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Malaysia's 2014 unprecedented flood catastrophe: A semiparametric estimation of evacuation decisions

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ABSTRACT In December 2014, Malaysia experienced its worst unprecedented flood catastrophe. This paper looks at the victims' evacuation decisions of that flood. This paper is unique because previous papers on Malaysian flood-related disasters are only confined to floods of regular or typical scales. This paper is also unique because it uses a semiparametric estimation approach to obtain the marginal impact of the variables of interest on evacuation decisions. This way, there are less distributional assumptions on the error term, and the estimation results would be more robust. Among some of the important findings from the estimations, we find that: (i) victims who have participated in flood awareness programmes are less likely to evacuate to evacuation centres, (ii) victims who are instructed to evacuate are 5 times likelier to do so, (iii) victims with tertiary education are also less likely to evacuate, (iv) larger households are likelier to evacuate, and (v) the further away victims' homes are from the evacuation centres the likelier they are to evacuate. These findings, some which may seem counterintuitive, are discussed in the conclusion and policy implication section of the paper.

KEYWORDS: evacuation decision, flood, disaster management, semiparametric estimation

1. Overview and selected literature

Malaysia experienced its worst unprecedented flood catastrophe in December 2014. The east coast states, Kelantan and Pahang, took the brunt of the magnitude and sudden flood onslaught. These are the two features of this flood – its geographical magnitude (areas with no previous records of flood were also inundated) and suddenness of occurrence (the unexpectedly speed at which riverbanks were breached). These two states would make up the geographical scope of this study as they were the ones most ravaged. In Malaysia, natural disasters such as floods are managed by a set of standard operating procedures (SOP) known as the Directive 20, issued by the Malaysian National Security Council (NSC). One of the most important aspects of this directive is mobilising flood victims to actually move to evacuation centres. This study looks at the determinants of actual evacuation decisions of the victims of the unprecedented flood disaster.

This study is also unique since previous studies on Malaysian flood-related disasters are only confined to floods of regular or typical scales, unlike the unanticipated extraordinary scale of the 2014 flood that wreaked havoc across the two east coast states. There is a surprising dearth of empirical work on flood victims' evacuation decisions in the Malaysian context. Other recent related past studies include those of Medina and

Moraca (2016) who looked at evacuation decisions in flood-prone areas of The Philippines, Mesa-Arango et al (2013) This study is also unique since previous studies on Malaysian flood-related disasters are only confined to floods of regular or typical scales, unlike the unanticipated extraordinary scale of the 2014 flood that wreaked havoc across the two east coast states. There is a surprising dearth of empirical work on flood victims' evacuation decisions in the Malaysian context. Other recent related past studies include those of Medina and Moraca (2016) who looked at evacuation decisions in flood-prone areas of The Philippines, Mesa-Arango et al (2013) who looked at evacuation destination type choice of the 2004 Hurricane Ivan's victims, Solis et al (2010) who looked at the determinants of hurricane evacuation choices of affected households, and Mozumder et al (2008) who looked at the evacuation behaviour of communities facing wildfire risks.

The only notable Malaysian study which is somewhat marginally related to what we are doing is that by Siti and Nik (2015), in which they look at how satisfied flood victims are with the services provided at the evacuation centres in the states of Kelantan, Pahang, and Terengganu. They conclude that flood victims are generally satisfied with the services provided at the evacuation centres. Other studies in the context of flood disasters in Malaysia include that by Raman et al. (2015) who look at how to best formulate and implement a disaster risk reduction strategy from the flood victims' perspectives. Their findings suggest that the motivation for preparedness in facing flood disasters should come from the people themselves, while rescue agencies should focus on mechanisms for information dissemination and protection of vulnerable segments of the communities. There is also a qualitative study on how knowledge of the Directive 20 among the various agencies in Malaysia's Kedah state could translate into preparedness in the event of actual disasters (Badruddin 2012). His findings conclude that such knowledge of the directive does indeed translate into better preparedness for disasters not necessarily limited to only flood disasters but also landslides, tsunamis, industrial pollutions, and droughts among others.

One of the most crucial tasks for the authorities during flood disasters is the search-and-rescue operation, in which victims would be instructed or advised to move to evacuation centres for safety purposes. There are however, victims who are either stubborn or ignorant to the evacuation instructions and choose otherwise. Such stubbornness and ignorance towards evacuation noncompliance could well boil down to whether they are first-time victims whether there are evacuation instructions from the authorities, whether there have been any flood disaster awareness programmes held at their community, whether they have participated in such programmes, and the distance of the nearest evacuation centre from the victims' affected area. Our paper looks at how these aforementioned aspects determine the victims' evacuation decisions.

2. Methodology

2.1 Data

At the initial stage of this study, we interviewed key personnel (i.e. district officers and village heads) from district offices and villages of the selected districts. This is to get a bird's eye view overall picture of the situation at ground zero when the flood was at its worst. From these interviews, we design the questionnaire to solicit responds from the flood victims of the 2014 massive flood. The empirical analysis of this paper is based on the unique data set obtained from the questionnaire survey. The survey was conducted at different districts (Sg. Isap, Sg. Lembing, Kg. Tiram, Bertam, and Lebir) of Pahang and Kelantan.

The survey questionnaire is divided into four major sections, requiring flood victims to answers questions pertaining to their demographic profile, and to the 2014 flood management before, during, and after the flood occurrence. There were 372 respondents in total, constituting the working sample of this study. The empirical findings are then verified through a focus group discussion, involving district officers, village heads, flood victims, representatives from flood-related agencies (e.g. the police, military, fire department, the Ministry of Health, the Department of Irrigation and Drainage), and representatives from NGOs (e.g. the Red Crescent Society).

2.2 Model specification

We model flood victims' evacuation decision (y) on a vector of explanatory variables (X) such that $\mathbf{y} = \mathbf{X\beta} + \boldsymbol{\varepsilon}$, where $\mathbf{y}$ and $\boldsymbol{\varepsilon}$ are $n \times 1$ vectors, while $\boldsymbol{\beta}$ is a $k \times 1$ vector. $\boldsymbol{\varepsilon}$ is the vector of error terms. $\mathbf{X}$ is an $n \times k$ matrix with k explanatory variables for *n* observations. This $\mathbf{X}$ vector consists of a sub-vector of the five variables of interest, i.e. first-time victims, evacuation instructions, flood disaster awareness programmes, programme participation, and locations of evacuation centres. The dependent variable y is binary with $y = 1$ as being an evacuee and 0 otherwise. The vector $\mathbf{X}$ also contains demographic-related variables, and variables on flood management in the three periods of flood (before, during, post).

Relative to parametric estimation, there are fewer distributional assumptions in semiparametric estimation, i.e. weaker assumptions on the error term distribution. Without the imposition of such distributional constraint, semiparametric estimators would therefore be more robust. At the same time, semiparametric estimators would be less efficient. Having said that however, parametric estimators would only perform better if its distributional assumption is correct; correct distributional assumption is seldom the case (Horowitz & Savin 2001). If the distributional assumption of the underlying error term is wrong, parametric estimators would fare worse, i.e. giving inconsistent estimation.

The semiparametric estimation procedure we use here is that by Gallant and Nychka (1987), i.e. known as the semi-nonparametric (SNP) approach which can handle a broader class of error distributions (De Luca 2008). Gallant and Nychka's work has been built on that of Phillips's (1983). As noted by De Luca, the SNP approach approximates the unknown distribution of the latent error term using a flexible functional form, i.e. more specifically, through a Hermite polynomial expansion. This approximation is used to derive a pseudo maximum likelihood estimator for the model parameters. The parametric

estimation of the probit model assumes a standardized Gaussian distribution for the error terms. In the less restrictive semiparametric or equivalently, a semi-nonparametric setting, only the mean of the error term is assumed to be have zero mean whereas its variance has no imposition of it being unit variance (Luca 2008; Melenberg & van Soest 1996; Gabler et al 1993). Following Phillips (1983) and Gallant and Nychka (1987) specification, approximation of the unknown density of the error term (ε) starts off with the form of a Hermite series such that,

$$h(\varepsilon) = \frac{P^2(\varepsilon)}{Q^2(\varepsilon)}\phi^2(\varepsilon|\tau, \Sigma)$$

where, $P(\varepsilon)$ and $Q(\varepsilon)$ are polynomials and $\phi(\varepsilon|\tau, \Sigma)$ is the multivariate normal density function with mean τ and covariance matrix Σ. Further details and explanation can be referred to from the direct sources and that of Van der Klaauw and Koning (1996).

3. Results & findings

3.1 Summary statistics

Table 1 presents the summary statistics of the variables used in this study. Variables which are continuous in nature include that of age, household size, and distance to evacuation centres. Reported figures for these variables are means. Remaining variables are dummies, with reported figures being the proportions. The means and proportions for each variable are grouped by evacuee status. About two-thirds of the sample are evacuees.

From Table 1, we can also see that higher proportions of evacuees claimed existence of flood awareness programmes in their communities and also higher proportions in the participation of such programmes, compared to non-evacuees. The distance to evacuation centres is much further for evacuees, i.e. on average about 2.2 kilometres away from their affected homes. The *p*-values column shows whether there is any statistical significance in the means and proportions between the two groups of evacuees and non-evacuees.

Table 1: Summary statistics

Variables	Evacuees	Non-evacuees	*p*-values	Overall
Demographic & socioeconomic				
Age	49.6 (14.9)	54.7 (16.7)	0.0032***	51.2 (15.6)
Male	0.57 (0.49)	0.62 (0.48)	0.3693	0.59 (0.49)
Malay	0.86 (0.34)	0.71 (0.45)	0.0010***	0.81 (0.38)
Married	0.75 (0.43)	0.80 (0.40)	0.2982	0.77 (0.42)
Household size	4.5 (2.4)	3.6 (2.2)	0.0012***	4.2 (2.4)
Income ≤ RM500	0.41 (0.49)	0.33 (0.47)	0.1856	0.38 (0.48)
Income >RM500-1,000	0.27 (0.44)	0.39 (0.48)	0.0216**	0.31 (0.46)
Job & education				
Have own business	0.37 (0.48)	0.47 (0.50)	0.0643*	0.40 (0.49)
Tertiary education	0.12 (0.32)	0.16 (0.36)	0.3176	0.13 (0.33)
Secondary education	0.41 (0.49)	0.31 (0.47)	0.0530*	0.38 (0.48)
Flood-related				
First-time victim	0.51 (0.50)	0.49 (0.50)	0.9351	0.50 (0.50)
Instructed to evacuate	0.94 (0.22)	0.42 (0.49)	0.0000***	0.77 (0.41)
Programme existence	0.54 (0.49)	0.38 (0.48)	0.0068***	0.49 (0.50)
Joined programme	0.51 (0.50)	0.35 (0.48)	0.0128**	0.46 (0.49)
Distance to centre	2.2 (2.3)	1.6 (2.2)	0.0902*	2.0 (2.2)
N	251 (67.5%)	121 (32.5%)		372 (100%)

Notes: Figures in parentheses are standard deviations. Figures are either means or proportions depending on whether variables are continuous or categorical.

3.2 Empirical results

Table 2 reports the marginal effects from three estimation models: (i) the parametric Linear Probability Model (LPM) which serves as a baseline model, (ii) the parametric binary probit model, and (iii) the semi-nonparametric (SNP) model, which is our model of interest. The first two parametric models follow restrictive distributional assumptions of a Gaussian distribution for its error term, i.e. zero mean and unit variance. The third model, the SNP model, has less distributional assumption, i.e. it only requires the error terms to have zero mean.

Comparing the marginal effects reported in Table 2, the SNP model appears to detect statistical significance in a larger number of variables, compared to the two parametric models. We focus our discussion of results from the SNP model. Among some of the important findings from the estimations, we find that: (i) victims who are instructed to evacuate are likelier to evacuate, (ii) victims who have participated in flood awareness programmes are less likely to evacuate to evacuation centres, (iii) the further away victims' homes are from the evacuation centres the likelier they are to evacuate, (iv) older victims are less likely to evacuate, (v) larger households are likelier to evacuate, and (vi) victims with tertiary education are also less likely to evacuate.

Victims who are instructed to evacuate are found to be 5 times likelier to move to evacuation centres than those who have not received any evacuation instructions. Our sample of victims reveals that 82% of those who were instructed to evacuate did eventually shift to evacuation centres. Whether or not a

victim is a first-timer in experiencing floods does not appear to have any significant impact on their evacuation decisions. Victims who have taken part in flood awareness programmes are however, found to be 5 times less likely to evacuate. This could plausibly due to the victims having the knowledge acquired from such programmes to take pre-flood precautions and therefore negating the needs to move to evacuation centres (i.e. the victims could have moved and stayed with relatives, or they could have installed the necessary flood barriers at their homes). Programme participation seems to be more important than whether or not there exists such flood awareness programmes at the community level. Programme existence does not have any impact on evacuation decisions. We also find that the further away victims' homes are from the evacuation centres, the likelier they are to evacuate, i.e. a kilometre increase in distance from the centre increases the likelihood of evacuating by about 78%. This might be due geographical fact that the immediate vicinity of an evacuation centre is probably the least likely to be inundated; the further away the distance from the centre, possibilities of the area being flood-prone increase. Therefore victims whose homes are far from the centre would be the ones who have real needs of evacuating.

Older victims are less likely to evacuate, i.e. an additional year in age would decrease the probability of evacuating by about 13%, ceteris paribus. This is understandable especially in the case of old, fragile, and immobile victims; they would mostly likely be physically deterred to evacuate without any special assistance from the authorities. Larger households are likelier to evacuate, i.e. an additional member of a household would see an increase of about 86% chances of the household evacuating. Large households in our sample typically consist of households with young children. It is therefore very plausible that the heads of such households would evacuate for safety purposes of their young broods. Victims with tertiary-level education are found to be 3 times less likely to evacuate, compared to those with primary-level education and below. This is probably because those with higher education are typically the ones with more resources, where in this case, they might be the ones with economical means to get away from the affected areas and stay at hotels.

The following figure shows two density plots of the error term. The dotted plot is the Gaussian density of the estimated mean and variance of the error term; the remaining plot shows the distribution of the error term when its distributional assumption is relaxed. This graphical finding further enhances our case of using the non-conventional parametric estimation in our empirical analysis.

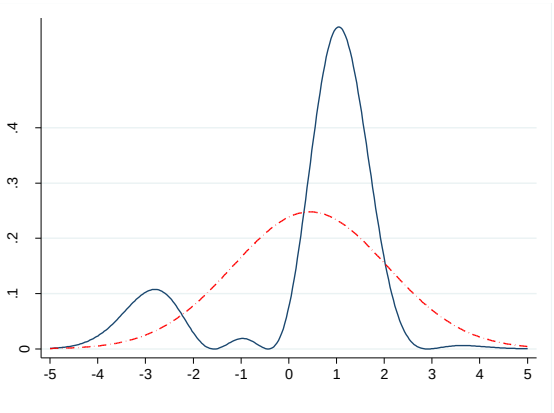

Table 2: Marginal effects from different estimation models

DV: Evacuated	LPM		Probit		SNP	
	dy/dx	Robust s.e.	dy/dx	Robust s.e.	dy/dx	Robust s.e.
Demographic & socioeconomic						
Age	0.004	0.011	0.002	0.013	-0.131***	0.040
Male	-0.012	0.049	-0.029	0.061	-0.616	0.580
Malay	-0.084	0.079	-0.071	0.063	-0.071	0.415
Married	0.013	0.058	0.002	0.064	-0.428	0.329
Household size	0.041	0.029	0.048	0.029	0.865***	0.314
Income ≤ RM500	-0.003	0.057	-0.021	0.075	-0.371	0.821
Income >RM500-1,000	-0.044	0.054	-0.079	0.082	-0.416	1.302
Job & education						
Have own business	-0.081	0.054	-0.108	0.069	-1.135	1.152
Tertiary education	-0.157*	0.087	-0.223*	0.122	-2.138**	1.008
Secondary education	0.018	0.047	0.048	0.065	-0.641	0.450
Flood-related						
First-time victim	0.034	0.055	0.054	0.062	0.779	0.711
Instructed to evacuate	0.714***	0.077	0.771***	0.071	4.343***	0.402
Programme existence	0.006	0.096	-0.018	0.125	-0.271	0.692
Joined programme	-0.200	0.124	-0.862	0.078	-4.552***	0.996
Distance to centre	0.031	0.021	0.044	0.030	0.778***	0.166

Notes: Significant at the ***1%, **5%, and *10% level. Squared and interaction terms have been included into the model specification, i.e. squared terms for age, household size, distance to evacuation centres, and an interaction term between programme existence and programme participation.

4. Conclusion & policy implication

From the estimation results, it is fairly reasonable to conclude that instructing the victims to evacuate to be an effective way to get the victims to evacuation centres and thus ensuring that their safety and welfare are taken care of. Search-and-rescue authorities should also be well-equipped with special tools and equipment especially when it comes to physically evacuating old, fragile and immobile victims. Such special tools and equipment requirements could be further extended to also having specially trained medical personnel who could safely handle the evacuations of, for instance, babies and heavily pregnant victims.

Our results show that participation in flood awareness programmes are more important that the programmes' mere existence. Victims who have participated in such programmes appear more likely to fend for themselves; they might also possess some degrees of preparedness in facing flood situations. Flood-related authorities should therefore ensure participation of vulnerable communities in flood awareness programmes, rather than merely organising such programmes. Relevant authorities such as the Malaysian Department of Survey and Mapping should also conduct more frequent re-measurement of high-lying areas. This would help ensure that assigned geographical locations of evacuation centres and food storage bases are secure and not threatened by any flood magnitude or suddenness.

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