2^1} \frac{1}{k_2} \frac{dk_2}{dm} - 1. \\
&= \left(\frac{l_1}{l_2}\right) e^{\alpha_m (p_1^1 - p_2^2)} \frac{1 - \alpha_m \beta w_1}{1 - \alpha_m \beta (w_1 + w_2)} - 1 \qquad (29) \\
E_2^m &= -l_2 x_2^1 w_1 t_1' \frac{1}{p_2^k k_2} \frac{dk_1}{dm} - 1 \\
&= \frac{1 - \alpha_m \beta w_2}{1 - \alpha_m \beta (w_1 + w_2)}. \qquad (30)
\end{aligned}
$$

The second line of (29) is obtained by incorporating the first-order condition of country 2 to the first line.

Since a lump-sum transfer has no effect on the infrastructure levels, the welfare changes of the recipient and the donor are exactly equal to the amount of money transferred. Consequently the lump-sum transfer benefits the recipient but aggravates the donor. As for the matching grant, (30) shows that E_2^m is always positive, but (29) shows that E_1^m may be either positive or negative. In other words, the recipient is always better off by the matching grant, but the welfare effect on the donor depends on the parameters. Note that the matching grant is Pareto-improving if $E_1^m > 0$. We investigate below how parameters affect the possibility of Pareto improvement.

Figure 1

(29) shows that E_1^m is more likely to be positive as the relative size of the donor, country 1, is larger. It is not straightforward to see the effects of wage rates, since w_1 and w_2 are appeared in several parts of (29). The curve $a - a$ in Figure 1 depicts the locus of $E_1^m = 0$ on the $w_1 - w_2$ plane.[4] If (w_1, w_2) lies above the curve $a - a$, $E_1^m > 0$ holds; the matching grant improves the welfare of the donor. Since we assume $w_1 > w_2$, only the area above the 45 degree line, $w_1 = w_2$ is relevant.

[4] Totally differentiating $E_1^m = 0$ with respect to w_1 and w_2 yields the following

$$
\frac{dw_1}{dw_2} = -\frac{(\partial E_1^m / \partial w_2)}{(\partial E_1^m / \partial w_1)} = -\frac{(1 - \alpha_m \beta w_1)[\beta - a_2^2 \{1 - \alpha_m \beta (w_1 + w_2)\}]}{\alpha_m \beta^2 w_2 + a_1^1 (1 - \alpha_m \beta w_1)\{1 - \alpha_m \beta (w_1 + w_2)\}}
$$

The denominator on the RHS is positive from the stability condition (22). It follows that $\frac{dw_1}{dw_2} > 0$ if $w_1 < \frac{a_2^2 - \beta}{a_2^2 \alpha_m \beta} - w_2$ and vice versa. The downward-sloping dotted line $b - b$ in Figure 1 is the locus of $w_1 = \frac{a_2^2 - \beta}{a_2^2 \alpha_m \beta} - w_2$. Thus the locus of $E_1^m = 0$ is increasing with w_2 in the area below dotted line $b - b$ in Figure 1, and decreasing in the area above that line. If the intercept of the vertical axis is sufficiently large such that $\frac{\ln(l_1/l_2)}{a_1^1 \alpha_m} > \frac{a_2^2 - \beta}{a_2^2 \alpha_m \beta}$ holds, the locus $a - a$ is decreasing for the whole range of w_2.

Comparing points B and D, it is observed that Pareto improvement is more likely as the wage rate of the donor (country 1) is higher. The effects of the recipient's wage rate are not monotonic. Comparison between points A and B suggests that the matching grant is Pareto improving when the recipient's wage rate is lower. But comparison between points B and C suggests the opposite. As we interpret w_2 as the level of the development of country 2, the above result implies that the matching grant is more likely to be Pareto-improving when the level of development in the recipient country is very low or sufficiently high.

Let us investigate the mechanism behind the non-monotonic relation between w_2 and the possibility of Pareto improvement. This result is obtained because the sign of $\frac{\partial E_1^m}{\partial w_2}$ may be negative (positive) when w_2 is low(high). Differentiating E_1^m on the second line of (29) with respect to w_2, we have[5]

$$\frac{\partial E_1^m}{\partial w_2} = \frac{l_1 x_1^2}{l_2 x_2^1} \frac{1}{k_2} \frac{dk_2}{dm} \left[\frac{x_2^1}{x_1^2} \frac{\partial}{\partial w_2} \left(\frac{x_1^2}{x_2^1} \right) + \frac{1}{\frac{1}{k_2}\frac{dk_2}{dm}} \frac{\partial}{\partial w_2} \left(\frac{1}{k_2} \frac{dk_2}{dm} \right) \right] \tag{31}$$

The first term in the bracket of the RHS is negative since $\frac{\partial x_1^2}{\partial w_2} < 0$; increase in w_2 induces a higher price of good 2, so trade volume decreases. The second term represents the intensity of response in infrastructure provision to the increase in the matching grant, which is positive in view of (26). For the specification used in this section, the recipient with a higher wage invests more actively against a marginal increase in aid. In sum, the wage rate of the recipient, w_2, has a negative effect on the volume of trade and a positive effect on the recipient's response to the aid. The absolute value of the first term is constant while that of the second term is increasing with w_2[6]. When w_2 is small, the second term is small, so $\frac{\partial E_1^m}{\partial w_2}$ may be negative. As w_2 increases, the second term increases, and may exceed the first term; $\frac{\partial E_1^m}{\partial w_2}$ may turn positive.

4.4 The effect on global welfare

We define global welfare as the sum of utilities of all households in the economy, that is, $W = l_1 v_1 + l_2 v_2$. This aggregation is applicable in the case of the quasi-linear preference assumed in this section; utility is measured in monetary terms. From (27) and (28), we evaluate the effect of the aid on global welfare at the initial equilibrium, where $s = m = 0$, as

$$\begin{aligned} dW &= l_1 dv_1 + l_2 dv_2 \\ &= \frac{1}{1 - \alpha_m (w_1 + w_2)} \left[\alpha_m \beta w_1 + (1 - \alpha_m \beta w_1) \left(\frac{l_1}{l_2} \right) e^{\alpha_m \left(p_1^1 - p_2^2 \right)} \right] p_2^k k_2 dm, \end{aligned}$$

which implies that

[5] The effects of w_2 on $\frac{x_1^2}{x_2^1}$ through transport costs are canceled out, so only two effects appear in (31).

[6] $\frac{x_1^2}{x_1^2} \frac{\partial}{\partial w_2} \left(\frac{x_1^2}{x_1^2} \right) = -\alpha_m a_2^2$, $\frac{1}{\frac{1}{k_2}\frac{dk_2}{dm}} \frac{\partial}{\partial w_2} \left(\frac{1}{k_2} \frac{dk_2}{dm} \right) = \frac{\alpha_m \beta}{1 - \alpha_m \beta (w_1 + w_2)}$

$$\frac{dW}{ds} = 0, \frac{dW}{dm} > 0.$$

Thus, a matching grant improves the global welfare while a lump-sum transfer does not affect it.

5 Endogenous Aid

So far we have treated the level of the matching grant, m, as an exogenously given parameter. This section deals with two mechanisms for determining the level of aid endogenously; bilateral aid and multilateral aid. In the bilateral aid, m is determined by the government of the donor country. The multilateral aid in this section is a simplified scheme of the practices of international agencies such as UNDP, the World Bank, or super-national authorities such as the EU, which have played important roles in providing aid for infrastructure development. In this scheme, we suppose that m is determined by an international agency so as to maximize the global welfare. However, this type of policy is still second best, since decisions on the levels of infrastructure are not fully controlled by the grant.

5.1 Bilateral aid

Let us formulate the problem of a donor who determines the level of the matching grant. Consider the following two-stage game. In the first stage, the government of country 1 determines both the level of transport infrastructure within its territory and the level of the matching grant. In the second stage, given the level of transport infrastructure in country 1 and the matching grant, country 2 determines its level of transport infrastructure. Country 1 chooses m and k_1 taking into account the response of country 2; it behaves as the Stackelberg leader. The problem to be solved by country 1's government is

$$\max_{k_1, m} v_1 \left(p_1^1, p_1^2, w_1 - \frac{p_1^k k_1 + m p_2^k k_2}{l_1} \right)$$

subject to

$$k_2 = K_2 \left[l_2 w_2, (1-m) p_2^k, k_1 \right].$$

The optimality conditions are

$$m \quad : \quad -l_1 x_1^2 w_2 t_2' \frac{\partial K_2}{\partial m} - m p_2^k \frac{\partial K_2}{\partial m} - p_2^k k_2 = 0, \tag{32}$$

$$k_1 \quad : \quad -l_1 x_1^2 w_1 t_1' - p_1^k - \left(l_1 x_1^2 w_2 t_2' + m p_2^k \right) \frac{\partial K_2}{\partial k_1} = 0. \tag{33}$$

On the LHS of (32), the first term represents the benefit of transport cost reduction for consumers in country 1 that is caused by the expansion of country 2's infrastructure in response to the matching grant. The second and third terms are the changes in expenditure for the matching grant. The condition for the infrastructure level (33) differs from (3) in that the former includes the third term on the LHS, which does not appear in the latter. This term is the indirect effect of increase in k_1 that induces response of country 2 by increasing k_2. This indirect effect encourages investment in country 1.[7]

For the specific functional form (17), we obtain explicit solutions as follows

$$m^s = \frac{\Gamma_1 - (1 - \alpha_m \beta w_2)\,\Gamma_2}{\Gamma_1 + \alpha_m \beta w_2 \Gamma_2}, \tag{34}$$

$$k_1^s = \left[\frac{\beta w_1 (\Gamma_1 + \alpha_m \beta w_2 \Gamma_2)}{p_1^k}\right]^{\frac{1-\alpha_m \beta w_2}{1-\alpha_m \beta (w_1+w_2)}} \left[\frac{\beta w_2 (\Gamma_1 + \alpha_m \beta w_2 \Gamma_2)}{p_2^k}\right]^{\frac{\alpha_m \beta w_2}{1-\alpha_m \beta (w_1+w_2)}}.$$

Note that m^s should be zero unless the inequality below holds,

$$\frac{\Gamma_1}{(1 - \alpha_m \beta w_2)\,\Gamma_2} - 1 = \frac{1}{(1 - \alpha_m \beta w_2)}\frac{l_1}{l_2} e^{\alpha_m (p_1^1 - p_2^2)} - 1 > 0$$

The above inequality is different from the condition of the Pareto improvement, (29). The set of parameters satisfying the latter condition is larger than that satisfying the former. In other words, the donor may not choose a positive matching grant even if the condition of Pareto improvement holds. This is because the donor chooses the level of infrastructure in a different manner: it takes into acount the indirect effect as discussed above.

Substituting m^s and k_1^s into country 2's transport infrastructure supply function (21), we get

$$k_2^s = \left[\frac{\beta w_1 (\Gamma_1 + \alpha_m \beta w_2 \Gamma_2)}{p_1^k}\right]^{\frac{\alpha_m \beta w_2}{1-\alpha_m \beta (w_1+w_2)}} \left[\frac{\beta w_2 (\Gamma_1 + \alpha_m \beta w_2 \Gamma_2)}{p_2^k}\right]^{\frac{1-\alpha_m \beta w_2}{1-\alpha_m \beta (w_1+w_2)}}.$$

Comparing the levels of transport infrastructure with the first-best levels given by (25), it turns out that $k_1^s < k_1^*$ and $k_2^s < k_2^*$. In other words, the levels of the transport infrastructure under bilateral aid are smaller than the efficient levels.

We examine the effects of wages in donor and recipient countries on the level of matching grant as follows

$$\frac{dm^s}{dw_1} = \frac{\alpha_m a_1^1 \Gamma_1 \Gamma_2}{(\Gamma_1 + \alpha_m \beta w_2 \Gamma_2)^2} > 0,$$

$$\frac{dm^s}{dw_2} = \frac{\alpha_m \Gamma_2 \left\{\beta - a_2^2 \left(\frac{l_1}{l_2}\right) e^{\alpha_m (p_2^2 - p_1^1)}\right\}}{(\Gamma_1 + \alpha_m \beta w_2 \Gamma_2)^2} \lesseqgtr 0. \tag{35}$$

The donor chooses the higher rate of matching grant when the wage rate in the donor country is higher. On the other hand, the wage rate in the recipient may have positive or negative effects on the rate of grant: it is likely to be positive when the relative size of the donor country is smaller, the wage rate in the donor is relatively higher, and the contribution of infrastructure for transport cost (β) is more significant.

[7] In view of (32), $l_1 x_1^2 w_2 t_2' + m p_2^k > 0$. Thus the third term of (33) has a positive value.

5.2 Multilateral aid

We suppose that an international agency designs the scheme of aid, in other words, determines the level of matching grant provided by the donor, so as to maximize the global welfare. In this case, both the donor and the recipient take the level of matching grant as given, and choose the level of infrastructure independently. The problem to be solved is

$$\max_m W = l_1 v_1 \left[p_1^1, p_1^2, w_1 - \frac{m p_2^k k_2 + p_1^k k_1}{l_1} \right] + l_2 v_2 \left[p_2^2, p_2^1, w_2 - \frac{(1-m)\, p_2^k k_2}{l_2} \right]$$

subject to

$$\begin{aligned} k_1 &= K_1 \left[l_1 w_1 - m p_2^k k_2, p_1^k, k_2 \right], \\ k_2 &= K_2 \left[l_2 w_2, (1-m)\, p_2^k, k_1 \right]. \end{aligned}$$

The optimality condition is

$$\left(\frac{\partial v_1}{\partial w_1^g} \right) \left(-l_1 x_1^2 w_2 t_2' \frac{dk_2}{dm} - p_2^k k_2 - m p_2^k \frac{dk_2}{dm} \right) + \left(\frac{\partial v_2}{\partial w_g^2} \right) \left(-l_2 x_2^1 w_1 t_1' \frac{dk_1}{dm} + p_2^k k_2 \right) = 0.$$

For the specifications (17), we obtain the explicit solution as follows

$$m^{**} = \frac{(1-\alpha_m \beta w_1)\, \Gamma_1 + \alpha_m \beta w_1 \Gamma_2}{(1-\alpha_m \beta w_1)\, \Gamma_1 + \Gamma_2}.$$

Comparing the above formula with (34), it is seen that $m^{**} > m^s$. In other words, the level of matching grant in multilateral aid is larger than that in bilateral aid. Furthermore, m^{**} is always positive, unlike the case of bilateral aid. This is consistent with the discussion in Section 4.4. Substituting m^{**}into (23) and (24), we have the levels of transport infrastructure under multilateral aid, as follows

$$\begin{aligned} k_1^{**} &= \left[\frac{\beta w_1 \Gamma_1}{p_1^k} \right]^{\frac{1-\alpha_m \beta w_2}{1-\alpha_m \beta (w_1+w_2)}} \left\{ \frac{\beta w_2}{p_2^k} \left[\Gamma_1 + \frac{\Gamma_2}{(1-\alpha_m \beta w_1)} \right] \right\}^{\frac{\alpha_m \beta w_2}{1-\alpha_m \beta (w_1+w_2)}}, \\ k_2^{**} &= \left[\frac{\beta w_1 \Gamma_1}{p_1^k} \right]^{\frac{\alpha_m \beta w_1}{1-\alpha_m \beta (w_1+w_2)}} \left\{ \frac{\beta w_2}{p_2^k} \left[\Gamma_1 + \frac{\Gamma_2}{(1-\alpha_m \beta w_1)} \right] \right\}^{\frac{1-\alpha_m \beta w_1}{1-\alpha_m \beta (w_1+w_2)}}. \end{aligned}$$

Comparing the above solutions with the first-best given by (25), it turns out that $k_1^{**} < k_1^*$ and $k_2^{**} < k_2^*$. The levels of the transport infrastructure under multilateral aid are still smaller than the efficient level.

It turns out that $\frac{\partial m^{**}}{\partial w_1} > 0$, $\frac{\partial m^{**}}{\partial w_2} < 0$. Unlike the case of bilateral aid, the effect of w_2 is unambiguously determined. The multilateral aid should be larger as the wage rate in the donor is higher, and that in the recipient is lower. In other words, more aid should be given as the difference in the levels of development between two countries becomes larger.

6 Conclusion

We developed a simple two-country model of international trade where transport cost between two countries is endogenously determined by the decision-makings on infrastructure provision by two governments. We investigate the consequences of independent decision-making by governments concerning infrastructure investment, and examine the effects of foreign aid on the levels of cross-border transport infrastructure and economic welfare of two neighboring countries. The results are summarized as follows:

1) A matching grant is always more effective than a lump-sum transfer.

2) A matching grant may be Pareto-improving. Pareto improvement is likely when:

(a) The relative size of the donor country is larger,

(b) The wage rate in the donor country is higher,

(c) The wage rate in the recipient country is very low or high.

3) A matching grant improves global welfare.

4) When the donor chooses the level of matching grant optimally, the level of infrastructure is smaller than the efficient level. Furthermore, if an international agency chooses the level of matching grant, larger aid is given but infrastructure is still under-provided.

The model presented here is extremely simplified, and the analysis deals with only limited cases. We suggest some topics to be studied in future works as follows:

1) Pricing strategies: Fees are commonly charged for the use of transport infrastructure, such as railways, toll roads, ports. If fares or tolls are policy variables for governments, there may be different policy implications of resource allocation: rules of infrastructure provision may change when user fees are levied.

2) Scale economy in production: When the production technology exhibits increasing returns to scale, complex phenomena such as concentration of industry location may arise. It is interesting to see how the results are affected by introducing scale economy in production. Trade models of the New Economic Geography provide a useful framework for analyzing of this problem.

3) Including the rest of the world: Cross-border transport infrastructure may be used by agents in third countries, who are affected by the policies of two countries. In this case, the discussion of global welfare may be modified.

4) Alternative financing schemes: Infrastructure is provided in many different ways, such as private provision, PFI, etc. It is useful to examine the consequences of these alternative schemes.

Appendix

The transport infrastructure supply function $K_i\left[I_i, p_i^k, k_j\right]$ is a solution to the following equation with respect to k_i

$$-l_i x_i^j\left(p_i^i, p_i^j, \frac{I_i - p_i^k k_i}{l_i}\right) w_i \frac{dt_i}{dk_i} = p_i^k, \quad i, j = 1, 2, \quad i \neq j. \tag{A1}$$

Totally differentiating (A1), we get

$$\left[-w_i t_i'\left(w_i t_i'\frac{\partial x_i^j}{\partial p_i^j}-\frac{p_i^k}{l_i}\frac{\partial x_i^j}{\partial w_i^g}\right)-x_i^j w_i t_i''\right]dk_i+\left[-\frac{w_i t_i'}{l_i}\frac{\partial x_i^j}{\partial w_i^g}\right]dI_i$$
$$+\left(\frac{k_i w_i t_i'}{l_i}\frac{\partial x_i^j}{\partial w_i^g}-\frac{1}{l_i}\right)dp_i^k+\left(-w_i t_i' w_j t_j'\frac{\partial x_i^j}{\partial p_i^j}\right)dk_j=0,$$

which implies that

$$\frac{\partial K_i}{\partial I_i} = \left.\frac{dk_i}{dI_i}\right|_{dk_j=0,dp_k^i=0} = \frac{-\frac{1}{l_i}\frac{\partial x_i^j}{\partial w_i^g}}{w_i t_i'\frac{\partial x_i^j}{\partial p_i^j}-\frac{p_i^k}{l_i}\frac{\partial x_i^j}{\partial w_i^g}+\frac{t_i''}{t_i'}x_i^j} \tag{A2a}$$

$$\frac{\partial K_i}{\partial p_i^k} = \left.\frac{dk_i}{dp_i^k}\right|_{dI_i=0,dk_j=0} = \frac{\frac{k_i}{l_i}\frac{\partial x_i^j}{\partial w_i^g}-\frac{1}{l_i w_i t_i'}}{w_i t_i'\frac{\partial x_i^j}{\partial p_i^j}-\frac{p_i^k}{l_i}\frac{\partial x_i^j}{\partial w_i^g}+\frac{t_i''}{t_i'}x_i^j} \tag{A2b}$$

$$\frac{\partial K_i}{\partial k_j} = \left.\frac{dk_i}{dk_j}\right|_{dI_i=0,dp_k^i=0} = \frac{-w_j t_j'\frac{\partial x_i^j}{\partial p_i^j}}{w_i t_i'\frac{\partial x_i^j}{\partial p_i^j}-\frac{p_i^k}{l_i}\frac{\partial x_i^j}{\partial w_i^g}+\frac{t_i''}{t_i'}x_i^j} \tag{A2c}$$

The second order condition requires that $v_i\left(p_i^i, p_i^j, w_i^g\right)$is concave with respect to k_i. The condition is reduced to

$$w_i t_i'\frac{\partial x_i^j}{\partial p_i^j}-\frac{p_i^k}{l_i}\frac{\partial x_i^j}{\partial w_i^g}+\frac{t_i''}{t_i'}x_i^j<0.$$

It follows that the denominators of (A2a), (A2b), and (A2c) are negative. Thus, we have

$$\frac{\partial K_i}{\partial I_i}>0, \frac{\partial K_i}{\partial p_i^k}<0, \frac{\partial K_i}{\partial k_j}>0.$$

The following relation is obtained from (A2a) and (A2b), which is used for the discussion in the text:

$$-\frac{1}{k_2}\left(\frac{\partial K_2}{\partial p_2^k}\right)-\frac{\partial K_2}{\partial I_2}=\frac{-\frac{1}{l_2 w_2 t_2' k_2}}{w_2 t_2'\frac{\partial x_2^1}{\partial p_2^1}-\frac{p_2^k}{l_2}\frac{\partial x_2^1}{\partial w_2^g}+\frac{t_2''}{t_2'}x_2^1}>0.$$

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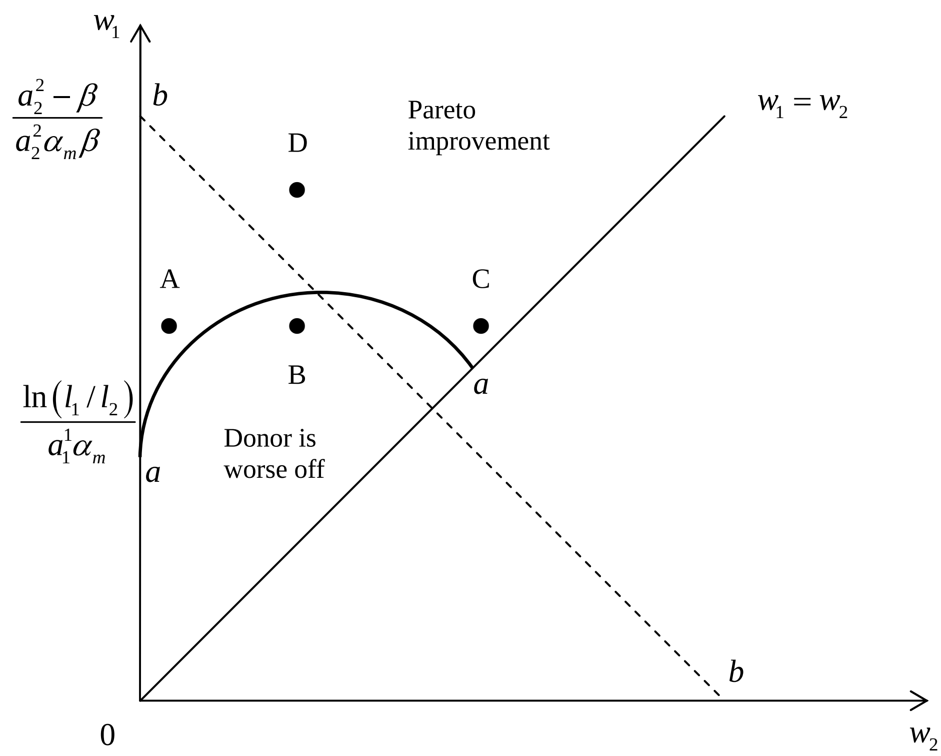

Figure 1 Income levels and possibility of Pareto improvement