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Economic Vulnerability and Flood Risk: Evidence from the East Coast Households of Peninsular Malaysia

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ABSTRACT---*The objectives of this paper are to compare the discrepancies in economic vulnerability levels and evaluate the effects of economic vulnerability on flood risk among affected households in the East Coast states of Peninsular Malaysia By developing its component within a household flood vulnerability index (FVI) from a sample of 380 households and employing a multiple regression analysis, the findings vary by district, state and region. Among others, Kota Bharu and Temerloh are the two districts' most economically vulnerable to floods with their highest economic FVI values of 0.736 and 0.631, respectively. Meanwhile, Pahang is the state's most economically vulnerable to floods with the highest economic FVI value of 0.655. Also, key determinants; proximity to river, businesses, flood insurance holders and economic recovery may influence any change in flood risk among the households. Therefore, decision and policy makers are recommended to explore possible ways of optimizing the flood recovery process from pre-disaster community procedures such as code adoption policies and early recovery decisions via vertical and organizational integrations among households, communities, businesses, donor agencies, infrastructural providers and local governments.*

Keywords---*East Coast states, economic vulnerability, flood risk, households*

I. Introduction

Flood disaster represents the most significant natural hazard in Malaysia. Also, it is known as the most common hazard since it occurs in the country almost every year. There have been various segments of affected population together with associated damages and losses to floods. The impact of economic losses due to floods is disproportionally greater in the developing countries than the developed nations as stemmed from scarce resources and low productivity (El-Masri & Tipple, 1997). According to the Malaysia's Department of Irrigation and Drainage [DID] (2007), the annual flooding affects more than 4.82 million (i.e. 22 percent) of the total population and about 29,000 km^2 (i.e. nine percent) of the total land area with an average of RM915 million is inevitably lost in Malaysia every year. Specifically, it was reported in the East Coast region of Peninsular Malaysia that the annual floods affect more than 1.49 million people and about 10,130 km^2 flood prone areas with the average of RM271 million is unavoidably lost across the states of Kelantan, Terengganu and Pahang (DID, 2007; Ranhill Consulting, 2011).

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Since vulnerability to remain high in many parts of the country especially within its East Coast region, the 2014's major floods caused substantial damages to properties, distresses, loss of human lives, dislocation of communications and economic activities, disruptions to low-lying agricultural lands and communities in rural, urban, residential and commercial areas. Those damages and losses in several locations across the states of Kelantan, Pahang and Terengganu were largely originated from serious aggravations in physical, social, economic and environmental vulnerabilities. Due to the increasing frequency and magnitude of extreme floods stemmed from urbanization, deforestation, population growth, climate change and consequent rise in sea level, the number of people vulnerable to extreme floods is expected to rise (Tyagi, 2009). Similarly, the trend of economic losses or impact due to floods has also continued to increase in recent years. Hence, the impacts from economic vulnerability and flood risk faced in Malaysia have not been regarded as a new issue. Therefore, the objectives of this paper are to compare the differences in economic vulnerability levels to floods via the use of a household flood vulnerability index *(FVI)* and evaluate the effects of economic vulnerability on flood risk among the East Coast households by district, state and region.

This paper is structured as follows. Several literatures on the economic vulnerability and flood risk are reviewed in Section 2. While Section 3 describes the methodology that is used in this study, the results are reported and discussed in Section 4. Finally, Section 5 wraps up with the policy implication and conclusion of the study.

II. Literature Review

Conceptually, economic vulnerability of an analysis unit (e.g. village, district, state and country) can be defined by the risk of a district seeing its development being hampered by the natural or external shocks (e.g. floods) it faces (Guillaumont, 2012). Further, economic vulnerability is a result from three main determinants namely the size and likelihood of external shocks, the exposure to these shocks and the resilience or capacity to react to shocks (Guillaumont, 2012). While the first two determinants; the size and likelihood of shocks and the exposure to these shocks mainly rely on the structural characteristics of a unit (e.g. state) such as economic diversification and human capital, the latter determinant; resilience depends on the current economic policy of the state. There are two trends that reflect the positive relationship between flood risk and economic damage from floods (Tyagi, 2009). Due to the climate change and inappropriate development practices, the frequency and magnitude of extreme floods appear to be increasing lately. Also, there has been a rise in vulnerability within the flood plain and flood prone areas rooted from the increasing number of affected people and economic assets being located there. Evidently, the developing countries including Malaysia are hit the hardest, both in terms of the total affected people and in the economic impact on national economies. Even worse, the available limited resources in the developing countries, which could be invested in development, must be diverted to flood rehabilitation, relief and recovery. Also, affluent groups of people and local economies can be severely affected.

From the empirical viewpoints, economic vulnerability to external shocks (e.g. natural disasters such as floods) is increasingly grown its significance in the literature. One example is by Villordon (2015) in the application of community-based *FVI* model. Villordon (2015) established correlations and relationships in understanding the social vulnerabilities and risks associated with the urban floods in the Philippines. The study was based on the questionnaires submitted by a total sample of 357 household respondents across the 12 affected communities in the Dumaguete City along the Banica River floodplain areas. Among others, the findings revealed that the community of Barangay Tabuc-tubig is the most economically vulnerable to urban floods. More specifically, its economic *FVI* showed that all households have good access to the improved sanitation but only half of the households have no access to improved water source. The presence of rats in the community was highly observed and many of them were surveyed to live within the water-logged areas in the vicinity. Also, about half of households' housing conditions were capable of withstanding from strong winds and water invasion during heavy flooding. Additionally, 40 percent of households were disclosed to have monthly incomes within the range of 1,000 - 3,000 pesos and none of them have their properties insured. Overall, considerably high levels of communities' resilience based on their withstand capacities and adaptation options, albeit higher levels of exposure factor, were effectively capitalized following the 2011's urban floods in the Philippines.

Other examples of flood vulnerability (i.e. including the economic vulnerability component) and flood risk assessments are performed by authors such as Balica and Wright (2010), Balica *et al.* (2013) and Behanzin *et al.* (2015). Balica and Wright (2010) applied the *FVI* methodology to assess vulnerability to floods for three spatial areas; river basin, sub-catchment and urban globally. From the findings, river basin and urban areas were unveiled to be economically vulnerable to flood. Of the indicators, land use, amount of investment, economic recovery, quality of infrastructure and human development index, i.e. with the exclusion of inequality, were found to be statistically significant to define the economic vulnerability to floods for river basin and urban areas. In a different occasion, Balica *et al.* (2013) studied on the Budalangi settlement within the district of Busia in Western Kenya to identify vulnerability and risk elements in flood-prone areas. By applying the *FVI* methodology, Balica *et al.* (2013) unfolded that the Budalangi area is economically vulnerable to floods. The economic vulnerability to floods was at high level in the Budalangi area since the area has not been insured, fewer industries, agriculture as the main economic activities and lower human development index estimates. Apart from that, Behanzin *et al.* (2015) launched a-GIS based flood vulnerability and risk assessment in the municipalities of Karimama and Malanville within the Benin Niger River Valley in West Africa. In the study, they disclosed that almost 90 percent of the district areas are in the footprint of flood hazard and potentially exposed to a high flood risk. Due to varying levels of flood vulnerability, they also revealed that Karimama is more vulnerable than Malanville especially due to weaker conditions of the economic vulnerability component sourced from income level, unemployment rate and household expenditure per capita indicators. Hence, Behanzin *et al.* (2015) asserted that a need to have access to high resolution data in undertaking a-detailed study on flood risk within the Niger River basin in preparing for the wake of extreme floods. Without the flood risk analysis, there is no viable option to reducing vulnerability, thus undermining the impact of development works.

III. Methodology

Theoretical Framework

This study adopts the Turner *et al.* (2003)'s expanded vulnerability framework as shown in Figure 1 in which their focus is on the local setting e.g. a village, town or district to be a unit of analysis. Vulnerability exists in a multifaceted coupled human – environment system with connections operating at different spatiotemporal scales. Thus, the framework provides the broad components and linkages that describe the coupled system's vulnerability to hazards. Also, the framework covers linkages to the broader human and environmental conditions and processes within the coupled system, perturbations and stressors or stress emerging from these conditions and the coupled system whereby vulnerability exists, including exposure and responses (e.g. adaptations, adjustments, coping and impacts) (Turner *et al.*, 2003). Since these elements are interactive and scale dependent, the analysis is affected up to the extent that the coupled system is conceptualized in this study.

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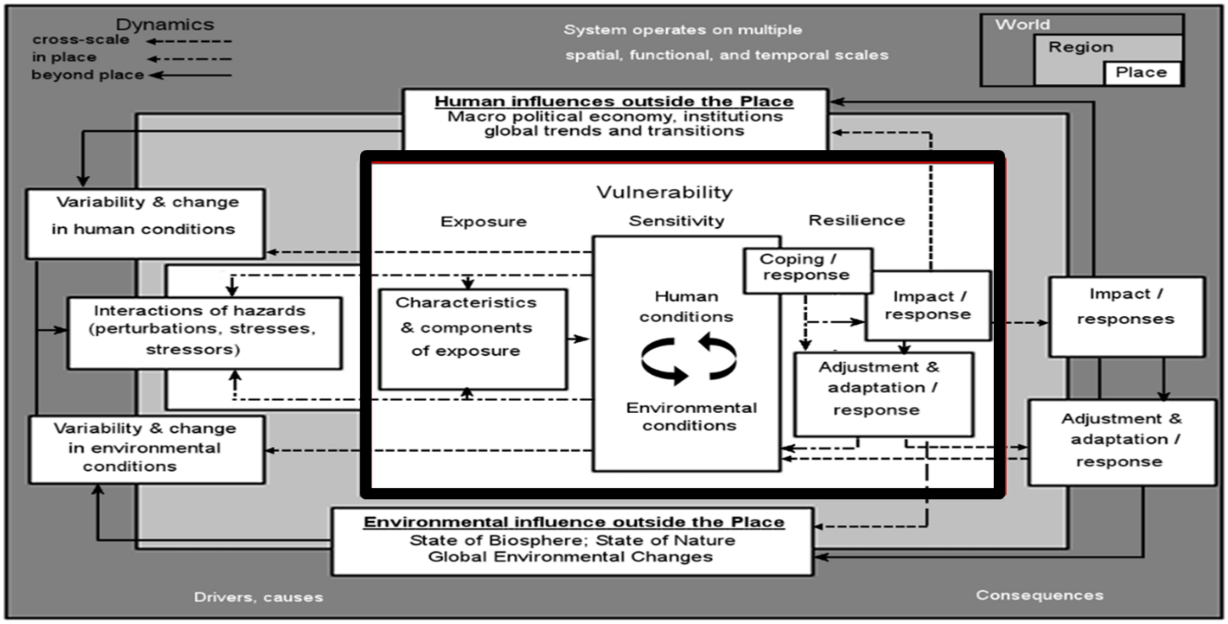

Figure 1. Interaction among available factors within the expanded vulnerability framework

Source: Turner *et al.*, 2003

Additionally, Figure 2 illustrates that the flood risk analysis constitutes as a combination of the two analytical analyses of flood vulnerability and flood hazard. Flood vulnerability analysis represents the study of a person's ability or element to withstand, neutralize, avoid or absorb the impact of hazardous floods. There are two steps involved in the analysis. The first step is to identify the potentially vulnerable households and elements via the data collection activities. The second step involves the identification and analysis of factors; exposure *(E)*, susceptibility *(S)* and resilience *(R)* associated with the multi-sided flood vulnerability with the key focus is on the economic aspect. Meanwhile, flood hazard analysis covers the identification of underlying causes that may influence the occurrence probability of a hazard (e.g. a flood) in an area within the specific timeframe. Feasibly, the analysis is done to evaluate the event based on the indication of physical and temporal characteristics. With the availability of the two analyses, the estimation on damages, losses and consequences that are heavily inflicted from a flood event can be undertaken. Thus, flood risk analysis is increasingly used as a key instrument of the disaster risk management.

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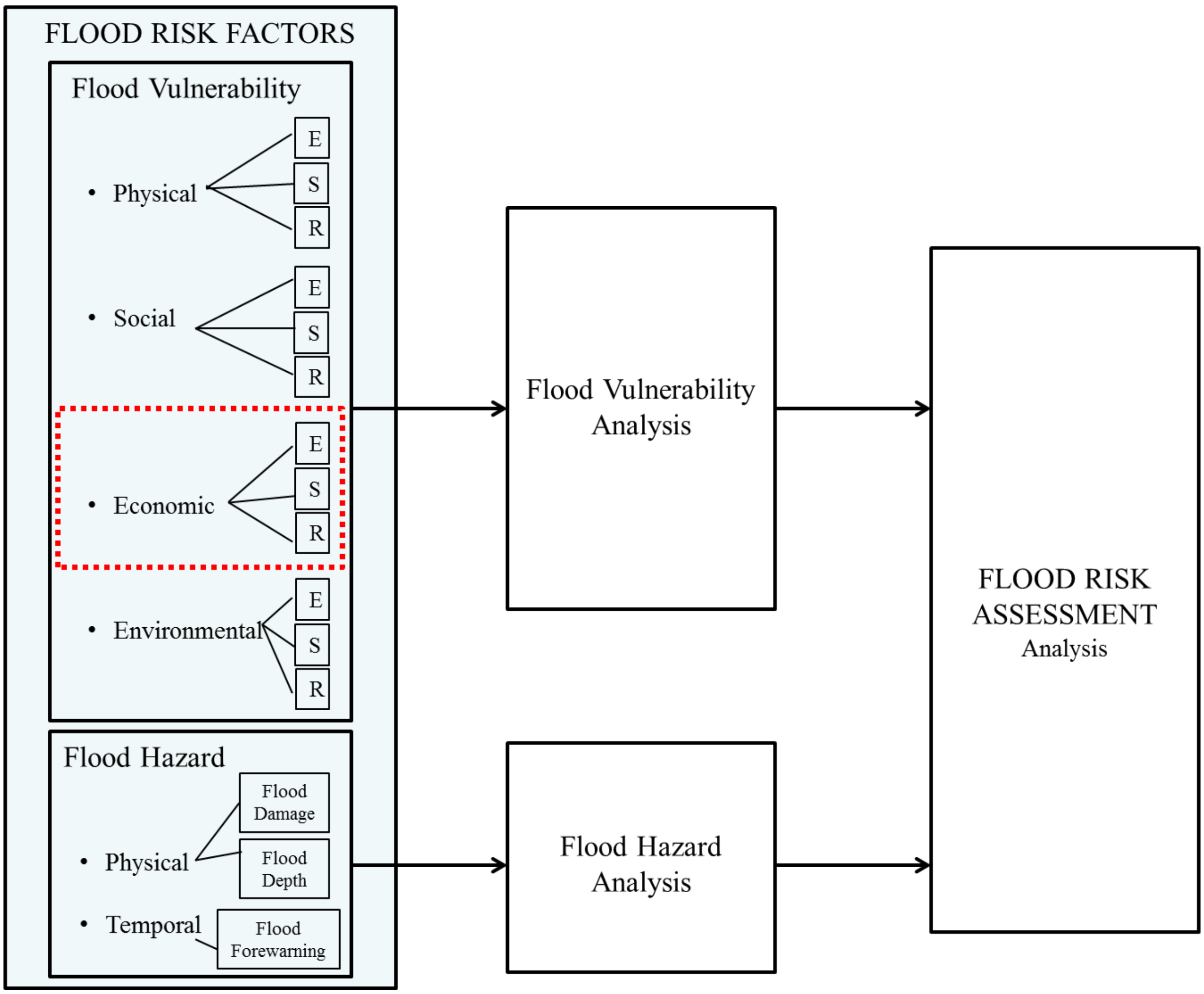

Note: *E*, *S* and *R*are vulnerability factors that denote as Exposure, Susceptibility and Resilience.

Figure 2. Flood Vulnerability and Flood Hazard as Flood Risk Factors

Source: Authors' Modifications from UNISDR, 2009

Study Area

This study investigates the coverage of 2014's major floods in the East Coast region of Peninsular Malaysia via focusing on the states of Kelantan, Pahang and Terengganu. Specifically, two districts in each state as seen in Figure 3 are chosen to be the study areas. The selection is based on considerably high severity flood levels that affected the surrounding communities in 2014.

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Figure 3. Geographical Area of the Study

Data and Sampling Method

In this study, the construction of economic vulnerability component under the household *FVI* is sourced from the primary and secondary data. While the primary data were collected through the households' submission of questionnaire sets, the secondary data were obtained from authoritative organizations in Malaysia such as Department of Irrigation and

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Drainage (DID), Meteorological Department (MET), Department of Statistics (DOS) and Jabatan Pembangunan Wanita (JPW).

Based on the overall affected households of 43,816 families within the six districts that survived from the 2014's floods (JPW, 2015), 380 household respondents in total were determined to be the sample of this study. Thus, this suffices to reach the 95 percent significance level in the produced results (Lin, 1976 as cited in Zikmund, 1991). Specifically, the sample comprises of 160 respondents from the districts of Kota Bharu and Kuala Krai, 60 respondents from every district of Kuantan and Kemaman and 50 respondents who came from each district of Kuala Terengganu and Temerloh. On the study samples, potential respondents who provided their feedbacks through submitted questionnaires were chosen via the combination of stratified and random sampling methods across the two severely affected districts of each state.

Modeling

To analyse the relationship between flood risk *(FR)* and economic vulnerability *(EcV)*, a multiple linear regression analysis is employed in this study. Four flood risk models, i.e. Equation [1] – Equation [4], were developed in the analysis. In each model, the dependent variable is *FR* whereas the independent variables are the economic *(EcV)* aspect of vulnerability and flood hazard *(FH)*. The details of the chosen independent variables are listedin Table 1. Additionally, two control variables, *HLCT* (housing location) and *HMTL* (housing material) are included in all models.

Table 1. Description on the Chosen Independent Variables in the Regression Models

State	**Component**	**Variable***	**Description**
Kelantan	Flood Hazard *(FH)*	*FDMG*	Flood Damage
		FDEP	Flood Depth
		FWNG	Flood Forewarning
	Economic	*PRXR*	Proximity to River

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Vulnerability

BIZS

Businesses

(EcV)

ECRY

Economic Recovery

Control

HLCT

Housing Location

HMTL

Housing Material

Terengganu

Flood Hazard

FDMG

Flood Damage

(FH)

FDEP

Flood Depth

FWNG

Flood Forewarning

Economic

BIZS

Businesses

Vulnerability

FINS

Flood Insurance

(EcV)

ECRY

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Economic Recovery

Control

HLCT

Housing Location

HMTL

Housing Material

Pahang

Flood Hazard

FDMG

Flood Damage

(FH)

FDEP

Flood Depth

FWNG

Flood Forewarning

Economic

PRXR

Proximity to River

Vulnerability

BIZS

Businesses

(EcV)

ECRY

Economic Recovery

Control

HLCT

Housing Location

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HMTL

Housing Material

East Coast

Flood Hazard

FDMG

Flood Damage

States

(FH)

FDEP

Flood Depth

FWNG

Flood Forewarning

Economic

PRXR

Proximity to River

Vulnerability

BIZS

Businesses

(EcV)

ECRY

Economic Recovery

Control

HLCT

Housing Location

HMTL

Housing Material

Note: * indicates the chosen three indicators of economic vulnerability that are highly correlated to flood risk as determined from the results of correlation analysis in Table A.1.

The complete models are shown in Equation [1] – Equation [4]:

Kelantan Model 1 *(KM1)*:

$$FR_{i1}^{EcV} = \alpha_0 + \alpha_1 FDMG_{i1} + \alpha_2 FDEP_{i1} + \alpha_3 FWNG_{i1} + \alpha_4 PRXR_{i1} + \alpha_5 BIZS_{i1} + \alpha_6 ECRY_{i1} +$$

$$+\alpha_7 HLCT_{i1} + \alpha_8 HMTL_{i1} + \varepsilon_{i1} \qquad [1]$$

Terengganu Model 2 *(TM2)*

$$FR_{i2}^{EcV} = \beta_0 + \beta_1 FDMG_{i2} + \beta_2 FDEP_{i2} + \beta_3 FWNG_{i2} + \beta_4 BIZS_{i2} + \beta_5 FINS_{i2} + \alpha\beta_6 ECRY_{i2} +$$

$$+\beta_7 HLCT_{i2} + \beta_8 HMTL_{i2} + \varepsilon_{i2} \qquad [2]$$

Pahang Model 3 *(PM3)*

$$FR_{i3}^{EcV} = \theta_0 + \theta_1 FDMG_{i3} + \theta_2 FDEP_{i3} + \theta_3 FWNG_{i3} + \theta_4 PRXR_{i3} + \theta_5 BIZS_{i3} + \theta_6 ECRY_{i3} +$$
$$+\theta_7 HLCT_{i3} + \theta_8 HMTL_{i3} + \varepsilon_{i3} \qquad [3]$$

East Coast States Model 4 *(ECM4)*

$$FR_{i4}^{EcV} = \vartheta_0 + \vartheta_1 FDMG_{i4} + \vartheta_2 FDEP_{i4} + \vartheta_3 FWNG_{i4} + \vartheta_4 PRXR_{i4} + \vartheta_5 BIZS_{i4} + \vartheta_6 ECRY_{i4} +$$
$$+\vartheta_7 HLCT_{i4} + \vartheta_8 HMTL_{i4} + \varepsilon_{i4} \qquad [3]$$

where $\alpha_i, \beta_i, \theta_i$ and ϑ_i (i = 0,1, 2,…, 8) are the coefficients of each equation. ε_i in each equation represents the white-noise error term, $\varepsilon_i = iid(0, \sigma_\varepsilon^2)$.

Justification of Variables

Flood Risk

Flood risk (FR^{EcV}) is defined as the function of flood hazard on an exposed target that is vulnerable to the hazard. To measure it, the value is expected to be in the interval between zero and one. Thus, it is regarded as the dependent variable to be regressed against the independent variables of flood hazard, flood vulnerability and control components. Among others, past authors like Samarasinghe *et al.* (2010) and Danumah *et al.* (2016) used it in their studies.

Flood Damage

Flood damage *(FDMG)* is indicated by the extent of impact faced by business, farmland and housing areas due to the occurrence of a flood event. It is measured in the local currency (RM). As the impact of floods becomes greater, vulnerability to floods increases, thus leading to a rise in flood risk. Past authors such as Asube and Garcia (1995) and Ouma and Tateishi (2014) claimed that flood damage is positively related with flood vulnerability and flood risk in their studies. Therefore, it is hypothesized in this study that flood damage is positively related with flood risk since it constitutes as a characteristic of flood hazard.

Flood Depth

Flood depth *(FDEP)* is defined as the inundation depth of a flood event. It is measured in metre. As flood depth gets deeper, vulnerability to floods becomes higher, thereby causing an increase in flood risk. Past authors such as Mohit and Sellu (2013), Ouma and Tateishi (2014) and Kissi *et al.* (2015) backed that flood depth is positively related with flood

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vulnerability and flood risk in their studies. In this regard, it is hypothesized for this study that flood depth is positively related with flood risk since it represents one of flood hazard characteristics.

Flood Forewarning

Flood forewarning *(FWNG)* is interpreted as the interval of time between identification, warning and impact of flood hazard. In term of its measurement, it can take the possible values i.e. ranging from zero to one. As the timing of warning dissemination delays, vulnerability to floods rises, thus rendering to increasing flood risk among the communities. Past authors such as Smith (1994) and Kreibich *et al.* (2005) claimed that flood forewarning is positively related with flood vulnerability and flood risk in their studies. Hence, it is hypothesized in this study that flood forewarning is positively related with flood risk since it is a flood hazard indicator.

Businesses

The indicator of businesses *(BIZS)* is represented by the proportion of individual business activities that are operated by households in a district. It is measured in the percentage value. As the number of businesses increases, the density of business areas becomes greater, thus contributing to a rise in vulnerability to floods. Past authors such as Bollin and Hidajat (2006) and Karmaoui *et al.* (2016) asserted that the indicator is positively related with the economic aspect of flood vulnerability and flood risk in their studies. Hence, it is hypothesized in this study that the indicator of businesses is positively related with flood risk since it is an exposure factor.

Proximity to River

Proximity to river *(PRXR)* is interpreted as the average proximity from business, farmland and housing areas owned by households to the water body or structure. The distance from those areas to a nearby river is measured in metre. As the distance of an area to the river becomes closer, economic vulnerability to floods is likely to increase, thereby leading to a rise in flood risk. Past authors such as Messner and Meyer (2005) and Abdullah and Tengku Ismail (2016) argued that proximity to river is positively related with the economic aspect of flood vulnerability and flood risk in their studies. Thus, it is hypothesized in this study that proximity to river is positively related with flood risk since it also acts as an exposure factor of economic vulnerability to floods.

Economic Recovery

Economic recovery *(ECRY)* is indicated by the extent of vulnerable economic development in affected areas to progressively recover from the floods. Hence, it is measured in the percentage value. Past authors such as Balica and Wright (2010), Kissi *et al.* (2015) and Karmaoui *et al.* (2016) claimed that economic recovery is negatively related with flood vulnerability and flood risk in their studies. Hence, it is hypothesized in this study that economic recovery is negatively related with flood risk since it constitutes as a resilience factor of economic vulnerability to floods.

Flood Insurance

Flood insurance *(FINS)* reflects the possibility of valuable belongings and properties to be insured at some degrees by rational households before the upcoming floods. It is a dummy variable as measured either one or zero. As many valuable things are insured, vulnerability to floods will be economically reduced, thus causing a reduction in flood risk. Past authors such as Balica and Wright (2010) and Karmaoui *et al.* (2016) asserted that flood insurance is negatively related with flood vulnerability and flood risk in their studies. Hence, it is hypothesized in this study that flood insurance is negatively related with flood risk since it represents a resilience factor of economic vulnerability to floods just like economic recovery.

Housing Location

Housing location *(HLCT)* is defined as the strategic location of a community to reside in an area. It is a dummy variable as measured either one (i.e. urban) or zero (i.e. rural). This aligns with that the severity of flood events in urban areas are more impactful than those in rural areas especially when considering the magnitude and duration of the events (Van Sluis & Van Aalst, 2006). However, its significant effect on flood risk in a model is held constant since it is a control variable of this study.

Housing Material

Housing Material *(HMTL)* is explained by the housing conditions of the households within a community such that a house is made of cement, wood, or cement and wood. It is a dummy variable as measured either one or zero. Past authors such as Villordon (2015) incorporated its effect in his study towards understanding the social vulnerabilities and risks of floods among the communities in urban areas. Just like housing location, its effect is held constant as it is also a control variable of this study.

Method of Analysis

Developing and Estimating the Economic Vulnerability from the Household *FVI*

Smith (2004) considers disaster risk as the product of two components i.e. probability and consequence. Meanwhile, Blaikie *et al.* (1994) treat disaster risk to be the mixture of hazard and vulnerability as per Equation [5] in the works of the Pressure and Release (PAR) model:

$$Risk = Hazard \times Vulnerability \qquad [5]$$

In the context of a flood event, Equation [6] is then adjusted from Equation [5]:

$$Flood\ Risk = Flood\ Hazard \times Flood\ Vulnerability \qquad [6]$$

On a separate basis, a vulnerability assessment is undertaken to determine the conditions of economic vulnerability to the flood effect at a particular time. Altogether, the combined effects of economic vulnerability indicators are evaluated in order to calculate the economic *FVI* values at the districts, state and regional levels using Equation [7]:

$$FVI_i = \left(\frac{E*S}{R}\right)_i ; i = SV \qquad [7]$$

where E is Exposure, S is Susceptibility, R is Resilience and $EcV$is Economic Vulnerability.

Prior to that, all datasets were normalized by using the normalization formula as expressed in Equation [8] in order to convert them into non-dimensional units by interpolating the maximum and minimum of obtained data variables (Connor & Hiroki, 2005; Balica *et al.* 2013):

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$$Z_{ij} = \frac{X_{ij} - Min(X_{ij})}{Max(X_{ij}) - Min(X_{ij})} \quad [8]$$

where X_{ij} denotes as the value of $j$indicator *(j = 1,2,…,40)* in the i district *(i = 1,2,…,6)* and Z_{ij} is the matrix that corresponds to the normalized score in which its scaled value ranges between zero and one. While the value of one refers to the maximum value, the value of zero represents the minimum value.

Generally, the produced results adhere to the value designations of *FVI* model that were developed in Balica (2007), Balica *et al.* (2013) and Villordon (2015). As such, Table 2 assists to interpret values of the *FVI* model signifying from very low to very high vulnerability to floods for a given area. Hence, the designations of *FVI* model are useful in providing a broad overview of flood vulnerability levels that would suggest for more appropriate measures to be potentially designed and implemented.

Table 2. The Interpretation of Household-Based FVI Values

Index Value	**Description**
0.75 – 1.00	<u>Very high vulnerability to floods</u> An area has a very high vulnerability to floods. Either the physical, social, economic, environmental or all aspects are very highly vulnerable to floods. Thus, the households should make more efforts to address the areas' low resilience.
0.50 – 0.75	<u>High vulnerability to floods</u> An area has a high vulnerability level to floods. Either the physical, social, economic, environmental or all aspects are highly vulnerable to floods. Hence, the households should make efforts to address the areas' high vulnerability.
0.25 –0.50	<u>Vulnerable to floods</u> An area has a moderate vulnerability level to floods. Either the physical, social, economic, environmental or all aspects are vulnerable to floods. Hence, more works could be done to improve the households' resilience.
0.01 – 0.25	<u>Low vulnerability to floods</u> An area has a low vulnerability level to floods. Either the physical, social, economic, environmental or all aspects are lowly vulnerable to floods. Hence, the households are well-prepared for a flood event.
< 0.01	<u>Very low vulnerability to floods</u> An area has a very low vulnerability level to floods. Either the physical, social, economic, environmental or all aspects are very low vulnerable to floods. Hence, the households are very well-prepared for a flood event.

Source: Balica, 2007; Balica *et al.*, 2013; Villordon, 2015

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Multiple Linear Regression Analysis

A multiple linear regression analysis was employed to analyze the prevailing effects of economic vulnerability on flood risk among the East Coast household respondents in the state and regional settings. Altogether, four flood risk models, i.e. Equation [1] – Equation [4] from Section 3.4, are established in the analysis. In every model, the dependent variable; flood risk to be regressed against the components of flood hazard, economic vulnerability and control variables. For more descriptions on the four flood risk models in the state and regional settings, their details are comprehensively discussed under the topic of modeling in Section 3.4.

IV. Discussion of Results

After applying the normalization formula in Equation [8], the normalized values of economic vulnerability indicators as reported according to the district, state and regional levels are exhibited in Table 3.

Table 3. *Normalized Values of Indicators by District, State and Region*

Level	Factor	Indicator	Kota Bharu (n_1 = 80)	Kuala Krai (n_2 = 80)	Kuala Terengganu (n_3 = 50)	Kemaman (n_4 = 60)	Kuantan (n_5 = 60)	Temerloh (n_6 = 50)
District	*E*	Businesses	0.600	0.125	0.580	0.233	0.567	0.200
		Land Use: Agriculture	0.508	0.483	0.500	0.500	0.497	0.499
		Land Use: Urban	0.494	0.429	0.492	0.471	0.477	0.457
		Proximity to River	0.360	0.304	0.335	0.478	0.390	0.235
		Heavy Rainfall	0.257	0.231	0.216	0.322	0.161	0.299
	S	Income Inequality	0.675	0.238	0.460	0.483	0.767	0.460
		Urban Growth	0.493	0.426	0.494	0.493	0.494	0.496
	R	Flood Investments	0.520	0.013	0.014	0.023	0.035	0.020
		Economic Recovery	0.496	0.350	0.585	0.367	0.625	0.473
		Flood Insurance	0.025	0.075	0.500	0.533	0.267	0.120

			Kelantan (n_7 = 160)	Terengganu (n_8 = 110)	Pahang (n_9 = 110)
State	*E*	Businesses	0.363	0.407	0.384
		Land Use: Agriculture	0.496	0.500	0.498
		Land Use: Urban	0.462	0.482	0.467
		Proximity to River	0.332	0.407	0.313
		Heavy Rainfall	0.244	0.269	0.230
	S	Income Inequality	0.457	0.472	0.614
		Urban Growth	0.460	0.494	0.495

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	R	Flood Investments	0.267	0.016	0.028
		Economic Recovery	0.423	0.464	0.549
		Flood Insurance	0.050	0.517	0.194

			East Coast States of Peninsular Malaysia (N = 380)
Region	*E*	Businesses	0.384
		Land Use: Agriculture	0.498
		Land Use: Urban	0.470
		Proximity to River	0.350
		Heavy Rainfall	0.248
	S	Income Inequality	0.514
		Urban Growth	0.483
	R	Flood Investments	0.103
		Economic Recovery	0.479
		Flood Insurance	0.254

Note: *E*, *S* and *R* are vulnerability factors that denote as Exposure, Susceptibility and Resilience.

From the table, there are low to moderate shares of businesses, land uses for agriculture and urban, proximity to river and heavy rainfall under exposure that potentially lead to elevating a district's economic vulnerability to floods. Also, there is the evidence of higher income inequality levels among the respondents to drive the increasing economic vulnerability is prevailed in the districts of Kota Bharu and Kuantan (Hashim, Hassan & Abu Bakar, 2018). Meanwhile, the existing flood investments (e.g. urban drainage improvement works) with relatively low shares for the districts of Kuala Krai, Kuala Terengganu, Kemaman, Kuantan and Temerloh are undertaken for the benefits of surrounding communities. By having Kemaman and Kuala Terengganu as the exception, the other four districts tend to be economically vulnerable to floods in view of those areas were only insured by fewer respondents. Plus, moderate levels of economic recovery process that took place in the six districts after the 2014's floods are seen to result in maintaining the areas' considerably high resilience to floods economically.

On the contrary, low to moderate shares of businesses, land uses for agriculture and urban areas, proximity to river and heavy rainfall under the exposure factor render to aggravating the economic vulnerability to floods in a state's setting. While moderate shares of income inequality and urban growth to drive the increasing economic vulnerability, relatively low to moderate shares of flood investments, economic recovery and flood insurance are seen to enhancing considerably high resilience to floods across the states.

In the regional's setting, higher values of indicators under the exposure and susceptibility factors will likely contribute to increasing the economic vulnerability to floods. However, low to moderate shares of flood investments, flood insurance and economic recovery may result in fortifying the regional's resilience to floods economically.

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By using the normalized values in Table 3, the aggregate values of exposure, susceptibility and resilience factors are calculated for the district, state and regional levels. As such, Table 4 displays the results by district, state and region.

Based on the results in Table 4, exposure and susceptibility constitute as the most dominant factors in affecting the economic vulnerability to floods across the districts, states and in the region. Furthermore, the relatively low resilience values in most cases render to putting the involved districts, states and region to be ranked as economically vulnerable to floods. Moreover, susceptibility represents the most significant factor in determining economic vulnerability to floods at the district, state and regional levels.

Table 4. *Aggregate Values of Factors by District, State and Region*

Level	**Factor**	**Kota Bharu ($n_1 = 80$)**	**Kuala Krai ($n_2 = 80$)**	**Kuala Terengganu ($n_3 = 50$)**	**Kemaman ($n_4 = 60$)**	**Kuantan ($n_5 = 60$)**	**Temerloh ($n_6 = 50$)**
District	*E*	0.014	0.002	0.010	0.008	0.008	0.003
	S	0.333	0.101	0.227	0.238	0.379	0.228
	R	0.006	0.0003	0.004	0.005	0.006	0.001
		Kelantan ($n_7 = 160$)		**Terengganu ($n_8 = 110$)**		**Pahang ($n_9 = 110$)**	
State	*E*	0.007		0.011		0.125	
	S	0.210		0.233		0.014	
	R	0.006		0.006		0.002	
		East Coast States of Peninsular Malaysia (N = 380)					
Region	*E*	0.008					
	S	0.248					
	R	0.017					

Note: *E*, *S* and *R* are vulnerability factors that denote as Exposure, Susceptibility and Resilience.

Given the aggregate values in Table 4, the results of economic *FVI* values by district, state and region are subsequently calculated. Hence, the results are reported in Table 5. From the table, Kota Bharu and Temerloh are the two districts' most economically vulnerable to floods as shown by their highest economic *FVI* values (Hashim *et al.*, 2018). This is likely to be the case due to the combined effects of exposure and susceptibility factors outweigh the communities' total accumulated resilience.

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Meanwhile, Pahang represents the state's most economically vulnerable to floods as shown by its highest economic *FVI* value. This is due to the main contribution of susceptibility factors such as income inequality and urban growth in the districts of Kuantan and Temerloh. Also, with lower resilience values on the other side, these may lead to yielding the state's highest economic *FVI* value as shown by both districts in Table 5.

Table 5. *Results of Economic FVI Values by District, State and Region*

Level	**Kota Bharu (n_1 = 80)**	**Kuala Krai (n_2 = 80)**	**Kuala Terengganu (n_3 = 50)**	**Kemaman (n_4 = 60)**	**Kuantan (n_5 = 60)**	**Temerloh (n_6 = 50)**	***FVI* Average**
District	0.736	0.552	0.521	0.442	0.548	0.631	0.572
	Kelantan (n_7 = 160)		**Terengganu (n_8 = 110)**		**Pahang (n_9 = 110)**		
State	0.251		0.440		0.655		
	East Coast States of Peninsular Malaysia (N = 380)						
Region	0.116						

When evaluating on the regional basis, the estimated economic *FVI* value for the East Coast States of Peninsular Malaysia gets even smaller to reach about 0.12 due to the inherent effect of aggregation method. Here, one reason is that aggregation simplifies the data analysis by reducing the number of analyses without having the ability to differentiate specific effects of individual sources or methods. Thus, the focus of a proper flood management in the district, state and regional settings should be aimed at reducing economic vulnerability as much as possible so that flood risk is potentially minimized and this can be achieved via integrating with the developmental process. In absence of flood management within the development process, this will inevitably contribute to increasing economic vulnerability and likely so to flood risk in the subsequent manner.

Further, to analyse the relationship between flood risk and economic vulnerability among the East Coast households particularly in the state and regional settings, a multiple linear regression analysis was employed in this study. Prior to that, a correlation analysis was undertaken and the corresponding results are shown in Table A.1. Hence, the results of the analysis justify the inclusion of all variables into four regression models.

In general, economic vulnerability to floods stems from various factors; the conditions of physical, business and community characteristics. Thus, Table 6 shows the results on regression models for Kelantan, Terengganu, Pahang and the East Coast States altogether.

Table 6. *Results on Regression Analysis of KM1, TM2, PM 3 and ECSM4 Models*

Variable	**Coefficient**	**Standard Error**	***t*-statistic**	***p*-value**
Dependent Variable: *FR*				
Kelantan Model 1 *(KM1)*				
C	0.065	0.030	2.167	0.032*
FDMG	1.420×10^{-6}	2.290×10^{-7}	6.219	0.000*
FDEP	0.018	0.012	1.446	0.150
FWNG	0.089	0.017	5.169	0.000*
PRXR	6.260×10^{-6}	1.940×10^{-6}	3.228	0.002*
BIZS	0.046	0.016	2.944	0.004*
ECRY	-0.074	0.031	-2.428	0.016*
HLCT	0.102	0.018	5.683	0.000*
HMTL	-0.020	0.012	-1.622	0.107
R^2	0.422		Prob (*F*-statistic)	0.000
Adjusted R^2	0.392			
Terengganu Model 2*(TM2)*				
C	-0.061	0.022	-2.853	0.005*
FDMG	7.920×10^{-6}	1.860×10^{-6}	4.247	0.000*
FDEP	0.068	0.011	6.277	0.000*
FWNG	0.108	0.015	7.319	0.000*
BIZS	0.021	0.011	1.897	0.061**
FINS	-0.019	0.010	-1.835	0.070**
ECRY	-0.205	0.022	-9.380	0.000*
HLCT	0.060	0.011	5.066	0.000*
HMTL	0.012	0.011	1.033	0.304
R^2	0.672		Prob (*F*-statistic)	0.000
Adjusted R^2	0.646			
Pahang Model 3*(PM3)*				
C	-0.031	0.033	-0.945	0.347
FDMG	5.100×10^{-6}	1.230×10^{-6}	4.159	0.000*
FDEP	0.020	0.015	1.322	0.189

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FWNG	0.033	0.020	1.647	0.103
PRXR	9.540×10^{-6}	5.440×10^{-6}	1.756	0.082**
BIZS	0.036	0.014	2.534	0.013*
ECRY	-0.006	0.037	-0.174	0.862
HLCT	0.051	0.019	2.635	0.010*
HMTL	0.017	0.015	1.106	0.271
R^2	0.305		Prob (*F*-statistic)	0.000
Adjusted R^2	0.250			

Note: * and ** indicate H_0: $\beta_i = 0$ being rejected at the five percent and 10 percent significance levels.

"Table 6 Continued"

Variable	Coefficient	Standard Error	*t*-statistic	*p*-value
Dependent Variable: *FR*				
East Coast States Model 4*(ECSM4)*				
C	0.068	0.016	4.362	0.000*
FDMG	1.160×10^{-6}	2.020×10^{-7}	5.735	0.000*
FDEP	0.031	0.008	4.151	0.000*
FWNG	0.074	0.011	6.955	0.000*
PRXR	4.470×10^{-6}	1.600×10^{-6}	2.966	0.003*
BIZS	0.032	0.009	3.373	0.000*
ECRY	-0.096	0.018	-5.226	0.000*
HLCT	0.069	0.010	7.101	0.000*
HMTL	-0.008	0.008	-1.014	0.000*
R^2	0.327		Prob (*F*-statistic)	0.000
Adjusted R^2	0.313			

Note: * and ** indicate H_0: $\beta_i = 0$ being rejected at the five percent and 10 percent significance levels.

All coefficients of the variables in the table except *FDEP* and *HMTL* in Kelantan Model 1, *HMTL* in Terengganu Model 2 and *FDEP*, *FWNG*, *ECRY* and *HTML* in Pahang Model 3 are statistically significant at the five percent and 10 significance levels. Therefore, these variables particularly economic vulnerability indicators such as *PRXR*, *BIZS* and *ECRY* in Kelantan Model 1 and the East Coast States Model 4, *FINS*, *BIZS* and *ECRY* in Terengganu Model 2 and *PRXR* and *BIZS* in Pahang Model 3 significantly influence any change in the flood risk realization among the households.

As proximity to river becomes closer and an area's density for considerable numbers of businesses increases, these would contribute to increasing flood risk among the households in Kelantan, Pahang and the East Coast states of Peninsular Malaysia altogether. For instance, the results indicate that a percent rise in businesses would lead to about 0.05 percent increase in the realization of flood risk among the households in Kelantan. However, a rise in flood insurance holders and/or responsiveness of local economic recovery would render to considerable flood risk reductions among the

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households in Kelantan, Terengganu and the East Coast states of Peninsular Malaysia altogether. For example, the results report that a percent increase in flood insurance holders would render to about 0.02 percent decrease in flood risk among the households in Terengganu.

In this respect, the significant findings on proximity to river from farmland and housing areas are aligned with Kissi *et al.* (2015). They revealed that most households in the Yoto district of Togo are adjacent to the river. As such, the closeness to the river structure facilitates them with the access to water for various purposes. Unavoidably, this may aggravate the communities' economic vulnerability to flood risk when the extreme floods are likely to strike. Also, this aligns with Abdullah and Tengku Ismail (2016) who highlighted that the flood event typically occurs due to the overflow of the river bank. Given the state of Kelantan to cover mostly low elevation lands and in proximity to the river, the risk of flooding increases as proximity to river becomes closer.

In line with the social vulnerability paradigm, economic vulnerability can be considered as rooted not only from the exposure to potential physical impacts of hazards but also from the societal conditions that potentially result in certain businesses and types of businesses incapable to cope with the environmental shocks including floods (Cutter, 1996; Dahlhamer, 1998; Cutter *et al.*, 2000). At the community level, businesses constitute as the foundation of local economies. In the face of floods, the destruction of exposed businesses produces direct business and job losses, negatively affects incomes and causes economic ripple effects such as various disruptions in the flow of goods and services as well as the supply-chain problems. Given a specific case of Kuala Krai in Kelantan, Nayan *et al.* (2017) showed that traded business goods (i.e. mean = 1.56, standard deviation = 0.894 with a share of 68 percent) represent the leading business type that experienced tremendous losses that were more impactful than business services (i.e. with a share of 32 percent) locally. As such, this was stemmed from the destruction of goods and premises, stalls or kiosks following the floods in 2014.

Although flood insurance is one of non-structural flood risk management tools, it is not a common practice in Malaysia (Ho, 2009). Since floods are considered as the "Act of God", the flood insurance industry is not well-developed in this country (Abdullah, 2004). However, there exist some private insurance companies that provide insurance schemes against flood losses at premium prices (Ho, 2009). Specifically, for the case of Kemaman in Terengganu, reasonably large respondents in Table 3 are found through the surveys to opt for a risk transfer mechanism before facing the floods in 2014. As such, they became the flood insurance holders under "MyKampung Insurance" introduced by the Alliance Insurance, thus enabling them to get certain flood compensations on their damaged houses associated properties as they attempted to financially recover from the floods. there exist some private insurance companies that provide insurance schemes against flood.

Following from major floods in 2014, the economic recovery outcomes are expected to rely on the combination of vulnerability and resilience factors of a working system in an area. The quicker the pace of recovery, the better the area's economic progression becomes as it recovers from the floods. To vary by degree, economic recovery processes and outcomes are affected not only from the direct physical impacts at the times of floods but also by the ways the floods create long term problems for business owners and businesses (Tierney, 2006). These may include prolonged business interruptions, difficulties in shipping and receiving goods and services, revenues decline due to the customers loss and other operational problems.

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V. Policy Recommendation and Conclusion

The assessment on economic vulnerability to floods is conducted among a total of 380 household respondents within six districts in Kelantan, Terengganu and Pahang. The findings of this study tend to vary by district, state and region. Among others, Kota Bharu and Temerloh are the two districts' most economically vulnerable to floods as shown by their highest economic *FVI* values of 0.736 and 0.631, respectively. This is due to the combined effects of exposure and susceptibility factors that outweigh the communities' resilience. Meanwhile, Pahang is the state's most economically vulnerable to floods as shown by the highest economic *FVI* value of 0.655. Evidently, this is contributed by the susceptibility factor that contains moderate to high shares of income inequality levels and urban growth rates in the districts of Kuantan and Temerloh. Further, regarding the effect of economic vulnerability on flood risk, this study unveils that the indicators; *PRXR*, *BIZS*, *FINS* and *ECRY* are found to be statistically significant at the five percent and 10 percent significance levels. Thus, these indicators are proven to significantly influence any change in the realization of flood risk.

On one hand, the proximity to river from business, farmland and housing areas and growing numbers of businesses are key determinants that contribute to increasing flood risk among the households in Kelantan, Pahang and the East Coast states altogether. In this regard, one policy recommendation is via reducing the economic exposure to floods among the affected communities especially in view of rising businesses and closer proximity to river from business, farmland and housing areas. Therefore, decision makers and policy makers are recommended to explore possible ways of optimizing the flood recovery process from pre-disaster community procedures such as code adoption policies and early recovery decisions via vertical and organizational integrations among households, communities, businesses, donor agencies, infrastructural providers and local governments.

On the other, a rise in flood insurance holders and responsiveness of local economic recovery would lead to the flood risk reduction among the households in Kelantan, Terengganu and the East Coast states altogether. In this respect, a policy recommendation is via increasing the economic resilience to floods among the affected communities particularly in the aspects of flood insurance holders and economic recovery. Therefore, the policy makers are recommended to reformulate the existing cost sharing policies through a clearly defined funding mechanism for accommodating various forms of interventions. With the availability of costs and risks sharing through multi-tiered financing of risk reduction measures such as the subscription of "MyKampung Insurance" by many of Kemaman households, this is foreseen to increase the sense of ownership, accountability and commitment to strategies of flood risk management among a group of people in a community, thus improving the sustainability of flood risk management in the district and state settings.

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necessarily reflect the views or policies of the ministry or the project team. Any errors are the sole responsibility of the authors.

Appendix

Table A.1: Results of Correlation Analysis

A correlation analysis underpins the strength and direction of association among the variables.

<u>**Kelantan Model 1 *(KM1)***</u>

		Dependent	**Flood Hazard**			**Economic Vulnerability**					**Control**	
		FR	***FDMG***	***FDEP***	***FWNG***	***PRXR***	***BIZS***	***INEQ***	***FINS***	***ECRY***	***HGLCT***	***HGMTL***
Dependent	***FR***	1.00										
Flood Hazard	***FDMG***	0.29	1.00									
	FDEP	-0.06	0.38	1.00								
	FWNG	0.32	-0.17	-0.22	1.00							
Economic Vulnerability	****PRXR***	**0.16**	0.19	0.13	0.01	1.00						
	****BIZS***	**0.11**	-0.04	0.02	0.14	-0.01	1.00					
	INEQ	0.06	-0.24	-0.24	0.16	-0.11	0.07	1.00				
	FINS	-0.05	-0.06	0.10	0.04	0.10	-0.05	-0.04	1.00			
	****ECRY***	**-0.09**	-0.23	-0.15	0.08	-0.17	-0.03	0.06	0.12	1.00		
Control	***HLCT***	0.27	-0.27	-0.52	0.16	-0.23	0.49	0.44	-0.11	0.05	1.00	
	H	-	-	-	-						-	1.00

	MTL	0.21	0.04	0.03	0.10	0.11	-0.02	-0.19	0.05	-0.08	0.13

Terengganu Model 2 *(TM2)*

		Dependent	**Flood Hazard**			**Economic Vulnerability**					**Control**	
		FR	***FDMG***	***FDEP***	***FWNG***	***PRXR***	***BIZS***	***INEQ***	***FINS***	***ECRY***	***HGLCT***	***HGMTL***
Dependent	***FR***	1.00										
Flood Hazard	***FDMG***	0.13	1.00									
	FDEP	0.25	0.11	1.00								
	FWNG	0.37	0.08	-0.10	1.00							
Economic Vulnerability	***PRXR***	0.09	-0.12	0.29	-0.22	1.00						
	****BIZS***	**0.18**	-0.09	-0.28	0.04	0.12	1.00					
	INEQ	0.08	-0.12	-0.15	-0.14	-0.23	-0.16	1.00				
	****FINS***	**-0.14**	-0.13	0.16	-0.21	0.32	0.10	0.29	1.00			
	****ECRY***	**-0.57**	-0.15	-0.02	0.11	-0.27	-0.01	0.22	0.15	1.00		
Control	***HLCT***	0.05	-0.31	-0.36	-0.26	-0.15	0.35	-0.02	-0.03	0.01	1.00	
	HMTL	-0.04	0.10	-0.24	-0.30	0.26	-0.27	-0.01	0.14	-0.12	-0.03	1.00

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Note: * represents the chosen three economic vulnerability indicators that are highly correlated to flood risk.

<u>Pahang Model 3 (*PM3*)</u>

		Dependent	**Flood Hazard**			**Economic Vulnerability**					**Control**	
		FR	***FDMG***	***FDEP***	***FWNG***	***PRXR***	***BIZS***	***INEQ***	***FINS***	***ECRY***	***HGLCT***	***HGMTL***
Dependent	***FR***	1.00										
Flood Hazard	***FDMG***	0.20	1.00									
	FDEP	0.12	0.60	1.00								
	FWNG	0.10	-0.22	-0.38	1.00							
Economic Vulnerability	****PRXR***	**0.10**	-0.39	-0.47	-0.03	1.00						
	****BIZS***	**0.27**	-0.19	-0.28	0.17	0.26	1.00					
	INEQ	0.03	-0.17	-0.26	0.34	0.14	-0.10	1.00				
	FINS	0.02	0.17	0.02	-0.08	0.01	0.15	-0.04	1.00			
	****ECRY***	**-0.09**	0.07	0.13	0.14	-0.16	0.09	0.01	0.18	1.00		
Control	***HLCT***	0.09	-0.47	-0.68	0.29	0.42	0.37	0.32	0.18	-0.11	1.00	

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	HMTL	-0.02	0.09	0.19	-0.28	0.03	-0.09	-0.06	0.17	0.07	-0.21	1.00

East Coast States Model 4 *(ECSM4)*

		Dependent	**Flood Hazard**			**Economic Vulnerability**					**Control**	
		FR	***FDMG***	***FDEP***	***FWNG***	***PRXR***	***BIZS***	***INEQ***	***FINS***	***ECRY***	***HGLCT***	***HGMTL***
Dependent	***FR***	1.00										
Flood Hazard	***FDMG***	0.27	1.00									
	FDEP	0.08	0.38	1.00								
	FWNG	0.28	-0.12	-0.24	1.00							
Economic Vulnerability	****PRXR***	**0.16**	0.27	0.09	-0.03	1.00						
	****BIZS***	**0.13**	-0.06	-0.15	0.10	0.04	1.00					
	INEQ	0.02	-0.18	-0.23	0.15	-0.09	-0.04	1.00				
	FINS	-0.02	-0.17	0.00	-0.12	-0.10	0.07	0.08	1.00			
	****ECRY***	**-0.23**	-0.07	0.00	0.11	-0.08	0.00	0.10	0.05	1.00		
Control	***HLCT***	0.17	-0.21	-0.51	0.09	-0.06	0.42	0.27	-0.01	0.00	1.00	
	HMTL	-0.11	0.01	0.11	-0.22	0.11	-0.12	-0.12	0.09	-0.05	-0.13	1.00

Note: * represents the chosen three economic vulnerability indicators that are highly correlated to flood risk.

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