Testing for Myopia and Amnesia in Property Prices. The Case of Infrequent Floods *

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Abstract

The paper explores the relationship between flooding events and the patterns of discounting of property prices. An estimation and testing strategy to implement a recently proposed theoretical framework is proposed and used with a recent natural experiment to demonstrate how this framework provides a test for myopic and amnesic responses to flooding frequency and severity in urban property prices. Infrequent floods is where myopic and amnesic perceptions of risk should dominate. In this regime observed quality adjusted prices are expected to drift away from a risk-adjusted constant quality property price towards the zero-risk constant quality property price as the years pass since the last flood. When a flood occurs, actors become aware of the true flood risk and observed prices quickly adjusts downwards towards the risk adjusted price. The city of Brisbane suffered two major devastating floods in 1974 and 2011. The construction of a dam with two compartments, flood and water reservoir, in

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the mid 1980s lead inhabitants and the market to underestimate the risk of another major event after that of 1974. The methodology proposed defines empirical estimates of zero-risk, risk-adjusted and actual quality adjusted prices which can be obtained using hedonic regressions and a difference-in-difference estimation. The test for amnesia and myopia is based on a bootstrap approach. Our dataset covers property transactions for an inner Brisbane (Australia) area located 5 km from Brisbane Central Business District(CBD) with 30% of each year's sales being properties in the flood plain (defined by the 2011 flood) and with proximity to a waterway within the tidal reaches of the Brisbane River. While minor flooding directly impacts only very few properties, the visibility of swollen waterways can provide reminders of flood risk in between major events. This ideal setting allows us to test for myopic and amnesic behaviour for this area over the period 1990-2015. We find strong support for the behaviour.

Keywords: risk-adjusted prices, constant quality prices, block bootstrapping
JEL: R21, Q51, C43, C15

1 Introduction

In this paper we explore the relationship between flooding events and the patterns of discounting of property prices. We develop an estimation and testing strategy to implement a recently proposed theoretical framework and use a unique natural experiment to demonstrate how this framework provides a test for myopic and amnesic responses to flooding frequency and severity in urban property prices.

The literature on the effect of floods on residential property prices is extensive. Empirically based studies (for recent summaries see de Koning, Filatova and Bin (2017) and Rambaldi, Fletcher,Collins, and McAllister (2013)) have found consistently that property prices are discounted following a major event. However, in some cases the discount is negligible and short lived while in other cases it persists over substantial periods. In this study we develop a framework to empirically implement the concepts of myopia and amnesia introduced by Pryce, Chen and Galster (2011) building from a brief theoretical framework proposed in Tobin and Montz (1994). The theoretical price responses arise from combining concepts from behavioural economics such as 'self attribution bias' and 'mental inertia' which leads humans to underestimate risk (see for example Kousky and Zeckhauser (2006), Allen (2009) and Della Vigna (2009)) and the sociology of risk where the nature of the information is viewed with scepticism (e.g. Williams (2008)) as individuals become cynical about science, politics and the media. In this paper we propose an empirical strategy to obtain estimates of the theoretical temporal responses proposed by Pryce, Chen and Galster (2011), we propose a test for myopic and amnesic behaviour, and discuss the implications for policy, regulation and adaptation strategies.

This paper is structured as follows. Section 2 presents the definitions of Myopia and Amnesia, reviews two of the scenarios considered in Pryce, Chen and Galster (2011) defined by the frequency of floods, and presents the natural experiment that gives rise to the data used in the empirical section of this study. Section 3 describes the proposed empirical strategy. Section 4 describes the data and provides the empirical results, Section 5 considers the policy responses in relation to insurance, regulation and adaptation strategies Section 6 concludes.

2 Myopia and Amnesia

What Pryce, Chen and Galster (2011) provide is a comprehensive synthesis of both why residential property prices matter, and about what unforeseen house price risks may be concealed but the nature of human decision-making. Prices matter to both individuals and economic fundamentals because a huge proportion of personal wealth and superannuation are tied in housing. By unforeseen property price risks, it's implied that prices are not knowable based on pure rational economics alone.

Those who set property values, property buyers, do not have the perfect knowledge that would be required in order to set economically rational prices. Pryce, Chen and Galster (2011) reviewed both theoretical frameworks (e.g. see Tobin and Newton (1986); Tobin and Montz (1994)) and empirical studies, (e.g. see Bin and Polasky (2004)). They proposed various scenarios by which buyers inaccurately value the impact of flood risk, arguing myopia and amnesia unpin a dynamic divergence between actual and perceived flood risk. In other words, property purchasers both underestimate future risks (i.e. myopia) and forget the past (i.e. amnesia).

Pryce, Chen and Galster (2011) structure their framework as a divergence of the zero-risk constant quality property price ($P(ZR)$ i.e. the price of properties which have zero flood risk, adjusted for hedonic characteristics) and the risk-adjusted constant quality property price ($P(RA)$ i.e. the price of properties which accurately price actual flood risk, adjusted for hedonic characteristics).

For properties with some flood risk, their actual prices, $P(A)$, tend upwards toward $P(ZR)$, depending on how recently floods have been observed. Figure 1 presents two scenarios adapted from those in Figures 2 and 3 of Pryce, Chen and Galster (2011). With very occasional flooding, flood-prone property prices approach $P(ZR)$ and periodically drop (top panel of Figure 1). More regular flood will see prices more regularly pulled down around $P(RA)$ (bottom panel of Figure 1).

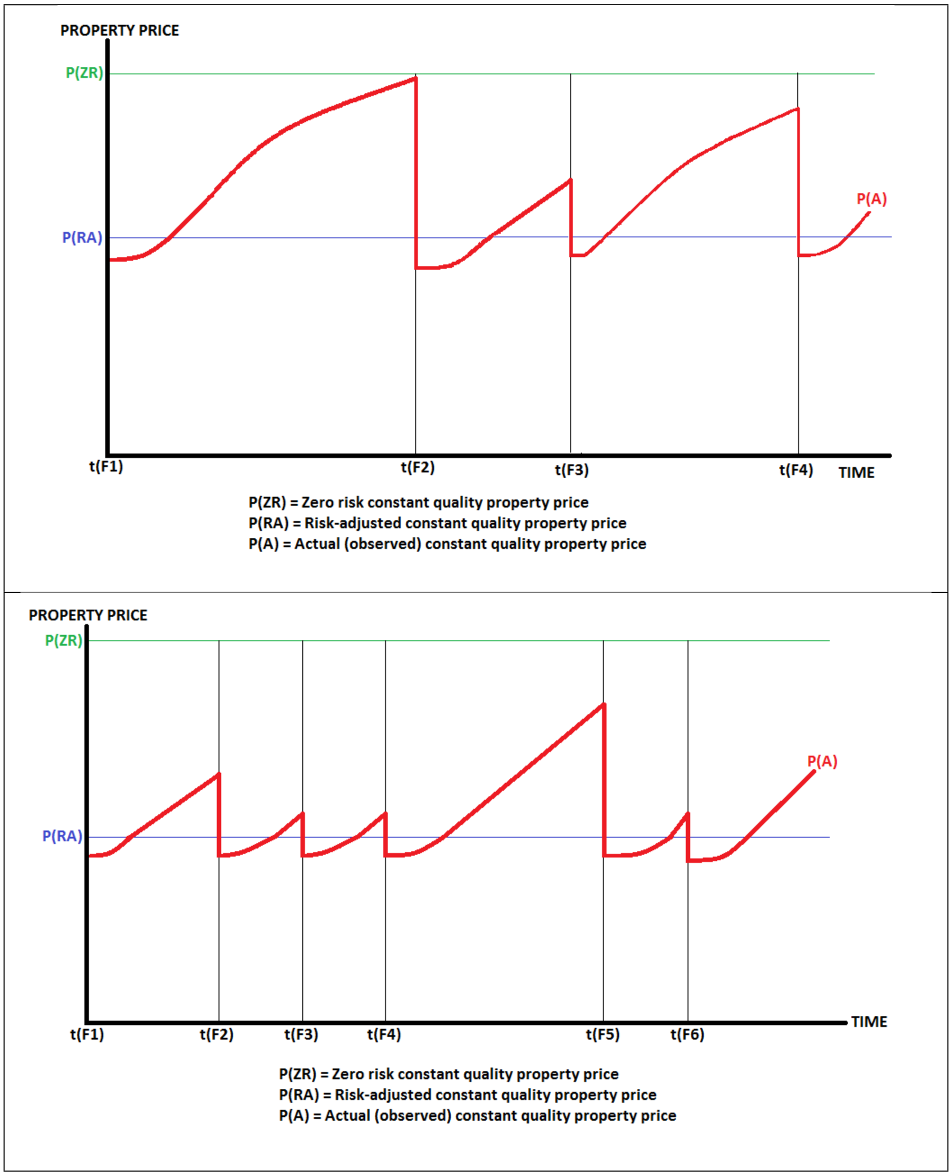

Figure 1: *Adapted from Pryce et al (2011)* - Figures 2 and 3

2.1 A Natural Experiment

The city of Brisbane (in the state of Queensland, Australia) suffered a devastating flood very early in its existence, 1893; however, two floods are present in the collective memory of the city, January 1974, and the most recent, January 2011. In this paper we concentrate on the January 2011 flood due to data availability and because this event is preceded by a series of historical circumstances that provide a unique scenario for a study into myopic and amnesic behaviour of real estate markets.

The state government of Queensland had approval to build a dam for water reservoir and hydroelectric generation in the upper catchment of the Brisbane river since November 1971 which was to be connected to the existing Somerset Dam constructed in the first half of the 20th century northwest of the city of Brisbane. Together they were to provide flood mitigation, hydroelectric power and drinking water. In January 1974 the city of Brisbane suffered a major flood (Bureau of Meteorology (2013)). The construction of the new dam, Wivenhoe Dam, containing two compartments, flood and water reservoir, commenced in 1977 and was completed by 1985. After the new dam was completed, the inhabitants and the real estate market of Brisbane grew increasingly confident, over the following 26 years, that the city was no longer in danger of a major flooding. However, in January 2011 after an extreme weather event and torrential rain, water from the Wivenhoe Dam had to be released over a short period of time as its integrity was beginning to be compromised, and Brisbane suffered a major flooding event (see Bureau of Meteorology (2016) and Appendix A). Our study covers property transactions over the period 1990-2015 for an inner Brisbane area located 5 km from Brisbane Central Business District (CBD), prime real estate location, with approximately 30% of each year's sales being properties in the flood plain. The Brisbane City Council has released updated data since the 2011 event, and thus we have accurate information on the flood levels suffered by each property in the sample during the 2011 flood. For a comprehensive paper on the 2011 Brisbane flood see van den Honert and McAneney (2011).

We do not identify the exact location of our case-study as agreed with stakeholders. We can say however that the location has some unique characteristics that add interest beyond the natural experiment that played out around the 2011 Brisbane River floods. Around 30% of properties sales in our data/location are for properties in the flood plain. These properties have median distance from a waterway of 540 metres (Table 5, compared to 840 metres for flood-free properties in our dataset, Table 4). These waterways are within the tidal reaches of the Brisbane River. While minor flooding directly impacts only very few houses, the visibility of swollen waterways can provide reminders of flood risk in between major events, and thus we expect the prices in the study area to show a pattern which combines these two theoretical scenarios.

While a major flood, Brisbane River flooding experienced, ocurred in 2011, Figure 2 shows other minor flooding events. Most interesting for our sample is a 1996 event. The Australia Bureau of Meteorology records descriptive information of floods too,

1996: "Heavy rainfalls and flooding were reported throughout the Brisbane catchment during the first week of May [1996] with widespread 7 day rainfall totals of up to 600mm. A tidal surge caused by the low pressure system and gale force winds caused higher than normal tides in the Brisbane River which also contributed to flooding in low lying areas" Bureau of Meteorology (2016).

2011:"Rainfalls in excess of 1000mm were recorded in the Brisbane River catchment during December [2010] and January [2011] with the vast amount of this rainfall falling in the 96 hours to 9am on the 13th of January [2011]. The most significant rainfall intensities were well above the 1% Annual Exceedance Probability (100 year Annual Recurrence Interval). Major flooding in the Bremer and Brisbane Rivers produced the largest flood heights at Brisbane and Ipswich since the

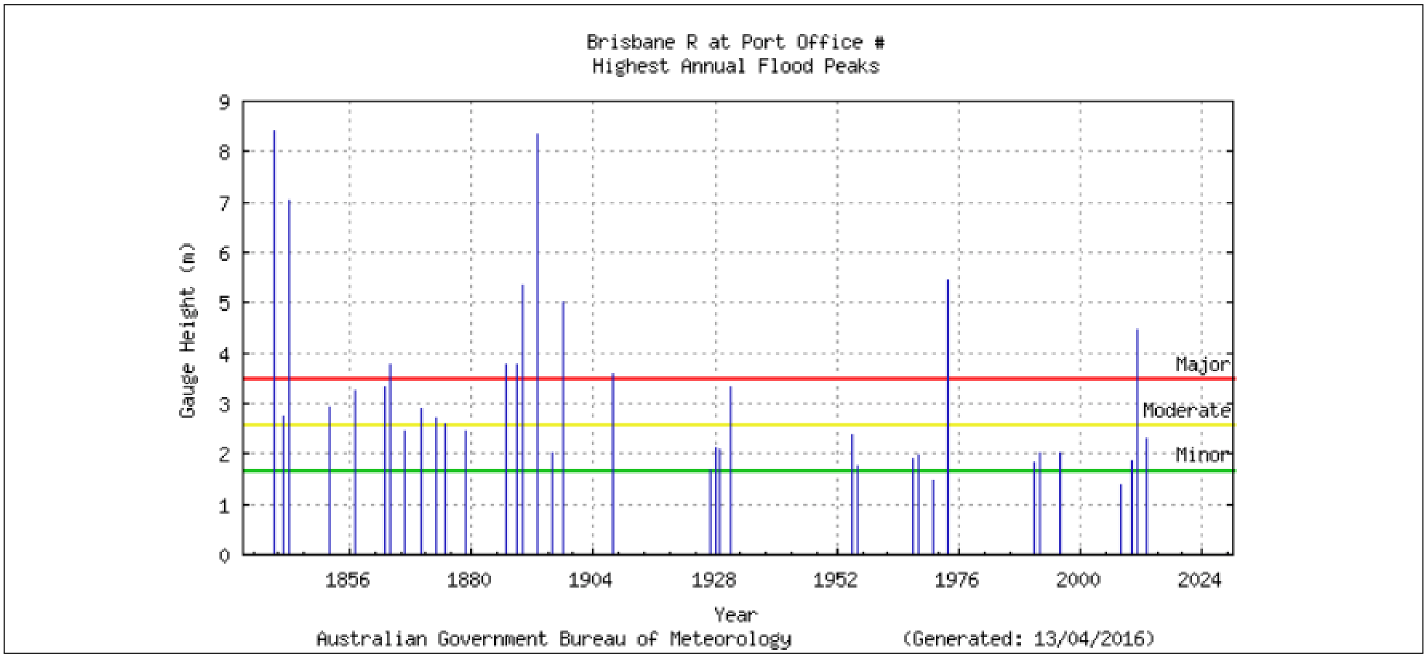

Figure 2: Brisbane Flood History- Source: Bureau of Meteorology (2016)

infamous '74 flood' " Bureau of Meteorology (2016).

For Pryce et al (2011) framework to hold, we expect to see divergence (and subsequent recovery, as myopia and amnesia kicks-in) between the actual price of flood-prone properties ($P(A)$) from the constant quality flood-free level ($P(ZR)$) in both 2011, and also in 1996. Because of characteristics of the suburb, specifically with the high proportion properties with visibility of regularly flooding waterways, we also expect the actual price of flood-prone properties ($P(A)$) to fluctuate below the the constant quality flood-free level ($P(ZR)$).

3 Empirical Approach

The aim is to obtain empirical estimates of $P(ZR)$, $P(RA)$ and $P(A)$. We first note these are quality adjusted prices. To obtain a quality adjusted price using a sample of sold properties, a price index needs to be constructed. In this study we construct two time-dummy hedonic price indices (see Bailey, Muth, and Nourse (1963), de Haan (2010),Hill (2013))[1], one for properties in the flood zone and one for those in the flood free area. These indices are then used to compute empirical estimates of $P(ZR)$ and $P(A)$. To assess statistical significance and test the hypothesis of myopic and amnesic behaviour in prices, we use a bootstrap approach. The level $P(RA)$ is obtained by estimating the per cent of discounting in property prices due to flooding risk using the 2011 event as the treatment. Details of the methodology are discussed in the next subsections.

[1]We will construct hedonic imputed price indices for the next version of the paper

3.1 Computing Quality Adjusted Price Indices

The quality adjustment is obtained using a hedonic price index approach. The model to obtain a time-dummy hedonic price index is of the form in (1),

$$\log(price_{it}) = \sum_{t=1}^{T} \delta_t D_{it} + \sum_{k=1}^{K} \beta_k x_{k,it} + \varepsilon_{it} \tag{1}$$

where x'_{it} is a row vector containing *land and structure hedonic characteristics*, and *location* variables for each property in the sample (see Table 1 in the data section for specifics), and $D_{it} = 1$ if i sold in year t, zero otherwise. These variables control for the price trends in the data and the hedonic adjusted indices are obtained by exponentiating $\hat{\delta}_t$ and rescaling to set the base period equal to 100.

The price index obtained from the sample in the flood zone area provides an index denoted by $P_{F,t}$, and we denote by $P_{NF,t}$ the quality adjusted price index for period t obtained from the sample of properties with zero risk of flooding. Properties are sorted into flood/flood-free samples depending on whether they flooded in the 2011 event (further details provided in the data section). The assumption here is that both the δ_t and the $\beta_k, k = 1, \ldots K$ vary across the two types (flood/flood-free). This is a testable hypothesis which is sample dependent. We formally test for parameter homogeneity as part of the empirical estimation.

From these two indices we compute estimates of $P(ZR)$ and $P(A)$ as follows,

for each t, $t = 1, \ldots, T$

$$\widehat{P(ZR)}_t = 100 \tag{2}$$

$$\widehat{P(A)}_t = \frac{P_{F,t}}{P_{NF,t}} \times 100 \tag{3}$$

These definitions allow us to establish where the actual quality adjusted prices are located at each period with respect to the risk-free and risk-adjusted quality adjusted price levels.

3.2 Testing Amnesic and Myopic Behaviour of $P(A)$

To test the hypothesis of amnesic and myopic behaviour in property prices, we propose to construct an empirical distribution of $P(A)$ using a bootstrapping approach. By (3) we know it is obtained from the price indices $P_{F,t}$ and $P_{NF,t}$ via estimating model (1), and thus the bootstrap design requires understanding of the structure of the underlying data for this model. We first note that the data have a clear time ordering that needs to be taken into account. However, within each time period, a year in our case, a number of properties are transacted for each flood type (flood/flood-free) and there is no natural ordering in this dimension. The proposal is then to use an i.i.d bootstrap within each time period and type (see Politis (2003) and the many references therein for a discussion on bootstrapping with dependent data, block sampling and subsampling, and Chapter 3 of Chernick (2008) for bootstrapping methodology to construct confidence sets). Our approach is summarised in the following steps,

- within each time period and flood type, *sample with replacement* properties that have sold to create a replication sample, r, of the same size as that of the observed data, i.e. N transactions over T periods with the same proportion of sales in the flood/flood-free areas for each time period.
- estimate the models (1) with sample r and construct the corresponding indices ($P_{F,t}/P_{NF,t}$)
- repeat the above R times. In the empirical implementation we use $R = 10,000$
- compute the quantiles, 0.025 and 0.975, from the R bootstrapped price indices of each type (i.e. $P_F(0.025)$, $P_{NF}(0.025)$, $P_F(0.0975)$, $P_{NF}(0.0975)$).
- compute an empirical 95% confidence interval for $P(A)_t$, $P(A)(0.0975)$ and $P(A)(0.025)$, using equation (3)

We use the confidence interval to test hypotheses of 'no amnesia' and 'no myopia' in property prices. If the distribution of the bootstrapped $P(A)$ includes $P(ZR)$, i.e., 100, we reject the null hypothesis of 'no myopia' and conclude there is evidence of myopia. Similarly, we reject the null of no amnesia if following a flood event the bootstrapped distribution goes below the $P(RA)$ and then recovers to levels above $P(RA)$.

3.3 The Risk Adjusted Price Level, $P(RA)$

In order to obtain $P(RA)$, we must find the amount of discount due to flooding (refer to Figure 1). We suggest two alternative empirical estimates can be considered, the first using a difference-in-difference approach, the second using a hedonic modelling approach.

To obtain the discount via a difference-in-difference approach, we define the flood event as a treatment, in our case the 2011 flood is the treatment. Using a standard setting we have a pre- and post treatment period defined by those properties that signed a sale contract after the flooding event, $After = 1$. Those properties that did not flood in this event are the control group. The treatment occurred in mid January 2011, and thus we define a transaction as treated if it was in the flood plain ($Flood = 1$) and the sale contract was signed from February 2011 onwards ($After = 1$). The difference-in-difference model is estimated as follows,

$$\log(price_{it}) = \beta_0 + \sum_{t=2}^{T} \delta_t D_{it} + \gamma_1 Flood_i + \gamma_2 After_i + \gamma_3 (Flood_i \times After_i) + u_{it} \qquad (4)$$

where,

$Flood_i = 1$ if the ith property was flooded in the event, zero otherwise

$After_i = 1$ if the sale contract for the ith property was after the flood, zero otherwise

The estimate of $100 \times \gamma_3$ provides a per cent average discount suffered by properties that were affected by the flood, which we denote by Dis_{DID}.

The difference-in-difference result can be compared to what is obtained by estimating a standard hedonic model with $Flood_i$ in the model and estimated over the sample of properties in the treated group ($After = 1$). To compute these we estimate (5)

$$\log(price_{it}) = \beta_0 + \sum_{t=\tau}^{T} \delta_t D_{it} + \sum_{k=1}^{K} \beta_k x_{k,it} + \phi Flood_i + e_{it} \tag{5}$$

Estimating the model for the sample of properties for which $After = 1$, labelled as $t = \tau, \ldots, T$ in (5) will provide an alternative estimate of the discount which we denote by $Dis_{HED} = \hat{\phi} \times 100$.

Thus, two alternative estimates of $P(RA)$ are then given by $P(RA)^{DID} = 100 - Dis_{DID}$ and $P(RA)^{HED} = 100 - Dis_{HED}$.

Description of the data and estimation results are presented in the next section.

4 Data and Results

The data in this study is an extension of Rambaldi, Fletcher,Collins, and McAllister (2013) which originally covered until early 2010. Variables definitions and descriptive statistics for the dataset used in this study, covering the period 1990 to 2015, including the hedonic characteristics for land, structure, location and flood status of each property used in the empirical part of the study are presented in the Appendix. Table 1 provides a summary of the available hedonic characteristics.

Table 1: Hedonic Characteristics Available in the Data

Type	Variables
Land	Lot size (sqMts), Vacant Distances to: River, Wateway, Industry, Parks, Bus stop, Schools, City, Shops, Rail station
Structure	Footprint (sqMts), Construction Period (Pre-War, Post War, Late 20th, 21st), Bedrooms, Bathrooms, Car parks
Flood	A property flooded in the January 2011 is in the floodplain
Sample period	1990-2015
After	Sale contract signed from February 2011 onwards
Transactions	3002 flood-free, 1250 flood plain, 865 for After=1

Since the 2011 flood, the Brisbane City Council (BCC) has been working on providing accurate information to residents. On 5 May 2017, it released an online tool "FloodWise Property Reports" (Brisbane City Council (2017)) based on recently completed studies, providing specific and detailed data for each parcel, which we use in this study to define which properties were flooded in the 2011 event. The sample contains 4252 transactions, out of which 1250 were flooded in the 2011 event.

4.1 Pre-testing and estimation of price indices

We first test whether the parameters of the model to construct the price indices, P_F (Flood) and P_{NF} (No Flood), given in (1), are common across the two types. Specifically we test $H_0 : \beta_k, k = 1, \ldots, K$ are common across all properties (i.e. in flood and flood-free areas). The computed f-statistic is 2.1775 (p-value=0.0297). Thus, we reject the null of common slope coefficients across the two types and construct the indices by estimating two separate models.

Estimates of P_F (Flood) and P_{NF} (No Flood) are presented in Figure 3. The figure shows prices increased six-fold over the period 1990-2015 in this area of Brisbane. The price index for those properties in the flood plain, P_F, is mostly below that obtained from the flood-free sample; however, it would appear they seem to overlap over a number of periods. The indices show prices grew at a lower rate around the Global Financial Crisis period (2008-2009), and the drop in P_F after the 2011 flood event is visually clear.

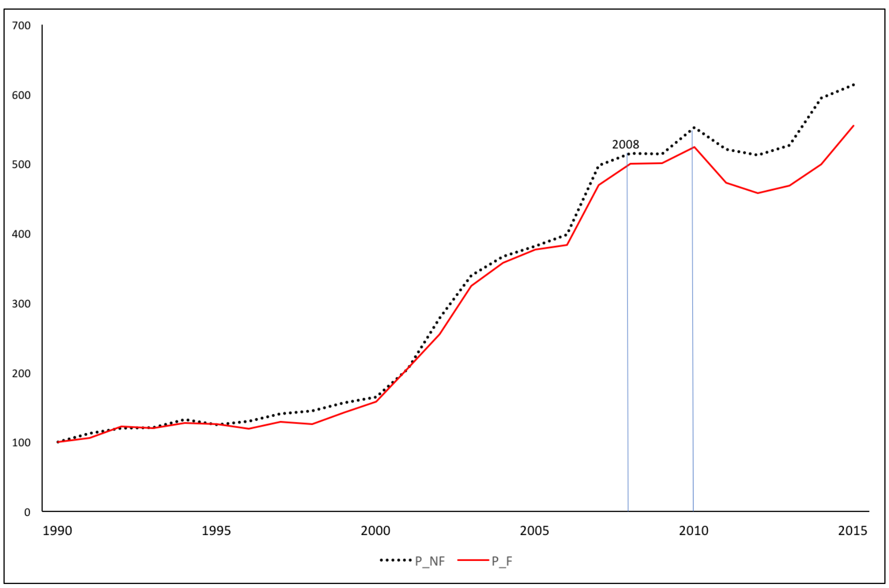

Figure 3: Price Indices for Properties Affected/Not Affected by the 2011 Flood Event

Before proceeding to the testing of the Pryce et al (2011) framework, we can consider whether the apparent recovering of the prices after the 2011 event in Figure (3) is statistically significant. To test this hypothesis we estimated a simple quadratic model as follows

$$\log(price_{it}) = \beta_0 + x_{it}'\beta + \phi Flood_i + \tau_1(Trend_{it} \times Flood_i) + \tau_2(Trend_{it}^2 \times Flood_i) + u_{it} \qquad (6)$$

where, β_k is a K by 1 vector of parameters, and the model is estimated over the sample which covers sales in the years 2010 to 2015. Correspondently, $Trend$ takes the values of 1 to 6 depending on the year of sale (i.e. 2010=1, 2012=2,...). The estimates are $\hat{\beta}_0 = 11.5167$, $\hat{\phi} = 0.1237$ (p-val = 0.1022), $\hat{\tau}_1 = -0.1630$ (p-val = 0.0008), and $\hat{\tau}_2 = 0.0242$ (p-val = 0.0004). This is depicted in Figure (4). These results provide some initial evidence that prices have recovered.

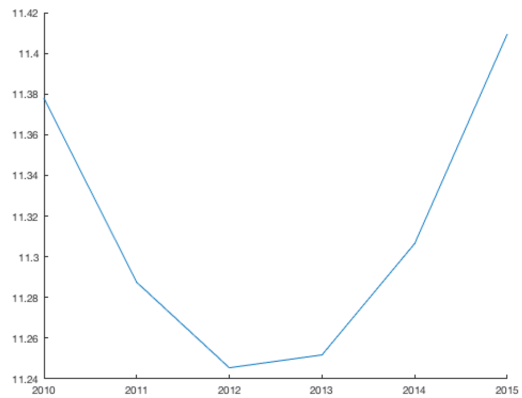

Figure 4: Estimated Quadratic Trend in Prices

4.2 Estimation of risk-adjustment discount

In Section 3.3 we propose two alternative modelling approaches to obtain an estimate of the size of the discount due to flooding risk. Here the aim is to try to establish what is the fully risk adjusted discount. By using alternative approaches we search for the minimum and maximum range where the discount lies.

Table 2 shows the estimates of the discount due to flood risk obtained from the difference-in-difference (DID) specification, model (4), and the hedonic alternative, model (5). The average estimated discount from the DID specification is 7.31%. For the hedonic specification, we estimated the model including all transactions after the flood for three alternative periods, 2011-2013 (478 observations), 2011-2014 (682 observations) and for 2011-2015 (865 observations), with the estimates using the sample from 2011-2013 providing the largest discount, 9.53%. In the next section the estimate of $P(RA)$ is provided as the range between these two values.

4.3 Estimates of $P(ZR)$, $P(RA)$, $P(A)$ and test for myopic and amnesic behaviour

Figure 5 presents the estimates of $P(ZR)$ (Zero Risk Constant Quality Price Index), the minimum and maximum empirical $P(RA)$ (Risk-Adjusted Constant Quality Price Index) based on the estimates presented in the previous sections, and the actual Quality Adjusted Price Index, $P(A)$, labelled "P(A)(Sample)", and the empirical 95% interval for $P(A)$ obtained from the bootstrap

Table 2: Estimated Discount due to Flood Risk

Model	Difference-in-Difference	Hedonic		
Sample	1990-2015	2011-2015	2011-2014	2011-2013
$Flood$	-0.0107 (-0.0843)	-0.0895 (-3.9221)	**-0.0953** (-3.6711)	-0.0780 (-2.2718)
$After$	-0.1359 (-11.033)			
$Flood \times After$	**-0.0731** (-2.5600)			
R-Sq	0.796	0.494	0.504	0.505
N	4252	865	682	478
Controls	time dummies	time dummies and hedonic characteristics		

exercise[2]. As discussed in Section 2, there was a heavy rain event in May 1996 which did not cause a generalised flood in Brisbane; however, there was localised flooding in low lying level areas of the city, which would have been visible in the study area due to proximity to waterways. The January 2011 event was a generalised event as the Brisbane river broke its banks affecting all suburbs adjacent to the river.

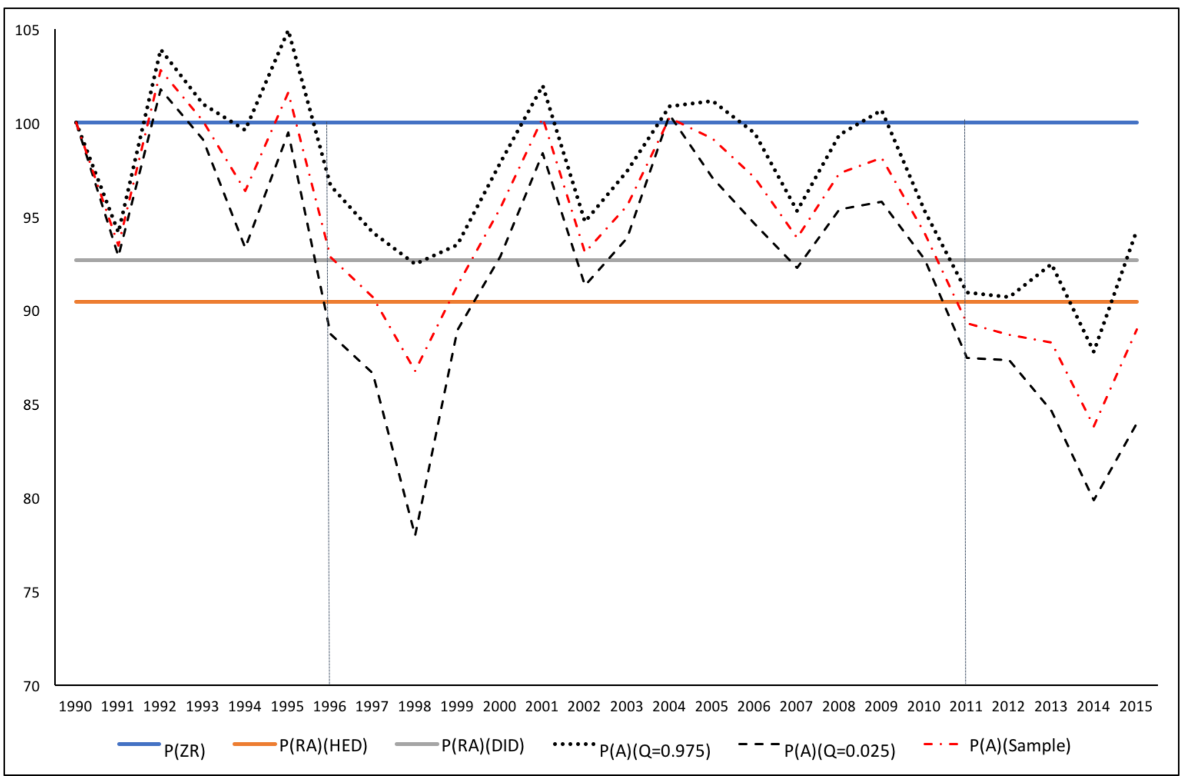

Figure 5: Test for Myopic and Amnesic Behaviour using Bootstrapped Estimates

The constructed 95% bootstrapped interval for $P(A)$ is above the $P(RA)$ level and it includes

[2]note that "P(A)(Sample)" and the 0.5 quantile estimate of the $P(A)$'s bootstrapped distribution overlap (the latter not shown).

$P(ZR)$ in a number of instances prior to 1996. A price signal is clear after the localised event of 1996, when the actual price is at the risk-adjusted price level. This is clear as the empirical distribution of the actual price contains the $P(RA)$ estimated range. However, prices stay at the risk-adjusted level for only two years and then the estimated distribution of $P(A)$ returns to levels that are close or equal to the $P(ZR)$ during the 00's and until 2010 with the exception of 2002 where the actual price distribution is very close to the $P(RA)$ level again. The Australia Bureau of Meteorology's Severe Storms Archive (Bureau of Meteorology (electronic)) shows rain with severe flash flooding affected Brisbane suburbs on 30 December 2001 which would have affected the study area and produced a price signal captured in the 2002 data. The Global Financial Crisis of 2007-2008 appears to produce some volatility in that P_F and P_NF separate from each other leading to an estimate of $P(A)$ which is below the zero-risk level although still above the risk-adjusted price level. In 2011 the distribution of $P(A)$ goes completely below $P(RA)$ estimates until 2014, but shows signs of recovering by 2015 when the distribution of the actual price is at the risk-adjusted price level again (i.e. it includes the $P(RA)$ estimates). This is the expected behaviour from Pryce et al (2011)'s theoretical framework to the case of an infrequent flood.

Overall, these estimates provide evidence to reject the null hypotheses of no myopic and no amnesic behaviour in the prices of property subjected to infrequent floods in Brisbane. We will have to wait for more years of data to see if the interval goes above the $P(RA)$ and towards $P(ZR)$, i.e. amnesia setting in again, or agents change their perceptions to the case of *frequent* floods. In this case, Pryce et al(2001)'s framework anticipates $P(RA)$ will no longer be constant, but have a downward trend. Figure 6 shows what the expected pattern would be.

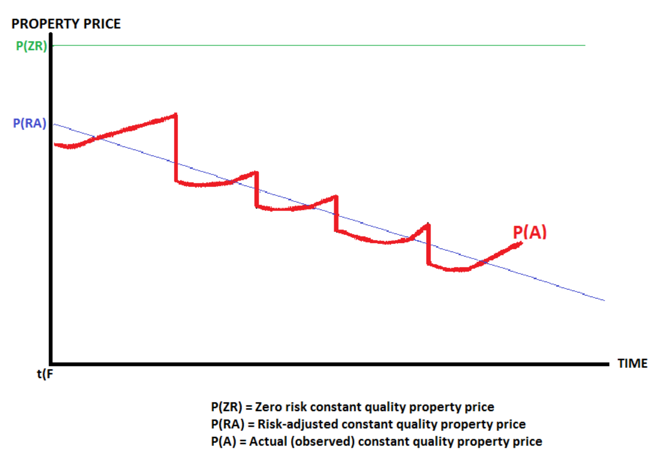

Figure 6: *Adapted from Pryce et al (2011)* - Figure 4

5 Discussion and Implications

Major catastrophic events require coordinated responses from both government and insurers. Taxpayers are usually left with large bills after a major catastrophe. Following the 2010/2011 floods that affected a large part of eastern Australia, the federal government imposed a twelve months levy, those earning between $50,000 and $100,000 a year would pay an additional 0.5 per cent flood levy tax, while those earning over $100,000 would pay an additional 1 per cent tax. Those affected by the floods were exempt. Large number of household that believed they were insured, had their claims denied. The insurance most had did not cover "riverine" floods. Is this the consumers' fault? The record shows, insurance companies and federal regulators were aware of the problem with the definition of "flood" (see Insurance Council of Australia (2008), Australian Competition and Consumer Commission (2008) for the discussions).

Following a number of flooding events in regional areas across two states (Queensland and New South Wales) in 2008, and the 2011 floods affecting the cities of Ipswich and Brisbane, the House of Representatives' Standing Committee on Social Policy and Legal Affairs of the Parlament of Australia held an inquiry and produced a report into the operations of the insurance industry during disaster events in February 2012. On the 18th of June 2012 the Federal Government enacted regulations to give effect to a definition of flood with a two year transition period.

In the long run reducing the risk of flood damage requires management by government across a number of areas such as land-use, building codes, and investment in physical mitigation measures. Clear adaptation strategies must be implemented.

6 Conclusions

This paper explores the relationship between flooding events and the patterns of discounting of property prices. We develop an estimation and testing strategy to implement a recently proposed theoretical framework and use a unique natural experiment to demonstrate how this framework provides a test for myopic and amnesic responses to flooding frequency and severity in urban property prices.

When floods are infrequent, buyers both underestimate future risks (i.e. myopia) and forget the past (i.e. amnesia). In this regime observed quality adjusted prices are expected to drift away from a risk-adjusted constant quality house price towards the zero-risk constant quality property price as the years pass since the last flood. Then, when a flood occurs, actors become aware of the true flood risk and observed prices quickly adjusts downwards towards the risk adjusted price.

The methodology proposed defines empirical estimates of zero-risk, risk-adjusted and actual quality adjusted prices which can be obtained using hedonic regressions and a difference-in-difference estimation. The test for amnesia and myopia is based on a bootstrap approach.

The city of Brisbane suffered a devastating flood in 1974, and by 1985 a dam with two compartments, flood and water reservoir, was built at the upper catchment of the Brisbane river. Over the following twenty six years both inhabitants and the real estate market concluded the city was no longer in danger of a major flooding. In January 2011 after torrential rain substantial releases from the dam had to be made leading to a major flood in Brisbane. Our dataset covers property transactions for an inner Brisbane area located 5 km from Brisbane Central Business District (CBD) with 30% of each year's sales being properties in the flood plain for the period 1990-2015. We implement the proposed approached and find strong support for the behaviour.

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Appendix

Table 3: Descriptive Statistics - Whole Sample

	min	max	median	mean	Std	Description/Source
Price (thousands)	9.7	3600	375.5	434.93	318.49	observed sale price (RP)
Age1	0	1	0	0.484	0.500	Pre-war (RP)
Age2	0	1	0	0.093	0.290	War (1942_1947) (RP)
Age3	0	1	0	0.304	0.460	After War (RP)
Age4	0	1	0	0.060	0.237	Late20thC (RP)
Age5	0	1	0	0.060	0.237	contemporary (RP)
NoH	0	1	0	0.023	0.151	Vacant Land
Land area	127.000	2555.000	607.000	605.396	202.350	Sq Mts -RP, BCC
Structure area	0	535.630	172.140	180.551	66.474	Sq Mts -DERM (LiDAR) 2010
Bath	0	4	1.000	1.448	0.721	RP, BCC, or RE
Beds	0	8	3.000	3.112	0.952	RP, BCC, or RE
Cars	0	8	2.000	1.638	0.792	RP, BCC, or RE
dist_river	17.436	3671.676	1703.389	1689.597	922.152	Mts -BCC and geospatial tools
dist_waterway	17.436	2147.959	732.750	750.478	463.513	Mts -BCC and geospatial tools
dist_industry	8.237	1844.367	1057.765	987.405	454.121	Mts -BCC and geospatial tools
dist_parks	0.000	638.425	162.961	189.904	136.166	Mts -BCC and geospatial tools
dist_busStop	3.177	488.568	151.565	174.147	100.820	Mts -BCC and geospatial tools
dist_schools	108.911	3342.636	1299.811	1381.371	702.989	Mts -BCC and geospatial tools
dist_city	4088.482	7899.440	5908.961	5873.433	959.630	Mts -BCC and geospatial tools
dist_Shosp	97.634	2572.540	1243.027	1287.023	596.785	Mts -BCC and geospatial tools
dist_rails	95.311	3661.013	1776.348	1749.646	872.990	Mts -BCC and geospatial tools
dis_hos	1238.348	4089.892	2552.549	2562.484	611.644	Mts -BCC and geospatial tools

Source/notes

RPdata.com (http://www.rpdata.net.au/) (RP) - Currently Corelogic

BCC Planning and Development Online (http://pdonline.brisbane.qld.gov.au/) (BCC)

Google View (GV) or www.realestate.com (RE)

Table 4: Descriptive Statistics - Flood Plain

	min	max	median	mean	Std	Description/Source
Price (thousands)	9.7	1520	334.750	368.639	228.104	observed sale price (RP)
Age1	0	1	0	0	0	Pre-war (RP)
Age2	0	1	0	0.086	0.280	War (1942_1947) (RP)
Age3	0	1	0	0.308	0.462	After War (RP)
Age4	0	1	0	0.063	0.243	Late20thC (RP)
Age5	0	1	0	0.057	0.232	contemporary (RP)
NoH	0	1	0	0.030	0.172	Vacant Land
Land area	171	2218	556	563.083	181.831	Sq Mts -RP, BCC
Structure area	0	500.89	156.79	162.964	62.632	Sq Mts -DERM (LiDAR) 2010
Bath	0	4	1	1.319	0.637	RP, BCC, or RE
Beds	0	6	3	2.934	0.907	RP, BCC, or RE
Cars	0	6	1	1.550	0.765	RP, BCC, or RE
dist_river	17.436	3538.351	1466.157	1466.063	838.445	Mts -BCC and geospatial tools
dist_waterway	17.436	2069.799	539.733	610.774	450.070	Mts -BCC and geospatial tools
dist_industry	8.237	1844.367	1055.923	977.793	450.070	Mts -BCC and geospatial tools
dist_parks	0.000	638.425	110.504	179.917	164.126	Mts -BCC and geospatial tools
dist_busStop	21.641	475.519	151.142	176.862	102.241	Mts -BCC and geospatial tools
dist_schools	191.961	3157.050	1163.445	1210.189	616.484	Mts -BCC and geospatial tools
dist_city	4088.482	7719.363	5651.909	5636.395	878.824	Mts -BCC and geospatial tools
dist_Shosp	166.964	2401.976	1060.084	1139.883	520.182	Mts -BCC and geospatial tools
dist_rails	124.875	3444.285	1552.928	1524.128	789.524	Mts -BCC and geospatial tools
dis_hos	1379.579	4089.892	2616.100	2585.189	619.701	Mts -BCC and geospatial tools

Sample Size = 1250

Source/notes

RPdata.com (http://www.rpdata.net.au/) (RP) - Currently Corelogic

BCC Planning and Development Online (http://pdonline.brisbane.qld.gov.au/) (BCC)

Google View (GV) or www.realestate.com (RE)

Table 5: Descriptive Statistics - Flood Free

	min	max	median	mean	Std	Description/Source
Price (thousands)	26.571	3600	400	462.527	345.604	observed sale price (RP)
Age1	0	1	0	0	0	Pre-war (RP)
Age2	0	1	0	0.096	0.295	War (1942_1947) (RP)
Age3	0	1	0	0.302	0.459	After War (RP)
Age4	0	1	0	0.058	0.234	Late20thC (RP)
Age5	0	1	0	0.061	0.239	contemporary (RP)
NoH	0	1	0	0.020	0.141	Vacant Land
Land area	127	2555	607	623.015	207.807	Sq Mts -RP, BCC
Structure area	0	535.630	180.250	187.874	66.665	Sq Mts -DERM (LiDAR) 2010
Bath	0	4	1	1.502	0.748	RP, BCC, or RE
Beds	0	8	3	3.186	0.960	RP, BCC, or RE
Cars	0	8	2	1.675	0.801	RP, BCC, or RE
dist_river	91.504	3671.676	1831.801	1782.674	939.417	Mts -BCC and geospatial tools
dist_waterway	41.756	2147.959	839.117	808.650	456.631	Mts -BCC and geospatial tools
dist_industry	23.583	1795.832	1059.455	991.408	448.165	Mts -BCC and geospatial tools
dist_parks	5.666	614.282	171.465	194.062	122.450	Mts -BCC and geospatial tools
dist_busStop	3.177	488.568	152.260	173.017	100.218	Mts -BCC and geospatial tools
dist_schools	108.911	3342.636	1392.004	1452.650	724.276	Mts -BCC and geospatial tools
dist_city	4186.145	7899.440	6065.026	5972.133	974.616	Mts -BCC and geospatial tools
dist_Shosp	97.634	2572.540	1308.757	1348.291	615.718	Mts -BCC and geospatial tools
dist_rails	95.311	3661.013	1932.469	1843.549	888.884	Mts -BCC and geospatial tools
dis_hos	1238.348	3980.884	2542.947	2553.029	608.111	Mts -BCC and geospatial tools

Sample Size = 3002

Source/notes

RPdata.com (http://www.rpdata.net.au/) (RP) - Currently Corelogic

BCC Planning and Development Online (http://pdonline.brisbane.qld.gov.au/) (BCC)

Google View (GV) or www.realestate.com (RE)