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# The impact of flood dynamics on property values

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A B S T R A C T

There is evidence that environmental amenities and dis-amenities may be nonlinearly related to property valuation. This would bring inconsistency in estimating environmental variables of the hedonic price model. To explore the linearity of the relationship this study analyses spatial and temporal variation impacts of the 2011 Brisbane flood on property markets using semi-parametric estimation. The results show that most environmental variables impacts on property values nonlinearly, and in particularly distance to the river, indicating that the amenity value of being close to a river outweighs the flood risks. The estimation of the combined impact of elapsed time and neighbourhood income indicates that the flood risk impact on property markets disappears over time.

## 1. Introduction

Many cities have been experiencing an increase in extreme weather events such as floods, cyclones, earthquakes, tsunamis and bushfires as a result of the prevailing effect of climate change globally (Salinger, 2005). Following such incidences, many economic activities are being severely disrupted and in some cases action is required to prevent a full scale economic downturn (Managi and Guan, 2017). Existing research provides insights into the direct and indirect impacts of such natural disasters across different sub-sectors of the economy as well as at globally (Rajapaksa et al., 2017a). In particular, a number of studies investigate the indirect costs associated with natural disasters for residents by means of estimating their impact on property values.

The impact of flooding and flood plains on property markets have been investigated by Rajapaksa et al. (2017b), Eves and Wilkinson (2014), Bin and Landry (2013), Petrolia et al. (2013), Breisinger et al. (2012), Samarasinghe and Sharp (2010), and Lamond et al. (2010). Their studies model flood risk from a number of different perspectives. Some investigate the influence of floodplain location (e.g., Samarasinghe and Sharp, 2010) whereas others focus on the actual flood incidence (e.g., Bin and Landry, 2013; Rajapaksa et al., 2016). Most studies have found that flooding and floodplain locations negatively impact on residential properties. For example, the flood discount as found by Bin and Landry (2013) appear to vary between 6 and 20% whereas Rajapaksa et al. (2016) put the discount at around 18%. Moreover, the latter shows the actual flood impacts is higher than flood risk information on property values. Zhai and Fukuzono (2003) investigated the actual impact of floods on land values based on the Tokai flood in Japan in 2000. They find that while floods have a negative effect on land prices, residents nevertheless prefer cheaper land notwithstanding the flood risk. Thus most were willing to stay closer to the river or water stream in spite of possible flood risk. For properties in closest proximity to the river, the positive effects of amenities (e.g., river view or water front) were expected to dominate the negative effect of floods exerting an upward price trend in spite of nearness to a river.

Existing studies also indicate that the negative impact of natural hazards is likely to fade off with time after the incidence (see, for example, Lamond and Proverbs, 2006; Bin and Landry, 2013; Rajapaksa et al., 2016). However, they also show that the effects are not constant over time and location, especially when other factors and consecutive hazard events become involved. For instance, according to Lamond and Proverbs (2006) property markets recover after 3 years whereas Bin and Landry (2013) find the recovery interval to be 5 years. Regions with more amenities are shown to recover faster − in spite of flood risks − than regions with low amenities (Rajapaksa et al., 2016). For instance, better infrastructure and recreational areas may increase the attraction in spite of the risks. Similarly, people are willing to stay close to more greenery areas (Athukorala et al., 2016).

Although much empirical work has been undertaken to explore the impact of flood hazards on the property market, there is a continuing

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lack of understanding about its heterogeneity and nonlinearity. For example, properties can be affected differently depending on a suburb's neighbourhood and socio-economic characteristics (Rajapaksa et al., 2017a,b) with some areas recovering rapidly while others continue to decline. In particular, inconsistencies created by the variable magnitude of flood risk and temporal differences provide an interesting question which are still largely unexplored (Liu and Shi, 2017). Moreover, it has been shown that hedonic property (HP) coefficients are not consistence across different studies (Sirmans et al., 2005).

In response to the limitations in the literature, we hypothesise that the flood risk on property markets varies spatially and temporarily and that rivers or streams exert both amenity and dis-amenity values in the determination of property prices. In order to test these hypotheses, property transaction data (n = 3154) within the Brisbane City Council (BCC) was collected for the period 2006–2013 which cover a series of events including the major flood in 2011. The semi-parametric generalised additive model (GAM) is employed to explore spatial and temporal variation. The results are of interest as they indicate the nonlinear impact of environmental variables. In particular, the combined impact of time and income show why properties in high-income areas recover faster following a flooding disaster. Overall, property prices are discounted by 5% being in flood-proven areas. The properties in high-income suburbs start recovering after two years while the property prices in low-income suburbs are continued to decline.

While previous hedonic studies[1] are mostly parametric, a few have considered either non-parametric or semi-parametric approaches (see Speyrer and Ragas, 1991; Pavlov, 2000; Bao and Wan, 2004; Bin, 2004; Brunauer et al., 2010; Chernobai et al., 2011; Shim et al., 2014; Karato et al., 2015). The semi-parametric approach is generally preferred as economic theory provides little support for the HP functional form (Kuminoff et al., 2010; Halvorsen and Pollakowski, 1981). That is, since HP theories do not provide much direction for variable specification (Parmeter et al., 2007) the rigid functional forms impact on the estimation coefficient. Moreover, according to Ekeland et al. (2004), the nonlinearity is an inherent feature of hedonic theory. Therefore, in this study the release of flood risk information followed by a major flood in Brisbane are estimated using GAM.

Among studies of non-parametric estimation of the HP function, those of Speyrer and Ragas (1991) and Bao and Wan (2004) are examples of the use of spline regression techniques. Pavlov (2000) uses kernel estimation while Brunauer et al. (2010) apply an additive mixed model to estimate the HP price function. The estimation is adjusted for spatial effect using a spatial scaling factor. More recently, Shim et al. (2014) have extended additive semi-parametric analysis by incorporating spatial effect in the error term.

Coulson (1992) observed the nonlinear behaviour of the impact of floor space on property prices using smoothing spline regression. Chernobai et al. (2011) were able to demonstrate the nonlinear effect of distance from a highway extension and its temporal variation. Their results showed that properties in medium distance to the highway has the greatest negative effect. Mason and Quigley (2013) estimated the non-parametric HP price function in examining house price movements. Recently, Karato et al. (2015) modelled time, age and cohort effects on Tokyo housing price using the GAM. They concluded that semi-parametric estimation is to be preferred so as to avoid the simultaneity effect of covariates. Speyrer and Ragas (1991) examined the impact of flood risk on property values using the spline regression technique.

The remainder of this paper is structured as follows: The following section discusses the area of study followed by semi-parametric generalized additive model specification of the HP function under the method section. The results of the empirical analysis are then provided followed by the conclusions.

## 2. Method

### 2.1. Study area and data

Natural disasters in Australia are more frequently at irregular intervals and have long been a part of Australian life. According to Bureau of Transport Economics (BTE) (2001) estimates, Queensland experienced the second highest frequency of natural disasters of any Australian state. It's capital, Brisbane, is particularly prone to flooding from the Brisbane river and occasionally cyclones. Parts of the city including the CBD are built in the flood-prone lower catchment area of the Brisbane river. The land use within the BCC is well-planned; including residential areas, industrial zones, recreational facilities and all other amenities. For further expansion and to facilitate investment, all amenities and risks, including flood-risk areas are mapped and are made available to the public − allowing public for adaptation. From December 2010 to January 2011, heavy rainfall was recorded across most of Australia, particularly in Western Australia, New South Wales and Queensland. Among the resulting numerous flood disasters, the Brisbane (Queensland) flood was classified as a major event, not only in Australian terms, but worldwide. Therefore, the property market behaviour in flood affected Brisbane suburbs in the period surrounding this event was considered to be a particularly appropriate case study.

This study's data comes from 6 flood affected suburbs within the BCC, representing high, medium and low-income communities.[2] Nearly 35 suburbs within BCC were affected by 2011 floods and for this study main flood affected suburbs were considered (more in results section). All property transaction data within selected suburbs for the period 2006–2013 are collected from the RPDATA website (www.rpdata.com).[3] For this study we collect only single dwelling transaction information. RPDATA provides the street address of each house, allowing geographical coordinates for each house to be obtained. Then, using geographical identifiers, geographical information system (GIS) techniques are used to collect supplementary data from other sources such as the Australian Bureau of Statistics (ABS). Selected variables for this study are presented in Table 1.

As Acharya and Bennett (2001) show, the value of a property is not only to be determined by its own characteristics but by other relevant factors. They include, inter alia, neighbourhood socio-economic status, land use patterns and environmental characteristics (see, Poudyal et al., 2009). The attributes considered in this paper are number of bedrooms, number of bathrooms, garage spaces, lot size and existence of a pool (see, Rajapaksa et al., 2016). Neighbourhood characteristics of a house include inhabitant's medium weekly income, and travelling distance to the nearest school. Environmental characteristics are also important determinants of housing prices. Distance to parks, forests, green space and river views are the most commonly cited variables.[4]

In this study flood-related variables are focussed on. To capture their influence, most existing studies use location in flood risk areas as dummy variable and distance to water bodies or rivers as key variables. However only a few studies have considered the depth of flood waters (Merz et al., 2004). In addition, it is noted that properties closer to

[1] Hedonic price analysis is commonly used for estimating the impacts of natural disasters (Managi, 2015; Managi and Sharma, 2016), environmental amenities (Poudyal et al., 2009) and disamenities (Tanaka and Managi, 2016).

[2] First, all flood affected suburbs within the BCC were selected. Then suburbs were ranked by taking the percentage of households belonging to high-, medium- and low-income groups considering 2011 Australian census and statistical survey. Then suburbs were selected from each of the three income groups.

[3] This database provides a comprehensive overview of Australian property sales, history and attributes. Subscription access is available to QUT students/staff.

[4] According to Lansford and Jones (1995), distance variables are more important than views when it comes to valuing environmental amenities. Hamilton and Morgan (2010) find that households are willing to pay higher prices for a more elevated view while Ham et al. (2012) show that open space land use is heterogeneous and the disaggregation of land use pattern provides better results.

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