How Do People Cope with Natural Disasters?
Evidence from the Great Hanshin-Awaji (Kobe) Earthquake in 1995*

by

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Abstract

This paper investigates the coping strategies employed by victims of the Great Hanshin-Awaji (Kobe) earthquake in 1995. Using a unique household data set, we show that households that held a large amount of collateralizable assets before the catastrophe and were free from a binding borrowing constraint were able to maintain their consumption levels by borrowing. In contrast, households subject to a binding borrowing constraint before the disaster were unable to borrow to cope with the losses inflicted by the earthquake. On the other hand, both types of households relied on private transfers, depending on the extent of the damage.

Introduction

In the early hours of January 17, 1995, the Hanshin (Kobe) area of Japan was hit by a major earthquake. Home to more than 4 million people, the area is densely populated and forms part of the second largest industrial cluster in Japan. The earthquake resulted in the loss of more than 6,400 lives, housing property losses exceeding US$60 billion, and capital stock losses of more than US$100 billion. The scale of these losses means that the earthquake was one of the largest economic disasters ever recorded in history (see Table 1; also see Horwich 2000 and Scawthorne et al. 1997).

From an economic point of view, the earthquake can be seen as a large and unexpected exogenous shock to the residents of the area. We exploit this surprise event to investigate the functioning of consumption insurance and the way in which households respond to exogenous shocks.[1] In this paper, we engage in two sets of analysis. First, we examine how household consumption behavior changed in relation to the magnitude of the negative shock caused by the earthquake in the Kobe area. Our analysis shows that even within the same region, households that experienced larger losses were more likely to decrease their consumption than households that experienced smaller losses. This finding is inconsistent with the efficient risk sharing hypothesis which suggests that identical households with the same *ex ante* exposure to a particular risk should have the same *ex post* outcome regardless of the size of the loss.

Second, we explore how households in the affected area coped with the losses caused by the earthquake. At the time of the event, only a small fraction of the households in the area held earthquake insurance and thus people with large losses were forced to rely on other coping mechanisms, including dissaving, borrowing and private/public transfers. Among these coping mechanisms, we focus on the determinants of borrowing and private transfers – two mechanisms which appear to have played a substantial role in providing mutual insurance in the wake of the disaster – and highlight differences between them. As regards borrowing, we assume that all borrowing is collateralized and the amount of borrowing does not exceed net financial worth. We observe a sharp contrast in coping mechanisms between households that had been under a borrowing constraint and those not under a borrowing constraint before the earthquake, regardless of *ex post* credit availability. Households who had held a large amount of collateralizable assets (e.g., equity in a house) and were free from a binding borrowing constraint before the disaster were able to maintain their consumption levels, despite the losses they suffered, by borrowing. In contrast, households that had been under a binding borrowing constraint before the event were unable to borrow to cope with the losses. In other words, the consumption of households that had not been under an *ex ante* borrowing constraint was not severely affected by the disaster but that of households under an *ex ante* constraint was. Interestingly, our results show that in contrast with borrowing, both types of households relied on private transfers, but the likelihood that a household did so depended on the magnitude of the loss suffered.

Our data set allows us to differentiate between a variety of shocks generated by the earthquake and provides us with a clean experimental situation.[2] We examine the relative effectiveness of a variety of risk coping devices against sudden natural disasters. To the best of our knowledge, only a few studies have employed household-level data to investigate the role of borrowing and private transfers as mechanisms to cope with natural disasters.[3]

The remainder of this study is organized as follows. The next section presents the model used for our analysis, while Section 3 provides a brief overview of the data set. Section

4 then presents the findings of our econometric analysis, while Section 5 concludes.

2. Theoretical Framework and Estimation Model

Households employ a variety of formal and informal risk coping mechanisms to deal with a range variety of shocks (Townsend 1987, 1994; Mace 1991; Cochrane 1991; Hayashi et al. 1996; Fafchamps 2003; Fafchamps and Lund 2003; Zhang and Ogaki, 2004). Consumption insurance across households is provided by a variety of market and non-market mechanisms, such as formal insurance markets, credit market transactions (Eswaran and Kotwal 1989),[4] and informal mutual transfers among relatives, friends, and neighbors. In addition, households' risk-coping behavior can be complemented by direct transfers from the government.

One way to investigate the implications of efficient risk sharing is to solve a benevolent social planner's problem by maximizing the weighted sum of people's lifetime utilities given the social resource constraints (Mace 1991). The derived set of allocations has the property that the *ex post* marginal utilities of consumption of households with the same *ex ante* exposure to the risk are identical. As a result, in the case of efficient risk sharing, idiosyncratic income shocks should not affect consumption after aggregate shocks are controlled for. The set of allocations is also derived by solving a household optimization problem with a complete contingent market. However, we should note that a complete set of Arrow-Debreu markets is not necessarily needed to attain full risk sharing. According to the mutualization hypothesis (see, e.g., Cass, Chichilniski, and Wu 1996), we do not need an unrealistically large number of complete contingent claims to attain a complete market. Instead, a combination of mutual insurance and securities contingent on aggregate states supports optimal risk sharing. Braun, Todd, and

Wallace (1999) extend the model developed by Cass, Chichilniski, and Wu (1996) to one with production in which risk is endogenous and beliefs about the aggregate state vary across individuals.

In the model that we use to examine households' mechanisms of coping with the Kobe earthquake, we assume that Japan is a closed economy and earthquakes represent an aggregate risk event from the perspective of the Japanese economy. We also assume that the pool of people with the same *ex ante* exposure to the earthquake risk was limited to those living in the Kobe area. This may be evident from the "hazard" map employed by earthquake insurers. The Japanese government strictly regulates earthquake insurance premiums and there were only four different insurance premiums across Japan. As shown in Figure 1, the Kinki region, which includes the Kobe area in the center, was rated as a "Tier 3" area in terms of earthquake insurance premiums, implying that the risk of earthquake damage was considered to be lower than in the "Tier 4" areas. Moreover, only a small fraction of households in Kobe had earthquake insurance: in December 1994, only 3 percent of the population in Hyogo Prefecture, where Kobe is located, was covered by such insurance.[5] Based on these observations, we believe our assumption that all households in the Kobe area had the same *ex ante* exposure to the event is justified.[6]

Given the situation just described, we first test the mutualization aspect of efficient risk sharing.[7] If we consider two *ex ante* identical households living within the same risk pool in the Kobe area, the consumption of both households should decrease by the same extent, regardless of any differences in the magnitude of the *ex post* realization of the risk because of the aggregate nature of the shock. If the effect of the earthquake on consumption differs depending on the extent of the losses sustained, this implies that the mutualization of the risk prior to the earthquake was imperfect.

However, even in the absence of mechanisms that provide efficient risk sharing, households can insure themselves against unexpected shocks. Following Zeldes (1989) and Ljungqvist and Sargent (2004, Chapter 16), we derive a household optimization model by assuming that a household chooses a path to maximize the conditional expectation of discounted lifetime utility subject to standard intertemporal budget constraints. Suppose a household's utility derived from household consumption c_{it} can be represented by concave instantaneous utility function $u(\bullet)$. Then household i's optimization problem is to choose the c that maximizes the conditional expectation of discounted lifetime utility subject to intertemporal budget constraints:

$$\begin{aligned} &\underset{\{c_{it}\}}{Max}\ E_t \sum_{j=0}^{\tau} \left(\frac{1}{1+\delta} \right)^{t+j} u(c_{it+j}) \\ &s.t.\quad A_{it+1} = (1+r)(A_{it} - L_{it} + y_{it} - c_{it}) \\ &\qquad A_{it} - L_{it} + y_{it} - c_{it} + z_{it} \geq 0, \\ &\qquad z_{it} \leq 0 \\ &\qquad A_{i0}\ given \\ &\qquad A_{iT} \geq 0, \end{aligned} \tag{1}$$

where A is the stock of the household's assets at the beginning of the period, L_{it} is the asset loss caused exogenously and exclusively by the earthquake, r and δ represent the real interest rate and the household's subjective discount rate, both of which are assumed to be constant, and income y_{it} includes labor and other income. We assume that y_{it} is exogenous in that the earthquake shock affects household income exogenously. Also, note that z_{it} refers to the household's borrowing limit.

Before we continue with the presentation of our analytical framework, it is useful to explain the definition of the borrowing constraint used in our analysis. Generally speaking, two borrowing constraints can be distinguished: a collateralized and an uncollateralized one. In the case of the former, net financial worth must be non-negative. In the optimization problem stated above (1), this is a situation where $z \leq 0$. This collateralized borrowing constraint with the condition $z \leq 0$ has also been called an ad hoc borrowing constraint (see Ljungqvist and Sargent 2004, p. 549 and p. 577). In contrast, the uncollateralized borrowing constraint allows borrowing to exceed the market value of current period financial net worth, i.e., $z > 0$. Uncollateralized borrowing includes the case of natural borrowing constraints described by Ljungqvist and Sargent (2004, p. 548 and p. 557) and Aiyagari (1994). Moreover, in the real world, uncollateralized borrowing can occur when a household buys a home with a mortgage and real estate prices decline sharply to the point where the sales value of the home falls below the outstanding loan amount.

In this paper, we adopt the former definition that rules out uncollateralized borrowing. There are theoretical and empirical reasons to exclude the possibility of uncollateralized borrowing. One reason is that we assume in the model that all loans are one period loans. If down payments (collateral) are required for all loans, then lending will be strictly less than net worth and z is strictly negative. The other reason is simply that our data set does not contain any information on the amount of household financial assets and total outstanding loans to distinguish between collateralized and uncollateralized borrowing.

In the estimation below, we classify households into those under a binding ad hoc constraint and those that are not by applying Wakabayashi and Horioka's (2005) estimation results using data collected in "normal" times, i.e., not in the special situation after the Kobe earthquake. The non-negativity of net financial worth implies that all lending is fully collateralized when $z_{it} = 0$. When $z_{it} < 0$, down payments (collateral) are required for all loans and the size of the amount of borrowing is less than a household's current net worth.

Let μ represent the Lagrange multiplier associated with the borrowing constraint $A - L + y - c + z \geq 0$. Combining the envelope condition derived from the first-order conditions, we obtain a consumption Euler equation, which is augmented by the possibility of a borrowing constraint (Zeldes 1989):

$$\begin{aligned} u'(c_{it}) &= E_t\left[u'(c_{it+1})\left(\frac{1+r}{1+\delta}\right)\right] + \mu_{it}, \\ A_{it} - L_{it} + y_{it} + z_{it} &\geq c_{it} \;\; if \;\; \mu_{it} = 0, \\ A_{it} - L_{it} + y_{it} + z_{it} &= c_{it} \;\; if \;\; \mu_{it} > 0. \end{aligned} \tag{2}$$

We can interpret the Lagrange multiplier μ as an indicator of the negative welfare effects generated when a borrowing constraint binds.[8]

If utility takes the form of a constant absolute risk aversion (CARA) function, then equation (2) can be approximately written as the following linearized version (Flavin 1999; Kochar 2003):

$$\Delta c_{it} = \frac{1}{\alpha}\left[\ln\left(\frac{1+r}{1+\delta}\right)\right] - \mu_{it-1} + e_{it}, \tag{3}$$

where Δ is a first-difference operator, e_{it} is a rational expectations error, and μ_{it} is the Lagrange multiplier associated with a borrowing constraint that is standardized by the marginal utility of future consumption.

In what follows, we derive the model's theoretical implications, which are tested in the empirical analysis. As stated, we assume that the borrowing constraint rules out uncollateralized borrowing and thus all lending is collateralized. Since a borrowing constraint is costly for a household, it takes measures to ensure that the constraint does not bind. However, some households face *ex ante* and/or *ex post* borrowing constraints. In terms of borrowing constraints, households experiencing the unexpected event of an earthquake can be classified into three types (Table 2). Conditional on whether a household experienced a housing or income loss, which is assumed to be known at the start of the current period, the relevant initial conditions are whether net financial worth is positive or zero and whether a loss occurs either in terms of housing or income. The availability of borrowing crucially depends on the time path of a household's net financial worth and borrowing constraint. In the following, we denote the point in time that the earthquake takes place as T and the period just prior to the earthquake as T-1.

The first type of households are those that were under a borrowing constraint both in the *ex ante* and the *ex post* period, i.e., $\mu_{i,T-1} > 0$ and $\mu_{iT} > 0$ (Type I in Table 2). In this case, we obtain the following condition, which implies that a household's consumption is always limited by the current resource constraint:

$$\Delta c_{iT} = (A_{iT} - L_{iT}) - A_{i,T-1} + \Delta y_{iT} + (z_{i,T} - z_{i,T-1}) \qquad (4)$$

It is straightforward to show that $A_{iT} = (1+r)(-z_{iT-1})$ by combining two budget constraints, i.e., $A_{iT-1} + y_{iT-1} - c_{iT-1} + z_{iT-1} = 0$ and $A_{iT} = (1+r)(A_{iT-1} + y_{iT-1} - c_{iT-1})$. Before the earthquake, income and consumption for this type of households were perfectly correlated: a one yen reduction in labor income resulted in a one yen reduction in consumption. Assuming $z_{i,T-1} = z_{iT}$ and $y_{i,T-1} = y_{iT}$, the first three terms mean that the household experienced a reduction in its net financial assets and reduces its consumption as a result of the limited scope of borrowing even if income remains unchanged, since the market value of its financial assets has fallen. In the case of a household that owns a home with a mortgage on it, the household cannot go to the loan market to roll over its mortgage when the value of the property has fallen due to the home being destroyed. Assuming that all loans are one period loans, if a household's exogenous income does not fully cover the loss, the household must decrease its consumption in accordance with the amount of loss due to the earthquake. This implies that the household's consumption will have to fall by *more* than its income. The negative effect is larger when the borrowing limit decreases, i.e., $z_{i,T-1} > z_{iT}$, but the effect may be mitigated if the household receives private/public transfers after the earthquake to compensate for the drop in consumption.[9]

We should note that the negative effect of the losses caused by an earthquake on household consumption is larger when we consider the service flow of consumption provided by assets such as a home. As an example, let us consider the case of household owning a house with a mortgage on it: if the house is destroyed by the earthquake, the household no longer enjoys the housing services but still has to make the monthly payments on its mortgage. In this case, the household must reduce its other expenditures to rent new accommodation even if income is unchanged. Put differently, if we assume that household assets provide consumption service flows and the earthquake affects the size of these flows, the negative impact on consumption would be even greater.

The second type of households consists of those which were free to borrow before the earthquake and found that the borrowing constraint suddenly binds as a result of the earthquake (Type II in Table 2). Since the borrowing constraint had not been binding before the event, but became binding afterwards, we obtain $\mu_{i,T\text{-}1} = 0$ and $\mu_{iT} > 0$. In this case, the discussion regarding the first type of household applies to the situation after the disaster. The difference is that this type of household may have employed borrowing for consumption smoothing before the earthquake.

The third type of households consists of those that did not face any borrowing constraint both before *and* after the earthquake, i.e., $\mu_{i,T\text{-}1} = 0$ and $\mu_{iT} = 0$ (Type III in Table 2). In this case, equation (3) fulfills the condition $\mu = 0$ and we expect that the borrowing of additional amounts was employed as a possible strategy to deal with the negative shock (Flavin , 1999; Kochar, 2003; and Fafchamps and Lund, 2003).

Based on the theoretical discussion above, we make the following three specific empirical predictions based on the nature of the borrowing constraint a household faced before and after the earthquake. First, we should observe that looking at those households that suffered losses, the proportion of Type I households that experienced a change in consumption should be greater than their share in the total population, while the proportion should be smaller for the other two types of households (Type II and Type III). Second, we expect to find that a lower fraction of Type I households than of the other two household types combined report that borrowing represents the primary coping mechanism. Third, suppose that Type I households that experienced a loss had the lowest utility from consumption and thus the most urgent needs, and the goal of transfers was to help these households cope with losses. Then we should observe that a large fraction of households that had been subject to a borrowing constraint *ex ante* reported that transfers were the most important coping measure or one of the coping measures they used.[10]

3. The Data Set

In our analysis, we rely on micro-level data from the *Shinsai-go no Kurashi no Henka kara Mita Shouhi Kouzou ni Tsuite no Chousa Houkokusho* (Research Report on Changes in Lifestyles and Consumption Behavior after the Kobe Earthquake) collected by the Department of Livelihood and Culture, Hyogo Prefecture.[11] The survey was conducted in October 1996 in the Higashinada, Kita, and Suma wards of Kobe City and in Akashi and Nishinomiya cities.

The questionnaire was mailed to 3,000 women above the age of 30, who were selected on the basis of a stratified random sampling scheme. In each city, the sample size was proportional to the population size. Effective responses were completed by 1,512 women and the response rate was 50.4 percent. It needs to be borne in mind that the respondents of this survey continued to live in these earthquake-hit areas 21 months after the earthquake, i.e., they were not necessarily the worst affected since, as Hayashi and Tatsuki (1999) have shown, those who moved to locations outside the affected areas suffered greater damage to their homes than those who remained within these areas. This suggests that the empirical findings in this paper may underestimate the impact of the earthquake.

Definitions and summary statistics of the variables used in this study are provided in Table 3. First, it should be noted that more than 60 percent of the respondents answered that the consumption behavior of the household prior to and after the earthquake differed. Although this variable is a binary variable and we cannot identify the direction of the change based on our data, it is plausible to assume that the earthquake seriously affected household consumption behavior in the affected areas.

Second, the survey recorded the details of the housing damage experienced by the respondents as a result of the earthquake. Shortly after the earthquake, local governments conducted metrical surveys and issued formal certificates to households detailing the damage to their housing, which households could later use to obtain compensations from the government. Therefore, we consider the information on housing damage to be fairly objective and accurate. Approximately 85 percent of respondents suffered damage to their home and 87 percent experienced damage to household assets. Approximately 17 percent of respondents answered that the damage to their home was major, another 25 percent indicated that the damage was moderate, and 43 percent reported minor damage. Approximately 10 percent replied that they suffered major damage to their household assets, while 77 percent reported minor damage. These figures demonstrate the seriousness of the economic losses caused by the earthquake.

Third, the questionnaire inquired about the most important risk coping strategy employed by households that were compelled to increase their expenditure unexpectedly due to the earthquake. Such households account for more than 80 percent of the sample and the data enable us to identify different types of risk coping strategies employed by households. Possible strategies include borrowing, such as from institutions, relatives, and/or friends, and private transfers, including the receipt of indemnities from insurance companies and gifts from other households.[12] Note that borrowing in our definition includes both formal and informal borrowing, and that private transfers are defined as formal and informal transfers, excluding public transfers. In addition, our data set also allows us to identify households that received government transfers (such as benefits from publicly provided lending schemes and subsidies for residents of the affected areas) or donations from a variety of non-profit organizations.[13] Since such government transfers were automatically provided and not given in response to requests by affected families, and since the amount of compensation per household was relatively small, we focus on borrowing and private transfers.

Since a number of households did not provide information on their coping strategies, we decided to exclude these households from our sample while conducting the econometric analysis. The questionnaire asked respondents both to indicate their most important coping strategy (single choice) and to detail *all* the coping mechanisms they employed (multiple choice). Looking at the most important means of coping, approximately 25 percent of respondents replied that they managed to cope by changing the composition of their consumption. Borrowing was the second most frequent main risk coping strategy, cited by 10 percent of respondents, followed by private transfers, cited by 4 percent. Looking at the responses to the second question, we find that changing the composition of consumption formed part of the coping strategies of more than 70 percent of households, and 30 percent relied on borrowing. The proportion of households that received private transfers exceeds 50 percent.

The remaining part of Table 3 reports household characteristics and regional dummy variables. First, prior to the earthquake, the rate of home ownership exceeded 70 percent, and more than 30 percent of respondents had an outstanding mortgage. The average age of respondents was 51 years, and the educational attainment status of the majority among them was high school or lower. A majority of respondents lived with their children and the proportion living in extended family duplex houses, so-called "nisetai jutaku," was close to a quarter. Four percent of respondents were single. In the econometric analysis, in order to control for any unobserved heterogeneity generated by regional differences in the effects of the earthquake, we included district-specific dummy variables.

Since our data set does not provide information on borrowing constraints, we determined whether a household faced a borrowing constraint using the coefficients estimated by Wakabayashi and Horioka (2005). We followed the procedure developed by Jappelli, Pischke, and Souleles (1998) which estimates the consumption Euler equation with explicit information on binding borrowing constraints by combining two data sets. Wakabayashi and Horioka (2005) employed micro-level data from the *Public Opinion Survey on Household Savings and Consumption* (*Chochiku to Shouhi ni kansuru Yoron Chousa*) conducted by The Central Council for Savings Information (now The Central Council for Financial Services Information) in order to examine whether households faced a binding borrowing constraint. As an indicator of whether a household faced a binding borrowing constraint, they relied on whether respondents to the survey complained about financial institutions' screening procedures. Variables they found to affect households' borrowing constraint include the square of income, financial assets, the household head's age, total loans outstanding, family size, house ownership and employment status.[14] We utilize the estimated coefficients of their probit model to impute the probability of each household in our data set being subject to a binding borrowing constraint. We then classify households based on the predicted probability so that 27.74 percent of all households are subject to a borrowing constraint, which is the result obtained by Wakabayashi and Horioka.[15] We should note that this method can only identify the presence of a borrowing constraint *ex ante*, since Wakabayashi and Horioka deal with normal times and not the special situation that arose after the Kobe earthquake. In other words, we cannot distinguish between households that are free from a binding credit constraint both before and after the event (Type III) and those that were free to borrow *ex ante*, but face a borrowing constraint *ex post* (Type II). After we excluded the observations whose variables were necessary to estimate the probability of being subject to a binding borrowing constraint, we classified 371 households as being subject to a borrowing constraint and 967 households as not being subject to a borrowing constraint before the earthquake.

Furthermore, as a robustness check, we also perform the regressions by treating households that own a home both before and after the earthquake as households that are free from a borrowing constraint before and after the disaster. If one assumes that a household can borrow up to its net worth, then these homeowners probably were not subject to a borrowing constraint. This is because they were required to provide a down payment (collateral) when they bought their house, and the accumulated equity in the house at the time of the earthquake likely exceeded the value of the down payment when they purchased the house. Therefore, unless they had other large unsecured loans, their net financial worth was positive. Hence, we will employ information on home ownership to check the robustness of our results.

4. Estimation Results

The first key question examined in this study is whether there was a change in households' overall consumption behavior after the earthquake. As a theoretical point of reference, we employ the full consumption insurance hypothesis. Although our data do not allow us to identify the direction of the change, it is natural to presume that household consumption was negatively affected. Thus, we are able to provide some direct evidence on the extent of risk sharing by examining the proportion of households that experienced a loss but did not change their consumption behavior. The distribution of households by the extent of earthquake-related damage by region is shown in Table 4(a). The table shows that, overall, the share of households that suffered major damage to their home is 13 percent. By region, the highest share was registered in Higashinada Ward (23 percent), while the lowest was found in Kita Ward (3 percent). Correspondingly, the share of households without any damage to their home was 14 percent in Higashinada Ward and more than 40 percent in Kita Ward, while it was 30 percent in Suma Ward and Nishinomiya City. Large variations are also observed in the share of households that suffered damage to household assets. The share of households without any damage to household assets ranges from 7 percent in Higashinada Ward to 38 percent in Kita Ward.

Table 4 (b) shows the shares of households reporting a substantial, slight, or no change in consumption behavior classified by the extent of damage they suffered. More than 80 percent of households that experienced major damage to their home changed their consumption behavior, while only half of the households without any damage to their home changed their consumption behavior. Looked at from a different angle, of households that changed their consumption substantially, more than 20 percent had experienced major damage to their home, while less than 6 percent had experienced no damage to their home. The table thus shows that the share of households that changed their consumption behavior is positively correlated with the extent of housing asset damage, implying a rejection of efficient risk sharing in the *entire* area.[16] A similar pattern can be found with regard to the change in consumption behavior in relation to the extent of damage to household assets.

Next, in Table 4(c), we compare the shares of households that changed their consumption behavior categorized by the extent of damage to their home for *each* region. In all regions, households that had suffered major or moderate damage tended to change their consumption behavior, while those that had suffered only minor or no damage were more likely to leave their consumption behavior unchanged. This finding suggests that even for each area, efficient risk sharing is also rejected. If we consider two *ex ante* identical households living within the same risk pool in each area, their consumption should decrease to the same extent under efficient risk sharing, regardless of any difference in the magnitude of the *ex post* realization of risks. Based on this observation, we can reject this efficient risk sharing hypothesis even if we assume that risk sharing networks are limited to each local area.[17]

Based on the findings of a lack of a complete mutualization of risks, our next task is to examine the effectiveness of different forms of risk coping. As described in the previous section, in theory there are three different types of households, as shown in Table 2; however, our data only allow us to distinguish between households that are subject to a borrowing constraint before the earthquake (Type I) and those which are free from a credit constraint before the disaster (Type II or III). As a proxy of Type III households, we treat homeowners both before and after the earthquake as households that were free from a borrowing constraint before and after the disaster.

Table 5 reports the share of households that adopted a particular mechanism as the most important coping strategy or one of the coping strategies, with households being categorized by their borrowing constraint and the extent of damage they suffered. For example, among households that were borrowing constrained before the earthquake (Type I households) and faced major damage to their home, 16.7 percent listed consumption reallocation as the most important coping strategy. Based on the results reported in the table, we observe that a larger proportion of households that were subject to a borrowing constraint before the earthquake changed their consumption behavior in response to any type of damage to their home or assets. This is only natural since these households (Type I) were less likely to depend on borrowing and, as a result, were forced to reduce expenditures. This finding is consistent with the first prediction discussed in Section 2, which suggested we should observe that looking at those households that suffered losses, the proportion of Type I households that experienced a change in consumption should be greater than their share in the total population, while the proportion should be smaller for the other two types of households (Type II and Type III).

Yet, the proportion of households that relied on borrowing is higher among households that faced a borrowing constraint before the event and suffered major damage to their housing or assets. This result seems to be in conflict with our prediction that the share of Type I households reporting that borrowing was their primary coping device should be lower than the sum of the shares of the other two types of households reporting the same. However, we note that the results reported in Table 5 were obtained without controlling for household demographics and other attributes, and these findings may be an artifact of omitted variable bias. As we will discuss later, the significance of borrowing for households that were subject to a borrowing constraint before the earthquake disappears after controlling for household characteristics. In contrast with borrowing, we do not find a large disparity in the use of private transfers among households with different borrowing constraints. Since households that had been subject to a borrowing constraint were not able to able to borrow, a larger fraction of those households were more likely to report private transfers as the most important coping device or at least one of their coping devices. It seems that private transfers were more important for *ex ante* and *ex post* unconstrained households. We will return to the issue of private transfers below.

First, however, we empirically examine the determinants of risk coping strategies controlling for other household characteristics. Since we do not explicitly model households' decisions with regard to the optimal combination of different risk coping strategies, we investigate the determinants of the two main coping strategies, i.e., borrowing, b, and receiving private transfer income, y^{PRT}. We employ the following ordered probit models for each risk coping strategy:

$$\Delta b_i = S_i\theta_1 + H_i\beta_1 + \varepsilon_{1i}, \tag{5}$$

$p_{1i} = 2$ *if* $\Delta b_i > 0$ and borrowing is the most important coping device,

$p_{1i} = 1$ *if* $\Delta b_i > 0$ and borrowing is one of the coping devices,

$p_{1i} = 0$ *otherwise*,

$$\Delta y^{PRT}{}_i = S_i\theta_2 + H_i\beta_2 + \varepsilon_{2i}, \tag{6}$$

$p_{2i} = 2$ *if* $\Delta y^{PRT}{}_i > 0$ and receipt of transfers is the most important coping device,

$p_{2i} = 1$ *if* $\Delta y^{PRT}{}_i > 0$ and receipt of transfers is one of the coping devices,

$p_{2i} = 0$ *otherwise*,

where S represents a matrix of household-specific shock variables, H is a matrix of household characteristics and other control variables. We assume that the error terms ε_1 and ε_2 are independent and normally distributed across observations. We do not directly observe the intensities of the risk coping strategies and thus these variables are treated as latent variables. However, our data set enables us to identify whether borrowing or private transfers is the most important coping strategy, one of the coping strategies, or not employed at all. Accordingly, the dependent variables are ordered discrete variables that take a value of 2 when a particular coping device is the most important, 1 when it is one of the measures employed, and 0 otherwise. In order to take into account that borrowing as a coping device was not available to all households, we estimate the models by dividing observations into those households that are subject to a borrowing constraint and those that are not following the procedure described in Section 3.

The estimation results of the ordered probit models for borrowing and transfers are shown in Table 6. The reported coefficients refer to the marginal effects evaluated at the average of each variable. Focusing on the coefficients on the shock variables, our findings can be summarized as follows. First, the columns for borrowing reveal a sharp contrast between households subject to and not subject to a borrowing constraint before the earthquake. The coefficients on the shock variables are not significant for households that were subject to a binding borrowing constraint, implying that these households may have been unable to utilize borrowing as a device to cope with the large negative shocks caused by the earthquake. On the other hand, for households not subject to a binding borrowing constraint, the coefficients on the shock variables are positive and statistically significant, showing that these households were able to cope with the damage to their homes by borrowing.

The last four columns in Table 6 present the determinants of private transfer. In contrast with the results on borrowing, we observe that all the coefficients for major and moderate damage to the home are positive and mostly statistically significant for both groups. For both types of households, those with greater damage to their home were more likely to rely on private transfers. This suggests that private transfers were a common device to cope with disaster damage regardless of the existence or otherwise of borrowing constraints.

It should also be noted that some of the coefficients on the dummies for Kita and Suma wards are negative in the private transfers equations. This suggests that in areas where the damage caused by the earthquake was less serious, people were less likely to receive private transfers, regardless of the extent of the damage sustained by individual households. Alternatively, it may imply that the importance of interregional private transfers was greater where the aggregate shock was more serious.

As a robustness check, we repeated our analysis using a sample consisting only of households that were homeowners both before and after the earthquake. As discussed in the previous section, these households may be seen as not being subject to a borrowing constraint before and after the disaster (Type III households in Table 2). Using this sample, we estimated equation (5) and the results are shown Table 7. Qualitatively, the results in Table 7 are the same as those of the borrowing equation reported in Table 6 for households not subject to a borrowing constraint, implying that these households were able to use borrowing as an effective mechanism to cope with major and moderate damage to their homes. These empirical results validate the prediction based on the theoretical model discussed in Section 2.

In summary, we observe a sharp contrast in coping mechanisms between households that before the earthquake were subject to a borrowing constraint and those that were not, regardless of *ex post* credit availability. Households that had large collateralizable assets (e.g., equity in a house) and were free from a binding borrowing constraint before the disaster were able to maintain their consumption levels by borrowing. In contrast, households that had been subject to a binding constraint before the event were unable to borrow to cope with the losses they suffered. In other words, the consumption of households that had not been subject to an *ex ante* borrowing constraint was not severely affected by the disaster, but that of households subject to an *ex ante* constraint was seriously affected. In contrast with borrowing, private transfers were used by both types of households, but the reliance on transfers depended on the extent of the damage households suffered.

5. Concluding Remarks

In this study, we examined the extent of risk sharing among people and people's risk coping behavior in response to the unexpected losses caused by the Kobe earthquake in 1995. Utilizing a unique household-level data set collected after the earthquake, we arrived at the following findings. First, in each region as well as in the area as a whole, households that suffered a large loss due to the earthquake tended to change their consumption behavior. This suggests that the efficient risk sharing hypothesis is rejected. Nevertheless, households were able to adopt a wide variety of risk coping devices to deal with the negative shocks caused by the earthquake. We then investigated the relative effectiveness of households' risk coping mechanisms. Our analysis showed that households that had a large amount of collateralizable assets before the catastrophe and were free from a binding constraint were able to maintain their consumption levels by borrowing. In contrast, households subject to a binding constraint before the disaster were unable to borrow to cope with the losses inflicted by the earthquake. In contrast with borrowing, private transfers were used by both types of households, but the reliance on transfers depended on the extent of the damage households suffered.

Our empirical findings have two important implications. First, further investigation is needed into the mechanism of efficient risk sharing. Although there are a large number of studies that have examined and tested the full consumption risk sharing model, few studies have looked at the way households respond and how risk coping measures are used. The results of our paper imply that a lack of well-functioning credit markets may be a cause of inefficiency arising in risk sharing. Our study focused on the case of economic losses caused by natural disaster; future studies should address other kinds of shocks.

The second implication is that government policies should take account of the heterogeneity across households in terms of their ability to employ different coping measures in response to the damage caused by a natural disaster. While governments can help households directly and indirectly to cope with various kinds of shocks, this is difficult in the case of a disaster on the scale of the Kobe earthquake, when the number of victims is very large and hence the amount of funds available per victim is relatively small. At the same time, if the government had encouraged households to obtain earthquake insurance, fewer households would have had to cut their level of consumption. Yet, designing an efficient insurance mechanism against earthquakes is not straightforward because earthquakes are rare events which makes it difficult to design and implement actuarially fair insurance. Since obtaining detailed long-term historical data on earthquake patterns is not easy, it is difficult to set appropriate insurance premiums. In addition, there is also a tendency for people not to protect themselves against the consequences of earthquakes because earthquakes are rare events (Kunreuther et al. 1978). Moreover, since an earthquake is a highly covariate risk which often cannot be diversified away within a country, insurers potentially would need to utilize international reinsurance markets. However, in practice, the size of the reinsurance market for catastrophe risk has been very small. These practical issues and policies for mitigating and coping with natural disasters should be examined formally in future studies.

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Table 1
Direct Damage from Natural Disasters

Event (Year)	Damage (US$ billion)
Hurricane Katrina, U.S.A. (2005)	125[a]
Tsunami, India (2004)	1.02[b]
Tsunami, Indonesia (2004)	4.45[c]
Tsunami, Maldives (2004)	0.47[d]
Tsunami, Sri Lanka (2004)	0.97–1.00[e]
Chuetsu Earthquake, Japan (2004)	28.3[f]
Hurricane Ivan, U.S.A. (2004)	3[a]
Earthquakes, Turkey (1999)	22[g]
Hurricane Mitch, U.S.A. (1998)	1.96[g]
Great Hanshin-Awaji Earthquake, Japan (1995)	95–147[g]
Hurricane Andrew, U.S.A. (1992)	26.5[g]
Great Kanto Earthquake, Japan (1923)	32.6[h] (based on 2003 prices)

Sources:
a. Authors' calculation based on information from Risk Management Solutions (RMS).
b. Asian Development Bank, United Nations, and World Bank (2005), "India: Post Tsunami Recovery Program-Preliminary Damage and Needs Assessment."
c. BAPPENAS and the International Donor Community (2005), "Indonesia: Preliminary Damage and Loss Assessment: The December 26, 2004 Natural Disaster."
d. World Bank – Asian Development Bank – UN System (2005), "Tsunami: Impact and Recovery."
e. Asian Development Bank, Japan Bank for International Cooperation, and World Bank (2005), "Sri Lanka 2005 Post-Tsunami Recovery Program-Preliminary Damage and Needs Assessment."
f. Niigata Prefecture, Japan.
g. Table 1 in Freeman, Keen, and Mani (2003).
h. Authors' estimates using information from the Cabinet Office and the Ministry of Finance of the Government of Japan.

Table 2
Classification of Households by Borrowing Constraint Status

	Subject to a borrowing constraint before the earthquake		Not subject to a borrowing constraint before the earthquake	
Ex ante status	$\mu_{iT\text{-}1} > 0$		$\mu_{iT\text{-}1} = 0$	
Ex post status	$\mu_{iT} > 0$	$\mu_{iT} = 0$	$\mu_{iT} > 0$	$\mu_{iT} = 0$
Type of household	Type I	Unlikely to happen	Type II	Type III

Table 3
Descriptive Statistics of the Variables Used

Description of Variables	Mean (Standard Deviation)
<u>Expenditure Shock[a]</u>	
Dummy = 1 if household consumption changed after the earthquake	0.627
Dummy = 1 if the household faced an increase in its expenditure due to the earthquake	0.803
<u>Shock Variables[b]</u>	
Dummy = 1 if the earthquake caused major damage to the home	0.174
Dummy = 1 if the earthquake caused moderate damage to the home	0.251
Dummy = 1 if the earthquake caused minor damage to the home	0.431
Dummy = 1 if the earthquake caused major household asset damage	0.094
Dummy = 1 if the earthquake caused minor household asset damage	0.773
Dummy = 1 if the earthquake adversely affected the health of a family member	0.213
<u>Coping Variables[b]</u>	
The most important coping strategy	
Dummy = 1 if a reallocation of consumption expenditure was the most significant means of coping (default category)	0.250
Dummy = 1 if borrowing was the most significant means of coping	0.096
Dummy = 1 if private transfers were the most significant means of coping	0.042
Dummy = 1 if public transfers were the most significant means of coping	0.074
All coping strategies	
Dummy = 1 if a reallocation of consumption expenditure was one of the means of coping (default category)	0.719
Dummy = 1 if borrowing was one of the means of coping	0.298
Dummy = 1 if private transfers were one of the means of coping	0.519
Dummy = 1 if public transfers were one of the means of coping	0.204

a. For all respondents.
b. For those reporting coping strategies.

Table 3 (continued)
Descriptive Statistics of the Variables Used

Description of Variables	Mean (Standard Deviation)
Household Characteristics[b]	
Dummy = 1 if the household owned a house prior to the earthquake	0.718
Dummy = 1 if the household had an outstanding mortgage prior to the earthquake	0.319
Age of the respondent	51.190 (10.842)
Age squared	2737.731 (1135.305)
Dummy = 1 if the highest level of education of the respondent was high school	0.518
Dummy = 1 if the highest level of education of the respondent was junior college or the equivalent	0.243
Dummy = 1 if the highest level of education of the respondent was university	0.137
Dummy = 1 if the respondent was single	0.042
Dummy = 1 if the respondent lived with children	0.623
Dummy = 1 if the respondent lived with parents or grandchildren (extended family)	0.198
Regional Dummy Variables[b]	
Dummy = 1 for Higashinada Ward (default category)	0.163
Dummy = 1 for Kita Ward	0.136
Dummy = 1 for Suma Ward	0.136
Dummy = 1 for Akashi City	0.370
Dummy = 1 for Nishinomiya City	0.181
Dummy = 1 for other areas	0.014

Note: Numbers in parentheses represent standard deviations.
a. For all respondents.
b. For those reporting coping strategies.

Table 4

Tests of Risk Sharing

(a) Distribution of Households by Extent of Damage and Region (%)

Region	Damage to home			
	Major Damage	Moderate Damage	Minor Damage	No Damage
All	12.90	17.54	40.93	28.63
Higashinada	23.26	25.00	37.79	13.95
Kita	2.56	7.26	50.00	40.17
Suma	13.86	18.32	36.63	31.19
Akashi	16.15	25.44	33.85	24.56
Nishinomiya	6.90	10.34	51.38	31.38
Region	Damage to Assets			Health Damage
	Major Damage	Moderate Damage	No Damage	
All	7.91	70.74	21.35	17.71
Higashinada	16.07	77.38	6.55	29.71
Kita	3.04	58.70	38.26	10.17
Suma	9.90	61.39	28.71	12.87
Akashi	9.89	80.88	9.23	25.38
Nishinomiya	1.74	70.83	27.43	7.17

(b) Distribution of Households by Extent of Change in Consumption and Extent of Damage (%)

		Consumption Changed Substantially	Consumption Changed Slightly	No Change
All		9.49	53.23	37.28
Home	Major Damage	23.08	57.14	19.78
	Moderate Damage	13.15	60.16	26.69
	Minor Damage	5.79	54.86	39.35
	No Damage	5.56	44.93	49.52
Assets	Major Damage	28.18	53.64	18.18
	Moderate Damage	8.44	57.99	33.57
	No Damage	5.94	37.95	56.11
Health		15.69	62.75	21.57

(c) Distribution of Households by Extent of Change in Consumption, Extent of Damage, and Region (%)

Region	Extent of Damage	Consumption Changed Substantially	Consumption Changed Slightly	No Change
Higashinada	Major or Moderate	15.00	66.25	18.75
	Minor/No	5.75	56.32	37.93
Kita	Major or Moderate	19.05	61.90	19.05
	Minor/No	3.92	52.45	43.63
Suma	Major or Moderate	16.39	54.10	29.51
	Minor/No	5.26	45.11	49.62
Akashi	Major or Moderate	17.22	57.22	25.56
	Minor/No	7.51	54.15	38.34
Nishinomiya	Major or Moderate	10.42	68.75	20.83
	Minor/No	5.98	45.73	48.29

Table 5
Most Important Risk Coping Strategies, by Extent of Damage and Borrowing Constraint (%)

	Home			Assets	
	Major Damage	Moderate Damage	Minor Damage	Major Damage	Minor Damage
Reallocation of Consumption					
Households subject to a borrowing constraint before the earthquake (Type I)	16.7	21.1	50.0	22.2	34.3
Households not subject to a borrowing constraint before the earthquake (Type II or III)	4.4	8.3	28.8	6.5	20.7
Households not subject to a borrowing constraint both before and after the earthquake (Type III)[a]	1.8	6.9	31.3	0.0	21.7
Borrowing					
Households subject to a borrowing constraint before the earthquake (Type I)	20.8	10.5	5.8	22.2	3.8
Households not subject to a borrowing constraint before the earthquake (Type II or III)	13.4	14.6	9.0	6.5	11.0
Households not subject to a borrowing constraint both before and after the earthquake (Type III)[a]	16.1	15.8	8.4	16.7	10.5
Private Transfers					
Households subject to a borrowing constraint before the earthquake (Type I)	0.0	2.6	7.7	0.0	4.8
Households not subject to a borrowing constraint before the earthquake (Type II or III)	2.9	3.1	6.8	22.2	4.4
Households not subject to a borrowing constraint both before and after the earthquake (Type III)[a]	3.6	2.0	6.2	0.0	4.1

a. We treat households that owned a house before and after the earthquake as households that were free from a borrowing constraint before and after the disaster, i.e., Type III households.

Table 6
Comparison of Different Risk Coping Strategies

Explanatory Variables	Borrowing				Private Transfers			
	Subject to a Borrowing Constraint Before the Earthquake		Not Subject to a Borrowing Constraint Before the Earthquake		Subject to a Borrowing Constraint Before the Earthquake		Not Subject to a Borrowing Constraint Before the Earthquake	
	One of the Means	Most Important	One of the Means	Most Important	One of the Means	Most Important	One of the Means	Most Important
Dummy = 1 if the earthquake caused major damage to the home	0.137 (0.090)	0.067 (0.060)	0.119 (0.041)***	0.135 (0.071)*	0.316 (0.055)***	0.108 (0.060)*	0.290 (0.037)***	0.130 (0.052)**
Dummy = 1 if the earthquake caused moderate damage to the home	–0.010 (0.086)	–0.003 (0.029)	0.111 (0.041)***	0.110 (0.053)**	0.270 (0.073)***	0.052 (0.032)	0.302 (0.049)***	0.091 (0.034)***
Dummy = 1 if the earthquake caused minor damage to the home	–0.091 (0.077)	–0.030 (0.025)	0.050 (0.044)	0.039 (0.035)	0.075 (0.093)	0.008 (0.012)	0.032 (0.075)	0.005 (0.011)
Dummy = 1 if the earthquake caused major household asset damage	–0.065 (0.100)	–0.020 (0.027)	–0.064 (0.061)	–0.040 (0.033)	0.111 (0.133)	0.015 (0.025)	0.049 (0.100)	0.008 (0.019)
Dummy = 1 if the earthquake caused minor household asset damage	–0.152 (0.088)*	–0.073 (0.057)	–0.004 (0.041)	–0.003 (0.032)	0.209 (0.128)	0.015 (0.010)	–0.019 (0.069)	–0.003 (0.011)
Dummy = 1 if the earthquake adversely affected the health of a family member	0.018 (0.065)	0.007 (0.024)	0.040 (0.030)	0.033 (0.027)	–0.013 (0.081)	–0.001 (0.007)	–0.024 (0.053)	–0.003 (0.007)
Dummy = 1 if the household owned its home prior to the earthquake	0.170 (0.094)*	0.093 (0.079)	0.025 (0.054)	0.017 (0.035)	–0.234 (0.163)	–0.014 (0.009)	–0.067 (0.071)	–0.012 (0.015)
Dummy = 1 if the household had an outstanding mortgage prior to the earthquake	–0.017 (0.121)	–0.006 (0.039)	–0.005 (0.029)	–0.004 (0.021)	0.142 (0.145)	0.022 (0.038)	0.034 (0.048)	0.005 (0.007)
Age of the respondent	–0.011 (0.038)	–0.004 (0.013)	0.003 (0.010)	0.002 (0.008)	–0.026 (0.046)	–0.002 (0.004)	–0.008 (0.016)	–0.001 (0.002)
Age squared	0.0002 (0.0004)	0.00006 (0.0002)	–0.00005 (0.0001)	–0.00004 (0.00007)	0.0003 (0.0005)	0.00003 (0.00005)	0.00003 (0.0002)	0.000005 (0.00002)

Note: This table reports marginal effects. Huber-White consistent robust standard errors are shown in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

Table 6
Comparison of Different Risk Coping Strategies (continued)

Explanatory Variables	Borrowing				Private Transfers			
	Subject to a Borrowing Constraint Before the Earthquake		Not Subject to a Borrowing Constraint Before the Earthquake		Subject to a Borrowing Constraint Before the Earthquake		Not Subject to a Borrowing Constraint Before the Earthquake	
	One of the Means	Most Important	One of the Means	Most Important	One of the Means	Most Important	One of the Means	Most Important
Dummy = 1 if the highest level of education of the respondent was high school	–0.099 (0.083)	–0.035 (0.032)	–0.028 (0.043)	–0.021 (0.033)	0.157 (0.116)	0.161 (0.015)	0.004 (0.069)	0.001 (0.010)
Dummy = 1 if the highest level of education of the respondent was junior college or the equivalent	–0.125 (0.090)	–0.038 (0.026)	–0.017 (0.049)	–0.012 (0.035)	0.140 (0.121)	0.018 (0.021)	0.059 (0.078)	0.010 (0.014)
Dummy = 1 if the highest level of education of the respondent was university	–0.152 (0.085)*	–0.039 (0.020)*	–0.056 (0.055)	–0.036 (0.031)	0.090 (0.134)	0.011 (0.021)	–0.019 (0.091)	–0.003 (0.012)
Dummy = 1 if the respondent was single	–0.092 (0.073)	–0.028 (0.021)	–0.015 (0.018)	–0.011 (0.013)	–0.022 (0.050)	–0.002 (0.005)	0.005 (0.033)	0.001 (0.005)
Dummy = 1 if the respondent lived with children	–0.047 (0.082)	–0.018 (0.034)	0.055 (0.029)*	0.039 (0.020)**	–0.019 (0.088)	–0.002 (0.009)	–0.038 (0.046)	–0.006 (0.007)
Dummy = 1 if the respondent lived with parents or grandchildren (extended family)	0.050 (0.075)	0.019 (0.031)	0.034 (0.030)	0.028 (0.027)	–0.131 (0.089)	–0.010 (0.007)	–0.075 (0.056)	–0.010 (0.006)
Dummy = 1 for Kita Ward	–0.144 (0.092)	–0.037 (0.020)	–0.056 (0.048)	–0.036 (0.027)	–0.242 (0.157)	–0.013 (0.008)*	–0.189 (0.079)**	–0.019 (0.007)***
Dummy = 1 for Suma Ward	–0.026 (0.102)	–0.009 (0.032)	–0.034 (0.045)	–0.023 (0.029)	0.088 (0.113)	0.011 (0.019)	–0.140 (–0.075)*	–0.015 (0.007)**
Dummy = 1 for Akashi City	–0.007 (0.087)	–0.002 (0.030)	–0.011 (0.036)	–0.008 (0.026)	–0.169 (0.108)	–0.015 (0.011)	–0.011 (0.058)	–0.002 (0.008)
Dummy = 1 for Nishinomiya City	0.036 (0.097)	0.138 (0.040)	0.009 (0.043)	0.007 (0.034)	–0.139 (0.125)	–0.010 (0.008)	–0.102 (0.742)	–0.012 (0.008)
Dummy = 1 if the respondent lived in another area	–0.036 (0.177)	–0.011 (0.050)	–0.068 (0.114)	–0.040 (0.053)	–0.149 (0.201)	–0.009 (0.009)	–0.065 (0.154)	–0.008 (0.015)
Sample size	152	152	430	430	189	189	473	473

Note: In this table, we reported the marginal effects. Huber-White consistent robust standard errors are shown in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

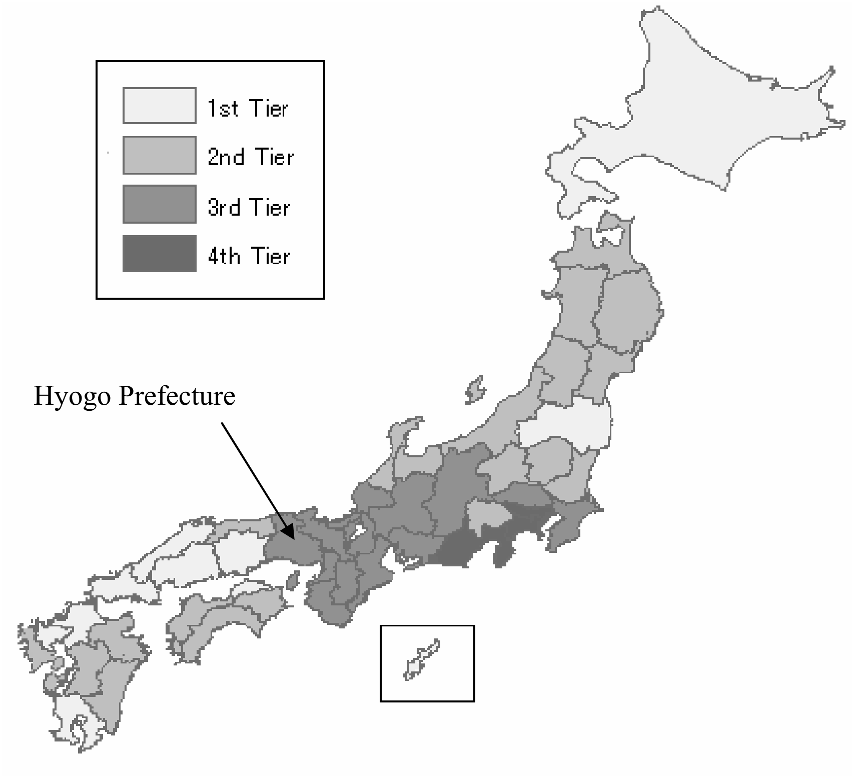
Table 7
Borrowing Behavior of Homeowners Before and After the Earthquake

Explanatory Variables	Borrowing	
	One of the Means	Most Important
Dummy = 1 if the earthquake caused major damage to the home	0.101 (0.043)**	0.116 (0.073) §
Dummy = 1 if the earthquake caused moderate damage to the home	0.109 (0.042)***	0.111 (0.055)**
Dummy = 1 if the earthquake caused minor damage to the home	0.033 (0.045)	0.026 (0.036)
Dummy = 1 if the earthquake caused major household asset damage	0.014 (0.066)	0.011 (0.057)
Dummy = 1 if the earthquake caused minor household asset damage	–0.011 (0.041)	–0.009 (0.034)
Dummy = 1 if the earthquake adversely affected the health of a family member	0.033 (0.030)	0.028 (0.028)
Dummy = 1 if the household had an outstanding mortgage prior to the earthquake	–0.003 (0.029)	–0.002 (0.022)
Age of the respondent	0.008 (0.011)	0.006 (0.009)
Age squared	–0.00010 (0.00010)	–0.00008 (0.00008)
Dummy = 1 if the highest level of education of the respondent was high school	–0.018 (0.045)	–0.014 (0.036)
Dummy = 1 if the highest level of education of the respondent was junior college or the equivalent	–0.015 (0.051)	–0.012 (0.038)
Dummy = 1 if the highest level of education of the respondent was university	–0.043 (0.057)	–0.030 (0.036)
Dummy = 1 if the respondent was single	–0.013 (0.018)	–0.010 (0.014)
Dummy = 1 if the respondent lived with children	0.050 (0.030)*	0.037 (0.020)*
Dummy = 1 if the respondent lived with parents or grandchildren (extended family)	0.026 (0.031)	0.022 (0.027)
Dummy = 1 for Kita Ward	–0.067 (0.048)	–0.044 (0.027)
Dummy = 1 for Suma Ward	–0.045 (0.046)	-0.032 (0.028)
Dummy = 1 for Akashi City	–0.021 (0.037)	–0.016 (0.028)
Dummy = 1 for Nishinomiya City	0.029 (0.042)	0.024 (0.038)
Dummy = 1 if the respondent lived in another area	0.017 (0.050)	0.014 (0.044)
Sample size	411	411

Note: This table reports marginal effects. Huber-White consistent robust standard errors are shown in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively. The *p*-value for § is 0.111.

Figure 1

Earthquake Insurance Premiums in Japan by Region
Before the Hanshin-Awaji Earthquake



Original data source: Ministry of Finance.
Note: Insurance premiums are lowest in 1st tier areas and highest in 4th tier areas.

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[1] A review of studies exploiting natural events as "natural experiment" instruments to examine various issues, including returns to education and responses to changes in income or fertility, is provided by Rosenzweig and Wolpin (2000).

[2] An earlier study to use the Kobe earthquake to examine – and reject – the full consumption insurance hypothesis is Kohara et al. (2006). However, the study suffers from serious attrition in the sample and from the limited information available on the scale of the

loss suffered by each household.

[3] In addition to the mutual insurance mechanisms of borrowing and private transfers, victims of natural disasters can of course also rely on self-insurance through dissaving – an issue that we examined in an earlier paper (Sawada and Shimizutani 2005). In this context, it is interesting to note that the high savings rate of the Japanese has been attributed to the high frequency of catastrophes such as earthquakes, volcanic eruptions, landslides, and typhoons (e.g., Skidmore 2001). Similarly, Horioka and Watanabe (1997) showed that Japanese households maintain significant amounts of precautionary savings, while Shimizutani (2002) pointed out that self-insurance also played an important role in response to a change in the income of a head of household.

[4] However, households often have limited access to credit markets (Jappelli 1990), a fact that can be attributed to high information costs and/or the lack of assets for collateral (Stiglitz and Weiss 1981). Borrowing constraints have a significant negative impact on a household's asset portfolio choice and risk coping abilities (Paxson 1990; Guiso et al. 1992).

[5] In Japan, earthquake insurance is complementary to fire insurance (houseowner insurance), and the amount insured ranges from 30 percent to 50 percent of that insured by the fire insurance, with a cap of 50 million yen on houses and 10 million yen on assets. The extent to which earthquake insurance is tax deductible is rather limited.

[6] Theoretically, we could test this assumption by examining the geographical distribution of earthquake insurance purchasers in Kobe before the earthquake. Another possible factor determining *ex ante* risk perceptions is geological information, and a comprehensive geological survey in the Kobe area was in fact conducted for the first time in 1999 (Kobe City 1999). However, we decided not to

use this information since it is unlikely that the people living in the area were familiar with the precise geological details before the earthquake.

[7] Given these assumptions, there are two robust testable restrictions of efficient risk sharing. The first is that within the Kobe area, we should see a mutualization of the risk. The second robust property of efficient risk sharing is that each household not subject to the *ex ante* risk should take on a little bit, though the amount of this type of sharing depends on the risk aversion and the relative size of the risk pool. Unfortunately, we are unable to assess the second property since our data sample is confined to people in the affected areas and does not provide information on non-affected areas.

[8] The term μ is equal to the increase in the expected lifetime utility that would occur if the current constraint were relaxed by one unit. Since a household is constrained from borrowing more but not from saving more, μ shows a positive sign.

[9] We ignore the case $z_{iT-1} < z_{iT}$ since this is unrealistic.

[10] Cox (1990) hypothesized this possibility and tested it using data on the United States. He found that empirical transfer patterns are consistent with those predicted from the model.

[11] The report was released on March 25, 1997, by Hyogo-ken Seikatsu Bunka-bu Seikatsu Souzou-ka Shouhi Seikatsu Taisaku-shitsu (Hyogo Prefecture, Department of Livelihood and Culture, Livelihood Creation Section, Office for Livelihood Policy).

[12] Unfortunately, our data set did not allow us to distinguish between risk sharing with other households in the affected areas and risk sharing among family members. In this paper, we exclude the possibility of self-insurance from our analysis, since the purpose here

is to examine the effectiveness of market and non-market insurance mechanisms across households. We included an investigation of self-insurance in an earlier study (Sawada and Shimizutani 2005) and found that dissaving was utilized only to cope with smaller asset damage.

[13] The allocation of donations to victims was centrally determined by a special public committee, the *Hyogo-Ken Nanbu-Jishin Saigai Gienkin Kanri-Iinkai*.

[14] Wakabayashi and Horioka (2005) assume that households that own their home can also face a binding credit constraint.

[15] We apply the coefficients in the first column of Table 3 in Wakabayashi and Horioka (2005) to the information available for each household in our data set. Since information on the amount of financial assets and total outstanding loans as well as the employment status of the household head are not available in our data set, we substitute the average figures from Table 1 in Wakabayashi and Horioka (2005) for these variables. The median annual household income is between approximately 6 and 8 million yen (approximately US$50,000–67,000).

[16] We formally tested and rejected the efficient risk sharing hypothesis in Sawada and Shimizutani (2005, 2007).

[17] One possible reason why the mutualization hypothesis does not hold is the limited extent of tax deductibility and coverage levels of earthquake insurance. Moreover, the fact that only a small proportion of residents in Kobe chose to purchase earthquake insurance, while others did not, suggests either (1) that households thought that the risks were not uniform in the areas that we treat as having the same *ex ante* exposure or (2) that households in the same *ex ante* risk pool had different priors with regard to the probability of an

earthquake, or borrowing constraints had prevented some households from buying insurance. Although our data do not allow us to identify households that purchased earthquake insurance, in either case, one would not be surprised to find that the mutualization hypothesis is rejected.