# Flood Risk, Climate Change, and Housing Economics: Four Fallacies of Extrapolation

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## Abstract

This paper argues that major gaps exist in the research and policy understanding of the intersection of flood risk, climate change and housing markets. Gaps have arisen because the housing economics literature on flooding has emerged without consideration of climate change. To extrapolate the findings of this research to gauge the effects of future floods—the frequency and severity of which are likely to be shaped by climatic instability—would fall foul of a series of methodological fallacies. We argue that the potential magnitude of the flood impact on house prices may be considerably greater and more complex in future because of: (a) shifts in the location and type of properties affected, (b) the systemic nature of the risks and costs implied by climate change to financial institutions and governments, (c) tipping points in market adjustment to extreme weather due to the dynamics of employment location effects, imperfect information and behavioural factors, and (d) the intersection of spatial-spillovers arising from the proximity of multiple flood-risk hot-spots. These factors have not characterised the historical floods considered by housing economists and so have tended not to be considered in existing estimates of the housing impacts. Yet, they are potentially crucial to the appropriate development of future methodologies and policy advice. A step change in the theoretical model implicit in empirical estimation is needed if we are to make plausible connections with long-term climate projections.

# 1. Introduction

The issues of flood risk and flood recovery have moved up the political and scientific agendas in recent years following increased frequency and severity in flood incidents and the likelihood that this trend will continue as a consequence of climate change (Stern 2006; Pitt 2008; IPCC 2007). In the US, floods have already been one of the most common and widespread natural disasters (FEMA, 2006, cited in Bin & Kruse, 2006); in the UK flood frequency has greatly increased in the last decade and is believed to rise in the future (Forsight, 2004). According to IPCC (2007, p.5), "warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level" [1]. These effects will, in turn, have potentially significant implications for human geography, economic and financial systems, and quality of life (Stern 2007, GHF 2009). Intervention strategies depend critically on the net costs and benefits of the different policy options available, and these calculations, in turn, rely heavily on our ability to quantify the impact of flooding on the human and natural environments.

In this article we argue that, in terms of helping us understand the implications of climate change for housing—particularly in countries like the UK which have extensive coastlines and where most major cities are located on the coast or major rivers—the existing literature is not well suited. Our contention is that, when it comes to considering the effects of anticipated global warming, current housing economics research on flooding is characterised by two categories of limitation. The first category includes methodological problems arising from poor data, reliance on relatively simple statistical techniques or inadequate sampling methods. We label these as "technical problems"—methodological hurdles that can be addressed using more advanced estimation methods and better research design. While many of these problems are less prevalent in recent studies, we highlight them because policy makers must nevertheless be aware of them when thinking about implications for current and future policy decisions.

A second category of problem is more fundamental. It arises from the premise of a stable climate. Extrapolating the results of this body of work to quantify the implications of effects of an unstable climate, would fall foul of a number of *fallacies of extrapolation*. Such an enterprise

[1] Alley, R. B. et al (2007) *A report of Working Group I of the Intergovernmental Panel on Climate Change: Summary for Policymakers*, Solomon, S., D. (eds.). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

would entail using research outputs for a purpose for which they were not intended, derived from studies based on assumptions fundamentally at odds with climate projections. Our goal is to tease-out these erroneous assumptions and highlight the fallacies of extrapolation that need to be addressed in order to make reasoned judgements about the likely housing impacts of future flood risk. Conventional wisdom on the house price impacts of flood risk, such as the "bounce-back effect", needs to be challenged when considered for this purpose; and a step change is needed in how housing economics connects with climate modelling generally. Our goal is not to disregard the contribution made by authors of work in this field, but to highlight the startling misunderstandings that can arise if existing results are applied simplistically and uncritically to the emerging "silent crisis" (GHF 2009) of Climate Change. We seek to highlight priorities and offer guidance for research going forward.

We focus on the UK but many of our arguments will be applicable to other countries facing anticipated increases in flood frequency and severity (see GHF 2009 p. 15-16, 20, 40, 49). The paper proceeds as follows: Section 2 summarises the current evidence on climate change and the anticipated implications for flood risk in the UK. Section 3 surveys the existing housing economics literature on flood risk and notes some of the common statistical and technical irregularities. Section 4 summarises the results of existing research on the house price impacts in terms of the "bounce-back" effect and other stylised outcomes. In Section 5 we set out our reasons for being sceptical about applying the bounce-back effect when to the effects of climate change. We structure our argument around four key fallacies: (i) *The Fallacy of Replication*, (ii) *The Fallacy of Composition*, (iii) *The Fallacy of Linear Scaling*, and (iv) *The Fallacy of Isolated Impacts*. We argue for a paradigm shift that recognises the crucial role of market imperfections, behavioural idiosyncrasies, macro feedback loops, tipping points and spatial interactions. Section 6 concludes with implications for housing research and public policy.

## 2. Climate Change and UK Flood Risk

According to what Stern (2008) judges to be the conservative estimates of the International Energy Agency (IEA 2007), overall global emissions are likely to reach 12-15 gigatons (Gt) by 2030. "There seems little doubt that, under [Business as Usual], the annual increments to stocks [of $CO_2$] would average somewhere well above 3ppm $CO_2$e, perhaps 4 or more, over the next century. That is likely to take us to around, or well beyond, 750ppm CO2e by the end of the century. If we manage to stabilize there, that would give us around a 50-50 chance of a stabilization temperature increase above 5$^{o}$C" (Stern 2008 p.5) [2]. Such an increase would lead to rising sea levels of ten metres or more and severe torrents in rainy seasons, as a result of thermal expansion of the oceans and melting ice sheets (Houghton 2009).[3]

Combined with increased storminess and precipitation, the effect will be to raise flood risk significantly in many areas. Forsight (2004) estimated that the number of people in England and Wales at high risk from coastal and river flooding could increase "from 1.6 million today, to between 2.3 and 3.6 million by the 2080s. The increase for intraurban flooding, caused by short-duration events, could increase from 200,000 today to between 700,000 and 900,000…" (Forsight 2004 p.18). These figures underestimate the overall flood risk as the Forsight report does not consider pluvial (surface water) flooding. Urbanisation and road building, and more intensive agricultural methods have increased the problems of both urban and rural run-off (Hollis 2003 quoted in RICS 2009, p.17). It is estimated that around 3.8 million properties are at risk of surface water flooding (EA, 2009).

Multiple sources of flood risk complicate considerably the forecasting of flood risk, adding to the already significant uncertainty associated with the underlying climate projections. Then there are the plethora of contingencies arising because of assumptions about future trajectories for $C0_2$ emissions, and the nature of government intervention and private sector response. It is therefore difficult to give precise estimates of the size of change of flood risk in particular areas. However, there is little doubt that flood risk would increase significantly over the next 70 years in England and Wales. Such change could reshape the social-welfare map of Britain. With changed flood risk will come a changed landscape of deprivation, housing shortages and homelessness as the housing market sorts households according to ability to pay for locations in the most desirable (lowest risk) areas. All this entails significant social upheaval,

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[2] Even these estimates may prove optimistic because they omit the very real possibilities for feedback loops to occur in the carbon cycle due to, for example, "release of methane from the permafrost, the collapse of the Amazon, and thus the destruction of a key carbon sink, and reduction in the absorptive capacity of the oceans" (Stern, 2008, p.5).
[3] "At an increase of 5$^{o}$C, most of the world's ice and snow would disappear, including major ice sheets and, probably, the snows and glaciers of the Himalayas. This would eventually lead to sea-level rises of 10 meters or more, and would thoroughly disrupt the flows of the major rivers from the Himalayas, which serve countries comprising around half of the world's population. There would be severe torrents in the rainy season and dry rivers in the dry season. The world would probably lose more than half its species. Storms, floods, and droughts would probably be much more intense than they are today" (Stern, 2008, p.6)

economic disruption and welfare loss for significant proportions of the population, not least for those whose main source of saving for retirement was the value of their home. There is a real imperative, therefore, to improve our understanding of likely scenarios and their geographical and economic context and interactions. An obvious place for the housing economist to start is the existing literature on the relationship between house prices and flood risk. Making sense of this literature in the context of these anticipated climatic changes may not be straightforward, however, as we now attempt to demonstrate.

## 3. Technical Problems in the Housing Economics of Floods

Until relatively recently, the housing economics literature on floods remained relatively small, and largely based on data from North American. Table 1 displays the key characteristics of selected studies which examine the extent to which flooding or floodplain designation affects house prices. Methods employed have included t-tests on average prices of properties before and after a flood event or within and outside of floodplain locations (Zimmerman, 1979; Babcock and Mitchell, 1980; Tobin and Montz, 1988); repeat sales analysis (Hallstrom and Smith, 2005, Lamond and Proverbs, 2006), difference-in-difference framework (Bartosova et al., 1999; Bin and Polasky, 2004) and hedonic approach (MacDonald et al., 1987; Bin and Kruse, 2008; Pope, 2008). Hedonic approach is most widely used, allowing for an estimate of the implicit price ("willingness to pay") for a reduction in flood hazard while controlling for property attributes (see Lancaster 1966, Rosen 1974, Freeman 1979 and Palmquist 1984). In an efficient market, such willingness to pay should be capitalised into property value, resulting in price differential between those with and without flood risk.

Indeed, many studies show that properties located in a floodplain are valued lower than comparable ones outside of a floodplain. But the magnitude of such a price discount varies, and is sometimes negligible. Drawing on data of home sales prices in Monroe, Louisiana, MacDonald et al. (1987) find that floodplain location lowers house prices by 6% to 8%. In Houston Texas, Skantz and Strickland (1987) show that property values in a floodplain are reduced by approximate 4%. Speyrer and Ragas (1991) reported that homes at high risk of flooding in New Orleans are valued 4.2% to 6.3% less than comparable flood-free homes. A recent study of Pope

(2008) also notes that floodplain location results in house price discount of 3.8%-4.5% in North Carolina.

Studies also conclude that, for properties in a floodplain, a particular flood event further decreases house values. This finding suggests that flood risks are partially incorporated into property values; a flood event improves people's awareness of flood risk and further decreases house prices. Fridgen & Schultz (1999), for example, found that floodplain location in Fargo, North Dakota and Moorhead, Minnesota, reduces house price on average by $8990; such a price discount rose to $10 241 after a major flood event. Similar conclusion is drawn by Bin and Polasky (2004) who found that houses located within the floodplain in North Carolina were worth on average 5.7% less than a comparable property located out-with the floodplain; such a price discount doubled after Hurricane Floyd.

In contrast with the negative effect of flood risk, a few studies show zero, or even positive, impacts of flood risks on house prices. Zimmerman (1979) found no significant difference between average house values for properties located within and outside of floodplains in New Jersey. Note this study only uses t-tests and does not control for property attributes. Recent study in the UK also reveals that high flood risk has no effect on property values in areas with no recent flood events (Lamond, 2009). Drawing on housing transaction data from Santa Rosa County during 2000 and 2006, Morgan (2007) even found positive effects of floodplain location. Such effects may reflect price premiums associated with waterfront amenities. As a single dummy variable indicating floodplain location cannot disentangle the effects of both waterfront amenities and flood risks, the study may underestimate the impact of flood risk..

Similarly, the findings concerning the effect of a flood event are far from uniform. Contrary to negative flood effects (e.g. Harrison et al., 2001; Bin & Polasky, 2004), Babcock and Mitchell (1980) reported that sales prices of properties within floodplains in Galt, Ontario, during the four years after a flood event were significantly higher than prices in the four years before the flood. This study is based on simple Kolmogorov-Smirnov tests without controlling for property attributes. Tobin and Montz (1989)'s study in three areas of Yuba County, California, found no significantly negative effect of flooding, and surprisingly, positive correlation between flood depth and house prices. The authors explained the latter as a result of renovation and quality improvement after flooding.

Two methodological issues might partially explain the mixed picture described above. First, sample sizes in some studies, especially the early ones, are very small; less than 100 sales (see

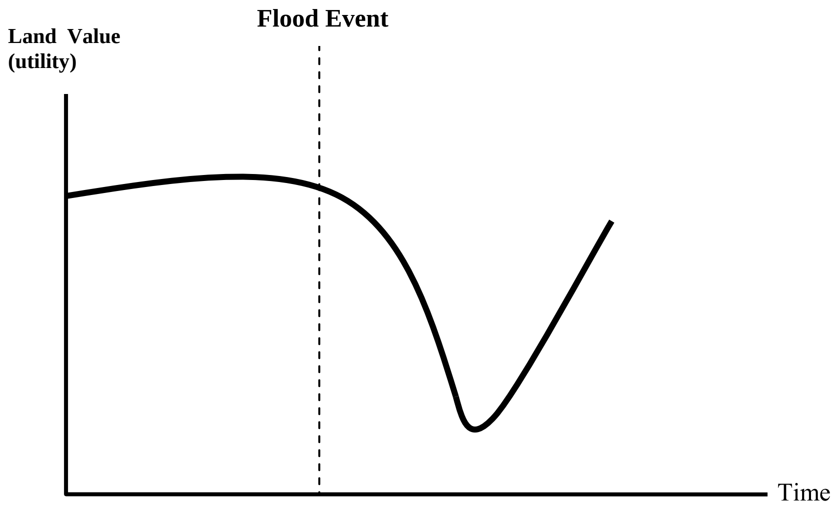
Table 1). Such small samples may not have sufficient statistical power or external validity to quantify effects with confidence—discrepancies between studies may simply be due to random sampling variation, because the mean is more sensitive to the sales of some particularly high or low priced properties in small samples. Secondly, there is variability in the extent to which other factors are controlled for, such as house type, location, waterfront amenities. These factors not only influence house prices, but have an important effect on the owners' experience of flood. For instance, owners in houses with more than one level might be subject to less damage during flooding, compared with those in bungalows. A multivariate meta-analysis of 19 US-based studies reveals that omission of quality characteristics of the house, such as age, maintenance level, central heating, waterfront amenities, results in an underestimate of the implicit price of flood risk (Daniel et al., 2009).

## 4. The Bounce-Back Effect

Literature on the impact of flooding on house prices is largely made up of flood-specific studies of varying quality. Improved sample sizes and technical proficiency will not, however, be sufficient to address a deeper set of problems which arise from the fact that most studies have been conducted within a paradigm that assumes no change to the climate. This results in a profound disconnect between the existing housing economics literature and the long-term predictions of climate models.

One important implication of a changing climate for the housing economics literature is the interpretation of the "bounce back effect", currently observed in housing market responses. The theoretical foundation comes from Tobin and Newton (1986) who adopted the concept of "utility" from the urban economics literature (Bish and Nourse, 1975; Grether and Mieszkowski, 1974) and assumed that changes in the utility derived from holding land/property are reflected in changes in the price of land/property. Tobin and Newton identify three profiles depicting flood impact on land/property values. The first stylised effect is the bounce back effect where house prices fall immediately after a flood event and then recover (Figure 1). This profile occurs when a long time gap exists between two flood events and people tend to forget flood risks. Montz (1992) further indicate that post-flood house price might exceed its pre-flood level because of renovation and quality improvement.

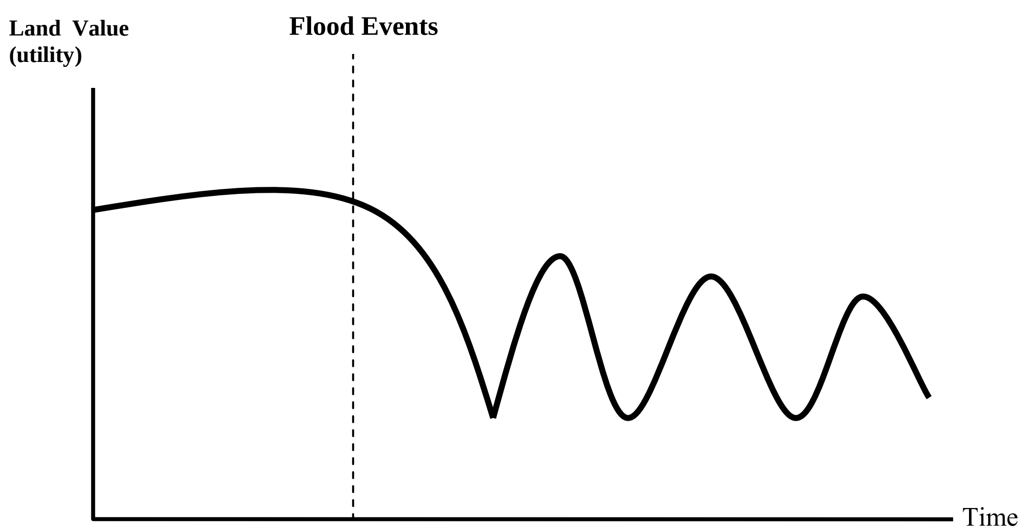
**Figure 1**




*Source: Tobin and Newton (1986)*

A second possible outcome concerns a substantial fluctuation of land values over time, as a result of periodic flooding and the ability of the market to recover (Figure 2). This profile occurs when the market has sufficient time between two flood events to recover.

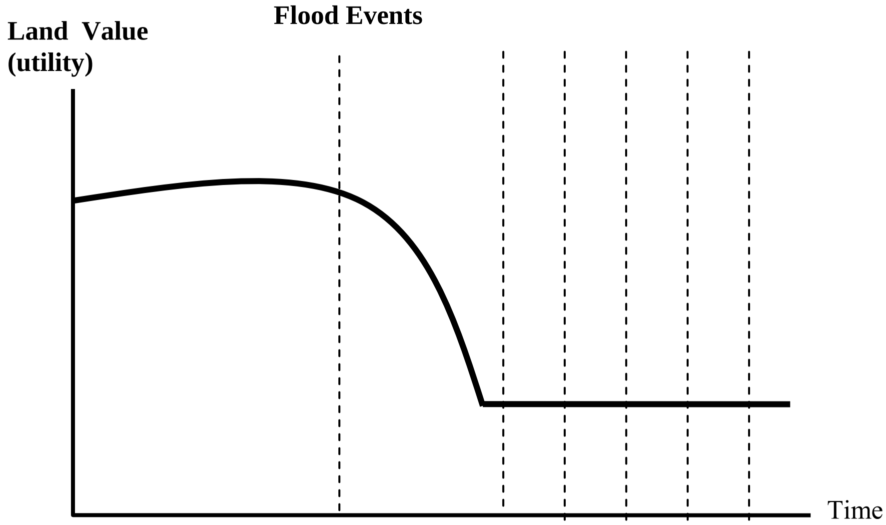
**Figure 2**




*Source: Tobin and Newton (1986)*

Finally, should flooding occur frequently then it is possible that property values remains low as the market does not have enough time to recover between events (Figure 3). In this case, flood risks have completely capitalised into house price. Hence, future flood has no impact on property values.

**Figure 3**




*Source: Tobin and Newton (1986)*

Empirical analysis of floods in Pennsylvania, California and Illinois has confirmed the existence of the bounce-back-effects by showing that selling prices fell following flood events but recovered to levels at or above pre-flood values (Tobin and Montz, 1994). Similar trajectories are observed by Lamond and Proverbs (2006)[4] who find that the effect of the 2000 flood in a small town in Yorkshire was temporary, lasting less than three years (p.363). They concluded that their results gave "confidence to the community, lenders and insurer to invest in the reinstatement of the property" (p.375). Further work by Lamond (2009) on 13 locations in England and Wales during 2000 and 2006 confirms their finding that flooding has only temporary impacts on property values in the UK market. Commenting on these studies, Brown (2009) deduced that "for the majority of homeowners, the medium term investment potential of their flood-plain properties is sound" (Brown 2009 p.19).

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[4] Surprisingly, Lamond and Proverbs (2006) is the first UK analysis of the house price impacts of floods to be based on transactions data—all previous UK research had relied on surveys of expert opinions such as BFRG (2004) and Eves (2004) or other indirect methods.

So, under the assumptions of perfect information and a stable climate, the bounce-back effect can be interpreted as good news—evidence of housing market resilience (hence the Brown 2009, interpretation). Under the assumptions of an unstable climate, and imperfect information, however, the bounce-back finding could be taken as evidence of the failure of housing markets to adjust to risks, which is particularly ominous if those risks are set to rise. That house prices fall at all in the event of a flood may be indicative that markets are not operating efficiently. If markets were efficient, observed market price would already account for the risk of flooding, and so one should observe no price change in the event of a flood, only variation across space (i.e. across risks). Moreover, that prices revert to previous levels may indicate market amnesia—the tendency for markets to forget, even if individuals who experienced the flood do not forget (the discrepancy between the knowledge of the market and that of incumbent households can arise because buyers may come from outside the area and be less than fully aware of the risks).

That prices, even of dwellings subject to coastal erosion (Defra 2009), can drift dreamily away from their risk adjusted values, implies that significant shifts in flood risk could occur as a result of climate change without this being reflected in observed market prices. Prices must, of course, adjust eventually (once a dwelling falls into the sea, the price will be zero even in a spectacularly buoyant market), but the adjustment is of the worst kind: sclerosis followed by dramatic tipping-points, rather than gradual convergence. A policy goal must be to help markets adjust gradually and well in-advance, so as to minimise the impact on households, to help households make contingency plans, adjust their financial expectations, and to minimise unanticipated loss. Perversely, subsidised insurance may mitigate such adjustment: a person who buys a dwelling for £200,000, only to find that it is only worth half that in ten years time when insurance companies are no longer willing to insure such properties, may not look favourably on the well intentioned attempts of current governments to suppress risk pricing in the insurance industry.

Price inertia and amnesia may also distort planning and investment decisions. Expectations about the future determine current decisions about where houses are built, roads constructed, firms located. Kenna (2008) notes, for example, that 133,600 new homes were constructed on floodplains in the UK over the period 1996 to 2005. These decisions have long-term implications because buildings and infrastructure built now are likely to be with us long into the future.

## 5. The Four Fallacies of Extrapolation

How we extrapolate house prices into the future is therefore of some consequence. We now set out our reasons for being sceptical about simple extrapolation of existing results in the housing economics literature that appear to show modest impacts of floods on prices or fully restorative bounce-back effects. We now elaborate the issues raised the previous section by highlighting four fallacies of extrapolation: (a) *The Fallacy of Replication*, (b) *The Fallacy of Composition*, (c) *The Fallacy of Linear Scaling*, and (d) *The Fallacy of Isolated Impacts*. These fallacies are not failings of the research findings themselves, but of attempts to extrapolate them to a future that is likely to be shaped by significant climate change.

### *a) The Fallacy of Replication*

*Properties that have experienced floods in the past have been of type x and not type y. Therefore, properties that flood in the future will be of type x and not type y.*

This syllogism is fallacious because properties that experienced floods in the past may not be typical of those that experience floods in the future. The fallacy is akin to the sample selection problem – the data on which we base our estimation may give a distorted picture because they are not typical of those for whom we are making predictions. For example, studies which look at the impact on average prices derived from transactions, face the problem of favourable selection bias: those that trade may be the least badly affected by floods. Consider the effect of Hurricane Katrina which destroyed or severely damaged 217,000 properties in 2005 (Paxson and Rouse 2008, p.38). Even if the selling prices of properties in New Orleans were to rebound, the trajectory would belie the abandonment and devastation of houses that fail to re-enter the selection of dwellings that transact. Hence, it is important to distinguish the average value of the housing stock from the average value of houses that transact. The former would be more meaningful if we are interested in gauging the impact on wellbeing and true economic cost. There are a number of reasons to believe replication bias will increase when we come to use past events to predict future effects.

Firstly, *the proportion of future flooded dwellings with waterfront views may change*. It is only fairly recently that studies on flood risk have discussed amenities associated with waterfront properties, such as views and access to boating, in hedonic analysis[5]. Bin and Kruse (2006), for example, examine the effects of costal flood risk and amenities on residential property values using data from Carteret County in North Carolina. The aurthors found that floodplain far away from coastal water lowers property values between 5-10%, while properties located within floodplain with wave actions have higher values. This finding suggests that the premium associated with proximity to coastal water outweighs the negative effect of flood risk. As the amenity effect of floodplain location is likely to lead to bias in regression analysis, Bin et al. (2008) controlled for both location in floodplain and distance to coastal water in their follow-up study using a subset of the data from Carteret County. Their results confirm that floodplain location lowers house prices.

An important implication of the amenity value of waterfront views is that, existing estimates which fail to disentangle this effect from the flood risk effect, may significantly underestimate the effects of increased flood risk due to climate change. This is because climate change is likely to extend considerably the range of dwellings affected by flood risk (Forsight 2004). While properties currently most affected by floods are those located on riverbanks and hence benefit from open vistas, in future, we may see a much higher proportion of properties that do not benefit from offsetting price effect of waterfront views. Moreover, the amenity value of waterfront views may be greatest on flat terrain where the absence of hills means that river locations have a monopoly on open vistas. When floods become more common in areas with greater topological variation, the value of views on water fronts may decline significantly relative to views obtained from living on a hill.

Secondly, *future flooded properties may be more likely to have lower physical resilience*. Areas with a long history of flooding may go through a process of design (local planners have screened out applications for building designs that fail to meet flood resilience specifications) or natural selection (only properties with appropriate structural features have survived repeated floods). This may end up with properties that are structurally resilient to floods. Climate change, however, implies that a much wider geographical spectrum of houses will be affected by flooding and subsidence caused by swelling and contraction of underlying soil types. Hence, the price

[5] Earlier work by BFRG (2004) and Eves (2004) mentioned positive values of floodplain amenities through views of chartered surveyors.

effects observed in the context of historical floods may be a poor guide to future price effects in areas previously untroubled.

There is considerable variability in the literature in the extent to which even basic dwelling characteristics are controlled for. Soule and Vaughan (1973), for example, only used analysis of covariance (ANCOVA) in their study of property values in three areas in Kentucky. Tobin and Montz (1988) also used simple tests to compare means/medians of property values before and after the 1985 flood event in Yuba County, California. Eves (2002) compared the average annual sales prices of flood-liable properties with those of flood-free ones in Southwest Sydney, Australia, between 1984 and 2000. Again, there were no explicit controls for housing quality which might explain price differentials. Clearly, however, physical characteristics of a dwelling can have a major effect on the owner's experience of a flood. For example, owners of houses with more than one level can move furniture and possessions upstairs to mimimise damage; the same is not true for those who live in bungalows.

Thirdly, *the behavioural response to floods may change as the climate changes*. To illustrate, consider the gradual, inexorable depreciation in value of houses built on land subject to coastal erosion (Defra 2009). Once market participants acknowledge that dwellings located on a retreating cliff edge face an irreversible and terminal negative shock, even though the exact date of that event cannot be known with precision, and even though the short run swings of market demand may cause price to deviate from the theoretical depreciation curve (Defra 2009), one can predict that prices will eventually slump to zero. This is very different to the price dynamics associated with intermittent events (such as earthquakes) that might cause dwellings to collapse but which have constant risk. Similarly, the difference between a one-off flood event in the context of a stable climate, and a flood event under the scenario of increasingly realisation that the climate is warming, is that the latter part of a terminal dynamic where expectations gradually adjust to the prospect of secular trends in flood risk. Particular flood events are then likely to act as catalysts in this expectations adjustment process, causing house prices to converge to their risk-adjusted levels, albeit in a disjoint and haphazard way.

An important implication is that the bounce-back effect may eventually vanish in areas subject to anticipated upward trajectories in flood risk. If so, the house price dynamics of neighbouhoods facing the spectre of  erosion may be a more useful analogy of how prices will adjust to global warming than temporary impact of historical floods, where houses prices converge not necessarily to zero (as in coastal erosion) but to some permanently reduced long-run average nonetheless.

The impact of shifting expectations is complicated by the bounded rationality associated with human decision making. The impacts of climate change, as described by the Foresight report flood risk scenarios, implies that future floods are likely occur in areas where there are no experiences of major floods in living memory. Thus, many "virgin risks" will be updating their prior beliefs and the Tversky and Kahneman hypothesis suggests that the increase in perceived risk will be much greater for such individuals. Consequently, we might anticipate a much larger price fall than the price fall associated with "experienced risks", ceteris paribus.

These two implications suggest that we must be cautious about extrapolating price falls from experiences regular minor floods to future major floods, or of extrapolating price falls from areas that currently flood frequently, to areas that currently do not flood frequently.

A further reason to expect the world to be different under climate change arises because the institutional response (both private and public) may be fundamentally different, ignorance of which leads to the *Fallacy of Composition*. It is to this we now turn.

## b) The Fallacy of Composition

*Significant financial safety nets are viable if a single area is flooded.*
*Therefore, significant financial safety nets will be viable if all areas are flooded.*

This fallacy says that behaviour of the entire system will reflect the behaviour of its constituent parts. The "paradox of thrift" is perhaps the best known economic illustration of this classical error where one mistakenly assumes that because increased saving from a single household is beneficial to that household, the same will be true of all households if they all increase their propensity to save. (The error is particularly acute during recessions where increased savings rates exacerbate the downward spiral of aggregate demand). Another example is that of a bank run—there's no problem for the bank if one customer retrieves her savings, but the effect is catastrophic if all savers attempt the same.

With respect to climate change, we highlight two likely examples of the composition fallacy—the assumption of complete insurance markets, and the assumption of state bailouts. The fallacy here would be to believe that because, in the past, insurance firms have been able to offer comprehensive cover, and governments have been able to offer aid and flood defences in the aftermath of floods, the same will be true in future.

*The Moral Hazards of Insurance*

While a number of studies have examined the effects of insurance on house prices, the full effect of insurance and mortgage rationing has not been explored at length. In an efficient market, the annual cost of insurance should be equal to average annual flood damage plus insurance administration costs (Foster 1976). This means that the long run cost of annual premiums equates to the long run cost of flood damage. By implication the price differential between flood-liable and flood-free properties should, in theory, be equal to the present value of the future flood insurance premiums required to offset the risk of flood loss on properties within the floodplain.

The picture is mixed in the existing studies. Using a hedonic approach in Louisiana, MacDonald et al (1987) find that the price differential between flood-prone and flood-free properties was equated with the present value of insurance premiums at a 2.8% discount rate for the below average priced home, 2.85% for the average priced home and 2.9% for the above average priced home. Schilling et al (1985) agrees that the price differential is simply the 'cash equivalence' of discounted insurance, and reports that the price discount in the floodplain in Louisiana equals the present value of insurance costs when calculated at a 5% discount rate. However, Donnelly (1989) argues that property buyers tend to discount property values more than the capitalised value of insurance premium. This could be caused by buyers' higher perceived risk than that of insurance appraisers due to information asymmetry (Speyrer and Ragas, 1991). The other explanation, perhaps more important, is that the reduction in property values from floodplain location also includes inconvenience and other non-monetary losses which cannot be covered by insurance, such as stress of being displaced from home.

Nevertheless, Harrison et al (2001) reached completely different conclusions that the price discount of floodplain location is less than the present value cost of future flood insurance premiums, as property buyers do not have sufficient information about flood risk and tend to underestimate risk. Using the 1994 National Flood Insurance Reform Act, which was designed to increase participation in the flood insurance scheme, as a natural experiment, the authors showed that floodplain location depressed property values in Alachua County, Florida, and such a price discount was much greater after the implementation of the Act. This result suggests that mandatory insurance increases individuals' awareness of flood risk. The explanation of information asymmetry is supported by Chivers and Flores (2002) which found that the majority of respondents in Boulder, Colorado, did not understand fully the extent of flood risk or cost of insurance, and therefore underestimated such costs when purchasing properties.

Information asymmetry leads to imperfection of the flood insurance market (Raschky and Wech-Hannemann, 2007). The UK flood insurance system deviates further from an efficient market, as the system guarantees almost complete insurance cover at subsidised rates (ABI, 2007). It is important to note that existing UK floods occur under a benevolent insurance regime, which has been founded on a gentleman's agreement between the Association of British Insurers and Government since the early 1960s (Arnell et al., 1984; Crichton, 2005). This agreement is based on a division of responsibility where the government provides flood protection (e.g. defences), and the insurance industry offer flood insurance (Huber, 2004; Crichton, 2005). Flood insurance is included in building cover together with fire and theft insurance to households in all areas. Essentially, low risks subsidise high risks whose premiums do not reflect their true risk (Huber, 2004).

This arrangement is not sustainable because, firstly, it implies severe moral hazards for those who live in high risk areas – subsidised premiums dampen the incentives for households to take reasonable measures to reduce their exposure to floods (Treby et al., 2006). Secondly, the system is vulnerable to systemic risk; it only persists because floods remain relatively infrequent and independent (Green and Penning-Rowsell, 2004). However, climate change implies widespread increases in flood risk that are not independent.

Indeed, following the huge insured losses for the widespread flooding in the UK in 1998, 2000 and 2007, the ABI has started to revise its stance by proposing differentiate premiums for homeowners in exposed areas (Crichton, 2005). Although the core of the gentlemen's agreement has not changed, the insurance industry only agrees to provide flood cover to properties which are defended under the flood risk of once in 75 years, i.e. the probability of the properties being flooded in any single year being lower than 1.3%, or to properties where such defences are under construction and will be completed before 2013 (DEFRA, 2008).

Perhaps the most critical implication of insurance rationing is the knock-on effect on access to mortgage finance. Few mortgage companies will offer loans secured on properties without buildings cover. All existing UK floods have occurred in a financial environment that ensures prospective buyers of flooded properties to obtain both insurance and mortgage finance. It is therefore not surprising that price effects have been negligible and temporary. However, as soon as that regime starts to break down, the price effects of floods could be dramatic as entire neighbourhoods become no-go areas for mortgage lenders and become virtually unsellable to all but risk taking cash buyers.

*The Moral Hazards of State Bailouts*

A similar fallacy of composition is committed when we assume that government intervention after a single area flood will be typical of the intervention for floods in all areas. Clearly, limits on government resources present constraints on the level of support and flood defence. As much as political parties would like to promise abundant resources for resilience and adaptation, pressures on the public sector borrowing requirement, tax revenues (particularly during recessions), inflationary pressures, and other demands on public funds (health, education, welfare system, pension time-bomb) will present future governments with tough choices. It is unrealistic to assume that all areas facing increased flood risk will receive the kind of flood defence investment experienced in the Lamond and Proverbs (2006) case study area where £10m was used for flood defense improvements.

The other issue of state bailout, discussed in the literature, concerns charity hazard, which refers to individuals' tendency not to obtain insurance cover or take mitigation measures against natural disasters, but to rely on expected financial aid from government or donations from other individuals (Browne and Hoyt, 2000). Studies on the 2000 European floods found that government financial relief led to potential charity hazard and contribute to imperfection in the flood insurance market (Raschky and Wech-Hannemann, 2007). However, in the UK context, the government leaves the responsibility for compensating flood damage to the private insurance industry according to the gentlemen's agreement. Only limited emergence relief is available including charitable aid through Mayors' Funds, and its payment is means tested (Arnell et al., 1984; Treby et al., 2006). However, it is not at all clear that households are aware of the limited responsibilities of government. For example, the Welsh Audit Office report of 2009 notes that, "… many residents of coastal areas still believe coastal defence to be entirely a responsibility of the authorities" (WAO 2009, p.10). Immediately after the 2007 Hull floods, for example, victims expressed despair at the lack of government aid (Stevens, 2007). Similar findings have been found in related literatures. One of the explanations put forward by Nelson (1981) for example, for the absence of a house price effect of proximity to the Three Mile Island nuclear disaster was that residents expectation of government aid (see Boyle & Kiel, 2001 for a review of the wider literature on using house prices to value environmental effects).

## c) The Fallacy of Linear Scaling

*The impact of a flood of severity y is of magnitude z.*
*Therefore, the impact of a flood twice the severity of y will be twice the magnitude of z.*

This fallacy says that one can legitimately extrapolate directly from the effects of small floods to gauge the effects of large floods. Such reasoning is flawed, as it fails to recognise tipping points in the impact of floods of different severity (depth, speed, and extent) and of different frequencies. Small, shallow floods of low velocity may have no effect on house prices, as might floods of low frequency. However, beyond a certain scale of flood severity and frequency, the house price effect is likely to increase disproportionately. This is partly because dwellings have a particular threshold of physical resilience below which the structural damage is negligible. While structures might be entirely unaffected by 2cm of flooding from slowly moving water, for example, the same structures are likely to be completely obliterated by floods one thousand times the depth moving at one thousand times the speed. Similarly, while residents willingness to pay for a property that floods once every hundred years may be indistinguishable from their valuation of a property that never floods, a property that floods every five years may be worth markedly less. Bartosova et al. (1999), for example, develop a continuous flood risk variable associated with flood return frequency, and find that property values in Wisconsin increase by 2.3% as flood risk diminishes by 10 years (flood intervals increasing by 10 years), with the negative effect disappearing entirely after time lapses between floods exceed 33.3 years.

The following section sets out three additional reasons why we should be sceptical of simple linear extrapolations of house price impacts: 1. employment location and labour market effects, 2. social network effects and 3. psychological/informational effects.

*Labour market effects*

A crucial driver of residential land values is access to employment measured by both proximity and the size of employment centre (Alonso 1964, Muth 1969, Papageorgiou and Casetti 1971, Romanos 1977, Yinger 1992, Ross and Yinger 1995, Glaeser and Kohlhase 2004, Osland and Thorsen 2008, Osland and Pryce 2009). Small floods may have minimal or temporary implications for employment, as local firms are able to weather the storm (Sarmiento 2007). Beyond a certain scale or frequency, floods will cause firms to relocate, especially when the benefits of moving premises to a low flood risk area outweigh the costs. How far firms have to move to find an economically viable location with low flood risk depends crucially on the extent of the area at risk of floods and the distance from the perimeter. While short or temporary relocations are unlikely to have much of an effect either on other firms or on house prices, long distances to the preferred relocation site is likely to have a critical effect on workers. Component suppliers, retail outlets, distribution firms, maintenance firms, office suppliers, are all interconnected in a chain of production. Therefore, the more firms move away, the more difficult it is for other firms to stay. These tipping points in firm location feed through to tipping points in household location, housing demand and house prices.

The longer-term outcome is likely to be complicated by the fact that firms may be less averse to floods than households. Where commercial use and residential use are in competition, this will mean that, in low flood-risk areas land prices may rise to the point where the marginal cost to the firm of locating on a low flood-risk site outweighs the costs, and so commercial users of land may actually gravitate towards high flood-risk locations.[6] The negative externalities of close proximity to employment (Osland and Pryce 2009) may further depress house prices in those areas, an effect that is likely to be exacerbated by the market sorting effects on the type of residents. As deprived households are priced out of low flood-risk areas, they will gravitate towards areas with lower prices due to higher levels of flood risk and other negative externalities. Concentrated deprivation may add further downward pressure to prices in those areas. Community resilience to extreme weather will not just about physical adaptation, it will be about whether people and firms choose to relocate and the factors that drive these decisions—the relative price of land, and the costs and benefits of moving and staying—will be determined by forces beyond the control of the individual household or the local community.

[6] though, clearly, beyond some level of flood frequency and severity, firms will also move away.

*Social Network Effects*

Most residential moves are short-distance (Clark &Huang, 2003). This is partly due to employment factors but also as a result of seeking to maintain family and social networks. However, there may be tipping point effects in such networks: as more people move away, there is less of a social incentive for those that remain to stay. And those that remain, may be the least mobile and least economically productive, exacerbating local economic decline. The idea that sources of nonlinearity are not exclusively economic is not a new proposition. Quercia and Galster (2000) found evidence of threshold effects in dynamics of a variety of neighbourhood attributes including changing neighbourhood racial group composition, income group composition, social and economic conditions (criminal activity, friendship, teenager child-bearing, marriage, educational attainment, employment and earnings, social relationships, health, and welfare dependency), and housing investment. Even one-off floods can have massive impacts on household location.[7] For example, residents have been slow to return to New Orleans, despite the fact that for certain social groups, "those who experienced flooding and did not return had reductions in earnings that were on average $192 larger" (Paxson and Rouse 2008, p.42). Whether the displaced will eventually return will be partly determined by how successfully they can find new social networks or collectively rebuild their existing network.

*Psychological and Informational Effects*

Humans have a tendency to underestimate risks that appear distant or global, or which others seem to accept without concern (Zeckhauser, 1996; Kousky & Zeckhauser, 2006). Recent studies indicate that buyers may not have full information about properties due to high search costs and sellers' unwillingness to reveal information of dis-amenities about their properties such as flood risk (Chivers & Flores, 2002; Lommand, 2009). Therefore, disclosure of flood risk would decrease house prices in flood risk areas. Troy and Romm (2004), for example, found no

[7] For example . According to Paxson and Rouse (2008), find that "Hurricane Katrina displaced approximately 650,000 people … and the return of displaced residents … has been slow. The fraction of households receiving mail (which, in the absence of reliable population estimates, is a good indicator of returns) was 49.5 percent in August 2006, and 66.0 percent in June 2007" (Paxson and Rouse, 2008, p.38).

significant difference in property values between comparable homes located within and out of floodplain in California prior to the introduction of the Hazard Disclosure Law. However, the authors found that properties located in the floodplain were worth 4.2% less than non-floodplain properties after the law was implemented. Similar conclusion has been reached by Pope (2008) who reported that properties located in a floodplain in North Carolina suffered 3.8%-4.5% discount in value after the introduction of the disclosure act.

Tipping points may, therefore, arise in house price adjustment due to sudden changes in public awareness. While individuals currently tend to forget their previous flooding experiences as time passes, this may not be true if floods become frequent and ubiquitous. Even in years when a particular household is not flooded, the prevalence of flooding elsewhere, accounts in news reports and social dialogue, will act as constant reminders of the household's flood risk. Recent flood events effectively raise people's awareness of potential flood risk (Fridgen & Schultz, 1999; Bin and Polasky, 2004).

Zeckhauser (2006) argues that patterns of framing and herd behaviour characterise economic responses to disasters, and describes the tendency for humans to commit JARring Actions – actions that Jeopardize Assets that are Remote. Catastrophic outcomes would occur when the cost of actions is imposed on others who are spatially or temporally distant. So, a world with a changed climate may be a very different place in terms of how people respond to risks. JARring Actions will continue but less so with respect to flooding because it will be a hazard once deemed remote and ignored, then remaining in sharp focus. People will not forget because the climate will not be permitted them that luxury and the bounce back effect will itself become a thing of the past.

### *Macro Feedback Loops*

Stern and others have detailed the potentially massive disruption to the global economy of a five degree rise in average temperature: "Human life would probably become difficult or impossible in many regions that are currently heavily populated, thus necessitating large population movements, possibly or probably on a huge scale. History tells us that large movements of population often bring major conflict." (Stern 2008, p.6; see GHF (2009) for an attempt to flesh out the human impacts of climate change, many of which are already apparent in many parts of the world).

The range of economic implications is beyond the scope of this paper to explore in detail. Needless to say, when projecting house patterns fifty to hundred years into the future (as is regularly the case in CLG Affordability Model estimates and Treasury forecasts), we must bear in mind that the world may be a different place then compared with now, particularly in terms of the stability of the international financial system and the prevalence of inter-continental migration. Both of these could have profound effects on UK housing markets through their affect on the availability of mortgage finance, insurance rationing, pressures on housing supply at the low end of the market and the demands placed on social housing provision.

## d) The Fallacy of Isolated Impacts

*The price of house A is reduced because it is flooded.*

*House B is not flooded.*

*Therefore, the price of house B is not reduced.*

This fallacy leads us to conclude that the effects of floods at one location will not have implications for locations that did not experience flooding. This is a spurious deduction because of spatial spillover effects. In the follow up survey of those who had moved away as a result of Hurricane Katrina, Paxson and Rouse (2008) found that 36 percent of those who had ***not*** experienced flooding had not returned to the New Orleans area. Clearly, therefore, it is not just the wellbeing of households directly experiencing floods that is affected. Those in surrounding neighbourhoods and communities are also likely to experience upheaval because of the impacts on infrastructure, supply chains, and access to amenities. Consequently, house prices of adjoining areas are likely to be depressed.

This uncovers an important methodological error in studies that compare the price of houses that were flooded with those that were not. There is an implicit assumption in this type of analysis that the houses that did not flood were immune to any house price effect. If, in fact, dwellings that did not flood were nevertheless subject to a negative price impact of the flood (due to spatial spillover effects), then the house price impact of the flood computed from such a simple comparison could greatly underestimate the true impact. This is essentially a failure to establish the counterfactual. To measure the impact of the flood, the trajectory of prices for flooded houses has to be compared with the trajectory that would have occurred if there had been no flood. Unfortunately, neighboring houses that did not flood may provide a poor guide to the latter trajectory.

An additional cause of spatial spillover effects may arise from households being imperfect informed about their own risk of flooding, and the impact of a particular flood event on these imperfections. If my neighbour's house floods but mine does not, it might nevertheless highlight the vulnerability my own house. Given the level of household ignorance of flood risk, there is considerable scope for a flood event to act as a stimulant to local awareness of flood risks. One might deduce, for example, that had a flood of slightly greater severity occurred, then one's dwelling would indeed have been flooded. A more severe event is less likely to occur than the one observed, so one might conclude that one's house is still less at risk than those flooded but that it is nevertheless subject to significantly higher risk than had previously been assumed. And the publicity and media coverage in the aftermath of such an event—stories of past floods, interviews with experts, publication of flood risk maps—will further reduce the gaps between assumed invulnerability and true flood risk. House prices the immediate vicinity and beyond will respond accordingly.

Hallstrom and Smith (2005) provide signs of such spatial spill-over effects, using data from Lee County located in the Florida Gulf coast, which just missed being hit by the 1992 Hurricane Andrew. The authors still found a 19% decline in house prices in floodplains as a result of the storm. Thus, studies which only compare house prices for flooded and non-flooded properties may underestimate the overall effect of a flood event in a housing market. It also means that house prices observed in the aftermath of a flood may be much closer to their true risk-adjusted price.

If dominos are sufficiently spaced, the impact of a falling domino can be treated as an isolated event. But with declining distance between tumbling dominos comes increased likelihood for cascade effects. So another important implication of spatial spillover effects is that that they can overlap if floods have occurred simultaneously in different locations in the same region. Under "normal" climatic conditions, the likelihood of such a coincidence may be remote. However, rising sea levels imply that all coastal areas and fluvial locations will be simultaneously experience an increase in flood risk, ceteris paribus. And for countries enclosed or largely enclosed by coastline, this implies the possibility of multiple flood hot-spots within single regions. Add to this the increased likelihood of extreme weather and storm surges, combined with similar patterns of urban development in different parts of a region, then chances of multiple floods occurring simultaneously in a single region may increase substantially. Overlapping spillover effects from multiple hot-spots of risk could imply spatial tipping points in areas caught in the intersection of concentric house price ripples. These spillover effects are therefore potentially vital to our understanding of the effect of climate change on the house price map of countries like the UK.

## 6. Conclusion

How can housing economics connect with climate change? One of the most potent aspects of global warming, for many countries, is the prospect of significant increases in flood risk. The intrinsic spatiality of flood risk, and the potential for house prices to reveal the money value of spatial variation in human welfare, indicate that housing economics may be uniquely placed to contribute to our understanding of the human consequences of climate change, and to help quantify the costs and benefits of intervention vs non-intervention.

Unfortunately, the housing economics literature on flood risk, as it stands, is written almost entirely under the implicit assumption of a stable climate. This is understandable, to some extent, and is not necessarily a criticism of the original studies. It does, however, raise two important issues. First, we must appreciate the fallacies associated with extrapolating from the results of this literature to the future implications of flood risk under the premise of global warming. Second, there is the issue of what changes are needed to this field of housing economics to facilitate more appropriate connections with climate change.

This paper described four fallacies that have the potential to distort our interpretation of the current literature when seeking to understand future risks. We labelled these: *the fallacy of replication* (the assumption that properties flooded in future will be the same as those flooded in the past), *the fallacy of composition* (the assumption that, because significant financial safety-nets are viable if a single area is flooded, equivalent safety-nets will be viable if all areas are flooded), *the fallacy of linear scaling* (the assumption that the negligible, transient effects of small and infrequent floods can be multiplied to give a measure of the impact of substantively more frequent and severe floods), and *the fallacy of isolated impacts* (the assumption that there are no spatial spillovers from the impacts of floods and that there is no overlap of impacts from multiple flood risk hot spots).

A step change is needed in how housing economics connects with climate modelling—new theoretical frameworks and estimation approaches need to be developed that yield estimates that rest on assumptions more aligned with the climate instability predicted. In particular, the four fallacies point towards the following areas where housing economics needs to develop in order to address the implications of meteorological projections:

1. Models of flood impacts need to differentiate the impacts of floods on different house types so that anticipated changes in the types of dwellings affected by future floods can be simulated.

2. Models need to be based on a paradigm incorporates the tendency for house prices to drift from their risk adjusted levels, and allow this tendency to change as floods become more frequent. Unlike other environmental effects, flood risk does not directly affect current utility. While hedonic methods are useful in measuring the effects of externalities that are current and persistent (such as air pollution – see Boyle 2001), the approach may not yield direct estimates of the impacts of risk. Bounded rationality and imperfect information mean that human decision making does not cope well with the prospect of uncertain loss. Also, house price dynamics will be fundamentally different in response to a flood event if it is perceived to be a one-off event, rather than a portent of inexorable rise in risk. The theoretical paradigm underpinning empirical modelling needs to shift from one that assumes perfectly informed, efficient markets to one that allows for amnesia, and myopia. One interpretation of the bounce-back effect, for example, is that it is evidence of these effects, rather than of genuine market resilience.

3. Models need to account for the fact that current insurance premiums may not fully reflect the risk of flooding, and that this arrangement may be neither desirable nor sustainable. Insurance provision and state safety nets may become very different in a world of frequent and severe flooding, so adjustments need

4. Models should attempt to trace out the non-linear nature of house price responses to floods of different severity and frequency.

5. The spatiality of flooding is fundamental to its effects and models need to allow for spatial spillovers and possible spatial tipping points.

From a public policy perspective, the foregoing discussion raises the prospect that the relatively modest negative effects on the house prices of floodplain locations in the medium term could be a portent of stilted and staccato adjustment to future changes in flood risk. Rather like the initial low cost of subprime mortgages to vulnerable homeowners in the US, the long-term effects of a benevolent outlook and subsidised insurance premiums could be calamitous. Using the current literature as a guide to the future costs of flooding could imply gross underestimation. Market prices are not just a guide for policy makers: they provide signals for commercial and household decision making. If current signals are misleading, governments may need to play in assisting market adjustment. A gradual shift towards full risk pricing, rather than a delayed, sudden one, is socially and economically desirable.

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**Table 1 A summary of empirical studies on flooding and house price**

| Studies | Year (Data) | Study areas | No. of properties | Methods | Flood variables | Other independent variables | Results |
|---|---|---|---|---|---|---|---|
| Zimmerman (1979) | 1970 | New Jersey | 226 | t-test | NA | NA | No significant difference between mean house value in and outside of the flood plains. |
| Babcock and Mitchell (1980) | 1974-1978 | Ontario US | 200 | Kolmogorov-Smirnoff Test | NA | NA | Flooding does not adversely affect house prices |
| MacDonald et al. (1987) | 1985 | Monroe Louisiana US | 217 | Hedonic approach | Dummies indicating locations in floodplain | Square feet of living area, number of bathrooms, air conditioning, fireplace, access to amenities | Flood plain location reduces house values by $2300 to $6200 |
| Skantz and Strickland (1987) | 1977-1981 | Houston Texas | 133 | Hedonic approach | Floodplain location | Square feet of living area, lot size, first mortgage guaranteed by government, month of sale, age, sold after rise of insurance rate | Flood plain location reduces property values by approx 4% |
| Tobin and Montz (1988) | 1986 | Yuba California US | 62 | Comparing average prices | NA | NA | House price declined by 17.7% immediately after the flood event but recovered with time. |
| Tobin and Montz (1989) | 1986 | Yuba California US | About 1,000 | Hedonic approach | Flood frequency and depth | House size, number of bedrooms and bathrooms, age, date sold, days on the market | Non-negative effect of flood frequency on price; positive relationship between price and flood depth |
| Speyrer and Ragas (1991) | 1971 to 1986 | New Orleans Louisiana US | 1998 | Hedonic approach | Flood zone in urban and suburban areas | Attributes and location, year dummies | Flood-prone location reduces property values by 4.2% in suburban areas and 6.3% in urban areas. |
| Bartosova | 1995- | Wauwato | 1431 | Hedonic | | Attributes (number of | Significant negative |

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| et al. (1999) | 1998 | -sa and Milwauke -e Wisconsi -n US | | approach | A continuous variable of flood risk derived by GIS measures | bedrooms and bathrooms, square footage, age etc.), neighbourhood characteristics (travel time to work, population density, income and poverty, home occupancy, racial composition), days on the market, tax rate, seasons and years. | relationship between flood risk and property values. But the magnitude of such effect is not uniform in a floodplain. |
| Bin and Polasky (2004) | 1992-2002 | Pitt County North Carolina US | 8375 | Hedonic approach | Floodplain location; houses sold after Hurricane Floyd | Attributes (age, number of bedrooms, new home etc.), dummies for townships, distances to the nearest creek or stream | Location in floodplain lowers average house sales price by 5.7%. This price discount doubled after the 1999 Hurricane Floyd. |
| Hallstrom and Smith (2005) | 1993-2000 | Lee County, Florida | 5212 | Repeat sales analysis | Location in FEMA floodplain | NA | Information acquired by buyers and sellers from Hurricane Andrew lead to a 19% decline in housing prices in flood zones. |
| Lamond and Proverbs (2006) | 2000-2006 | Barlby, North Yorkshire, UK | 159 (96 in flooded area) | Regression | Location in flood-zone interacted with years | Dwelling types (detached or not) | No significant long-term impact on property prices in the floodplain. In the short term, prices did not fall but failed to keep up with the growth in value of the rest of the market. After two years this shortfall dissipated. |

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| Bin and Kruse (2006) | 2000-2004 | Carteret North Carolina US | 4342 | Hedonic approach | Location in 500-year floodplain, in 100-year floodplain, and in 100-year floodplain subject to additional wave actions | Number of bathroom, property age, square meters, perimeter of property in meters, municipality, percent of nonwhite population, percent of owner-occupied homes, distance in meters to waterways, years, township | Location in a floodplain that is not adjacent to the coastal water lowers property values by 5-10%. However, location within a flood zone that is vulnerable to wave action is associated with higher property values. |
| Morgan (2007) | Jan 2000 – Feb 2006 | Santa Rosa County, US | 20,882 | Hedonic approach | Floodplain location | Attributes: age, age squared, floor size etc. | Positive effects of floodplain location, reduced but still positive effects of floodplain location after the major flood event Ivan. |
| Bin et al. (2008) | 2000-2004 | Carteret except barrier islands North Carolina US | 3106 | Hedonic approach through a spatial autoregressive error model | Dummies indicating location in 500-year floodplain, and in 100-year floodplain | Number of bathroom, property age, square meters, lotsize, new-home, post-FIRM properties, first row from coast-water, distance to waterways, distance to downtown city, distances to nearest highway and park, years, township | Price discount is significantly larger in locations with higher flood risk. Location within a 500-year floodplain lowers average property value by 6.2% ($9,849) whereas location within a 100-year floodplain lowers the average property's value by 7.8% ($12,325). |
| Pope (2008) | Jan-Sep 1995; Jan-Sep 1996 | Wake County North Carolina US | 15514 | Hedonic approach | Location in floodplain, interaction of location in floodplain and post disclosure act | Attributes such as number of bathrooms, age, fireplaces, garage, distance to waterway, census tract dummies | After the disclosure act, location in a flood-zone lowers house price by 3.8-4.5% ($5,434-$6,435). |