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Cyclonic storm-surge risk: a hedonic case study of residential property in Exmouth, Western Australia

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ABSTRACT.

Australia is particularly vulnerable to coastal hazards as 85% of the population lives along the coast and there is growing demand for coastal development. The town of Exmouth in north-western Australia was used as a case study to investigate economic strategies for coastal disaster risk reduction as it typifies expanding coastal development in areas prone to extreme weather events, such as cyclones. The extent to which perceptions of risk of cyclonic storm-surge inundation and flooding influenced the price buyers paid for residential property from 1988-2013 were examined using a Hedonic Price model. This incorporated dwelling variables, proximity to the coast, Cyclone Vance storm-surge levels (4m) and 1-in-100 year flood levels. The analysis indicated that prices did not reflect the real societal cost of risk and the influence of greater coastal amenity over-rode any sensitivity to potential risk by buyers. This study is highly relevant in view of the expansion of residential settlement and industry along the coast of northern Australia and the predicted effects of extreme weather events under climate change scenarios.

KEYWORDS: Property prices, economic instruments, environmental management

MOTS-CLES: Prix des propriétés, instruments économiques, gestion environnementale
1. Introduction

Recent major natural disasters in Australia have highlighted how some of the economic costs of living in risk-prone areas are borne by the rest of society. Australia is particularly vulnerable to coastal hazards as 85% of the population lives along the coast and there is a growing demand to construct residential buildings, amenities, transport networks and industrial developments. This study aimed to determine if coastal property buyers factored potential risk of cyclonic storm-surge inundation and flood risk into their property purchase decisions. The town of Exmouth, located in north-western Australia near the World Heritage Site of Ningaloo Reef, was used as a case study as it typifies expanding coastal and industrial development in areas prone to extreme weather events. Cyclones are regularly experienced in Exmouth and these cause strong winds, heavy rain and storm-surge, leading to inundation of the low-lying coastline. Further, flooding during cyclonic events associated with run-off from a low mountain range located east of the town is of particular concern. In 1999, the town was affected by the category five Cyclone Vance which severely damaged buildings and other public and private infrastructure in the town.

Previously, town planning limited development to the north-eastern part of Exmouth, in areas of higher elevation, away from the coastline and creeks. More recently, however, there has been residential development in low-lying areas including a marina constructed to provide real estate that is high in coastal amenity value. Properties in the marina are only about 1-2 m above the mean sea level. Construction of the marina has also resulted in the loss of disaster-mitigating natural capital functions in the area and there has been a loss of the fore dunes and secondary dunes as well as compaction of land immediately north of the marina behind the coastal dune system. Originally, this area functioned as a natural flood detention area, capturing excess water during heavy storms and cyclone events, and gradually allowing it to percolate into the ocean (Western Australian Government Dept. of Water & SKM, 2007). Channels and other protective engineering structures have been built to compensate for the loss of these functions, but these might be insufficient to withstand large flooding or cyclonic storm-surge inundation events (WA Government Dept. of Water & SKM, 2007). Erosion, as a result of storm-surge, will exacerbate the situation, and there is additional concern in the context of an almost 1 m predicted sea level rise along the coast of WA by the end of the century (WA Government Planning Commission, 2013).

2. Methods

The Hedonic Price model (HPM) theoretically specified by Rosen (1974) was used to disaggregate the impact of risk factors (location in the flood zone or areas prone to cyclonic storm-surge) on residential property prices from other attributes of residential property in Exmouth. This method has been extensively used to determine the effect of various property characteristics, such as the structure (e.g., lot size, number of bedrooms), the neighbourhood (e.g., distance to schools, average commute time), and the environment (e.g., proximity to recreational areas, degree of air pollution). The HPM has been increasingly applied to natural disaster risk, ranging from floods, earthquakes, hurricanes, fire, and volcanic eruptions to wind and erosion (Nakagawa et al., 2009; Keskin, 2008; Stetler et al., 2010; Rambaldi et al., 2011). The underlying theory of this is that, just like positive environmental features, such as a scenic view can create an increase in property prices, greater exposure to a natural hazard can be reflected through diminished prices. Location of a property in a cyclone-prone area, flood-hazard zone, or along an earthquake fault line, can influence an
individual's perception of possible threat to life and property, and this may be reflected in the price he or she is willing to pay at the time of purchase.

Property sales data from 1988-2013 for Exmouth were used in a HPM to assess the perception of risk through location in areas prone to cyclonic storm-surge inundation, 100-year Average Return Interval (ARI) flooding and areas that were damaged by Cyclone Vance in 1999. Table 1 presents a summary of the data used in the analysis; most of the variables, with the exception of those depicting distance from urban amenities and lot size, were converted to dichotomous variables.

*Table 1 Summary of the variables used in the HPM analyses carried out for Exmouth properties (1988-2013)*

<table>
<thead>
<tr>
<th>Variables</th>
<th>Data source</th>
<th>Data type in original data set</th>
<th>Converted form used in the HPM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dwelling-specific variables</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of bedrooms, bathrooms, family rooms,</td>
<td>Western Australian Valuer General (Landgate)</td>
<td>Numeric</td>
<td>Dichotomous</td>
</tr>
<tr>
<td>dining rooms, games rooms, lounges, studies,</td>
<td></td>
<td>(m²)</td>
<td>No change</td>
</tr>
<tr>
<td>kitchens, pools, carports or garages</td>
<td></td>
<td>Date (Year)</td>
<td>Dichotomous</td>
</tr>
<tr>
<td>Lot size</td>
<td></td>
<td>Alpha-numeric</td>
<td>Dichotomous</td>
</tr>
<tr>
<td>Year the dwelling was built</td>
<td></td>
<td>Alpha-numeric</td>
<td>Dichotomous</td>
</tr>
<tr>
<td>Wall and roof material</td>
<td></td>
<td>Alpha-numeric</td>
<td>Dichotomous</td>
</tr>
<tr>
<td>Property classification</td>
<td></td>
<td>Alpha-numeric</td>
<td>Dichotomous</td>
</tr>
<tr>
<td>Property classes</td>
<td></td>
<td>Alpha-numeric</td>
<td>Dichotomous</td>
</tr>
<tr>
<td>Land-use type</td>
<td></td>
<td>Alpha-numeric</td>
<td>Dichotomous</td>
</tr>
<tr>
<td>Distance from urban amenities</td>
<td>Straight-line distance of each of the properties from the nearest grocery store, coffee shop, restaurant, pub, book shop, and entertainment venue (Walk Score 2013)</td>
<td>Numeric (m)</td>
<td>No change</td>
</tr>
<tr>
<td><strong>Risk variables</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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2.1. Risk variables

Proxies used in the HPM equation were those representing risk exposure, based on location of property, and those representing risk awareness (Table 2). Variables that denoted the degree of exposure to risk were based on previous studies that used dichotomous variables for risk, where the value of one denotes that a property is located in a risk-prone area and zero if it is not (Bin et al., 2008; Dei Tutu & Bin, 2002; MacDonald et al., 1987; MacDonald et al., 1990; Shilling et al., 1989; Shabman & Stephenson, 1996).

Information from a scenario analysis carried out for Exmouth (Roberts, 2012), where the centroids of the transacted properties were overlaid with the storm-surge risk areas, was used to derive variables denoting areas at risk of storm-surge heights of 4 m. The coefficients of this variable measured the price difference between properties in the cyclonic storm-surge-prone area and other areas. The working hypothesis was that if a property was located in an area of risk of cyclonic storm-surge inundation, it would have a lower price than those located outside the risk zone, ceteris paribus. The price differential would therefore provide the discount value on the price of risk in this area.

Table 2 The variables used to denote risk exposure and risk awareness in the Hedonic Pricing study and the number of transacted properties for Exmouth (1988-2013)

<table>
<thead>
<tr>
<th>Variables</th>
<th>Number of transactions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inundated by a 4 m storm-surge</td>
<td>44</td>
</tr>
<tr>
<td>Located in the 100-year ARI flood plain</td>
<td>180</td>
</tr>
</tbody>
</table>
2.2. Correction for auto-correlation

As temporal auto-correlation results from property sales over multiple years, especially when annual sales in a market are sparse, the additional effect of time must be captured as part of the equation. The HPM study for Exmouth used dichotomous variables for each year over the study period in order to correct for temporal auto-correlation as specified by Taylor (2003) and used by Morgan (2007) and Bin et al. (2008). The data were also tested for possible effects of month and quarter of sale, but these were found to be insignificant. Bivariate correlation between sales prices and each of the variables in the dataset was carried out to determine those most suitable to be included in the final HPM. Those found to be significantly correlated (p<0.01 and <0.05) were selected.

3. Results

Applying the HPM specification of Rosen (1974) and the results of the bivariate correlation to property sales prices, the following equation was specified:

\[
\text{Property Sale Price} = \alpha_0 + \beta_1 S_1 + \beta_2 N_1 + \beta_3 R_k + \epsilon
\]

where structural characteristics (\(S_1\)) = lot size (m\(^2\)), age of house (years), presence of a family room, property classification (flat, villa, house, single unit, duplex unit), wall material (iron, steel frame, brick, fibro, asbestos); neighbourhood characteristics (\(N_1\)) = distance to the nearest grocery shop (km); risk characteristics (\(R_k\)) = 4 m cyclonic storm-surge inundation risk, 100-year ARI flooding, sale of property within six months, one year and two years after cyclone Vance, and interaction effects between location in the 100-year ARI areas and sale after cyclone Vance; \(\epsilon\) = residual error; \(\alpha_0\) = intercept; and \(\beta_1, \beta_2, \beta_3\) = coefficients of the structural characteristics, neighbourhood and risk characteristics, respectively.
3.1. Risk variables

Eight risk variables representing cyclonic storm-surge inundation and flooding in the Exmouth town site were tested (Table 3). Although it was expected that these variables would have a negative impact on property prices, this was not the case. Prices were, in fact, much higher in areas prone to cyclonic storm-surge (4 m) and 100-year ARI flood risk. The devastation caused by the category 5 Cyclone Vance, which severely damaged buildings and major public infrastructure in the town, had no effect on price. Even the prices of properties located in 100-year ARI areas that experienced flooding because of Cyclone Vance were not discounted for risk.

The first HPM analysis used the variables specified for the structural characteristics ($S_i$) and neighbourhood characteristics ($N_j$) as described in the above equation. The risk characteristic ($R_k$) tested was a 4 m cyclonic storm-surge and there were 44 property sales transactions within this risk area during the study period. The summary statistics are presented in Table 3 and linear, semi-log and log-log functional forms were significant ($p<0.1$). The coefficient values, and their level of significance for the HPM, showed that the variable representing the risk of a 4 m cyclonic storm-surge (Table 3) was positive and significant ($p<0.01$). The finding of this model indicated that buyers paid higher prices for properties located in risk-prone locations when compared to other areas, and buyers did not discount for risk as expected. An examination of the data showed that of the 44 properties sold in the 4 m storm-surge zone, 98% of these transactions were within the past 10 years (i.e. after 2000). Of these, 52% and 36% were located in the marina and recreational open space zones, respectively, and these were located at a distance of 130 – 700 m from the original shoreline of Exmouth Gulf.

Table 3 Summary of the coefficients and significance values for the risk variables under the Hedonic Pricing analyses carried out for Exmouth (1988-2013)

<table>
<thead>
<tr>
<th>Variables</th>
<th>Number of transactions</th>
<th>Coefficients values and level of significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inundation by a 4 m storm-surge</td>
<td>44</td>
<td>Linear: 83,241**  Semi-log: 0.42**  Log-log: 0.35**</td>
</tr>
<tr>
<td>Located in a 100-year ARI flood plain</td>
<td>180</td>
<td>Linear: 40,305**  Semi-log: -0.05  Log-log: -0.04</td>
</tr>
<tr>
<td>Post-cyclone Vance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Six months</td>
<td>52</td>
<td>Linear: 13,887  Semi-log: 0.06  Log-log: 0.06</td>
</tr>
<tr>
<td>One year</td>
<td>93</td>
<td>Linear: 15,181  Semi-log: 0.08  Log-log: 0.08</td>
</tr>
<tr>
<td>Two years</td>
<td>150</td>
<td>Linear: 8,103  Semi-log: 0.08  Log-log: 0.05</td>
</tr>
<tr>
<td>Interaction variables</td>
<td></td>
<td></td>
</tr>
<tr>
<td>100-year ARI * sold 6 months after Vance</td>
<td>4</td>
<td>Linear: 78,660  Semi-log: 0.51**  Log-log: 0.45**</td>
</tr>
</tbody>
</table>
To determine the effect of Cyclone Vance, three separate regressions were run to test if there were any effects on property prices within 6-months, one-year and two-years after the event (Rk). Cumulatively, there were 52 sales transactions 6-months after cyclone Vance, 93 within a year after, and 150 sales in the two years following the event. The log-log model showed the highest $R^2$ value, where the variables used accounted for 83% of the variation in house prices. Given that the Durbin-Watson statistic (that tests for the presence of auto-correlation) was within the required range, this was considered the most appropriate functional form. The HPM carried out to determine if there was any effect on properties sold within six months, one year and two years after Cyclone Vance were not significant, indicating that there was no effect on sales prices if a property was sold within these time frames.

The location of a property within the 100-year ARI flood zone was the second risk characteristic (Rk) tested in a HPM model. There were 180 property sales transactions in the 100-year ARI area during the study period. Summary statistics indicated that the log-log was the best functional form ($R^2 = 0.84$). Although the coefficient for 100-year ARI risk was negative, it was not significant indicating that this also did not have an effect on sales price.

Finally, HPM analyses were undertaken to determine the possibility of interaction of Cyclone Vance with the 100-year ARI risk. Three separate regressions were carried out to represent the three risk characteristics (Rk), which comprised of the interaction effect between location in a 100-year ARI zone and the property being sold within 6 months, a year or two years following cyclone Vance. There were 4, 6 and 11 transactions that were located in the 100-year floodplain and sold within 6 months, one year and two years of Vance, respectively. The positive significance of the coefficient in the semi-log and log-log HPMs implied that, even for properties located in the 100-year floodplain, the experience of Cyclone Vance did not result in any discount on property prices.

### 3.2. Other variables

Variables depicting properties with iron roofs or, if the property was a duplex unit, villa, house, flat or single unit, had a positive coefficient ($p<0.01$), indicating preference for such houses. The variable for asbestos walls, resulted in lower property prices, and the significance of this coefficient ($p<0.01$) indicated that buyers took this into serious consideration. Surprisingly, lot size and property age appeared to have no effect on price in the semi-log function, although the findings showed an increase in price if there was a family room in the house. The coefficients of these in the linear and log-log forms show a decrease in price for age of dwelling. Contrary to the findings of the bivariate model, the further away a property was from the shopping area, as represented by the variable indicating distance to a grocery store, the lower the price, which indicated that property owners had greater preference for properties with more access to urban amenities. This result was considered to be the most accurate finding, as multivariate regression models are considered to provide the better results than bivariate methods (Gujarati, 2006).
4. Discussion

This study found that properties located in the 4 m storm-surge prone areas at Exmouth had higher property values than others. Further investigation indicated that the positive effect created by greater access to coastal amenity influenced decisions to purchase property outweighing any concerns about cyclonic storm-surge inundation and flood risk. Similarly, a HPM analysis carried out by the Sydney Coastal Councils (2011), found that properties located on the beachfront along the Collaroy-Narrabeen area in New South Wales were 40% more valuable with buyers paying, on average, >$1 million for such properties. Properties near Noosa Heads in Queensland with access to the ocean and with a view of the beach were also found to be more valuable (Pearson et al., 2002). The Heinz Centre (2000) found that coastal properties in the USA were 4-8% more valuable than comparable inland property. Since all of the properties at risk of a 4 m storm-surge in Exmouth are located in the marina village, there are other associated benefits that could have been confounding the analysis. The houses are more modern, and the surrounding area is landscaped to provide an aesthetically pleasing environment, whereas other areas in the town are comparably less attractive.

The results of the HPM for 100-year ARI floods indicated that buyers do not factor the threat of cyclonic storm-surge and associated flooding due to rainfall into their property prices. A USA study which also used HPMS to investigate the major event versus 100-year floodplain interaction effect, found different results to those at Exmouth (Bin & Polasky, 2004; Morgan, 2007). This was attributed to the requirement, by law, for these properties to obtain insurance. However, there is no compulsory insurance requirement for home owners in Exmouth, or other parts of north-western Australia. The absence of a monetary signal via insurance to create awareness of risk in Exmouth could therefore be another reason buyers failed to factor risk into the prices they paid for coastal property. It also suggests that knowledge and awareness of risk may be insufficient to change economic behaviour.

A survey of local risk perceptions in the USA found that the presence of shoreline armouring, seawalls, and other structural devices created a sense of safety from coastal risk, to the extent that it suppressed the need to purchase flood insurance (Kriesel & Landry, 2004). This is another element which may also explain the findings of this study. At Exmouth, the flood drainage channels established in the marina village were built to direct excess flooding into the ocean. However, since their establishment, there has not been an opportunity to test the ability of these channels to mitigate flooding in the town site. The presence of these may be instrumental in creating a perception of safety among those purchasing property in this area.

4.1. Effect of Cyclone Vance

HPM analyses carried out to assess prices following Cyclone Vance, and the increased awareness and concern about potential danger, revealed no effect. This finding is different to that of Hallstrom & Smith (2005), who found a decrease in property prices in Florida, following Hurricane Andrew in 1992, even in areas that were not affected. This may be because those property owners living in risk-prone areas in the USA are compelled to pay higher insurance premiums following such major events. This is not, however, the case in Exmouth and can imply lower sensitivity to potential risk among buyers. On the other hand and, more importantly, it indicates the importance of the absence of a monetary signal of risk, and its translation into economic behaviour.
Analyses carried out to assess the interaction effect of properties sold after Cyclone Vance, located in 100-year ARI flood areas, found an increase, rather than a decrease in sales price. This is similar to findings of Skantz & Strickland (1987), for Houston, Texas, who found that major events did not affect prices even for properties located in flood prone areas. They attributed this to the availability of subsidized insurance, where owners did not have to factor in the full cost of risk into their purchase decisions. This was corroborated by their finding that a sharp increase in insurance premiums a year later resulted in a drop in property prices.

Another reason why buyers have not discounted for risk-prone property in Exmouth could be the expectation of compensation from the government, a classic example of moral hazard. As was demonstrated with the relief provided through a nation-wide levy to property-owners affected by the Queensland flooding and cyclone in 2011 (Australian Government Treasury, 2011), the problem lies in an imbalance between social and private costs. While property owners enjoy the amenity gained from living close to the coast, they do not bear the full cost of their decisions, either through insurance, or by paying for damages following a major event. This creates an inequitable situation, where the rest of society, who do not partake of these benefits, is forced to fund emergency, response and long-term rehabilitation costs.

A HPM analysis of the interaction between risk of 4 m storm-surge and the Cyclone Vance effect was not carried out because, at the time of cyclone, the construction of the marina had not yet commenced. But, given that buyers did not discount for property prices, even directly following a severe cyclone, it was not expected that there would be any effect for at-risk properties in the marina area which came on the market two years later.

4.2. Policy implications

The lack of the impact of risk of disaster on property sales requires policy that will serve to internalise the social costs of disasters into the private calculations of property owners and developers. This can be done in various ways where, for example, the local government can implement land-use control measures. Implementing and enforcing this may require various economic instruments to encourage developers and local communities to behave more in accordance with federal and state controls. Determination of areas subject to cyclonic storm-surge inundation and zoning by degree of risk are essential parts of the implementation of land-use controls. Monetary obligations to incorporate the threat of flood-risk may be the only way that more judicious land-use controls are enforced.

This, in turn, leads to various other policy implications. It is >15 years since Cyclone Vance and, over time, memories of such catastrophic events fade and other priorities take precedence. Several of the marina properties have come on the market in recent years and buyers may not be aware of the extent of risk to which they are exposed. Marina property sales are targeted at employees of major oil and gas companies and the nature of such industries attract people from other southern capital cities of Australia who are probably not aware of the extent of cyclonic and other coastal risk in towns such as Exmouth.

Another management pathway associated with cyclonic storm-surge inundation and flooding risk is the designation of high-risk areas through mapping, and making this information publicly available to future property buyers in the area. The basis of this management action is that, if people are aware of risk, they will translate this knowledge into action, by paying lower prices for properties
located in high-risk zones. The rationale is that the lower price reflects the potential costs of damage they may bear in the future. Alternatively, they may undertake risk mitigation measures to minimize potential damages.

From the perspective of property buyers, awareness of risk alone may not, however, always translate into action. For instance, an investigation into flood insurance purchase for coastal properties in the USA, found that only 49% of households maintained flood insurance, despite mandatory purchase requirements for federally-backed mortgages (Kriesel & Landry, 2004). This implies that regulatory measures alone are not sufficient to change economic decisions to buy risk-prone property. Given that Australia has no mandatory insurance programme such as the National Flood Insurance Program in the USA, this begs the question of whether such legal requirements would change the way the Australian property buyers perceive and make decisions regarding coastal risk. Monetary signals through higher insurance premiums or other forms of economic incentives may be more effective in influencing property purchase behaviour; in the USA, studies have shown that buyers who pay high insurance premiums for flood risk-prone properties pay lower prices at the time of sale (Troy & Romm, 2004).

Natural disaster insurance is the most commonly explored economic strategy applied to risk. It serves to correct market failures arising from the externalities created by developers and property buyers, and failure on the part of the state and local governments. Following the 2011 Queensland floods, in eastern Australia, a national disaster insurance review recommended flood insurance for riverine events. This approach could be extended to include cyclonic storm-surge inundation, whereby a compulsory private insurance scheme, possibly subsidised in the short-term through a federal government fund, could be used for high-risk areas. Conditions should be built in to alleviate any perverse incentives that might arise from such a programme. Natural disaster insurance, however, cannot internalise the risks created to other parts of the community through development in high-risk areas. It also fails to internalise the social cost of disasters created by property developers. The use of subsidised insurance in the long-term for high-risk properties could also create distortions in the market, resulting in reduced participation and under-insurance, thereby subverting the original goals.

5. Conclusion

The aim of this investigation was to determine, by using a HPM on property sales data from Exmouth, if the purchase price of real estate factored in coastal disaster risk. Results indicated that neither location in risk-prone areas, nor the experience of the 1999 Cyclone Vance, had any effect on residential property prices. This study has highlighted the need to assess the economics of planning and coastal property development in disaster-prone areas where un-bridled development, growing coastal populations and injudicious land-use planning amplifies the predicted disaster risk due to climate change and extreme weather events.

Bibliography and references


