Labor Market Dynamics after the Natural Disaster: Evidence from Post-tsunami Aceh Panel Data

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Labor Market Dynamics after the Natural Disaster: Evidence from Post-tsunami Aceh Panel Data*

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Abstract

Using field survey panel data, this paper estimates the elasticity of labor supply responses to the disaster aid intervention and the lifetime earning effect over seven years after the 2004 Indian Ocean tsunami in Indonesia. Significant extensive margin labor supply responses to labor demand shocks were found resulting from the provision of deficient boats through humanitarian aid and reconstruction programs. The return to fishing spiked high right after the tsunami due to the general equilibrium effect, in consistent with estimated shadow wages, increasing fishing intensity at the intensive margin. Random coefficient panel regression identifies a job selection process, partly driven by learning on unobserved comparative advantage, resulting in a large disparity in lifetime earnings by the job transition sequences. The result suggests that the aid had an unintended consequence in creating welfare costs for job switchers through the labor market adjustment process.

Keywords: Roy model, labor misallocation, shadow wage, disaster aid, panel data

JEL Classification: Q54, H84, J43, O12

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1 Introduction

Beyond the massive physical damages on homes, infrastructure and human life, natural disasters can undermine long-term growth by adversely affecting economic behavior of disaster victims. Deprived of their traditional source of occupation, displaced workers need to search subsistence employment in a deeply disrupted labor market and adjust work hours to meet basic consumption needs. Reconstruction work and humanitarian aid can offer an alternative sources of employment in a post-disaster phase, but lead to aid dependency and labor misallocation as unintended consequences on people's long-term livelihood.

In low-income developing economies, the primary sector like agriculture and fishery offers essential livelihood, whereas agricultural households face a greater risk of economic losses by natural disasters than non-agricultural households. Both the recovery of primary industry and the creation of non-agricultural employment through aid are essential for displaced rural families back to work (Lanjouw and Lanjouw, 2001; Foster and Rosenzweig, 2004). As identified in the literature, the primary determinants of the labor supply of agricultural households after the disaster include their comparative advantage (Foster and Rosenzweig, 1996), the ex-post risk coping motive (Kochar, 1999; Rose, 2001), and reconstruction aid (Kirchberger, 2017). Using experimental data from Indonesia, Cameron and Shah (2015) found that individuals who experienced disasters tend to be risk-averse and less entrepreneurial.[1] Understanding the labor supply behavior of disaster-affected households, and how aid impacts local labor market conditions requires rigorous empirical analysis.[2]

This paper analyzes the post-disaster labor market dynamics in the unique context of coastal fishing villages in Aceh, a province of Indonesia, which was struck by a magnitude 9.1 earthquake on December 26, 2004. For twenty years prior to the disaster, Aceh had been separated from mainland Indonesia due to an insurgency movement (*the Free Aceh Move-*

[1] There is little consensus about the direction in which natural disasters affect individual behavior. For example, in case of the 2011 Great East Japan earthquake, Hanaoka, Shigeoka, and Watanabe (2018) found men who suffered from the earthquake became more risk-tolerant. Callen (2015) looked at the case of the Indian Ocean tsunami and found that the disaster increased patience of wage workers in Sri Lanka.

[2] There are number of papers which look at the short-term effect of natural disasters on asset distribution (Carter et al, 2007), wage responses (Mueller and Quisumbing, 2011), and local labor market (Zissimopoulos and Karoly, 2010). However, there appears to be less focus on the long-term economic impacts of a disaster and the aid on the labor market.

ment) and during this period, the local market was largely cut off from the external world. Households living in the province traditionally engaged in subsistence fishing or farming. With an epicenter just off the coast of Sumatra, the 2004 earthquake and tsunami killed around 166,000 individuals in Aceh, razed virtually all of the fishing communities' economic assets, and increased inflation and unemployment. Subsequent to the disaster, the affected communities experienced the large arrival of aid activities supporting the restoration of housing, fishing boats, and public buildings. The scale of external aid was unprecedented, opening Aceh's society to the world, and creating a temporary reconstruction boom.

Given its scale, disaster aid in Aceh influenced the labor market by creating demand for local employment and changing the returns to works. As most pre-tsunami fishermen in coastal villages had lost their fishing boats (the main asset for their production), the fishing employment hinged primarily on the replacement of fishing boats distributed through in-kind aid programs. The village's local fish market was segmented and underdeveloped with imperfect competition among local suppliers. Thus, local prices were very sensitive to the influx of aid (like the general equilibrium (GE) price effect found by Cunha et al (2019) for the Mexican transfer program) and other local supply shocks. Given the full disruption of local market by the tsunami, the sector productivity shock was not negligible. Besides, the imperfect quality of boats delivered by non-governmental organizations (NGOs) (FAO, 2005)[3] created another supply shocks in the fishing sector by preventing displaced fishermen from returning to fishing, raising the market price of fishes in many communities.

Furthermore, employment opportunities related to reconstruction programs temporarily expanded, thereby shifting labor demand in the non-fishing jobs outwards. However, due to the lack of aid alignment and a short duration of labor contracts in the market employments, households face a large uncertainty in non-fishing wages, affecting their job selection behavior. [4]

[3]FAO reports that a rush of boat orders with unrealistic delivery times resulted in high incidence of the quality failure of aid boats. It would take a boat builder 12 days to make a boat before the tsunami, but the surge in demand for boats after the tsunami required that a boat be completed in one day.

[4]Although the Aceh-Nias Rehabilitation and Reconstruction Agency (BRR), a special agency established by the Presidential Regulation on April 16, 2005, was tasked to centrally oversee the aid delivery process, reconstruction efforts were largely uncoordinated with significant disparity in aid activities across districts. Also, aid was mandated to continue only for five years, thus labor demand in non-agricultural sector related

This paper evaluates the long-term effect of the aid on individuals' labor adjustments at both extensive and intensive margins and on their lifetime earnings. In the model, an individual faces uncertainty on their skills and productivity realization in each sector. A labor market equilibrium model identifies the channels how the aid affected inter-industry job movements at the extensive margin through labor demand shocks, the GE effect (change in shadow wages), and learning on unobserved comparative advantage. Using a household-level panel data over seven years, it estimates the elasticity of labor supply related to each channel and evaluates the efficiency of the labor adjustments by estimating the difference in lifetime earnings by the job transition sequences across the affected population.

The empirical section analyzes patterns of household career decisions where at least about a half of households seem to have experimented with new jobs by switching in and out of the non-fishing sector. The panel data is used to estimate a random coefficient (RC) model following Arellano and Bonhomme (2012) that identifies heterogeneous returns by the tsunami victims. The RC method allows the correlation between unobserved individual-level factors and job choices, as well as the learning effect of the unobserved heterogeneity without imposing parametric assumption. The selection model is applied to detailed production data of fishing families to estimate the selection rule and the marginal product of labor (shadow wages) over time based on an agricultural household model (Jacoby 1993). The potential endogeneity of aid allocation is also discussed.

At the extensive margin, the paper identifies significant and large labor supply elasticity to aid-related labor demand shocks in each village, caused by the provision of faulty aid boats (for the fishing sector) and inter-regional variations in the intensity of reconstruction programs (for the non-fishing sector). The returns to fishing spiked high right after the tsunami due to the GE effect, in consistent with the estimated shadow wages, creating an incentive to fish longer at the intensive margin. The RC panel model finds that the labor selection process, driven by learning of unknown comparative advantage, resulted in a significant disparity in lifetime earnings by each job sequence. Workers who restarted fishing earlier and remained in fishing recovered their livelihood faster, whereas job switchers were

to the aid ceased upon the termination of aid in 2009.

more exposed to the local market shocks resulting in depressed consumption levels relative to permanent fishermen.

The results are consistent with Belasen and Polachek (2009) and Kirchberger (2017) in finding a positive effect on earnings and a negative effect on employment in the fishing sector in the short-term. Although these differential effects dissipate over time, the result demonstrates significant disparity in livelihood recovery by job selections: displaced workers that restarted fishing earlier after a natural disaster could recover faster than job switchers. This result suggests significant welfare cost due to labor misallocations caused by job shopping and displacements. In a policy perspective, aid policy was designed more effectively with appropriate quality monitoring in villages with powerful community leaders, showing that the village governance and social capital are critical for the sustained livelihood recovery.

The paper is structured as follows. Section 2 explains data and the context. Section 3 provides theoretical framework based on a generalized Roy model. Section 4 and 5 carry out empirical analyses on job transition decisions and implications for the consumption distribution. Section 6 estimates the shadow wages to verify the general equilibrium effect. Section 7 concludes.

2 Data and Context

2.1 Aceh Panel Survey Data

The data are drawn from a large field survey of fishermen from coastal villages in Aceh, Indonesia.[5] Extensive fieldworks were conducted in the early 2005 right after the tsunami and in 2007, 2009, and 2012. The data were gathered at three levels: household, village head, and local heads of fishermen' association (*Panglima Laot*). In 2005, information on pre-tsunami household characteristics was also retrospectively collected.

The initial survey was conducted six months after the tsunami in 2005 and covered 544

[5] The data were collected for a research project ("Population and Economic Recovery in Coastal Aceh: Aid and Village Institutions" (Principal Investigator: J. Vernon Henderson, Brown University/LSE/NBER).

pre-tsunami fishermen in 111 fishing villages to benchmark destruction and village conditions. The survey covered the universe of fishing villages in the tsunami affected *kabupatens* (Banda Aceh and Aceh Besar).[6] In the fishermen's survey, the targeted population was fishing households living in these coastal villages that were heavily affected by the tsunami.[7]

The 2007, 2009, and 2012 surveys extended the coverage to 199 fishing villages in 32 subdistricts within five districts that focused on the aspects of the aid effort and institutional structure of villages.[8] Within the three districts (Banda Aceh, Aceh Besar, and Aceh Jaya) that were most heavily damaged by the tsunami, the team also surveyed fishing families, following a panel of 593 fishing families in 106 villages within 11 subdistricts.[9] The targeted population is pre-tsunami boat owners as well as new fishing families (who had never owned a boat before the tsunami but received new boats from aid agencies to be a new boat owner) living in the affected coastal villages. The survey on fishing households represented 25 percent of pre-tsunami boat owners and 45 percent of surviving boat owners in these villages. The sampling frame was drawn from the list of fishing boat owners assembled by *Panglima Laot*, and the fishing households were proportionally sampled from the list in each village. This paper uses the overlap sample of 573 households that were surveyed in all recent surveys in 2007, 2009, and 2012 to examine the labor supply behaviors and lifetime earnings of affected fishing families over time.

2.2 Context and Descriptive Evidence

2.2.1 Destruction and reconstruction: tsunami and aid effects

Table 1 presents an overview of the tsunami destruction and aid in 80 villages included in my sample. Destruction was massive with low average survival rates of pre-tsunami

[6] A district (*kabupaten*) and sub-districts (*kecamatan*) are subdivisions of a province in Indonesia.

[7] For this reason, our sample is not representative of the general population of Aceh, but it represents the average fishermen in the province and complements the sample of Indonesia's national household survey (SUSENAS).

[8] The five districts include Banda Aceh (capital city), Aceh Besar, Aceh Jaya, Aceh Barat, and Pidie.

[9] The 2005 survey focused on pre-tsunami boat owners and captains, but the 2007, 2009, and 2012 surveys added new boat owners, extending the sample coverage to 593 families by 2009. In the analysis, the main sample covers 573 families that were successfully tracked in 2012, forming the three-year household-level panel from 2007 to 2012.

households (78 percent), houses (12 percent), and fishing boats (4 percent).

The aid process in Aceh was immense and included the delivery of in-kind aid (houses and fishing boats) and the reconstruction of public buildings. Aid was mostly brought by international NGOs and the BRR, whereby latter was defined to be short-lived and was disbanded in 2009 as planned. To deliver aid, international NGOs contacted village heads to identify the recipients and mobilize local hired and volunteer labors.

Aid provided 13 fishing boats to an average village, replacing 80 percent of destroyed boats on average by 2007. Another major in-kind aid was the provision of housing, providing about 170 temporary and permanent houses to average villages (1,669 houses at maximum in some villages). The speed of housing construction was quicker and almost fully replaced destroyed houses by 2007. Lastly, 96 percent of destroyed public buildings had been replaced by late 2009. The housing and public buildings reconstruction varied by districts in Aceh (Figure 1), creating disparity in labor demand in service sectors that never existed before the tsunami.

The raw data indicate a high failure rate of boats provided through aid programs. The local head of the fishermen's association reported the average failure rate of 32 percent, showing that many boats given in aid were too lightweight or improperly designed for use and sank or fell apart after a few outings due to bad design by 2007. As indicated in Table 1, the incidence of quality failure led to a significant reduction in the supply of operational production asset given through aid, reducing the average replacement rate of destroyed capital to 58 percent. As a result, not all surviving fishing captains owned fishing boats in 2007 (67 percent at median), thus shifting the labor demand for labor hired as crew downward. This shows that boat quality failure created significant labor demand shock in the local labor market.

[insert Figure 1 and Table 1]

2.2.2 Labor market developments after the tsunami

Most pre-tsunami fishermen were displaced by the tsunami and, consequently faced significant economic hardship during the post-disaster period. Immediate humanitarian aid programs helped the poor maintain their family member's caloric consumption through cash transfers or public work programs. However, creating sustainable sources of employment in post-disaster environments needs to be the critical policy challenge for aid organizations to prevent affected population from falling into chronic poverty and persistently slow growth in labor earnings (World Bank, World Development Report 2013). The Aceh panel survey has collected data on household's primary occupation, fishing labor hours and conditions, and the participation in volunteer labors in the village. Detailed information on pre-tsunami fishing activities was also collected.

Figure 2 shows the change in the fraction of workers employed in each of the four sectors —fishing, agriculture, trade and services— and the underemployment rate from the overlap sample of 80 villages in recent three survey rounds. In the pre-tsunami period, fishing was the dominant industry in Aceh. The impact of the tsunami on fishing community was substantial: the fishing reefs and mangroves were devastated and the underemployment rate spiked up to 40 percent from the pre-tsunami level of 10 percent. During the first six months after the tsunami, about 70 percent of households worked in temporary jobs under cash-for-work programs or made a life by receiving living cost allowances from village offices, which explains the largest share of workers in the "other services" in 2005 in Figure 2. Fishing sector temporarily recovered in 2007, but by 2009 the share of fishing industry declined again.

Other service industries continued to develop due to an increased labor demand in the construction sector (called "spending effect" by Corden (1984)) for rebuilding private houses and public buildings (e.g. hospitals, schools, and mosques). While aid activities were spatially concentrated in the north-western part of Aceh, only a few agencies provided an assistance in remote areas (further down the south part in Aceh Jaya) and in the isolated northwestern island in Pulo Aceh. Except for construction business, non-fishing sector in Aceh was mainly trading (e.g., fish-related retail business and transportation) which however relies on fishing activity. The trading sector is household production on a very small scale, producing simple goods, unlike small modern factories which produce exportable goods (Foster and Rosenzweig, 2004). As most aid efforts came to an end in

2009, public investments wound down, increasing the general underemployment rate.

Table 2(a) and (b) summarizes a shift of fishing status of 573 households from 2007 to 2012. It shows a decline in the proportion of fishermen from 71 percent in 2007 to 60 percent until 2012, while a shift in the composition showing a steady decline in fishing captains and a simultaneous increase in fishing crew from 2007 to 2009. The distribution of workers became more diversified: many former fishermen, especially those with higher education and with trauma (psychological and physical reactions) from the tsunami, started working in non-fishing jobs.

Conditional on those who were fishing, table 2(b) shows the evolution of labor supply at the intensive margin. The intensity of fishing was the highest in 2007 when family spent more time in fishing with less engagement in volunteer labors. The distribution of work hours got wider after 2009 as some families continued to fish intensively while others start spending more time on volunteer labors.

[insert Table 2(a) and (b) and Figure 2]

3 Conceptual Framework: the Generalized Roy Model with Learning

This section formalizes a framework which navigates us to identify parameters that trigger the labor supply adjustments during the aid intervention period and affect lifetime earnings of disaster-affected families. The framework shapes the empirical model to test the hypotheses implied by the theory in later sections.

3.1 Set-up

Let us consider the Roy model where fishing families choose a sector which maximizes the utility (French and Taber, 2011). There are two sectors: fishing (F) and non-fishing (NF). Family enterprise owners sell fish at price p_j^F and receive revenues to pay shadow wage for family and hired workers. The non-fishing market works are mainly aid-related services with the price normalized at $p_j^{NF} = 1$. Individuals incur non-pecuniary mobility cost c_{ij} if they leave traditional fishing network. The utility function of each sector is defined as follows:

$$U_{ij}^F = p_j^F Y_{ij}^F, \quad U_{ij}^{NF} = Y_{ij}^{NF} - c_{ij} \tag{1}$$

where i and j denote household and village.

The price p_j^F is endogenously determined depending on the degree of market competition and openness in each village j. For a long period of insurgency movement, the local market in Aceh province was closed and trade with other provinces had been restricted. In the aftermath of the tsunami, the product market was devastated by the tsunami. Thus, in the initial stage, the local market condition varies by the supply of production capital (i.e., fishing boats) provided through humanitarian aid and the survival rate of local population.

As discussed in section 2, a part of production capital provided in aid was built in poor quality. Let the fraction α_j of total supply of aid boats N_j was in poor quality. As the supply of operational boats was limited, fewer people could resume fishing as boat owners. This also limited the labor demand for hired labors (as crew members). Thus, the in-kind aid supply shock led to significant reduction in fish production, making the market competition imperfect, and affected the local price.

The output price responsiveness also depends on the reservation wage in alternative jobs $\bar{w}_j$ and the strength of social capital c_{ij}. The fishing market participants decline as the reservation wage in non-fishing jobs rises and the social capital weakens, pushing up the local price. Consequently, the output price in the initial period can be denoted as $p_1^F(\alpha_j N_j, \bar{w}_j, c_{ij})$ with positive price elasticity to aid-related supply shocks in the product market ($\varepsilon_{p^F,\alpha} = \frac{\alpha_j}{p_1^F}\frac{\partial p_1^F}{\partial \alpha_j} > 0, \varepsilon_{p^F,\bar{w}} = \frac{\bar{w}_j}{p_1^F}\frac{\partial p_1^F}{\partial \bar{w}_j} > 0$) and negative price response to social capital ($\frac{\partial p_1^F}{\partial c_{ij}} < 0$).

In equilibrium, individual's participation in fishing follows the utility maximization ($U_{ij}^F > U_{ij}^{NF}$) under the endogenously determined output price in equilibrium:

$$p_1^F(\alpha_j N_j, \bar{w}_j, c_{ij}) Y_{ij}^F > Y_{ij}^{NF} - c_{ij} \tag{2}$$

Let us assume the Cobb-Douglas production function Y_{ij}^F where the factor inputs (labor L and production capital K) are complementary. Non-fishing production Y_{ij}^{NF} depends on aid agency-specific capital M that varies by district:

$$
\begin{aligned}
Y_{ij}^F &= e^{\beta^F} K_{ij}^{\gamma_1^F} L_{ij}^{\gamma_2^F} e^{u_{ij}^F} \\
Y_{ij}^{NF} &= e^{\beta^{NF}} M_j^{\gamma^{NF}} e^{u_{ij}^{NF}}
\end{aligned}
\tag{3}
$$

where u_{ij}^F and u_{ij}^{NF} are sector-specific error terms that include individual's unobserved skill θ_{ij}^s in adapting to new market environment after the tsunami, as well as productivity shocks ξ_{ij}^s where $s = F$ or NF. Own and hired labors are paid shadow wages equal to the marginal product of labors in the initial period: $w = p_1^F \frac{\partial Y^F}{\partial L}$. Conditional on those who participate in fishing, the individual optimally choose hours of of work L.[10]

The natural way to conceptualize the labor decision with individual unobserved heterogeneity is the random coefficient model (Arellano and Bonhomme, 2012). Following Suri (2011), sector-specific unobserved skills are projected to comparative advantage $\theta_{ij} = \theta_{ij}^F - \theta_{ij}^{NF}$ with a sorting parameter ϕ_j. After multiplying eq. (3) with the output price and taking logs, sector earnings are defined as follows:

$$
\begin{aligned}
y_{ij}^F &= \beta^F + p_1^F + \gamma_1^F k_{ij} + \gamma_2^F l_{ij} + (\phi_j + 1)\theta_{ij} + \xi_{ij}^F \\
y_{ij}^{NF} &= \beta^{NF} + \gamma^{NF} m_j + \theta_{ij} + \xi_{ij}^{NF}
\end{aligned}
\tag{4}
$$

where variables in capital letters in Eq. (3) are expressed in small letters after taking the natural log of each variable. Combined with Eq. (2), the extensive margin labor decision follows the reduced-form discrete choice model where the probability of fishing depends on the price elasticity to the aid-related supply shocks in each village $p_1^F(\alpha_j N_j, \bar{w}_j, c_{ij})$, along with factor inputs $X_{ij} = [k_{ij}, l_{ij}, m_j]$, unobserved comparative advantage θ_{ij}, the selection

[10] Although this section does not explicitly model the intensive margin labor decision, we look into the determinants of hours of works later in the empirical section 4.5.

rule ϕ_j, and idiosyncratic productivity shocks $(\xi^F_{ij}, \xi^{NF}_{ij})$:

$$\Pr(d_{ij}) = \Phi(\alpha_j N_j, \bar{w}_j, c_{ij}, X_{ij}, \theta_{ij}, \phi_j) \tag{5}$$

where Φ is the distribution function of normal distribution.

3.2 Dynamic job decision and learning effect

A worker seeks to maximize lifetime earnings, but faces uncertainty as to their comparative advantage and sectoral returns (similar to Gibbonz, Katz et al, 2005). The imperfect information on the matching of own abilities in each sector and on the market condition was particularly a problem in our context as the local market was severely interrupted by the tsunami.

In this context, the model is modified to incorporate the possibility of learning on unknown comparative advantage $\theta_{i1} \sim N(\mu_i, \sigma^2_{\theta_i})$ and sector productivity $\xi^s_{it} \sim N(0, \sigma^2_{\xi^s_i})$ where $s = F$ or NF. Subscript t indicates time. Subscript for district is dropped to simplify the notation hereafter in this section. Both parameters are assumed to be independently normally distributed where μ_i is prior belief on the comparative advantage and $(\sigma^2_{\theta_i}, \sigma^2_{\xi^s_i})$ are the variances of each factor. Workers update beliefs on θ_i after observing a given realization of outputs following the Bayesian learning process (suggested by job shopping model in Johnson (1978)).

$$\theta_{it+1} = \theta_{it} + \lambda^s_{it+1}(y^s_{it+1} - Ey^s_{it+1}) \tag{6}$$

The learning mobility differs by previous period's job choice d_t. The second term in the right-hand side is a surprise factor, i.e., the realization of actual outputs relative to the expected outputs. Depending on the previous period's job decision, eq. (6) can be simplified as follows:

$$\begin{aligned} \lambda^F_{it+1}(y^F_{it+1} - Ey^F_{it+1}) &= \lambda^F_{it+1}(e_{t+1} + \xi^F_{it+1}) \quad \text{if} \quad d_{it} = F \\ \lambda^{NF}_{it+1}(y^{NF}_{it+1} - Ey^{NF}_{it+1}) &= \lambda^{NF}_{it+1}\xi^{NF}_{ij} \quad \text{if} \quad d_{it} = NF \end{aligned}$$

In making job decisions, the output price is assumed to follow the first-order autoregressive process: $p^F_{t+1} = p^F_t + e_{t+1}$ where $e_t \sim N(0, \sigma^2_p)$. The surprise factor is weighted by $\lambda^F_{it+1} = \frac{\sigma^2_{\theta_i}}{\sigma^2_{\theta_i} + \left[\frac{1}{(1+\phi_{t+1})^2}\right]\left(\sigma^2_p + \sigma^2_{\xi^F_i}\right)}$ and $\lambda^{NF}_{it+1} = \frac{\sigma^2_{\theta_i}}{\sigma^2_{\theta_i} + \sigma^2_{\xi^{NF}_i}}$ which represent the quality of signals.

For example, eq (6) implies that the learning mobility from time t to $t+1$ depends on the change in output price, the level and variance of productivity shock in the fishing sector, and the sorting parameter for workers who chose to fishing in the previous period; whereas only productivity shock in the non-fishing sector matters for those working for the non-fishing sector in the previous period.

Formally, the probability of fishing in a dynamic model, equivalent to the static version in eq. (2), is defined as follows:

$$\begin{aligned}
\Pr(d_{it+1}) &= \Pr(y^F_{it+1} > y^{NF}_{it+1} - c_i) \\
&= \Pr\left(\theta_{it+1} + \frac{\xi^F_{it+1} - \xi^{NF}_{it+1}}{\phi_{t+1}} > \frac{\Omega_{it+1} - c_i}{\phi_{t+1}}\right) \\
&= 1 - \Phi\left(z_{it+1} \leq \frac{\Omega_{it+1} - c_i}{\phi_{t+1}}\right) \qquad (7)
\end{aligned}$$

where $\Omega_{it+1} = (\beta^{NF} + \gamma^{NF} m) - (\beta^F + p^F_{t+1} + \gamma^F_1 k_i + \gamma^F_2 l_{it})$ and $z_{it+1} = \theta_{it+1} + \frac{\xi^F_{it+1} - \xi^{NF}_{it+1}}{\phi_{t+1}}$. The distribution of z is a linear combination of the posterior distribution θ_{it+1} and the difference in idiosyncratic productivity shocks scaled by the selection rule ϕ_{t+1} at time $t+1$: $z_{it+1} \sim N(E(\theta_{it+1}), \sigma^2_{\theta_i} + \frac{\sigma^2_{\xi^F_i} + \sigma^2_{\xi^{NF}_i}}{\phi^2_{t+1}})$. I estimate eq. (7) in the section 4 with controls for θ_i and state dependency in determining job transitions.

The discrete choice model in eq. (7) gives additional predictions to carry over the empirical analyses in the following sections.

First, the job switching decision depends on the location of the threshold $(\frac{\Omega_{it+1} - c_i}{\phi_{t+1}})$ which is determined not only by factor inputs and social capital (k_i, l_{it}, m, c_i) but by the evolution of output prices p^F_{t+1} and the selection rule ϕ_{t+1}. While the lack of operational in-kind aid may initially raise the output price as discussed above (the GE effect), output price may stabilize in later periods as the market adjusts, shifting the threshold to right. If $\phi_{t+1} > 0$, this reduces the probability of fishing. If $\phi_{t+1} < 0$, the selection rule becomes opposite.

Subsection 4.5 examines the changes in the selection rule and the effect on intensive margin labor supply responses. The GE effect is also examined later in section 6.

Second, the probability of fishing depends on the mean of a random variable z_{it+1}. As the mean is determined by unobserved individual heterogeneity θ_{it+1} which evolves following the learning function (eq. (6)), the job transition needs to account for the learning speed of individual unobserved heterogeneity. The model predicts larger learning effect when noise parameters $(\sigma_p^2, \sigma_{\xi_i^s}^2)$ are small and the selection effect (ϕ_{t+1}) is large. I will empirically examine this later using the RC regression model in the section 5.

3.3 Earning outcomes of job selection

The job switching decision as defined in eq. (7) has significant implications for individuals' lifetime earnings. The earning outcome depends on the job sequence that can be defined as the following generalized production function:

$$\begin{aligned} y_{it} &= d_{it}y_{it}^F + (1-d_{it})y_{it}^{NF} \qquad (8) \\ &= [\beta^{NF} + \gamma_1^{NF}m + \theta_{it}] + [(\beta^F - \beta^{NF}) + (p_j^F + \gamma_1^F k_i + \gamma_2^F l_{it} - \gamma^{NF}m) + \phi_t\theta_{it}]d_{it} + u_{it} \end{aligned}$$

where $u_{it} = d_{it}\xi_{it}^F + (1-d_{it})\xi_{it}^{NF}$. The slope coefficient (the first square bracket) and the return to fishing (the second square bracket) depend on θ_i, thus eq. (8) is estimated by a random coefficient model. The model implies the following channels whose sign conditions are tested in next sections:

4 Empirical Analysis

4.1 Determinants of job transition patterns

This section estimates the determinants of labor supply responses over time at the extensive margin. Table 3 presents the frequencies of job transition sequences in the most recent three rounds of the panel survey, $(d_{i,2007}, d_{i,2009}, d_{i,2012})$ where d_{it} is 1 if households choose fishing as their primary job, 2 if other market occupations, and 0 if unemployed.

Right after the tsunami in 2005, households worked under cash-for-work programs. As communities received aid, new opportunities arose and households selected different career paths. The probit regression, defined as eq. (9) below, estimates the determinants of the job transition histories. In this regression, households are categorized into: "always fishing" (1,1,1), "permanent leavers for the market sectors" (0,0,0), or those who were unemployed at some points in their career. In estimating the model, an overlap sample of 573 household surveyed over all three rounds in 2007, 2009, and 2012 is used.

$$P(d_{ijk,2007}, d_{ijk,2009}, d_{ijk,2012}) = \Phi(\beta_0 + \beta_1\alpha_j + \beta_2\bar{w}_{jt} + \beta_3 X_{ijk} + \kappa_k) \tag{9}$$

for household i in village j in district k. $\Phi(\cdot)$ follows the standard normal distribution. The coefficient β_1 captures labor supply responses to higher fraction of poor quality aid boats in each village α_j. β_2 estimates the labor supply responses to the exposure to reconstruction aid programs $\bar{w}_{jt}$, measured by the number of overall aid projects.

X_{ijk} controls for households' characteristics on capital and efficiency labor, as proxied by their pre-tsunami status as a boat owner and captain (capturing high social status in the community), pre-tsunami ownership of large boats (capturing high fishing productivity), and the household head's education level (graduated from senior high school or above). κ_k is the district dummies that deal with district specific unobserved characteristics. To adjust seasonal working patterns (e.g., fishing in the peak or slack season), it controls for the months when interview took place.

[insert Table 3]

4.2 Identification issue: the endogeneity of aid

The identification of the effect of aid on the labor supply may be biased if the allocation of aid is endogenous (Chen, Mu, and Ravallion, 2009). The villages that received faulty boats in aid or more aid agencies operating in their community may systematically differ from others. Table 4 shows the OLS estimates that clarify what village characteristics are correlated with in-kind aid quality and overall reconstruction programs.

The result in column 1 shows that boat aid quality tends to deteriorate in remote rural areas with poor access to roads which were too dangerous for aid agencies to operate. The aid quality is also highly correlated with the types of local village heads or donors involved in the aid delivery. In-kind aid in the form of boat provision was more effective in villages with more powerful fishing community head (as *panglima teupin*), a tribal head who controls both village and fishing community affairs, while the boat quality was problematic in places where local government or the BRR delivered aid. The existence of a boat workshop in building and reparing boats also matters. The fraction of faulty boats is lower in villages with the boat workshop than villages without an access to the boat building facility.

Similarly, column 2 clarifies the characteristics of villages that receive more reconstruction aid. More aid programs existed in the location closer to the capital city and in less devastated places with higher survival rate. Communities with a powerful leader could also attract more aid to the village.

The following sections match the differences in village characteristics which are correlated with aid activities by conditioning the type of community leaders and NGOs along with district dummies and the village location to minimize the non-randomness associated with the placement of aid.

[insert Table 4]

4.3 Results: determinants of job stayers and leavers

Table 3 shows a high degree of serial correlation in job choices: more than 50 percent of households in the sample remained either in the fishing or non-fishing sector for three consecutive periods. In Table 5, columns 1-2 estimate the probability of choosing always fishing-sector while columns 3-4 estimate the probability of choosing non-fishing market jobs for all periods. Estimates in columns 1 and 3 are for the entire sample, thus mix both *involuntary* and *voluntary* job changes. To estimate the voluntary job change, columns 2 and 4 restrict the sample to households that failed to receive boats from aid agencies. As this subpopulation had no production capital to fish, the job change is due to the incentive effect aid (i.e., the GE effect) accounting for the mechanical involuntary choice depending on the receipt of the aid.

The result confirms that household job decisions were significantly responsive to the availability of good quality boats provided by aid agencies in their communities. An increase in the fraction of faulty aid boats in the village limited opportunities to be crew and reduced the probability of moving back to fishing on a permanent basis. Each column runs another regression with the fraction of faulty aid boats interacted with fishermen's pre-tsunami social status. The positive interaction term in column 2 and the negative interaction term in column 4 suggest that high status fishermen could better adjust to the aid quality related labor demand shock, but those with low status (or less productive fishermen) were less able to deal with a lack of fishing job opportunities and instead work for market jobs.

For other variables, high education dummy is significantly negative for the probability of being always fishermen, implying that families headed by high skilled individual were more likely to opt out from traditional fishing. An increase in the number of aid projects reduces the probability to be always fishermen but significantly increases the probability to be always non-fishermen. This suggests that households living in places where aid agencies were clustered benefited from ample market job opportunities. The similar estimate of the distance from Banda Aceh gives a consistent story that households living in villages near the capital city with a higher concentration of outside job opportunities are more likely to permanently work for non-fishing jobs.

Columns 5-6 estimate the probability that households experienced unemployment at some point in their career. Households with high social status and more market job opportunities faced lower likelihood of being unemployed after the tsunami (columns 5-6).

[insert Table 5]

4.4 Dynamic panel regression on job switching decisions

Table 3 also highlights many job switchers across sectors, i.e., those with (2,1,1), (2,2,1), (1,1,2,), (1,2,2), (1,2,1), (2,1,2), or experienced unemployment in their career. Using the panel sample 573 households, a random effect panel regression estimates the determinants of the job switching behavior:

$$P(d_{ijkt}=1)=F(\beta_0+\beta_1 d_{ijkt-1}+\beta_2\alpha_j+\beta_3\bar{w}_{jt}+\beta_4 X_{ijk}+\kappa_k+\theta_i) \tag{10}$$

where d_{ijkt} is 1 if households worked for fishing sector at time t. Columns 1 and 2 of table 6 present dynamic panel regression estimates under two parametric assumptions on a distribution function $F(\cdot)$ with controls of the type of community leaders and NGOs that are correlated with the placement of aid. The model allows for both state dependence and individual unobserved heterogeneity θ_i, such as unobserved skill factors, mental conditions, or risk preferences that may drive job switching decision. We allow the serial correlation of θ_i later in section 5.

In both random effect logit and probit specifications, the estimated state dependence parameter β_1 is quite large. This is consistent with the learning function (eq. (6) in subsection 3.2) and captures the serial correlations in d_{it}, p_t^F, and θ_i. The estimated coefficients on each covariate show that households social status (as pre-tsunami boat owners and captain) and larger family size tend to increase the probability of switching into fishing, while older aged household heads with higher education are more likely to work in the non-fishing jobs. As found in Table 5, an increase in the fraction of poor quality aid boats in the village significantly reduces labor demand for fishing in the local labor market, thus reducing fishing households at the extensive margin.

The random effect variance $\ln(\sigma^2_{\theta_i})$ is large and contributes to large proportion of the total variance, showing the significance of household unobserved heterogeneity. The error correlation ρ shows strong persistence in the unobservable factors in determining the job transitions.

[insert Table 6]

4.5 Labor supply responses at the intensive margin

Previous subsections show how labor was reallocated across sectors at the extensive margin after the tsunami. Another margin of interest is the changing work intensity of affected households for day-to-day works compared to their leisure or volunteer works for rebuilding their community after the tsunami. Volunteer labor included local public labor activities, assembled several times a month by the village head, for maintenance, clean-up and renovation of public capital.

A standard consumer optimization over consumption and leisure predicts backward-bending labor supply curve as the real wage rises (Blundell and MaCurdy, 1999). As the wage level is close to zero right after the tsunami, substitution effect dominates as shadow wages in fishing rise for the GE effect, creating a stronger incentive to fish for longer hours. In reality, however, those with stronger altruistic motive to neighbors may prefer to allocate longer hours to volunteer for community works. Volunteer days are also viewed as informal taxation, and regular participations in volunteer labors might be required as a key part of village life (Olken and Singhal, 2011; Freire, Henderson, and Kuncoro, 2017). This subsection estimates the elasticity of their time allocation for day-to-day works in response to the aid-related labor demand shocks.

The panel survey gathered data on hours of fishing during the most recent trip at each interview point, conditional on their job decision at the extensive margin, in 2007-12. Although hours of works are not observed in the manufacturing and service sectors, the survey provides data on the number of volunteer labor days per week.

Column 1 of table 7-(a) uses the random effect panel model that estimates the log of fishing hours on the same covariates as used in eq. (10). It estimates the labor supply elasticities at the intensive margins on average while accounting for state dependence for those participated in fishing. Column 2 is the cross-sectional estimates for each survey round from the Heckman selection estimates that address the selectivity bias.

Conditional on those who chose to fish, aid recipients, especially youth, spent longer hours on fishing. Older household heads fished less due to their physical constraint. Once the inverse-Mills ratio (the sorting parameter ϕ in eq. (4)) is controlled, the dummy variable for the recipient of boat aid is negatively signed, highlighting the significant selection effect due to unobservable factors. About 10 percent of households in the present sample self-financed a boat when they failed to receive a boat through aid. The negative aid effect on fishing hours under the Heckman selection model imply that those who purchased boats worked longer than the recipients of boat aid.

Interestingly, the selection rule changed in sign from 2007 to 2009-12 which indicates that the composition of fishermen changed in later years. The positive inverse-Mills ratio in 2007 indicates the positive selection that those chose to fish worked longer. The selection term gets negative in later years, showing that the average intensity of fishing gets weaker as the economy recovers back to the normal.

Household in less affected communities with higher survival rates fished less intensively than more affected areas after the tsunami. This may reflect the general equilibrium effect caused by the tsunami and aid which raised shadow wages for fishermen in the earlier period, thus giving stronger incentive to fish more intensively. Later in section 6, I estimate the shadow wage to empirically test this conjecture.

Table 7-(b) estimates the Tobit model that regresses the number of volunteer labor days (per week) on same covariates as included in eq. (8). While none of the household characteristics are significant, the result shows that households in more devastated villages with lower survival rate of households contributed more to volunteer labors to rebuild local public goods. This reflects strong altruism to support neighbors in Aceh villages after the tsunami. The community leader type also matters, and those living in villages governed by tribal leader were more organized to help each other through the volunteer labor activities.

[insert Table 7]

5 Heterogeneity in consumption level by job transition sequences

Which career transition sequences as found in section 4 resulted in faster recovery in the living standard? Job turnover and household consumption level are closely related. Job switching into a better occupation generally increases earnings, whereas unemployment leads to income losses. In the rural economy without social insurance system, job displacements by natural disasters significantly lower income level by destroying production capitals, thus labor adjustments play an important role in mitigating the adverse welfare impact.[11]

As implied by the literature, raw data show that consumption distribution has widened over time in Aceh based on weekly market expenditure data that I deflate by the consumer price index in Aceh province from the BPS (*Badan Pusat Statistik*). The increase in consumption inequality will be partly explained by factors specific to regions or occupations.

Table 8 summarizes the inequality decomposition of the real market expenditure per household member (measured by *the Generalized entropy index* with the inequality sensitivity parameter (α) of two, and *the Atkinson inequality index* with the inequality aversion parameter (e) of two) into between-group (by occupation status or sub-districts) and the within-group components. The between-group inequality explains only a small portion of the overall inequality, while the within-group inequality explains most variations in overall inequality dynamics. This suggests that household-specific factors made significant contribution to the earning dynamics, including their labor supply responses at the extensive and intensive margins.

[insert Table 8]

5.1 Estimation of heterogeneous returns by job sequences under the RC panel model

As the benchmark, table 9 first shows the OLS panel regression estimates on the average consumption level for stayers (1,1,1) and leavers (0,0,0) relative to job switchers (in column 1), and the average return to fishing in the random effect and fixed effect models (in columns 2 and 3). The estimates imply that permanent leavers to manufacturing and service sectors

[11] As discussed in the previous literature, the consumer welfare level will be heterogeneous in the rural economy context depending on how rural households responded in the labor market to smooth consumption against the income shocks (see Kochar, 1999; Rose, 2001; Jayachandran, 2006, Belasen and Polachek, 2009, and Mueller and Quisumbing, 2011).

tend to fare better with higher living standard on average, while the average return to fishing is marginally positive. On average, families with younger household heads and land owners fared better with higher per capita consumption level. An increase in faulty aid boats reduced the average household consumption level, although not significant, due to the negative income shock. Intensive reconstruction works led to higher standard of living on average. The average consumption level significantly drops after the aid process completed in 2012.

The average return, however, gives a partial picture as the return to job choice varies by household's job selections. The dynamic panel regression in section 4.4 underscores that household-level unobserved factors specific to each sector drove the job transitions. The intensive margin estimates in section 4.5 also shows that the differential responses in time allocation for fishing against volunteer labors depend on observed and unobserved household characteristics. Each labor supply decisions may yield heterogeneous returns.

In this regard, the RC panel data model (Arellano and Bonhomme, 2012) is used to estimate the distribution of returns to the labor supply. The job selection depends on the utility maximization: $d_{it} = 1[U_{it}^F > U_{it}^{NF}]$. The RC model as derived in eq. (8) non-parametrically estimates the distributional effect of fishing decision without imposing any restrictions on $(\delta_{i0}, \delta_{i1})$:

$$y_{it} = \delta_{i0} + \delta_{i1} d_{it} + \delta_{i2} z_{it} + \varepsilon_{it} \tag{11}$$

where y_{it} is household i's per capita real market expenditure (in natural log). d_{it} is one if households chose to work for fishing. Eq. (11) allows the correlation between the random coefficients $(\delta_{i0}, \delta_{i1})$ and d_{it}. As derived in eq. (8), δ_{i0} includes an individual-specific parameter θ_i as well as the inter-village variations in aid activities m_j; while δ_{i1} captures the sorting process $\phi\theta_i$, individual-level variations in capital and labor, and output price p_t^F. z_{it} includes household head's age, wife's survival, land ownership, the receipt of boat aid, and pre-tsunami social status as boat owner and captain. Distance from the capital city and district dummies are also included. Standard errors are clustered at the district level and bootstrapped with 1,000 replications.

[insert Table 9]

5.2 Results

Assuming the strict exogeneity of fishing decision ($d_{it} \perp \varepsilon_{it}$), figure 3 shows the quantile estimate of the return to fishing $\hat{\delta}_{i1}$. About two-third of households experienced positive returns by fishing.

Next, individual effects (δ_{i0}, δ_{i1}) is now allowed to differ by job sequences. Besides the estimates under the strict exogeneity in column 1 of table 10, the result in column 2 allows the correlation between d_{it} and $\Delta\varepsilon_{it}$ under sequential orthogonality assumption $E(\varepsilon_{it}|\delta_{i0}, \delta_{i1}, d_{it}, d_{it-1}, \cdots) = 0$. Under the sequential orthogonality, individuals may react to an unexpected income shocks every period by changing jobs, thus learning to shocks in each period is captured.

The result shows that the average effect varies a lot by job transition sequences. When learning is allowed, the dispersion in the average earning gets wider. The average earning is the highest for those who selected into fishing from the initial period ((1,0,·) or (1,·,0)), whereas it gets negative or statistically zero for workers in other occupations. The result also shows that the average return to fishing gets significantly lower in the later stage as shown by the negative estimates for workers who remained in the fishing sector in 2012 ((·,0,1) or (0,·,1)). Instead, workers who remained in the non-fishing market sector, mainly as small enterprise owners, received relatively higher earnings in the later stage.

This result implies that the relative return to fishing was higher right after the tsunami but decreased over time, while workers who succeeded in continuing their small business could earn higher earnings in the later years.

[insert Table 10 and Figure 3]

6 Estimation of shadow wages: the general equilibrium effects

Why was fishing more profitable than non-fishing right after the tsunami? One potential channel is that workers in the fishing sector experienced significantly higher growth in earnings after the tsunami as similarly found after the 2006 Yogyakarta earthquake in Indonesia (Kirchberger, 2017). Although no wage data exist in the survey, shadow wages can be calculated as the marginal product of labor based on the Cobb-Douglas (CD) or the Translog production function (Jacoby, 1993; Trung and Oostendorp, 2017) based on the Heckman selection model (with the square and interaction terms for the Translog production):

$$\begin{aligned}\ln(R_i|L_i, K_i, X_i, d_i = 1) = \beta_0 + \beta_1 \ln(L_i) + \beta_2 \ln(L_i)^2 + \beta_3 \ln(K_i) \\ +\beta_4 \ln(L_i) \times \ln(K_i) + \beta_5 X_i + \gamma\phi(z_i\delta) + \varepsilon_i \qquad (12)\end{aligned}$$

where R_i is fishing revenues (in real Rupiah value, deflated by provincial CPI), K_i is production capital as measured by length and engine capacity of fishing boats and L_i is hired labor in the fishing production. X_i controls for household head's age, education level, family size, pre-tsunami fishermen social status, seasonality, and district dummies. $\phi(z_i\delta)$ is the inverse Mills ratio from the selection equation. In agrarian market, credit transactions with middlemen lock households to fishing, restricting their intersectoral mobility. Outstanding credit loans with the middlemen is not significantly correlated with weekly fishing returns in each survey round, thus is used as an exclusion restriction in the selection equation.

The return to fishing may also rise if local prices of fishes increase in response to shocks occurred in Aceh's fish market. If the community received fewer operational boats or the survival rate of population was smaller, survived fishermen who succeeded in owning a boat had stronger bargaining power when selling fish catches in the local fish market. If the market is segmented where fishes are locally consumed, the shortage of fish production leads to higher sales price, thus boat owners in the segmented market likely receive higher returns by selling fish catches. On the other hand, the sensitivity of fish prices to local shocks will be smaller in the community with an integrated fish market where fishes are exported to foreign communities.

From the fishermen community survey, table 11 shows the evolution of the fish market structure in Aceh from pre-tsunami period to 2012. Fish catches have been mainly sold through middlemen and locally consumed, showing that the fish market was highly segmented in most of the communities in Aceh. After 2009, some communities, mainly in Pulo Aceh and Aceh Jaya, started to export fish catches to other provinces or foreign countries. In the communities with the segmented fish market, data also confirm that the unit prices of main fishes (tuna and small fishes) were significantly higher right after the tsunami in 2007 compared with later years. To account for the difference in the price sensitivity to local shocks by the market structure, I estimate the shadow wages for the overall sample as well as the sub-sample of a segmented community.

Based on production function results of table 12, the shadow wage is calculated as $\hat{\beta}_1 R_i/L_i$ for the CD regression and as $[\hat{\beta}_1 + 2\hat{\beta}_2 \ln(L_i) + \hat{\beta}_4 \ln(K_i)]R_i/L_i$ for the Translog regression for each year. In both production function specifications, figure 4-(a) shows that shadow wages were the highest right after the tsunami. Shadow wages appear to get particularly high in the early period of 2007, while the distribution of shadow wages shifts left in later years, especially after the aid completed in 2012. Figure 4-(b) shows the shadow wages estimated only for the segmented fish market, confirming the same pattern.

As a robustness check, eq. (10) is estimated using the household fixed effect panel regression. The panel data allows me to decompose the error structure into household and year fixed components and an idiosyncratic error term ($\varepsilon_{it} = \eta_i + \delta_t + \upsilon_{it}$). The fixed effect regression can remove household unobserved heterogeneity that could potentially be correlated with the intensity of fishing labors. Column (4) of table 12 shows the fixed effect regression estimates under two production function specifications, controlling for district-specific time trends that account for some serial correlations in productivity shocks. The distribution of shadow wages is similarly calculated using the panel regression estimates in figure 4-(c). Even after household-level unobserved heterogeneity is controlled, the shadow wage is the highest in 2007 and declines in later years, confirming the Heckman selection results. As found in section 5.2, this gives consistent evidence that workers who engaged in fishing received significantly higher shadow wages in the aftermath of the tsunami.

Higher return to fishing, backed by a spike in shadow wages, reflects that more workers moved to non-fishing employments as discussed in subsection 2.3. The reduction in fishing labor supply relative to labor demand increased the equilibrium shadow wage for fishing as predicted in the hypothesis 4 in section 3. Higher return to fishing in the early period also reflects the fact that a spike in shadow wages resulted in stronger incentive to work longer on the ocean at the intensive margin as found in section 4.5.

[insert Tables 11 and 12, and Figure 4]

7 Conclusions

After the large displacement in Aceh's local labor market brought about by the 2004 Indian Ocean tsunami, what determined the long-term labor market adjustment process and explained the disparity in lifetime earnings? What determined tsunami-affected family's labor supply behavior and work attitude? Although disaster aid program offered various job opportunities, precisely how aid programs affect employment dynamics in the disaster-affected economy remains an open question. Despite its policy relevance, little evidence exists on the effects of the aid on the long-term labor market dynamics. This paper provides the micro-evidence in this area by using the panel data of fishing families surveyed in Aceh's devastated coastal villages that allows us to track the transition of their job choices and work intensity over seven years.

This paper finds that physical damage inflicted by the tsunami was mitigated by aid to some extent in the short-run, and had growth implications through victims' behaviors in the long-run. Specifically, in-kind aid and overall reconstruction aid affected the labor demand in the fishing and non-fishing industries, determining fishermen's initial occupations at the extensive margin. Conditional on the labor demand shock by the aid and demographic controls, panel regressions show that fishermen's job selection was significantly driven by unobserved comparative advantage. The paper finds that the selection rule into fishing was positive right after the tsunami in 2007 but became negative in later period. Some fishing families worked more intensively in response to higher shadow wages right after the tsunami and benefited significantly in terms of higher living standards.

While the return to fishing recovered fast from the early stage as a result of aid delivery, the expansion of the non-fishing market sector had a temporary effect: workers who restarted fishing earlier recovered their livelihood levels faster, while income levels of job switchers were more exposed to the change in local labor market conditions.

As found in the wake of other disasters, the post-tsunami Aceh panel data confirms a pattern of an enormous labor market displacement followed by eventual recovery. The unique finding from the micro-level panel surveys from Aceh is the heterogeneity in the livelihood recovery rate from the job selection process. Fast growth in shadow wages for fishing families indicates the resilience of incomes of households that remained in the fishing industry. This evidence suggests that the primary industry offers an important source of employment for the survival of displaced families after natural disasters. In a policy perspective, the result implies that aid policy was designed more effectively with appropriate quality monitoring in villages with powerful community leaders, showing that the village governance is critical for the sustained industrial recovery.

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Table 1: Destruction of population, houses, and capital: village characteristics

	Average	SD	Min	p50	Max
Survival of population					
Pre-tsunami households	239.6	381.3	30	169.5	3312
Post-tsunami households	144.5	108.0	27	114.5	740
Survival rate of households	0.78	0.24	0.06	0.81	1.22
Pre-tsunami fishing captains	29.4	39.2	0	17	250
Post-tsunami fishing captains	14.0	13.9	0	9.5	64
Survival of houses					
Number of houses pre-tsunami	257.9	721.8	32	120	6500
Number of houses post-tsunami	18.8	55.6	0	0	368
Survival rate of houses	0.12	0.29	0.00	0.00	1.00
Number of aid houses built	171.4	199.2	0	131	1669
Replacement rate	*1.1*	*0.7*	*0.0*	*1.0*	*5.4*
Survival of fishing boats					
Number of boats pre-tsunami	25.5	22.5	0	20	113
Number of boats post-tsunami	1.2	4.2	0	0	29
Survival rate of boats	0.04	0.14	0.00	0.00	0.85
Number of aid boats provided	12.9	14.9	0	7	74
Replacement rate	*0.79*	*0.92*	*0.0*	*0.6*	*5.7*
Fraction of bad aid boats	0.32	0.42	0.0	0.0	1.0
Replacement rate (excluding bad aid boats)	*0.58*	*0.88*	*0.0*	*0.3*	*4.7*
Demand and supply of fishing boats in 2007					
Number of operational boats/surviving captains 1/	0.77	0.80	0.00	0.67	3.67

Note: replacement rate is the number of aid (boat or houses) divided by pre-tsunami assets lost by the tsunami. Aid houses include both temporary and permanent housing.

1/ Total number of available boats (those which were survived or received in aid) divided by the number of survived captains in 2007.

Table 2(a): Breakdown of primary job of household heads
(In percent)

	2007	2009	2012
Fish (Captain)	65.1	51.4	49.9
Fish (Crew)	6.5	12.8	10.9
Other fishing	0.5	1.8	0.7
Agriculture	4.1	7.7	14.4
Construction	4.8	3.7	2.5
Trade	7.8	10.4	10.3
Services	7.1	8.6	8.2
Unemployed/In school	4.2	3.7	3.0
	100	100	100

Note: Other fishing includes aquaculture and fish processing; trade includes fish related trader, coffee shop, retail shop, restaurant, transportation, and technician (boat builder, mechanics, plumber, electrician, carpenter); service sector includes private service (banker, administrative office), public service (government official, teacher, doctor, police), and manufacturing.

Table 2(b): Extensive and intensive margin labor supply responses

	Pre-tsunami	2007	2009	2012
Extensive margin response				
Fish	1.00	0.71	0.65	0.60
Intensive margin response				
Fishing hours	10.31	9.24	8.72	8.54
	(3.59)	(2.86)	(4.03)	(4.12)
Number of fishing trips	0.85	5.81	4.45	4.90
	(1.45)	(0.67)	(2.15)	(1.88)
Volunteer labor day	…	0.56	1.08	0.95
	…	(0.62)	(1.07)	(1.90)

Note: standard errors in the brackets.

Table 3: Job transition sequence frequencies

2007	2009	2012	Freq.	Percent	Category
0	0	0	2	0.35	Experienced unemployment
0	0	1	0	0.00	Experienced unemployment
0	0	2	5	0.87	Experienced unemployment
0	1	0	1	0.17	Experienced unemployment
0	1	1	10	1.75	Experienced unemployment
0	1	2	3	0.52	Experienced unemployment
0	2	0	0	0.00	Experienced unemployment
0	2	1	1	0.17	Experienced unemployment
0	2	2	7	1.22	Experienced unemployment
1	0	0	6	1.05	Experienced unemployment
1	0	1	3	0.52	Experienced unemployment
1	0	2	4	0.70	Experienced unemployment
1	1	0	10	1.75	Experienced unemployment
1	1	1	240	41.88	Always fishing
1	1	2	53	9.25	A single transition into non-fishing
1	2	0	6	1.05	Experienced unemployment
1	2	1	27	4.71	Multiple transitions
1	2	2	58	10.12	A single transition into non-fishing
2	0	0	0	0.00	Experienced unemployment
2	0	1	0	0.00	Experienced unemployment
2	0	2	4	0.70	Experienced unemployment
2	1	0	1	0.17	Experienced unemployment
2	1	1	36	6.28	A single transition into fishing
2	1	2	12	2.09	Multiple transitions
2	2	0	3	0.52	Experienced unemployment
2	2	1	24	4.19	A single transition into fishing
2	2	2	57	9.95	Always non-fishing
			573	100	

Category: 0=unemployed, 1=fishing, 2=other work

Table 4: Determinants of in-kind aid quality and reconstruction aid exposures
(village level regressions)

	(1)		(2)		(3)	
Dependent variable	Fraction of faulty aid boats		Ln(number of aid projects)		Ln(number of NGOs)	
Governed by tribal fishermen leader (*panglim teupin*)	-0.145**	-0.191***	0.183*	0.174*	0.152***	0.163***
	[0.031]	[0.017]	[0.059]	[0.057]	[0.001]	[0.008]
Pre-tsunami village head remained in the office	0.041***	0.048***	0.001	-0.012	-0.064***	-0.079**
	[0.001]	[0.005]	[0.019]	[0.024]	[0.000]	[0.010]
Boat donor: BRR/Government	0.212**	0.149**	-0.114	-0.093	0.051	0.089*
	[0.034]	[0.024]	[0.045]	[0.042]	[0.036]	[0.024]
Boat NGO: Triangle (TGH)	-0.117**	-0.069	-0.029	-0.054	0.018***	-0.034
	[0.015]	[0.025]	[0.022]	[0.025]	[0.000]	[0.014]
Boat NGO: International Medical Corps (IMC)	0.323***	0.404***	0.315***	0.242***	0.076	-0.03
	[0.008]	[0.008]	[0.009]	[0.015]	[0.038]	[0.038]
Boat NGO: Oxfam	-0.303	-0.289	0.235	0.227	0.208	0.192
	[0.321]	[0.322]	[0.307]	[0.315]	[0.490]	[0.511]
Boat workshop in the village	-0.117**	-0.084**	0.105*	0.092*	0.210*	0.182
	[0.024]	[0.009]	[0.028]	[0.027]	[0.069]	[0.069]
Log(distance to Banda Aceh)	0.121***	0.050**	-0.225***	-0.183***	-0.300**	-0.216***
	[0.000]	[0.008]	[0.018]	[0.015]	[0.034]	[0.017]
Survival rate of households	-0.116		0.028		0.155	
	[0.050]		[0.033]		[0.092]	
Survival rate of houses		0.196***		-0.227***		-0.268***
		[0.004]		[0.010]		[0.002]
Constant	0.063***	0.165***	3.915***	3.854***	3.103***	3.018***
	[0.004]	[0.008]	[0.082]	[0.096]	[0.041]	[0.059]
Observations	80	78	80	78	80	78
R squared	0.270	0.293	0.101	0.113	0.179	0.190
District fixed effects	Y	Y	Y	Y	Y	Y

*** p<0.01, ** p<0.05, * p<0.1; Robust standard errors clustered at the district level are in parentheses.

Table 5: Determinants of job transition

	Always fishing: (1,1,1)				Permanent switchers: (2,2,2)				Experienced unemployment	
	(1)		(2)		(3)		(4)		(5)	(6)
Boat aid recieved	0.277***	0.275***			-0.120***	-0.119***			-0.001	
	[0.008]	[0.007]			[0.018]	[0.020]			[0.025]	
Fraction of faulty aid boats in the village	-0.115	-0.265**	-0.456***	-0.562***	0.035***	0.141***	-0.025	0.392***	0.042	0.049
	[0.132]	[0.132]	[0.111]	[0.166]	[0.011]	[0.024]	[0.030]	[0.060]	[0.037]	[0.067]
--- x Pre-tsunami boat owner and captain		0.181***		0.149**		-0.144***		-0.838***		
		[0.005]		[0.075]		[0.042]		[0.045]		
Pre-tsunami boat owner and captain	0.058*	0.017	0.096*	0.076	0.008	0.049***	-0.016	0.167***	-0.039**	-0.105**
	[0.034]	[0.034]	[0.053]	[0.060]	[0.013]	[0.018]	[0.028]	[0.025]	[0.019]	[0.049]
Pre-tsunami large boat	0.002	0.002	0.132**	0.134**	0.030***	0.027***	0.106*	0.084	-0.005	-0.015
	[0.026]	[0.024]	[0.066]	[0.067]	[0.007]	[0.008]	[0.060]	[0.074]	[0.041]	[0.050]
High education dummy	-0.111**	-0.108*	-0.156	-0.156	0.036	0.038	0.055	0.074	0.003	0.024***
	[0.055]	[0.056]	[0.160]	[0.158]	[0.047]	[0.049]	[0.114]	[0.122]	[0.016]	[0.000]
Log(number of aid projects)	-0.050**	-0.050**	-0.326**	-0.313**	0.062***	0.065***	0.160***	0.167***	-0.039***	0.071***
	[0.025]	[0.025]	[0.131]	[0.137]	[0.011]	[0.010]	[0.034]	[0.020]	[0.009]	[0.024]
Log(distance to Banda Aceh)	-0.175***	-0.171***	-0.278**	-0.277**	0.024**	0.024***	0.201***	0.251***	-0.101***	-0.124***
	[0.028]	[0.027]	[0.128]	[0.129]	[0.009]	[0.007]	[0.066]	[0.069]	[0.025]	[0.030]
Survival rate of households	0.445***	0.431***	0.127	0.109	0.066*	0.085***	0.192***	0.360***	0.094**	-0.062
	[0.086]	[0.088]	[0.264]	[0.271]	[0.035]	[0.033]	[0.041]	[0.067]	[0.047]	[0.086]
Observations	469	469	125	125	469	469	127	127	469	125
Sample	All	All	No aid received	No aid received	All	All	No aid received	No aid received	All	No aid received
District fixed effects	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Seasonality is controlled	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Controls for aid placement 1/	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

*** p<0.01, ** p<0.05, * p<0.1; All estimates are marginal effects of probit model. Robust standard errors clustered at the district level are in parentheses. Always non-fishing (2,2,2) is one for those who continued to work in manufacturing or service sectors (outside fishing or agricultural sectors).

1/ Control variables include all village-level characteristics (such as village leader and donor types, the existence of boat workshop in the village) included in Table 4.

Table 6: Determinants of dynamic job decision at the extensive margin

	Outcome variable: Fish	
	RE Logit	RE Probit
	(1)	(2)
Fish(t-1)	0.783**	0.459**
	[0.398]	[0.225]
Boat aid recieved	1.142***	0.662***
	[0.005]	[0.002]
Fraction of faulty aid boats in the village	-0.542*	-0.319**
	[0.289]	[0.162]
Household head age	-0.055***	-0.032***
	[0.005]	[0.003]
Pre-tsunami boat owner and captain	0.459***	0.267***
	[0.078]	[0.049]
Pre-tsunami large boat	-0.187	-0.109
	[0.223]	[0.131]
High education dummy	-0.605	-0.353
	[0.431]	[0.246]
Log(number of aid projects)	-0.346*	-0.202*
	[0.198]	[0.114]
Log(distance to Banda Aceh)	-0.706***	-0.412***
	[0.201]	[0.114]
Survival rate of households	1.564***	0.912***
	[0.196]	[0.111]
Log(family size)	0.534***	0.306***
	[0.136]	[0.073]
Post-2012 dummy	-0.274	-0.162
	[0.215]	[0.120]
Constant	3.370***	1.969***
	[0.834]	[0.470]
$Ln(\sigma 2)$	0.525**	-0.539**
	[0.236]	[0.215]
ρ	0.339***	0.369***
	[0.052]	[0.050]
Log-likelihood	-638.359	-637.878
Observations	1,202	1,202
District fixed effects	Y	Y
Controls for aid placement	Y	Y

*** p<0.01, ** p<0.05, * p<0.1; Robust standard errors clustered at the district level are in parentheses.

Table 7: Determinants of labor supply behavior at the intensive margin

(a) Fishing hours

Dependent variable	Log(fish hours)			
	(1)		(2)	
	All years	2007	2009	2012
Log(fish hours (t-1))	0.087***	...	...	...
	[0.017]	...	...	...
Boat aid recieved	0.001	-0.010	-0.133***	-0.194***
	[0.022]	[0.010]	[0.023]	[0.005]
Fraction of faulty aid boats in the village	-0.010	0.000	0.085	-0.136***
	[0.114]	[0.020]	[0.106]	[0.024]
Household head age	0.001	0.074**	0.168***	0.324***
	[0.001]	[0.031]	[0.049]	[0.039]
Pre-tsunami large boat	-0.039***	0.027**	0.136***	0.078**
	[0.009]	[0.012]	[0.040]	[0.031]
Log(number of aid projects)	0.010	-0.040	0.028	-0.067**
	[0.021]	[0.025]	[0.018]	[0.030]
Survival rate of households	-0.044	-0.216	-0.197	-0.290***
	[0.207]	[0.164]	[0.125]	[0.066]
Post-2012 dummy	-0.070***	...	...	...
	[0.010]	...	...	...
Constant	2.310***	2.155***	2.368***	2.236***
	[0.126]	[0.129]	[0.218]	[0.219]
Selection equation				
Dummy: debt to middleman	...	0.635***	0.504***	0.364***
	...	[0.014]	[0.047]	[0.052]
ρ	...	0.155***	-0.974***	-0.954***
	...	[0.031]	[0.014]	[0.005]
ϕ	...	0.043***	-0.446***	-0.474***
	...	[0.011]	[0.021]	[0.016]
Observations	495	469	458	461
Specification	Panel	Heckman	Heckman	Heckman
Log-likelihood	...	-239.5	-342.7	-356.4
District fixed effects and seasonality controlled	Y	Y	Y	Y
Controls for aid placement	Y	Y	Y	Y

(b) Volunteer labors

Dependent variable	Volunteer labor days			
	(3)		(4)	
	All years	2007	2009	2012
Volunteer labor days (t-1))	0.023	...	...	...
	[0.093]	...	...	...
Household head age	-0.003	-0.097	0.116	-0.365
	[0.006]	[0.208]	[0.249]	[0.440]
Log(number of aid projects)	0.205*	-0.018	0.200	0.092
	[0.121]	[0.107]	[0.127]	[0.207]
Log(distance to Banda Aceh)	0.008	0.646***	0.220	-0.239
	[0.179]	[0.160]	[0.181]	[0.298]
Governed by tribal fishermen leader (*panglima teupin*)	0.498***	0.239	0.046	1.193***
	[0.172]	[0.148]	[0.178]	[0.286]
Survival rate of households	-1.241***	-0.952**	-0.902*	-1.935**
	[0.460]	[0.399]	[0.468]	[0.769]
Post-2012 dummy	-0.271**	...	...	...
	[0.125]	...	...	...
Constant	0.853	-0.436	-0.072	2.831
	[0.764]	[1.039]	[1.225]	[2.083]
Observations	938	469	458	461
Specification	Panel	Tobit	Tobit	Tobit
Log-likelihood	-1,469.1	-507.8	-653.9	-744.2
District fixed effects and seasonality controlled	Y	Y	Y	Y
Controls for aid placement	Y	Y	Y	Y

*** p<0.01, ** p<0.05, * p<0.1; Robust standard errors clustered at the district level are in parentheses. Basic household characteristics such as pre-tsunami boat owner and captain, and high education dummy are also included.

Table 8: Decomposition of consumption inequality

By occupation status

	Real consumption per members (average)		
	2007	2009	2012
Fishing	112,113.7	66,906.5	66,867.7
Agriculture	56,414.9	47,612.5	43,836.8
Trade and others	94,144.6	73,184.5	63,356.1
Unemployed/in school	66,364.2	52,442.5	62,155.8
Generalized entropy index (α=2)			
Overall	0.45	0.50	0.58
Within-group	0.44	0.49	0.57
Atkinson index (e=2)			
Overall	0.53	0.58	0.58
Within-group	0.50	0.57	0.57

By district/subdistrict

	Real consumption per members (average)			
	Pre-tsunami	2007	2009	2012
Banda Aceh	185,278.2	103,107.2	71,282.7	85,510.1
Aceh Besar	130,896.5	88,182.4	63,900.9	60,846.4
Aceh Jaya	…	187,527.4	73,600.5	46,187.4
Generalized entropy index (α=2)				
Overall	0.53	0.45	0.50	0.58
Within-district	0.52	0.40	0.49	0.56
Within-subdistrict	0.45	0.30	0.42	0.46
Atkinson index (e=2)				
Overall	0.50	0.53	0.58	0.58
Within-district	0.49	0.45	0.56	0.56
Within-subdistrict	0.46	0.36	0.45	0.46

Note: The generalized entropy index with the inequality sensitivity parameter (α=2) and the Atkinson inequality index with the inequality aversion parameter ($e = 2$) are used.

Table 9: Average earning effect of job choice: OLS panel regression

	Outcome variable: Log(real consumption per capita)		
	(1)	(2)	(3)
Log(real consumption pc) (t-1)	0.234***	0.234***	-0.215**
	[0.041]	[0.041]	[0.030]
Dummy: always fishing	0.002		
	[0.049]		
Dummy: permanent switchers	0.067***		
	[0.010]		
Fish		0.030	0.163*
		[0.039]	[0.053]
Fraction of faulty aid boats in the village	-0.015	-0.012	
	[0.024]	[0.027]	
Household head age	-0.009***	-0.008***	-0.026***
	[0.002]	[0.002]	[0.001]
Pre-tsunami boat owner and captain	0.002	-0.003	
	[0.033]	[0.039]	
Pre-tsunami large boat	-0.027	-0.020	
	[0.046]	[0.048]	
High education dummy	0.048	0.058	-0.048
	[0.063]	[0.075]	[0.023]
Log(number of reconstruction projects)	0.084***	0.092***	
	[0.025]	[0.024]	
Owned land	0.133***	0.133***	0.116
	[0.004]	[0.004]	[0.041]
Log(distance to Banda Aceh)	0.076*	0.086**	
	[0.043]	[0.042]	
Post-2012 dummy	-0.052***	-0.054***	
	[0.009]	[0.007]	
Constant	8.468***	8.399***	14.198***
	[0.434]	[0.464]	[0.361]
Observations	1,174	1,174	1,174
Specification	RE	RE	FE
District fixed effects	Y	Y	Y
Controls for aid placement	Y	Y	Y

*** p<0.01, ** p<0.05, * p<0.1; Robust standard errors clustered at the district level are in parentheses. RE=random effect, FE=household fixed effect regressions.

Table 10: Average earning effect of job choice by job transition sequences

	Outcome variable: Log(real consumption per capita)	
Job sequences	Strict exogeneity	Learning allowed
(0, 1, ・)	-0.059	-0.064
	[0.107]	[0.146]
(1, 0, ・)	0.761***	1.216***
	[0.084]	[0.130]
(・, 0, 1)	0.210	-0.187
	[0.133]	[0.195]
(・, 1, 0)	0.492***	0.310**
	[0.105]	[0.148]
(0, ・, 1)	0.002	-0.054
	[0.118]	[0.115]
(1, ・, 0)	0.792***	1.100***
	[0.070]	[0.085]
District fixed effects	Y	Y

*** p<0.01, ** p<0.05, * p<0.1; Bootstrapped standard errors (1,000 replications) clustered at the district level are in parentheses.

Table 11: Evolution of fish marketing: is local market segmented or integrated?
(the fraction of households in each category)

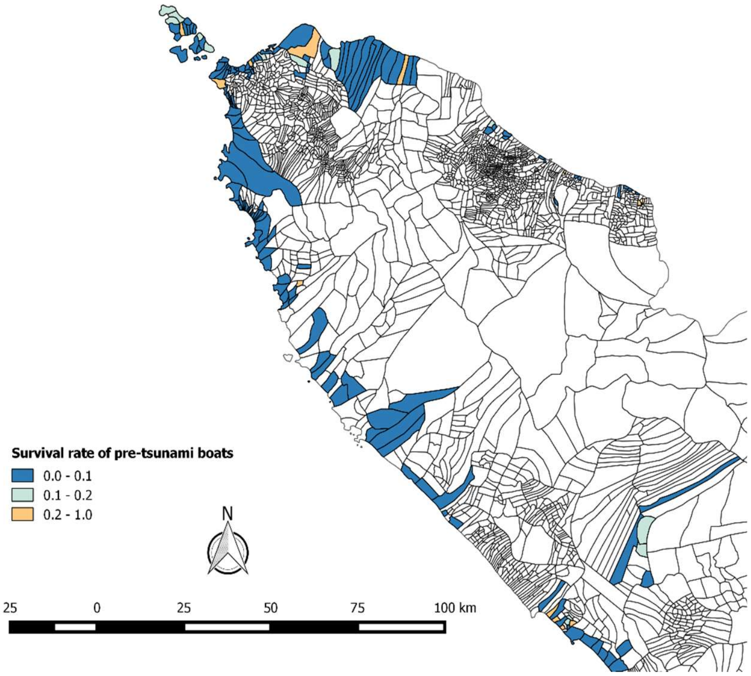
	Pre-tsunami	2007	2009	2012
Export to other province or foreign country	0.000	0.070	0.259	0.131
Sold in other villages within Aceh	0.571	0.249	0.298	0.275
Sold and consumed locally	0.429	0.681	0.443	0.594

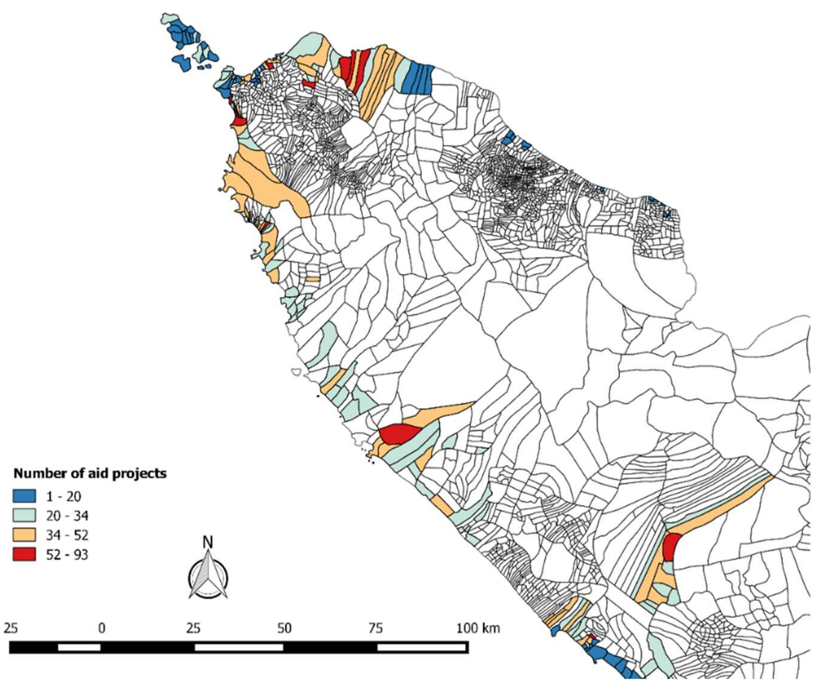
Source: Aceh panel surveys, 2005, 2007, 2009, and 2012

Table 12: Production function estimation for the shadow wage calculations

	Outcome variable: Log(real fishing revenues)							
	In 2007		In 2009		In 2012		All years	
	CD	Translog	CD	Translog	CD	Translog	CD	Translog
	(1)		(2)		(3)		(4)	
Household head age	-0.012***	-0.011***	-0.004	-0.003	-0.012	-0.010	-0.019*	-0.018*
	[0.004]	[0.004]	[0.003]	[0.004]	[0.021]	[0.019]	[0.005]	[0.005]
Pre-tsunami boat owner and captain	0.124	0.169*	-0.039***	-0.024**	-0.017	-0.038		
	[0.078]	[0.088]	[0.013]	[0.011]	[0.064]	[0.111]		
Log(fishing hours)	0.435***	-3.945**	0.683***	0.669	0.437*	2.572*	0.537***	0.437
	[0.098]	[1.944]	[0.141]	[1.797]	[0.225]	[1.337]	[0.051]	[0.674]
Log(boat length, in meters)	0.450***	-1.736	0.844***	0.348	1.451***	4.983***	0.616	0.431
	[0.116]	[2.302]	[0.230]	[0.335]	[0.182]	[0.327]	[0.225]	[1.627]
Log(boat engine capacity, in HP/PK)	0.361**	-0.980	0.439***	-0.834*	0.309***	0.131	0.220**	0.873
	[0.157]	[0.709]	[0.126]	[0.458]	[0.057]	[0.481]	[0.029]	[0.367]
Log(fishing hours) squared		0.234		-0.440		0.165		0.176
		[0.202]		[0.383]		[0.425]		[0.331]
Log(fishing hours) x Log(boat length)		0.845		0.198		-1.457***		0.113
		[0.947]		[0.219]		[0.136]		[0.772]
Log(fishing hours) x Log(boat engine capacity)		0.572**		0.565***		0.061		-0.315
		[0.261]		[0.200]		[0.198]		[0.164]
High education dummy	-0.170	-0.155	0.138*	0.154*	0.347*	0.415*	-0.214***	-0.187**
	[0.170]	[0.147]	[0.079]	[0.088]	[0.209]	[0.213]	[0.010]	[0.034]
Log(family size)	-0.004	-0.059	0.088	0.076	0.191*	0.16	0.282	0.329
	[0.080]	[0.111]	[0.122]	[0.135]	[0.102]	[0.132]	[0.201]	[0.161]
Constant	10.008***	19.417***	7.839***	10.197***	7.820***	1.739	10.019***	9.256*
	[0.321]	[3.594]	[0.713]	[2.193]	[0.333]	[1.219]	[0.454]	[2.883]
Selection equation								
ϕ	0.732***	0.693***	-0.373***	-0.481***	0.258	0.721***	-0.079	-0.051
	[0.067]	[0.074]	[0.076]	[0.107]	[0.947]	[0.285]	[0.102]	[0.185]
Observations	672	672	526	526	488	488	944	944
Specification	Heckman		Heckman		Heckman		Panel - household FE	
Left censored observations	244	244	229	229	214	214	…	…
Log-likelihood	-864.67	-851.60	-697.37	-692.39	-626.20	-622.07	-896.109	-890.617
District fixed effects and seasonality control	Y	Y	Y	Y	Y	Y	Y	Y
District-specific time trend controlled	...	...	...	...	...	...	Y	Y

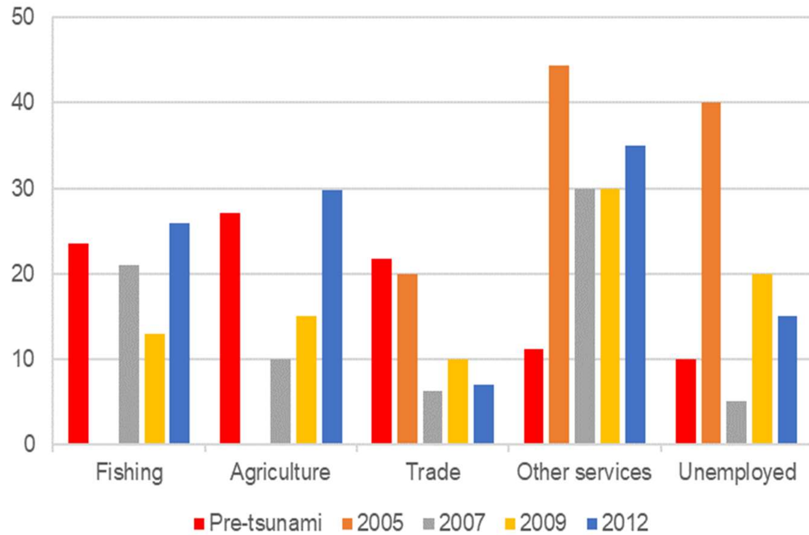
*** p<0.01, ** p<0.05, * p<0.1; Robust standard errors clustered at the district level are in parentheses.





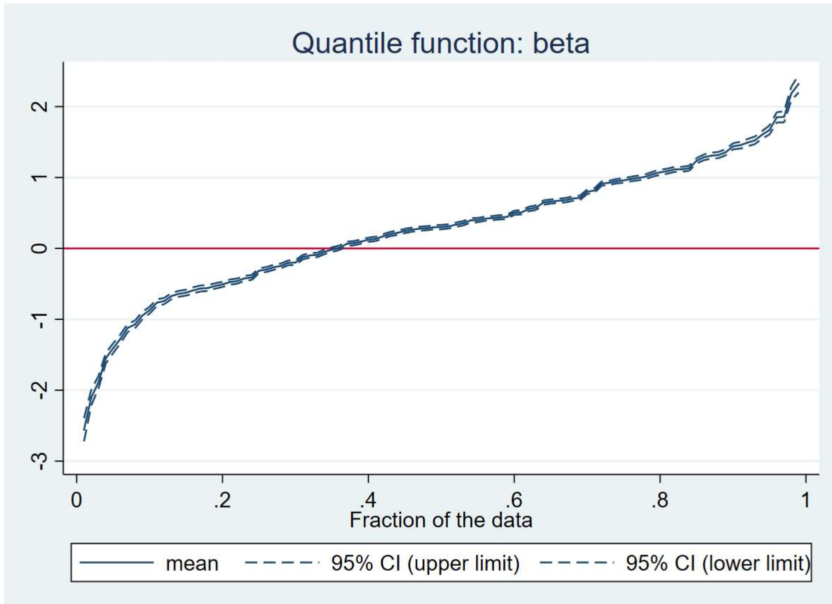
Source: Aceh post-tsunami village survey

Figure 1: Tsunami damages



Note: "Other" sector includes transportation, construction, public services and manufacturing industries.

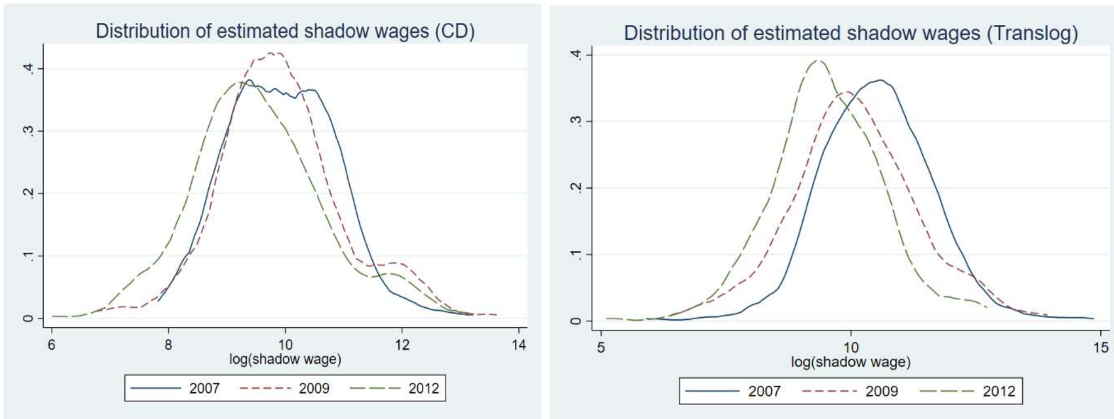
Figure 2: Occupational structure from pre-tsunami to 2012



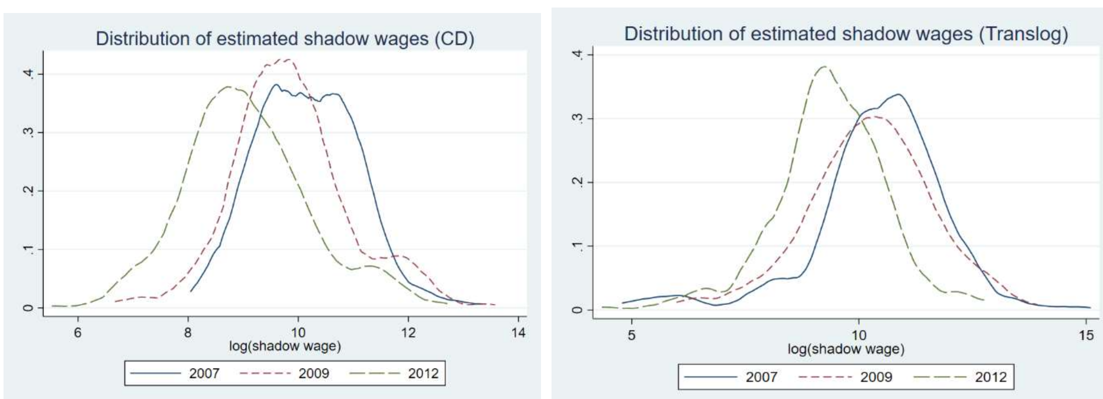
Note: The figure shows the quantile regression estimates of the return to fishing β_i, obtained using Mallows (2007) non-parametric deconvolution algorithm. The solid line represents the point estimate, and dashed lines show 95% bootstrapped confidence bands with 300 replications.

Figure 3: Quantile estimates of the return to fishing

(a) Heckman selection model: total sample



(b) Heckman selection model: the subsample of residents in the segmented market



(c) Fixed effect panel regression

Figure 4: Production function estimates on shadow wages, 2007-2012