The cost of floods in developing countries' mega cities: A hedonic price analysis of the Jakarta housing market, Indonesia

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Abstract

Many mega cities in developing countries experience floods annually that affect a large number of people in urban areas. In spite of this, so far there have not been relatively limited number of empirical studies evaluating the cost of floods in developing countries' megacities. By conducting a hedonic price analysis—providing evidence regarding the impacts of floods on the housing market—this paper estimates the cost of floods in developing countries' mega cities. A robust regression technique on a relatively simple linear transformation model and a maximum likelihood estimation technique on the spatial lag version of the simple linear transformation model are utilised to estimate the correlation between level of 2007 floods and monthly housing rental prices in Jakarta, Indonesia. This paper concludes that a one percent increase in floods is associated with an 11.4 percent lower monthly housing rental price.

Key words: Environmental economics, hedonic price analysis, spatial analysis, flood.

JEL Code: Q51; Q54; R32; O21

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1. Introduction

Climate change is increasing extreme weather and climate events, especially in developing countries. These countries are more vulnerable due to their geographic exposure, poverty, high dependence on agriculture, rapid population growth and limited capacity to cope with an uncertain climate. This leads to increased human exposure to natural disasters such as heatwaves, droughts, storms and floods, which are becoming more frequent as the world gets warmer (Stern, 2007). Among these major weather events, floods have been recognised as the major cause of economic damage worldwide which, in turn, affects a large number of people (UNISDR, 2002). More specifically, this phenomenon has become an annual event over the past few decades

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in many developing countries' megacities, and has heavily impacted Asia, where there is a large concentration of people in urban areas. (World Resources Institute, 2015).

In 2014, the level of urbanization in developing countries is approximately 48.4%, whereas in the Asian region, the proportion of people living in urban areas is approximately 47.5% (UN, 2014). Urbanization in developing countries has brought on urban management challenges related to the lack of physical infrastructure and inadequate urban services (Cohen, 2004). In some cities, urban expansion has been unplanned or inadequately managed, leading to rapid sprawl, pollution, and environmental degradation, accompanied by unsustainable production and consumption patterns (UN, 2014).

An apparent lack of capability in managing urban development, as a result of high rates of urbanization and large populations, along with increasing climate variability and rising sea levels are typically suspected as the main causes of these floods. It is not uncommon that these floods annually cause serious natural disaster events in developing countries (UN and WB, 2010).

A study undertaken by the World Resources Institute (2015) considered Indonesia to be one of the countries with the greatest number of people exposed to flood risk, having ranked 6th out of 164 countries in 2010. This city comprises the largest urban area in Indonesia with a population density of approximately 14 thousand persons per km^2 (Yusuf and Resosudarmo, 2009). In this city, the cause of flooding is not only due to increasing climate variability and rising sea levels, but also because of the extensive use of ground water; i.e. causing several parts of Jakarta subsidence (World Bank, 2011). Therefore, flooding is an annual disaster event in Jakarta and most of the time affects a significant number of residents in the city. For example, the 2007 floods were one of the most significant, inundating almost 36% of Jakarta city, in some areas to a depth of seven meters, resulting in over 70 deaths and 340,000 displaced people (Jha et al., 2012; Budiyono et al., 2016).

Due to growing concern over the impact of floods on Jakarta, local government and non-government organisations have been developing several intervention programs, including better managing the risk of disaster, and resettlement of urban poor populations at the lower end of the scale, up to reducing greenhouse gas emissions (Baker, 2011). Several of these activities are as follows. Since 2012, with World Bank support, the Jakarta government developed projects to dredge a number of vital floodways and retention basins, and rehabilitated embankments and mechanical equipment that are part of Jakarta's flood management system. This includes work on 11 floodways or canals, comprising a total length of 67.5 kilometers, and four retention basins covering an area of 65 hectares. About 42 kilometers of embankments are rehabilitated or constructed within these floodways and retention basins (World Bank, 2016).

However, some constraints have proven to be an obstacle to the success of these initiatives. In 2013 and 2014, Jakarta was again hit by major floods (Budiyono et al., 2016). Among the constraints are much-needed upgrades to city infrastructure, the significant lack of research and data regarding floods to support decision-making, and the absence of community engagement—both government and community—to take the necessary actions. The cost of the projects needed to mitigate floods in Jakarta is also not trivial. The Jakarta Water Management Agency estimated the city needs Rp 118 trillion (USD9.2 billion or approximately twice the total revenue of Jakarta government in 2015) to make Jakarta flood-free (Tambun et al., 2015). Therefore, reducing the flood risk in Jakarta still remains a challenge to be tackled for the Indonesian government, as a key priority within disaster management.

Although, as mentioned before, flooding is a significant occurrence for consideration by any government in developing countries, there has been little research and limited evidence of evaluating the cost of these floods in developing countries' megacities. Most of the research conducted has focused on flood risk in developed countries, particularly the United States of America, and has studied the impact of flooding on the price differential of property values and their relation to insurance costs (Carbone et al., 2006; Bin and Landry, 2013; Bin and Polasky, 2004; Bin et al., 2008; Atreya et al., 2013).
In an attempt to fill this research gap, this paper will apply a hedonic property value analysis using a combination of data obtained from the Indonesian Family Life Survey (IFLS), and flood-level data in Jakarta obtained from the United Nations Department of Safety and Security (UNDSS). The main objective is to analyse whether or not major flood events are directly correlated with property values in Jakarta.

The paper is divided into five sections; the background and motivation of the research; the use of the hedonic property value method in previous studies; a description of the methodology and data utilized in the paper; the empirical results obtained from the data; the policy implications; and the concluding statements.

2. Literature Review

A study conducted by Rosen (1974) is considered as the basis for using the hedonic property price model to estimate the value of the environmental amenities. The argument is that the attributes of the residential properties — recognised as heterogeneous goods, such as structural, neighborhood and environmental characteristics—are reflected in the price differentials that affect lessee preferences in a market clearing equilibrium condition (Rosen, 1974). The advantage of using this method over other preference estimation techniques is that it makes use of actual market transactions to recover value estimates for non-market attributes (Bin et al, 2008).

Since then it has been widely utilized in the environmental economics literature to estimate the price difference between residential properties located within or outside floodplain regions. Some of them can be seen in Table 1. Most of these studies demonstrate a negative relation between the housing prices and flood events, whereby the properties located in the floodplain are likely to be impacted by a price decrease, in comparison to those properties located in non-floodplain areas. Further to this, following a flood phenomenon, the houses located in floodplain areas are forced to pay an increased insurance premium. Skantz and Strickland (1987) note that house-price reactions to flood events initially declined and later regained their lost value due to the market forgetting about the flood event. Using a semi-logarithmic functional form for the hedonic property value analysis, they found there was no immediate decline in flooded-home prices after the flood event. This was due to the flood insurance premium being subsided by the federal government. A year later, when the government cut the economic support, floodplain houses experienced a decrease in property values.

Table 1. Summary of existing hedonic price studies related to flood events

No	Author (publication year)	Method	Location	Results
1	Skantz and Strickland (1987)	Hedonic	TX, USA	Negative; not significant
2	Bin and Polasky (2004)	D-D Hedonic	NC, USA	-5.7%; significant
3	Carbone et al. (2006)	D-D Hedonic	FL, USA	-20% to -30%; significant
4	Daniel et al. (2007)	Hedonic	Netherlands	-7% to -13%; significant
5	Bin et al (2008a)	Spatial hedonic	NC, USA	-12.1%; significant
6	Bin et al. (2008b)	Hedonic	NC, USA	-7.3%; significant
7	Pope (2008)	Spatial FE hedonic	NC, USA	-4%; significant
8	Samarasinghe and Sharp (2008)		New Zealand	-6.2%; significant
9	Kousky (2010)	D-D Hedonic	MI, USA	-2.6%; significant
10	Bin and Landry (2013)	D-D hedonic	NC, USA	-5.7%; significant
11	Kousky and Walls (2013)	Simulation	MI, USA	-0.7%; not significant

12	Rabassa et al. (2013)	Spatial hedonic	Buenos Aires, Argentina	-17.3%; significant

Bin and Polasky (2004) also utilized the hedonic property price function to estimate the flood hazard effects on property values in Pitt County, North Carolina. The methodology used an OLS regression analysis which found that after Hurricane Floyd in 1999, houses located in a floodplain were impacted by a price discount. The marginal effect estimated for the property values located in the floodplain was approximately $ 7,463, i.e. the property value in the floodplain was lowered by that amount of money.

This formed the basis of the study undertaken by Bin and Landry (2013), which re-examined and compared findings with a previous flooding event regarding lessee preferences in a market clearing equilibrium condition—1996 Hurricane Fran—using difference-in-difference (DID) and spatial effect models (spatial lag and spatial error). They found that average real property values decreased by approximately 5.7% after Hurricane Fran compared to approximately 8.8% after Hurricane Floyd; however, in between both hurricanes, they increased by about 2.2%. This price increase is due to the lessee becoming more insensitive to flooding events since the perception of flood risks and cost associated with it are not persistent over time.

Most of the published literature analysing the relationships between floods and hedonic property value concerns the US (Table 1). There are some studies regarding other developed countries, such as the Netherlands (Daniel et al., 2007) and New Zealand (Samarasinghe and Sharp; 2008); and a very few on developing countries. Among the very few on developing countries is by Rabassa et al. (2016) which attempts to find out whether flood events are associated with property values in La Plata city, Argentina. Using data from land parcel sales in 2004, they found that property sale prices were affected by a discount of approximately 17.3% for properties located in flood-prone areas, as opposed to those situated outside of the floodplain.

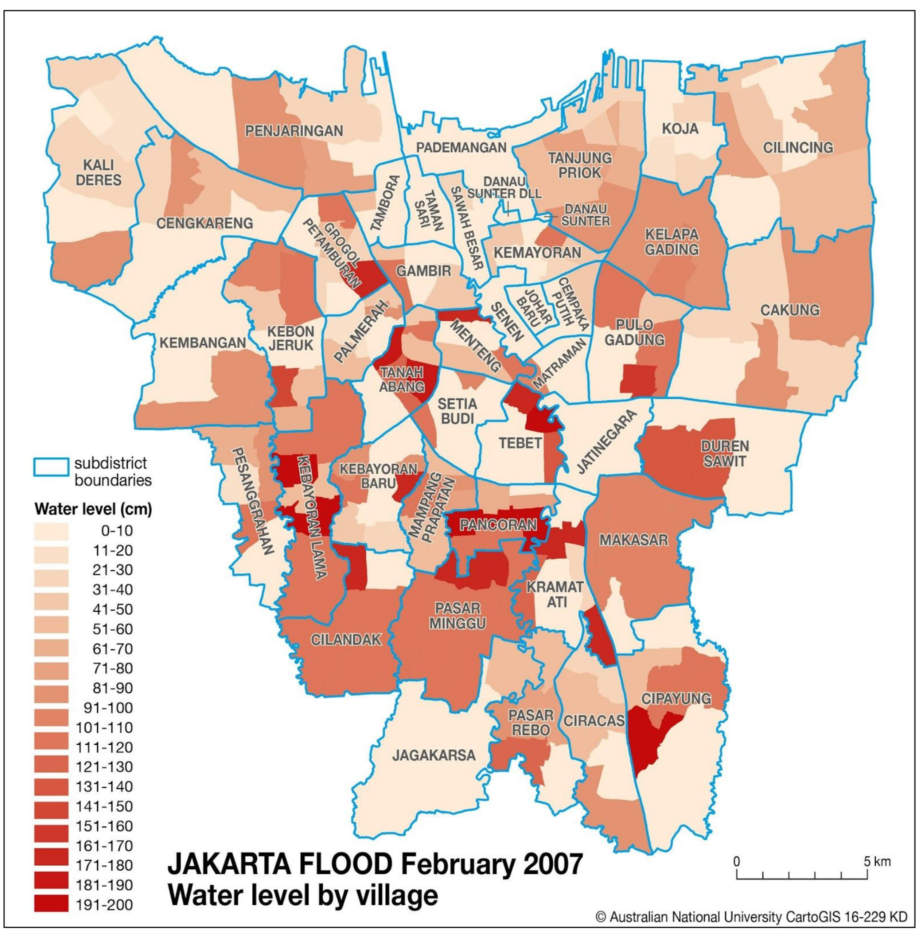
Another important thing to note about most previous studies is that they cover flood events that not occur on an annual basis. Floods in the southern part of the US might happen frequently, but they occur once every few years; i.e. not annually. Hence the prices just after the shock might not yet be equilibrium prices.

This paper will apply the hedonic price method to see whether the annual flood events have an impact on the housing value, measured by monthly rental property price, in Jakarta, Indonesia. Since this is an annual event, though the size might vary annually, we can expect the housing rental market to be in its equilibrium condition.

3. Study Area and Data Sources

The city of Jakarta, the capital of Indonesia, is study area of this paper. Jakarta has been one of the fastest-growing megacities in the world. Approximately 6.5 million people resided in this city in 1980 compared to more than 10 million people in 2016 (CEIC, 2017). The city lies on a low, flat alluvial plain formed by the mouth of the Ciliwung River (main river) where it meets Jakarta Bay. This river travels through the middle of the city and divides it into western and eastern areas. The Pesanggrahan and Sunter are less turbulent rivers and cross the western part of Jakarta. Thus, most of the city is prone to swampy and flooded conditions, especially during the rainy season (typically from October to April). Those parts of the city further inland are slightly higher but are also at risk of experiencing flood events (Baker, 2011).

Figure 1 shows a map of the study area and the flood water levels during the February 2007 flood event per kecamatan (sub-district) level. As seen, locations with the highest flood level (dark red) are adjacent to the Ciliwung, Pesanggrahan and Sunter rivers especially in the southern area of Jakarta. However, the area of the city with more water coverage was northeast Jakarta, which includes the subdistricts of Kelapa Ganding, Pulo Gadung, Cakung, Danau Sunter, Kemoyoran, Tanjung Priok and Cilincing.



Source: United Nations Department of Safety and Security (UNDSS), 2007.

Figure 1 - Map of Jakarta after the flood disaster in 2007

The map (Figure 1) and the data for the flood water levels by village or *kelurahan* in Jakarta were taken from the United Nations Department of Safety and Security (UNDSS), which surveyed Jakarta in February 2007. The city is divided into five districts (known as *kotamadya*), which divide into 42 subdistricts (known as *kecamatan*). Each subdistrict is comprised of several kelurahan; approximately 2 to 5. The UNDSS collected and reported the water levels of the 2007 Jakarta flood from news sources (radio and television), and United Nations Staff Reports to UNDSS Offices and Police Stations.[3]

The flood water level to be studied in this paper (which is in Figure 1) corresponds to the water level (measured in centimeters) registered immediately following the flood event on 6 February 2007. This information was gathered at the village level. For our analysis in this paper, we calculate the weighted average flood water level in each subdistrict. The village area (measured in square meters) within each subdistrict is used as a weight to estimate the average water level for each subdistrict. The reasons for aggregating the flood information at subdistrict level are as follows. First, floods in one kelurahan will certainly affect their neighbouring kelurahan; second, floods are typically managed at subdistrict level; and third, for security reasons, our household information only contains coded locations at the subdistrict level.

The other data used for this paper is cross-sectional, extracted from the 2007 Indonesia Family Life Survey (IFLS) dataset. The dataset contains information on monthly house rent, housing characteristics and neighborhood characteristics[4]. There are as many as 1,573 observations for the city of Jakarta. This sample arguably represents the population of Jakarta.

The variables selected for the hedonic price analysis are those commonly used in hedonic property value studies (Yusuf and Koundouri, 2005; Yusuf and Resosudarmo. 2009) and are available in the IFLS dataset. Monthly house rental price expressed in rupiahs (Indonesian currency) is used as a proxy of housing value. Meanwhile, housing characteristic variables are house size (expressed in square meters); wall, roof and floor materials; and water source availability inside the house. The wall, roof and floor materials are dummy variables which have been assigned a value of one if they are a more suitable material; i.e. cement/brick for walls, concrete/roof tiles for roof and cement/stone for floor), or otherwise they are given a value of zero. Water source is also a dummy variable of 1 if there is a water source inside the house or otherwise zero.

[3] https://trip.dss.un.org/dssweb/WelcometoUNDSS/tabid/105/

[4] https://www.rand.org/labor/FLS/IFLS.html

These variables are expected to have a positive relationship with the monthly house rent.

We also include neighborhood characteristics at the kelurahan level in Jakarta. These neighborhood characteristics are unemployment rate, percentage of people with university education, whether or not public transport is accessible, and distance to the district center. The information extracted is at the village level (*kelurahan* level in Jakarta).

The variables for the unemployment rate and distance to the center of Jakarta are expected to be negatively associated to the dependent variables; the variables for the percentage of people in the village with a university education, and accessibility of public transport, are estimated to be positively related to monthly housing rent.

Table 2 provides a detailed description and summary of the variables that are utilized in the hedonic price model.

Table 2. Summary statistics of variables in the hedonic equation

	Mean	Std. deviation
Dependent variable		
Montly rent (million rupiahs)	5.672	21.200
Housing characteristics		
House size (m^2)	74.524	189.086
Wall material is cement/brick (1,0)	0.879	0.326
Roof material is concrete/roof tiles (1,0)	0.477	0.500
Floor material is cement/stone (1,0)	0.846	0.362
Water source inside (1,0)	0.553	0.497
Neighborhood characteristics		
Unemployment rate at the neighb. (pct)	5.548	3.359
People w. univ. educ. the neighb. (pct)	9.310	10.970
Accessible by public transport (1,0)	0.757	0.429
Distance to district centre (km)	6.970	6.508
Environmental variable		
Flood in water level (cm)	42.325	23.135

Source: 2007 Indonesian Family Life Survey (IFLS) and United Nations

Department of Safety and Security (UNDSS).

4. Methodology

The basic model adopted in this paper is one commonly utilized in a hedonic property value analysis.

$$y = \beta_0 + x_1 \beta_1 + x_2 \beta_2 + f\beta_3 + [f x_1]\beta_4 + \varepsilon \qquad (1)$$

where y is the logarithmic form of the monthly rent of the house which is the proxy for housing value, x_1 is a vector of housing attribute variables (such as house size, wall, roof and floor materials, and water source availability) and x_2 is a vector of neighborhood characteristics (unemployment, people with education, accessibility to public transport and distance to district center). The variable f is the logarithm form of the flood water level and fx_1 is interaction variables between the structural characteristics variables and the flood variable. Meanwhile ε is the error term.

In this hedonic analysis, it is assumed that the lessee makes a rental decision accepting all the housing characteristics, and so the property value is a function of heterogeneous characteristics of the property. It is suspected that this hedonic property value function is a nonlinear function toward its characteristics and many of the variables involved are not normally distributed; and so, a transformation function technique is usually adopted. The Box–Cox transformation model is most commonly used in hedonic price analysis (Cropper et al., 1988; Yusuf and Resosudarmo, 2009). In this paper, we adopt a simpler transformation technique; we transform and normalize the monthly housing rent and flood variables using logarithmic transformation with interactions between the flood variable and household characteristics. A robust regression technique is applied to equation (1) to produce a robust estimate of variance and to ensure that coefficients estimated are more efficient (Hubert, 1973).

As mentioned before, the flood water level in this paper is an average flood water level in subdistrict areas. One reason for analyzing subdistrict areas is to take into account the impact of nearby flooding on the value of property in a certain area. A subdistrict in the Jakarta context is relatively large enough, however, there is still a possibility that average flood water levels in neighboring subdistricts affect the property value in a subdistrict (Yusuf and Resosudarmo, 2009). Anselin (1988) introduced a concept of spatial dependence to determine the relationship among the property values located in neighboring locations. Several studies have incorporated this analysis to estimate the real impact of all the housing attributes—such as Daniel et al. (2007), Bin et al. (2008), Cho et al. (2009), Samarasinghe and Sharp (2010), Bin and Landry (2013) and Rabassa et al. (2016)—which suggests the presence of this spatial effect in a cross-sectional hedonic price analysis. Ignoring this estimation, the resulting coefficients from the OLS model could be inefficient or inconsistent (Anselin, 1988).

To capture the neighboring spillover effect, this research paper uses the spatial lag model proposed by Anselin (1988) and adopted by various studies (Leggett and Bockstael, 2000; Brasington and Hite, 2005; Daniel et al., 2007; Bin et al., 2008; Cho et al., 2009; Yusuf and Resosudarmo, 2009; Samarasinghe and Sharp, 2010; Bin and Landry, 2013; Rabassa et al., 2016). This assumes that the housing rental price depends both on its characteristics (structural and neighborhood) and on neighboring house rental prices; i.e. the spatial lag model includes the spatially-weighted sum of neighboring house rental prices as the independent variable in the functional form of the housing price formation:

$$y = \beta_0 + \rho Wy + x_1 \beta_1 + x_2 \beta_2 + f \beta_3 + [f x_1]\beta_4 + \varepsilon \quad (2)$$

where ρ is the spatial dependence parameter and W is an nxn standardised spatial weight matrix (where *n* is the number of observations). The spatial matrix, W, tells us whether any pair of observations are neighbors. If, for example, house *i* and *j* are neighbors, then $w_{i,j} = 1$ and zero otherwise, for all $i \neq j$. Please note that $w_{i,i} = 0$ for all *i*. Whether or not any pair of houses is neighboring in this paper is determined by them sharing some common borders (contiguity). The spatial weight matrix is usually standardised, such that every row of the matrix is summed to 1. This enables us to interpret the spatial lag term in a spatial model as a simply a spatially-weighted average of neighboring house prices. The spatial lag model will be estimated using a maximum likelihood regression technique (Anselin, 1988).

5. Results and Discussion

Table 3 shows the results of estimating the basic and spatial lag models; i.e. equations (1) and (2), respectively. From the result for the spatial lag model, it can be seen that the ρ estimate is at significant at 10%; and by comparing results for the basic and spatial lag models, it also can be seen that though most coefficients are almost similar, the coefficients for employment rate, percentage of people with a university degree and flood water level are relatively different. These results indicate that spatial dependency plays an important role in the process of formulating housing rental prices in the Jakarta housing market; i.e. estimated coefficients of the basic model are likely to be inefficient or inconsistent. The result for the spatial lag model is argued to be superior to those for the basic model.

Table 3. Results of basic and spatial lag models

	Basic	Spatial lag
Housing characteristics		

House size (m2)	0.0099		0.0087	**
	(0.0113)		(0.0042)	
Wall is cement/brick (1,0)	-0.8482	**	-0.9223	*
	(0.4169)		(0.4915)	
Roof is concrete/roof tiles (1,0)	-0.3407		-0.3658	
	(0.3799)		(0.4091)	
Floor is ceramic/stone (1,0)	0.8219	*	0.8261	*
	(0.4948)		(0.4745)	
Water source inside (1,0)	0.5899		0.4718	
	(0.4355)		(0.4125)	
Neighborhood characteristics				
Unemployment rate (%)	-0.0161		-0.0015	*
	(0.0168)		(0.0172)	
Distance to district center (km)	-0.0208	***	-0.0167	**
	(0.0070)		(0.0072)	
People w. univ. education (%)	0.0244		0.0649	**
	(0.0235)		(0.0278)	
Public transport access (1,0)	0.1853	*	0.1731	
	(0.1101)		(0.1196)	
Interacting variables				
Size*log(flood)	-0.0021		-0.0018	*
	(0.0029)		(0.0011)	
Wall*log(flood)	0.4535	***	0.4767	***
	(0.1151)		(0.1387)	
Roof*log(flood)	0.1356		0.1376	
	(0.1031)		(0.1102)	
Floor*log(flood)	0.0442		0.0420	
	(0.1342)		(0.1318)	
Water*log(flood)	-0.1650		-0.1271	
	(0.1167)		(0.1120)	
Environmental variable				
Log(flood)	*-0.2980*	**	*-0.4291*	***
	(0.1350)		(0.1613)	
Constant	13.2354		10.7902	
Rho	-		*0.1890*	*
Number of observations	1231		1195	

Note: ***Significant at 1% level. **Significant at 5% level. *Significant at 10% level. Numbers in brackets are standard deviations.

Let us observe the results for the spatial lag model. Three out of five house structural characteristics, i.e. house size, floor material and water source, are positively associated with the house rental price. This is as expected. Estimated coefficients for house size and floor material are significant at 5% and 10% significance levels, respectively. The other two estimated coefficients, i.e. for wall and roof materials, are negatively related to the dependent variable. This is unexpected. The coefficient of wall material has a 10% significance level, which could be because the non-cement/brick wall houses in the sample are dominated by more expensive wood or other material houses or are dominated by more less expensive cement/brick houses.

All estimated coefficients for neighborhood qualities have the expected sign. Three out of four coefficients for neighborhood characteristics comply with expectations and are statistically significantly correlated with housing rent price; i.e. with the coefficient for the unemployment rate at 10%, distance to the center at 5% and the percentage of people with a university degree at 5%. A higher unemployment rate is associated with a lower housing rental price. Distance to the center of Jakarta is negatively associated with housing rental price; meaning the closer the house is to the business center, the higher the rental price charged to the tenant. Finally, the coefficient for the percentage of people with a university degree is positively related to housing rental price.

Regarding the interaction terms, two out of five have a significant correlation with monthly housing rental price. The coefficient for interaction between house size and flood water level is negative and significant at a 10% level. This is as expected, that for a given size of house, a higher flood water level is associated with a lower housing rental price. The coefficient of the wall and log (flood) interaction term is at a 1% significance level. The sign, however, is unexpectedly positive, which is mostly due to a measurement error in defining a better quality of wall.

On the main variable of analysis in this paper, namely flooding, it can be seen that the coefficient of the flood variable is negative and statistically significant at 1%. This coefficient suggests that a higher flood water level is associated with a lower housing value. Further analysis is needed to understand the full association between flood water level and housing rental prices. The first derivation of the spatial lag model for the hedonic housing value is as follows:

$$\frac{\partial y}{\partial f} = \beta_3 + x_1\beta_4 \qquad (3)$$

Let us insert in equation (3) the average value of x_1 , then we have $\frac{\partial y}{\partial f} = -0.1144$. This indicates that, on average, an increase of flood water level by 1% is associated with an 0.11% lower housing value. Comparing this result with results from previous studies for other countries recorded in Table 1, it can be seen that 0.11% is low compared to results from previous studies. Hence, this result shows that adopting results from developed countries to the case of developing countries could be misleading.

Inserting the average flood water level in Jakarta in 2007, which was approximately 42.3 cm, it can be roughly concluded that flooding in Jakarta lowers the monthly housing value by approximately Rp. 650 thousand. If this figure can be interpreted as the average monthly willingness of a household to 'permanently' get rid of the cost of flooding, and assuming that there are approximately 10 million people or 1.8 million households in Jakarta having houses with an average lifetime of 25 years and a discount rate of 5% annually, it can be estimated that the total willingness of all households in Jakarta to permanently get rid of the cost of flooding is approximately Rp 42.6 trillion or approximately 7.5% of Jakarta's GDP in 2007.

6. Flood and Human Health Condition

In an attempt to understand why people's attitudes differ regarding houses in flood prone areas and those that are not; i.e., in general, people place less value on houses in flood prone areas, this paper explores the relationship between human health conditions and housing characteristics including flood water levels. Human health indicators utilized in this paper are number of restricted activity days (or number of days with daily activities disrupted due to feeling sick in the past 4 weeks) and case of stomach ache (whether or not there is a member in the household who suffered stomach ache in the past 4 weeks; one if yes there is, and otherwise zero) which are available in the IFLS dataset for 2007.

We adopt the basic and spatial lag models as shown in equations (1) and (2), respectively, where y is the logarithmic form of the number of restricted activity days or the case of stomach ache. Table 4 presents the results of estimating the relationship between number of restricted activity days and flood water level, implementing the basic and spatial lag models; and Table 5 for the case of stomach ache.

Comparing results using the basic model and the spatial model in Tables 4 and 5, it can be seen that implementing a spatial lag model is not needed to estimate the human health impacts of flooding, since coefficients estimated using the basic model and those using the spatial lag are relatively similar and none of estimated ρ is significant at the convenience level. In other words, apart from the level of flooding in the area, floods in neighbouring areas are not associated with human health condition.

Table 4. Number of restricted activity days and flood level

	Restricted days	
	Basic	**Spatial lag**
Housing characteristics		

House size (m2)	0.0064	*	0.0066	
	(0.0034)		(0.0044)	
Wall is cement/brick (1,0)	-0.0402		-0.0464	
	(0.3384)		(0.3953)	
Roof is concrete/roof tiles (1,0)	-0.0638		-0.0627	
	(0.2679)		(0.3297)	
Floor is ceramic/stone (1,0)	0.6539	*	0.6478	*
	(0.3732)		(0.3932)	
Water source inside (1,0)	-0.5666	**	-0.5760	*
	(0.2500)		(0.3325)	
Neighborhood characteristics				
Unemployment rate (%)	-0.0104		-0.0101	
	(0.0130)		(0.0139)	
Distance to district center (km)	-0.0157	***	-0.0150	***
	(0.0059)		(0.0056)	
People w. univ. education (%)	-0.0369	**	-0.0382	*
	(0.0175)		(0.0219)	
Public transport access (1,0)	0.0732		0.0639	
	(0.0985)		(0.0950)	
Interacting variables				
Size*log(flood)	-0.0010		-0.0010	
	(0.0009)		(0.0011)	
Wall*log(flood)	-0.0251		-0.0216	
	(0.0988)		(0.1142)	
Roof*log(flood)	-0.0020		-0.0038	
	(0.0739)		(0.0893)	
Floor*log(flood)	-0.1959	**	-0.1987	*
	(0.1013)		(0.1077)	
Water*log(flood)	0.1891	***	0.1950	**

	(0.0693)		(0.0900)
Environmental variable			
Log(flood)	*0.1923*	*	*0.1995*
	(0.1101)		(0.1462)
Constant	1.2756		1.5272
Rho	-		*-0.1645*
Number of observations	766		746

Note: ***Significant at 1% level. **Significant at 5% level. *Significant at 10% level. Numbers in brackets are standard deviations.

Table 5. Case of stomach ache and flood level

	Stomach Ache			
	Basic		**Spatial lag**	
Hosing Characteristics				
House size (m2)	-0.0004		-0.0006	
	(0.0008)		(0.0008)	
Wall is cement/brick (1,0)	-0.0539		-0.0551	
	(0.1241)		(0.1432)	
Roof is concrete/roof tiles (1,0)	0.0407		0.0404	
	(0.0967)		(0.1011)	
Floor is ceramic/stone (1,0)	0.3102	**	0.3027	**
	(0.1310)		(0.1354)	
Water source inside (1,0)	0.0996		0.0971	
	(0.0991)		(0.0999)	
Neighborhood characteristics				
Unemployment rate (%)	-0.0033		0.0004	
	(0.0088)		(0.0092)	
Distance to district center (km)	0.0070	*	0.0079	**
	(0.0043)		(0.0042)	
People w. univ. education (%)	-0.0027		0.0053	
	(0.0113)		(0.0132)	
Public transport access (1,0)	-0.0402		-0.0352	
	(0.0673)		(0.0662)	
Interacting variables				
Size*flood	0.00001		0.00001	
	(0.00002)		(0.00002)	
Wall*flood	0.0054	*	0.0058	*
	(0.0030)		(0.0033)	

Roof*flood	-0.0028		-0.0027	
	(0.0020)		(0.0021)	
Floor*flood	-0.0089	***	-0.0090	***
	(0.0034)		(0.0029)	
Water*flood	0.0043	**	0.0041	**
	(0.0021)		(0.0021)	
Environmental variable				
Flood	*0.0065*	**	*0.0057*	*
	(0.0031)		(0.0034)	
Constant	0.4994		0.5319	
Rho	-		*-0.0832*	
Number of observations	1,339		1,305	

Note: ***Significant at 1% level. **Significant at 5% level. *Significant at 10% level. Numbers in brackets are standard deviations.

Flood coefficients in both number of restricted activity days and cases of stomach ache are significant at the 10% and 5% level, respectively, and have the expected sign. A higher level of flood water level is associated with a higher number of restricted activity days and with a higher incidence of stomach aches in a household. Estimated coefficients among the interactive variables are not all significant and have signs as expected. Among those coefficients that are significant at least at a 10% level, the coefficient for the interactive form of having a water source inside the house and the level of flooding are not as expected in both the restricted activity days and stomach ache equations. Having a source of water inside the house turns out to be associated with a higher number of restricted activity days and cases of stomach ache for a given level of flood water. In the stomach ache equation, the coefficient for the interactive form between wall type and flood water level is not as expected; i.e. having a cement/brick house is associated with a higher incidence of stomach aches in a household for a given level of flood water.

Using a similar strategy to that in equation (3), we estimate the overall association between human health condition and flood water level. The results are $\frac{\partial y}{\partial f} = 0.0345$ in the case of restricted activity days and $\frac{\partial y}{\partial f} = 0.0055$ in the case of stomach ache; i.e. an increase in flood water level by 1% is associated with a 0.03% higher number of restricted activity days in a household, while a 10 cm increase in flood water level is associated with a 5.5% increase in the probability of having a stomach ache incident in the household. From these results, it can be argued that houses in flooding areas have been associated with a worsening in human health conditions. And this could be a reason that people put a lower value on a house in a flood prone area than on in an area that does not flood, given similar characteristics of the house and the neighborhood.

Furthermore, in general, using this result, it can be estimated that flooding in Jakarta is associated with approximately 1 restricted activity day and approximately a 23% probability of having a stomach ache incident in a household annually; or, in total, flooding in Jakarta is associated with approximately 2.1 million cases of restricted activity days and approximately 0.4 million cases of stomach ache annually.

Conclusion

This study is an attempt to estimate the cost of flooding in developing countries' megacities by conducting a hedonic price analysis of the Jakarta housing market, which estimates the correlation between levels of flooding and monthly housing rental prices in Jakarta in 2007. Data on the flood water levels by village or *kelurahan* in Jakarta were obtained from the United Nations Department of Safety and Security (UNDSS), which collected and reported the water levels of the 2007 Jakarta flood from news sources (radio and television), and United Nations Staff Reports to UNDSS Office and Police Stations. Data on monthly housing rental prices and other information related to house and neighborhood characteristics are taken from the IFLS for 2007.

The empirical results in this paper indicate that floods have a negative association with housing rental prices. It is estimated that a one percent high flood water level is associated with an 0.11% lower monthly housing rental price; or, on average, flooding in Jakarta is associated with lowering monthly housing values by approximately Rp. 650 thousand. Furthermore, if this number can be interpreted as an average monthly willingness of a household to 'permanently' get rid of the cost of flooding, and assuming that there are approximately 1.8 million residential houses in Jakarta with an average lifetime of 25 years and a discount rate of 5% annually, this paper estimates that the cost of flooding for households in Jakarta is approximately Rp 42.6 trillion or approximately 7.5% of Jakarta's GDP in 2007.

This paper also found that a lowering of human health conditions could be the reason that households put less value on houses located in flood prone areas compared to those on higher land. This paper estimates that a one percent higher flood water level is associated with a 0.03% higher number of restricted activity days in a household, and a 10 cm increase in flood water levels is associated with a 5.5% increase in the probability of a stomach ache incident in the household. In general, using this result, it can be estimated that flooding in Jakarta is associated with approximately 1 day of restricted activity days and approximately a 23% probability of having a stomach ache incident in a household annually; or, in total, flooding in Jakarta is associated with approximately 2.1 million cases of restricted activity days and approximately 0.4 million cases of stomach ache annually.

The Jakarta Water Management Agency estimated the city needs Rp 118 trillion \ to make Jakarta flood-free (Tambun et al., 2015). This number is higher than the paper's estimate of the cost of flooding for households in Jakarta; i.e. approximately Rp 42.6 trillion. As can be seen, therefore, it will be challenging for the Jakarta government to extract resources from its society to fund projects eliminating floods in the city. External resources from the central government are most likely needed to resolve the problem of floods in Jakarta.

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