

THE IMPACT OF FLOODS ON HOUSE PRICES:

An Imperfect Information Approach with Myopia and Amnesia

Tuesday, 28 September 2010

Gwilym Pryce^a, Yu Chen^b and George Galster^c

^a Corresponding author; Urban Studies (School of Social and Political Sciences), University of Glasgow, Glasgow, G12 8RS; email g.pryce@lbss.gla.ac.uk.

^b Urban Studies (School of Social and Political Sciences), University of Glasgow, Glasgow, G12 8RS; email y.chen@lbss.gla.ac.uk.

^c Department of Urban Studies and Planning, Wayne State University, Detroit MI 48202 USA; email aa3571@wayne.edu.

Abstract

How will housing markets respond to increased frequency and severity of flooding expected with global climate change? Existing models yield poor predictions because they assume perfect information and rational decision-making processes in the housing market. This paper sets out a plausible alternative framework for analysing housing price responses to flood frequency and severity based on findings of behavioural economics and the sociology of risk, which emphasize myopic and amnesiac perceptions of risk. It utilises this framework to analyze graphically a variety of flood scenarios and their implications for housing prices and government intervention.

Acknowledgement:

This paper is based on work from the EPSRC funded CREW (Community Resilience to Extreme Weather) project. We are grateful to Jessica Lamond, Eric Levin, members of the CREW team and anonymous referees for useful comments. Any remaining errors are, of course, our own.

Introduction

Being able to predict the house price impacts of floods is important for at least three reasons. Firstly, spatial variation in the price of a unit of housing services can, in principle, reveal the money value of the welfare loss associated with vulnerability to flooding. Given that the cost of insurance claims may understate the total impact of floods on human wellbeing¹, there is a potentially important role for housing economics in weighing up the costs and benefits of potential interventions. Following a decade of major floods across the world, assessing the case for such interventions has become a major policy concern (Pitt, 2008). These concerns will further rise given a growing scientific consensus that climate change is expected to amplify the prevalence and severity of flood risk, due to changes in winter precipitation, sea levels, storm surges, and extreme weather events (Foresight, 2004; Stern, 2006, 2008; IPCC, 2007; Houghton, 2009).

Secondly, housing is a major source of collateral for the financial system. Being able to simulate house price impacts may therefore help reveal the true exposure of financial institutions to future flood risk. The US subprime crisis has illustrated the vulnerability of the world financial system to the changes in the value of real estate in specific locations, and so an important implication of growing flood dangers is the wider destabilising effect that unanticipated house price declines could have.

Thirdly, fragility and poor performance of pension funds has encouraged many households to make housing their major source of saving for retirement. The potential for floods to wipe-out housing wealth accumulated over a person's lifetime is of particular concern in societies where there are high rates of homeownership and of households with undiversified portfolios (Cauley *et al.*, 2007).

¹ Some households are uninsured and there are emotional and health effects not covered by insurance policies.

Despite the importance of predicting how floods will affect housing prices, the housing economics literature has made an inadequate contribution because its models have been built on assumptions about efficient markets and rational decision makers. Unfortunately, these assumptions are at odds with the literatures on behavioural economics and the sociology of risk, as we shall demonstrate.

This paper responds to this shortcoming by developing a new framework for modelling the housing market response to flood dangers that is founded upon myopic, amnesiac risk assessment by housing market actors. After a brief summary in the next section of the theoretical and empirical studies on flooding and house prices, we endeavour in the third section to distil the key insights from the literatures on behavioural economics and the sociology of risk into four propositions that provide the foundation of our framework. In the fourth section we analyze diagrammatically a variety of flood scenarios to illustrate the usefulness and provocative implications of our framework. Finally, we discuss our approach could provide a sounder housing economic analysis of flood risk under a changing climatic regime and thus a more appropriate basis for future policy interventions.

Existing Literature about the Effect of Floods on House Prices

The long-dominant neoclassical paradigm in housing economics for conceptualizing the relationship between house prices and environmental disamenities has been hedonic theory (Rosen, 1974; Harrison *et al.*, 2001). Hedonic theory implicitly assumes that the household will choose a dwelling that maximises expected utility, wherein the various attributes of the dwelling and environs are assessed in evaluating utility. The rational decision maker should be willing to pay a premium to avoid flood hazards, the amount depending on the perceived expected value of utility lost from floods. This differential premium across

properties varying in their flood hazards should be fully capitalized into house prices insofar as information about the frequency and severity of flooding associated with each location is accurate and widely known (MacDonald *et al.*, 1987).² Thus, with the exception of transitory post-flooding price reductions while homes are being repaired, the hedonic approach would predict no temporal variation in home prices and flood occurrences in an efficient market.

Tobin and colleagues (Tobin & Newton, 1986; Tobin & Montz, 1994) contributed an important advance by arguing that utility reduction from flooding (and thus home price) depends on the spatial, temporal and hydrological aspects of the flood. They suggested that there are different temporal profiles depicting flood impacts on home prices, depending on how often floods occur compared to the time required to restore the property to pre-flood utility. At one extreme with rare flooding, house prices fall immediately after a flood event and then recover fully after repairs and remain at this higher level until the next rare flood. In this case, over the long-term, neither past nor prospective flood damages are capitalized. At the other extreme with flooding occurring so frequently that housing utility has insufficient time to recover much if at all, house prices remain low. In this case, flood damages have been almost completely capitalised into house prices *ex post facto*. Cases of intermediate flood frequencies yield in their formulation an inter-temporal housing price pattern with incomplete and imperfect capitalization of flood damages.

Though the Tobin *et al.* approach offers a useful perspective, it is under-developed. First, their model appears to assume no market foresight regarding floods, hence prices capture only actual losses of utility, not future risks. Second, their model does not distinguish between risk-adjusted house prices and observed (actual) house prices or their interrelationship, yielding two additional ambiguities. Firstly, it is unclear whether the price

² Even the presence of (unsubsidized) flood insurance should not upset this efficient market outcome, because the differentials in premiums required holding consumers harmless from flood risk should themselves be perfectly capitalized into housing values.

fall following a flood described in their model is due entirely to the physical damage to the property or because of inadequate capitalisation. The former allows one to retain the neoclassical assumption that risk-adjusted prices do not diverge from observed prices, while the latter assumes that observed prices drifted away from their risk-adjusted levels prior to the flood. Secondly, their model suggests that capitalisation occurs if frequency of flooding is sufficiently high, yet it is not clear whether this means that the housing market is perfectly informed (expected costs of rare floods are so infinitesimally small that the house price effect is indistinguishable from zero) or *imperfectly* informed (frequent floods are necessary to remind residents of the future risks).

Neither the hedonic nor the Tobin *et al.* approaches offer convincing explanations for the findings of the statistical and survey literature. Some statistical studies have found that home prices are discounted for substantial periods in locations with high flood risks (Barnard, 1978; Donnelly, 1989; Speyrer & Ragas 1991; Bartosova *et al.*, 1999; Harrison *et al.*, 2001; Bin *et al.*, 2008). Other studies have observed negligible price effects (Zimmerman, 1979; Bialaszewski & Newsome, 1990). Nevertheless, a consensus has been reached that a price discount due to flood risks, if any, is greater after a flood than before (Bartosova *et al.*, 1999; Eves, 2002; Bin & Polasky 2004). Proponents of the efficient market models may suggest that this finding only reflects transitory adjustments while repairs are underway on damaged properties. Indeed, several studies have suggested relatively rapid rebounds of housing prices in the wake of floods (Babock & Mitchell, 1980; Montz, 1992; Lamond & Proverbs 2006). We think it more plausible to posit that these findings indicate imperfect capitalization due to imperfect risk assessment, as a flood informs people about true flood risks.

Our interpretation is buttressed by survey findings showing that a large proportion of households are ignorant of flood risk, particularly when floods have not occurred for

some time. Homeowner surveys in Boulder, Colorado, for example, revealed that the majority of homeowners in the floodplain lacked information of flood risk when they bid for a house, and 70% of respondents said they would have lowered their bid if they had known the actual cost of flood insurance (Chivers & Flores, 2002). In the UK, the Environment Agency/DEFRA 2004 survey of households in areas flooded in 1998 and 2000 found that, before the floods occurred, only 24 per cent of households were aware of the risk of flooding (Burningham *et al.*, 2008). Further, the 2005 British Market Research Bureau survey estimated that, 41 per cent of the five million people in two million properties in England and Wales that live in flood risk areas were unaware of the flood threat (BMRB, 2005).

The Literature on Myopic, Amnesiac Decision Making

We need a new theoretical perspective to make sense of the existing evidence, a perspective that takes a less naive view of how humans assess the risk of natural disasters. Two literatures are of particular relevance to this enterprise. First, the behavioural economics literature has shown how aspects of individual decision making deviate from the conventional neoclassical economic model. Second, the sociology of risk literature has demonstrated the role of institutions and social forces in exacerbating and concealing perceived risk. We argue below how insights from these two bodies of work lead us to expect that housing market actors will assess flood risk on the basis of:

(a) *Myopia*—discounting information from anticipated future events, with the discount rising progressively as the event becomes less imminent; and

(b) *Amnesia*—discounting information from past events, with the discount rising progressively as time elapses.

Myopia and amnesia mean that perceived risk can diverge considerably from actual risk, particularly if a long period has elapsed since a local flood has occurred. This in turn means that *observed* home prices may diverge from *zero-risk* prices and truly *risk-adjusted* prices for an extended time, concepts that have not been previously distinguished in the existing housing economics literature on flooding. Moreover, we will argue that in a regime of climate change we are likely to witness two important tendencies:

(c) *Contingency*—the tendency for myopia and amnesia to diminish in housing market importance as floods become more frequent and information and communication technologies improve, thereby leading to a (non-linear) convergence of observed and risk-adjusted home prices; and

(d) *Path Dependency*—the tendency for the convergence path of observed home prices towards risk-adjusted prices to be idiosyncratic, contingent on the sequence of flood experiences in each area.

Consider now the rationale behind each of these four propositions that constitute the foundation of our framework and our contribution to advancing scholarship in this realm.

Proposition (a): Housing market response to flood risk will be characterised by myopia

There are four main reasons why we expect individuals to discount information regarding the future. First, there may be a negative relationship between temporal distance and the perceived salience of information. As empirical support, DellaVigna & Pollet (2007) found little statistical relationship between stock returns and predictable demographic changes arising from cohort effects, suggesting shortsighted market information and capitalization. DellaVigna (2009, p.352) concludes that stock returns across a variety of industries are “consistent with inattention to information further than approximately five years into the future. ... information that is further into the future ... is less likely to be salient.”

Interviews conducted by Burningham *et al.* (2008) concluded that future flood risks were “invisible” (to use Beck’s 1992b terminology) and thus dismissed. Hence, we might expect predictions of rising flood risk five, ten or twenty years into the future to be met with inattention and as a result, future flood risk may have little perceptible impact on current home prices.

Numerous theoretical formulations of human decision-making have reached similar conclusions regarding information salience declining with temporal distance. Tversky & Kahneman (1973) highlight the importance of “availability heuristics” in shaping perceptions of risk. “[A] person is said to employ the availability heuristic whenever he estimates frequency or probability by the ease with which instances or associations could be brought to mind” (Tversky & Kahneman, 1973). An individual may assess the likelihood of an event as higher when examples come to mind more readily because such examples provide an availability heuristic. Unusual events in the distant future may be more difficult to imagine and identify with, and therefore will have little effect on current perceptions of risk. Others have formulated this phenomenon as “self attribution bias,” defined as the “tendency to discount information that is inconsistent with one’s priors” (DellaVigna, 2009, p.343). One’s priors are fundamentally shaped by lived experience (Allen, 2009), which may then cultivate “mental inertia,” the behavioural tendency to resist extrapolation (Kousky *et al.*, 2008). This over-reliance on experience helps explain why 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). Kousky & Zeckhauser (2006) argue that such patterns of framing and herd behaviour characterise economic responses to disasters, and lead humans to commit JARring actions—actions that Jeopardize Assets that are Remote.

A second explanation for myopia—not unrelated to the first—is the nature of the information itself. Because data on the future arise almost exclusively from statistical forecasting models produced by institutional information providers indistinguishable from the power structures that exert social control, the response of individuals may be to associate climate predictions with attempts by vested interests to exert power. Indeed, institutionalised scientific knowledge may be seen as much the cause of disasters (and of inadequate preparation for and response to them) as the solution. In this view of the world, scientific and institutional organisations “obscure the link between their generation and control of risks, and can counter prevailing mandates, thereby exacerbating rather than reducing risks” (Williams, 2008, p.1117). Hence, individuals have become “more cynical about science, politics, business and the media” (Williams, 2008, p.1117).

That individuals appear all too willing to accept conspiracy theory explanations of the data rather than acknowledging the spectre of climate change is ostensibly confirmed by a recent UK BBC opinion poll commissioned in February 2010, which asked respondents whether they agreed with the statement, “Climate change is happening and is now established as largely man-made” (BBC, 2010 p.1). Since the previous poll in November 2009, a major scandal regarding leaked emails between climate scientists had received extensive media coverage in the lead up to the Copenhagen Climate Conference in December 2009.³ Only 26% of respondents in the February 2010 poll said they agreed, down from 41% in November 2009. Those who believed either that “Climate change is happening, but it is environmentalist propaganda that it is man-made” or that “Climate change is not happening” had risen from 23% to 35% in three months.

Alternatively, public myopia may occur as a result of the failure of institutions themselves to acknowledge and communicate the true risks of climate change. “In

³ The leaked emails were interpreted by climate change sceptics as evidence that data on global warming had been manipulated, and led to Professor Phil Jones of the Climatic Research Unit at the University of East Anglia stepping down pending an enquiry (see Jha 2009).

situations of high uncertainty, organizations deploy science and technology in combination with a misplaced faith in their capabilities (including presumed infallibility) so as to redefine risks as more manageable and acceptable” (Williams, 2008, p.1117, summarising the work of Tierney 2006). Similarly, individuals may have misplaced confidence in the role and ability of governments to provide technical solutions or maintain coastal and flood defences (Wales Audit Office, 2009).

A third set of explanations for myopia relate to limitations of human cognition and/or the costs of cognition. Climate models are highly technical and their outputs are probabilistic. Human intuition has not evolved to facilitate absorption of such information and so there may be innate human inability to respond appropriately to data couched in terms of density functions and contingent scenarios. Psychological studies show that “attention is a limited resource” (DellaVigna, 2009, p.349). As a result, humans respond to complex problems by “processing only a subset of information” and by employing “simplifying heuristics” (DellaVigna, 2009, p.349). Rather than devising a rational response strategy which requires negotiating the complex decision sequences and cost/benefit calculations implied by probabilistic climate change scenarios and associated mitigation and adaptation strategies, individuals may tend towards caricatured extremes, flipping between denial of the risks and the fatalistic polar view that rising temperatures are unstoppable. Note that both viewpoints render behavioural change pointless. Such responses may be a form of cognitive dissonance—an attempt to rationalize past or planned decisions about house purchase and consumption choices.⁴ Rather than acknowledging the existence of growing flood risk, and the implication that it was a mistake to purchase a dwelling on a flood plain and then taking corrective (if costly)

⁴ The dissonance arises from the apparent conflict between the belief that a person has made the right decision to purchase a house on a flood plain and the scientific evidence to the contrary.

action, owners may deny the evidence that flood risks are increasing, resorting to conspiracy theories and climate scepticism to disregard evidence to the contrary.

Finally, myopia may be caused by “framing effects.” House purchase decisions do not occur in a vacuum, nor are they confined to the sterile conditions of pure financial calculation. Acquiring a home is an emotional process fused with hopes, ambitions regarding status, and imagined lifestyle aspirations. Houses become extensions of our personality, symbols of achievement, and places where memories are made and preserved. They are objects of affection, sentiment, and symbolism. These frames are reinforced by the media portrayal of what the habitats of the successful look like (Lorenzo-Dus, 2006). Estate agents attempt to exploit these frames in their marketing (Pryce & Oates, 2008). Compared to this heady mix of emotion, aspiration and symbolism, the dangers of future flooding wield little influence on the present task of home acquisition and pricing.

Proposition (b): Housing market response to flood risk will be characterised by amnesia

The counterpart of future temporal distance is the declining salience of information from the past. Similar explanatory arguments therefore apply. For example, as recollection of a flood experience decays over time, construction of an Availability Heuristic based on that event becomes more difficult as memories fade.

One way to characterise this memory loss is in terms of non-Bayesian updating where individuals overweight information from the present. As households weigh recent flood information more heavily than aged floods, they will overestimate the risks of flooding in the immediate aftermath of a flood, but their perceptions of risk decline rapidly as the months pass with no repeated flood event. This could be viewed as a variant of the “Law of Small Numbers” (Tversky & Kahneman, 1971; DellaVigna, 2009, p.344), where

individuals are essentially basing their risk estimates on an overly small sample of (current) time periods.⁵

An important distinction in the context of the amnesia proposition is the difference between *market* amnesia and *individual* amnesia. Market amnesia can occur even when individuals have intact memories, due to the existence of private information asymmetries. For example, owners of recently flooded houses may be perfectly aware of the flood risks but potential buyers coming from outside the area may not be: “The ability to recognise and read such clues takes time and is a skill that new residents in particular are likely to lack” (Burningham *et al.*, 2008, p.235). “For the community as a whole, turnover of property will ensure that the average experience with flood will also decline with time. The rate of forgetting will vary with the stability of the local area” (Lamond & Proverbs, 2006, p.366). Information asymmetry may be exacerbated by owners and real estate professionals who conceal flood risks in an attempt to allay stigmatisation of the neighbourhood and the consequent reduction in home prices. In a study of floods in Lully, Geneva, November *et al.* (2009, p. 192) observed that “[N]ew residents were easily convinced by the promoters, the architects, and indeed the authorities, who described the basement flooding of the partially built houses in 2001 as a one-off event.” Perversely, amnesia may be exacerbated by the interventions of public institutions. Decisions by local authorities to award planning permission on flood plains may act as signals of reduced flood risk, and protection measures introduced to reduce risk may give a false sense of security. November *et al.* (2009, p. 191) found“... the [Lully residents’] memory of the risk and all its various components seems to have been lost due to the adoption of successive protection measures...”.

⁵ Tversky & Kahneman (1971) originally formulated the “Law of Small Numbers” to describe the tendency of individuals to exaggerate how likely a small sample is to be representative of the parent population. For example, “people exaggerate the likelihood that a short sequence of flips of a fair coin will yield roughly the same number of heads as tails” (Rabin, 1998, p.25).

Proposition (c): Myopia and amnesia will diminish in housing market importance as floods become more frequent and information and communication technologies improve, thereby leading to a (non-linear) convergence of observed and risk-adjusted home prices

The degree to which myopia and amnesia are important determinants of choices and risk assessments is endogenous, contingent on the frequency and severity of flooding and therefore on wider climatic determinants. As the planet warms, myopia and amnesia influences will evolve over time in potentially non-linear ways, heightening the non-linear adjustment of house prices to changes in flood risk. It is thus somewhat ironic that we argue through propositions (a) and (b) that massive housing market inefficiencies arise currently in how homes endangered by floods are priced, that the source of these inefficiencies will wither as climate changes progress. We should not be misinterpreted as implicitly advocating a *laissez faire* strategy of “wait for the long run when the market will work well again,” because the long run probably constitutes an intolerably extended period during which wrenching dislocations and major private and social costs will be incurred during the adjustment, as we shall explain below.

We have argued that, markets tend to forget previous flood experiences as time passes. When a flood occurs, people are reminded of the risk and awareness rises, not only for the average individual but also for the market as a whole (Bin & Polasky, 2004). Even those not affected directly will experience heightened awareness. We can think of the flood as providing the missing Availability Heuristic, and leading to what November *et al.* (2009, p. 189) term the “Lully Effect”—“how a critical event can refocus attention on known but partially forgotten hazards, encouraging people to think about why such risks had been forgotten in the first place, and helping to foster a more concerted effort to manage flood risk in the future.”

Crucially, as the planet warms and floods become more frequent and severe, households will be presented with a readily available heuristic through media accounts and images, and through their own recurrent experiences of floods. Amnesia rarely has time to take hold in such a world. Moreover, one might reasonably speculate that the future will be characterised by improved information and knowledge transfer that will reduce myopia. We know already that, “analysis of lay knowledge of flood risk ... points to the importance of visual clues (including the height of the water) in local assessments of risk.” (Burningham *et al.*, 2008, p.235). Society may be able to find ways to exploit the ergonomics of human knowledge by creating flood risk mnemonics, “making flood risk locally visible, for instance by marking the level of past flood waters on prominent buildings” (Burningham *et al.*, 2008, p.235). Both amnesia and myopia will then decline as the prevalence, severity, and mediated visibility of floods increases in the future.

Major floods can also be a catalyst for institutional change and a coordinating effect on disparate sources of knowledge that lead to improvements in the recording and awareness of risk. November *et al.* (2009, p. 193) note how the Lully flood was the “...driving force behind a restructuring of local government departments, including the creation of a new post specifically to scrutinise planning applications in order to assess the likelihood of associated flood risks.” They also demonstrate how those possessing scientific and observational knowledge were brought into contact for the first time, yielding a collective experience that was “committed to memory, both in the minds of individuals and in the relevant political, technical and administrative bodies” (November *et al.*, 2009, p.194). This evolution of knowledge is unlikely to occur as a smooth, linear transition, but one punctuated by the catalysing effect of major catastrophes. As further developed in the next section, we are therefore likely to observe a pattern of inertia in observed home prices

followed by tipping points to convergence with risk-adjusted prices as the symptoms of climate change become sufficiently local to permeate knowledge, forcing individuals and markets to embrace the risks long projected by meteorological models.

The non-linear nature of this home price adjustment process may be heightened by “institutional time inconsistency”—charity hazards associated with false assumptions about government protection and the moral hazards of complete insurance markets will be revealed for what they are. If government is assumed to provide full compensation in the event of a disaster and/or current home insurance premiums do not reflect the true risk of floods, there is little incentive for home buyers and sellers to assess flood risk accurately. Observed prices can drift widely from fully risk-adjusted prices under such circumstances. Indeed, it is still the case in countries such as the UK that home insurance companies may not fully price flood risk (Green & Penning-Rowell, 2004; Crichton, 2005). In other words, households in low-risk areas effectively cross-subsidise those located in high-risk areas. This arrangement is not sustainable, however, in a future characterised by climate change because the system is vulnerable to systematic risks; it only persists because floods remain relatively infrequent and independent (Green & Penning-Rowell, 2004). The “social compact against industrially produced hazards and damages, stitched together out of public and private insurance agreements” (Beck, 1992a, p.100) will eventually collapse as ecological threats “exceed the usual mechanisms of assessment and regulation, and become uninsurable” (Williams, 2008, p. 1123).

Already insurers in the UK have not guaranteed insurance cover for homes built on flood plains since 2009 with the probability of being flooded in any single year higher than 1.3% (DEFRA, 2008). As flood risk increases in severity and ubiquity, insurance rationing is likely to become more prevalent. This has major implications, even for households willing to accept the loss and inconvenience of flooding, because mortgage lenders may

refuse to offer mortgage finance for uninsurable homes in high flood risk areas. The risk of insurance rationing is likely to increase the likelihood of credit rationing, and even if neither are a problem at the point of purchase, the prospect that such a scenario may be binding in future means that the buyer faces the risk that they will have problems upon resale. As insurance rationing spills over into mortgage rationing, house prices will adjust rapidly and decisively. And one might anticipate the changes to occur even in advance of an area being red-lined. As soon as there is uncertainty about future insurance and mortgage provision for an area, one would expect prices to be affected as buyers contemplate not being able to sell their homes or not making the capital gains they hope for. Current policies to encourage subsidised (as opposed to full-cost) insurance may therefore unwittingly exacerbate or initiate a future tipping-point effect in home price adjustment to flooding wrought by climate change.

In summary, that myopia and amnesia are endogenous leads to the possibility of tipping points occurring in home price adjustment. This may occur either as a result of increased knowledge due to greater frequency and severity of floods, or due to changes in the availability and cost of insurance. These effects are neither mutually exclusive, nor independent. For example, a shift in insurance premiums towards the true risk of flooding will provide a very powerful market signal of flood risk. So, insurance trajectories and market information trajectories will be closely intertwined, leading to a pronounced future tipping point in home price adjustment.

Proposition (d): The convergence path of observed home prices towards risk-adjusted prices will be idiosyncratic, contingent on the sequence of flood experiences in each area

“Recently experienced floods appear to set an upper bound to the size of the loss with which managers believe they ought to be concerned” (Kates, 1962, p.140). Stated more

formally, Tversky & Kahneman (1973) argue that updating of risk in the aftermath of an event is much greater when starting from zero perceived risk—what Kousky *et al.* (2008) call “virgin risk”—than when starting from a perceived risk that is greater than zero—i.e. “experienced risks”. The implication here is that, those who have recently experienced relatively minor floods may, somewhat perversely, be inoculated against recognising the significant increases in the severity and frequency of floods implied by climate change, particularly when these increases are incremental. For such individuals, a growing gulf can occur between perceived risk (and hence perceived market values of homes) and the actual risk (and risk-adjusted prices). This implies that path dependency may be intrinsic to the way that observed home prices adjust to the growing threat of floods.

Consider two identical geographic areas, i and j , both subject to an identical, rising trajectory of flood risk. While the probability of flooding in these two areas is identical on any given day, the pattern of actual flood events will be different because of random variation. This means that, if area j experiences a minor flood event in time period 1 followed by a long period (T) without floods, home prices may not only recover but have an increased resistance to official pronouncements of increased flood risk, compared to area i where a major flood event occurs during the same period. Observed home prices in area j may therefore drift higher above their risk-adjusted levels than they do in area i . Nevertheless, observed prices in both areas will eventually converge to their risk-adjusted levels as floods become sufficiently frequent to prevent amnesia and myopia from having a material effect, though the convergence will be more cataclysmic in area j .

A New Framework for Understanding the Impacts of Floods on Housing Prices: A Diagrammatic Exposition

In this section we advance the conceptualization of flood impacts on home prices beyond hedonic theory and that of Tobin *et al.* by emphasizing the relationship between risk-adjusted house prices and observed (actual) house prices and how market assessments of the former are influenced by endogenous amounts of myopia and amnesia, following the propositions developed in the prior section. We illustrate our framework in diagrammatic expositions of alternative scenarios regarding the frequency and severity of flooding. We do not develop here a rigorous theoretical or econometric model, but hope to do so in future work.

The Effects of Myopia and Amnesia on Patterns of Home Prices and Perceived Flood Risks in an Area of Rare, Frequent, and Increasingly Frequent Flood Regimes

As a point of departure we portray the pattern expected in a geographic area with an efficient housing market, distinguishing between risk-adjusted home prices (P_{RA}), zero-risk prices (P_{ZR}) and observed prices (P_A).⁶ Figure 1 illustrates how flooding (at times t_{F1} and t_{F2}) would have only a temporary impact on observed home prices (P_A) in a particular area if market valuations were already fully risk-adjusted across locations with a non-zero flood probability (P_{RA}) and zero flood probability (P_{ZR}). The occurrence of a flood does not affect the probability of future floods, so the value of a home is not diminished by a flood, other than through a temporary reduction in quality while repairs are completed.

[Figure 1. Fully Risk-Adjusted Prices and Short-Run Responses to Flooding]

⁶ Throughout we assume that all prices are adjusted for any changes in quality of the dwelling parcel.

In the world of imperfect information, however, different patterns emerge. We now provide a diagrammatic application of our framework to consider the temporal pattern of home prices in a particular area under three alternative regimes of flooding: rare, frequent, and increasingly frequent, assuming that all floods are of equal severity.⁷

In the regime of rare floods, it will be likely that myopic, amnesiac market actors will dominate at a given time. As shown in Figure 2, P_A in this regime will drift away from P_{RA} towards P_{ZR} as the years pass since the last flood at t_{F1} . Then, when a flood occurs at t_{F2} , actors become aware of the true flood risk and P_A quickly adjusts downwards towards P_{RA} . If myopia were particularly strong and the local media particularly sensationalist in their exaggeration of future flood risk, actors may *overestimate* risks in the immediate aftermath of a flood. If so, this could produce a fall in P_A below P_{RA} in excess of that associated with short-term damage repairs.

[Figure 2. House Prices with Amnesia and Myopia: The Case of Infrequent Floods]

In the case of an area that floods frequently, the difference between P_{ZR} and P_{RA} is greater than for a low-risk area. Of more interest, P_A may rarely deviate significantly from P_{RA} because floods occur often enough to remind actors of the true risks. Thus, on average, the difference between P_A and P_{RA} is lower here than for a low-risk area and the bias of $P_A > P_{RA}$ is less (See Figure 3).

[Figure 3. House Prices with Amnesia and Myopia: The Case of Frequent Floods]

Finally, consider in Figure 4 the regime of increasingly frequent floods wherein P_{RA} falls over time, instead of remaining constant as previously. In this case, P_A drifts from

⁷ The impacts of flood severity will be discussed below.

P_{RA} following a similar trajectory to that which occurs in a world with constant flood risks. When a flood occurs, P_A adjusts sharply not only to the risk that characterised the market at the time of the previous flood t_{F1} , but to the new, higher risk. The increased frequency of floods constrains the drift of P_A away from P_{RA} , but myopia means that P_A are always drifting due to perpetually out-of-date flood risk estimates.

[Figure 4. House Prices with Amnesia and Myopia: The Case of Increasingly Frequent Flood]s

The Effects of Myopia and Amnesia on Patterns of Home Prices and Perceived Flood Risks Across Areas

The prior section considered how housing prices would respond over time to floods in a particular geographic area characterized by a particular flood risk regime. Here we consider the aggregation of these price patterns at a given time across areas of differing flood risks.

In general, we would expect to find a non-linear relationship between *average* home prices (signified by \underline{P} hereafter) and flood risk at a given time when measured across a large cross section of areas (see Figure 5). For sake of simplicity, it is based on a *linear* relationship between the *average risk-adjusted* price across areas, \underline{P}_{RA} , and probability of flooding, ϕ . Other things being equal, when the risk of flooding is low at ϕ_1 , the *observed* average house price, \underline{P}_{A1} , is virtually indistinguishable from the observed price when flood risk is zero (ϕ_0), P_{ZR} , as explained in Figure 2 the context of a single area. In moderate-risk areas like at ϕ_2 , the associated average prices observed \underline{P}_{A2} will be somewhat less than P_{ZR} but nevertheless diverge substantially from \underline{P}_{RA} , due to myopia and amnesia effects, as explained above in the context of Figure 3. In areas of higher flood risks ϕ_3 , \underline{P}_{A3} converges towards \underline{P}_{RA} because, as the frequency of flooding rises, the amnesia effect is

reduced. So, the difference between \underline{P}_{A2} and \underline{P}_{A3} average house prices observed across areas with low and high flood risk, respectively, is comparatively large. In the extreme, ϕ may grow so large that $\underline{P}_A = \underline{P}_{RA}$.⁸

Figure 5 holds important implications. First, consider areas currently experiencing low flood risk but in the near future will experience significantly increasing flood risk. In these places, average house prices will at first only slowly diverge from continuing low-risk areas, but then more rapidly as floods become more frequent. Second, the curvature on the observed average price \underline{P}_A graph in Figure 5 is crucial. A curve similar to that of (a) in Figure 6 implies a rather orderly adjustment trajectory for observed house prices. \underline{P}_A will steadily adjust downwards as flood risk rises, allowing for a relatively gradual and panic-free market accommodation. If, however, the adjustment curve is more akin to that of (b), then there may be severe and unpredictable tipping points where prices in particular areas suddenly collapse.

[Figure 5. Hypothesised Relationship between Mean House Price Across Areas at Time t and Flood Frequency, ϕ]

[Figure 6. Potential Tipping Points in the Updating Process of Average Housing Prices]

⁸ If Myopia and exaggeration of future risks were particularly strong in the aftermath of floods in a frequent-flooding regime, observed average prices might conceivably overshoot and thus fall below risk-adjusted prices for a certain range of flood frequency.

Adding a Third Dimension: Flood Severity and Path Dependency

So far, our expositions have assumed floods of a given severity. There are, however, profound implications when we permit varying flood depth. We depicted the relationship between risk-adjusted prices and flood frequency as a straight line in previous diagrams, to highlight the discrepancy between observed and risk-adjusted prices. In reality, it is likely that \underline{P}_{RA} will themselves have a non-linear relationship with flood risk.

The costs of infrequent floods of a given severity are likely to be low as the effects are unlikely to affect the daily lives of residents and the benefits of living in an area. Lamond & Proverbs (2006) note that 91% of respondents in Lewes were satisfied with their area of residence despite of their awareness of flood risk and unavailability of further flood defence; and fewer than half of flood victims would consider moving away. As floods of a given severity become more frequent, however, impact on quality of life is likely to increase at a disproportional rate. The marginal impact on wellbeing beyond a certain level of frequency will then perhaps decline as regular flooding becomes a fact of life. One might anticipate a similar pattern of effects with regard to flood severity: for a given level of frequency, the marginal risk-adjusted house price impact will be small, then increase, and then perhaps decline, with the rise of flood severity.

We have tried to represent these effects in the slopes of the three-dimensional surface of Figure 7, which depicts the relationship between risk-adjusted house prices \underline{P}_{RA} , flood frequency ϕ and flood severity s . Note that we have omitted \underline{P}_A and plotted only \underline{P}_{RA} (one could imagine \underline{P}_A as an additional surface lying above the \underline{P}_{RA} surface for the most part, touching only at the vertical axis and at the extremities of severity and frequency).

Figure 7 also shows how a particular flood, x , of frequency ϕ_x , can be represented as a vertical segment of this surface. The varying depth of the flood across different neighbourhoods allows us to trace out a range of severity levels from a single event. We

could also use the diagram to show how two floods of equal severity would have very different home price impacts depending on their estimated frequency (e.g. \underline{P}_{RA} will be much lower if one expects to be flooded to a depth of two metres once every other year than if one expects to be flooded to a depth of two metres once every thousand years).

Any one flood may not, however, reveal a full spectrum of severity across space because the maximum severity may be limited, and so it may be that only a portion of the line segment can be plotted for a particular flood. We have highlighted this as the “observed range of severity from flood event x ”. With projected climate change, we would expect to observe more floods at the higher frequency portion of the surface and for an increasing proportion of those floods to display a wide spectrum of severity.

[Figure 7 Risk-adjusted Prices and the Severity and Frequency of Floods]

As noted above, the severity of floods also has implications for path dependency of \underline{P}_A because market adjustment in an area that experiences a flood of low severity may perversely be hindered by the false sense of security that such a flood induces. We can represent this by redrawing Figure 4 (see Figure 8) to include the observed price trajectory of a second area j which is identical to area i in every respect, including its propensity to flood and its \underline{P}_{RA} . However, because areas i and j experience a different sequence of flood event severity, their \underline{P}_A trajectories can diverge considerably. Area j in Figure 8 experiences a minor flood at t_{F1j} and a long period without floods. This causes the risk perceptions of actors to become disconnected from the growing flood risk and declining \underline{P}_{RA} . Even though areas i and j have identical trajectories for \underline{P}_{RA} , their observed prices may be considerably different for a time. A severe flood in area j at t_{F2j} , however, brings abrupt price adjustment.

Eventually, \underline{P}_A in both areas will converge to their common \underline{P}_{RA} as climate change progresses.

[Figure 8: Path Dependency in Observed House Prices for Identical Areas, i and j]

Implications

In this section we consider the implications of our framework for the interpretation and construction of house price models, and for government policy.

Implication for the Interpretation and Construction of House Price Models

The first implication is that our framework provides an alternative interpretation of post-flood recovery of homes. Rather than showing market robustness to flooding, the bounce-back phenomena may be indicative of market myopia and amnesia with potentially worrisome implications for the long-term adjustment process. Our framework also suggests empirically testable hypotheses for assessing market efficiency in flood pricing. In an efficient market, home prices in a locality should decline only slightly for a short period following a flood, regardless of the time since the prior flood. In an myopic-amnesiac market, home prices in a locality should decline substantially and for an extended period following a flood.

Secondly, our analysis suggests that the price declines in the aftermath of a flood are not informative in terms of helping us assess the impacts of climate change—they merely reveal the extent of drift from risk-adjusted price. Such estimates of price declines are of little use, however, in gauging the long-run impacts associated with global warming. This is partly because the height to which prices rose prior to the flood event are partly dependent on the severity of the previous flood (due to path dependency—see Figure 8) and the time

elapsed since that flood (amnesia). Moreover, in the event of climate change that leads to increasingly frequent floods, *convergence* will make such temporary gulfs between observed and risk adjusted prices will become a thing of the past—myopia and amnesia will desist. This implies that current post-flood price bounce-back effects may tell us little about future welfare impacts. Similarly, the relationship between observed house prices and flood risk will be of little consequence because the meaning of those observed prices will be ambiguous unless they are observed soon after a flood.

A third implication of our framework is more promising for housing economic research. Because memories are fresh and publicity is pervasive in the aftermath of a flood, we have argued that prices observed immediately after a flood⁹ are likely to reveal the variation in risk-adjusted prices across space. Therefore, much greater focus should be given to the spatial pattern of prices in the aftermath of floods, as this potentially allows one to see the price level that markets will eventually converge towards for floods of a particular frequency. This also gives housing economists an imperative to consider multiple floods of varying frequency to trace out the entire surface depicting the relationship between risk-adjusted prices, flood severity and flood frequency. This meta task should be the primary objective of housing economists interested in the impacts of changing flood risks due to climate change because it allows for translation of a given geography of flood risk estimates associated with a particular climate scenario into risk-adjusted house price estimates.

Implications for Government Policy

From a public policy perspective, our framework suggests the likelihood of irregular and non-linear adjustment processes, characterised by inertia, cumulative internal tension

⁹ Or perhaps a little after the flood, allowing for any overshoot to be rectified.

followed by abrupt adjustment. We have argued that a world of strongly myopic and amnesiac flood risk assessment by market actors, exacerbated by subsidized flood insurance, is a world ripe for illusory escalation in home prices, followed by catastrophic declines in the face of temporal increases in the frequency and severity of flooding. If the hypothesized average home price—flood risk adjustment curve is indeed akin to (b) in Figure 6, there may be severe and unpredictable tipping points where home prices in particular areas suddenly collapse, causing acute negative home equity issues, repossessions, panic selling, and out-migration. Such sudden adjustment could have destabilising effects well beyond the local housing market, as the recent U.S. subprime mortgage crisis has demonstrated.

Such non-linear market adjustments to intensifying risk is an important and worrying prospect because it potentially compounds the impact of other tipping points associated with the *rapidity of climate change* (and hence flood risk), which have already been identified as plausible trajectories for global warming (Stern, 2006). The implication for governments, then, is the importance of reducing the magnitude of tipping-points in house price adjustment. A key goal of housing policy should be to facilitate a gradual adjustment path through improved information dissemination and removal of obstacles to price adjustment to prevent long-term price bubbles accumulating. Subsidised insurance regimes are highlighted as particularly problematic in our schema because they delay such adjustment and may store up sudden price collapse. Governments should also be clear and realistic about the scope for publicly provided flood defence. Limited public resources almost inevitably imply that a limited number of areas will be protected. The sooner those areas are made known the better so that consumers and investors can then make informed choices.

Another key implication for policy makers is the market sorting effect of price adjustment. Other things equal, an expanding geography of significant flood risk will cause prices to fall eventually in those areas, and prices in remaining low-risk areas to rise. Low-income households will find it increasingly expensive to reside in neighbourhoods with low flood risks and thus will be sorted by the market into higher-risk areas.¹⁰ This sorting can, however, be ameliorated by boosting housing supply (especially of subsidized dwellings) in low risk areas.¹¹ Additional land for such residential construction can be released by encouraging the relocation of agriculture and certain types of industry to zones with medium flood risks.¹² Regional structures of governance may encourage this process through strategic infrastructure planning, informed by house price simulation models of future geographies of land prices and optimal firm location. Housing economic models, albeit ones based on appropriate behavioural assumptions, therefore have a potentially important role to play in helping society adjust to climate change.

Conclusion

In this paper we have demonstrated an imperative for fundamentally revising the conventional full-information, efficient-market interpretation of house price responses to floods, by drawing on the literature on behavioural economics and sociology of risk. We posited that in estimating the risk of flood damage to a particular property, market actors evince myopia and amnesia and that these effects, in the context of climate change, will take on a derived and transformative dynamic. We used these insights to outline an

¹⁰ Note that this effect cannot be averted by temporarily buttressing subsidized insurance or making unrealistic promises about flood defence—the effect will be only to delay the inevitable and result in a more abrupt (and hence more harmful) adjustment.

¹¹ We recognize that the class bias to sorting is imperfect inasmuch as some higher-income households may currently be residing in homes that are in risky locations but are nevertheless expensive due to their water views. For more discussion, see Pryce *et al.* (2009).

¹² This process of land-use reallocation may occur in due course if markets operate efficiently because residential demand for low flood risk locations will drive up commercial rents and firms with lower rates of aversion to flood risk than homeowners will relocate to areas with medium flood risks.

alternative framework where perceived flood risk (and observed home prices) likely diverge considerably from actual risk (and risk-adjusted prices), particularly if a long period has passed since the last flood. In our framework, home price adjustment to ever-increasing levels of risk associated with global climate change is likely to evince an uneven pattern of inertia followed by rapid, tipping-point declines. We have shown how this new perspective holds important implications for the estimation and interpretation of empirical models of house prices and flood risks, as well as for public policy. Given the huge potential dislocations associated with these catastrophic adjustments, it behoves housing economists to map out the relationship between risk-adjusted prices and flood severity for floods of varying frequency. To predict the dynamics of market behaviour accurately, behavioural factors must be incorporated into models of the housing economy in a way that captures the complex, inter-connected nature of the system. Only by understanding the nature of this system will governments be able to identify appropriate policy responses. Finally, though we have couched our analysis in terms of floods we hope that our framework is applicable to housing market responses to a range of other natural disasters.

References

- Allen, C. (2009) The Fallacy of “housing studies”: Philosophical problems of knowledge and understanding in housing research, *Housing Theory and Society*, 26(1), pp.53-79.
- Babcock, M. & Mitchell, B. (1980) Impact of flood hazard on residential property values in Galt (Cambridge), Ontario, *Water Resources Bulletin*, 16(3), pp. 532-537.
- Barnard, J. (1978) Externalities from urban growth: The case of increased storm runoff and flooding, *Land Economics*, 54(3), pp. 298-315.
- Bartosova, A., Clark, D., Novotny, V. & Taylor, K. (1999) *Using GIS to evaluate the effects of flood risk on residential property values*. Institute for Urban Environmental Risk Management. Technical Report 1. (Milwaukee, WI: Marquette University).
- BBC (2010) *BBC Climate Change Poll – February 2010*, Conducted by Populus, Summary available from http://news.bbc.co.uk/nol/shared/bsp/hi/pdfs/05_02_10climatechange.pdf (accessed 9th March 2010).
- Beck, U. (1992a) From industrial society to the risk society: Questions of survival, social structure and ecological enlightenment, *Theory, Culture & Society*, 9, pp.97-123.
- Beck, U. (1992b) *Risk society: Towards a new modernity* (London: Sage).
- Bialaszewski, D. & Newsome, B. A. (1990) Adjusting comparable sales for floodplain location: the case of Homewood, Alabama, *The Appraisal Journal*, 58(1), pp. 115 - 118.
- Bin, O. & Polasky, S. (2004) Effects of flood hazards on property values: Evidence before and after Hurricane Floyd, *Land Economics*, 80(4), pp. 490-500.

- Bin, O., Kruse, J. & Landry, C. (2008) Flood hazards, insurance rates, and amenities: Evidence from the coastal housing market, *Journal of Risk and Insurance*, 75 (1), pp. 63-82.
- Cauley, S.D., Pavlov, A.D. and Schwartz, E.S. (2007) Homeownership as a constraint on asset allocation, *The Journal of Real Estate Finance and Economics*, 34(3), pp.283-311.
- BMRB (2005) *Environment agency launches campaign to tackle flood apathy*. Available at: www.marketresearchworld.net (accessed September 2009).
- Burningham, K., Fielding, J. & Thrush, D. (2008) 'It'll never happen to me': Understanding public awareness of local flood risk, *Disasters*, 32(2), pp. 216-238.
- Chivers, J. & Flores, N.E. (2002) Market failure in information: The national flood insurance program, *Land Economics*, 78(4), pp. 515-521.
- Crichton, D. (2005) *Flood risk and insurance in England and Wales: are there lessons to be learned from Scotland?* Technical Report (London: Benfield Hazard Research Centre, University College London). Available at <http://www.abuhrc.org/rp/publications/pages/tech.apsx>.
- DEFRA (2008) *ABI/Government statement on flooding and insurance for England* (London: Defra).
- DellaVigna, S. (2009) Psychology and economics: Evidence from the field, *Journal of Economic Literature*, 47(2) pp. 315-372.
- DellaVigna, S. & Pollet, J.M. (2007) Demographics and industry returns, *American Economic Review*, 97(5), pp. 1667–1702.
- Donnelly, W.A. (1989) Hedonic price analysis of the effects of a floodplain on property values, *Water Resources Bulletin*, 25 (3), pp.581-586.

- Eves, C. (2002) The long-term impact of flooding on residential property values, *Property Management*, 20 (4), pp. 214-227.
- Foresight (2004) *Foresight future flooding* (London: DTI).
- Green, C. & Penning-Rowsell, E. (2004) Flood insurance and government: 'parasitic' and 'symbiotic' relations, *The Geneva Papers on Risk and Insurance*, 29(3), pp. 518-539.
- Harrison, D.M., Smersh, G.T. & Schwartz Jr, A.L. (2001) Environmental determinants of housing prices: The impact of flood zone status, *Journal of Real Estate Research*, 21 (½), pp.3-20.
- Houghton, J. (2009) *Global warming: The complete briefing*, 4th Edition (Cambridge: Cambridge University Press).
- IPCC (2007) *Climate change 2007: The physical science basis*. Report of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Summary for Policy Makers (Cambridge: Cambridge University Press).
- Jha, A. (2009) Climate research chief Phil Jones stands down pending inquiry into leaked emails, *Guardian*, 1st December 2009.
- Kates, R. (1962) *Hazard choice perception in flood plain management*. Department of Geography Research Paper No. 78. University of Chicago.
- Kousky, C. & Zeckhauser, R. (2006) JARring actions that fuel the floods, in: R. Daniels, D. Kettl & H. Kunreuther (Eds) *On risk and disaster: Lessons from Hurricane Katrina*. (Philadelphia: University of Pennsylvania Press) pp.59-73.
- Kousky, C., Pratt, J. & Zeckhauser, R. (2008) Virgin versus experienced risks, Mimeo, forthcoming in: Erwann Michel-Kerjan and Paul Slovic (eds), *The irrational economist. Making decisions in a dangerous world*, (New York: Public Affairs Books).

- Lamond, J. & Proverbs, D. (2006) Does the price impact of flooding fade away? *Structural Survey*, 24 (5), pp. 363-377.
- Lorenzo-Dus, N. (2006) "Buying and selling: mediating persuasion in British property shows" *Media Culture & Society*, 28 (5), pp. 740-761.
- MacDonald, D.N., Murdoch, J.C. & White, H.L. (1987) Uncertain hazards, insurance, and consumer choice: Evidence from housing markets, *Land Economics*, 63 (4), pp. 361-371.
- Montz, B. (1992) The effects of flooding on residential property values in three New Zealand communities, *Disasters*, 16 (4), pp. 283-298.
- November, V., Penelas, M. & Viot, P. (2009) When flood risk transforms a territory: The Lully effect, *Geography*, 94(3), pp.189-197.
- Pitt, M. (2008) *The Pitt Review: Lessons learned from the 2007 floods* (London: Cabinet Office).
- Pryce, G. & Oates, S. (2008) Rhetoric in the language of real estate marketing, *Housing Studies*, 23 (2), pp. 319-348.
- Pryce, G., Chen, Y. & Mackay, D. (2009) *Flood risk, climate change, and housing economics: Four fallacies of extrapolation*. Paper presented at International Sociological Association Housing Conference, Glasgow, September.
- Rabin, M. (1998) Psychology and economics, *Journal of Economic Literature*, 36(1), pp.11-46.
- Rosen, S. (1974) Hedonic prices and implicit markets: product differentiation in pure competition, *Journal of Political Economy*, 182, pp. 132-157.
- Speyrer, J. & Ragas, W.R. (1991) Housing prices and flood risk: An examination using spline regression, *Journal of Real Estate Finance and Economics*, 4, pp. 395-407.

- Stern, N. (2006) *The economics of climate change: The Stern review* (London, HM Treasury).
- Stern, N. (2008) The economics of climate change, *American Economic Review*, 98 (2), pp. 1-37.
- Tobin, G. & Montz, B. (1994) The flood hazard and dynamics of the urban residential land market, *Water Resources Bulletin*, 30 (4), pp. 673-685.
- Tobin, G. & Newton, T. (1986) A theoretical framework of flood induced changes in urban land values, *Water Resources Bulletin*, 22 (1), pp. 67-71.
- Tversky, A. & Kahneman, D. (1971) Belief in the law of small numbers, *Psychology Bulletin*, 76(2), pp. 105-10.
- Tversky, A. & Kahneman, D. (1973) Availability: A heuristic for judging frequency and probability, *Cognitive Psychology*, 5(2), pp. 207-32.
- Wales Audit Office (2009) *Coastal erosion and tidal flooding risks in Wales* (Cardiff: WAO).
- Williams, S. (2008) Rethinking the nature of disaster: From failed instruments of learning to a post-social understanding, *Social Forces*, 87 (2), pp. 1115-1138.
- Zeckhauser, R. (1996) The economics of catastrophes, *Journal of Risk and Uncertainty*, 12, pp. 113-140.
- Zimmerman, R. (1979) The effect of flood plain location on property values: three towns in northeastern New Jersey, *Water Resources Bulletin*, 15 (6), pp. 1653-1665.

Figure 1. Fully Risk-Adjusted Prices and Short-Run Responses to Flooding

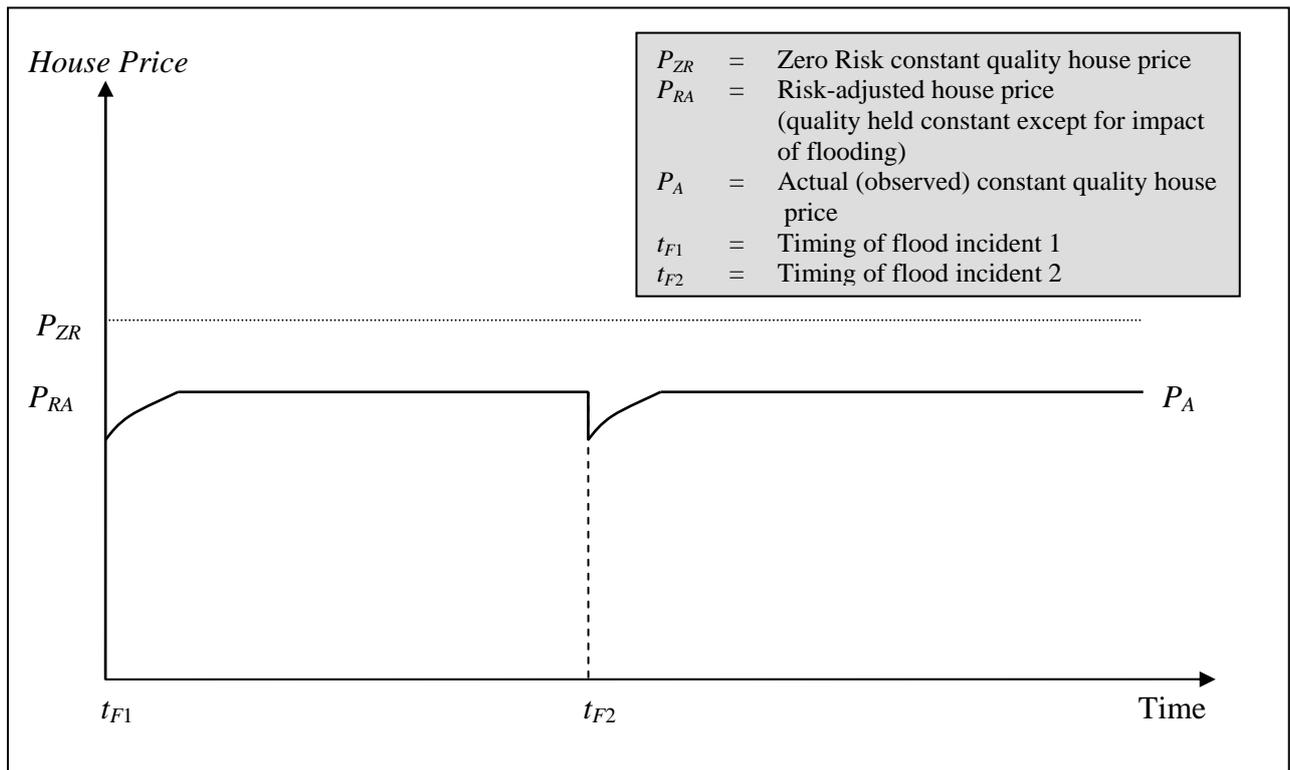


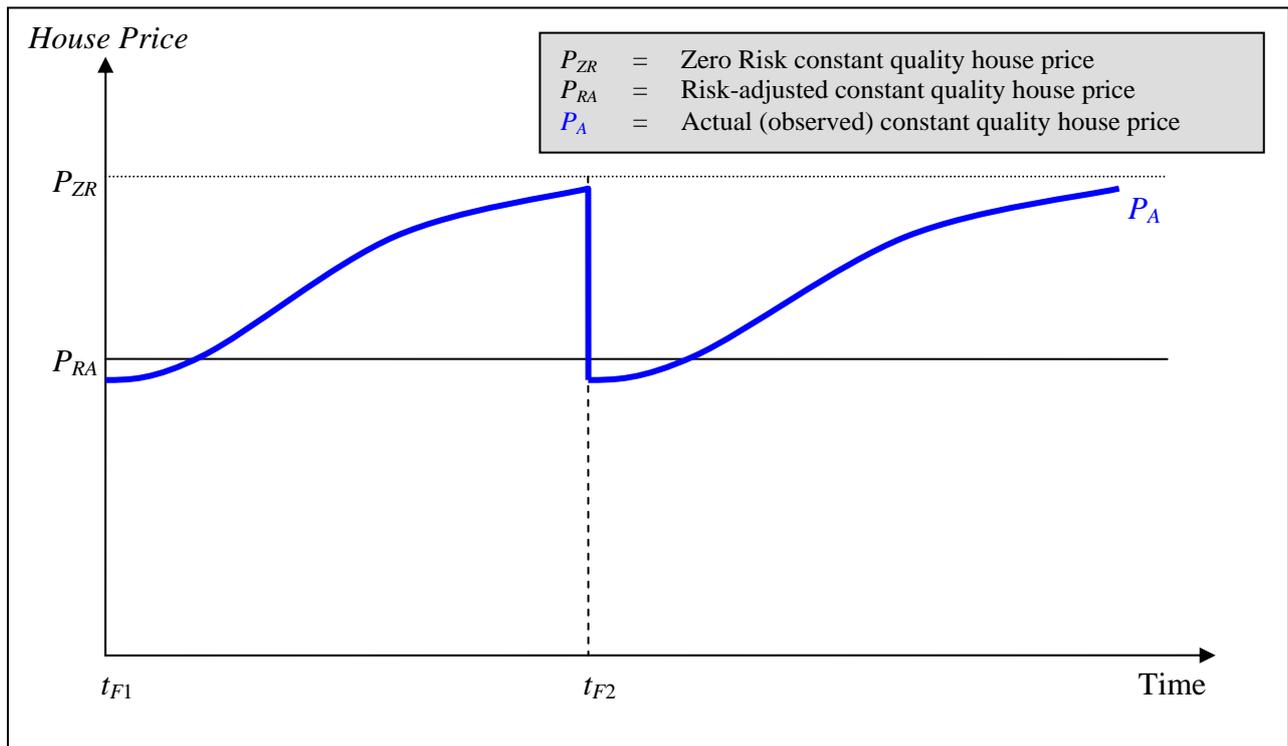
Figure 2. House Prices with Amnesia and Myopia: The Case of Infrequent Floods

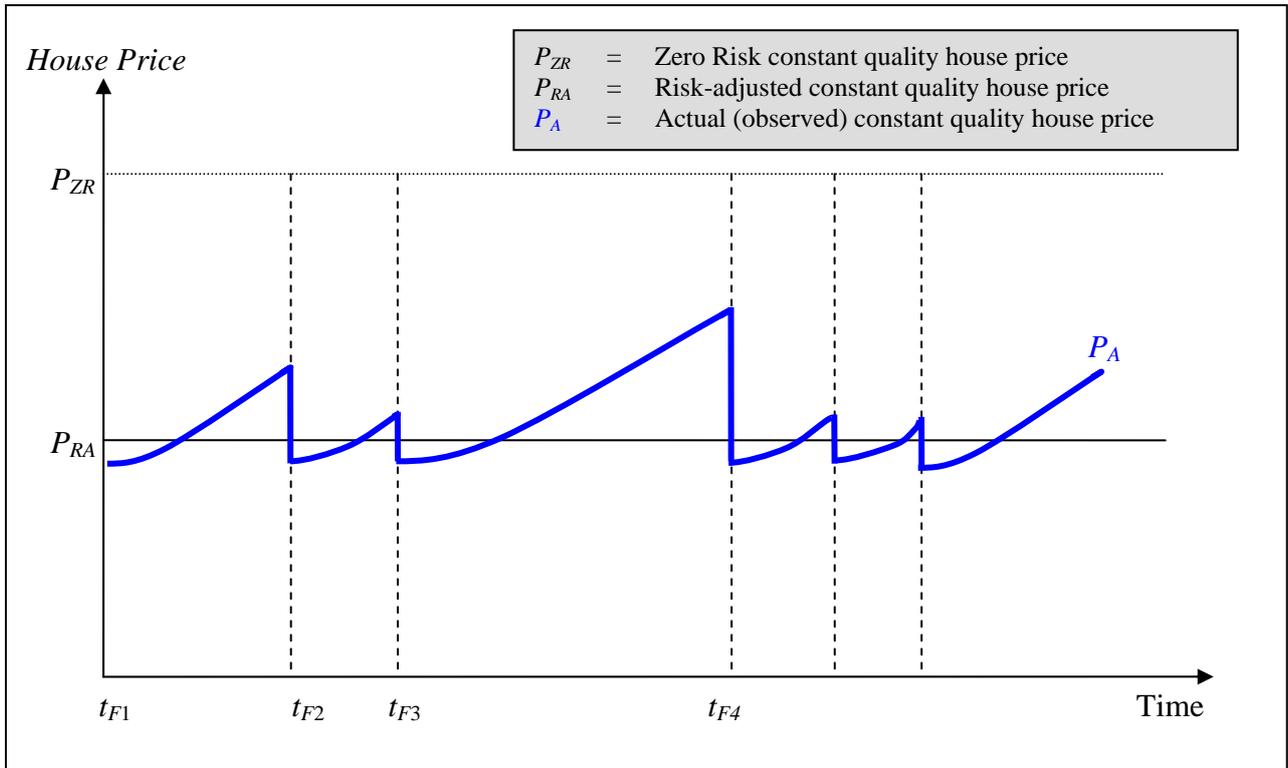
Figure 3. House Prices with Amnesia and Myopia: The Case of Frequent Floods

Figure 4. House Prices with Amnesia and Myopia: The Case of Increasingly Frequent Floods

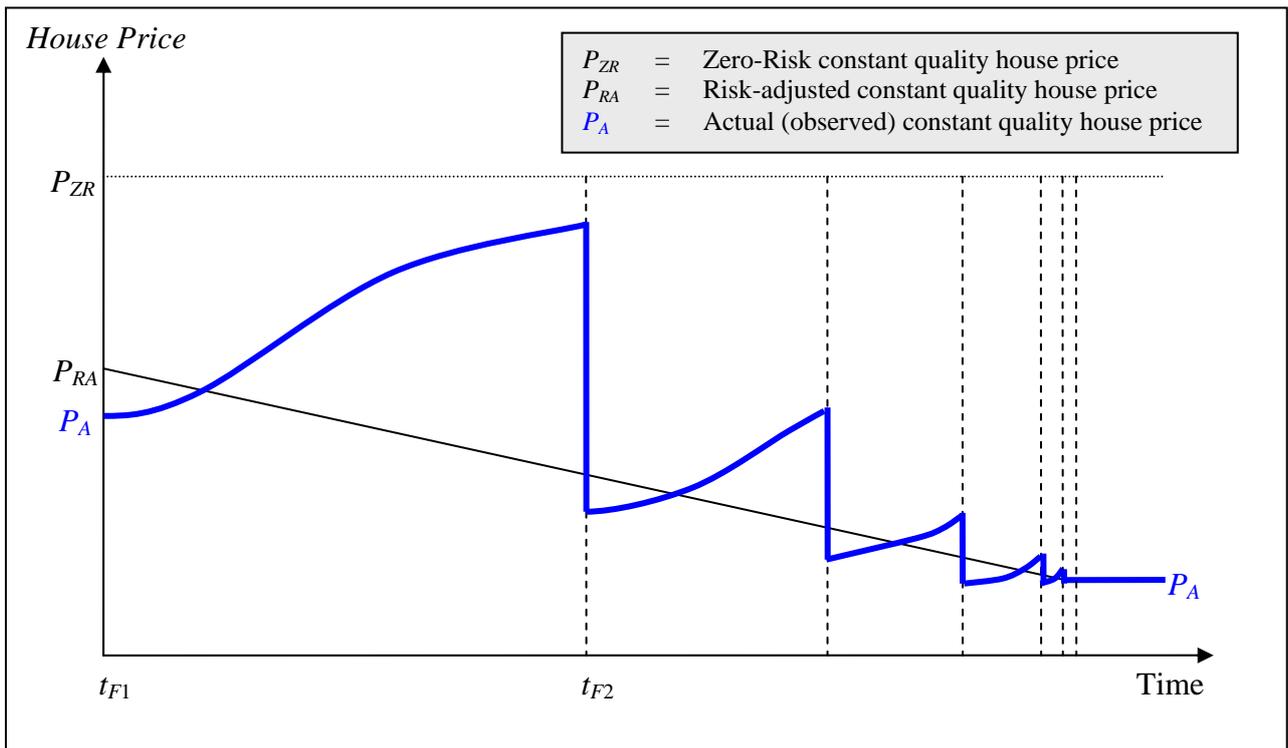


Figure 5. Hypothesised Relationship between Mean House Price across Areas at Time t and Flood

Frequency, ϕ

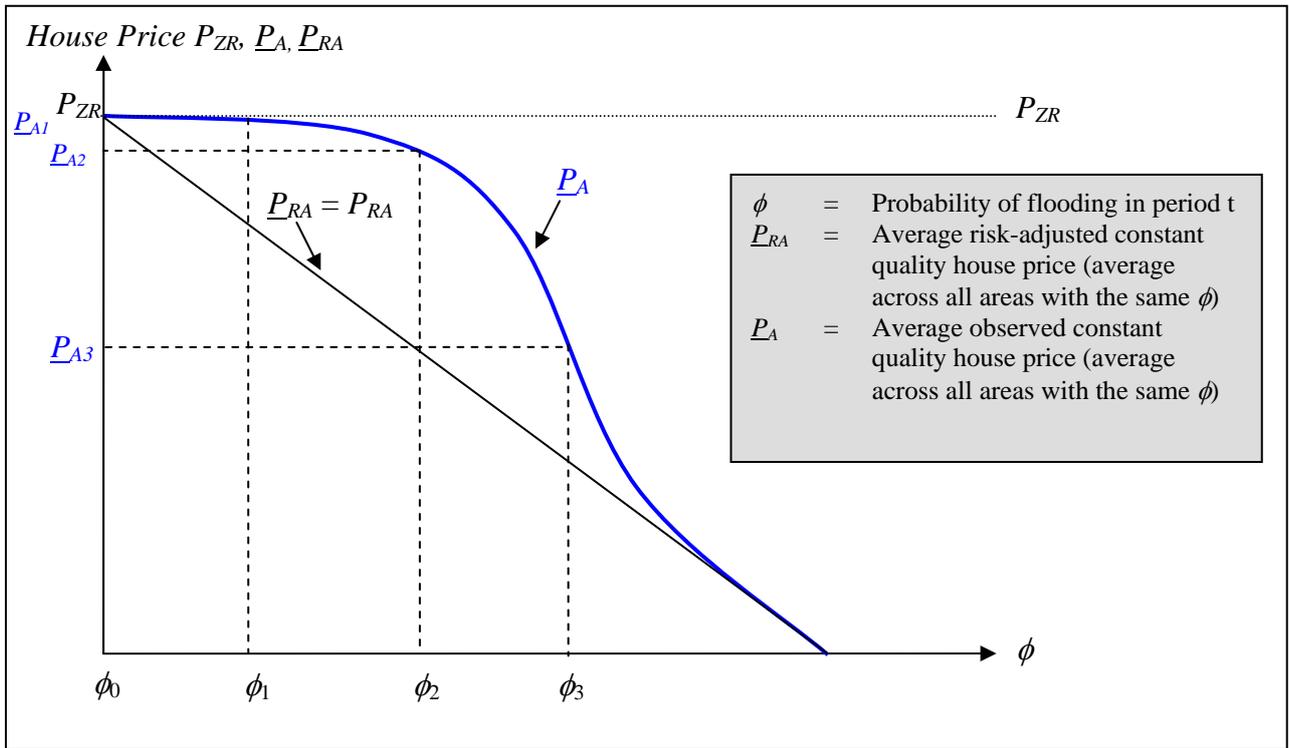


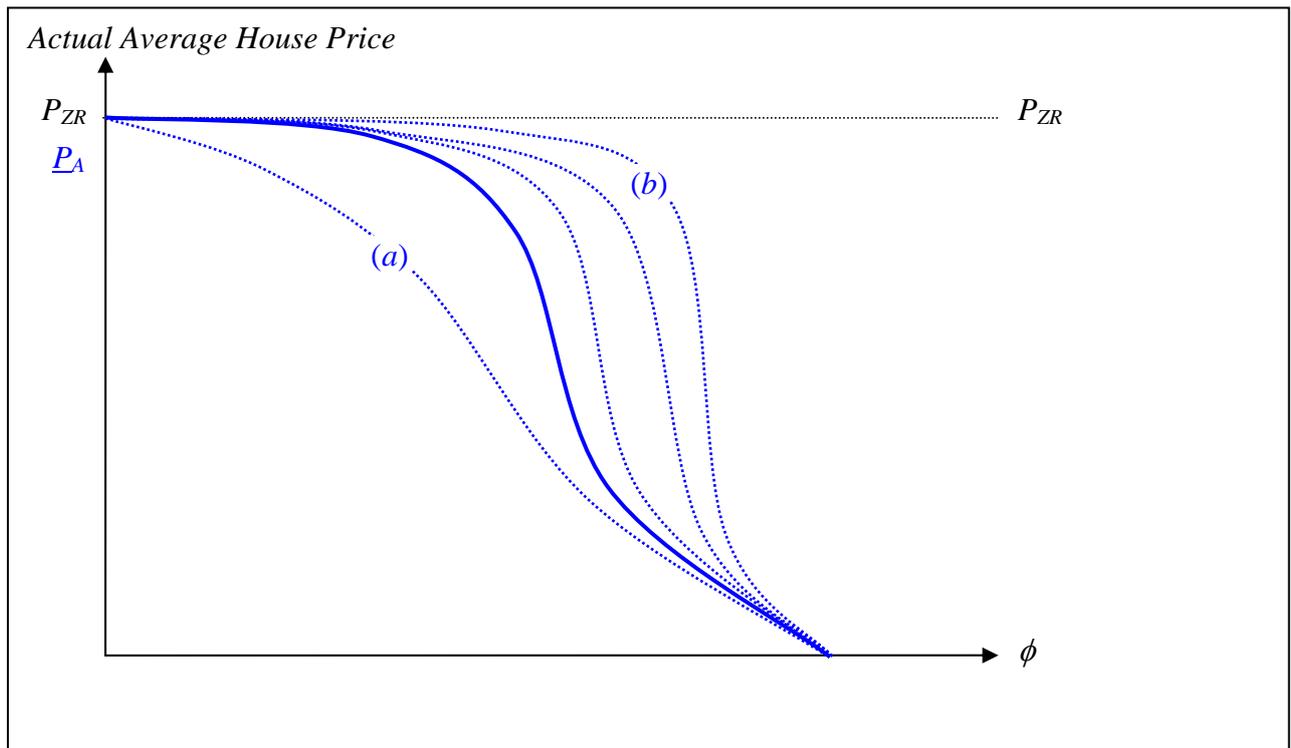
Figure 6. Potential Tipping Points in the Updating Process of Average Housing Prices

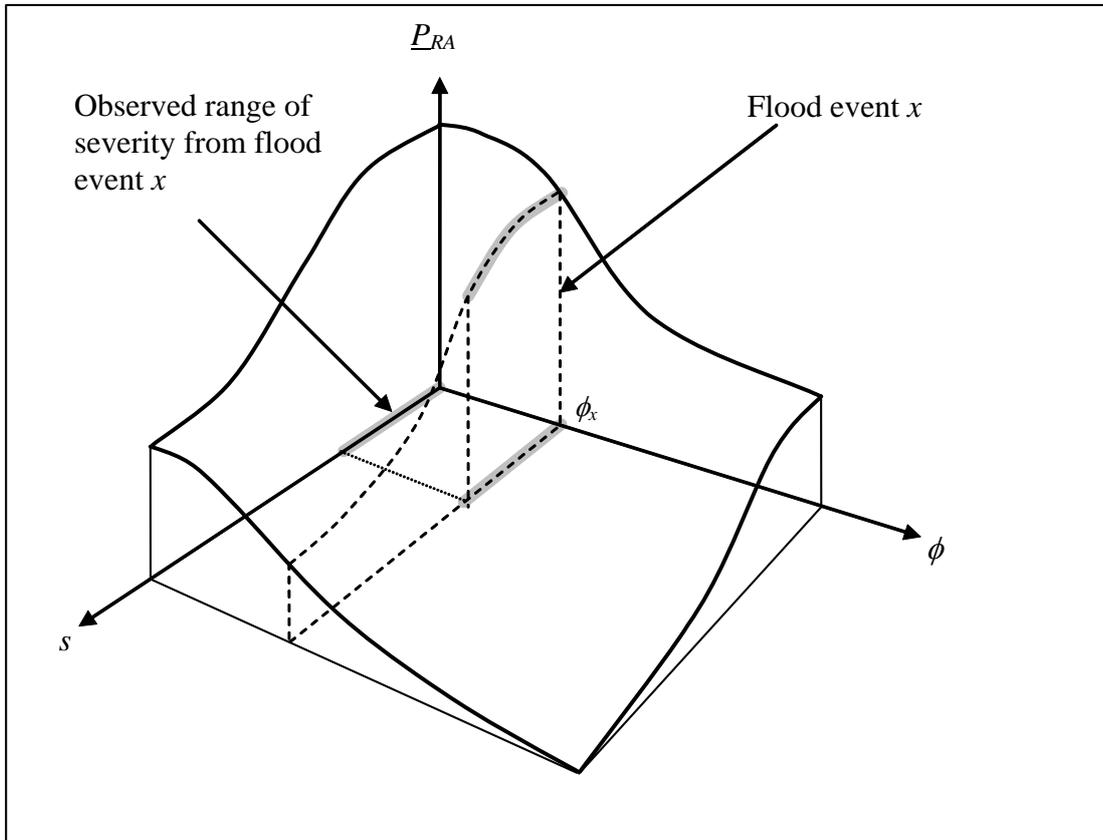
Figure 7 Risk-adjusted Prices and the Severity and Frequency of Floods

Figure 8: Path Dependency in Observed House Prices for Identical Areas, i and j

