# Population Outflow from Earthquake-Stricken Areas and Resident-led Reconstruction: A Theoretical Analysis

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# Population Outflow from Earthquake-Stricken Areas and Resident-led Reconstruction: A Theoretical Analysis

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**Abstract**

We build a cultural transmission model to consider an effective measure for mitigating population outflow from areas affected by the Great East Japan Earthquake. In an economy with firms and two heterogeneous agents (residents *within* earthquake stricken areas and *around* these areas), when the stable interior steady state exists in our system, first we analyze how subsidies to firms affect the steady state population share for residents in earthquake stricken areas. Depending on conditions, the policy may either succeed (an increase in the population share compared to the case with no policy) or fail (a decrease in the share). Second, even if the subsidy policy fails, resident-led reconstruction efforts could potentially increase the steady state population share for residents when subsidy is simultaneously given. From the analysis, we find that resident-led reconstruction efforts can be an effective measure to mitigate the population outflow in earthquake stricken areas.

**Keywords:** Great East Japan Earthquake, migration, cultural transmission

**JEL Classification: O15, O18, Z1**

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## 1 Introduction

The Great East Japan Earthquake on March 11, 2011 had a tremendous impact on the economy of Japan. Among the various problems caused by the earthquake, in this paper we will focus on population outflow from earthquake stricken areas.[1] Population outflow from the earthquake stricken areas leads to a decrease in number of persons engaged in recovery in the affected areas. Accordingly, it can be argued that population outflow itself is an important issue in the recovery. The progress of such an undesirable situation motivates us to address the following question: what is an effective measure to mitigate population outflow.

For considering this issue, it will be useful to examine some precedents such as the Great Hanshin-Awaji Earthquake of 1995. At that time, reconstruction efforts in which the government took the initiative played an important role. In the context of the issue of population outflow, subsequent studies clarify that reconstruction efforts led by the government as a measure to mitigate the population outflow have limitations (Iwasaki et al. (1999), Tanaka and Shiozaki (2008), and Harada (2012)).[2]

According to Kohsaka (2012), this is partly because resident participation in reconstruction efforts is neglected. She also points out that ignoring the interests of the residents would result in losing the stable order of a local community at that time. Based on the facts, she stresses on the relevance of reconstruction efforts in which the residents took the initiative (we call it resident-led reconstruction).[3] It is necessary that residents make an effort to find a solution themselves by sharing roles with local governments.

Even though the relevance of resident-led reconstruction has been widely emphasized in the case studies above, it is theoretically not clear how resident-led reconstruction efforts affect the population outflow. In the present paper, we analyze how resident-led reconstruction efforts affect population in earthquake stricken areas, and clarify its relevance as an effective measure to mitigate population outflow.

To investigate the question, we develop a cultural transmission model with firms and two heterogeneous residents. The model developed in this paper is in line with the cultural transmission model by Bisin and Verdier (2001). The cultural transmission model is developed in order to explain the endogenous evolution of individual types. Bisin and Verdier derive the population dynamics of two heterogeneous agents who have their own cultures, where the agents interact through time with each other.[4] Francois and Zabojnik (2005) introduce production into the cultural transmission model by Bisin and Verdier. They consider an economy comprising an entrepreneur and a contractor, assuming each population being unity. There are two types of contractors: trustworthy and opportunist. Francois and Zabojnik consider modern production between an entrepreneur and a contractor, which succeeds only if the entrepreneur cooperates with trust. Trustworthiness in an economy is an important factor because it is seen as a surrogate of social capital in an economy. They clarify an effective measure to increase the steady state population share for trustworthy in an economy.

We consider an economy comprising firms and residents. In addition, two types of heterogeneous agents (people *within* earthquake stricken areas and people *around* these areas) are introduced among the residents. Thus, our model has two types of actors comprising three units, as did Francois and Zabojnik (2005). Further, we employ population dynamics *à la* Francois and Zabojnik in order to capture a process of transition between two regions. There are two differences between our model and that of Francois and Zabojnik (2005). First, our formalization concerning firm's investment before production differs. While Francois and Zabojnik (2005) assume constant, we assume that it is a function of a share of firms. Based on the assumption, resident-led reconstruction can be introduced in our model. Second, our formulation regarding the dynamic equation with respect to shares of firm line differs. While it is increasing in Francois and Zabojnik's model, it is mountain-shaped in ours. Our model analyzes an aspect that Francois and Zabojnik's model cannot focus on.

We explain the subsidies to firms in our model as follows. Setting a target level of firms' share in earthquake stricken areas, the government provides subsidies to firms when a level of firms' share exceeds the target level (see sections 3.1–3.2 for details). According to the degree of the government's eagerness for reconstruction, the amounts of subsidy differ (i.e., more (less) the government's eagerness, more (less) the amount of subsidy). Next, we explain resident-led reconstruction efforts in our model. Like the subsidy, setting a target level of firms, people in earthquake stricken areas cooperate with each other when the level of firms exceeds the target level (see equation (27)). Because of this cooperation, they can obtain profits, compared to a situation without cooperative behavior. According to the degree of their eagerness for cooperation, the amount of profits they obtain differs (i.e., more (less) the eagerness, more (less) the amount of profits). In particular, if the degree of residents' eagerness for cooperation is suffciently larger than the government's eagerness, we refer to such cooperative behavior as resident-led reconstruction.

In our analysis, when the stable interior steady state exists in our system, we analyze how the policy affects the steady state population share for residents in earthquake stricken areas. The following results are obtained by the analysis. First, depending on whether the steady state firms' share is above or below the threshold of firms share, effects of subsidies on steady state share of residents in earthquake stricken areas largely differ. If the steady state firms' share is above the threshold, subsidies to firms will lead to success in that there will be an increase in steady state population share for residents in the earthquake stricken areas (Subsection 4.2). On the other hand, if it is below the threshold, the policy will fail (Subsection 4.3). This implies that population share for residents in earthquake stricken areas will become zero in the long-run. This suggests that only subsidies to firms, as a part of government-led policy, may have limitations to mitigate population outflow. Second, we analyze how resident-led reconstruction efforts, along with simultaneous subsidies, affect steady state population share for residents in earthquake stricken areas. The following remarkable finding is observed: even if the subsidy policy fails (like in the case examined in Subsection 4.3), resident-led reconstruction efforts can increase the steady state population share for residents in earthquake stricken areas (subsection 5.2). This finding suggests that resident-led reconstruction efforts, simultaneously with subsidies, can be an effective measure to mitigate population outflow.

The rest of the paper is organized as follows. Section 2 provides our model. Section 3 clarifies the conditions under which the stable interior steady state exists. Section 4 analyzes the effect of subsidies on the steady state population share for residents in earthquake stricken areas. Section 5 analyzes the effect of resident-led reconstruction efforts, simultaneously along with subsidies, on the steady state population share for residents in earthquake stricken areas. Section 6 concludes this paper.

## 2 The model

### 2.1 Production

We consider an economy with firms and two heterogeneous residents (people *within* earthquake stricken areas and people *around* these areas, hereafter also referred to as S-type and A-type, respectively). Firms decide on whether to engage in a cooperative production for reconstruction or not according to the profit maximizing principle. We assume that a firm cannot observe resident types, that is, S-type or A-type, in advance. For this reason, a firm that decides to engage in cooperative production meets every resident, and each time gives a random proposal on cooperative production to them. Only when a resident accepts the firm's proposal, cooperative production will be implemented. In the following analysis, we normalize both the total number of firms and the total number of residents as unity.

At time $t$, marginal profit that is generated from each cooperative production is denoted as $\pi(p_t)$, where $p_t \in [0, 1]$ is the share of firms that are involved in cooperative production at time $t$.[5] We assume that a function $\pi(\cdot)$ is continuous, $\pi(0)$ is finite valued, and $\pi'(p) < 0$, $\pi''(p) < 0$. The condition $\pi'(p) < 0$ is assumed in order to capture a decrease in marginal profits generated from cooperative production as the number of firms increase.

Marginal profits from cooperative production $\pi(p)$ is distributed between a firm and a resident according to the following: the firm's share and the resident's share are $\alpha\pi(p)$ and $(1 - \alpha)\pi(p)$, respectively, where $\alpha$ is a parameter in $(0, 1)$.

## 2.2 Firm

Let $\beta_t \in [0, 1]$ be the share of S-type at time $t$. In the case where a firm meets S-type with probability $\beta$, as a result of cooperative production, a firm obtains a share of marginal profits $\alpha\pi(p)$. Let $k(p)$ be a marginal amount of investment by a firm in earthquake stricken areas *before* cooperative production can occur. We assume that $k'(p) < 0$, $k''(p) < 0$. The condition $k'(p) < 0$ is assumed in order to capture the expectation that efforts by a firm before production become smaller as firms increase (scale effects). Thus, a firm obtains a net marginal profit from cooperative production $\alpha\pi(p) - k(p)$ with probability $\beta$. In the case where a firm meets A-type with probability $1-\beta$, the firm does not expect realization of cooperative production with the resident since there is no need of support for reconstruction. In this case, instead of engaging in cooperative production, a firm would do other activities such as sightseeing, which costs marginally $b$. That is, a firm bears a marginal expense $b$ with probability $1-\beta$. From these, a firm's expected net marginal profit is given by $E[p, \beta] := \alpha\beta\pi(p) - [\beta k(p)$

$+ (1-\beta)b]$. We assume that a decision to enter or exit by a firm depends on the sign of $E[\cdot]$. The number of firms increases in case where $E[\cdot]$ is positive, and vice versa. When the sign of $E[\cdot]$ is zero,

$$\alpha\beta\pi(p) - [\beta k(p) + (1-\beta)b] = 0, \tag{1}$$

nobody enters or exits. By arranging equation (1) with respect to $\beta$, we obtain

$$\beta = \frac{b}{\alpha\pi(p) - k(p) + b} = 1 - \frac{\alpha\pi(p) - k(p)}{\alpha\pi(p) - k(p) + b}. \tag{2}$$

Equation (2) is line $\dot{p} = 0$ in the $(p, \beta)$ space, which is employed in the following analysis.

Now, we assume the following in order to facilitate our analysis:

**Assumption 1.**

$$\alpha\pi(p) - k(p) > 0, \ \forall p \in [0, 1]. \tag{3}$$

Assumption 1 implies that a net marginal profit from each cooperative production is always positive. From Assumption 1, the right hand side of equation (2) is always in (0, 1). In the following analysis, we assume that $p$ is a jump variable, that is, for a given $\beta$, $p$ satisfying equation (2) is immediately determined.

### 2.3 Two types of residents

First, we formalize the utility function for S-type. In earthquake stricken areas, they need active support for reconstruction. Accordingly, S-type would accept a proposal from a firm for cooperative production. As a result of cooperative production, they receive a share of marginal profits $(1-\alpha)\pi(p)$. They also obtain a non-pecuniary reward $\gamma > 0$ through cooperative production, where $\gamma$ represents the non-pecuniary fulfillment involved in active engagement in reconstruction of their hometown. In addition, they obtain $k(p)$, which is a marginal profit obtained other than the production itself. Lastly, it costs $F > 0$ to remain in the earthquake stricken areas. From these, we assume the utility function for S-type as follows:

$$u^S(p) = x\,[(1-\alpha)\pi(p) + \gamma + k(p)] - F, \tag{4}$$

where $x$ is a characteristic function whose value is unity in the case of cooperative production, otherwise zero. The expected utility for S-type is given by

$$\bar{u}^S(p) = p\,[(1-\alpha)\pi(p) + \gamma + k(p)] - F. \tag{5}$$

Next, we formalize the utility function for A-type. People around the affected areas can normally lead their daily lives because the damages are not so serious compared with the situation in the earthquake stricken areas. Their decision to engage in cooperative production for reconstruction is based on their utility maximizing behaviors. Their decision is based on the corresponding utilities for each action, where these utilities are assumed to be evaluated solely based on their pecuniary considerations. If the utility associated with cooperative production is higher than the other activity, they will engage in cooperative production, and vice versa. From these, we assume the utility function for A-type as follows:

$$u^A(p) = x \max\{(1-\alpha)\pi(p), b\}, \tag{6}$$

where from A-type's points of view $b$ can be seen as marginal gains obtained from an economic activity other than participation in cooperative production. The expected utility for A-type is given by:

$$\bar{u}^A(p) = p \max\{(1-\alpha)\pi(p), b\}. \tag{7}$$

We assume that the following relationship holds:

$$(1-\alpha)\pi(p) < b. \tag{8}$$

Equation (8) implies that the share of marginal profits from cooperative production in earthquake stricken areas is always lower than marginal gains from economic activities in relatively less-damaged areas. Equation (8) implies that A-type does not always participate in cooperative production. Thus, the expected utility is $pb$ from equation (7).

### 2.4 Population dynamics

In this subsection, we formalize the dynamics of population share for residents in the earthquake stricken areas. Let $d^S$ denote the probability that a person in an earthquake stricken area remains there. Thus, a probability that he moves to another area is given by $1-d^S$. We can interpret $d^S$ and $1-d^S$ as probabilities that he *himself* decides to either stay or migrate, respectively. Then, the probability that a person stays in an earthquake stricken area *against his will* is given by $(1-d^S)\beta_t$. Let $P_t^{SS}$ be a transition probability that a person in an earthquake stricken area at time $t$ remains there at the next time. Then, we obtain $P_t^{SS} = d^S + (1-d^S)\beta_t$. On the other hand, let $P_t^{SA}$ be a transition probability that a person in an earthquake stricken area at time $t$ moves to other area at the next time. Then, we obtain $P_t^{SA} = (1-d^S)(1-\beta_t)$. Likewise, $P_t^{AA}$ and $P_t^{AS}$ can be obtained. Then, we obtain the following:

$$P_t^{SS} = d^S + (1-d^S)\beta_t, \tag{9}$$

$$P_t^{SA} = (1-d^S)(1-\beta_t), \tag{10}$$

$$P_t^{AS} = (1-d^A)\beta_t, \tag{11}$$

$$P_t^{AA} = d^A + (1-d^A)(1-\beta_t), \tag{12}$$

The population share in earthquake stricken areas at time $t + 1$ is given by

$$\beta_{t+1} = \beta_t P^{SS} + (1 - \beta_t)P^{AS}. \tag{13}$$

By substituting equations (9) and (11) into equation (13), we obtain

$$\beta_{t+1} - \beta_t = \beta_t (1 - \beta_t)(d^S - d^A). \tag{14}$$

In the following analysis, in place of equation (14), we will employ the following differential equation.

$$\dot{\beta} = \beta(1 - \beta)(d^S - d^A). \tag{15}$$

According to the right-hand side of equation (15), the population dynamics of residents in earthquake stricken areas depend on the sign of the difference $d^S - d^A$. Following Francois and Zabojnik (2005), we assume that the difference $d^S - d^A$ is an endogenous variable, which depends on the difference of excess utilities for each type.

The excess utilities for S-type and A-type are given by

$$\Delta^S := \bar{u}_t^S - \bar{u}_t^A = p_t [(1 - \alpha)\pi(p_t) + k(p_t) + \gamma - b] - F, \tag{16}$$

$$\Delta^A := \bar{u}_t^A - \bar{u}_t^S = p_t [b - (1 - \alpha)\pi(p_t) - k(p_t)] + F, \tag{17}$$

respectively. Note that $\bar{u}_t^A$ in equation (16) would be evaluated from the perspective of S-type if he or she were put in the A-type position. Likewise, note that $\bar{u}_t^S$ in equation (17) would be evaluated from the perspective of A-type if he or she were put in the S-type position. The difference in both equations (16) and (17) is just a non-pecuniary fulfillment $\gamma$. Equation (16) has a $\gamma$ due to evaluation of the S-type. On the contrary, $\gamma$ is not contained in equation (17) because of evaluation of the A-type.

It is reasonable to say that the probability that a person continues to remain in an earthquake stricken area will rise if the utility associated with staying in the affected areas is higher than the utility associated with moving to another area. Accordingly, let us assume that $d^S$ is an increasing function of the difference of excess utilities $\Delta^S$. Likewise, we also assume that $d^A$ is an increasing function of $\Delta^A$. Therefore, $d^S - d^A$ depends on $\Delta^S - \Delta^A$ . Without loss of generality, the difference of the excess utilities for each type can be represented as $p_t\,[(1-\alpha)\pi(p_t)+k(p_t)+\gamma-b]-F$. From this, $d^S - d^A$ can be given as

$$d^S - d^A = \Phi\,(p\,[(1-\alpha)\pi(p)+\gamma+k(p)-b]-F)\,, \tag{18}$$

where $\Phi : \mathrm{R} \rightarrow [-1, 1]$ is a continuous map satisfying $\Phi(0) = 0$, $\Phi'(\cdot) > 0$. By substituting equation (18) into equation (15), we obtain

$$\dot{\beta} = \beta(1-\beta)\Phi\,(p\,[(1-\alpha)\pi(p)+\gamma+k(p)-b]-F)\,. \tag{19}$$

## 3 Steady states

### 3.1 The $\dot{\beta} = 0$ line

In this section, we clarify characteristics of the steady state equilibrium given by differential equations (2) and (19). First, from equation (19), we have $\dot{\beta} = 0$ for the relation $\phi\,(p) = 0$, [6] where

$$\phi\,(p) := p[(1-\alpha)\pi(p)+\gamma+k(p)-b]-F. \tag{20}$$

In order to identify $p$ satisfying $\phi\,(p) = 0$, we analyze the shape of the function $\phi$ . The first derivative of $\phi$ with respect to $p$ is given by [7]

$$\phi\,'(p) = (1-\alpha)\pi(p)+k(p)+\gamma-b+p\,[(1-\alpha)\pi'(p)+k'(p)]\,. \tag{21}$$

The sign of $\phi'(p)$ is undetermined for any $p \in (0, 1)$ because the first three terms in the right hand side of equation (21) are positive and the last three negative. Now, we assume the following condition:

**Assumption 2.**

$$(1-\alpha)\pi(1) - k(1) < b - \gamma < (1-\alpha)\pi(0) - k(0). \quad (22)$$

Assumption 2 is the necessary condition for the interior steady state to exist. Under this assumption, we find the steady state in our model.

Equation (21) leads to the relation $\phi'(0) > 0 > \phi'(1)$ from Assumption 2. The second derivative of $\phi$ with respect to $p$ is given by

$$\phi''(p) = 2\,[(1-\alpha)\pi'(p) + k'(p)] + p\,[(1-\alpha)\pi''(p) + \mathrm{k}''(p)]\,. \quad (23)$$

Since $\pi'$, $\pi''$, $k'$, $k'' < 0$, $\phi''(p)$ is negative. From these, for a suffciently small number $\varepsilon > 0$, $\phi(p)$ is increasing for $p \in (0, \varepsilon)$ and $\phi(p)$ is decreasing for $p \in (1-\varepsilon, 1)$. Accordingly, a function $\phi$ is mountain-shaped.

Since a function $\phi$ does not depend on $\beta$ (see equation (20)), line $\dot{\beta} = 0$ consists of two vertical lines parallel to the $\beta$ axis. Figure 1 shows the lines $\dot{\beta} = 0$ in the first quadrant of the $(p, \beta)$ space, where one passes the point $p^A$ and the other $p^B$.

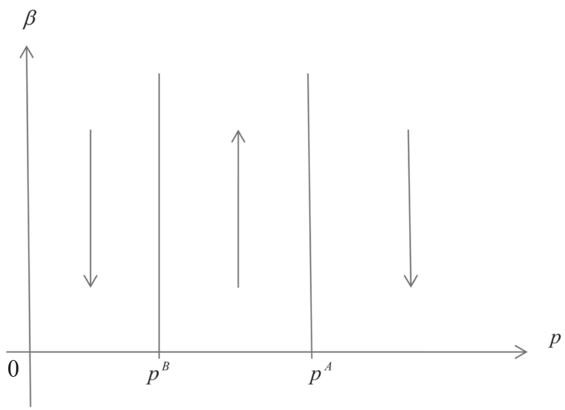


Fig.1 the $\dot{\beta} = 0$ lines

### 3.2 The $\dot{p} = 0$ line

Second, the shape of line $\dot{p}$ = 0 (see equation (2)) depends on the shape of a net marginal profit from cooperative production $\alpha\pi(p) - k(p)$. For simplicity, we assume the following condition:

**Assumption 3.**

There exists a $\hat{p} = \arg\min_{p \in (0,1)} \alpha\pi(p) - k(p)$ satisfying the following:

$$\text{If } 0 < p < \hat{p} \text{ (resp. } \hat{p} < p < 1\text{), then } \alpha\pi'(p) - k'(p) < 0 \text{ (resp. } \alpha\pi'(p) - k'(p) > 0\text{).} \quad (24)$$

Under Assumption 3, the shape of $\alpha\pi(p) - k(p)$ is single-deeped, and accordingly the shape of the $\dot{p} = 0$ line is single-peaked.

Figure 2 shows the line $\dot{p} = 0$ in the first quadrant of the $(p, \beta)$ space.

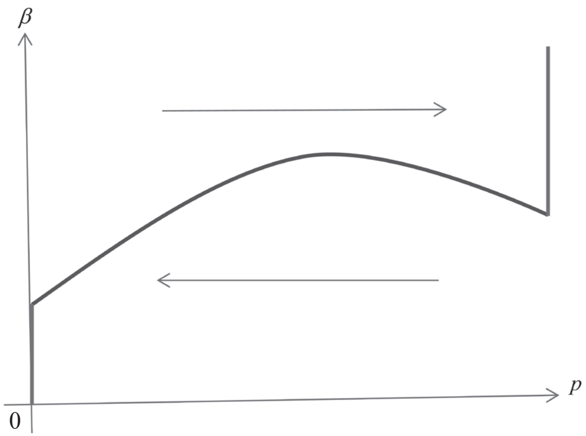


Fig.2 the $\dot{p} = 0$ line

As shown by the phase diagrams below (Figures 3, 4, and 5), the number of the stable steady states differs based on whether $\hat{p}$ is more or less than $p^A$.

### 3.3 Case (I): $\hat{p} \geq p^A$

First, we consider the case where $\hat{p} \geq p^A$ . In this case, as we see below, the stable steady states are the interior solution ($p^A$ , $\beta^A$) and the origin (0, 0). Moreover, we classify the case into two subcases (i.e., $\beta(1) \geq \beta^B$ and $\beta(1) < \beta^B$). The reason for this classification is that depending on the presence of $\beta(1)$ above or below $\beta^B$, the set of initial values in the ($p, \beta$) space convergent to the ($p^A$ , $\beta^A$) differs.

#### 3.3.1 Subcase (I)-(i): $\beta(1) \geq \beta^B$

Figure 3 shows the phase diagram in the case where $\beta(1) \geq \beta^B$.

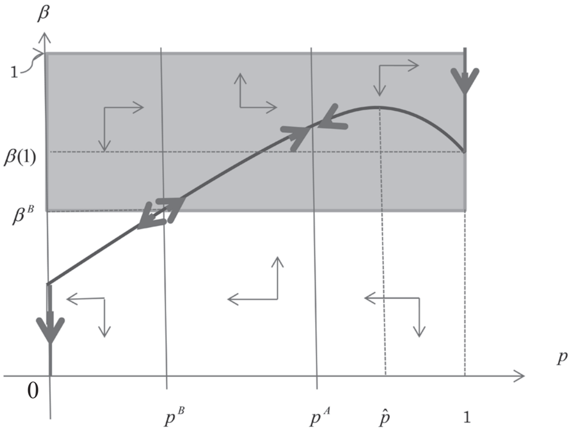

Fig.3 Phase diagram in case of $\hat{p} \geq p^A$ and $\beta(1) \geq \beta^B$

Recall that the adjustments of firms are conducted instantaneously since $p$ is a jump variable, whereas the adjustments of the residents change gradually. In other words, adjustment in the horizontal direction is immediate, and subsequently, adjustment in a $\beta$ is conducted along the $\dot{p} = 0$ line. Then, we find that ( $p^A$ , $\beta^A$ ) and (0,0) are stable. Any initial value such that $\beta > \beta^B$ will lead to convergence on ( $p^A$ , $\beta^A$ ). Conversely, any initial value such that $\beta < \beta^B$ will lead to convergence on (0,0). The shaded area in Figure 3 is the set of the initial values convergent to ( $p^A$ , $\beta^A$ ). Note that ( $p^B$, $\beta^B$) is unstable.

### 3.3.2 Subcase (I)-(ii): $\beta(1) < \beta^B$

Figure 4 shows the phase diagram in the case where $\beta(1) < \beta^B$.

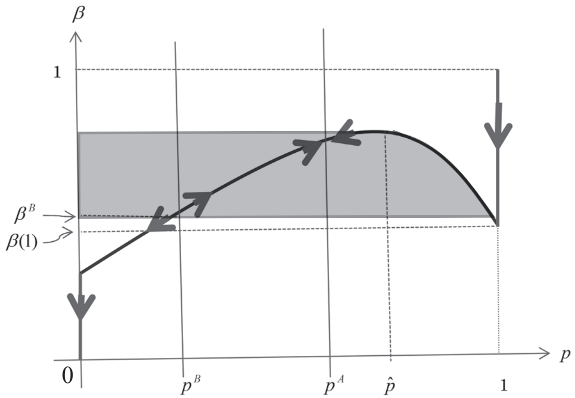


Fig.4 Phase diagram in case of $\hat{p} \geq p^A$ and $\beta(1) < \beta^B$

The stable steady states are ( $p^A$, $\beta^A$ ) and (0,0). Unlike the previous case, the set of initial values convergent to the ( $p^A$, $\beta^A$ ) are limited to the shaded area in Figure 4.

### 3.4 Case (II): $\hat{p} < p^A$

Figure 5 shows the phase diagram in the case where $\hat{p} < p^A$. In this case, the stable steady state is just the origin (0, 0). Any point in the ( $p$, $\beta$) space converges to (0, 0).

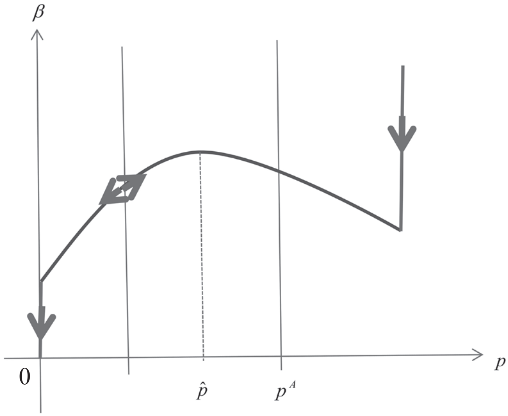


Fig.5 Phase diagram in case of $\hat{p} < p^A$

# 4 Subsidy

## 4.1 Subsidies to firms

We consider subsidy to firms as a reconstruction effort adopted by the government in order to hinder a decrease in marginal profit of residents accompanied by an increase in firms. Specifically, setting a target level of firms' share in the earthquake stricken areas, the government provides subsidies to firms when a level of firms' share exceeds the target level. A marginal profit function for cooperative production in which the policy is incorporated is given by

$$\begin{cases} \pi(p) \text{ if } p < \tilde{p}, \\ \tau_1 \pi(\tilde{p}) + (1 - \tau_1)\pi(p) \text{ if } p \geq \tilde{p}. \end{cases} \tag{25}$$

A $\tilde{p} \in [0, 1]$ represents the target level, which can be interpreted as the timing of the government's intervention. A $\tau_1 \in (0, 1]$ represents a proxy parameter of how actively the government provides firms with subsidies, which can be interpreted as the degree of the government's eagerness for reconstruction efforts.

In the case where the stable interior steady state exists before the policy, which is denoted as ( $p_0^A$ , $\beta_0^A$ ), we analyze how the policy affects the steady state population share for S-type. To begin with, we define a function $\phi$ associated with the case of $\tau_0$ (i.e., no subsidy) as $\phi_0$ . In the following, we consider the case where $\tilde{p} < p_0^A$ , which means that the policy is conducted at a relatively early stage compared to the share of firms in earthquake stricken areas in a steady state associated with no subsidy. [8] $\phi$ and $\phi_0$ are represented in Figure 6.

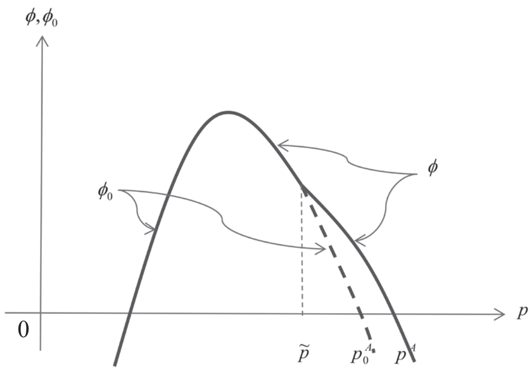


Fig.6 Functions $\phi$ and $\phi_0$

For $p > \tilde{p}$, the difference between $\phi(p)$ and $\phi_0(p)$ is given by

$$\psi(p) := \phi(p) - \phi_0(p) = p\,[(1-\alpha)\tau_1\,(\pi(\tilde{p}) - \pi(p)) + k(p)]\,. \tag{26}$$

Since $\pi$ is a decreasing function of $p$, $\pi(\tilde{p}) - \pi(p)$ is positive, and accordingly, $\psi(p) > 0$. Thus, the relation $p_0^A < p^A$ holds.

From this, we obtain the following.

**Proposition 1.** If $\tilde{p} < p_0^A$, then line $\dot{\beta} = 0$ moves rightward after the policy intervention.

Figure 7 shows a shift in line $\dot{\beta} = 0$ in this case.

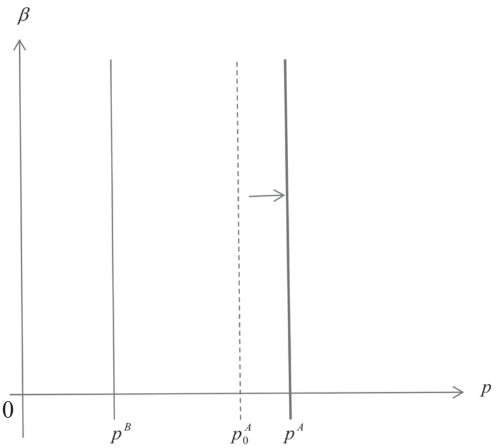


Fig.7 Rightward shift in the $\dot{\beta} = 0$ line associated with $p_0^A$

Note that the $\dot{p}$ = 0 line simultaneously shifts with a shift in $\dot{\beta}$ = 0. Moreover, the $\dot{p}$ = 0 line defined over $p \geq \tilde{p}$ shifts downward. Thus, a variation in $\beta$ corresponding to the steady state, which is realized after the policy intervention, depends on the effects of the relative positions between lines $\dot{\beta}$ = 0 and $\dot{p}$ = 0.

## 4.2 Success

We consider the case where $p^A \leq \hat{p}$. In the case, $\beta_0^A < \beta^A$ holds.

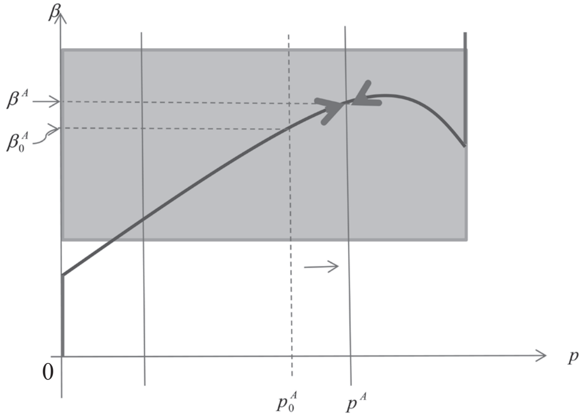


Fig.8 Success (case(I)-(i))

### 4.3 Failure

Conversely, we consider the case where $p^A > \hat{p}$. In subcase (I)-(i), if we take an initial value arbitrarily in the shaded area in Figure 3, a cycle occurs. In subcase (I)-(ii), an arbitrary initial value in the shaded area in Figure 4 converges to (0, 0).

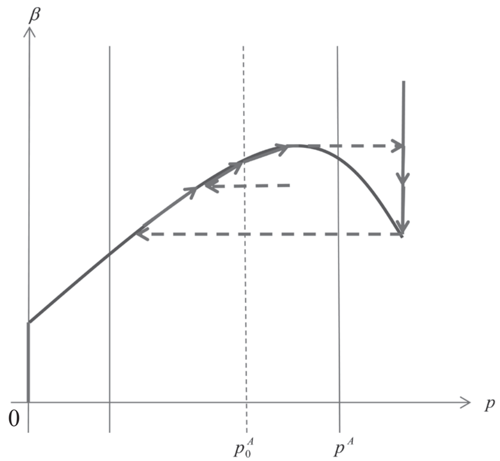


Fig.9 Failure (case (I)-(ii)) : occurrence of cycle

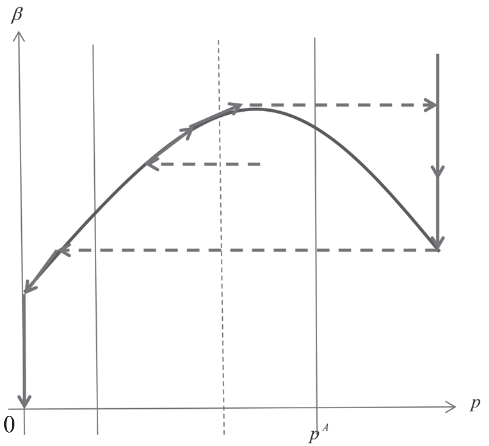


Fig.10 Failure (case (II)) : converge to (0,0)

# 5 Resident-led reconstruction

## 5.1 Resident-led reconstruction

As we saw in the previous section, subsidy to a firm, which is a policy led by the government, can succeed by causing an increase in $\beta$ (Subsection 4.2). On the other hand, it can fail as well (Subsection 4.3). This suggests that sole reliance on the subsidy policy may have limitations in mitigating population outflow. Under what conditions could such a consequence be avoided?

In this section, we analyze how what we call resident-led reconstruction efforts affect the steady state population share for S-type when subsidies are simultaneously given to firms. Recall that $k(p)$ is a marginal amount of investment by a firm in the earthquake stricken areas *before* cooperative production. In other words, it can be viewed as a marginal profit for S-type. Since the residents' marginal profits decrease as firms increase, by the assumption that $k(p)$ is a decreasing function of $p$, S-type would have an incentive to undertake measures to hinder a decrease in their marginal profits.

Under these circumstances, each S-type would share mutual interests. Therefore, we consider cooperative behavior for S-type. Likewise, in case of the subsidy policy (Subsection 4.1), setting a target level of firms, S-type are unified when the level of firms exceeds the target level. A marginal profit function for the residents in which such behaviors for S-type are incorporated is given by

$$\begin{cases} k(p) \text{ if } p < \tilde{p}, \\ (1+\tau_2)k(p) \text{ if } p \geq \tilde{p}, \end{cases} \tag{27}$$

where $\tau_2 \in (0, 1]$ is a proxy parameter, which refers to the degree of eagerness of S-types for cooperation. In the following, to facilitate our analysis, we assume that the timing for residents' cooperative behaviors is equal to the government's intervention timing $\tilde{p}$.

By substituting equations (25) and (27) in equation (2), we obtain the following:

$$\beta = \begin{cases} \frac{b}{\alpha\pi(p)-k(p)+b} \text{ if } p \leq \tilde{p}, \\ \frac{b}{\alpha\pi(p)-k(p)+b+\alpha\tau_1\left[\tilde{\pi}-\pi(p)\right]-\tau_2 k(p)} \text{ if } p > \tilde{p}. \end{cases} \tag{28}$$

We define resident-led reconstruction efforts based on the relative magnitudes of two parameters $\tau_1$ , $\tau_2$ as follows.

**Definition 1** If $\tau_1, \tau_2$ satisfy the condition

$$\frac{\tau_2}{\tau_1} > \alpha \cdot \max_{p\in[\tilde{p},1]}\left[\frac{\tilde{\pi}-\pi(p)}{k(p)}\right], \tag{29}$$

then we call this situation "a resident-led reconstruction."

If $\tau_2$ is suffciently larger than $\tau_1$ , in other words, the degree of residents' eagerness for cooperative behavior is suffciently higher than government's eagerness for reconstruction efforts, then reconstruction efforts are resident-led. From Assumption

1 and equation (29), for $p > \tilde{p}$, the line $\dot{p} = 0$, associated with post-government intervention, is always located *above* the one associated with pre-government intervention. From this, we obtain the following proposition.

**Proposition 2** If reconstruction efforts are resident-led, policy measures cause line $\dot{p} = 0$ to shift upward.

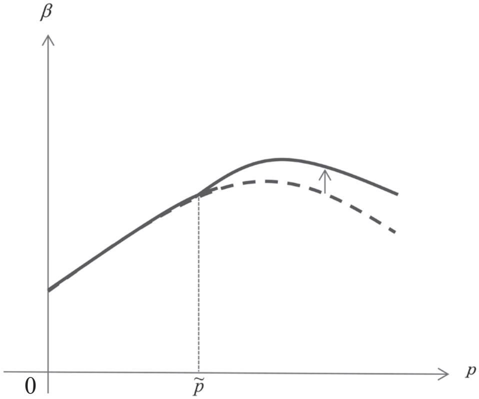

Fig.11 Upward shift in the $\dot{p} = 0$ line

### 5.2 Success

We again consider the case of subsection 4.3 (i.e., $\hat{p} < p^A$). As shown in Figure 12, if the relation $p^A < \hat{p}$ holds under resident-led reconstruction efforts, ( $p^A$, $\beta^{A*}$) is the stable steady state. Any initial value in the shaded area in Figure 12 will lead to ( $p^A$, $\beta^{A*}$). This suggests that resident-led efforts can cause an increase in the population share for S-type (i.e., $\beta_0 < \beta^{A*}$) even if the subsidy policy fails.

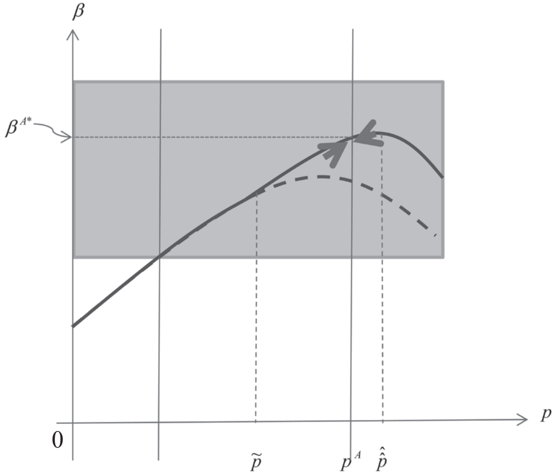


Fig.12 Success in residents led reconstruction efforts

# 6 Concluding Remarks

In this paper, we have developed a cultural transmission model with firms and two heterogeneous agents. By analyzing how resident-led reconstruction efforts, combined with subsidy, affect the resident population in earthquake stricken areas, we clarify its relevance as an effective measure to mitigate population outflow.

The results from the analysis in sections 4 and 5 are summarized in Table 1.

| Sec.4 | | Sec.5 | |
|---|---|---|---|
| Subsidy($\tau_1 > 0$) | | Subsidy and R.-led efforts ($\tau_1 > 0, \tau_2 > 0$) | |
| | $\beta$ | | $\beta$ |
| $p^A < \hat{p}$ | ↑ | $p^A < \hat{\hat{p}}$ | ↑ |
| $\hat{p} < p^A$ | * | $\hat{\hat{p}} < p^A$ | * |

* : occurrence of cycle or convergent to (0,0).

Table 1 Changes in $\beta$

The symbol “↑” means that the steady state population share for S-type, which is realized after the policy becomes larger compared to the share before the policy. The asterisk symbol “＊” means that any initial value in the $(p, \beta)$ space is convergent to (0,0), or occurs as a cycle. In this sense, the symbols “↑” and “＊” correspond to the cases of success and failure, respectively. In section 4, when the subsidy policy leads to the relation $p^A < \hat{p}$, any initial value in the shaded area (Fig. 8) is convergent to $(p^A, \beta^A)$ $(> (p_0^A, \beta_0^A))$. In section 5, resident-led reconstruction efforts combined with the subsidy lead to the relation $p^A < \hat{p}$, and any initial value in the shaded area (Fig. 12) is convergent to $(p^A, \beta^{A*})$. Note that $\beta^{A*} > \beta^A$. From our analysis, resident-led reconstruction efforts can enhance the effects of subsidies to firms on the population outflow. Thus, it can be said that our findings theoretically support the relevance of resident-led reconstruction efforts.

Finally, we note the following two points. First, resident-led reconstruction effort by itself has limited effects on population outflow compared to the effects of a mixed policy (i.e., the combination of resident-led reconstruction effort and subsidies). Thus, resident-led reconstruction efforts also require collaboration with government-led policies in order to become effective measures to alleviate the population outflow. The second point is concerning our definition of resident-led reconstruction efforts. In our model, based on the relative magnitudes of the two parameters $\tau_1$, $\tau_2$, it is formalized briefly. We consider that our definition can be made more elaborate by examining various case studies regarding resident-led reconstruction efforts. This aspect will be taken up by us in future research.

## Notes

1 If we look at statistics (Reconstruction Agency, 2012), the first three prefectures in the order of largest number of residents evacuated are Miyagi, Fukushima, and Iwate; the fourth is Yamagata, which is a neighboring prefecture that did not have any earthquake stricken areas. This enables us to observe that most people move to a relatively less-damaged area within the prefecture they live in, or some people evacuate to a neighboring prefecture such as Yamagata.

2 Harada (2012) points out the case of Nagata ward, Kobe as an example of government-led reconstruction efforts. Although new buildings were built, redevelopment of areas resulted in a decrease in population in the Nagata ward.—Iwasaki et al. (1999) and Tanaka and Shiozaki (2008) conducted follow-up investigations regarding subsequent population movements in Takatori-east district and Osuga- west district, both belonging to Nagata-ward, respectively. According to their studies, the percentage of people who returned to their original residential areas to those who migrated after the earthquake is no more than 20%–30%.

3 See also Niisato and Hashimoto (2014).

4 Since Bisin and Verdier (2001), a line of research has developed. The methodology has been applied to closely related issues. Important theoretical contributions have been made by Hauk and Saez-Marti (2002), Tabellini (2008), Guiso et al. (2008), Bisin et al. (2009), Calabuig and Olcina (2009), Bidner and Francois (2010), and Hayashi et al. (2011). Bisin and Verdier (2010) provide a comprehensive survey of the theoretical and empirical literature.

5 In the following, we omit a subscript $t$ unless necessary.

6 We also have $\dot{\beta} = 0$ for $\beta = 0, 1$. However, we will exclude the cases in the following because these are inconsistent with the observed facts.

7 Strictly speaking, a function $\phi(p)$ has a kink at $p = \tilde{p}$. Thus, $\phi(p)$ is not differentiable at $p = \tilde{p}$. However, it does not substantially affect the following analysis.

8 We can also consider the case where $\tilde{p}$ is larger than $p_0^A$. In this case, the policy intervention is ineffective because the steady state associated with the post-government intervention is the same as the one corresponding to pre-government intervention. Specifically, $\phi_0(p)$ is given below $p$-axis in Figure 3. Accordingly, $p_0^A$ has no change, and hence, $\dot{\beta} = 0$ has no movements.


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