

Adaptor of last resort? An economic perspective on the Government's role in adaptation to climate change

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ADAPTOR OF LAST RESORT?

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role in adaptation to climate change**

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Cover image: West End post-2011 floods © Feral Arts Flickr Creative Commons

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ABSTRACT

Individuals and societies have always adapted to change, whether catastrophic or slow onset. Over the last two centuries, however, governments have significantly extended their role as ultimate social manager of risk. It is as yet unclear whether, how, or to what extent governments will add adaptation to climate change to their portfolio of responsibilities. This report investigates this question on the basis of review and analysis of economic and policy thinking on the issues, and by using a new dataset on the 2011 Brisbane flood.

Uncertainties about the future impacts of climate change obviate definitive conclusions about future adaptation actions and insights for specific situations cannot be generalised. Economic precepts suggest that governments should limit intervention to cases of genuine market failure, such as the provision of information on likely impacts of climate change including at the local level, or to support people affected by uninsurable events. But any role as 'insurer of last resort' needs to be circumscribed by rigorous social cost-benefit analysis to ensure that government intervention is beneficial, in the context of the need to adapt to climatic changes. Although the phenomenon of 'government failure' is generally ignored in the adaptation literature (and often by policy makers), it too can stymie efficient adaptation.

A standard justification for government intervention is market failure, including misperception of risk by individuals and businesses. We use Brisbane property prices before and after the January 2011 flood, as well as property-level flood risk information to test the hypothesis that buyers do not accurately perceive the risk of riverine flooding. The results indicate that buyers do take risk into account, and even discriminate between zones of differing flood risk.

The concepts of 'government as insurer of last resort' and 'government as insurer of first resort' as alternative forms of intervention in markets are examined with a view to disambiguation. In contrast to much current thinking in academic and government circles, we conclude that the government should not act as an 'adaptor of first or last resort'. Rather, government can best contribute to efficient adaptation by reducing the economic costs and institutional barriers to adaptation faced by individuals and organisations. Comprehensive micro-economic reform, and the promotion of institutional flexibility are potential 'no regrets' strategies because they will also promote economic growth and welfare.

EXECUTIVE SUMMARY

The primary objective of this project is to investigate the issues associated with government assuming the role of 'insurer of last resort' with respect to adaptation to climate change. The term itself is ambiguous, and encompasses more than the role of insurer of financial risk alone. The first stage of the project therefore involved an analysis and review of the economics and policy literature to clarify the scope with which government could usefully play the broader role of 'adaptor of last resort'.

Some of the impacts of climate change are likely to resemble today's hazards, perhaps with greater intensity or greater frequency. Further, government intervention is typically justified on the basis of market failure, including a misperception of risk. The second part of our project therefore investigates as a case study the effect on Brisbane property prices of the 2008 online release of flood risk information and the effect of the 2011 flood. Our aim was to test the hypothesis that owners of residential buildings in Brisbane did not perceive the risk of riverine flooding. By examining changes in property sale prices, we were able to draw inferences as to how property market participants perceived the risk of floods.

Government as manager of risk

Individuals and societies have always adapted to change, whether catastrophic or slow onset. Over the last two centuries, however, governments have significantly extended their role as ultimate social manager of risk. Since the nineteenth century, governments have progressively adopted roles in areas such as limited liability for corporations, workers' compensation, social security, consumer protection and the environment. Whether, how, or to what extent governments will add adaptation to climate change to their portfolio of responsibilities is a question that governments are and will be grappling with.

Governments can reduce the risk faced by their citizens in two major ways. Risk can be reduced by regulation: for example, by banning a harmful substance or imposing building standards in floodplains. Risk can also be reallocated within society. By offering government-sponsored insurance for otherwise uninsurable events such as terrorist attacks, for example, airlines and their passengers share their risk with taxpayers in general.

However, governments cannot alleviate all risk, in part for similar reasons why they cannot 'run' an economy efficiently using a strict deterministic planning model. The large number of variables, many of which are unobservable to planners, and multitude of individual preferences precludes this. The cascade of uncertainties that accompany expected climate change impacts, including timing, intensity, nature, local effects, and frequency of events, poses a similar problem. Despite the best intentions of the techno-scientific community and governments, it is unlikely that top-down adaptation programs could deliver efficient outcomes.

Market failure and government failure

A standard justification for government intervention in economic activity is 'market failure', which denotes some flaw that results in inefficient, Pareto sub-optimal outcomes. Information asymmetry (where information is only available to some parties to a private market transaction) is often the underlying cause of market failure. In insurance markets, different levels of information available to an insurer and the insured party can result in adverse selection or moral hazard. Governments can often

remedy the effects of market failure by instituting property rights, providing information, taxing negative externalities, or by direct regulation.

Market failure can also arise where people misperceive risk. For example, some Brisbane residents may have considered that the construction of the Wivenhoe dam following the 1974 flood had obviated the risk of major flooding. Others may have been new to the city and had not realised that floods were a potential hazard. Myopia or simply wishful thinking may have also played a role. A key function of government in such circumstances is to provide information to increase awareness.

However, not all government assistance is necessarily helpful in dealing with risks and change. For example, the almost permanent provision of drought support to farmers in marginal agricultural areas of Australia has perpetuated losses in the agricultural sector and discouraged efficient adjustment by farmers. Provision of insurance subsidies or ex post financial assistance to victims of floods runs a similar risk of 'charity hazard' and increasing dependence on support from the public sector rather than adjustment to the risks involved.

Other, more direct government intervention can also have adverse side-effects, which may well outweigh any welfare-enhancing effects of regulation of financial interventions by governments. An example is governments buying out properties at risk of inundation and converting the land to parks or other public amenities. Potential buyers with high preferences for living near the river are effectively 'crowded out', even if they would have been willing to bear the cost of periodic flood damage or the additional cost of building a dwelling that is not prone to flood damage (such as a 'traditional Queenslander' house). This represents costs in addition to budgetary outlays, which need to be considered against any benefits of flood risk reduction.

Brisbane property prices and the perception of flood risk

Since a standard justification for government intervention is market failure, including misperception of risk, we used Brisbane property prices to test (see Chapter 4) the hypothesis that buyers had not correctly perceived the risk of riverine flooding. Sale prices in flood zones fell in July 2008 when flood risk information was made available online, and again after the January 2011 flood. Prices in spatially proximate areas did not fall as much.

Treating the changes in sale prices in flooded and non-flooded areas before and after the January 2011 flood as a 'natural experiment', (see Chapter 2), we used regression analysis to identify the causal effect of the flood on property prices. In order to check the robustness of the results of changes in property prices at the suburb level, parallel analysis was carried out at the street level where some houses on a particular street were flooded, and others were not. Further testing of properties that had been sold both before and after the flood confirmed the robustness of our findings. A similar analytical approach was applied to changes in property prices after July 2008 when online flood risk information was released.

Our findings were as follows:

- The January 2011 flood caused an average 6.2% fall in property prices for flood affected properties.
- Property prices for properties identified as having flood risk fell by 2.9% as a result of the online release of flood zone information in July 2008.

- Property prices were affected by some risks, but not others: for each metre height of the flood rising with a 1 in 20 or 1 in 50 year likelihood caused property prices to drop by 0.5%.

Our findings also suggest that purchasers of riverine property in Brisbane do discriminate on the basis of perceived risk. In areas that are expected to flood frequently (1 in 5 years), buyers appear to have already factored in flood risk so that prices were not affected significantly when the flood occurred. We have interpreted this to mean that high incidence floods are usually less damaging due to their lower height, and because minor flood defences (e.g. sand bags) can easily be arranged. Nor did prices fall significantly in areas where there is a risk of 1 in 100 year flooding, presumably because such events are too rare to be of concern from year to year. However, prices did drop significantly for properties at risk of 1 in 20 and 1 in 50 year floods. If our interpretation is accepted, there may be an arguable case for ensuring that government information about flood risk differentiates between degrees of risk, to allow people to form their own judgements.

Government as ‘insurer of first resort’ and ‘insurer of last resort’

There is no precise definition or generally accepted concept of government acting as ‘insurer of last resort’, particularly for future climate change. The term can have several meanings, ranging from government acting as an insurer or re-insurer to simply assisting in the last resort. Some degree of disambiguation is therefore required.

The phrase ‘last resort’ is generally identified with ‘lender of last resort’ as a function exercised by central banks. However, one of the objectives of central banks is to prevent contagion in terms of panic spreading among banks about the liquidity of the financial system. In the case of adaptation to climate change, there is no corresponding issue of contagion, so that the central banking model is not particularly relevant.

A model based on government acting as a provider of subsidised insurance or re-insurance is also considered to be potentially problematic due to responses that are likely to involve moral hazard and adverse selection. Moreover, subsidised insurance may act as a disincentive to more concrete adaptation measures.

We distinguish between two broader conceptualisations of the terms ‘insurer of first resort’ and ‘insurer of last resort’. Where government acts as ‘insurer of first resort’, it generally adopts a role of direct intervention in a market in competition with private providers. The Australian Government’s ownership of Medicare is an example, where a government owned business enterprise operates in an otherwise competitive health insurance market. Where government acts as an ‘insurer of last resort’ in terms of risk management, it intervenes only when an existing private market encounters difficulties and cannot cope without assistance. An example is the guarantee scheme for Authorised Deposit Taking Institutions introduced during the Global Financial Crisis, for a payment in return for backing from the government.

A role for government?

Governments could adopt a wider role as ‘adaptor of last resort’. This might involve the funding of various adaptation programs, provision of disaster assistance, and subsidies to those who take some specified adaptive action. However, such a role would need to be justified by rigorous cost-benefit analysis in order to ensure that a society’s resources were not wasted. Widespread government involvement in adaptation responses would run the risk of fiscal churn as money was directed from one group of

taxpayers to another, as well as deadweight losses if taxation were increased to pay for the programs. Furthermore, there would be no guarantee that governments could play such a role more efficiently than the private sector.

A more fruitful role for governments is in maximising the options for adaptation available to their citizens. Individuals (and their communities) will be more readily able to take decisions flexibly and in accord with local circumstances, than can centralised intervention. In economic terms, the quasi-option value of the flexibility created could add significantly to social wellbeing.

A key aspect of increasing options for individuals to adapt to climate change is the reduction of barriers, including regulatory frameworks, institutional rigidities and barriers to efficient adaptation arising from price distortions. Thus, the need for climate change adaptation reinforces the more general need for ongoing comprehensive micro-economic and institutional reform.

1. OBJECTIVES OF THE RESEARCH

Many, if not most publications on adaptation to climate change assume implicitly that adaptation measures will or should be deterministic in nature. The solution to expectations of increased frequency or intensity of floods, for example, is typically seen as the construction of a levee or sea wall. Only rarely are alternatives such as migration or use of market-based instruments such as charging higher local government rates for additional maintenance or infrastructure considered.

The implicit assumption is that either or both of the public or private sectors of society will divert some of their existing resources to 'obvious' adaptation measures. A broader economic perspective, on the other hand, would recognise that trade-offs would inevitably be required against other social preferences and priorities, including health, education, etc.

Deterministic solutions often ignore externalities because they do not adopt a rigorous social cost-benefit approach from the perspective of society as a whole. For example, a levee that protects one community may well increase the volume and velocity of floodwaters and thus increase the damage to downstream communities. The problem is compounded by the production of pseudo-economic studies that treat avoided damage as benefits to be reaped, rather than estimating society's willingness to pay to avoid the effects of the flood.

Even more problematic is the avoidance of the problem of uncertainty. Again, many studies propose deterministic solutions but neglect to specify decision-criteria, including particularly timing, for implementation. By implication, adaptation measures are seen as being implemented immediately or in the near future, perhaps on the basis of some version of the so-called 'precautionary principle'. Extending the approach to the absurdity end of the spectrum, it is possible to envisage a plethora of projects that would inevitably bankrupt most countries, if implemented in their totality. More specifically, there is a significant risk that much of the project expenditure could be wasted if the timing, intensity or frequency of climate change effects did not materialise as expected on the basis of current knowledge.

While this project cannot address all of these issues, it seeks to redress the balance by taking an economic perspective. In doing so, we acknowledge that a limited number of others have sought to do the same from various perspectives, including the Productivity Commission (2013).

1.1 *Original proposal*

The objectives in our original proposal were as follows:

1. identification of potential risks in government assuming the role of insurer of last resort;
2. modelling and other analysis of the fiscal flows and the distributional implications;
3. analysing and documenting potential tensions between the principle of subsidiarity and vertical fiscal imbalance, and;
4. develop proposals for obviating identified adverse fiscal effects where government does take on the role of insurer of last resort.

The first of these objectives has been fulfilled through desk-top research, including an extensive literature search and review of key issues.

Completion of work on the other objectives was necessarily contingent on being able to obtain data on government disaster assistance payments. It had been envisaged that the financial assistance payment data would be combined with micro-simulation modelling by NATSEM of income distributions in areas which received payments.

Our attempts to obtain sufficiently disaggregated spatial data on Australian Government Disaster Relief Payments (AGDRP) flows following the January 2011 Brisbane floods have been unsuccessful, despite continuous contact with the Australian Government departments of Human Services and Attorney-General since the middle of 2012. As at the time of writing (3 April 2013) we had not received any data from the Department of Human Services, despite having made the original request in August 2012.

We have for some time been unsuccessful in making contact with our original Partner Investigator, Professor Alan Duncan (Director, NATSEM), and understand that Professor Duncan is either on extended leave or has resigned his position, with Associate Professor Robert Tanton currently acting as Director (<http://www.natsem.canberra.edu.au/natsem-people/director/>). It has therefore not been possible to carry out quantitative analysis of the type originally envisaged to investigate income-related equity and taxation issues.

1.2 Refined research objective

Although government disaster relief appears to be predicated on providing assistance to those on low incomes, disasters typically also affect asset values. Given that some disaster victims are income poor but asset rich, there is a valid case for investigating the effect of a disaster such as the 2011 Brisbane floods on house prices in flooded districts relative to house prices in non-flooded areas.

As far as we are aware, no detailed study of this aspect has been undertaken before.

Analysis of the effects of a flood, or, indeed, any disaster, on the value of dwellings is important for at least the following reasons:

- an income-poor owner-occupier who is not insured for major damage caused by a flood is likely to find it difficult to effect repairs that will return the building to a fully habitable state, even if not to its original state;
- even if an owner-occupier or investor-landlord is insured for flood damage, repairs to a flood-damaged houses tend to take at least several months because of the need to thoroughly clean and dry walls and floors before replacing cladding and carpets. An income-poor owner, or an investor who relies on income from tenants, may be forced to sell at a significantly reduced price. In the case of owner-occupiers, a fall in asset value will reduce their ability to adapt by moving to a less risky location elsewhere; and
- changes in perceptions of risk can be inferred from changes in prices of properties in flood-affected areas, or areas that are considered to be at risk of flooding.

The objectives for the study were therefore amended to the following:

- identification of potential risks in government assuming the role of insurer of last resort;
- modelling and analysis of relative changes in property prices following a flood;
- use of anecdotal information to relate, as far as possible, the fall in prices after a flood to increases in insurance premiums and reductions in asset values; and
- modelling and analysis of relative changes in property prices following the release of flood-risk information by local government authorities.

It is argued in Chapter 3 that any role for government in adaptation to climate change should be a limited one. However, it is often argued that people misperceive risk and that governments therefore need to play a key role in overcoming this deficiency.

A key underlying objective of our study was therefore to test the hypothesis that people are generally not responsive to available information about risk. Our findings are based principally on evidence from changes in Brisbane property prices in response to two instrumental events:

1. the online release in 2008 of flood risk data by the Brisbane City Council; and,
2. the effect of an actual flood in January 2011.

2. RESEARCH ACTIVITIES AND METHODS

2.1 Analysis of Government's role in adaptation to climate change

The first of the four objectives for this project, as identified in chapter 1 above, was the 'identification of potential risks in government assuming the role of insurer of last resort' in the area of adaptation to climate change. The primary method adopted in reviewing the potential roles of government in adaptation to climate change was desktop research that incorporate an extensive literature review

The task was not straightforward because of the relative paucity of publications on risk reallocation (risk shifting) by governments, particularly in the area of adaptation to climate change. The uncertainties involved in future climate change, and the focus of much of the literature on risk reduction, particularly for catastrophe scenarios, are probably the main reasons for this imbalance.

A key aspect of the literature review was an analysis, principally from an economic perspective, of the various ways in which governments have traditionally managed public risk. The conventional rationale for government intervention is 'market failure'. Less often discussed is the corresponding issue of 'government failure', but we address both issues where appropriate in reviewing the literature.

There are many historical examples of government managing public risk through regulatory intervention. An example is clause 35 of Magna Carta (1215 version) which established a number of uniform weights and measures across the realm. The construction of the Great Wall in China is another example. Such interventions essentially reduced public risk. Market mechanisms may in some instances also result in 'risk reduction'. Examples include the widespread adoption of the QWERTY keyboard as a standard, and the domination of VHS over Betamax for video recorders. The use of security services in the commercial sector, provision of 'protection' by the mafia, as well as the use of mercenaries in wider conflicts (e.g. Iraq) provide examples of private sector solutions to functions normally reserved to states.

The 'pooling' or 'shifting' of risk has a long tradition in private insurance markets. However, governments have also intervened in recent times in private markets to shift risk. Obvious examples include the provision of social security schemes such as pensions or unemployment benefits. In such cases, provision of financial assistance shifts the risk of an impecunious old age or lack of income from the individual to taxpayers in general. Government guarantees to private sector insurance companies effectively constitute public sector re-insurance financed by taxpayers.

Drawing on these and other examples of roles adopted by governments in risk reduction and risk shifting, we examine the desirability of government acting as 'insurer of last resort' for adaptation to climate change. The term 'insurer of last resort' can be interpreted literally in the sense of governments providing insurance against climate-generated catastrophes. This would constitute a fairly narrow perspective on an issue as pervasive as climate change, so the term 'insurer of last resort' has been interpreted metaphorically in the wider sense of manager of public risk. A better descriptor might be 'adaptor of last resort' to convey government's role as ultimate manager of any residual risk that cannot be met by normal market mechanisms. It is for this reason that we have amended the title, in order to remove any ambiguity in meaning.

A paper on this aspect of our research was presented to a high-level seminar at the Department of Climate Change and Energy Efficiency in Canberra on 12 February 2013. Feedback obtained has been used to refine our analysis, as have comments from two anonymous NCCARF reviewers.

2.2 Causal inference and natural experiments

To estimate the effect of both the 2011 flood and the provision of flood risk information on house prices, we employ a strategy based on laboratory experiments. This strategy isolates the casual effect of an intervention on an outcome.

For instance, one might be interested in the causal effect of a new drug on health outcomes. Inferring causality from laboratory experiments relies on assumptions. Where the floods and information release meet the same assumptions, we can use the same strategy to isolate the causal effect of the floods and flood risk information on house prices. Such scenarios are termed *natural experiments*. In this chapter we explain our methodology through a discussion of laboratory experiments, then we show how our context of the Brisbane property market follows the same approach. Finally, we discuss our empirical strategy in detail.

Inferring causality requires investigation of two different states of the world: one state that did occur and that can be observed; and a second state that did not occur and cannot therefore be observed. The problem in causal inference is the attempt to compare something that is observable with something that is not. For instance, saying that a drug alleviated the effects of an illness is a statement about a world where someone took the drug compared to a world where the same person did not take the drug. It is, of course, impossible to observe both of these ‘with the drug’ and ‘without the drug’ states.

The impossibility of observing both ‘with’ and ‘without’ states can lead one to misattribute a factor for the cause. For instance, taking a tablet may make a person feel better. One might be inclined to infer from this that the tablet worked. But it is also plausible that the person would have felt better even without a tablet. After all, illnesses do not typically last forever

Laboratory experiments – or randomised control trials – are a tool that allows robust causal inferences to be drawn in a way that obviates the impossibility of observing two different states of the world. Consider a drug company trialling a new flu-relief drug. The company wants to make sure that its product works and does not wish to fall foul of a misattribution. It therefore establishes a *control* group that does not take the drug, as well as a *treatment* group that does take the drug. The effects across both groups can be compared (in a sense to be made precise below) to identify the causal effect. For the comparison to be meaningful, we must expect that the change in health outcomes for both the treatment and the control group will be the same in the absence of taking the drug. This is because the treatment and control groups are meant to mimic two mutually exclusive states of the world, – one where the drug is taken, and the world where the drug is not taken.

Experiments achieve comparability of the control and treatment groups through *randomisation*. Drawing on the pool of participants in the trial, the experimenters randomly select a treatment group and a control group. Because the groups are chosen randomly, there is no reason to believe that the groups differ in their general health or their response to a specific drug. For instance, some people – for whatever reason – will recover from illnesses far more quickly than others. Randomly allocating people to take the drug means that the proportion of people who recover from the flu

more quickly can be expected to be the same in both groups. That is, we expect the change in average health outcomes of both groups to be the same. One can extend this argument to show that, for a well-designed experiment, any other causal factors that could explain health outcomes (of which there are many) can be ignored, leaving the focus on the effect of immediate interest: that of the drug alone.

Experiments allow us to obtain the causal effect of interest by comparing two groups over time, thus creating four basic groups. The experimental participants are classified by whether they take the drug (treatment group) or the placebo (control group), and are then split into two further groups: before and after taking the placebo or the drug. For each group, we obtain the average value of the outcome of interest. For the flu-drug example this would be some specific measure of health. Table 1 shows this grouping, with Y_i the average health outcome for each group $i = A, B, C, D$.

Table 1. Average health effect of two groups; the control group taking a placebo and the treatment group the active drug

	Control	Treatment	
Before	A	B	$Y_B - Y_A$
After	C	D	$Y_D - Y_C$
Difference	$Y_C - Y_A$	$Y_D - Y_B$	$(Y_D - Y_B) - (Y_C - Y_A)$

Table 1 also illustrates the 'difference-in-differences' methodology that is used to infer causality in experiments. As the name suggests, subtraction is used at two levels to obtain an estimate. One change in average health is obtained by subtracting the average health of the treatment group before they take the drug (Y_B) from the average health after they take the drug (Y_D). If the drug has a positive effect on health, the average health levels in the 'after' period (Y_D) can be expected to be higher.

However, it would be premature to conclude that the drug is the cause of improved health. It is also necessary to know what would have happened in the absence of taking the drug. It is the role¹ of the group taking the placebo to control for differences in general health effects over time ($Y_C - Y_A$). Had the flu lost its potency over time, there would be an expectation that average health outcomes would increase over time in response to the diminished strength of the flu.

The above procedure yields two 'differences', giving the average casual effect $(Y_D - Y_B) - (Y_C - Y_A)$. The experiment² therefore allows us to isolate the causal effect of the drug on health, despite the multitude of factors that could obscure the relationship.

In this analysis, we use so-called 'natural experiments' where fully controlled experiments are not feasible³. Natural experiments arise where a treatment occurs that

¹ That is, the 'control' group substitutes for the state of the world that is not observable.

² Note that we can equivalently take the difference across treatment and control groups in the second period and subtract the first period difference to find the effect of the drug.

³ Natural experiments are commonly used in both economics and epidemiology. An early and famous case is the identification of the cause of a cholera outbreak in London

effectively randomises the population into groups. Under such conditions, we can obtain a robust estimate of the causal effect of interest.

2.3 Two natural experiments in Brisbane: the July 2008 online release of flood risk information, and the January 2011 flood

A natural experiment using the difference-in differences approach was used to investigate the causal effect of both the online publication of flood risk information in 2008 and the 2011 flood on house prices. Flooding of some houses at random, but not others, is not possible, so a formal laboratory experiment was not possible. At issue was the fact that it is not possible to simultaneously observe two mutually exclusive states of the world: the sale price of a house that was flooded (or the release of flood risk information), and the same house without a flood event (or the absence of information release). It is possible, however, to observe a group of houses that were flooded (or deemed a flood risk) and a group that were not flooded (or not deemed a flood risk) and compare the changes in house prices over time across these groups. This section addresses only the example of the 2011 flood to simplify the discussion, but the same approach was applied to the phenomenon of the online release of flood risk information in 2008.

The argument for causal inference in an experiment relies on randomised selection of the treatment and control groups. The expected change in outcomes for the two groups can thus be expected to be the same on average. It is also possible to exploit the fact that the 2011 flood was – in a sense – random. The flood affected some houses but not others, a fact that could not be influenced by anyone's choice. It is also reasonable to expect that non-flooded houses near the flood lines would have been subject to the same general trends and influences as those that were flooded, had the flood not occurred. If this is accepted, the non-flooded houses can be used as a control group to estimate the causal effect of the flood on property prices. The control group takes the place of what would have happened to the flooded houses on average if the flood had not occurred.

To employ this strategy, we must choose a plausible control group. To illustrate the problem of choosing a plausible control group, let us start with an absurd example: it would have clearly been inappropriate to use property sales in Perth as a control group for flooded properties in Brisbane. Although they may share the same macroeconomic environment, there is little reason to believe that the underlying trends over time are equivalent in these distant cities. There are many factors that influence house prices in Perth that will not influence house prices in Brisbane. Using sales from all of Queensland, or even all of metropolitan Brisbane is subject to the same problem.

The base control group chosen was all property sales within suburbs in the Brisbane Local Government Area (LGA) whose boundaries were encroached by the 2011 flood line. It seems reasonable to suppose that – on average – houses in the same suburb are subject to the same trends over time. However, some suburbs are large, and it is at least arguable that properties located at opposite extremities may be subject to different trends. To alleviate such concerns, the second sample chosen was smaller still, being restricted to property sales solely on streets that had been at least partially flooded. Although one can think of counter examples, it seems reasonable to expect

in 1854. The majority of those contracting the disease were found to use water provided by a company that drew supplies downstream from the outfall of raw sewage into the Thames. Those using water sourced from a source upstream had a lower incidence of cholera. http://en.wikipedia.org/wiki/Natural_experiment viewed 28 March 2013.

that houses on the same street (some flooded, some not) face the same, or very similar trends in property prices over time. By restricting properties to those on the same street, the control group can be considered to be an even more plausible solution to our problem of causal inference. Nevertheless, this precaution was found to be unnecessary because the results of both approaches to choosing a control group were found to be qualitatively equivalent.

It is worth noting the strength of what can be obtained with such parsimony of information. House prices can be affected by many factors, including the size of the house, number of bedrooms, bathrooms, location of schools, quality of the kitchen, etc. All of these can potentially influence the outcome variable, the sale price. If the objective were to explain house prices, all of this information would be required. However, the objective of the analysis in this report is to explain the *effect of the flood on house prices*, not house prices *per se*. Where it is reasonable to expect changes in prices over time to be the same in both the treatment and the control groups, the additional house attributes can be ignored in identifying any causal effect of the flood on house prices.

To assess the causal effect of the flood, property sales were separated into four groups (see Table 2). Spatially, properties that were at least partially flooded were distinguished from those that were not flooded at all. Temporally, residential property prices were separated into before and after the January 2011 flood. This demarcation creates four categories of properties and periods:

1. property outside 2011 floodlines, sold before 2011 floods
2. property within 2011 floodlines, sold before 2011 floods
3. property outside 2011 floodlines, sold after 2011 floods
4. property within 2011 floodlines, sold after 2011 floods

Error! Reference source not found. shows how these groups can be used to obtain the causal effect of the flood on property prices, where Y_i represents the sale price of the property.

Table 2. Average house sale prices of flooded and non-flooded properties – 2011 Brisbane flood

	Not flooded	Flooded	
Before Jan 2011	A	B	$Y_B - Y_A$
After Jan 2011	C	D	$Y_D - Y_C$
Difference	$Y_C - Y_A$	$Y_D - Y_B$	$(Y_D - Y_B) - (Y_C - Y_A)$

2.4 Regression methods

Rather than calculate the average effect of the flood on house prices from a tabular format, it is possible to use regression analysis. Regression methods provide the same estimate of the flood-effect, as well as providing additional diagnostic features. A particular benefit of the approach is that it permits testing of the strength of the relationship. A second benefit is that additional variables can be added to increase the explanatory power of the analysis. For instance, the effect of both the floods and the online release of flood information can be investigated in the one regression. The tabular format in **Error! Reference source not found.2** can be mapped to the regression model in equation 1 below.

The table has a 2 by 2 structure, with the average value of property sales in each group's cell. The regression model similarly has a 2 by 2 structure: flooded and non-flooded groups; before and after the flood. Instead of cells, groups are represented by the binary variables F (flooded) and PF (post flood). The variable F takes a value equal to 1 where the property was flooded in January 2011 and 0 otherwise, even if the property was sold prior to the flood. Another way of interpreting this variable is that the properties are divided into two areas, defined by the January 2011 floodline. If the property lies inside the floodline, F takes a value of 1.

Additionally, the sample is divided into property sales before, and after 15 January 2011, so that the variable PF_t takes a value of 1 for property sales after 15 January 2011, and 0 otherwise. The dependent variable p_{ht} is the price of house h sold at time t in and e_{ht} is a residual, giving the following regression model :

$$p_{ht} = a_0 + a_1 F_h + a_2 PF_t + a_3 F_h \cdot PF_t + e_{ht} \quad \text{Eq. 1}$$

The coefficients (a_0, a_1, a_2, a_3) can be combined to form the average value for each group (see **Error! Reference source not found.**). For instance, suppose we want to know the average sale price for flooded properties sold prior to the January 2011 floods. In this case, F would take a value of 1, PF would take a value of 0 and, because of this, the interaction term $F \cdot PF$ would also take a value of zero. The average property value is thus $a_0 + a_1 \cdot 1 + a_2 \cdot 0 + a_3 \cdot 1 \cdot 0 = a_0 + a_1$. The same procedure can be applied to the three other groups. The average values thus obtained can then be used to difference the differences in order to identify the causal effect of the flood on property prices. Using Table 3 for illustration, it is apparent that the causal effect is equal to the coefficient a_3 on the interaction term $F \cdot PF$.

Table 3. Illustration of difference-in-differences using regression methods

	Not Flooded	Flooded	Difference
Before flood	a_0	$a_0 + a_1$	a_1
After flood	$a_0 + a_2$	$a_0 + a_1 + a_2 + a_3$	$a_1 + a_3$
Difference	a_2	$a_2 + a_3$	a_3

The strategy of identifying the effect of the Brisbane flood on property prices a_3 , rests on two key assumptions that link our methodology to the experimental ideal. First, that there is no other (omitted) variable that explains both which houses were flood affected and the change in property prices. We are confident that this condition is satisfied

because the flood affected houses randomly: although lower lying properties are more likely to be flooded, no individual could have determined or predicted precisely which properties would be flooded and which would not. Second, we require that, absent the flood, the prices of houses in both treatment and control regions of the sample can be expected to follow a common trend. As discussed above, we use non-flooded properties in flooded suburbs as our base control group. For robustness we have also used non-flooded properties on flooded streets as a different control group. With common trends in both flooded and non-flooded regions, we have an unbiased estimator of the causal effect of the flood.

For additional robustness, we also extend the error term e_{ht} . We do this by including additional temporal, spatial and property level components. Temporally, we include monthly and month-yearly time dummies. Monthly dummies account for potential seasonal effects in housing markets (e.g. December is considered to be a ‘quieter’ month in terms of sales). Month-yearly dummies control for any secular shock to the property market in a specific month in a specific year (for instance, interest rates). That is, month-yearly dummies extend the monthly dummies to allow house prices in January 2009 to experience a different shock to that of January 2010. Spatially, we include suburb dummies to control for the fact that local amenities, such as access to large shopping centres, may differ, and therefore affect prices. We also run a regression on the sub-sample of properties that had repeated sales. This allows us to control for any property level characteristics that did not change over time through the inclusion of a property level dummy variable. Our most general error term is shown in equation (2), with D_j vectors of dummy variables for $j = \{s, m, my, y, h\}$ and s indicating suburb, m for month, y for year and h for property, and u_{ht} as the new idiosyncratic error term.

$$e_{ht} = D_s + D_m + D_{my} + D_y + D_h + u_{ht} \quad \text{Eq. 2}$$

Data

The data used in this study comprise property sales in the Brisbane Local Government Area (LGA) over 2007-2012. We have property level data on the extent of the 2011 flood, flood risk, and sales. The data were combined to generate the main dataset, comprising the universe of house sales in the Brisbane LGA over the period 2007-2012, their flood risk, and whether or not these houses were flooded. The property sales data also come from the Queensland Valuation and Sales database. These data were provided under license, which precludes us from releasing them.

Flood data were obtained from the Queensland Government Information Service (Queensland Government Information Service, 2012a). The flood map ‘is considered to be the best estimate of the actual flood inundation extent based on the available verifiable data’ (Queensland Government Information Service, 2012a). The maps are based on aerial imagery taken at the time of the floods. The data may suffer from a degree of inaccuracy in the Brisbane CBD owing to buildings and heavy riverbank vegetation obstructing views of the flood lines. Additionally, it is possible that the floods had begun to recede at the time of the photos, and debris lines were used as a high water mark where obvious.

The cadastral database provides the spatial property boundary data and was obtained from QGIS (Queensland Government Information Service, 2012b). The database is updated fortnightly to reflect changes in boundaries through subdivision, as well as updated surveys. Our data are dated 7 May 2012, fourteen months after the flood.

The FloodWise property report data come from the Brisbane City Council's online portal.⁴ The information was made freely available online in July 2008, lowering the effective cost of obtaining this information. Discussions with Queensland Government officials indicated that information used in the generation of these reports is confidential, and we were unable to obtain the original reports. We therefore used current reports (downloaded in February 2013) as a proxy for the July 2008 reports. Since we have also been informed that the information contained in the reports does not change much over time, the more recent data are likely to be a reliable proxy of the original dataset. An additional benefit is that it was possible to obtain a measure of the height of the January 2011 flood from the current reports. FloodWise property reports were extracted from the website for all property sales in flooded suburbs. Suburbs were defined as being flooded if the 2011 flood line encroached on the suburb boundary, irrespective of the extent of flooding.

The datasets were combined to create a database consisting of all property sales, an objective measure of flood risk and whether or not properties were flooded in January 2011. Unique property identifiers (specifically the plan number, plan sequence and lot number) were used in the process. The construction of the database followed three steps.

First, a layer of flooded properties was constructed by intersecting the flood data with the cadastral data using Quantum GIS⁵. Figure 3. show the 2011 flood over the cadastral boundary. Figure 1 shows the intersected layer, comprising of the sections of properties that were flooded. The second step involved identification of the address for each property that was flooded. The shapefile data of the intersected properties yielded a list of flooded properties. The list of flooded properties was then merged with a list of all residential property sales in Brisbane over the period 2007–2012.

This was combined with the information contained in the FloodWise property reports. We obtained 43 582 reports: since many properties were sold multiple times, this covers 47, 759 property sales. FloodWise property reports were not available for 4055 property sales.

Our base sample consists of 47, 759 residential properties with a sale agreement date⁶ between 1 January 2007 and 31 December 2012 in the 80 suburbs that were flooded in the Brisbane LGA. We chose to restrict the analysis to properties sold in suburbs that were flooded to ensure that our comparison group was as similar to the flooded properties as possible. Since houses in the same suburb share many amenities, trends in the prices of properties in the same suburb provide a good study of what would have happened to prices in flooded regions absent a flood. 16.2 per cent of these sales (7721 properties) occurred within the 2011 flood lines and 34.5 per cent of property sales (16,463) had a flood risk identified in the FloodWise property reports.

Two key dates are relevant to our sample: July 2008 and 15 January 2011. July 2008 coincides with the online release of the FloodWise property reports: since we cannot obtain a more precise date, we have removed all observations from July 2008. We do not believe that there were any policies introduced at the end of the 2007–08 financial year that would influence house prices with an identified flood risk any differently from those without an identified flood risk. About 67.3 per cent of properties (32,122) were sold after July 2008. The 15 January 2011 is the date of the peak of the flood, and we

⁴ <http://flood.brisbane.qld.gov.au>

⁵ <http://www.qgis.org/>

⁶ As dates are crucial in our analysis, we exclude 1881 property sales that have no agreement date in the QVAS dataset.

use this to demarcate property sales before the flood from property sales after the flood. Some 25 per cent of sales (11,925 properties) took place after the 15 January 2011.

Finally, we note that a particular development sold 50 properties ⁷(flats) in June 2008. The average price of these properties was AUD \$3.27 million, whereas the average sale price in the rest of the sample was AUD \$580,000. As the sale happened immediately prior to the online release of the FloodWise property reports, and these riverside properties were a deemed flood risk, there is a danger that any effect we find could be explained by the high prices of these 50 properties. We nevertheless chose to retain these properties in the sample rather than discarding them as unrepresentative outliers, since they are relevant to our analysis. In any case, the overall conclusions from quantitative analysis of the effect of the 2008 online release of information and the 2011 flood do not change, whether or not we exclude these 50 properties.

By way of summary, we present four time-series plots:

⁷ These were probably flats. We were unable to distinguish between houses and flats in the data available to us.

1. Figure 2, presents the average monthly sale price over January 2007–December 2012, with July 2008 sales omitted. The online release of the flood risk information in 2008, as well as the 2011 flood coincide with a downward spike in prices.
- 2.

3. Figure 6. presents the same time series with the 50 development properties removed. Again, we see a drop in prices coinciding with the online release of the flood information.

The next two graphs demarcate sales into the treatment and control groups used in our investigation.

- 4.

5. Figure 3 shows the monthly average sale price for properties, demarcated by whether they are in a zone identified in the FloodWise property reports as facing a flood risk. A steep drop in price for properties deemed to be a flood risk occurs around July 2008. This provides confidence that there is a difference in prices after July 2008 between properties with an identified flood risk and those not identified as bearing any flood risk. Again, removing the 50 properties still leaves a discernible drop.
- 6.

7. Figure 4 repeats the process for the two groups defined by the 2011 floodlines. We notice a drop in average sale price in flooded areas, and little or no change in trend in the non-flooded region. These two plots suggest that the two shocks – the online release of flood risk information, and an actual flood – caused a drop in house prices.

These observations are tested using regression analysis in Chapter 4.

3. APPENDIX – TABLES AND GRAPHS

Figure 1. The information contained in each 'FloodWise property report'

PROPERTY DETAILS

Street Address	[REDACTED]
Lot on Plan	[REDACTED]

FLOOD LEVEL INFORMATION

Note: Please read the Disclaimer, Explanations and Terms and Definitions to help you understand and interpret the information contained in this report.

Minimum Ground Level based on most recent Council information	1.2 m AHD
Maximum Ground Level based on most recent Council information	1.5 m AHD
Highest defined flood level (DFL) (or 100 Year ARI Flood Level)	1.8 m AHD
Highest flooding source from	CREEK/WATERWAY
Flooding may also occur from *	Not available
Approximate depth of flooding on this property defined flood level (DFL) less the minimum ground level	The minimum ground level is above the Defined Flood Level
Minimum habitable floor level Highest defined flood level (DFL) in metres + 500 mm	1.3 m AHD

**If flooding also occurs from an overland flow path, see the information below:*

Flood levels from overland flow path flooding are difficult to predict and may result in a higher overall flood level than that indicated from other sources. Please read the information about overland flow given in the Definitions section. Please note that the depth of a potential overland flow path cannot be determined in this report.

Source:

http://www.floodcommission.qld.gov.au/data/assets/pdf_file/0014/9500/QFCI_Exhibit_563_Floodwise_Property_Report_template_-_BCC.pdf . It has been taken from attachment 17 of http://www.ewn.com.au/media/queensland_floods_commission_bcc.pdf

Figure 2. The 2011 flood lines over the property boundary cadastral for the city of Brisbane.

Data: (Queensland Government Information Service, 2012a, 2012b)

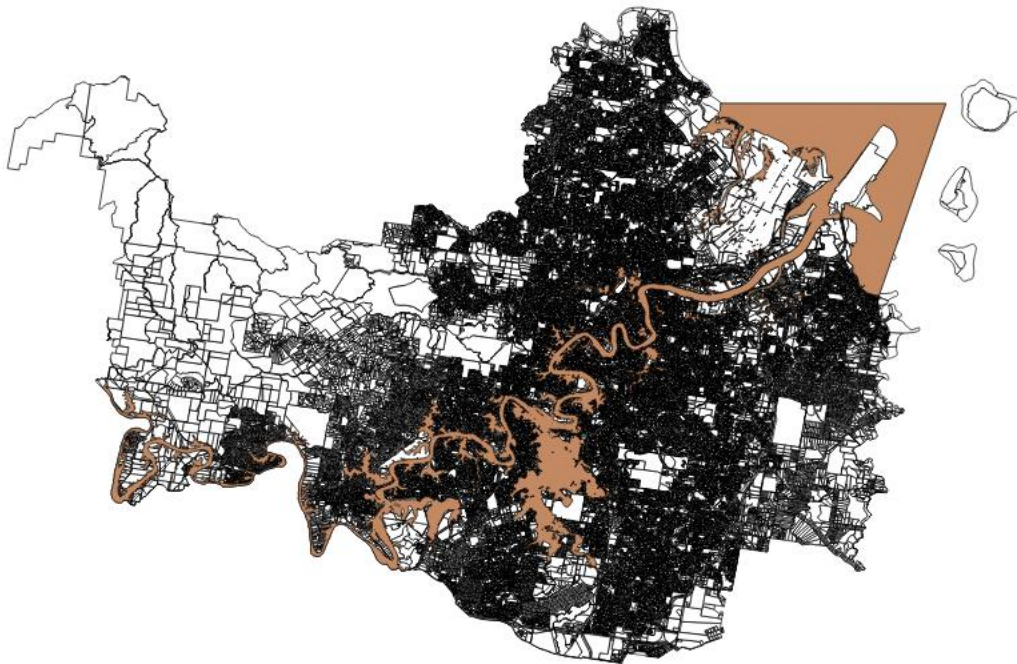


Figure 3. The Brisbane floods layered over the property boundaries.

This is a zoomed in version of Figure 2.. Data: (Queensland Government Information Service, 2012a, 2012b)



Figure 1. The flood layer is combined with the cadastral layer to obtain the boundaries and properties that were flooded (See Figure 2.Figure 3.)

Data: (Queensland Government Information Service, 2012a, 2012b)

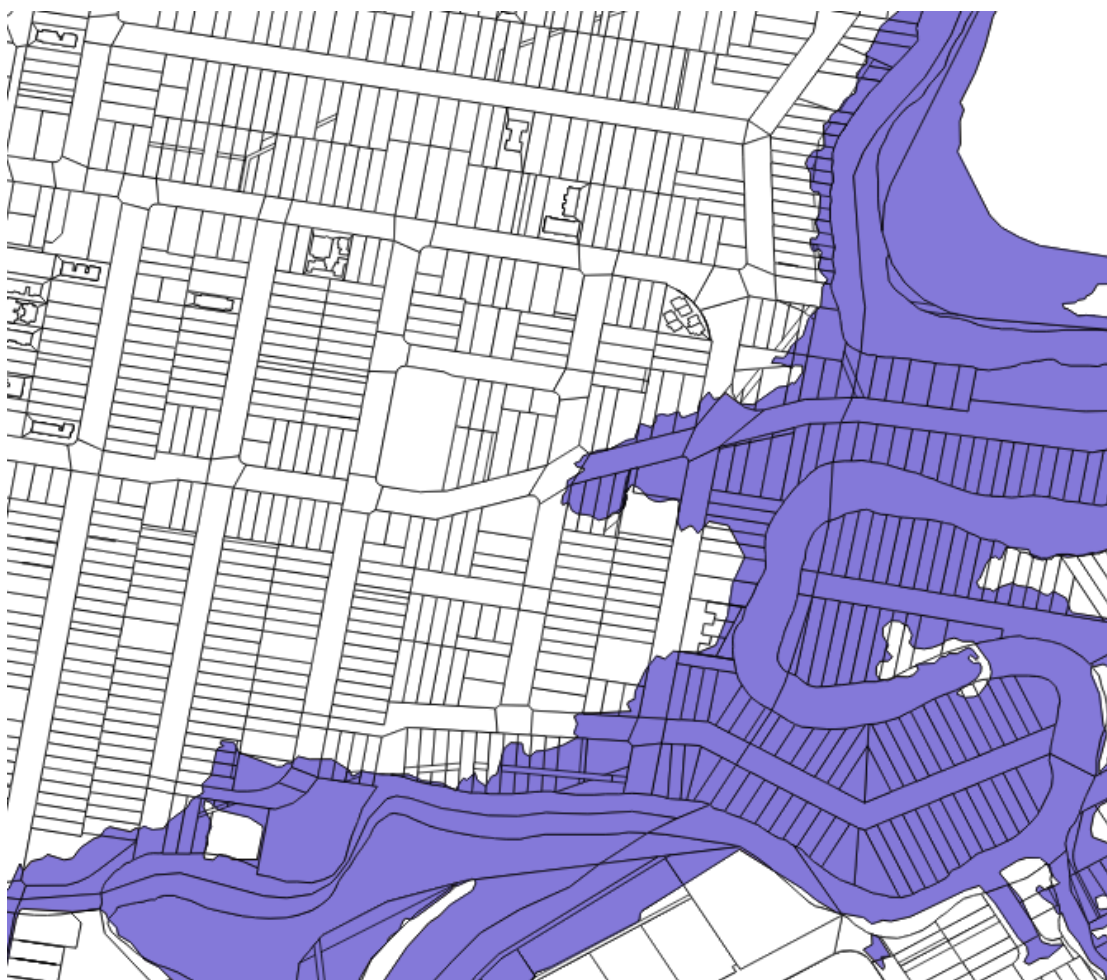


Figure 2. Mean monthly house prices in Brisbane flooded suburbs, January 2007–December 2012.

The two vertical bars refer to the dates of the FloodWise property reports released online and the January 2011 flood.

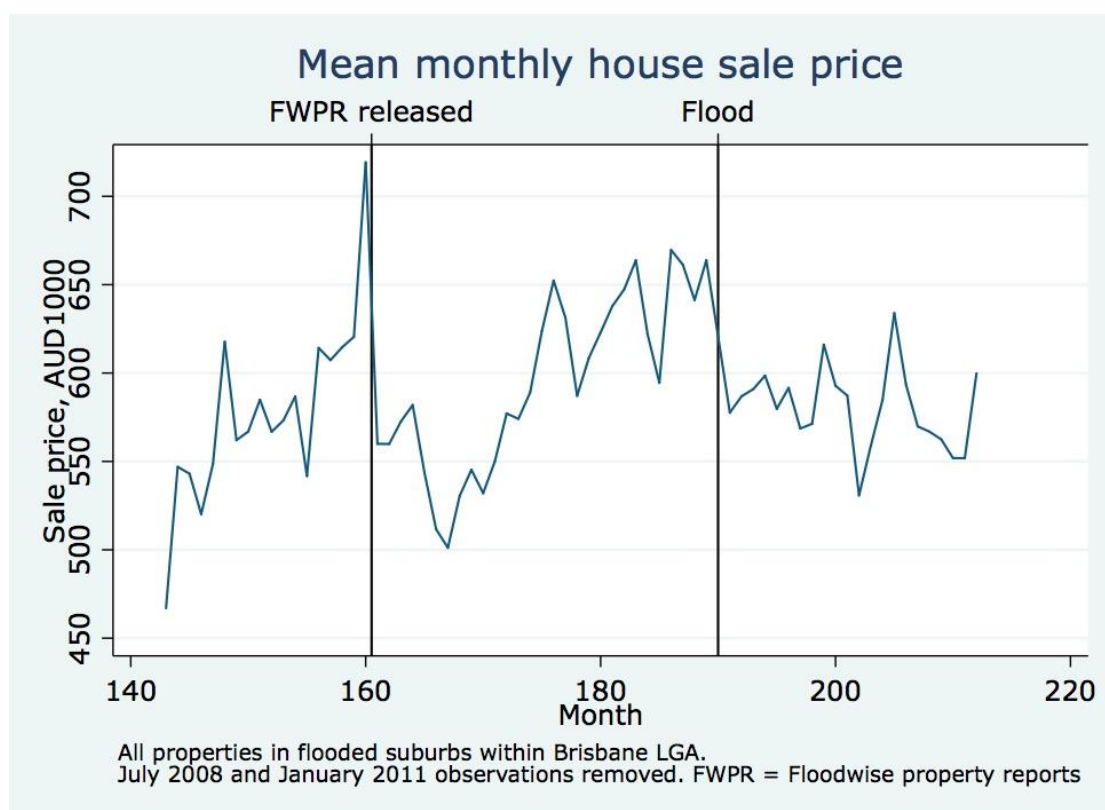


Figure 6. Mean monthly house prices in Brisbane flooded suburbs with properties from the Waterfront development excluded, January 2007–December 2012.

The two vertical bars refer to the dates of the FloodWise property reports released online and the January 2011 flood

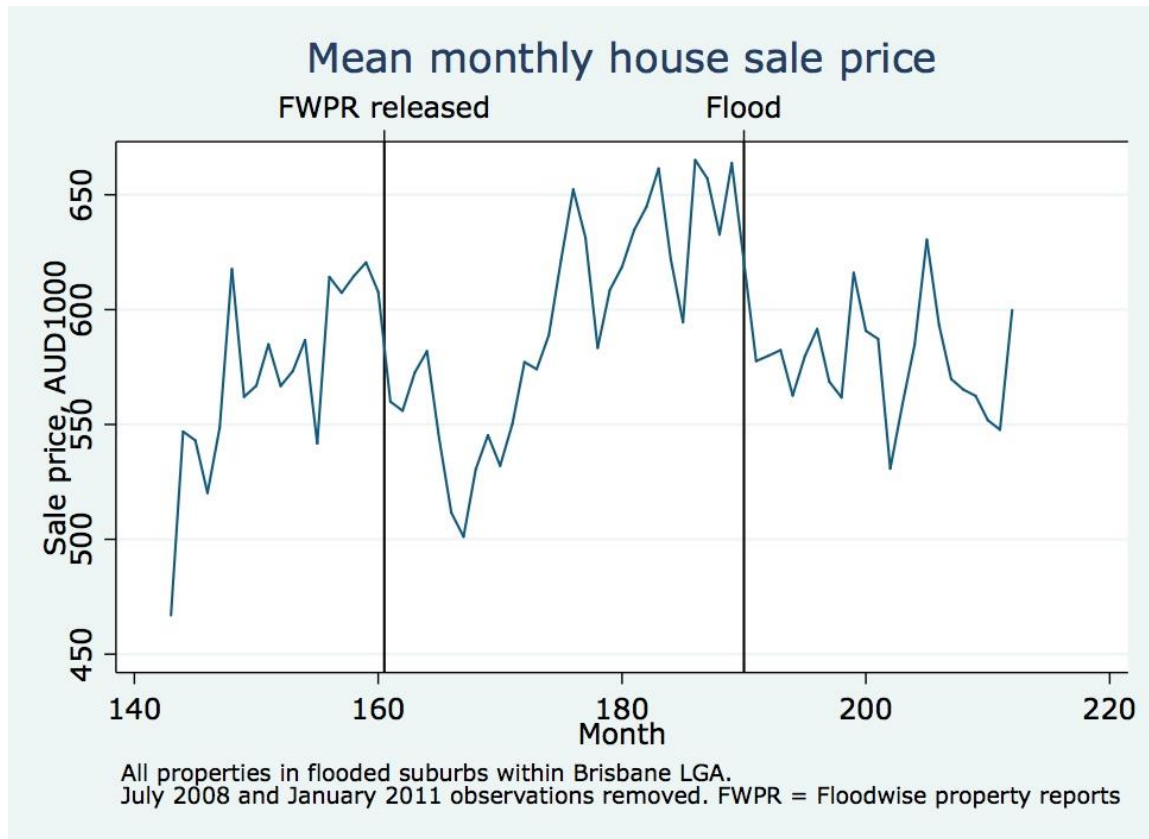


Figure 3. Mean monthly property sale price, demarcated into properties that had a defined flood risk in the FloodWise property report and those that had no risk.

The two vertical bars refer to the dates of the FloodWise property reports being released online and the January 2011 flood

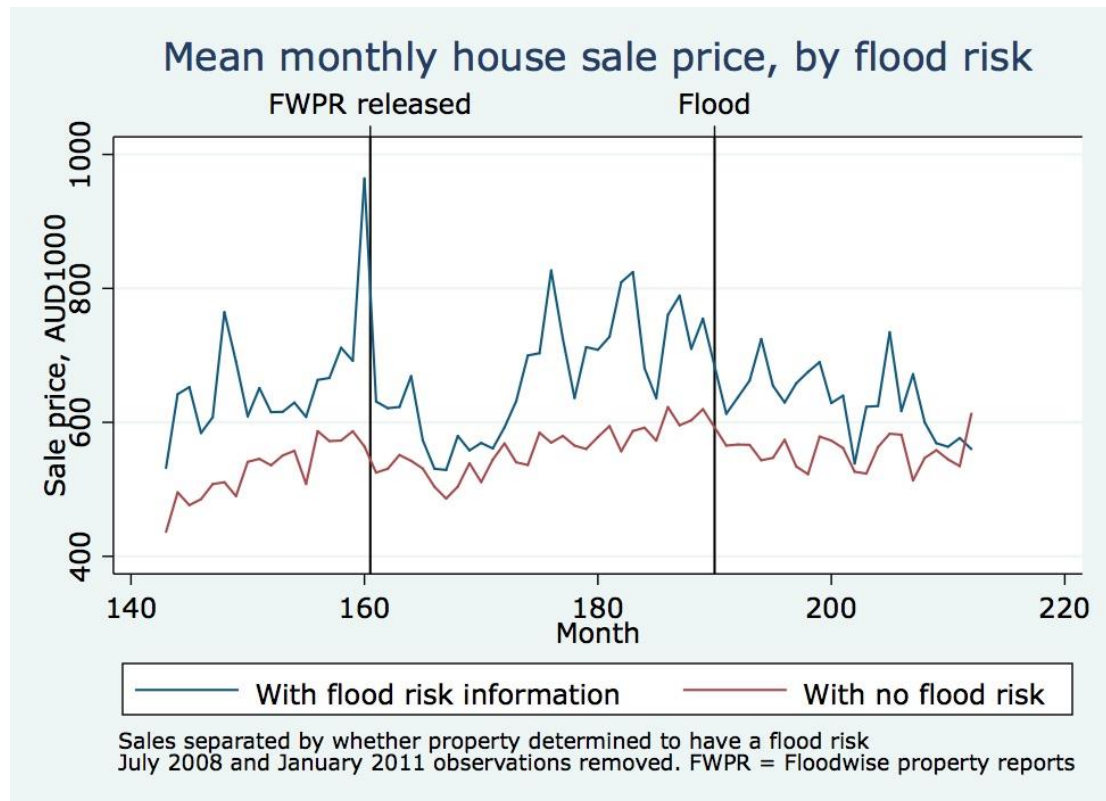
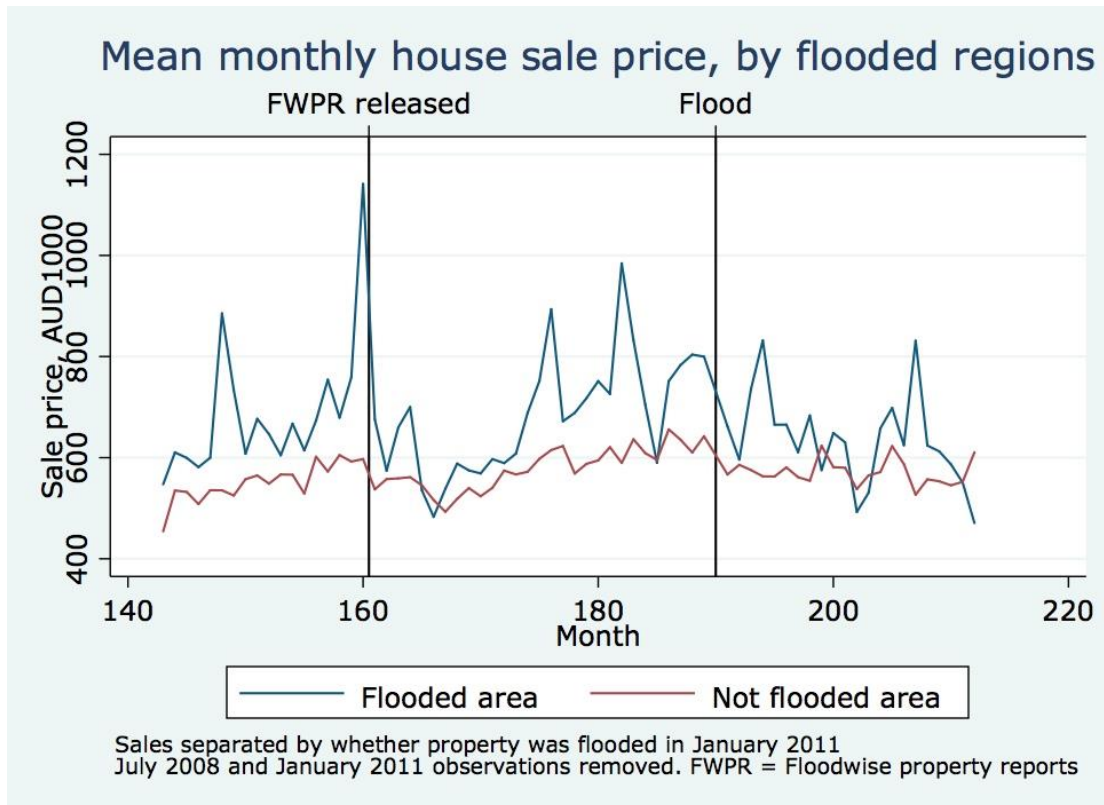


Figure 4. Mean monthly property sale prices for properties in suburbs that were flooded in January 2011, demarcated into the region that was flooded in January 2011 and the region that was not.

The two vertical bars refer to the dates of the floodwise property reports released online and the January 2011 flood.



3.1 Reality testing

In order to test the realism of our results as well as the information on which we relied, we discussed them with the following stakeholders. The list is in no particular order of precedence, and we are most grateful for both the advice provided and the time made available to us. We acknowledge that our interlocutors do not necessarily agree with our views or our results.

- Ray White Real Estate, Indooroopilly, Brisbane
- Doug Disher Real Estate, Toowong, Brisbane
- Herron White Todd, Chermside, Brisbane
- Queensland Reconstruction Authority, Brisbane
- Brisbane City Council
- Suncorp, Brisbane
- Insurance Council of Australia, Sydney
- Department of Climate Change and Energy Efficiency, Canberra

4. AN ECONOMIC PERSPECTIVE ON THE GOVERNMENT'S ROLE IN ADAPTATION TO CLIMATE CHANGE

The analysis in this project is based on general economic perspectives. Expanding the economic perspective on adaptation to include more political considerations such as equity objectives may suggest a greater role for government. Conversely, taking an Ostrom-style polycentric view of society may argue for an even more limited role for government in adaptation, particularly if social networks function well (Osberghaus et al 2010).

The existing literature in the general area of risk management by governments is comparatively thin, with Moss (2002) being a notable exception. This chapter therefore reviews a broad spectrum of the literature that is relevant to managing the more specific emerging risk of climate change. Its key purpose is to identify the most appropriate role for government in the process of adaptation to climate change.

Much of the adaptation literature focusses on concepts such as 'building resilience', 'vulnerability' and 'adaptive capacity', each presumably requiring some degree of government intervention. Generally, such approaches are vaguely defined, lack decision-criteria as to the magnitude and timing of implementation of adaptation measures, or are based on arbitrary and mathematically flawed composite indexes. They are not examined here.

In line with general economic perspectives on adaptation, it has become a commonplace for key policy reviews (e.g. Stern 2006; Garnaut 2008; Productivity Commission 2013) to specify the provision of information on climate change and its attendant risks as a key role for government, principally on the ground of market failure. However, evidence is rarely, if ever, produced to support the implicit assumption that individuals and markets cannot themselves identify and respond to risks associated with future climate change. We therefore conduct an innovative natural experiment in the next chapter of the effect on risk perceptions in the Brisbane property market of government provision of flood risk information, and examine the effect of an actual flood.

We begin the current chapter by outlining the historical evolution of management of risk by governments, especially over the last 150 years or so. Because climate change represents a new era of emerging economic shocks and structural change, it is particularly relevant to ask what basis there might be for government intervention. We therefore examine conventional issues surrounding market failure that are relevant to climate change. This is balanced by a section on government failure, the analogue to market failure, a topic that is typically ignored in studies on adaptation.

Significant uncertainty, and the likely amorphous nature and pervasiveness of climate change have led to a farrago of different approaches and perspectives to analysing adaptation. We present an illustrative selection of publications, but do not review them in detail.

A popular strand of thought is that governments should subsidise insurance premiums, or adopt the role of re-insurer for risks that, like terrorism, would otherwise not be covered by insurance companies on a purely commercial basis. Despite a general level of agreement in the literature that government insurance subsidies are likely to result in moral hazard and other inefficiencies, there is little empirical evidence available on which to base firm conclusions.

Following some disambiguation the term 'insurer of last resort', including by reviewing the function of government as 'lender of last resort' in the financial sector, we distinguish between government acting as 'insurer of first resort' and 'insurer of last resort'.

Finally, we argue that the key role of government acting metaphorically as 'insurer (or adaptor) of last resort' should be to increase as far as possible the options for individuals and organisations to adapt to climate change in an efficient manner. The use of 'real options' in addressing investment in projects or programs under conditions of uncertainty is increasingly recognised. However, the same principle can be applied at an economy-wide level in arguing for comprehensive micro-economic reform and institutional flexibility.

4.1 The evolution of public risk management

Societies have always faced a range of risks, from war and pestilence to extreme weather events and natural catastrophes like earthquakes. But private markets have generally been able to reduce the degree of much of the risk borne by individuals through the pooling (spreading) of risk. Moss (2002, p.33) notes that, as early as 1542, Dutch whalers sold their catch even before setting sail in a form of forward contract to protect themselves against changes in prices, and a futures market for rice had emerged in Japan by the mid seventeenth century. Marine insurance in Europe for many centuries was based on 'bottomry' (a loan or mortgage used to finance a voyage, rather than payment of a premium), ensuring that a merchant who lost their cargo or ship did not need to repay the loan (Bernstein 1996, p. 92).

In the absence of complete private markets, governments have also sought to reduce some risks. An example is the Great Wall, and its predecessors, in China. The Code of Hammurabi specifies that a lord (seignior) whose rented field was flooded or suffered from drought and therefore produced nothing, was entitled to withdraw from the contract without payment (Pritchard 1958, p. 144, clause 48). Clause 35 of Magna Carta (1215 version) reduced commercial risk by specifying uniform weights and measures across the realm, including specifically for wine, ale, corn and cloth (Stephenson & Marcham 1937, p. 120).

Individuals are generally able to reduce risk associated with their activities in one of two ways. Where independent alternatives exist, the nature, timing or location of activities can be diversified. A wheat farmer, for example, may be able to plant several different crops or operate two geographically dispersed properties. Where a sufficiently large number of individuals engage in similar activities, a particular individual may be able to pool, and hence reduce their risk through an intermediary such as an insurance company. For example, insurance against theft of household items can spread risk among the residents of a particular neighbourhood.

Governments are also able to reduce the risk faced by their citizens. A common method of doing so is the setting of standards, allocation of property rights, or the imposition of regulations to govern the behaviour of citizens and their activities. Speed limits for motor vehicles, building standards for dwellings, the banning of fires during hot, dry weather, limits on watering gardens during drought, etc, are examples of a direct regulatory approach to reducing risk faced by the community. The creation of property rights and introduction of tradeable fishing quotas, on the other hand, could be thought of as a market-based approach to reducing the risk of overfishing and the collapse of a commercial fishery.

An alternative means by which governments can influence the degree of risk faced by individual citizens is to reallocate its incidence (i.e. shift the risk) between the parties to a transaction or between participants in an activity. An example is nineteenth century legislation granting limited liability to investors in a joint stock company. Shareholders had previously been liable to creditors up to the full value of all their assets if the company failed. By limiting their liability to the value of the shares, governments shifted part of the risk of investing away from investors to creditors. Consumer protection legislation has shifted risk from consumers to producers and vendors. Social security laws, such as old age pensions, have shifted the risk of impecuniousness from the elderly to taxpayers in general.

As Moss (2002, p. 18) points out, there is a considerable body of literature on risk reduction by government. What is remarkable is the relative paucity of publications about the reallocation of risk. Moss (2002) appears to be virtually the sole and seminal work in the area of overall risk management by government.

Much of the development in the role of government roles as ultimate manager of public risk has occurred since about the middle of the nineteenth century. This process has been paralleled by the evolution of Tort Law in the courts. The landmark English case of *Rylands v Fletcher* [1868; UKHL], for example, established the basis for actions in negligence by allocating full liability to the party that built on their land a reservoir that flooded a neighbour's coal mine. Subsequent decisions have both moderated and extended this principle: in the 'snail in the bottle' case of *Donoghue v Stevenson* [1932, UKHL 100], for example, it was held on appeal that there was a general duty of care by manufacturers for foreseeable events.

Climate change represents a new area of economic shocks and financial risk. The scientific literature indicates that it is likely that heavy rainfall events will be more frequent in the 21st century, that tropical cyclones will be more intense (although there is less certainty about the direction of change in their frequency), and that warm spells or heat waves are very likely to increase in length, frequency and/or intensity (IPCC 2012, p. 13). Some of these changes will result in more frequent or more pronounced, but unpredictable incidence of economic loss from climate-induced events such as flood or fire.

4.2 The economic basis for management of risk by government

A standard textbook justification for government intervention in economic activity is the presence of market failure. The term 'market failure' indicates the inability of a market to itself deliver a Pareto-efficient, socially optimal quantity of production or consumption. Unfortunately, the term 'market failure' is sometimes misused to convey a sense of dissatisfaction with market outcomes because the market is perceived to not deliver some desired good or service. This misinterpretation can lead to unjustified calls for government intervention.

In the absence of clearly defined property rights that permit bargaining between the parties involved, externalities can be a source of market failure. Public goods which are 'non-excludable' and 'non-rival' (e.g. National Defence), principal-agent problems, and non-competitive markets are other sources of potential market failure. Where the parties to a transaction have different degrees of knowledge about the nature and implications of the transaction (asymmetric information), market failure can occur through 'adverse selection', 'moral hazard', or both.

Famously portrayed by Akerlof (1970)⁸ in the context of the sale and purchase of 'lemon' automobiles, adverse selection can result in fewer trades than would otherwise be the case, so that community welfare is reduced. Adverse selection arises because buyers and sellers possess different amounts of information about a used car. Buyers in particular will only be willing to pay a lower price than that sought by the seller unless they are made fully aware by the seller of any defects that the car may have.

Adverse selection is also a common feature of markets that involve risk. If an insurer, for example, provides life insurance to everyone for the same premium, people with life-threatening conditions are more likely to take out policies, while healthy individuals will be less inclined to do so. The higher number of payouts relative to premiums will drive up future premiums, so that even fewer healthy people will take out the life insurance policy, thus further increasing the loss (relative to premiums) suffered by the insurer, until premiums become prohibitively expensive, or the insurer ceases trading.

The purchase or construction of dwellings in flood zones may have constituted a form of adverse selection, if local governments were aware of the risk, but buyers were not. Without information about flood risk, buyers would have been more prepared to buy in flood zones than would otherwise have been the case. A key lesson for adaptation policy is therefore that provision of quality information by governments will increase the likelihood of efficient adaptation by individuals because they will either avoid risky situations or take mitigative action like building houses higher than expected flood levels.

A case can be made for government intervention, for example, at state or federal level, to ensure that publication of flood risk information is made compulsory for local government. House prices that better reflect risk will lead to socially more desirable outcomes, although they may reduce the financial ability of existing homeowners to adapt by moving out of flood zones. However, councils in Queensland may have been reluctant to publish flood maps for fear of legal liability, including for reduced house prices in the area (Queensland Floods Commission of Inquiry 2012, pp. 128-132). But DEFRA (2011, p.19) notes that the provision of flood datasets for free to the public 'could have a negative impact on private companies who specialise in producing and selling flood risk information'. In this regard it is worth noting that the claim that the only nation-wide database on properties subject to flooding (the National Flood Information Database) was created by the general insurance industry (Insurance Council of Australia 2011, p. 7).

Moral hazard generally refers to a situation where someone's downside (negative) risk has been reduced and they compensate by lowering their own implementation of mitigative actions. In an insurance context, an example might be someone with flood insurance who feels secure in the knowledge that any damage to the contents of the house will be recouped from the insurance company and subsequently does not take as much care as they would otherwise have done to place valuable furniture above likely flood height during a likely inundation event (Zeckhauser 1995). On the other hand, Demsetz (1969, p. 7) queries the presumed negative influence of moral hazard on insurance markets, pointing out that the additional cost involved from such behaviour would be treated by an insurance company as a straightforward cost of doing business and therefore taken into account in setting premiums.

⁸ In a detailed empirical study of sales of used cars, Tadelis & Zettelmeyer (2011) demonstrate that provision of information about a vehicle's condition and the estimated cost of any repairs, resulted in both increased prices and a higher probability of a sale taking place

An example of behaviour that appears to have reflected moral hazard is given by Suncorp Group (2011, p. 13) about the construction of protective flood levees:

'It is worth stressing, however, that levees and dams do not eliminate the risk entirely. In particular, ... the maintenance of levees is critical in determining the level of risk reduction they provide. Unfortunately, ... Suncorp has come across a number of examples where poorly maintained levees are likely to be ineffective in a flooding event e.g. where a gap has been carved into the levee. From Suncorp's perspective it is both unacceptable and unsustainable for insurance to be expected to pick up risk that should have been mitigated in such a way.'

It might also be argued that this example also involves a market failure due to a principal-agent problem. The government agency responsible for the construction of the levee was not faced with an appropriate incentive to maintain it on behalf of its principals, members of the community who live in the flood zone. A further compounding factor may be capacity or budgetary constraints on the part of local councils, two potential barriers to adaptation that were identified by the Productivity Commission (2013, p. 16).

Moss (2002, pp. 11–12, 39–52) argues that adverse selection and moral hazard are not the only factors that may lead to failure in markets for allocating and distributing risk. Misperception of risk of death or injury in hazardous professions such as the defence forces may be just as important in preventing the efficient functioning of insurance markets. It was because of such misperceptions that legislative requirements were imposed on employers to insure their employees against on-the-job accidents. A key justification is that someone other than the individual worker is able to make a more rational evaluation of the risk involved. Optimism bias, reliance on heuristics to simplify situations involving complex probability, the framing of an issue or problem, and a recent experience or memory can also result in misperception of risk, as demonstrated in the work of Kahneman & Tversky (1979, 1981).

Although more research is required, it is likely that misperception regarding flood risk can occur. Reviewing experience in Australia, Canada, the USA and New Zealand, Yeo (2003) concludes that property values have been found to both rise and fall after floods, and that the evidence is similarly contradictory when areas have been designated as floodplains. However, the evidence is far from conclusive because the studies reviewed were undertaken for different reasons and used different data and definitions. Using studies of flooding in Cologne and drought in Zimbabwe, Grothmann & Patt (2005), for example, argue that adaptive responses depend heavily perceptions of the ability to adapt, as well as on perceptions of the need to do so. Our own research (Chapter 4) appears to indicate that people are in fact aware of flood risk.

As well as perception problems in private markets, Moss (2002, pp. 45–47, 306–309) contends that 'commitment problems' can require government intervention in private markets. For example, young people have few financial assets but bountiful human capital, while the elderly tend to hold the reverse portfolio. Because the elderly face the risk of losing their financial assets without the opportunity to make good the loss with their human capital, they would gain from trading some of their existing financial assets for (future) earnings by the young. Except in the case of slavery, such markets do not exist, and governments have been forced to introduce old age pensions and other social security schemes. Chapman (2006) devised a solution to an analogous problem in the form of income-contingent student loans sponsored by the Australian government, while Dobes & Chapman (2011) have proposed a mortgage-contingent loan scheme for elderly victims of storm surge and coastal erosion.

Moss (2002, pp. 46-47) further argues that it is not possible for the private sector to commit future generations to risk-sharing arrangements implemented in the present, so that a government role, through legislation, is required. It is not explained, however, how this could be achieved in practice. In Australia at least, Parliament cannot bind future parliaments. Laws (and even constitutions) can be changed, so that current legislation would be of little use in seeking to bind future generations.

An important rationale for government to address market failure is that of internalising externalities. An example of an externality that might arise due to climate change is that householders install noisy air conditioners in response to higher temperatures, whether the air conditioners are privately financed or subsidised by government (e.g. for the vulnerable elderly). Similarly, beach defences against storm surge and erosion by owners of beachside residences are likely to deny free access to the general public. In the case of private beaches, the opposite situation can also occur if the beachfront is extended by natural processes or by mechanical sand nourishment. The United States Supreme Court ruled in 2010 that a sudden and significant accretion in beachfront land belonged to the State of Florida as owner of the seabed, rather than the littoral property owners, so that the public now had access to the previously private seashore (<http://www.supremecourt.gov/opinions/09pdf/08-1151.pdf>).

In the case of noise, various alternatives exist to ameliorate any negative effect on neighbouring residences. A noise tax could reduce the problem by reducing the number of air conditioners installed, but would defeat the purpose and intent of adaptation to increased temperatures. Alternatively, the government could define property rights to peace and quiet, leaving neighbours to bargain about ways of reducing noise. Barriers erected around air conditioners, for example, might reduce the noise to some extent. Another approach might be to reduce legal barriers (government failure) to reducing noise: in the ACT for example, air conditioners cannot be mounted on the roof facing the street where noise would presumably be less intrusive, so necessarily face neighbouring properties at the back or sides.

A final but critical consideration that is generally ignored or omitted in discussion of potential government roles in adaptation is that the community as a whole should benefit from any intervention by government. That is, a cost-benefit analysis that takes into account all social costs and social benefits, including the value of quasi-options, should demonstrate that a proposed intervention is likely to be worthwhile. It is instructive that, out of about 10 pages devoted to discussion of reform priorities, the Productivity Commission (2013, pp. 13–23) makes this point explicitly at least four times.

4.3 Government failure

Although intervention in the economy by government is commonly justified (Zerbe & McCurdy 1999, pp. 559-561) by academic economists on the basis of market failure, it is not necessarily the case that such interventions will improve economic efficiency. A key problem is that market failure is in reality ubiquitous because of the way that it is defined. In the real world, markets inevitably involve transaction costs. It follows that the classical assumptions about costless transactions and costless access to information by buyers and sellers cannot hold. As Zerbe & McCurdy (1999, p. 561) note, Coase (1937) posited the now well-known concept that firms exist because they can reduce the transaction costs faced by individual entrepreneurs.

Where market failure is defined as a departure from an ideal optimum of costless transactions, it follows that its manifestation is inevitable in the real world whenever trades between economic actors are precluded or reduced. Demsetz (1969)

characterises this methodology for defining market failure as the 'nirvana' approach. The question then becomes whether government or the private sector can provide goods and services at lower transaction costs, a question that can only be resolved empirically through detailed cost-benefit analysis of alternative institutional arrangements. Unfortunately, there is no relevant normative theory of market and government failure that can answer the question of which system is more efficient.

Zerbe & McCurdy (1999) further draw attention to the need for empirical evidence, highlighting several classic textbook cases that have been wrongly presented as externalities requiring government intervention. Perhaps the best known example is that of the lighthouse. In his classic textbook on economics, Samuelson (1967, pp. 151–152) states that it would not be commercially feasible for a private individual to build and operate a lighthouse because it is not possible to collect fees from passing ships, so that this 'public good' is better provided by the state. However, Coase (1974) demonstrated that a series of writers from John Stuart Mill onwards were ignorant of the fact that lighthouse services were in fact privately provided in Britain until the nineteenth century, so that the ostensible market failure was merely a myth.

The lighthouse example is not the only unsubstantiated anecdote to have gained currency among academic economists and policy makers. Spulber (2002) presents an anthology of another dozen. Apple growers were said by various economic economists to benefit freely from pollination services obtained from bees, and beekeepers were seen as benefitting without payment for the nectar produced from apple orchards. However, Cheung (1973) showed that beekeepers in fact provided pollination services to orchardists on a contractual basis, as evidenced by the yellow pages telephone book in some cities. Liebowitz & Margolis (1990) debunked the popular market failure myth that path dependence ensures that the QWERTY keyboard persists despite being technically inferior to the Dvorak configuration. A similar myth is 'busted' when Liebowitz and Margolis (1999) examine the alleged market failure of the consumer-preferred VHS videorecorder outperforming its allegedly technically-superior Betamax competitor.

Myths, urban or otherwise, are not restricted to academic economists. Unfortunately, the replication by government agencies of anecdotal material can also foster the popular acceptance of unsubstantiated claims of the need for government intervention, possibly at the expense of economic efficiency.

At one time, the official website of the Australian Department of Climate Change included a statement to the effect that 'early planning for the impacts of climate change is likely to bring considerable advantages. Many decisions made today will have consequences for decades. *It is cheaper, for example, to design new housing or infrastructure to cope with a future climate than to retrofit later.*' (<http://www.greenhouse.gov.au/impacts/howtoadapt/indexs.html>; viewed 6 July 2008, emphasis added). This view does not appear to have been based on any study or evidence, and ostensibly ignores the difference between present and future values. Given the significant uncertainties associated with the potential impacts of any future climate change, especially localised differences, it is not clear how such a general claim could be justified. Had a nation-wide policy been implemented without evidence, it is likely that significant and unnecessary social costs would have been incurred, over and above any corresponding benefits.

It is thus necessary to demonstrate genuine market failure, as well as net social benefits, to justify government intervention, but this is not a sufficient condition. Justification for intervention also requires an empirical investigation of the social costs and benefits of alternative institutional arrangements, including the market itself.

Pointing out that *'the theoretical benchmark of Pareto optimality could be used to assess government performance just as it is used to assess market performance'*, Winston (2006, p. 3) conducts an empirical review of scholarly assessments of (American) federal policies that were intended to 'enhance microeconomic efficiency' (p. 10). Acknowledging the possibility of publication bias, he concludes (p. 11) that his assessment of the empirical evidence *'reveals a surprising degree of consensus about the paucity of major policy success in correcting a market failure efficiently'*.

Whether Australian policy makers have been more successful than their American counterparts is a moot point, despite the significant microeconomic reforms of the late 1980s. Massy (2011) analyses in detail the folly of statutory intervention that culminated in the collapse of the Australian Wool Corporation's reserve price scheme. In its review of the Australian Government's National Drought Policy, the Productivity Commission (2009, p. xx) concludes that subsidies and relief payments to farmers are ineffective and 'can perversely encourage poor management practices', especially by those 'least prepared to manage climate variability' (p. xxviii). Other examples of ineffectual and inefficient government intervention abound, despite the best intentions of policy makers.

Direct participation in markets by government entities can also 'crowd out' private investment: Australia Post, for example, still holds a monopoly in areas that could readily be served by private enterprise. Framers of statutes may need to compromise efficiency considerations for political reasons, or may be unduly influenced by particularly vocal rent-seeking vested interests ('stakeholders') or the perceived needs of 'marginal seat' constituents. Regulatory capture can derail even the best-framed industry oversight, and lack of adequate control can result in unintended consequences, as with the ill-fated home insulation scheme that was aborted in 2010.

An example of government potentially 'crowding out' investment in adaptation by individual property owners is the voluntary buy-back scheme for residential properties subject to frequent creek and other local flooding by Brisbane City Council (2011). Owners of properties along the Brisbane River have recently begun building modern versions of old-style 'Queenslander' houses on stilts. As of June 2012, over 140 homes had been raised since the January 2011 floods (Moore, 2012). Any additional cost is presumably outweighed by the utility gained from living near the water⁹, an option that would be precluded by compulsory property acquisition or building regulations. However, non-riverside 'creek' properties acquired by the Council under its buy-back scheme are converted into non-residential uses such as parks and drainage easements, making them unavailable for potential use by purchasers willing to adapt to local flooding.

Adaptation measures by government can also result in maladaptation, including the creation of unintended negative externalities. Macintosh (2012) investigates in detail the maladaptation due to misconceived 'climate change' planning regulations in Victoria. In their study of flood responses in Norway, Naess et al (2005) report that local government construction of dikes, under pressure from vested interests, to fix short-term problems resulted in damage to fish spawning grounds as well as removal of vegetation favoured by birds.

⁹ Carey (2011) reported that 'residents in flood-prone parts of Brisbane [before the flood] have largely ignored an opportunity to sell their properties to the local council', but it is not clear if this was because prices offered were considered too low, or owners were simply not prepared to move from what they considered to be an attractive location. Budgetary limits may also have limited the rate of take-up.

Even government competition policy can impede adaptation. In 2008, the Insurance Council of Australia (IAC) sought authorisation from the Australian Competition and Consumer Commission (ACCC) that would permit insurance companies to offer flood insurance based on a common (but not necessarily uniform) definition of the term 'flood'. The application was rejected, principally because of objections by consumer groups, that the proposed, broader definition (which would have removed the distinction between natural and man-made flooding) would confuse consumers. Somewhat speciously, the ACCC also determined that rejection of the IAC proposal would not matter because 'the broader reform agenda' then being discussed by 'governments and the insurance industry' would resolve the issue (ACCC Determination 2008, p.15). It is ironic that the insurance industry was criticised after the January 2011 Queensland floods (e.g. ABC News, 14 February 2011) for not having a common definition of 'flood' to make it easier for consumers to comprehend insurance policy terms, rather than responsibility being attributed to a government agency in the form of the ACCC or to consumer groups.

Use of popular analytical approaches such as multi-criteria analysis and various composite indexes that emphasise criteria of concern to decision-makers rather than those of consumers can compound problems. If governments are to intervene in adaptation measures, then it is essential that they identify the priorities and preferences particular to local consumers and residents. Only by conducting rigorous cost-benefit analysis can social well-being be maintained (Dobes & Bennett 2009; Productivity Commission 2013).

Regular provision of government disaster relief (essentially ex post insurance) can potentially result in an expectation that it will always be provided, thereby discouraging private risk spreading through insurance. At a Press Conference during her visit to the site of the Coonabarabran bushfires, Prime Minister Gillard (2013) stressed that AGDRP payments to victims were not intended as substitutes for private insurance cover, stating that 'people should be insured'. The phenomenon is sometimes known as 'Samaritan's Dilemma' or 'charity hazard' (Raschky & Weck-Hannemann 2007), a form of moral hazard. On the other hand, the Australian Local Government Association (ALGA 2011, p. 7) has claimed that its member councils had advised it that their 'decisions on the level and type of [insurance] cover have not been influenced by the availability of disaster relief provided by states/territories'.

While much evidence is necessarily anecdotal, Boon et al. (2012) and Clark et al (2012) also report an apparently growing expectation of government assistance¹⁰, noted in connection with the 2009 'double flood' in Ingham, and Cyclone Larry in Innisfail in 2006. One anecdote recounted by Clark et al (2012, p. 416) was the delivery of dog food by helicopter to an Innisfail resident, as well as residents of nearby *'Bambaroo wanting to get the chopper there ... but they could actually turn around and drive to Townsville ...'*

Finally, institutional rigidity can reduce the effectiveness of government intervention, or increase its social cost. The post-Hurricane Katrina experience in the United States is well documented. Because of its internal procedures and protocols, the Federal Emergency Management Agency took a number of counterproductive initiatives that worsened the situation in New Orleans. The Red Cross was denied access to the city, hospital supplies and other relief goods were confiscated by FEMA and never reached those in need. Successful assistance was provided only by organisations that ignored FEMA or flouted its decision-making processes (Sobel & Leeson 2006, p. 57).

¹⁰ A similar observation was made during our discussion with the Queensland Reconstruction Authority in March 2013.

Walmart, on the other hand, had, on commercial grounds, deliberately stocked its stores with bottled water before the hurricane struck. It was able to supply local residents even though official supplies did not reach the city for days after the disaster.

Dobes et al (2012, p. 18) report an institutional rigidity not directly related to emergency services that nevertheless diminishes the potential for post-disaster assistance. Restoration of power is considered to be a high post-cyclone priority by Cairns residents, but out-of-state emergency workers were not qualified to assist after cyclone Yasi because they did not possess the requisite Queensland electricity trade certificates. Mutual recognition of certification of basic trades by the states would not only assist during post-disaster situations, but would have more general economic benefits by increasing the mobility of skilled labour across Australia.

4.4 Formulating policy in the face of uncertainty and the amorphous and pervasive nature of climate change

Economists have been able to successfully formulate policy responses for reducing emissions (mitigation) by drawing on a long history of relevant economic theory. Notwithstanding considerable debate, including at the political level, the key approaches proposed were carbon pricing and its close relative of trading a fixed quantum of emissions. The task was made easier because scientists nominated specific greenhouse gases whose increased atmospheric concentrations are considered to cause climatic change.

No comparably straightforward approach has emerged in the literature on adaptation to climate change. The effects of climate change will differ between even proximate geographical areas. Nor is it possible to forecast with any accuracy the localised timing, intensity or frequency of the effects of climate change, or even the number of people affected. Unlike mitigation, a public good on a global scale, adaptation may be a private good or a public good. Further, the amorphous and pervasive nature of climate change means that there is no common quality that captures the essence of 'adaptation' activity.

Unsurprisingly, a farrago of perspectives exists; invariably reflecting the special interests or conceptual frames of the proponents. Preston (2010) advocates regulation combined with judicial review, while McDonald (2010, pp. 257) raises the possibility of increased uncertainty arising from tort litigation due to different geographical circumstances. Insurers are paying increasing attention to extreme events and new forms of reducing their exposure to them (e.g. Kunreuther & Michel-Kerjan, 2009). Planners and engineers tend to look to the presumed safety of increased standards (e.g. Standards Australia/Standards New Zealand 2009) and tighter design guidelines (e.g. Engineers Australia 2004; Royal Academy of Engineering 2011). Prioritised fortification of infrastructure is espoused by du Vair et al (2002). Julia & Duchin (2007) consider world trade to offer an efficient adjustment mechanism for agricultural outputs, and Mendelsohn (2006) takes a similar position for traded goods more generally. Hallegatte et al (2007) draw on mean rainfall and temperatures in 17 European cities as analogues of a future climate and its economic impact on Paris. Historians have also sought to draw on cases such as the abandonment of Viking settlements in Greenland (Orlove 2005) and Van der Eng (2010) shows that well-functioning regional rice markets in Java in the 1930s ameliorated the effects of drought. Petheram et al (2010) remind us that knowledge held by indigenous peoples may provide useful lessons for adaptation. Woodruff et al (2006) appear to favour early action to avoid health hazards of climate change, while proponents of 'clumsy muddling through' like Verweij & Thompson (2006) would probably prefer to hasten slowly in the face of 'wicked problems' such as climate change. Finally, Butzengeiger-Geyer et al (2011)

review market mechanisms that have been advocated for mitigation, with a view to applying them to adaptation, although they concede that it would first be necessary to define a 'unit' of adaptation.

The range of assumptions made and perspectives taken reflect the fact that there is deep uncertainty about the likely effects of climate change. Analysts and policy-makers have therefore been reduced to generalising and extrapolating case studies based on changes in single variables or circumstances: for example, the effect of lower rainfall, or the effect in a specific region of higher temperatures. The analytical complexity of examining the myriad possible scenarios of combinations and interactions of different climatic effects naturally precludes policy formulation regarding essentially unpredictable conditions.

Our approach in this report is therefore designed to identify a role for government that is not grounded in unrealistic assumptions and scenarios based solely on the world as we know it today.

4.5 What issues will need to be addressed in terms of adaptation to climate change?

In considering the role that government should play in adaptation to climate change, it is important to identify the issues and impacts that it would need to address.

The number of adaptation measures that may need to be taken by the inhabitants of any country is potentially limitless because of the different combinations of impacts and geographic areas that might occur. Local differences in temperature (minimum, maximum, night-time, daytime, etc), evaporation, rainfall, sea level rise, extreme weather events, humidity, population, available technology, etc, can result in many different climate scenarios over time. An overlay of the cascade of uncertainty in predicting the timing of climate change impacts, as well as their frequency and intensity make planning of adaptation measures as unrealistic as attempts by centrally planned economies to exercise detailed control of economic activity, as the Soviet command economy showed.

It would be pointless to attempt a detailed list of adaptation measures that will need to be taken by society, either by the private sector or the public sector. However, Stokes & Howden (2010) present a compendium of studies of current Australian agricultural outputs from the perspective of adaptation to past climate variability and potential climate change. The vicissitudes of climatic variability have been particularly challenging for the Australian agricultural sector, so its responses and continuing needs are likely to provide some indication of the need for government to act as an insurer of first or last resort.

The major effects of climate change that are common to most agricultural outputs are carbon dioxide fertilisation for C₃ plants, increased heat and water stress, and changes or increases in pests and weeds. Except perhaps for increased carbon dioxide fertilisation (a general benefit, although there are exceptions), farmers have in the past adapted to extremes in heat, pests and precipitation in the following ways:

- changed seasonal planting schedules to match changes in temperatures and soil moisture, including the use of specialised software tools;
- switching to different crops and/or livestock, or some combination that reduces risk through diversification;
- sequential sowing in the absence of expected rain or water availability;

- adjusting the size of the crop sown to match expected rainfall and soil moisture;
- more efficient management of water resources, including investment in technology such as drip irrigation. In the case of rice in the Riverina, drill sowing, rather than aerial sowing into flooded bays has not only reduced water requirements, but has also reduced damage to seedlings by ducks;
- greater spacing between plants (or less livestock per area), to conserve water;
- extended fallow periods and stubble retention to conserve soil moisture;
- re-location of farms to adjust to changing conditions;
- breeding of new strains and cultivars;
- planting of shade trees, especially for livestock;
- agistment of livestock as an option during localised drought;
- in the case of forestry, increased spacing and thinning to reduce water stress, better fire management, and planting of climatically suitable species.

Contributors to the Stokes & Howden (2010) volume also called for greater government provision of research and development funding, collection and dissemination of knowledge from farmers in marginal areas on practical approaches to climatic adaptation. Recommendations for the use of economic instruments was more the exception than the rule, save for the chapter on cotton where water trading is suggested as an adaptation measure (p. 61), and suggested modification of Federal and state drought assistance schemes to encourage adaptation (p. 163).

Indeed, the volume as a whole appears to start from the implicit premise that current Australian agricultural production patterns need to be maintained in the face of climate change. Because social costs and benefits are not included as part of the analysis, the option to abandon at least some aspects of current production patterns is not subjected to rigorous evaluation. Nor are any of the chapters devoted to specific new crops that could be substituted for current production patterns.

Most striking, however, is that there appears to be little scope or need for government to act as an insurer of first or last resort. Australian farmers have historically adapted to climatic variability and uncertainty. There is no reason why they should not continue to do so, with government assistance focused on funding research and development and the provision of information where justified by cost-benefit analysis.

Construction of sea walls or migration to higher ground are standard examples used to illustrate adaptation possibilities. In contrast to the detailed study by Stokes and Howden (2010) of the specific impacts of climate change and potential adaptation measures, however, most of the literature on adaptation strategies is not particularly specific. Articles on resilience and adaptive capacity invariably resort to methodologically flawed composite indexes (Dobes & Bennett 2009; Cox 2009, Fuessel 2009; Pollitt 2010), and rarely propose any but the most obvious measures. This lack of specificity is understandable because of the uncertainties attached to timing, intensity and frequency of localised climate change impacts.

Some commentators assume implicitly that the impacts of climate change will manifest themselves primarily as catastrophic events, one of the reasons for much of the focus on measures based on insurance (e.g. World Bank 2010). Unfortunately, there is no satisfactory theory of catastrophes so that it is not clear a priori what government's role should be. According to Yezer (2000, p. 1), the academic 'literature is thin, [but] it includes a surprising diversity of theoretical models and empirical results'.

Nevertheless, it is likely that responses to catastrophic events will continue to be driven by political imperatives. Drawing on survey data, Healy & Malhotra (2009) found that American 'voters reward the incumbent presidential party for delivering disaster relief spending, but not for investing in disaster preparedness'. On the other hand, one outcome of the inquiry into the 2009 Victorian bushfires has been discussion of the concept of 'shared responsibility' between government, emergency services agencies, communities and individuals for minimising the risk of disasters. The term is also to be found in the February 2011 adoption by the Council for Australian Governments (2012) of the National Strategy for Disaster Resilience.

The term 'shared responsibility' is not well defined and a 2012 workshop demonstrated that its implications for policy and practice are unclear even to the emergency services community (McLennan et al., 2012). It is possible that it is intended to mean that risk for specific aspects of disaster scenarios should be assumed by the party best placed to deal with it, effectively the principle of subsidiarity.

What future role will be played by government in adaptation is as uncertain as the climate itself. However, we have assumed below that government will continue to play a role in at least adapting to climate change in areas where it provides services to the public, including particularly infrastructure, health, and education. Normal political pressures are also likely to mean that government will be engaged in areas subject to interest group pressure, like agriculture and manufacturing, as well as in disaster assistance. In other words, even if adaptation is feasible without government assistance, governments will continue to be involved in some way.

4.6 Insurance and climate change

Insurance is often seen as one means of offsetting damage incurred from the impacts of climate change. The global private insurance industry is heavily exposed to weather-related disasters. The weather-dependent share of global insured catastrophe losses has been estimated at around 90 per cent (Mills 2005). Jaffee & Russell (1997) and Kunreuther & Michel-Kerjan (2009) provide a useful overview of weather-related insurance.

It has been hypothesized that if weather-related disasters increase as a result of climate change, insurers might retreat and shift risk management functions to governments and individuals (Mills 2005). Furthermore, the practicalities of present-day insurance schemes do not engender much confidence in the long-term viability of such an approach in terms of adaptation to climate change.

Ordinary vanilla-flavour insurance normally involves a simple pooling of risk. In return for annual premiums, policyholders may be compensated from the premiums paid by all those in the pool if an adverse event occurs: insurance is thus an example of a financial put option purchased by policyholders. If the value of losses claimed against the insurance company exceeds the premiums paid to it, the insurance company may become insolvent (e.g. in the case of a major disaster), or will raise premiums. Insurance companies can also spread their risk by pooling with other insurance companies as part of a national or multi-national re-insurance scheme.

Efficient insurance systems require the pooling of risk for uncorrelated events, with perfect information about the risks available to both insurers and the insured. In practice, asymmetric information can generate adverse selection and moral hazard. In an adaptation context, an example of adverse selection might be the purchase of flood insurance by the owner of a property at risk, but where the insurer is not fully aware of the risk or cannot reflect it in premiums. Where compulsory insurance is imposed by

governments to reduce adverse selection in potential disaster situations, compulsion may diminish the ability to reduce risk through aggregation: declaration of an event as a disaster involves highly correlated losses in the insured pool.

An owner who obtains insurance may rely on the availability of compensation for flood damage and neglect to take action to limit that damage, a case of 'moral hazard' that is generally obviated by insurers imposing 'deductibles', coinsurance or coverage exclusions that force the insured party to bear the cost of some proportion of any damage (Priest 1996). These problems will be compounded if climate change increases the number of correlated risks, with likely increases in insurance premiums.

Adverse selection and moral hazard are common issues facing insurers and re-insurers. In the case of climate change, two further problems are likely to limit the feasibility of insurance. Widespread effects such as higher temperatures may cause drought so that crops fail, as well as having negative health effects for those susceptible to heat waves. If temperatures rise across the globe, the impacts will be similar, so that risks will be correlated, rather than independent, negating the benefits of pooling risk. Even with global re-insurance, insurance schemes may not be entirely viable.

Index, group or parametric insurance offers a partial solution to correlated risk because a defined geographic area is insured on the basis of exceeding or falling below a given parameter. For example, farmers in a particular region may receive insurance payouts if seasonal rainfall is less than a pre-specified amount. Because the result is easily observable the scheme has low administrative costs, but those farming moister bottom land may in fact produce a crop, and obtain an insurance payout, while those in drier areas only receive the insurance payout. Index insurance largely avoids problems of adverse selection and moral hazard but has generally been applied only in the agricultural sector where a unique variable or parameter such as rainfall can be used to proxy an outcome such as yield per hectare. It could potentially be applied to disaster situations where there is correlated risk across a group or area, provided that a unique, easily measured index or parameter could be specified.

Another issue that is likely to arise in the future is the response to slow onset climate change. If it becomes clear that temperatures or sea levels will continue to rise in the future, then some risks will become certain at given points in time. Where there is foreknowledge of a risk or impact, the principle of fortuity is broken and insurance is generally not offered. For example, insurers will generally not insure a pre-existing medical condition for health or life insurance. A beachside resident in danger of coastal erosion or storm surge would similarly be unlikely to obtain insurance once it became clear that their house was subject to imminent threat.

Disaster or catastrophe insurance, on the other hand, generally involves low frequency but high cost damage events. Unless an insurer has large capital reserves, it is possible that they will not be able to meet all claims made because the risk is correlated with virtually all residents of a given geographic area being affected. Barnett (1999, p. 149), for example, reports that 'nine property and casualty insurance companies became insolvent after Hurricane Andrew [Florida, 1992]', with similar experiences after major Californian earthquakes.

Catastrophe bonds have been marketed since 1997, with the first one issued in Australia by Swiss Re in 2006 against earthquakes and tropical cyclone damage (Haynes, 2006). Their distinguishing feature is that they essentially involve investors in capital markets betting against disasters, and therefore reducing the need for capital

reserves on the part of insurance companies. Cavallo and Noy (2009, p. 23) describe catastrophe bonds as follows:

'A tradable instrument that facilitates the transfer of the risk of a catastrophic event to capital markets. A typical structure is one in which the investors purchase a safe bond, such as a U.S. treasury bond, for the desired amount of coverage and deposit it with a Special Purpose Vehicle (SPV) institution, which is legally distinct from the parties. The investors collect the interest on the bond plus the insurance premium that is paid by the insured party while the disaster does not occur. If the disaster strikes, however, their claim is extinguished and the SPV sells the bond and transfers the funds to the insured.'

Other complex financial derivatives can also be devised to share risk between insurers and capital markets in order to reduce the cost of re-insurance for catastrophic events. One example is Catastrophe Equity Put Options or CatEPut, a type of security first issued in 1996 by Centre Re. These CatEPuts enable a corporation to exchange a pre-specified value of its shares (stock) for cash from an insurance company in the event of a catastrophe occurring within a pre-specified period (Lin & Wang 2009, p. 287). They involve a double trigger: the shares must be below a certain level and losses must exceed a trigger level. Whether capital markets would also be willing to bet against more predictable disasters due to climate change is unknown, but probably not likely. It is therefore not clear that catastrophe bonds or equity put options offer a solution to adaptation need, because their prices would rise as risk increased.

Despite the attention it has received in the climate change literature, insurance may be something of a distraction in developing a long-term adaptation strategy. It is a purely financial instrument that transfers wealth from one section of society to another in compensation for damage incurred.

In sum, insurance is a viable instrument for risk reallocation when the probability distribution of risk is stationary, but its success in the long-term is far from assured in a world of more frequent, intense and likely correlated events. Much as aspirin can relieve immediate pain without addressing the underlying cause, insurance contributes little to actual adaptation in the sense of biophysical or other adjustment. Indeed, under certain conditions, it may even discourage adaptation to unpredictable climate change by engendering a false sense of financial security, a condition that Taleb (2012) would probably classify as 'fragile'.

4.7 Government as 'insurer' of first and last resort

There is no precise definition or generally accepted concept of government acting as 'insurer of last resort', particularly for future climate change. The term can have several meanings, ranging from government acting as an insurer or re-insurer to simply assisting in the last resort. This section attempts some degree of disambiguation in examining the various possible roles.

Many commentators assume implicitly that the impacts of climate change will manifest themselves primarily as catastrophic events (e.g. Berz 1999), one of the reasons for much of the focus on measures based on insurance (e.g. World Bank 2010). Unfortunately, there is no satisfactory theory of catastrophes so that it is not clear a priori what government's role should be. According to Yezer (2000, p. 1), the academic 'literature is thin, [but] it includes a surprising diversity of theoretical models and empirical results'.

Governments do, however, also act as ultimate managers of public risk in situations that do not involve disasters or catastrophic situations.

The term 'last resort' is today generally associated with central banking functions, so we examine government's role in this area in case there are analogies to climate change.

The term 'insurer' requires examination of how insurance markets can be used to adapt to climate change

If governments are to act in the role that provides direct insurance to offset the negative effects of climate change, examination of analogous roles in flood insurance is likely to provide useful insights

We then take a broader conceptual view of the term 'insurer of last resort', and distinguish interventions that involve government acting as 'insurer of first resort'.

Drawing on our reviews of these approaches, we propose a broader role for government as 'adaptor of last resort'.

4.7.1 Government as 'lender of last resort'

The concept of 'last resort' support by government is most closely identified with central banking. In their review of support for troubled financial institutions in Australia, Fitz-Gibbon and Gizycki (2001, p. 1) define last resort lending as the *'discretionary provision of liquidity to individual financial institutions (or to the market as a whole) by the central bank to overcome a shortfall in liquidity caused by a withdrawal of funds from those institutions because of doubts about their financial standing'*. They point out (p. 2) that the case for a lender of last resort role is based on 'the existence of information asymmetries in banking markets and the systemic consequences of bank failure', but that its provision involves costs due to the moral hazard of greater risk-taking by banks.

Henry Thornton (1802) and Walter Bagehot (1873) are generally credited with the first exposition of the so-called 'classical' perspective of the 'lender of last resort' concept. Although Bordo (1990) distinguishes four functions, Thornton and Bagehot considered the long-term role of a central bank as ensuring a steady expansion of the money supply to match economic growth (Humphrey 1975). Its role as a lender of last resort was not to prevent shocks, but to stop the spread of panic by increasing liquidity significantly in the short term. Its primary responsibility was seen as being to the market as a whole, with unsound or imprudent banks being left to fail or being required to pay penalty rates for any support.

A particular distinguishing feature of the banking sector is that the failure of one bank can lead to a contagious loss of confidence in the market as a whole. The failure of a manufacturing firm, on the other hand, is likely to strengthen remaining firms because of increased market share. The risk of contagion of some sort is, however, not a known feature of climate change impacts at this stage, so any role for government in terms of managing risk on the model of 'lender of last resort'.

4.7.2 Government as regulator of insurance markets

In 1968, the United States Congress established a National Flood Insurance Program (NFIP) on the basis that viable market for insurance could not be provided by the private sector alone. The Program arose out of a widespread belief that adverse selection was a potential problem for private insurers because only those in flood

zones would pay premiums, so premiums would be high but not sufficient to cover catastrophic losses. A further consideration was the 'rising cost of taxpayer-funded disaster relief for flood victims' (Kunreuther & Michel-Kerjan, p. 84).

The NFIP was intended originally to offer subsidised insurance for existing buildings in areas where local communities enacted floodplain management regulations. A low take-up rate led Congress in 1973 to limit Federal disaster assistance to non-participating communities, and federally regulated mortgage lenders could lend only for properties covered by flood insurance. It was necessary in 1994 for Congress to introduce financial penalties on lenders, because 'the major 1993 floods in the Midwest revealed that the mandatory purchase [of insurance] requirement was not being widely enforced' (Kunreuther & Michel-Kerjan, p. 86).

As a result of the 2005 hurricane season, however, the NFIP was forced to borrow over \$US20billion from the US Treasury because its annual premium income was only about \$US2.8billion. Such losses due to catastrophic events had been anticipated at the time of establishing the NFIP 'even if the premiums that are subsidized (25 per cent of all flood policies) were charged the full actuarial rate' (Kunreuther & Michel-Kerjan, p. 112). That is, taxpayers were effectively still paying for disaster relief, but through the medium of government-subsidised private insurance.

The Australian Government does not subsidise insurance against natural disasters. In 1967, devastating bushfires occurred in Hobart, and were followed in the early 1970s by a series of cyclones that culminated in Cyclone Tracy on Christmas Day 1974 in Darwin, only some eleven months after a major flood in Brisbane. In December 1976, the Government tabled a proposal to provide reinsurance for natural disaster policies issued by insurance companies, although bushfires, tropical cyclones, storm surge and earthquakes were excluded. Although the proposal was never actioned, Walker (2010, p. 204) discerns a positive effect on the insurance industry which was forced to deal with natural disasters itself. The involvement of scientists in committee discussions on the proposal made insurance companies aware of local academic disaster expertise, resulting in more realistic hazard risk assessments and the use of reinsurance.

The experience of the January 2011 Brisbane floods revealed significant under-insurance by those affected. In a survey of 1200 Australian households in late 2011, Tooth (2012) found that part of the reason for under-insurance by Australian households generally appears to be lack of clarity about the extent of flood cover in insurance policies, as well as socio-economic attributes such as age, income, language spoken at home and the influence of family and friends. In response to a question about a 10 per cent price reduction in premiums from the removal of stamp duty on insurance policies, 12 per cent of those without contents insurance said that they would take out insurance and 15 per cent of those who were aware they were under-insured thought it very likely that they would increase their cover. Bird et al (2013, p. 34) report similar uncertainty levels about the extent of flood cover among Brisbane residents, but the non-random survey was limited to about 80 people in only four flooded suburbs.

The Natural Disaster Insurance Review established by the Australian Government recommended in 2011:

'That an agency sponsored by the Commonwealth Government be created to manage the national coordination of flood risk management and to operate a system of premium discounts and a flood risk reinsurance facility supported by a funding guarantee from the Commonwealth'. (Trowbridge et al 2011, p. 3)

In effect, the Review recommended continued taxpayer support for disaster victims, but through the medium of a new government agency that appears to bear at least a passing resemblance to the form and intent of the American NFIP.

Review Panel members noted the reported experience of NRMA Insurance that many insurance purchasers who are located in flood risk zones nevertheless opt out of the flood cover section of a policy (Trowbridge et al 2011, p. 24). The Panel recommended that all insurance policies must include flood cover with no provision for opting out, but stopped short of calling for compulsory insurance for all building owners. Since no cost-benefit analysis appears to have been conducted, it is not clear what evidence was used to choose this as the preferred solution. It is hardly surprising that the Productivity Commission (2013, pp. 30–31) opposed subsidised insurance, and recommended that insurers should only be required to offer flood insurance ‘if it can be demonstrated that the benefits to the wider community would exceed the costs’.

4.7.3 A broader conception of Government as ‘insurer’ of first or last resort

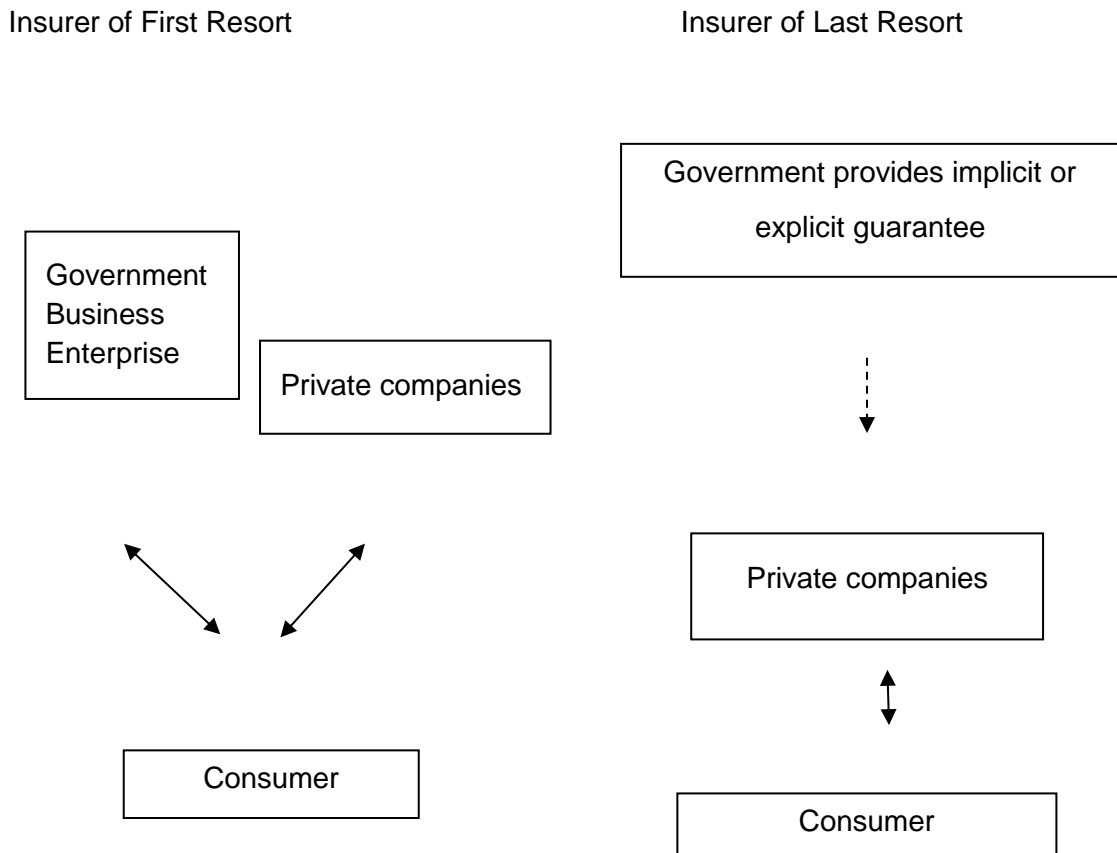
It is also possible to think of the term ‘insurer’ of last resort more broadly, so that it is not interpreted literally to refer solely to the insurance market. Rather, it can connote the wider role of government acting as a ‘backstop’ manager of public risk in various ways and circumstances, analogously to the central bank role of ‘lender of last resort’.

Governments can intervene directly in a market by providing services that are similar to other suppliers (Figure 9) directly to consumers. For example, Medibank Private, a health insurer is operated by the Australian Government in competition with the private sector. From 1992 to 2006 the government retained majority ownership of Telstra, which competed over that period with private telecommunications companies. If other suppliers fail, the government can increase its own supply of the goods or services required, acting as an ‘insurer of first resort’.

Direct government participation in markets can induce countervailing risks, including moral hazard and ‘crowding out’. Expectations of disaster relief, a form of ex post insurance provided by governments, can result in under-insurance before an event by individuals (Bruggeman et al., 2010). Following the Victorian bushfires, free food and clothing provided to victims reduced business opportunities for local stores, delaying the commercial recovery of some towns. Following cyclone Yasi in 2011, commercial suppliers of fresh food were willing to incur significant additional expense to resupply Cairns rather than lose market share, raising the question of the need for government-sponsored relief beyond assistance that is not commercially available at all (Dobes et al., 2012).

A less intrusive approach is for government to remain at arm’s length from markets, acting in the capacity of ‘insurer of last resort’, in a similar way to the role of a central bank as ‘lender of last resort’. Unlike the ‘insurer of first resort’ model, an ‘insurer of last resort’ does not participate actively in a market in competition with commercial suppliers and therefore does not supply goods or services directly to consumers. Only if the market itself fails, does it become involved by facilitating the resurrection or continued operation of all or some of the firms that constitute that market.

Figure 9. Government as ‘insurer of first resort’ and ‘insurer of last resort’



Examples of governments acting as ‘insurer of last resort’ include involvement in markets for terrorism insurance and for liquidity in financial markets. Following the 11 September 2001 attacks on the Twin Towers in New York and the Pentagon in Washington, insurance companies feared bankruptcy if they offered unlimited terrorism insurance. A number of governments responded by extending ‘insurer of last resort facilities’ to the insurance industry for terrorism-related insurance cover. The Australian Government passed the Terrorism Insurance Act 2003, to override relevant exclusion clauses in insurance contracts (Australian Reinsurance Pool Corporation 2012).

Similarly, in order to stabilise Australian financial markets following the failure of major overseas banks in the Global Financial Crisis, the Australian Government introduced a guarantee scheme for authorised deposit-taking institutions (ADIs) for about 16 months from the end of November 2008 (Australian Government, 2012). Because banks and other ADIs paid a fee for government backing for large deposits and wholesale funding, the government effectively acted as an insurer of last resort, or re-insurer.

4.7.4 A ‘real options approach to government as ‘insurer of last resort’

None of the above is intended to suggest that government has no role in assisting the community to adapt to climate change. Indeed, the reverse is true, but in a way that may seem counter-intuitive to non-economists. From a political perspective too, it is inconceivable that governments would not be active in responding to the challenges of adaptation.

The term ‘insurer of last resort’ connotes a role for government as a regulator, planner and funder of adaptation measures *in extremis*. But these functions are likely to be or become economically inefficient, reducing society’s overall well-being, including its ability to redistribute resources to the less affluent, and therefore its ability to adapt to climate change. In the long run, the situation is likely to be unsustainable because of the inevitable maladaptations that will be involved.

Regulation, undifferentiated by circumstance or location, can impose significant opportunity costs on communities. Insurance and reinsurance schemes against catastrophic events is likely to result in moral hazard, adverse selection, and direct subsidies by taxpayers in general, a situation little different in principle from the current practice of ex post disaster assistance. Subsidising adaptation to the myriad of possible climatic impacts, catastrophic as well as slow-onset, would require significant increases in taxation, resulting in corresponding deadweight losses for society as a whole and unnecessary fiscal churn.

Equally, the cascade of uncertainties associated with climate change scenarios and the prediction of impacts, mean that individuals and governments may engage in costly premature adaptation or misconceived ‘climate proofing’. Conversely, they may procrastinate unduly and adapt inadequately, resulting in equally unnecessary social cost. The uncertainty is also likely to mean increased levels of litigation by ‘ratepayers, regulators and utility stockholders’ on levels of reliable service under conditions of climate change (Child 2013).

In the face of an uncertain future climate, the government’s role should be one of facilitating adaptation by creating as many opportunities and options as possible for individuals, corporations and communities to adapt in a way that best suits local conditions and preferences at different times. In economic jargon, the government should be a creator of ‘call options’ that allow learning and flexible adjustment over time, rather than providing financial assistance after the event in the form of ‘put options’¹¹. This is particularly the case because of the deep uncertainty about the timing, frequency, intensity and specific location of likely climate change impacts.

‘Real options’ at the project level

Hertzler (2007) applies them to agriculture, and Linquiti & Vonortas (2012) present a detailed example involving the potential construction of sea walls in Dhaka and Dar es Salaam.

An intuitive approach, real options are ideal for both individuals and governments addressing the uncertainties associated with climate change. In particular, the flexibility they engender can justify some degree of initial precautionary action on the part of government, without incurring the full and immediate cost of a full and deterministic solution. For example, the construction of a wide foundation for a sea wall provides the flexibility to use sandbags at short notice, construction of a one-metre high wall, or a ten-metre high wall, depending on circumstances and future need. Immediate construction of a ten-metre high wall, an inflexible, deterministic approach, would be comparatively expensive, and may never be justified despite providing virtual certainty of avoidance of inundation.

¹¹ Whereas a put option such as insurance can be exercised if there is a loss in value of an underlying financial asset, a call option provides the right, but with no obligation, to reap the benefit of an increased asset value.

Hertzler (2007) applies real options to agriculture and Dobes (2008) uses a range of examples to illustrate their general applicability. Simulations of different approaches by Linquiti & Vonortas (2012) indicate that it may not always be necessary to undertake constant review and analysis of a real option in order to determine the precise timing of expansion of investment or project abandonment. Using the example of a sea wall, they demonstrate that a satisficing solution is for the responsible authority to construct an initial wall with a safety factor of, say, half a metre in height. Whenever the sea comes within a half metre of the top of the wall, the wall is extended in height by a similar amount. Real options have also been used on a continental, transformational scale by private individuals: Australia's cattle king, Sir Sidney Kidman is an example (Dobes 2012).

Although the use of real options in the face of uncertainty, is an intuitive strategy that is used in everyday life (e.g. carrying an umbrella if there is uncertainty about rain) and business, current government administrative and budgetary arrangements are geared to deterministic project management with fixed periods within which expenditure is to occur... Public servants are rewarded not for abandoning projects if circumstances change, but rather for expending pre-determined budgets on time and on budget.

If adaptation is to be 'mainstreamed', care will be required to avoid 'gold plating' projects by making them 'climate proof' from the outset. Where mainstreaming is encouraged, it should be in terms of maintaining project flexibility to allow sequential adaptation in the future through expansion or abandonment, if required. Public Service program managers will need to be rewarded for abandoning ineffective or inefficient programs and projects, and program and project budgets will need to include funding for monitoring the effectiveness and efficiency of adaptation measures until an option to abandon or expand is exercised.. Because the exercise of a 'real option' may take many years, it is also not clear how funds are to be earmarked. Maintaining significant reserves in case a set of real options needs to be implemented in the future runs the risk of considerable opportunity cost in terms of reduced expenditure in other socially desirable areas. On the other hand, failure to earmark funds in advance may result in unwarranted abandonment of projects in future.

'Real options' at the macro level of the economy and society

From the perspective of society as a whole, experimentation and incremental learning is likely to be less risky than large programs applied uniformly across the whole country. If one or two locations fail to adjust efficiently to climate change in a flexible, decentralised system, the consequences will be relatively limited compared to the impact of an unforeseen flaw in a large government program. Even if some locations suffer, others will benefit from the lessons learned, so that society as a whole benefits. Taleb (2012) makes a similar point in a more general context.

A key means of increasing the flexibility of potential adaptation responses by all actors in the economy is to minimise economic and institutional distortions and rigidities (Dobes 2012; Productivity Commission 2013). Minimisation of economic distortions requires a comprehensive program of micro-economic reform designed to maximise the influence of markets in individuals' choices of adaptation measures. Equally, it would be necessary to address inefficiencies due to any relevant market failure on the basis of rigorous social cost-benefit analysis. To the extent that a thoroughgoing reform of economic distortions increased general economic growth, it would represent a 'no regrets' adaptation strategy.

The benefits of increased flexibility in factor and product markets are conventionally considered primarily in terms of promoting greater efficiency and responsiveness to

structural change. However, the number of potential scenarios posed by climate change is potentially infinite, so that identification and removal of specific barriers to adaptation is unlikely to be feasible, and may even engender a false sense of security. Even if a large proportion of barriers were identified today, they may not be as relevant in the future, under changing circumstances, as those that were not initially identified.

From this perspective, the role of government should be much broader: a comprehensive micro-economic reform that removes the maximum possible number of distortions is required because it is not possible to foretell which ones will be important, or when. The role of government at the level of the macro-economy therefore needs to be the creation of as many real options as possible.

In terms of cost-benefit analysis, the additional quasi-option value that would be generated by comprehensive micro-economic reform would increase the net present value above that of removal of currently identifiable barriers to climate change alone. Unfortunately, it is this less travelled and more arduous road of micro-economic reform that is so neglected by government agencies (at all levels) responsible for developing policy on adaptation to climate change¹².

Increasing institutional flexibility also has the potential to have beneficial effects. For example, mutual recognition between the states of skills required for emergency management would permit better use of resources in disaster situations across Australia. Eburn (2011) draws attention to current gaps in the Commonwealth's statutory powers with respect to emergency services, but provision of reserve powers to local authorities to act in emergencies when state agencies are unable to operate effectively at the site of a disaster (the principle of subsidiarity) may also warrant greater investigation. Coordination problems such as the unavailability of federal disaster funding for collection of green waste before a cyclone is a further example¹³ of the need to address institutional rigidity.

¹² Productivity Commission (2013, p. 105) puts the opposite case that 'while broad-based economic reforms should be high priority, they are not sufficient to address all barriers to climate change adaptation. Some reforms that increase prosperity could in some circumstances increase exposure to climate change impacts – for example, higher incomes may raise the demand for larger, more expensive houses located in areas at high risk from natural hazards'. This argument ignores both the efficiency principle of consumer sovereignty and the likelihood that higher incomes may conversely promote the construction of better-adapted houses such as modern versions of 'old Queenslanders' on stilts.

¹³ Noted by Dobes et al (2012, p. 35). There is an understandable reluctance on the part of Commonwealth authorities to fund prior removal of loose vegetation because of the potential moral hazard of local governments misusing funding for general waste removal. However, loose debris and vegetation can become airborne during a cyclone, causing additional damage to property. Their removal prior to the cyclone would reduce the social cost of damage after it. There would be merit in further exploration and resolution of issues such as this.

5. BRISBANE PROPERTY PRICES AND THE PERCEPTION OF FLOOD RISK

A strong theme that emerged out of our review of the literature in chapter 3 was that the role of government in adaptation to climate change should be a limited one. In the main, it should be directed towards freeing up the economy and institutional arrangements to ensure sufficient flexibility for adjustment in the face of an uncertain future climate. Governments may also have a role to play where genuine market failure exists.

One role for government that is consistently referred to, including in the Stern (2006) and Garnaut (2008) reviews, is the provision of information about the impacts of climate change and associated risks. This proposition presupposes that some form of market failure exists, necessitating government intervention.

However, the literature review (see Chapter 3) did not discover any significant hard evidence regarding the perceptions of risk on the part of those who face potential disaster situations. It was therefore a key objective of this project to analyse sale prices of residential properties that are located in flood zones along the Brisbane River. Property prices are an ideal means of determining whether allowance has been made for risk in what constitutes a significant asset for most households.

The first aspect that was investigated was the effectiveness of any provision of information about risk by governments. Although information about riverine flood zones had been available for some time, the release of the information by the Brisbane City Council in an online format reduced the search cost of accessing it. We therefore tested the hypothesis that release of information about flood risk was reflected in changes in property prices, and was therefore an effective government initiative.

The second aspect that was investigated was the effect of the January 2011 flood. It would not be surprising to most people to find that property prices fall following damage caused by a flood. Taking the proposition further, it might be argued, for example, that property prices can be expected to fall further in areas that are subject to more frequent (i.e. higher probability of) flooding. We therefore analysed the data in disaggregated form to see if the hypothesis that property prices fall after a flood event holds equally or different levels of risk.

5.1 *The 2011 Brisbane flood*

Comparisons are often made with major flood events on the Brisbane River, including in particular those in 1841, 1893, 1898, 1908, 1931, 1974 and 2011. The purpose of such comparisons varies depending on the context, but the 2011 flood has been represented as being ‘... the second highest ... since the beginning of the 20th Century’ (van Honert & McAneney 2011) and therefore worse than the one in 1974. This can lead to the conclusion that Brisbane residents should have been aware in 2011 of a risk at least as big as that in 1974, or its opposite, that the 2011 flood was unprecedented and could therefore have not been anticipated.

Comparisons of flood levels may be valid within a specific context, but they are not necessarily generally applicable because of geomorphological and other changes to the river over time. A bar at the mouth of the river was removed in 1864 so that recorded flood levels before that date needed to be reduced to ensure consistency with records of subsequent floods. Dredging in 1917 has been estimated to have reduced subsequent flood heights by about 1.52 metres (City Design 1999, p. 4). The Wivenhoe

dam and the Somerset dam (on the Stanley River, a tributary of the Brisbane River and upstream from Wivenhoe) were constructed in response to the floods of 1974 and 1931 respectively. However, simulations of rainfall levels that caused significant historic floods indicate that the Wivenhoe dam's mitigation effects diminish as the magnitude of the flood increases, partly because heavy rain in the catchment would be likely to fill the dam to spillway level (City Design 1999, pp. 7–9).

Without appropriate adjustments to recorded river heights, it would not be possible to produce accurate flood forecasts or flood recurrence data based on associated rainfall events in catchments. Flood risk information based on unadjusted data would consequently be misleading. Indeed, City Design (1999, pp. 5, 10) concluded that the adjusted historical flood record resulted 'in a more even distribution of floods' over the period 1841 to 1996, and that the height of a 1 in 100 year flood was 1 to 2 metres higher than current development levels.

A secondary complication is the need to be specific about the nature of a flood in Brisbane. The 2011 flood was primarily due to heavy rainfall in the Bremer and Brisbane River catchments, although rain also fell in metropolitan Brisbane. More typically, flood events in Brisbane are caused by local rainfall resulting in heavy runoff and flooding of drains and creeks. According to McKay (1976) Brisbane experienced 'severe flooding in one or more [of the six] local creeks' on 40 occasions over the 30-year period between 1943 and 1972. It is worth noting that the Brisbane City Council Voluntary Home Purchase Scheme which commenced in 2006 is intended only for 'homes affected by a creek or local flood event that has a 50 per cent chance of occurring each year [that is, a 1 in 2 year flood event]' (http://www.brisbane.qld.gov.au/downloads/community/community_safety/Voluntary_Home_Purchase_Scheme_fact_sheet.pdf viewed 15 March 2013).

This chapter does not examine issues to do with creek or local flooding. Its focus is purely on riverine flooding in Brisbane.

5.2 Main results of the regression analysis

The results of regression analysis (see Chapter 2 for explanation) are presented in tables 5 to 10 below). The main result is presented first, followed by additional results. Finally, tables are presented to illustrate tests of the robustness of the main results. Occasionally we refer to results that are not presented in this paper. We have not included these highly specific results because they are incidental to the main results. They are, however, available from the authors on request.

The main finding is a six per cent drop in house prices because of the January 2011 flood, and a three per cent drop in house prices due to a property being classified a flood risk in the July 2008 online release of flood risk information. We also find that the floods affected the sales price of high valued houses, but not low valued houses.

Further, the expected peak height of floods occurring with an annual probability of 2 per cent (1 in 50 year flood) and 5 per cent (1 in 20 year flood) are found to experience reduced sales prices. On the other hand, expected peak flood heights of very rare (one per cent per annum probability, 1 in 100 year) or very frequent (twenty per cent probability, or 1 in 5 year) floods did not experience appreciable falls in sales prices.

In the main regressions, the control group used was the houses that were not themselves flooded, but were located in suburbs that did experience flooding. Additional regressions allow us to account for a range of other factors that may be relevant. For instance, we investigated two additional types of control groups: non-

flooded properties on flooded streets and 'no flood risk properties' on streets that do have at least one property deemed at risk.

5.3 Explanation of results in Tables

In all tables, different columns refer to different specifications of the error term, which differ according to the inclusion of some combination of suburb, month or year effects through dummy variables (shown at the bottom of the table). The transition from the basic case outline in Chapter 2, to that with dummies is very simple for our purposes of investigating the causal effect of the flood and risk assessment on sales values: the causal effect is still the interaction term. What the dummy variables do is to give each suburb (for suburb dummies) a different constant. In all regressions, the log of sale price is the dependent variable. Finally, unless stated otherwise, we combine both the flood and the online release of information in each regression.

Focussing on column (1) of Table 5, which is the regression without any additional dummy variables, we see that the 2011 flood caused a 6.26 per cent drop in sale prices of flooded properties. Moving to the right across the table, we see that the size of the effect drops in absolute terms when suburb dummies are included. Allowing for shocks at the suburb-month-year level finds an effect of 3.64 per cent. As a comparison, 3.64 per cent of the average property sale price is AUD \$21,262. On the other hand, the estimated causal effect of the flood does not change when we include month-year dummies. Because these dummies capture the effect of any interest rate influences, our results are robust to such considerations. The fall in prices is statistically significantly different from zero under all specifications of dummy variables.

Despite anecdotal comments from real estate agents that very few Brisbane residents would have been aware of flood risk information before the 2011 flood, the online release of flood risk information in July 2008 was also found to have significantly reduced prices. The base results in column (1) of Table 5 suggest that the online release of information caused a 2.96 per cent fall in property sale prices for properties that were classified as having any flood risk. The effect increases where we include suburb dummies. However, we fail to find a result that is significantly different from zero at the ten per cent level where we allow for suburb-month-year variation. The t-statistic of -1.53 might not meet standard significance levels, but it is not small enough on its own to immediately rule out an effect of the online release of information. Further, this insignificance is not the result of the inclusion of the 50 high-valued property sales immediately prior to the online release of information, as the t-statistic (and coefficient) are very similar when these properties are excluded (not shown).

Finally, we note some additional information that can be obtained from Table 5. Properties deemed a flood risk are on average 6 to 11 more expensive than properties not deemed a flood risk, and flooded properties 0 to 2 per cent more expensive than properties deemed a flood risk. This latter result occurs because all flooded properties were deemed a flood risk.

5.3.1 Property market response to different levels of risk

The FloodWise Property Reports (FWRP) contain additional information that we exploit to investigate how the residential property market responded to details in the reports. In particular, the reports provide information concerning the expected heights (in metres) of 1 in 5, 1 in 20, 1 in 50 and 1 in 100-year floods. Note that these are expected heights based on government modelling, and not actual events. We exploit the online release of this information in July 2008, which provided the market with an objective

assessment of risk that was previously costly to obtain. This is used to identify how the market responded to information about various risks.

Table 5 presents the results of this investigation, which reveals that the expected heights of the 1 in 20 and 1 in 50 year floods caused a reduction in sales prices. To be precise, an increase in the expected height of a 1 in 20 (1 in 50) year flood decreased property prices by 0.5 (0.49). The similarity between these two estimates is likely to be due to the very high correlation between the expected heights of the 1 in 20 and 1 in 50 year floods¹⁴. On the other hand, the property market did not change in response to the 1 in 5 or the 1 in 100 year floods.

This information is particularly important, as it reveals how property markets adapt to different types of risks. The findings can be summarised as being consistent with the property market not responding to information concerning very frequent or very rare risks, but rather to a 'middle ground' of risks.

5.3.2 Causal effects for high and low valued properties

Our final set of regressions in Table 7 investigates whether the causal effects of the flood and the information changes by house type. As we only have a limited amount of information in our dataset, we restrict this investigation to high and low valued properties. We split the sample by the median valued property and re-run the regressions shown in Table 5 on these two sub-samples.

A significant effect of the 2011 flood is found only for high valued properties. Although there is a negative estimate for low valued houses, this is not significantly different from zero at conventional significance levels. On the other hand, the effect of the online release of risk information in 2008 suggests that both low valued properties and high value properties dropped in price if the property was deemed to be at risk. The effect of being identified at risk was greater for low valued properties.

5.3.3 Robustness

One potential concern with the above analysis is that the control group of non-flooded properties may not be expected to follow the same path as flooded properties. We have therefore also estimated the results using a control group consisting of non-flooded properties sold on streets that were flooded, as well as not-at-risk properties on streets that had at least one property deemed at risk. Reductions in the size of the sample, and hence the control groups, do not change the results found in Table 5.

The results using the reduced sub-sample of flooded streets can be found in Table 8. Here, we see that the 2011 flood caused a drop in property prices of the order of 5.4 to 8.5 per cent. This effect is *larger* than the effect found with the broader sample and its control group of all non-flooded houses in suburbs that were affected by the flood. Further, we find (but do not show) that we cannot reject the null hypothesis that the pre-flood trends in property prices are equivalent¹⁵.

To test the robustness of the analysis of information provision in 2008, a different sample is used to the one used in Table 8. This is because nearly all properties on streets that were flooded were considered a flood risk. Therefore, we changed the sample to include all properties deemed at flood risk, as well as all other properties sold on these streets. Table 9 shows that the smaller sample yields a similar effect of

¹⁴ The correlation coefficient is 0.9852

¹⁵ Specifically, a t-test of equality of the trends across flooded and non-flooded areas was not rejected at the ten per cent level.

flood risk designation to that in the broader sample of properties in flooded suburbs in Table .

The final check for the robustness of our results investigates whether the flood effect can be explained by property level characteristics. To carry out this test, we use a subsample of properties that were sold multiple times. In the same way that we use month dummies to control for seasonal effects, we can use property level dummies that control for property-level characteristics that remain constant between sales. Although properties occasionally change or are improved, there would still be a great deal about a property that remains constant over time.

Table 10 indicates that the effects of the flood and the provision of online risk assessments are robust to property-level characteristics for properties sold multiple times. Additional analysis finds that the inclusion of additional property characteristics like the number of bedrooms, bathrooms, garages and property size did not significantly change the size of the price effect for a randomly selected sample (not shown).

Table 5. Main regression results into the effect of the online release of flood information and the 2011 floods

The dependent variable is the log of sale price, and the sample consists of all property sales in Brisbane LGA suburbs whose boundaries were encroached by the 2011 floodlines, for sales from 2007–2012, with July 2008 property sales removed.

Dummy specification	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Property flooded in January 2011	0.0214** (0.00944)	-0.00115 (0.00912)	0.0215** (0.00940)	0.0208** (0.00942)	0.0200** (0.00933)	-0.0132 (0.00989)	-0.00179 (0.00903)
Property sold after 15 Jan 2011	-0.00937* (0.00564)	-0.0179*** (0.00515)	0.0745** (0.0365)	-0.00669 (0.00568)	0.125*** (0.0481)	0.0526 (0.0452)	0.0782* (0.0421)
Property flooded in January 2011 and sold after 15 January 2011	-0.0626*** (0.0163)	-0.0529*** (0.0150)	-0.0619*** (0.0162)	-0.0629*** (0.0163)	-0.0604*** (0.0162)	-0.0364** (0.0180)	-0.0507*** (0.0150)
FWPR indicates a flood risk	0.111*** (0.00979)	0.0617*** (0.00916)	0.114*** (0.00976)	0.109*** (0.00977)	0.109*** (0.00973)	0.0533*** (0.0106)	0.0607*** (0.00910)
Property sold after 30 June 2008	0.0713*** (0.00608)	0.0713*** (0.00563)	-0.0455*** (0.0125)	0.0667*** (0.00612)			0.190*** (0.0676)
Flood risk at property, and property sold after FWPR released (July 2008)	-0.0296*** (0.0108)	-0.0359*** (0.00988)	-0.0317*** (0.0108)	-0.0280*** (0.0108)	-0.0268** (0.0108)	-0.0183 (0.0120)	-0.0343*** (0.00980)

Dummy specification	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Constant	13.07*** (0.00490)	13.09*** (0.00467)	13.13*** (0.0127)	13.07*** (0.00492)	13.09*** (0.0123)	13.13*** (0.0117)	12.93*** (0.0159)
Suburb dummies		Yes					Yes
Month dummies			Yes				
Year dummies				Yes			
Month-year dummies					Yes		Yes
Suburb-month-year dummies						Yes	
Observations	44,318	44,318	44,318	44,318	44,318	44,318	44,318
R-squared	0.013	0.185	0.019	0.015	0.028	0.293	0.199

Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1, FWPR: FloodWise Property Report issued by Brisbane City Council

Table 6. Investigation of the effect of estimated flood risk for various flood probabilities as designated in the FloodWise property reports The dependent variable in all regressions is the log of sales price and all regressions have suburb, month and year dummies. Different columns investigate different flood risks.

Type of flood	1 in 5 year	1 in 20 year	1 in 50 year	1 in 100 year
	(1)	(2)	(3)	(4)
Property flooded in January 2011	0.0563* **	0.0470* **	0.0453** *	0.0593* **
	(0.0079 2)	(0.0084 3)	(0.00864)	(0.0079 3)
Property sold after 15 January 2011	-0.0292	-0.0292	-0.0293	-0.0303
	(0.0317)	(0.0316)	(0.0316)	(0.0316)
Property within 2011 floodlines, sold after 15 January 2011	- 0.0693* **	- 0.0637* **	- 0.0613** *	- 0.0697* **
	(0.0144)	(0.0146)	(0.0147)	(0.0145)
Property sold after 30 June 2008	- 0.112** *	- 0.107** *	-0.106***	- 0.113** *
	(0.0120)	(0.0122)	(0.0122)	(0.0121)
Expected height of 1 in 5 year flood zone, and sold after 30 June 2008	- 0.00440			
	(0.0029 1)			
Expected height of 1 in 5 year flood zone	0.0120* **			
	(0.0025 1)			
Expected height of 1 in 20 year flood, sold after 30 June 2008		- 0.00498 **		

Type of flood	1 in 5 year	1 in 20 year	1 in 50 year	1 in 100 year
		(0.0019 4)		
Expected height of 1 in 20 year flood		0.00735 ***		
		(0.0017 5)		
Expected height of 1 in 50 year flood, sold after 30 June 2008			- 0.00486* **	
			(0.00158)	
Expected height of 1 in 50 year flood			0.00649* **	
			(0.00144)	
Expected height of 1 in 100 year flood, sold after 30 June 2008				- 0.00217
				(0.0020 0)
Expected height of 1 in 100 year flood				0.00375 **
				(0.0017 6)
Constant	12.99** *	12.99** *	12.99***	12.99** *
	(0.0082 5)	(0.0083 0)	(0.00831)	(0.0082 7)
Observations	47,190	47,342	47,342	47,204
R-squared	0.190	0.188	0.188	0.188

Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Table 7. The effect of the online release of flood information and the 2011 floods, by high and low valued properties

High and low valued properties are demarcated by the median sale price within the sample. The sample consists of all property sales in Brisbane LGA suburbs whose boundaries were encroached by the 2011 floodlines, for sales from 2007–2012, with July 2008 property sales removed. The dependent variable is the log of sale price.

	(1)	(2)	(3)	(4)
	Low value	Low value	High value	High value
Property flooded in January 2011	0.0186 (0.0120)	0.0126 (0.0124)	— (0.00515) 0.00140	0.0145** (0.00529) *
Property sold after 15 Jan 2011	— 0.0065 8	— 0.00147	— 0.0104** *	— 0.0523** *
	(0.0065 3)	(0.0493)	(0.00393))	(0.0180)
Property flooded in January 2011, and sold after 15 January 2011	— 0.0066 1	— 0.00175	— 0.0249** *	— 0.0329** *
	(0.0211)	(0.0206)	(0.00946)	(0.00917)
FWPR indicate a flood risk	0.103** *	0.0539** *	0.0326** *	0.0323** *
	(0.0124)	(0.0117)	(0.00592)	(0.00588)
Property sold after 30 June 2008	— 0.0162* *	— 0.0521** *	0.0615** *	— 0.0267** *
	(0.0072 2)	(0.0153)	(0.00451)	(0.00959)
Property at risk of flooding, and sold after FWPR released (July 2008)	— 0.0227*	— 0.0260**	— 0.0113*	— 0.0169** *
	(0.0136)	(0.0127)	(0.00655)	(0.00638)
Constant	13.47**	13.42***	12.77***	12.73***

	(1)	(2)	(3)	(4)
	Low value	Low value	High value	High value
	*			
	(0.0059 1)	(0.0112)	(0.00372)	(0.00637)
Suburb dummies		Yes		Yes
Month dummies		Yes		Yes
Year dummies		Yes		Yes
Observations	22,039	22,039	22,279	22,279
R-squared	0.015	0.148	0.015	0.111
Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1				

FWPR: Flood Wise Property Report (issued by Brisbane City Council)

Table 8 Regression results into the effect of the 2011 floods, with the sample restricted to property sales in streets that were flooded

The dependent variable is the log of sale price. The sample only includes sales from 2007–2012, with July 2008 property sales removed.

	(1)	(2)	(3)
Property flooded in January 2011	0.121*** (0.00979)	0.118*** (0.0121)	0.117*** (0.00986)
Property sold after 15 Jan 2011	0.0342*** (0.0123)	0.0865 (0.0934)	0.00740 (0.0577)
Property within 2011 floodlines, sold after 15 January 2011	−0.0847*** (0.0190)	−0.0576** (0.0246)	−0.0547*** (0.0177)
Constant	13.11*** (0.00671)	13.10*** (0.0230)	13.01*** (0.0157)
Suburb-month-year dummies		Yes	
Suburb dummies			Yes
Month dummies			Yes
Year dummies			Yes
Observations	16,605	16,605	16,605
R-squared	0.010	0.349	0.204

Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Table 9 Regression results into the effect of the online release of flood information, with the sample restricted to property sales in streets that had a property sale where the property was deemed a flood risk

The dependent variable is the log of sale price. The sample only includes sales from 2007–2012, with July 2008 property sales removed.

	(1)	(2)	(3)
Flood risk as reported in FloodWise Property Report	0.109*** (0.0115)	0.0872*** (0.0137)	0.0942*** (0.0111)
Property sold after 30 June 2008	0.0609*** (0.0106)		–0.121*** (0.0192)
Flood risk at property, after FWPR released (July 2008)	–0.0332** (0.0137)	–0.0162 (0.0160)	–0.0270** (0.0127)
Constant	13.08*** (0.00909)	13.13*** (0.00568)	13.00*** (0.0134)
Suburb-month-year dummies		Yes	
Suburb dummies			Yes
Month dummies			Yes
Year dummies			Yes
Observations	23,739	23,739	23,739
R-squared	0.008	0.345	0.204

Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

FWPR: Flood Wise Property Report (issued by Brisbane City Council)

Table 10 Regression results into the effect of the online release of flood information, with the sample restricted to properties that were sold multiple times

The dependent variable is the log of sale price. The sample only includes sales from 2007–2012, with July 2008 property sales removed.

	(1)	(2)	(3)	(4)
Property sold after 15 Jan 2011	0.0391* **	0.0463* **	0.00437	0.0757
	(0.0053 2)	(0.0057 2)	(0.0390)	(0.0476)
Property within 2011 floodlines, sold after 15 January 2011	– 0.0563* **	– 0.0729* **	– 0.0756* **	– 0.0692* **
	(0.0161)	(0.0122)	(0.0121)	(0.0120)
Property sold after 30 June 2008	0.0594* **	0.0499* **	– 0.0502* **	0.0379
	(0.0075 8)	(0.0080 5)	(0.0170)	(0.0435)
FWPR indicated flood risk at property, sold after July 2008	– 0.0312* *	– 0.0350* **	– 0.0367* **	– 0.0356* **
	(0.0131)	(0.0123)	(0.0121)	(0.0121)
Constant	13.09***	13.08***	13.05***	12.98***
	(0.0043 1)	(0.0102)	(0.0105)	(0.0213)
Observations	5,260	5,013	5,013	5,013
R-squared	0.086	0.121	0.145	0.201
Number of individual properties	2,535	2,530	2,530	2,530

Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

FWPR: Flood Wise Property Report (issued by Brisbane City Council)

6. DISCUSSION

Discussion has already been incorporated above as part of each analytical section. Results have also been reviewed in various sections above, and an overview of the report is provided in the Executive Summary.

Although we believe that our results are robust, we note the existence of other views, particularly regarding perception of risk. For example, Tooth (2012, p. 37), in reporting the results of a December 2011 online survey of 1200 households (of which 300 in High Risk areas for storm surge, cyclones and floods), states that:

'A common concern is that people have invested in a home, unaware of the risks to their home and the associated financial consequences. ... For all risks, between 12 and 14 per cent of households disagreed or strongly disagreed that they had an understanding of the risks before choosing to live in their current location. Of particular interest is the extent to which a lack of understanding of risk was associated with people moving into high risk areas. ...In particular, over 20 per cent of respondents who assessed themselves as relatively highly exposed to flood considered that they did not understand the risk prior to choosing to live in their location.'

Further, there was general agreement in our discussions with real estate agents and valuers that Brisbane residents had not been particularly perceptive with regard to flood risk before January 2011.

Nevertheless, we believe that it would be difficult to dismiss our findings on the basis of survey results and ex post views of risk perceptions by others. Survey respondents may have been influenced by media reports of councils allowing development in high-risk areas and therefore engaged in strategic behaviour that is not uncommon in surveys. Similarly, views about others' prior perceptions of risk well after the event may not be entirely objective either, even if sincerely held.

Moreover, our analysis is based on objective data rather than statements by others. Unless property prices in the treatment and control groups were affected by some unknown factor, there is no reason to believe that our results are wrong.

Finally, our findings also suggest that purchasers of riverine property in Brisbane do discriminate on the basis of perceived risk. In areas that are expected to flood frequently (1 in 5 years), buyers appear to have already factored in flood risk so that prices were not affected significantly when the flood occurred. We have interpreted this to mean that high incidence floods are usually less damaging due to their lower height, and because minor flood defences (e.g. sand bags) can easily be arranged. Nor did prices fall significantly in areas where there is a risk of 1 in 100 years flooding, presumably because such events are too rare to be of concern from year to year. However, prices did drop significantly for properties at risk of 1 in 20 and 1 in 50 year floods.

Our interpretation of our findings that buyers do discriminate between degrees of risk was supported in discussion with real estate agents and others in Brisbane. If our interpretation is accepted, there may be an arguable case for ensuring that government information about flood risk differentiates between degrees of risk, to allow people to form their own judgements.

7. GAPS AND FUTURE RESEARCH DIRECTIONS

It is understandable the nascent adaptation literature should still rely to a large degree on analogies and assumptions. It is pertinent, however, that our empirical results regarding property prices in Brisbane raise an important question mark over the common assumption that ordinary citizens are not capable of accurately perceiving risk in complex situations. We would therefore encourage greater emphasis on reviewing what appear to be self-evident truths, much as many myths and fables in the economics literature have been subjected in recent years to greater scrutiny (e.g. Spulber 2002).

In particular, we consider that the following areas merit more attention:

Whether markets would produce information about risks of floods or other climate-induced hazards in the absence of government intervention. Although much of the original data was made available by various government bodies to the Insurance Council of Australia, it is worth noting that the claim that the only nation-wide database on properties subject to flooding (the National Flood Information Database) was created by the general insurance industry (Insurance Council of Australia 2011, p. 7). A question that requires an answer is – given an increasing intensity or frequency of floods and other natural hazards, and hence increasing premiums, would the insurance industry have ultimately developed its own database of flood zones?

A more comprehensive examination of government failure in policy formulation and implementation and how it can be minimised in the area of adaptation to climate change.

In line with the underlying message in Productivity Commission (2013), greater emphasis in research on rigorous cost-benefit analysis (including use of real options). In particular, use of choice modelling to estimate economic benefits, rather than conceptually flawed use of costs avoided.

A rigorous cost-benefit analysis of the apparently accepted wisdom regarding buildings and infrastructure: that construction of climate adapted buildings is cheaper than retrofitting, especially for long-lived infrastructure.

There is often a presumption of ‘betterment’ in terms of reconstruction of infrastructure affected by disasters, including an implicit assumption that it needs to be funded by government (e.g. Productivity Commission 2013, p. 268). More cost-benefit analysis should be undertaken that includes the alternative of ‘worsenment’. For example, it may well be cost-beneficial to avoid resurfacing a road (or part of a road) that is subject to flooding. The section that floods regularly could be left as a gravel road and may be cheaper to repair on each occasion.

We have concluded that changes in property prices in Brisbane reflect a degree of discrimination on the part of buyers regarding risk. Nevertheless, given opinions expressed by others (including by Dr Richard Tooth, on the basis of a survey of households in high-risk areas) we consider that there would be merit in further testing our findings.

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