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Yasuyuki Sawada
University of Tokyo
Satoshi Shimizutani
Hitotsubashi University

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Are People Insured Against Natural Disasters?

Evidence from the Great Hanshin-Awaji (Kobe) Earthquake in 1995[*]

Yasuyuki Sawada[**] and Satoshi Shimizutani[***]

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Abstract

We investigate whether people were insured against unexpected losses caused by the Great Hanshin-Awaji (Kobe) earthquake in 1995. The unique household data employed led to several empirical findings under a natural-experimental situation. The complete consumption insurance hypothesis is rejected overwhelmingly, suggesting the ineffectiveness of the formal and/or informal insurance mechanisms against the earthquake. We also investigate possible factors that inhibit full risk-sharing. Transfers may be particularly ineffective as insurance against losses for co-resident households. Households borrow extensively against housing damages, whereas dissavings are utilized for smaller asset damages, implying a hierarchy of risk-coping measures, from dissaving to borrowing.

Keywords: natural disasters; risk-sharing; risk-coping strategies

1. Introduction

In the early hours of January 17, 1995, the Hanshin (Kobe) area in Japan was hit by a major earthquake. The area is densely populated comprising more than 4 million people and is a part of the second largest industrial cluster in Japan. The earthquake induced a human loss of more than 6,400, a housing property loss greater than USD 60 billion, and a capital stock loss of more than USD 100 billion, making it the largest economic damage recorded in history [Table 1, Horwich (2000); Scawthorn et al. (1997)]. Given the fact that only 3% of the property in Hyogo Prefecture, where Kobe is located, was covered by earthquake insurance, it is reasonable to assume that the earthquake was entirely unexpected in this area. On the other hand, the insurance coverage for the Tokyo Metropolitan Area, which was hit by a massive earthquake in 1923, was 16.0% [Yamaguchi (1999)].[1] As an unexpected, exogenous event, an earthquake provides an unusual, clean experimental situation under which we can investigate the functioning of markets and the manner in which households respond to exogenous shocks. In other words, we exploit this rare natural event, which cannot be influenced by households, as an instrument to identify market completeness, the effectiveness of formal and/or informal insurance, and household behavior.[2]

There are two sets of analyses implemented in our paper. First, we test the complete consumption insurance hypothesis by employing the empirical strategy of Cochrane (1991) and

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[1] In fact, serious limitations do exist in private but highly-regulated insurance markets for earthquakes in Japan [Saito (2002); Yamaguchi (1998)]. Froot (2001) also observed that, in the United States, most insurers purchased relatively limited catastrophe reinsurance against natural disasters. He concluded that this is attributable to supply restrictions associated with capital market imperfections and market power exerted by traditional reinsurers. Nonetheless, Brookshire et al. (1985) showed that the housing market in the United States exhibits an effective response to the risk of damage caused by natural disasters.

[2] In a closely related paper, Rosenzweig and Wolpin (2000) review the literature exploiting natural events as instruments to estimate returns to education and to identify human behavior against income and fertility changes.

Mace (1991). It should be noted that our empirical analysis does not limit us from testing the existence of formal insurance markets. Instead, we examine the validity of a wide variety of formal and informal insurance mechanisms such as borrowing and receiving private and/or public transfers against the earthquake [Mace (1991)]. According to our analysis, the complete risk-sharing hypothesis is overwhelmingly rejected, which suggests the ineffectiveness of the formal and/or informal insurance mechanisms against the earthquake.

Second, we investigate possible factors that inhibit consumption insurance by comparing the effectiveness of different risk-coping strategies, i.e., dissaving as well as borrowing and receiving private and/or public transfers.[3] According to our empirical results, transfers are likely to be ineffective against negative shocks, particularly for co-resident households. We have also found that the risk-coping means are specific to the nature of the loss caused by the earthquake. For instance, households borrow extensively against housing damages, whereas dissavings are utilized to compensate for smaller damages caused to assets. This implies the existence of a hierarchy of risk-coping measures, starting from dissaving to borrowing.

Two aspects differentiate our study from earlier studies. First, we utilize shocks generated by a natural disaster, an aspect that has been rarely utilized in the previous studies on full consumption insurance such as Cochrane (1991), Fafchamps (2003), Hayashi et al. (1996), Mace (1991), Kohara, Ohtake, and Saito (2002), and Townsend (1994). In order to test the complete insurance model, these existing studies typically employed income changes, information on illness, involuntary job loss, and strikes as explanatory variables, which are not perfectly exogenous to the decision problems faced by a typical household, resulting in a

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[3] In a closely related study, Zhang and Ogaki (2004) test the risk-sharing hypothesis against the permanent income hypothesis.

possible estimation bias [Cochrane (1991); Mace (1991); Townsend (1994)]. On the other hand, since we used the direct shock variables resulting from the unexpected earthquake, we believe that our results are less susceptible to econometric problems. In fact, a paper by Kohara, Ohtake, and Saito (2001) has tested and rejected the full consumption insurance hypothesis against the Great Hanshin-Awaji earthquake by employing region-specific slope dummies for the income change variables. Our empirical analysis confirms their findings by employing direct shock measures from a richer data set collected in the earthquake-hit areas. This data set allows us to differentiate a wide variety of shocks generated by the earthquake.[4] We believe that our data provides us with a clean experimental situation.

Second, unlike the study by Kohara et al. (2001), we explicitly investigate the reason behind the strong rejection of the full consumption hypothesis. Moreover, unlike previous studies on household behavior against general shocks, such as Horioka, Murakami, and Kohara (2002) and Kochar (1999), this study examines the relative effectiveness of various risk-coping devices against sudden natural disasters. To the best of our knowledge, no previous study has employed household-level data in order to investigate quantitatively the role of savings, borrowing, and other risk-coping devices against natural disasters in Japan.[5]

The remainder of this study comprises three sections: Sections 2 and 3 establish the theoretical and econometric frameworks, respectively. In Section 4, after a brief overview of the data set, we present the findings that emerged from our econometric analysis. The final section contains a summary with concluding remarks.

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[4] The official data set employed by Kohara et al. (2001) suffers from a serious attrition problem during the earthquake. The data set retains only one quarter of the original households in the areas hit by the earthquake.
[5] Previous related studies found that Japanese households maintain significant amounts of precautionary savings [Horioka and Watanabe (1997); Horioka, Murakami, and Kohara (2002); Shimizutani (2002); Zhou (2003)]. Skidmore (2001) have attributed the high savings rate of Japanese to the high frequency of catastrophes such as earthquakes, volcanic eruptions, landslides, and typhoons.

2. The Model Framework

In developed as well as developing countries, people are at the risk of ex post shocks in their day-to-day lives [World Bank (2001)]. For example, accidents, sickness, or sudden death can disable the head of a household or even an entire family. Macroeconomic instabilities or recessions, which tend to generate harsh inflation/deflation and widespread unemployment, can also significantly reduce the real value of household resources. However, natural disasters can generate the most serious consequences ever known. Households have developed formal and informal risk-coping mechanisms against a wide variety of shocks [Besley (1995); Fafchamps (2003); Townsend (1994, 1995)]. We classify such insurance opportunities as mutual and self-insurance opportunities [Hayashi et al. (1996)]. We then formulate simple theoretical and empirical frameworks to examine the effectiveness of these two mechanisms against the unexpected damages caused by natural disasters.

Mutual insurance provides consumption insurance opportunities across households through a variety of either market or non-market mechanisms. First, formal insurance markets act as effective consumption insurance by nature. Second, households can utilize credit market transactions to smooth consumption by reallocating future resources to current consumption. It can be theoretically shown that the lack of consumption insurance is compensated for by easy access to the credit market [Eswaran and Kotwal (1989)]. [6] Third, through informal arrangements of state-contingent mutual transfers among relatives, friends, and neighbors, a

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[6] However, due to various reasons, households often have limited access to credit markets [Jappelli (1990)], which can be attributed to the high information cost and/or lack of assets for collateral [Stiglitz and Weiss (1981)]. The existence of credit constraints has significant negative impacts on a household's asset portfolio choice and the risk-coping abilities [Paxson (1990); Guiso et al. (1992)]. However, Horioka and Kohara (1999), and Sawada et al. (2003) observed that less than 10% of the households face credit constraints in Japan. Therefore, the overall impact of credit constraints may not be very significant in Japan.

household can achieve consumption smoothing [Cochrane (1991); Hayashi et al. (1996); Mace (1991); Townsend (1987, 1994, 1995)].[7]   Finally, the government can also complement the risk-coping behavior of households by various methods.   Direct public transfers through means-tested targeting, tagging, or geographical/group targeting such as unemployment insurance or workfare can act as a formal safety net for households facing difficulties.

With regard to self-insurance, in the event of unexpected negative shocks, households can utilize their own financial and physical assets that have been accumulated beforehand [Guiso et al. (1992); Caroll and Samwick (1998); Zhou (2003)].[8]   Such precautionary savings can be in the form of bank deposits, cash holdings, jewelry, and physical assets such as land and real estate. In Japan, a major portion of household assets is commonly held in the form of cash and cash equivalents including bank accounts [Allen and Gale (2000); Chapter 3] as well as land and real estate.

The Full Consumption Insurance Model

First, we formulated a complete insurance market model in a pure exchange economy to characterize the role of mutual insurance [Cochrane (1991); Mace (1991); Saito (1999); Ljungqvist and Sargent (2000), Chapter 7; Townsend (1987)].   The assumption of complete markets for contingent claims may appear unrealistic; however, as explained by Mace (1991), de facto household-level insurance can be attained through a wide variety of realistic market and

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[7] It is also important to note that the self-enforcement mechanisms of this self-interested mutual insurance scheme could be sustained as sub-game perfect Nash equilibria in a repeated game framework [Coate and Ravallion (1993); Kocherlakota (1996)].

[8] Zhou (2003) observed that precautionary saving arising from earnings uncertainty comprises 5.56% of the total savings of salaried worker households and, a remarkable 64.3% of the total savings of agricultural, forestry, fishery, and self-employed households.

non-market mechanisms. Examples of such mechanisms include credit, stocks, and security markets; government's state-contingent transfers such as unemployment insurance and disaster insurance schemes; and informal transfer networks among family members or close communities. Our aim is to test the efficacy of informal/formal networks and/or markets to achieve efficient resource allocation.

Let us assume that households trade dated claims contingent upon sequence of states at time t, $s^t = [s_0, s_1, s_2, \cdots, s_t]$, where s_t refers to publicly observable states at time t. All of these claims are traded at time zero and there exists a complete set of securities for these contingent claims that are traded at the price p (s^t). In other words, households purchase a history-dependent consumption plan. Then, the optimization problem of a household, i, having concave instantaneous utility, u ($\bullet$), of the household consumption, c, can be represented as follows:

$$Max \ \sum_{t=0}^{\infty} \sum_{s^t \in \Omega^t} \left(\frac{1}{1+\delta}\right)^t \pi(s^t) u\big[c_{it}(s^t)\big]$$

$$s.t. \ \sum_{t=0}^{\infty} \sum_{s^t \in \Omega^t} p(s^t)\omega_{it}(s_t) \geq \sum_{t=0}^{\infty} \sum_{s^t \in \Omega^t} p(s^t)c_{it}(s^t),$$

(1)

where π is the probability attached to a particular history of states, ω represents the household's stochastic endowment that is exogenously given and depends on the realization of s_t, and Ω^t represents a set of the entire history of all possible states at time t. By solving this problem, we obtained a set of the first-order necessary conditions:

$$\left(\frac{1}{1+\delta}\right)^t \pi(s^t)u'[c_{it}(s^t)] = \lambda_i p(s^t),$$

(2)

for all states where λ is a Lagrange multiplier associated with the life-time budget constraint in the problem (1). Under the complete market assumption, the prices of contingent claims, $p(s^t)$, will be the same for all households in the equilibrium. We impose a common-knowledge assumption that there exists an objective probability, $\pi(s^t)$, for the occurrence of s^t. Further, assuming a common time discount rate across households in equation (2), we obtain the following:

$$\frac{u'(c_{it})}{u'(c_{it-1})} = \frac{u'(c_{jt})}{u'(c_{jt-1})}, \tag{3}$$

for all states. It should be noted that this is an efficiency condition, which can be derived from a benevolent social planner's problem, maximizing the weighted sum of people's utilities [Mace (1991)]. Let us suppose that the utility function takes the form of a constant absolute risk aversion function, i.e., $u(c_{it}) = -(1/\alpha) \exp(-\alpha c_{it})$. By arranging equation (3), we obtain:

$$\Delta c_{it} = \Delta\left(\frac{1}{N}\sum_{j=1}^{N} c_{jt}\right), \tag{4}$$

where Δ is a first-difference operator and N represents the number of households in an insurance network. The equations (3) and (4) indicate that, under full insurance, idiosyncratic household income changes should be absorbed by all other members in the same insurance network. As a result, idiosyncratic income shocks should not affect consumption changes.

On the other hand, when contingent claims are not traded among households, the security prices can differ across them. Hence, we can denote the shadow price for such claims

by $p_i(s^t)$. In this case, derived from a modified version of equation (2), we obtain the following:

$$\Delta c_{it} = \underbrace{\Delta\left(\frac{1}{N}\sum_{j=1}^{N}c_{jt}\right) + \Delta\left(\frac{1}{N}\sum_{j=1}^{N}\log p_j(s^t)\right)}_{\text{Aggregate component}} - \underbrace{\Delta\log p_i(s^t)}_{\text{Individual component}}. \tag{5}$$

Equation (5) indicates that a household's consumption level is affected by aggregate factors as well as the idiosyncratic shadow price, which is endogenously determined by individual endowments and consumption preferences.

Forms of Risk-Sharing and Self-Insurance

Even in the absence of complete markets for contingent claims, households are able to insure themselves against unexpected shocks [Saito (1999)]. Accordingly, the second model of this study conforms with the self-insurance model elaborated by Zeldes (1989), Deaton (1991), and Ljungqvist and Sargent (2000, Chapter 13). It should be noted that we augment the self-insurance model by the addition of transfer income and/or borrowing possibilities. This implies that we also relax the unrealistic assumption of a complete lack of income insurance.

A household's decision is to choose a consumption path in order to maximize the conditional expectation of discounted lifetime utility subject to usual intertemporal budget constraints with exogenous interest rate, r, and possibilities of credit constraints. If the income is stochastic, analytical solutions to this problem cannot generally be derived [Zeldes (1989)]. However, we can derive a set of first-order necessary conditions by forming a value function and

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Bellman equation to obtain an optimum solution. Let μ represent the Lagrange multiplier associated with credit constraints.[9] Combining the envelope condition derived from the first-order necessary conditions, we obtain a consumption Euler equation, which is augmented by the possibility of a binding credit constraint as follows [Zeldes (1989)]:

$$u'(c_{it}) = E_t\left[u'(c_{it+1})\left(\frac{1+r}{1+\delta}\right)\right] + \mu_{it}. \tag{6}$$

We can interpret the Lagrange multiplier, μ, as an indicator of negative welfare effects generated by binding credit constraints. It should be noted that the Lagrange multiplier, μ is a negative function of the current asset, income, and the maximum value of borrowing. It is evident that a decrease in these variables of a credit-constrained household, given other variables, leads to an increase in the marginal utility of current consumption causing, in turn, the Lagrange multiplier to increase. It is important to notice that the self-insurance model represented by equation (6) involves much weaker restrictions than the risk-sharing model of equation (3). Acceptance of equation (6) cannot rule out the rejection of equation (3) at all [Saito (1999), p.53].

If the utility function is again supposed to take the form of a constant absolute risk aversion (CARA) function, then the augment Euler equation (6) can be written as follows:

$$\Delta c_{it} = \frac{1}{\alpha}\left[\ln\left(\frac{1+r}{1+\delta}\right) + \ln(1+e_{it}) - \ln(1+\mu'_{it-1})\right], \tag{7}$$

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[9] This term, μ, is equal to the increase in the expected lifetime utility that is possible if the current constraints are relaxed by one unit. Since the household is constrained from further borrowing but not from further saving, μ enters with a positive sign.

where e is a rational expectation error and μ' is the Lagrange multiplier associated with the credit constraints standardized by the marginal utility of future consumption. From the intertemporal budget constraints, we have: $y_t^T + y_t^N - n_t = s_t + c_t$, where y_t^T, y_t^N, n_t, and s_t are transfer income, non-transfer income, a negative shock to the assets, and net savings, respectively. We assume that transfer income is determined endogenously, while non-transfer income and an asset shock are exogenously given. Since net saving flows are defined as gross asset accumulation minus gross borrowing, we have the following linearized version of equation (7) from the income and savings perspective [Flavin (1999) and Kochar (2003)]:

$$\Delta b_{it} + \Delta y_{it}^T + \Delta d_{it} = -\Delta y_{it}^N + \Delta n_{it} + \frac{1}{\alpha}\left[\ln\left(\frac{1+r}{1+\delta}\right)\right] - \mu'_{it-1} + e_{it} , \qquad (8)$$

where b and d are borrowing and dissaving, respectively. The last two terms on the right-hand side represent the effects of credit constraints and the mean zero independent expectation error. It should be noted that μ' is a negative function of initial income and assets. Therefore, for example, those who own assets or are less credit-constrained can achieve a smaller amount of left-hand side variables. Equation (8) formally shows that there are three possible risk-coping strategies against realized negative shocks, whose absolute values are represented by $-\Delta y_t^N + \Delta n_t$, namely, borrowing additional amounts, receiving transfer income, or increased dissaving.

We investigate the responses against various negative shocks caused by the earthquake. However, since we do not explicitly model the decisions in relation to various risk-coping strategies, we cannot estimate equation (8) directly. Alternatively, we examine the following three cases: first, the case with neither dissaving nor transfers; second, the case with constrained credit and dissaving; and, third, the case with binding credit constraints without transfers.

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In the first case, dissaving as a means of risk-coping is assumed to be impossible. An upper limit inherently exists on dissaving due to the fact that $\Delta d_t \leq d_t$. Therefore, in cases with a large negative income shock, dissaving proves to be ineffective as a risk-coping device. This occurs if the maximum possible amount of dissaving, d_t, is smaller than the absolute magnitude of the negative shock, $-\Delta y^N_t + \Delta n_t$. As a result, in an extreme case where $\Delta d_{it} = 0$ and transfers are limited as well, borrowing becomes the only risk-coping device:

$$\Delta b_{it} = -\Delta y^N_{it} + \Delta n_{it} + \frac{1}{\alpha}\left[\ln\left(\frac{1+r}{1+\delta}\right)\right] - \mu'_{it-1} + \varepsilon_{1it}, \tag{9}$$

where, under weaker assumptions, ε_1 will include transfers and dissaving components.

Second, we consider the case where both borrowing and dissaving are constrained and thus, a transfer income is the only instrument to cope with unexpected shocks. In this case, a transfer income is the only available risk-coping device:

$$\Delta y^T_{it} = -\Delta y^N_{it} + \Delta n_{it} + \frac{1}{\alpha}\left[\ln\left(\frac{1+r}{1+\delta}\right)\right] - \mu'_{it-1} + \varepsilon_{2it}, \tag{10}$$

where, under weaker assumptions, ε_2 will include effects through borrowing and dissaving.

Finally, we consider the case of binding credit constraints and no transfers. When the household absolutely cannot use borrowing to cope with the realized shock and thus $\Delta b_t = 0$, the household utilizes dissaving and/or transfers to compensate for the losses caused by the unexpected shock. Moreover, we assume that a transfer network is also limited and cannot be utilized effectively. The household tries to accumulate precautionary savings in advance and

employ them as a risk-coping device against unexpected events:

$$\Delta d_{it} = -\Delta y_{it}^N + \Delta n_{it} + \frac{1}{\alpha}\left[\ln\left(\frac{1+r}{1+\delta}\right)\right] - \mu'_{it-1} + \varepsilon_{3it}, \qquad (11)$$

where, under weaker assumptions, ε_3 will include borrowing and transfer components.

3. The Econometric Framework

The Full Consumption Insurance Model

In the empirical analyses, we first test the full consumption insurance model of equations (4) and (5). Following Cochrane (1991) and Ravallion and Chaudhuri (1997), an estimation equation for equations (4) and (5) can be expressed as follows:

$$\Delta c_i = \sum_{k=1}^{K} \delta_k R_k^a + X_i \gamma + u_i, \qquad (12)$$

where k is an identifier of regional insurance networks and R^a is a dummy variable, which is equal to one if i-th household is located in the region, k. We utilize the area dummies for the variable R^a to control the average consumption in equations (4) and (5). The matrix, X, comprises indicators of household income shocks and asset shocks. The final term on the right-hand side of the equation is a well-behaved error term. On comparing equations (4) and (5), it is evident that the null hypothesis of a full consumption insurance market is that all the

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elements of a vector, γ, in equation (12) are jointly zero. Unfortunately, we do not have either the consumption or expenditure data. Nevertheless, the qualitative information on consumption changes is available. From the data, we can construct a dummy variable, I^c, which takes the value of one if the household consumption has changed and the value of zero otherwise. Accordingly, we estimate the following binary-dependent variable model for equation (12):

$$I^c_i = 1 \ if \ \Delta c_i \neq 0,$$

$$I^c_i = 0 \ otherwise. \tag{13}$$

We assume that the error term in equation (12) follows normal distribution and estimate the model of equations (12) and (13) by using the probit model. Although we cannot identify the direction of consumption changes from our data, we can observe whether consumption has changed—this information is used as a dependent variable. Even in such cases, the rejection of the null hypothesis should coincide with the rejection of the necessary condition for the full insurance model, while the failure to reject does not necessarily support the full insurance model.

Forms of Risk-Sharing and Self-Insurance

The second empirical model is in keeping with Flavin (1999) and we estimate equations (9), (10), and (11). By doing so, we investigate the responses of the three risk-coping strategies, i.e., borrowing, receiving transfer income, and dissaving against various negative shocks caused by the earthquake.[10] Since the adoption of risk-coping strategies are observed as discrete

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[10] Our empirical model of self-insurance is similar to Takasaki et al. (2004), which examined the risk-coping strategies of Amazonian households in response to the flood and health shocks.

variables, based on the different risk-coping strategies, we estimate three binary-dependent variable models. Based on equations (9), (10), and (11), we assume the dependence of three different risk-coping strategies through the correlations of error terms, ε_m, m=1, 2, and 3. Under the assumption of joint normality of the error terms, our model is a three-equation multivariate (trivariate) probit model for equations (9), (10), and (11) as follows:

$$\Delta b_i = S_i \boldsymbol{\theta}_1 + H_i \boldsymbol{\beta}_1 + \varepsilon_{1i}, \tag{14}$$

$$\Delta y^T_i = S_i \boldsymbol{\theta}_2 + H_i \boldsymbol{\beta}_2 + \varepsilon_{2i}, \tag{15}$$

$$\Delta d_i = S_i \boldsymbol{\theta}_3 + H_i \boldsymbol{\beta}_3 + \varepsilon_{3i}, \tag{16}$$

$$p_{1i} = 1 \ if \ \Delta b_i > 0 \ and \ 0 \ otherwise, \tag{17}$$

$$p_{2i} = 1 \ if \ \Delta y^T_i > 0 \ and \ 0 \ otherwise, \tag{18}$$

$$p_{3i} = 1 \ if \ \Delta d_i > 0 \ and \ 0 \ otherwise, \tag{19}$$

where we need to impose the conditions var(ε_{1i}) = var(ε_{2i}) = var(ε_{3i}) = 1 for identification. In equations (14), (15), and (16), S represents a matrix of household-specific shock variables generated by the earthquake and that H is a matrix of household characteristics and other control variables, some of which are proxy variables of credit constraints. We do not directly observe the intensities of the risk-coping strategy, i.e., Δb, Δy^T, and Δd; hence, our dependent variables in equations (17), (18), and (19) express whether a household adopted a particular risk-coping device against the earthquake, which can be represented by a discrete variable, p_m, m = 1, 2, and 3. The variance-covariance matrix of ε_{mi} is symmetric and the covariances are assumed to be non-zero.

In order to estimate the parameters under this setting, we can employ the log-likelihood

function, which depends on the trivariate standard normal distribution function.   We utilize the algorithm given in Cappellari and Jenkins (2003) in order to estimate the trivariate probit model using the method of simulated maximum likelihood, also known as the Geweke-Hajivassiliou-Keane (GHK) estimator.

4. The Data Set and Empirical Results

The data set employed in this study is the survey data collected by the Hyogo Prefecture on consumer life after the earthquake, *Shinsai-go no Kurashi no Henka kara Mita Shouhi Kouzou ni Tsuite no Chousa Houkokusho* (Research Report on Changes in Lifestyles and Consumption Behavior Following Disasters), which is summarized by Hyogo Prefecture (1997).[11]   The survey was conducted in October 1996 in the Higashinada-ku, Kita-ku, and Suma-ku districts of Kobe, Akashi, and Nishinomiya cities, the six areas seriously affected by the earthquake.   The survey was completed by 1,589 women aged above 30, who were selected on the basis of a stratified random sampling scheme.   The respondents continued living in these earthquake-hit areas twenty-one months after the onset of earthquake.   This may generate a sample selection bias because several people relocated to other areas after the earthquake.   The data limitation does not allow us to correct the potential endogenous sample selection bias. Nevertheless, a survey by Hayashi and Tatsuki (1999) reveals that on an average, the degree of damage caused by the Great Hanshin-Awaji Earthquake to houses was larger for those who moved to locations outside the earthquake-hit areas than those who remained within the areas. This suggests that the empirical findings reported in this paper underestimate the negative impact

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[11] The data set 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).

of the earthquake.

The definitions and summary statistics of the variables are given in Table 2. The first key question covered in the survey was whether a household's overall consumption behavior changed prior to and after the earthquake. Approximately 62.7% of the respondents answered in the affirmative. While we cannot identify the direction of the change from our data, it is only natural to presume that, largely, the household consumption behavior was negatively affected. We use this variable as a dependent variable to test the full-insurance model. The second key variable is a binary variable, which takes the value of one if a household reported as having faced unexpected pressure to increase the expenditure in order to cope with the shock caused by the earthquake and zero otherwise. More than 80% of households reported that their expenditures increased unexpectedly due to the earthquake.

While estimating various risk-coping models, we employ binary-dependent variables of the three risk-coping strategies, i.e., borrowing, receiving public and private transfers, and dissaving.[12] Figure 1 represents the sample structure. As indicated in Table 2, approximately 20% of all respondents replied that their expenditure remained unchanged with respect to the earthquake. Nevertheless, a substantial number of households did not disclose their coping strategies against the shock caused by the earthquake. We have decided to exclude these households from our sample when we investigate risk-coping models because necessary information is not available to conduct our econometric analysis. Among the respondents who faced an increase in their expenditure due to the earthquake, approximately 25% managed to cope by changing the constituents of consumption and more than half utilized their dissavings.

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[12] The questionnaire inquired about both the most important strategy (single choice) as well as other strategies (multiple choices). The estimation described in this study only utilized the single-choice answers. Borrowings included those from financial institutions, relatives, and/or friends. Dissavings included saving for retirement, children (e.g. costs of education), houses (purchases or renovation), durables (e.g. automobiles), leisure (personal trips), and unexpected events (disasters or sickness).

Borrowing and receiving transfers were also considered as significant risk-coping strategies for approximately 10% and 12% of valid responses, respectively.

In the following section in Table 2, two income shock variables are shown.   The first is a dummy variable, which takes the value of one if there exists a household with a positive income shock caused by the earthquake; approximately 6.3% of all households fell into this category.   The second is a dummy variable, which takes the value of one for those households that face a negative income shock caused by the earthquake; such households accounted for approximately 33.9% of all households, indicating a significant portion of households with declining income.

With regard to the remaining variables, Table 2 shows the summary statistics for those households whose consumption decisions were disrupted by the earthquake.   We obtain three sets of independent variables.   The first set of variables comprises a wide variety of shock variables.   The survey was carried out in order to record the details of the damage caused to the respondents by the earthquake, such as damages to the house, the household assets, and the health of the family members.   It should be noted that, shortly after the earthquake, the local governments conducted metrical surveys and issued formal certificates for housing damages using which the households could later obtain government compensations.   Therefore, we believe that the information obtained on housing damages is fairly objective and accurate.   It should be noted that 85.6% and 86.7% of the respondents suffered from damages to their house and household assets, respectively.   These figures are indicative of the seriousness of the economic loss caused by the earthquake.

The second set comprises household characteristics.   First, the rate of housing ownership is approximately 72% prior to the earthquake, with approximately 40% among them

having outstanding housing loans. The average age of the respondents is 51 years, and a majority of the respondents are high school graduates or lower. Majority of the respondents live with their children, and the rate of joint-family/co-residence is approximately 20%. On the other hand, nearly 4% of the surveyed respondents are single.[13]

Finally, to control for the unobserved heterogeneity generated by the difference in the influences of the earthquake, we include the district-specific dummy variables. Since, among other things, the effects of the earthquake are determined by the proximity to its hypocenter, we believe that the inclusion of the district dummies is a reasonable choice.

Estimation Results: *Full Consumption Insurance*

The estimation results for the full-insurance model are shown in Table 3. We employ two different sets of shock variables, i.e., two income shock variables and a set of various shock variables, as shown in specifications (I) and (II), respectively. According to Table 3, in both cases, the joint test overwhelmingly rejects the null hypothesis of the full-consumption model.

We also test the full consumption insurance hypothesis by using sample A or sample B represented in Figure 1 [Table 3, specifications (III) and (IV), respectively]. With regard to sample A, which is composed of the households that were forced to increase their expenditure after the earthquake, the consumption of the households was significantly affected by the shocks from the earthquake. Accordingly, we reject the full insurance hypothesis strongly. However, with regard to sample B, i.e., those who were insulated from the earthquake, the joint test of zero coefficients for the full insurance hypothesis cannot be rejected at 1% level of statistical

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[13] Also, household income at the time of the survey was recorded by income category. The median annual household income is approximately between 6 million and 8 million yen (approximately USD 50,000-67,000).

significance [Table 3, specification (IV)]. This implies that the earthquake did not create serious shocks leading to a change in the consumption of these households in sample B.

In summary, we conclude that formal and informal mutual insurance mechanisms are incomplete against the earthquake, particularly for those who were forced to increase their expenditure because of the earthquake. Particularly, the magnitude of coefficients in relation to major or moderate damages to houses and household assets is considerable [specification (I) of Table 3]. This finding suggests that the lack of insurance for real estates and physical assets is particularly serious.

Estimation Results: *Forms of Risk-Sharing and Self-Insurance*

In order to estimate the trivariate probit model of risk-coping behaviors represented by equations (9), (10), and (11), we employ sample A in Figure 1. The estimation results reported in Table 4 can be summarized in the following findings. First, the column for borrowing reveals that people primarily coped with major or minor housing damages by borrowing. Additionally, we observe that borrowing was possible particularly for those who owned houses prior to the earthquake, which suggests the importance of collateral in obtaining a loan after the earthquake. Alternatively, a credit-constrained household might have been unable to utilize borrowing as a risk-coping device against negative shocks caused by the earthquake. The marginally significant and positive coefficient of the co-residence dummy variable is consistent with anecdotal evidence that the constructions of *Nisetai Jyu-taku* (two-generation houses) by using housing loans assumed great popularity among the households who lost their houses because of the earthquake.

With regard to transfers, the second column in Table 4 represents the estimation results of the transfer model. While moderate housing damages may be coped with by receiving transfers, interestingly, co-resident households, which account for 20% of all households in our sample, shy away from systematically using transfers against the earthquake shocks. We test the null hypothesis that the sum of the coefficients of moderate housing damages and co-residence is zero. The Wald statistics for this null hypothesis is 0.56, thus failing to reject the null hypothesis. This finding suggests that co-resident households are subject to a spatially undiversified informal safety network and thus, for them, transfers are ineffective risk-coping devices against shocks from the earthquake. We may conclude that the ineffectiveness of transfers, particularly for co-resident households, is one of the important reasons due to which we reject the complete consumption insurance hypothesis strongly.

With regard to the effectiveness of self-insurance, we can consider the final column for dissaving in Table 4. Since the coefficient on the dummy variable for minor household asset damage is positive and marginally significant, we may conclude that dissaving was employed as a risk-coping device against minor damages to the households' assets. Along with the finding that dissavings were utilized to compensate for smaller losses while larger shocks were coped by borrowing, our empirical findings suggest the existence of a hierarchy of risk-coping measures, starting from dissaving to borrowing. Moreover, those with outstanding housing loans prior to the earthquake were less likely to use dissaving as a coping strategy, as they probably had not accumulated sufficient precautionary savings.[14]

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[14] Interestingly, the coefficient on age squared is only marginally insignificant, suggesting that age has a nonlinear but positive impact on the probability of adopting dissaving conditional on the age of the respondent. Since the coefficients of age and age squared are 0.0449 and 0.0066, respectively, if a respondent's age is greater than 68 years, the age has a significant positive impact on the probability of adopting dissaving as a risk-coping strategy. This might be reflective of life-cycle effects. Under a finite horizon, the optimal amount of precautionary savings is a positive function of the length of the remaining life [Caballero (1990)].

Finally, estimated correlations among the error terms in the case of trivariate and probit models are shown in Table 5. The likelihood test statistics for the null hypothesis that the covariances are jointly zero, is 165.77. This result overwhelmingly rejects the null hypothesis of independent error terms, a finding that supports the adoption of the multivariate probit model. More importantly, the covariances for the error terms of borrowing and dissaving equations and of transfer and dissaving equations are both negative. These findings imply that borrowing/transfers and dissaving are substitutes. This suggests that self-insurance acts as a compensation for the lack of mutual insurance. On the other hand, the covariance of error terms of borrowing and transfers is positive, suggesting a complementary relation between borrowing and receiving transfers. This may indicate that the rich, with collateralizable assets, can obtain both loans and transfer incomes, while the poor are excluded from both a credit market and an insurance network against natural disasters. This finding is contrary to the results by Cox and Jappelli (1990) using the US data, which found that credit-constrained households are more likely to receive transfers.

4. Concluding Remarks

In this study, we examined people's safety and management of unexpected resource losses caused by a sudden earthquake that occurred in Kobe in 1995. We utilized a unique household-level data collected shortly after the earthquake. First, according to our estimation results, the complete risk-sharing hypothesis was overwhelmingly rejected. Nevertheless, even with the unavailability of complete markets for contingent claims, households are capable of

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The positive coefficient on the age variable might capture this effect—older persons are more willing than younger persons, who have more years to live, to dissave in order to cope with shocks.

adopting a wide variety of risk-coping devices against negative shocks created by the earthquake. We then investigated the effectiveness of a household's risk-coping mechanisms against the shock caused by the earthquake. Firstly, transfers are likely to be ineffective against the loss caused by the earthquake, particularly for co-resident households. Moreover, we observe that the means for coping are specific to the nature of shocks caused by the earthquake. For example, borrowing was extensively used to recover the housing damages, while dissavings were utilized to compensate for the loss of smaller household assets. Additionally, we observed that dissaving and borrowing/transfers are likely to be substitutes. These findings suggest the existence of a hierarchy of risk-coping, starting from dissaving to borrowing.

Our empirical results imply a serious lack of insurance markets for damages to real estates and physical assets. These findings are not surprising if we consider the low participation rate of earthquake insurance. Without effective ex ante measures, the actual economic losses caused by an earthquake as enormous as the Great Hanshin-Awaji earthquake prove to be extremely large for the government to support effectively. In fact, after the earthquake, the central and local governments provided the largest financial support in the history of Japan to reconstruct the affected areas and to facilitate economic recovery of the victims. Despite the extensive support provided by the government, direct transfers to victims who lost their houses were merely USD 1,000-1,500 per household due to a high rate of casualty.

In the process of preparing well-designed social safety nets against future natural disasters, there exist two policy implications based on our analyses: first, in its attempt to provide ex post public support in the event of a natural disaster, the government may create a moral hazard problem by encouraging people to expose themselves to greater risks than required [Horwich (2000)]. Our empirical results suggest that providing subsidized loans, rather than

direct transfers, to victims can be a good example of facilitating risk-coping behavior; such interventions are less likely to create serious moral hazard problems. Second, it would be imperative to design ex ante risk-management policies against the earthquake. For example, development of markets for earthquake insurance would lead to the efficient pricing of insurance premium and efficient land market prices reflective of the amount of risk involved with lands [Saito (2002)]. This development would generate proper incentives to invest in mitigations such as investments in earthquake-proof constructions against future earthquakes. These ex ante measures would significantly reduce the overall social loss caused by the earthquake. Issues such as these will be important research topics in the future.

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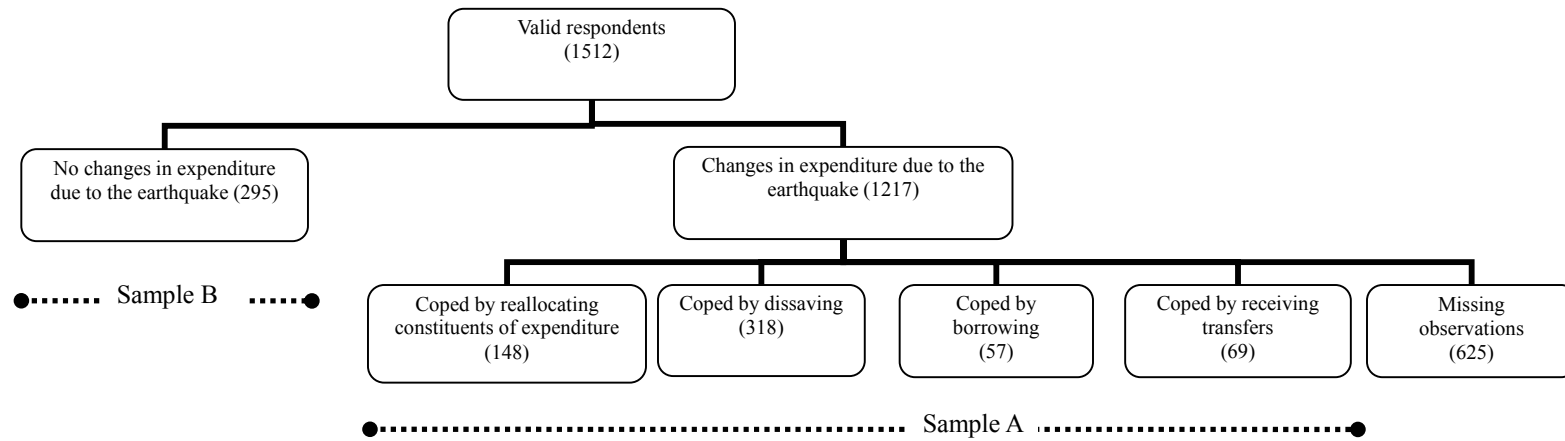
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Figure 1

The Structure of Data

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                          ┌─────────────────────┐
                          │  Valid respondents   │
                          │       (1512)         │
                          └─────────────────────┘
              ┌──────────────────────┴──────────────────────┐
    ┌──────────────────────┐              ┌──────────────────────────────┐
    │ No changes in expenditure │          │ Changes in expenditure due to the │
    │ due to the earthquake (295)│         │      earthquake (1217)            │
    └──────────────────────┘              └──────────────────────────────┘
  ●······· Sample B ······●    ┌──────┬──────┬──────┬──────┬──────┐
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| Coped by reallocating constituents of expenditure (148) | Coped by dissaving (318) | Coped by borrowing (57) | Coped by receiving transfers (69) | Missing observations (625) |

●··· Sample A ·······························●

Note: Numbers in parentheses represent the number of respondents.

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Table 1
Direct Damages from Natural Disasters

Event (Year)	Damages (US $ billion)	Loss as percentage of GDP
Chuetsu Earthquake in Japan (2004)	28.3[b]	0.6[c]
Hurricane Ivan in the United States (2004)	3[d]	0.04[d]
Earthquakes in Turkey (1999)	22[a]	5[a]
Floods in China (1998)	30[a]	0.7[a]
Hurricane Mitch in Ecuador (1998)	2.9[a]	14.6[a]
Hurricane Mitch in Honduras (1998)	3[a]	20[a]
Hurricane Mitch in Nicaragua (1998)	1[a]	8.6[a]
Hurricane Mitch in the United States (1998)	1.96[a]	0.03[a]
Floods in Poland (1998)	3.5[a]	3[a]
Great Hanshin-Awaji Earthquake in Japan (1995)	95–147[a]	2.5[a]
Hurricane Andrew in the United States (1992)	26.5[a]	0.5[a]
Cyclone/floods in Bangladesh (1991)	1[a]	5[a]
Great Kanto Earthquake (1923)	32.6[c] (in 2003 price)	43.6[c]

Source a: Table 1 in Freeman, Keen, and Mani (2003); b: Niigata Prefecture, Japan; c: the authors' estimates using information from the Cabinet Office and the Ministry of Finance of the Government of Japan; d: the authors' calculation based on the information from Risk Management Solutions (RMS).

Table 2
Descriptive Statistics of the Variables Used

Variable Description	Mean
Expenditure shock	
Dummy = 1 if the household consumption behavior changed prior to and after the earthquake	0.627
Dummy = 1 if the household faced an increase in its expenditure due to the earthquake	0.803
Coping Variables	
Dummy = 1 if reallocations of the constituents of the expenditure were the most significant means of coping (default category)	0.250
Dummy = 1 if dissaving was the most significant means of coping	0.537
Dummy = 1 if borrowing was the most significant means of coping	0.096
Dummy = 1 if receiving transfers was the most significant means of coping	0.117
Income Shock Variables	
Dummy = 1 if the income shock due to the earthquake was positive	0.063
Dummy = 1 if the income shock due to the earthquake was negative	0.339
Shock Variables	
Dummy = 1 if major housing damage was caused by the earthquake	0.174
Dummy = 1 if moderate housing damage was caused by the earthquake	0.251
Dummy = 1 if minor housing damage was caused by the earthquake	0.431
Dummy = 1 if major household asset damage was caused by the earthquake	0.094
Dummy = 1 if minor household asset damage was caused by the earthquake	0.773
Dummy = 1 if health-related shocks were caused to the family by the earthquake	0.213

Note: Numbers in parentheses represent standard deviation.

Table 2 (continued)
Descriptive Statistics of the Variables Used

Variable Description	Mean (Standard Deviation)
Household Characteristics	
Dummy = 1 if household owned a house prior to the earthquake	0.718
Dummy = 1 if household had outstanding housing loans 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 equivalent	0.243
Dummy = 1 if the highest level of education of the respondent was university or higher	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	0.198
Regional Dummy Variables	
Dummy = 1 for Higashinada-ku (default category)	0.163
Dummy = 1 for Kita-ku	0.136
Dummy = 1 for Suma-ku	0.136
Dummy = 1 for Akashi city	0.370
Dummy = 1 for Nishinomiya City	0.181
Dummy = 1 for other area	0.014

Table 3
Tests of Complete Insurance

Explanatory Variables	Specification (I)	Specification (II)	Specification (III)	Specification (IV)
Sample	All	All	Sample A	Sample B
	Coefficients (Std. Err.)	Coefficients (Std. Err.)	Coefficients (Std. Err.)	Coefficients (Std. Err.)
Income Shock Variables				
Dummy = 1 if the income shock due to the earthquake was positive	0.052 (0.146)			
Dummy = 1 if the income shock due to the earthquake was negative	0.351*** (0.077)			
Shock Variables				
Dummy = 1 if major housing damage was caused by the earthquake		0.434*** (0.155)	0.554** (0.232)	0.888 (0.719)
Dummy = 1 if moderate housing damage was caused by the earthquake		0.393*** (0.121)	0.606*** (0.203)	-0.568 (0.496)
Dummy = 1 if minor housing damage was caused by the earthquake		0.094 (0.091)	0.126 (0.174)	0.158 (0.195)
Dummy = 1 if major household asset damage was caused by the earthquake		0.602*** (0.196)	0.281 (0.300)	0.506 (0.737)
Dummy = 1 if minor household asset damage was caused by the earthquake		0.418*** (0.098)	0.108 (0.178)	0.299* (0.179)
Dummy = 1 if health-related shocks were caused to the family by the earthquake		0.359*** (0.108)	0.436*** (0.163)	0.623* (0.327)
Constant	0.442*** (0.107)	-0.201 (0.144)	-0.134 (0.251)	-0.382 (0.361)
Wald test statistics for a null hypothesis under which the coefficients on shock variables are jointly zero [p-value]	20.74 [0.00]***	74.71 [0.00]***	31.16 [0.00]***	15.01 [0.04]**
Sample size	1332	1289	512	246

Note: We employed a dummy variable as a dependent variable; it took the value of one if the household consumption behavior changed prior to and after the earthquake and the value of zero otherwise. We also included the regional dummy variables that have not been reported here. The symbol *** indicates statistical significance at the 1% level.

Table 4
Comparisons of Different Risk-Coping Strategies
(Sample A; multivariate Probit models)

Explanatory Variables	Borrowing	Receipt of Transfers	Dissaving
	Equation (9) and (14)	Equation (10) and (15)	Equation (11) and (16)
	Coefficients (Std. Err.)	Coefficients (Std. Err.)	Coefficients (Std. Err.)
Dummy = 1 if major housing damage was caused by the earthquake	1.172 (0.424)***	0.414 (0.315)	0.237 (0.243)
Dummy = 1 if moderate housing damage was caused by the earthquake	1.160 (0.386)***	0.708 (0.273)***	-0.037 (0.203)
Dummy = 1 if minor housing damage was caused by the earthquake	0.793 (0.363)*	0.017 (0.250)	0.030 (0.179)
Dummy = 1 if major household asset damage was caused by the earthquake	-0.396 (0.376)	-0.195 (0.371)	0.339 (0.292)
Dummy = 1 if minor household asset damage was caused by the earthquake	-0.424 (0.244)*	-0.305 (0.228)	0.332 (0.186)*
Dummy = 1 if health-related shocks were caused to the family by the earthquake	-0.031 (0.210)	0.242 (0.201)	0.030 (0.151)
Dummy = 1 if household owned a house prior to the earthquake	0.445 (0.229)*	-0.091 (0.227)	0.252 (0.160)
Dummy = 1 if household had outstanding housing loans prior to the earthquake	-0.091 (0.205)	0.189 (0.204)	-0.244 (0.152)*
Age of the respondent	0.104 (0.069)	0.094 (0.068)	-0.0449 (0.047)
Age squared	-0.0011 (0.00067)*	-0.0011 (0.00067)*	0.00066 (0.00047)
Dummy = 1 if the highest level of education of the respondent was high school	-0.403 (0.264)	0.121 (0.320)	-0.081 (0.212)
Dummy = 1 if the highest level of education of the respondent was junior college or equivalent	-0.214 (0.297)	0.432 (0.346)	-0.133 (0.240)
Dummy = 1 if the highest level of education of the respondent was university or higher	-0.330 (0.345)	-0.033 (0.409)	-0.012 (0.266)
Dummy = 1 if the respondent was single	0.583 (0.422)	0.220 (0.429)	-0.271 (0.312)
Dummy = 1 if the respondent lived with children	0.250 (0.197)	0.026 (0.188)	-0.263 (0.140)*
Dummy = 1 if the respondent lived with parents or grandchildren	0.325 (0.193)*	-0.471 (0.229)**	-0.030 (0.151)
Constant	-4.327 (1.835)**	-3.014 (1.780)	0.322 (1.228)
Sample size	522	522	522

Note: We also included the regional dummy variables. In this table, we reported coefficients rather than 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 5
Covariances of error terms
(Sample A; multivariate Probit models)

	Covariance	Standard Error
Covariance between ε_1 and ε_2	0.105	(0.125)
Covariance between ε_1 and ε_3	-0.808	(0.127)***
Covariance between ε_2 and ε_3	-0.924	(0.139)***

Note: * and ***, indicate statistical significance at the 10% and 1% levels, respectively.