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Conference Paper

Natural Disaster, Migration, and Regional Development

55th Congress of the European Regional Science Association: "World Renaissance: Changing roles for people and places", 25-28 August 2015, Lisbon, Portugal

Provided in Cooperation with:

European Regional Science Association (ERSA)

Suggested Citation: Ikazaki, Daisuke (2015) : Natural Disaster, Migration, and Regional Development, 55th Congress of the European Regional Science Association: "World Renaissance: Changing roles for people and places", 25-28 August 2015, Lisbon, Portugal, European Regional Science Association (ERSA), Louvain-la-Neuve

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Natural Disaster, Migration, and Regional Development*

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Abstract

As described in this paper, a simple matching theory is constructed to ascertain how natural disasters affect regional economic activities and migration.

Section 2 introduces a simple matching theory model based on previous studies. Section 3 describes integration of the elements of natural disasters into the model of section 2. It is assumed that agglomeration increases not only productivity but also congestion cost. When a natural disaster occurs, production factors are decreased, thereby reducing productivity. Consequently, people move from the affected areas to other cities: population drain occurs.

Section 4 extends the model presented in section 3. In section 4.1, regional loyalty is considered. Presuming that the utility difference between the domicile and other regions is low, people will tend to remain in their hometown even if monetary gains could be made by migrating to other areas. In that case, multiple steady states exist. In 4.2, we assume that productivity depends on public capital, which is degraded by a natural disaster. It is shown that once migration and a population drain occur, fiscal policies to recover public capital might deteriorate the regional economy further and might engender further population outflow.

JEL Classification: C78, Q54, R11, R23

Key Words: Natural disaster, Migration, Matching theory, Regional development

* This work was supported by JSPS KAKENHI Grant Numbers 25245042 and 25516007.

1. Introduction

As described in this paper, a simple matching theory is extended to elucidate how natural disasters affect regional economic activities and interregional migration. If one considers a typical framework of neoclassical growth theory, then natural disasters do not affect the long-run growth rate because growth rates in the neoclassical growth model depend only on exogenous technological progress. If one assumes endogenous growth theory, then natural disasters might increase or decrease the per-capita growth rate in the steady state.

From an empirical perspective, some might insist that natural disasters will decrease the growth rate; others would not. Benson and Clay (2000) examined the negative impacts of natural disasters because they eliminate or degrade production factors and therefore decrease productivity. Benson and Clay (2004) further insisted that major natural disasters produce severe and negative short-run economic impacts. Disasters also appear to have adverse longer-term consequences for economic growth. Nevertheless, negative impacts are not inevitable: some papers show positive effects and negative effects. For example, firms might replace and update facilities or machines (Tol and Leek, 1999). Reconstruction demand might create multiplier effects (Albara-Bertrand, 1993).

As described in this paper, we specifically examine the regional economy rather than the national economy. Especially, we discuss how natural disasters affect the output, unemployment rate, population change and other important variables in disaster-affected areas.

Section 2 introduces a simple model of matching theory based on previous studies. This theory explains how the unemployment rate, a measure of market tightness, the wage rate, and other important variables are determined.

Section 3 presents integration of the elements of natural disasters into the model of section 2. We assume externalities of two types related to agglomeration. On the one hand, it increases productivity. On the other hand, some negative externalities are

related to congestion. Second, natural disasters pull down production factors and therefore degrade productivity. Subsequently, population drain occurs.

Section 4 extends the model of section 3. In 4.1, we consider regional loyalty. Migrating to other regions involves some costs. These costs reflect regional loyalties, social capital that people have produced through daily life activities, moving costs including psychological burdens, and so on. Damage induced by natural disasters decreases the utility of each household. However, presuming that the utility between the household and other regions are not so different after the disaster, then people might remain in their hometown even if migration can increase their expected monetary gains. In this case, natural disasters need not increase population drain. Section 4.2 presents the assumption that productivity depends on public capital, which will be degraded severely by natural disasters. Immediately after a natural disaster, public capital decreases. People in this region will migrate to other regions. The effects of fiscal policies to recover public capital are also discussed. Results show that once migration and a population decrease occur, such fiscal policies might deteriorate the regional economy: excess supply of public capital increases the burden of the region and decrease the utility of a household. If so, fiscal policies might engender further population outflow.

Section 5 explains the main conclusions of this paper.

2. Basic model of Matching

This section introduces a simple matching model. The matching technology determines the total number of matches in the economy. Following the basic framework of matching theory (e.g., Diamond, 1982; Mortensen, 1982; Pissarides, 1985, 2000), the matching function can be specified as

$$M=mU^{\alpha}V^{1-\alpha}, \tag{1}$$

where M stands for the total number of matches, U denotes the number of unemployed, V represents the number of vacancies, and where m and α are parameters ($m > 0$ and $0 < \alpha < 1$). Let us define $\theta \equiv v/u$ as a measure of market tightness. The jobs are assumed to be lost at a rate λ per period. Then the dynamic behavior of unemployment rate is given as

$$du/dt = \lambda(1 - u) - mu^\alpha v^{1-\alpha}, \quad (2)$$

where $u \equiv U/L$ and $v \equiv V/L$ (L denotes the population). In the steady state, the unemployment rate becomes

$$u = \lambda / (\lambda + m\theta^{1-\alpha}). \quad (3)$$

This economy has only one factor of production: labor. If a firm hires a worker, then it can produce y units of output and pay a wage which is denoted as w . Each firm can earn net profit $(y - w)$ by hiring one unit of labor in every period until the match is dissolved. Let us represent the present discounted value of each firm that produces goods as Π_e , the present discounted value of a vacant job as Π_v , and the search cost for the firm as δ . Then we obtain following two Bellman equations.

$$r\Pi_e = y - w + \lambda(\Pi_v - \Pi_e) \quad (4)$$

$$r\Pi_v = -\delta + m\theta^\alpha(\Pi_e - \Pi_v) \quad (5)$$

The free entry condition means $\Pi_v = 0$. From equations (4) and (5), we obtain

$$\Pi_e = (y - w)/(r + \lambda) = \delta / m\theta^\alpha. \quad (6)$$

Equation (6) is regarded as the labor demand curve in the matching theory. This labor demand curve is the relation between w and θ .

Let V_e denote the discounted value of each employee; V_u is the present discounted value of each unemployed person who seeks a job. Bellman equations are given as

$$rV_e = w + \lambda(V_u - V_e), \quad (7)$$

$$rV_u = b + m\theta^{1-\alpha}(V_e - V_u). \quad (8)$$

We assume that w is determined endogenously through a process of bargaining between the worker and the firm. The worker and the firm try to arrive at a cooperative outcome through mutual agreement (see Nash, 1953). As described in this paper, the bargaining solution is to determine w to maximize $(V_e - V_u)^\gamma (\Pi_e - \Pi_v)^{1-\gamma}$, where γ denotes the bargaining power of the worker. Conditions for the maximum are

$$\gamma\{(V_e - V_u) + (\Pi_e - \Pi_v)\} = (V_e - V_u), \quad (9)$$

$$(1 - \gamma)\{(V_e - V_u) + (\Pi_e - \Pi_v)\} = (\Pi_e - \Pi_v). \quad (10)$$

From equations (9) and (10), one obtains

$$\gamma(\Pi_e - \Pi_v) = (1 - \gamma)(V_e - V_u). \quad (11)$$

Equation (6) and $\Pi_v = 0$ imply that

$$\gamma(\Pi_e - \Pi_v) = \gamma\Pi_e = \gamma(y - w)/(r + \lambda) = \gamma\delta/m\theta^\alpha = (1 - \gamma)(V_e - V_u). \quad (12)$$

From equations (7), (8), and (12), we obtain

$$w = (1 - \gamma)b + \gamma y + \gamma \delta \theta. \quad (13)$$

Equation (13) is regarded as a labor supply curve in the matching theory. In our model, equations (6) and (13) determine the wage rate and the measure of market tightness (see Figure 1). Once θ is determined, we can derive the steady state values of u and v (see Figure 2). It can be readily shown that $\partial \theta^*/\partial \gamma > 0$, $\partial v^*/\partial \gamma > 0$, and $\partial u^*/\partial \gamma < 0$. Asterisk shows the values of steady state in this paper.

From equations (8) and (11), V_u and V_e are given as

$$V_u = (1/r) \cdot \{b + \gamma \delta \theta^*/(1-\gamma)\}, \quad (14)$$

$$V_e = (b/r) + \gamma \delta \theta^*/(1-\gamma) \{1/r + 1/m\theta^{*1-\alpha}\}. \quad (15)$$

Figure 1 and Figure 2

about here

3. Simple model of Natural Disaster and Interregional Migration

Hereinafter, we present consideration of how natural disasters affect important variables such as per-capita income, population, and the unemployment rate.

3.1 Marshallian Externalities

This subsection specifically examines the production function and utility. First, we presume that the production function of firm j is given as $Y_j = AL_L^\xi N_j$, where A and ξ are the parameters ($A > 0$ and $0 < \xi < 1$), N_j represents the number of workers employed in firm j , L_L denotes positive externalities from the regional population and $L_L = L$ in equilibrium (L is the regional population). We use the idea of Marshallian externality (Marshall, 1890).¹ Each firm takes the value of L_L as given. Output per worker (denoted as y) is given as $y = AL_L^\xi$. Therefore, labor productivity increases with the regional population.

Let us describe households. An employee's utility W_e is given as $W_e = V_e - h(L)$, where $h(L)$ captures the negative externalities of congestion. Assume that $h'(L) > 0$ and $h''(L) > 0$. If unemployed, the household utility W_u is represented as $W_u = V_u - h(L)$.²

Assuming $b=0$ throughout this paper, then from equations (6), (13), and (14), it can be shown that $\partial V_u / \partial L > 0$ ($\partial V_u / \partial L = (\partial V_u / \partial \theta^*) \times (\partial \theta^* / \partial y) \times \partial y / \partial L > 0$). Furthermore, we assume that $\partial^2 V_u / \partial L^2 < 0$. This is true when ξ is small. Then, we can depict an inverted U-shaped relation between utility (W_u) and the regional population (L). If the regional population is small, then positive externalities of agglomeration (say, Marshallian externalities) exceed the negative externalities of congestion. The utility level of each unemployed person is positively correlated with the regional population. However, negative effects overcome positive ones if the regional population is large. In this

¹ Generally speaking, these positive externalities might derive from the number of employed workers rather than the regional population. However, such a setting does not affect our main results.

² More precisely, the present discounted value of negative externalities is defined as $\int \exp(-rt) h_a(L_t) dt$. Presuming that $h_a'(L_t) > 0$, $h_a''(L_t) > 0$, and $L_t = L$ for all t , then $\int \exp(-rt) h_a(L_t) dt = (1/r) h_a(L)$. Here, we define $(1/r) h_a(L) = h(L)$.

situation, the utility level of each unemployed person is negatively correlated with the regional population.

3.2 Population distribution before the natural disaster

We assume that the common utility level of households is established for other regions. Let W' represent that common utility level. This view is similar to the open city model. Therefore, households that go to live in other regions can enjoy welfare level W' . Households in a region consider this utility level W' as given. If people migrate from other regions to this region, then they become unemployed. The expected utility of each person is given as W_u . Generally speaking, they might be able to find a job immediately after migration. However this generalization does not affect our results. Therefore, we assume that the utility of each immigrant becomes W_u shortly after migration. It is noteworthy that $W_e - W_u = V_e - V_u > 0$. The households in other regions have an incentive to migrate to this region if $W_e > W_u > W'$. The unemployed households in this region have an incentive to migrate to other regions if $W_e > W' > W_u$. All households in this region have an incentive to migrate to other regions if $W' > W_e > W_u$. The population in this region increases because of migration if and only if $W_u > W'$. Figure 3 presents a comparison of the utility level of a representative unemployed worker (W_u , depicted as the dotted line) and W' .

Figure 3

about here

Presuming that the population given in the initial stages is smaller than L_1 or larger than L_2 , then the households here have an incentive to migrate to other regions because the utility level established in this region is less than the W' level provided in other regions. If the population in this region is given as between L_1 and L_2 , then the households in other regions have an incentive to migrate to this region because the utility level established in this region is higher than the utility level of other regions. Therefore, the stable equilibria are 0 and L_2 ; the unstable equilibrium is L_1 .

We would like to know how the natural disaster affects population dynamics. Therefore, we assume that the population level is L_2 at time 0. If so, then the regional population is L_2 ; per-capita output is given as AL_2^{ξ} for all t .

3.3 Population dynamics after the natural disaster

Presuming that a natural disaster occurs at some date and that it has harmful effects on regional economic activities, then it is assumed that the per-capita output (labor productivity) becomes sAL^{ξ} rather than AL^{ξ} after the disaster, where $0 < s < 1$. Labor productivity for a given regional population declines as a consequence of the natural disaster because productive factors are destroyed by the natural disaster.³

Some insist that positive effects as well as negative effects arise after a natural disaster (Tol and Leek, 1999; Albara-Bertrand, 1993). However, this paper presents specific examination of the negative effects of natural disaster because we would like to ascertain the effects of natural disaster on a regional economy (especially, the economy of affected areas) rather than the national economy.

We have assumed $L=L_2$ before the disaster. The steady state value of the regional population declines after the natural disaster (see Figure 3). In this case, per-capita output declines through two channels. First, the natural disaster alters the production

³ We implicitly assume the existence of factors of production other than labor. Presuming that the parameter A depends on these factors, it is natural to consider that A becomes sA by the natural disaster. In section 4, we consider this point in detail.

function. Second, a fall in the population counteracts the positive effect of agglomeration. Per-capita output decreases from AL_2^ξ to sAL_3^ξ , where L_2 are as described before and L_3 are given in Figure 3.

In this simple setting, the natural disaster reduces the population drain and income reduction (assuming that $L=L_2$ before the natural disaster). However, the utility of unemployed households is unchanged. The population drain alleviates congestion. Actually, the population outflow continues until the level of W_u becomes W' . The natural disaster decreases θ^* because $\partial\theta^*/\partial y > 0$. The unemployment rate will soar and the representative utility of employed people will decline by natural disasters (see also equation (15)). Therefore, the average utility in the disaster-affected region will decrease because of the natural disaster.

4. Extensions of the model

4.1 Regional Loyalties

In this subsection, we extend the model introduced in sections 2 and 3. First, presuming that migrating to other regions involves some costs, then these costs reflect regional loyalties, social capital that one has constructed during one's life, moving costs including psychological burdens, and so on. We express this cost as F and F' . Therefore, households in this region enjoy the utility level denoted as $W' - F$ (we define W' in section 3) if they migrate to other regions. Households in other regions have an incentive to migrate to this region if the utility level of unemployed households in this region is higher than $W' + F'$. We maintain other assumptions that we made in the previous section. Per-capita output is given as AL^ξ before the natural disaster. If a natural disaster strikes, then per-capita output becomes sAL^ξ rather than AL^ξ .

First, we will specifically examine the circumstances prevailing before the natural disaster. We depict this case in Figure 4. Presuming that the population at time 0 is smaller than L_1 or larger than L_6 , then the households here have an incentive to migrate to other regions because the utility level established in this region is less than $W' - F$. If

the initial value of the regional population is smaller than L_1 , then this region disappears because the population converges to 0 in the long run. If the initial value of the regional population is larger than L_6 , then the regional population converges to L_6 . If the population in this region is given as between L_1 and L_3 , or between L_4 and L_6 , then the population remains unchanged. If the population in this region is given as between L_3 and L_4 , then the regional population converges to L_4 . In the steady state, the regional population is between L_1 and L_3 or between L_4 and L_6 . In the model we consider in section 3, the only stable equilibrium is given as L_2 in Figure 3. However, if one considers the term ‘regional loyalties’, there are many steady states.

Figure 4 and Figure 5

about here

Presuming that a natural disaster occurs at some date and the production function moves to sAL^ξ , then the utility curve shifts downward (see Figure 5). If the population before the natural disaster is between L_1 and L_2 , then the regional population converges to 0: if the population before the natural disaster is small, then the natural disaster makes it impossible for the affected region to maintain economic activities.

If the population in this region before the natural disaster is given as between L_2 and L_3 , or L_4 and L_5 , people do not migrate to other regions and people in other regions do

not immigrate into this region. The regional population remains unchanged. If the regional population before the natural disaster is larger than L_5 , then the post-disaster regional population converges to L_5 .

The utility level of the representative unemployed person decreases after the natural disaster unless the initial level of population is L_6 . In the model we analyze in section 3, the natural disaster affects the regional population, but the utility level of the unemployed person remains unchanged. In the extended model here, not only the population distribution but also the utility level will become altered: the unemployment rate will soar; the utility level of the employed person will decline; and the average level of utility in this disaster-affected area also declines after a natural disaster.

4.2 Production Function with Infrastructure

For the previous part of this paper, we assumed that per-capita output y is given as $y = AL^\xi$. Here, we introduce another production function. Presuming that the output per worker is defined as $y = AG^\beta$, where G is public capital or, infrastructure, then each firm takes the value of G as given. Public capital is provided by a government. Other settings are as explained before.

To provide public capital G , the local government in this region must bear εG units of output. If public capital is provided by a central government, then εG is interpreted as the maintenance cost of G . If public capital is provided by a local government, then εG includes not only the maintenance cost but also the construction cost. This difference does not influence the main conclusions of our manuscript. Therefore, we assume that public capital is provided by the central government and maintenance is undertaken by the local government.

To maintain G units of public capital, which is provided by a central government, the local government must collect εG units of the final good in every period. Presuming that the local government imposes a tax on firms, and that each firm must incur τ units of output if it hires one unit of labor, then the budget constraint of the local government

is given as $\tau(1 - u^*)L = \varepsilon G$. Let us call $(y - \tau)$ the net output per worker. Not so much y as $(y - \tau)$ affects the labor market. For example, the labor demand curve and labor supply curve respectively become $(y - \tau - w)/(r + \lambda) = \delta / m\theta^\alpha$ and $w = \gamma(y - \tau) + \gamma\delta\theta$. We assume that the local government will determine the tax rate to maximize net output, $Y^{net} \equiv \Sigma(y - \tau)$. Here, we assume that $\lim_{G \rightarrow 0} (\partial Y^{net} / \partial G) > 0$, $\partial^2 Y^{net} / \partial G^2 < 0$, $\lim_{G \rightarrow \infty} (\partial Y^{net} / \partial G) < 0$, and $\partial^2 Y^{net} / \partial G \partial L > 0$. These inequalities hold if we impose appropriate parameter restrictions. The condition for the maximum is $L \cdot \partial y / \partial G [(1 - u^*) - y \cdot \partial u^* / \partial y] = \varepsilon$. The optimal value of public capital G^* , can be represented as a function of the regional population, $L: G^* = G^*(L)$.

The increments of G exert three effects on net output. First, it will increase the net output per worker, y . Second, it will reduce the unemployment rate, u^* . Third, it will increase the maintenance cost of public capital. In Figure 6, we present a graph of Y^{net} as a function of G for a given value of regional population L . In a typical case, it is possible to show an inverted U-shaped relation between Y^{net} and G . If a regional population increases, then the graph of Y^{net} shifts upward. The optimal value of public capital increases concomitantly with the regional population ($G^{*'}(L) > 0$). Therefore, the net output per worker is a function of regional population on the condition that the value of public capital is given as $G^*(L)$. It is noteworthy that $\partial y / \partial L > 0$ because $y = A[G^*(L)]^\beta$. The central government is assumed to have provided public capital in an optimal manner before the natural disaster.

Figure 6

about here

In a typical case, it is possible to show an inverted U-shaped relation between regional population and the utility of an unemployed person. Therefore, we can use Figure 5 again to analyze the interregional migration.

Presuming that natural disasters occur at some date and that public capital is degraded, and that public capital becomes $s'G$ rather than G in the aftermath of the natural disaster, and that before the natural disaster, the regional population, L^0 , is between L_1 and L_3 or between L_4 and L_6 , then the natural disaster lowers the utility of the unemployed person because it reduces y . If the population before the natural disaster is between L_1 and L_2 , then the regional population converges to 0. If the population in this region before the natural disaster is between L_2 and L_3 , or L_4 and L_5 , then regional population remains unchanged. If the regional population before the natural disaster is larger than L_5 , then the post-disaster regional population converges to L_5 . These results are similar to those described in section 4.1.

Hereinafter, we specifically examine the case in which $L_5 < L^0 < L_6$. As discussed above, a natural disaster decreases the regional population from L_0 to L_5 . Public capital changes from $G^*(L^0)$ to $s'G^*(L^0) \neq G^*(L_5)$.

One can analyze how fiscal policies designed to recover public capital affect people's economic activities. Presuming that the government promotes public investment to recover public capital to $G^*(L^0)$ from $s'G^*(L^0)$, then this reconstruction planning is promoted by a central government. $G^*(L^0)$ is no longer optimal if the regional population becomes L_5 . Presuming that $\partial Y^{net} / \partial G < 0$ at $G = s'G^*(L^0)$, then the reconstruction plans for public investment increases y , but reduces the net output because public capital is in excess supply and the maintenance cost is too high if we consider the fact that population after the natural disaster is given as L_5 . Let us interpret $L_{large} = L^0$ and $L_{small} = L_5$, where L_{large} and L_{small} are given in Figure 6. Such is the case in which $s'G^*(L^0) > G^*(L_5)$. In this case, such fiscal policies will accelerate the population drain. If $\partial Y^{net} / \partial G > 0$ at $G = s'G^*(L^0)$, then public investment to recover public capital might increase the net output. In this case, the utility of residents in the region

might increase. However, once people migrate to other regions, it might be difficult to increase the number of households to the originally prevailing level.⁴ Therefore, once the economy attains a new steady state, it is difficult for government to restore a population to an affected area. The government must conduct fiscal policy in an expeditious manner to maintain populations in affected areas.

4. Concluding Remarks

As described in this paper, we extend a simple matching model to analyze how natural disasters affect regional economic activities. In section 2, we discussed a simple matching model. In section 3, we integrated the elements of natural disasters to the model of section 2. The main results of section 3 are as follows: first, natural disasters produce a population drain and increase the unemployment rate. Second, the utility of employed people will decrease by natural disasters. Third, the utility of unemployed people remains unchanged because the falling population in that region has two opposite effects on their utilities. On the one hand, their expected income when they become employed will decline because of the population drain. On the other hand, negative costs of congestion decrease because of the population drain. These two effects offset each other and the utility of unemployment remains unchanged.

In section 4, we introduce ‘regional loyalties’. People tend to bear costs of some kinds when they migrate to other regions from their hometown. If one considers ‘regional loyalties’, then natural disasters need not reduce the regional population. The utility of a representative unemployed person will decrease and the unemployment rate will increase if we consider the term ‘regional loyalties’. We also pointed out the possibility of multiple steady states.

In the latter part of section 4, we consider how fiscal policies to recover public

⁴ Vigdor (2008) demonstrated that the disaster has no effect on the long-run equilibrium if the disaster-affected area is a ‘high-demand city’. However, if the city is a ‘low-demand city’, then the initial equilibrium point is no longer attainable.

capital affect the regional population and labor market in that region. Regional population might decrease after a natural disaster occurs. If so, fewer people must bear the burden of higher maintenance costs. Furthermore, if additional public capital is too great, then regional households must fund maintenance and disposable income will decrease. In that case, fiscal policy might accelerate the population outflow, increase the unemployment rate, and decrease the utility of representative household in disaster-affected areas.

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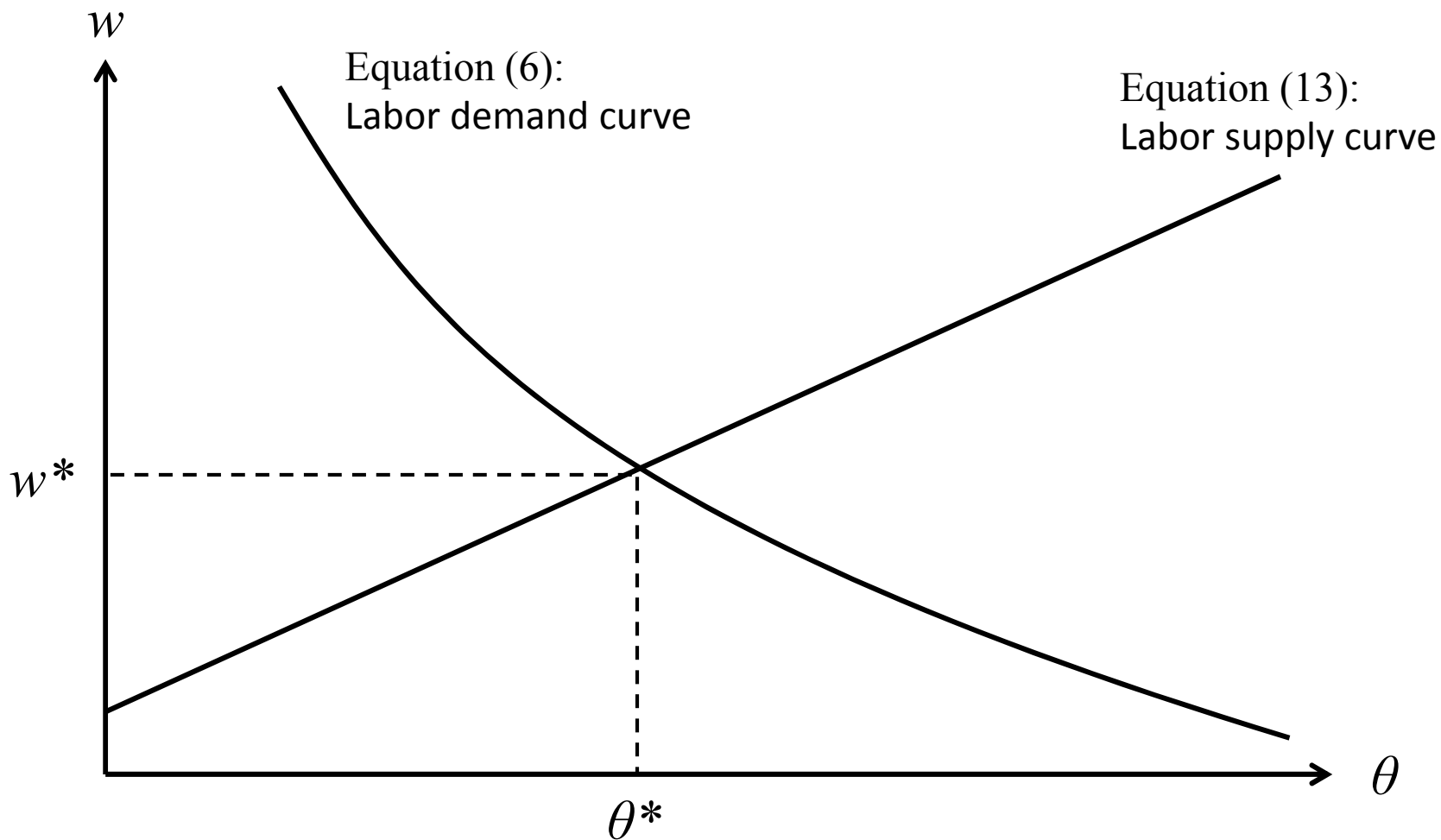


Figure 1: The relationship between w and θ

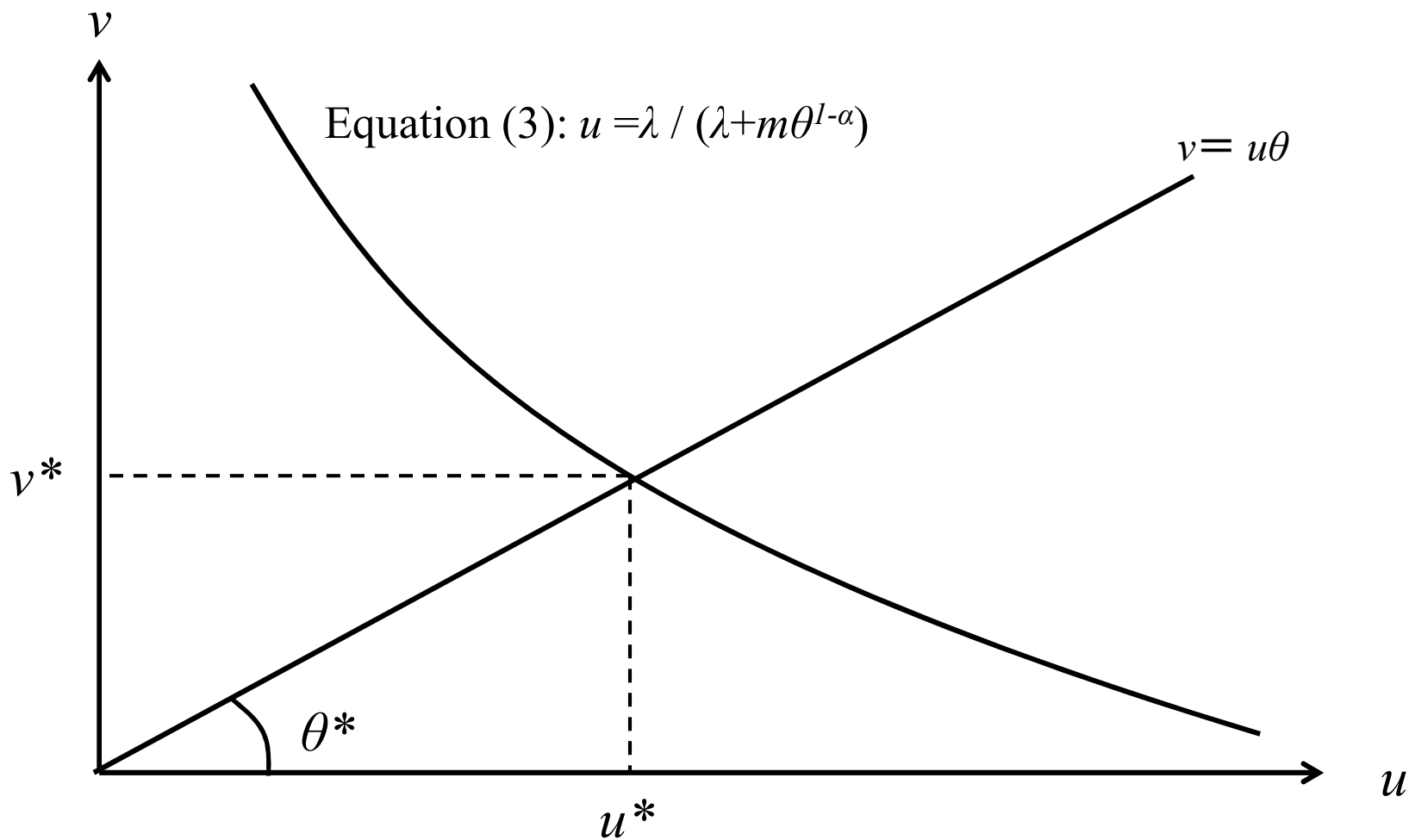


Figure 2: The relationship between u and v

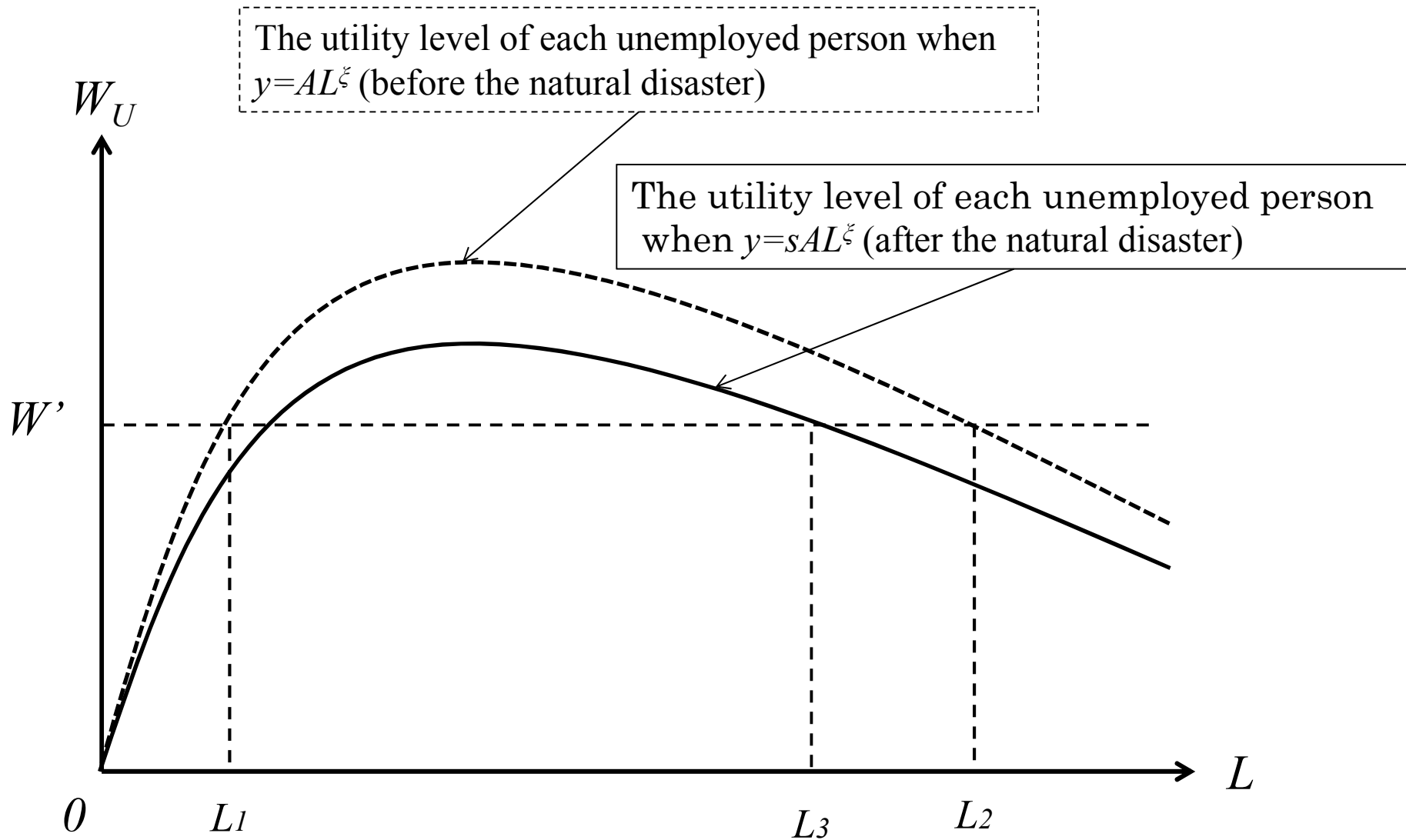


Figure 3: The relationship between L and W_u

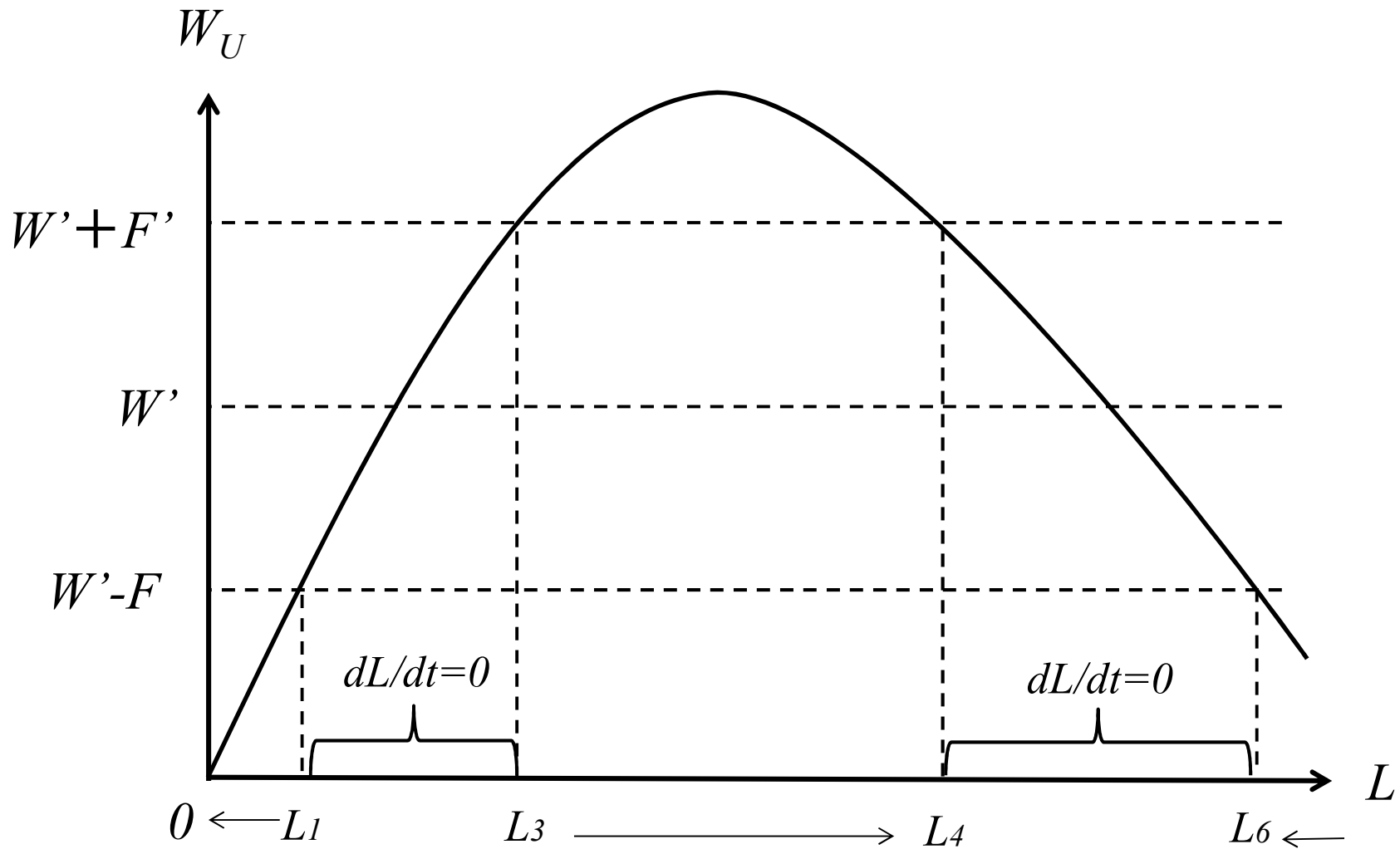


Figure 4: The relationship between L and W_u before the natural disaster when utility includes regional loyalties

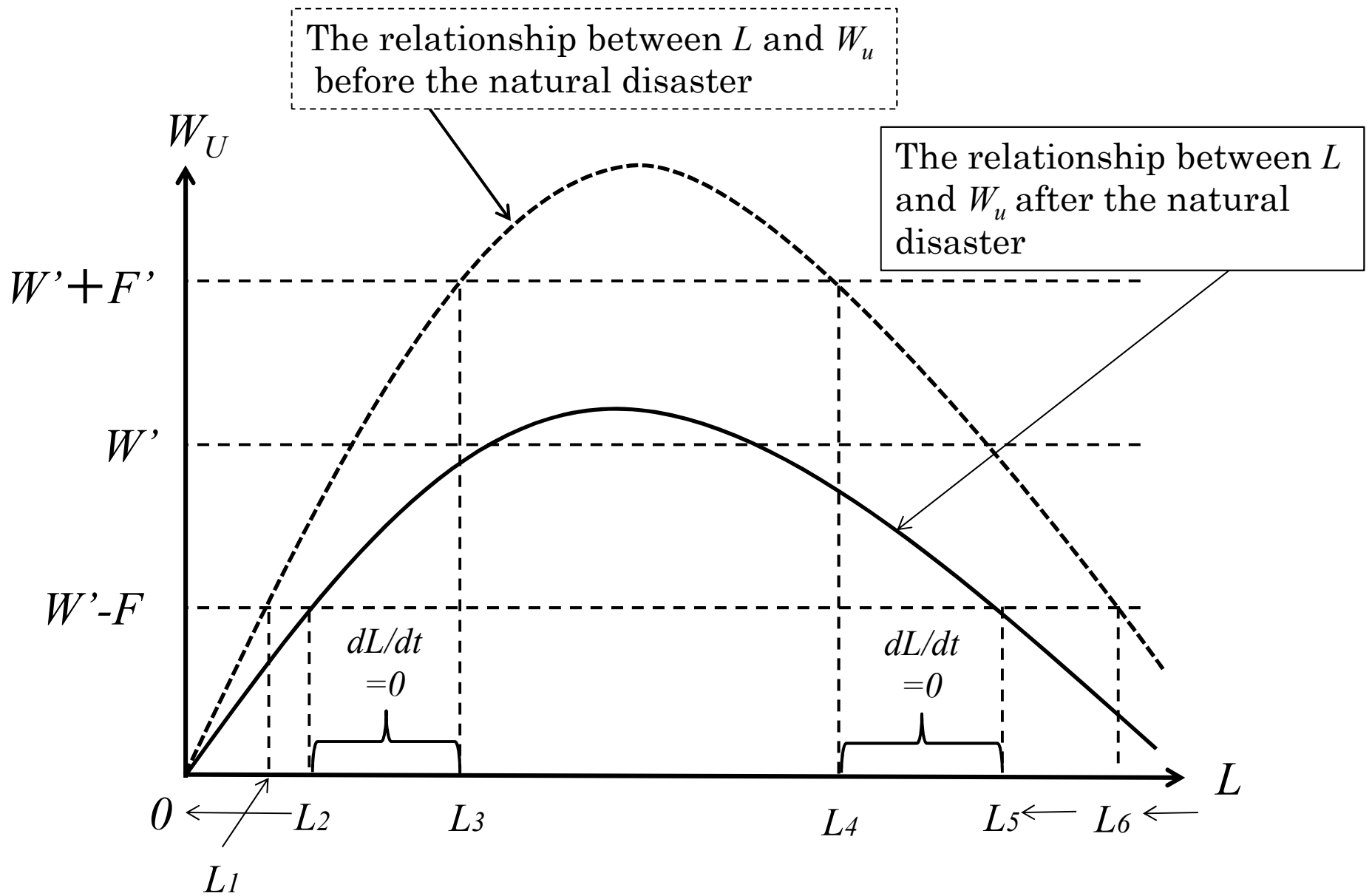


Figure 5: The relationship between L and W_u after the natural disaster when utility includes regional loyalties

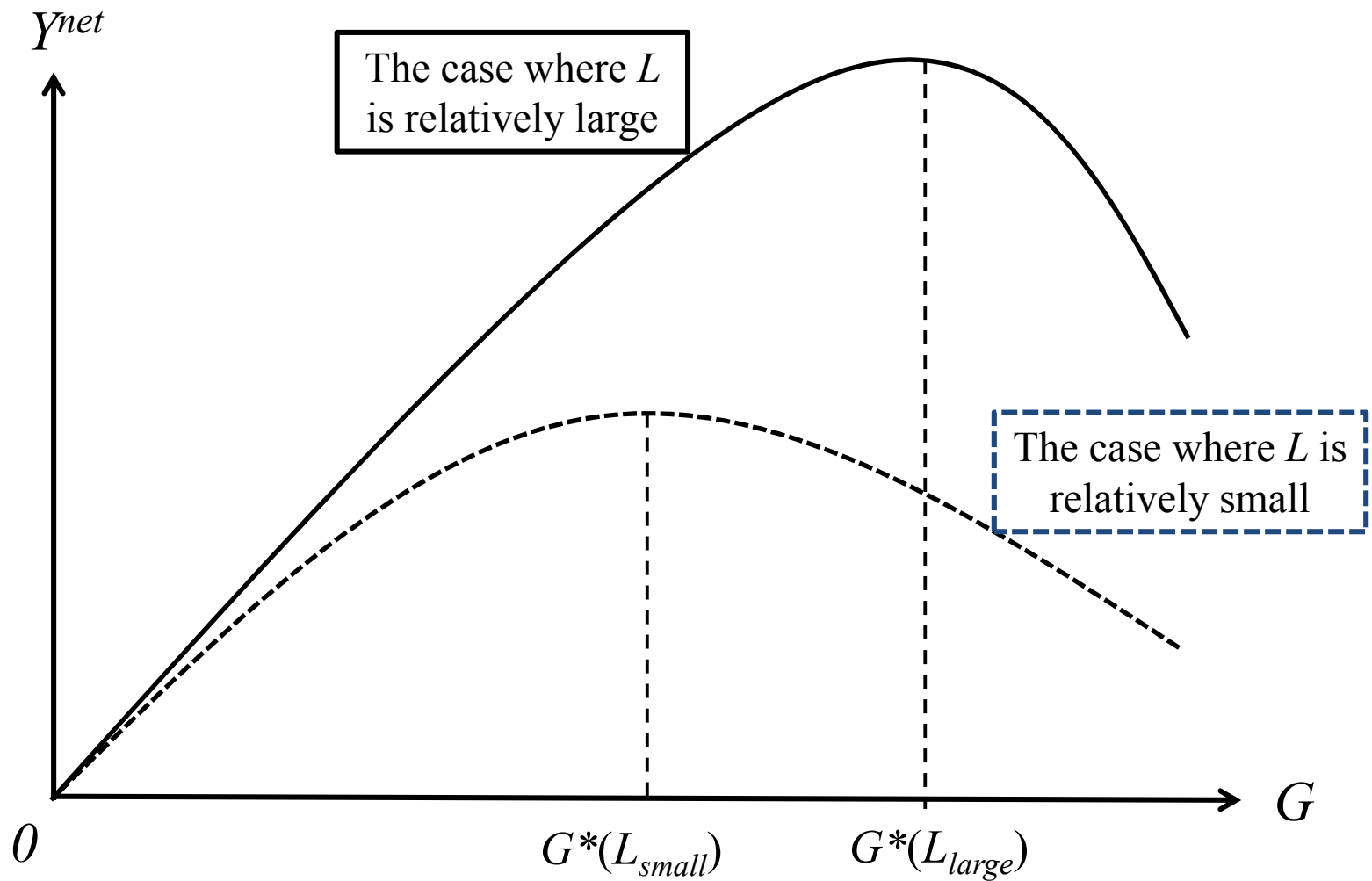


Figure 6: The relationship between G and Y_{net}