THEORETICAL FOUNDATIONS FOR MODELING THE IMPACT OF FLOODS ON HOUSE PRICES:

AN IMPERFECT INFORMATION APPROACH WITH AMNESIA AND MYOPIA

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Paper Submitted to ENHR Conference, June 2009

Working Draft -- Please do not quote

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Abstract

This paper is fundamentally motivated by the intensifying threat of global climate change and the associated increase in the frequency and severity of surface flooding of urbanized areas. How will housing markets respond to this intensifying risk? Existing models of the impact of flooding on house prices have tended to assume perfect information (or well known flood probabilities) and rational decision making processes in the housing market. Yet, there is now a considerable body of evidence indicating that households tend to have poor knowledge of their exposure to flood risk, and do not make particularly rational decisions in the presence of complex risk scenarios. This paper attempts to set out a plausible theoretical framework for analysing the housing market response to flood frequency and severity. We then utilise this framework to work through the implications of climate change for the housing market. We highlight the implications of the model for government intervention.

1. Introduction

Flooding has resulted in huge damage in modern society (FEMA, 2006; Pitt, 2008). The number of people under flood threat is anticipated to rise significantly as a result of climate change which the IPCC and UKCIP estimate will cause increased winter precipitation, rising sea levels, and greater frequency and prevalence of storm surges and extreme weather events. This paper is fundamentally motivated by the intensifying threat of climate change and flooding of urbanized areas. Juxtaposed against this issue of immense importance is urban economists' underdeveloped understanding of how urban property markets respond to such flood risks. Existing models of the impact of flooding on house prices have tended to assume that the probabilities of floods are well known and inform house buying and selling decisions in a rational way. House prices fall in the aftermath of a flood only because of the physical impact on the quality of the dwelling. Once the clean-up operation is complete, prices bounce back to their previous, fully risk-adjusted levels. If the timing of floods is unknown before the event, the probability of the event *is* known, and so market prices reflect these probabilities.

This interpretation is not fully consistent with evidence on housing price responses to floods, and a broader theoretical and empirical literature emerging from behavioural economics. Our goal is to advance a new theoretical foundation for modelling what we foresee will be the ever-rising impact of floods on housing prices. Our formation will utilize new insights from behavioural economics and offer more convincing explanations for emerging empirical evidence than past approaches. Moreover, it carries within it implications for tipping-like adjustments that foreshadow harrowing potential responses of property markets to climate change.

Our paper begins with a brief review of the theoretical and empirical studies on flooding and house prices. We then present our alternative theoretical foundation, which is characterized by market actors making housing pricing decisions based on amnesia and myopia, that is, whereby recent experiences are heavily weighted and temporally distant events are discounted. Finally, we consider how housing markets founded on our behavioural model may respond in catastrophic, tipping-like fashion to the ever-increasing frequency and severity of flooding that is the likely consequence of global climate changes underway.

2. Related work

Tobin and Newton (1986) integrates literature from flood hazard research and urban economics, and develops a theoretical model to explain the effects of flooding on property prices. The authors adopt the concept of "utility" from the urban economics literature (Bish and Nourse, 1975; Grether and Mieszkowski, 1974) and assume that changes in the utility derived from holding land/property are reflected in changes in the price of land/property. Thus one can hypothesise that the price of land decreases when its utility is reduced by flooding. The authors argue that the extent of this reduction in utility depends on spatial, temporal and hydrological aspects of flood events. There are three profiles depicting flood impact on land/property values. Firstly, house price falls immediately after a flood event and then recovers. This profile occurs when there is a long time gap between two flood events and the market has enough time to recover to pre-flood levels or above. Secondly, in case of periodic flooding, the frequency of floods and the ability of the market to recover results in a substantial fluctuation of land values over time. Finally, should flooding occur frequently then house prices remain low as the market does not have enough time to recover between events. In this case, flood risks have completely capitalised into house price.

While temporal factors and flood experiences are clearly important in explaining the relationship between property values and flood events, Tobin and Montz (1994) extends the above theoretical framework by acknowledging the importance of other socio-economic factors. In particular, they indicate that a shortage of land and demand pressures result in a quick recovery of house prices.

In empirical studies, the conventional lens through which the relationship between flooding and house prices is viewed is hedonic theory (Lancaster, 1966; Rosen, 1974; Freeman, 1979; Palmquist, 1984).[1] It is assumed that the household consumer will rationally choose a location (dwelling) that maximizes expected utility, where the various attributes of the dwelling are assessed in evaluating utility. Because flooding potential forces the consumer to consider this hazard to prospective utility, the rational decision maker should be willing to pay a premium to avoid such hazards (the amount depending on the perceived expected value of utility lost from floods). This differential premium (or willingness to pay) across properties varying in their flood hazards should be capitalized into the prices of housing in these alternative locations (MacDonald et al. 1987). Insofar as information about the frequency and severity of flooding associated with each location is accurate and widely known, this capitalization should be complete. 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 in an identical fashion.

[1] For an early, non-hedonic formulation based on expected use value of land, see Tobin and Newton (1986).

An extended empirical literature stemming from this hedonic framework has, indeed, found that housing prices are discounted in locations with high flood risks (see, e.g., Bernard, 1978; Donnelly, 1989; Holway and Burby, 1990; Bartosova et al. , 1999; Harrison et al. , 2001; Eves, 2002; Troy and Roman, 2004; Bin and Polasky, 2004; Bin et al., 2008). Some hedonic studies have observed, however, that the price discount on damaged properties is greater after a flood than before (Bartosova et al., 1999; Eves, 2002). This could be interpreted as evidence of imperfect capitalization, but proponents of efficient market models may retort that such reflects only transitory adjustments involving repairs to damaged properties. Indeed, other studies have suggested relatively rapid rebounds of housing prices in the wake of floods that would be consistent with the repair-lag explanation (Babock and Mitchell, 1980; Montz and Tobin, 1988, 1989; Montz, 1992; Eves, 2002).

An obvious weakness of the existing literature is that it makes no attempt to account for individual/consumer behaviour. Therefore, it fails to clarify the relationship between risk adjusted prices, zero risk prices and observed prices. We argue here that perceived risk may diverge considerably from actual risk, particularly if a long period of time has passed since a flood has occurred in the vicinity. There is now extensive evidence that individuals respond to risk in ways that reflect apparently non-rational, or bounded-rational, decision-making mechanisms. Individuals tend to weigh recent flood information more heavily than aged floods. They tend to forget their previous flooding experiences as time passes. Then a recent flood event effectively raises people's awareness of potential flood risk (Fridgen & Schultz, 1999; Bin and Polasky, 2004). In addition, humans have a tendency to underestimate risks that appear distant or global, or which others seem to accept without concern (Zeckhauser, 1996; 2006). 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.

Another weakness of the literature is that spatial spill-over effects of a flood event are largely neglected. So far no work has been done to assess whether non-flooded properties close to flooded areas are subject to price discount. Due to spatial approximation, these non-flooded properties might receive a wake-up call about potential flood risk, and adjust their prices accordingly. In the following sections we set out a theoretical framework that captures, and allows us to test for, behavioural responses to environmental shocks taking into account spatial spill-over effects.

3. A New Theoretical Framework for Understanding the Impacts of Floods on Housing Prices

We think it useful to summarize the literature from behavioural economics as suggesting that, in estimating the monetary risk of flood damage (i.e., the expected value of the products of probabilities of flooding of various severities and their associated damages) to a particular property, market actors evince *amnesia* (i.e., progressively discount information from more past periods) and *myopia* (i.e., progressively discount information expected from more future periods). We also assume that a flood event has spill-over effect which discounts property prices for those located within and in the proximity of the flood areas. Expressed symbolically in terminology to be applied below, we specify that the actor at the start of period t will *perceive* the risk of a flood F at a given location i during period t as:

$$R(F_{it}) = f([\ F_{it-n}/(1+r1)^{n}\ ] , [\ pr(F_{it+m})/(1+r2)^{m}\ ] , [\ F_{itd}/(1+r3)^{d}\ ])$$

where:

[F_{it-n}]= a vector designating past instance(s) of flooding of various severities at location i that occurred n periods ago

pr(F_{it+m}) = a vector designating scientifically derived probabilities of future flooding of various severities at location i

[F_{itd}] = a vector designating instances of flooding of various severities each occurring at a distance d from location i

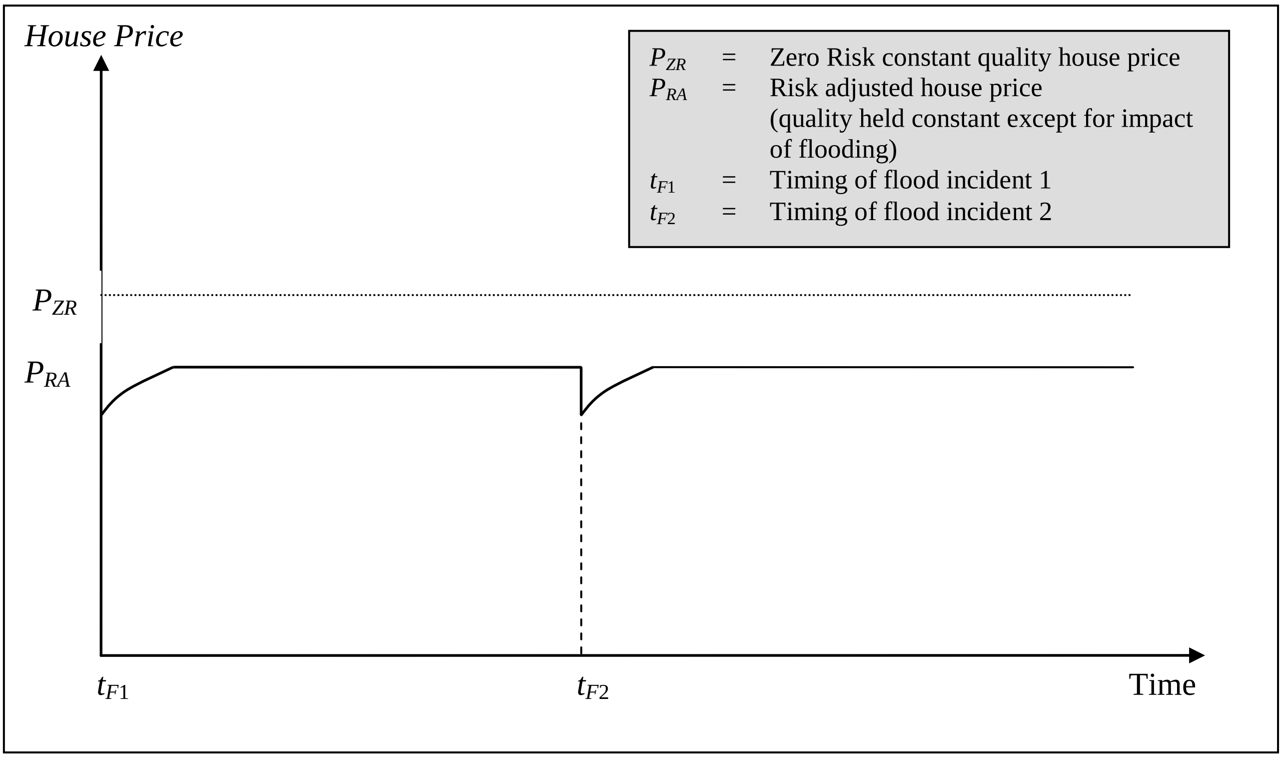
r1, r2, r3 = rates of discount over past time, future time, and distance, respectively

What such decision-making calculus means for the housing market's response to flooding is explored in the next section.

3.1. The Effects of Amnesia and Myopia in Rare, Frequent, and Increasingly Frequent Flood Regimes

We start from an efficient market, with an explicit description of the relationship between risk adjusted prices (P_{RA}), zero risk prices (P_{ZR}) and observed prices. Figure 1 illustrates how instances of flooding (at time periods t_{F1} and t_{F2}) would have only a temporary impact on constant-quality house prices in a particular geographic area if market valuation were fully risk adjusted across locations with a non-zero flood probability (P_{RA}) and zero flood probability (P_{ZR}). From the perspective of efficient markets, house prices in each location capture not only the size and quality of the dwelling and access to surrounding amenities, but also the probability of flooding in that location. The occurrence of a flood does not affect the probability of future floods any more than the outcome of throwing a six on a fair die affects the probability of throwing a future six, so the value of a house is not in any way diminished by the effect of a flood occurrence, other than through a temporary reduction in quality while repairs and cleaning are completed.

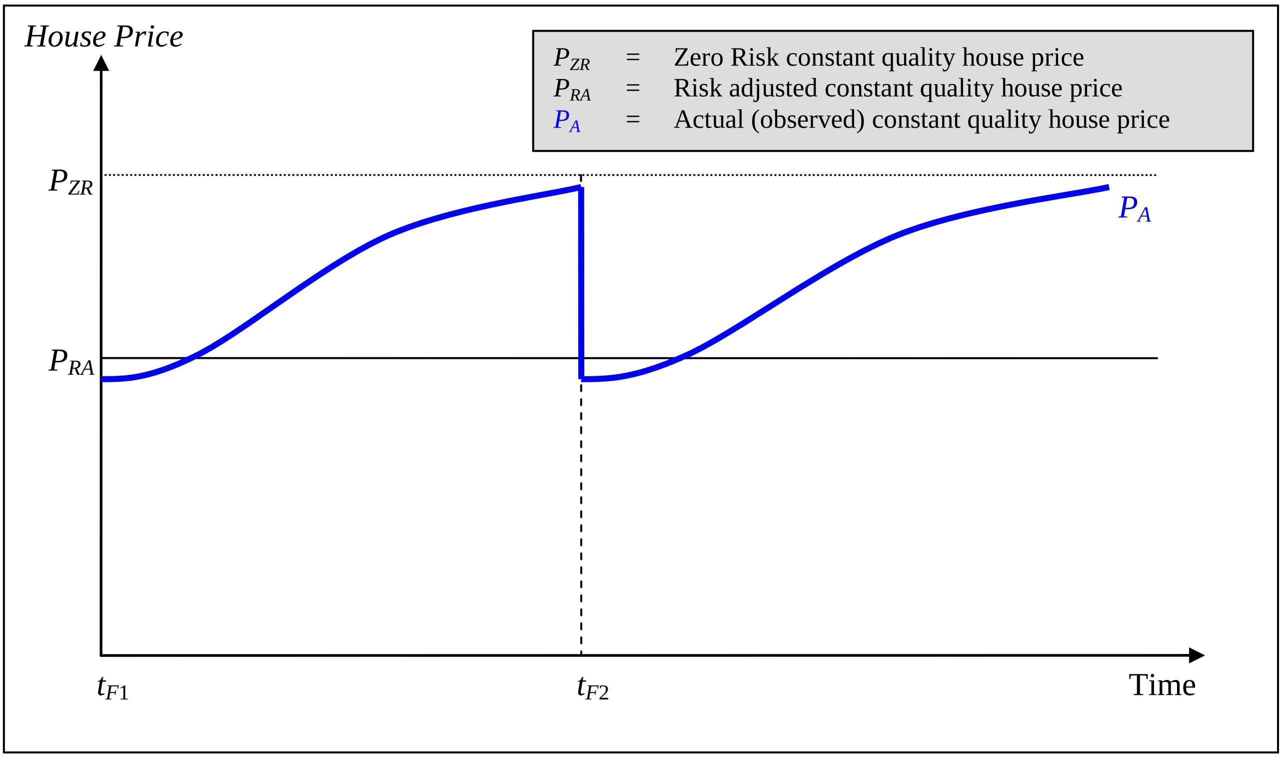
Figure 1. Fully Risk-Adjusted Prices and Short-Run Responses to Flooding



In the world of imperfect information posited in Section Two, how does the experience of flooding affect the market's estimation of flood risk? If myopia is strong, estimates of future flood probabilities provided by public agencies will be viewed as unreliable, or many actors simply may be unaware of them, i.e., r2 is high. If amnesia is strong (r1 is high), historical flooding experiences will be viewed as imprecise guides for the future, unless it has been recent. Consider the temporal pattern of house prices in a particular area in three alternative regimes of flooding: rare, frequent, and increasingly frequent. For simplicity, assume that all floods are of equal severity.

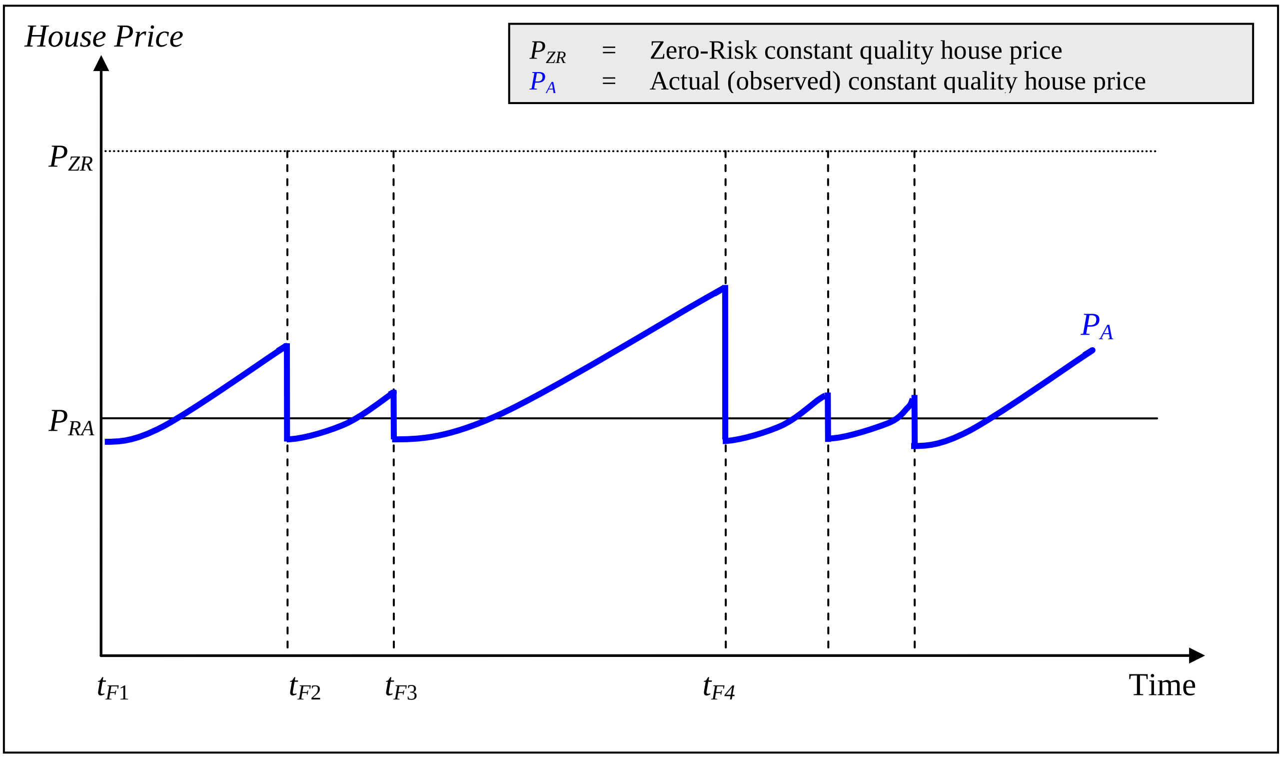
In the regime of rare floods in the given area, if it has been a long time since a flood has occurred it will be likely that amnesiac, myopic market actors behave in ways suggestive of significant underestimation of flood risk at a given point in time. As shown in Figure 2, actual house prices P_A in this regime (illustrated by the blue line in Figure 2) will drift away from their risk-adjusted levels P_{RA} towards the zero-risk price level, P_{ZR}, as the years pass since the last flood at t_{F1}. Then, when a flood occurs at t_{F2}, actors become all too aware of the true level of flood risk. Prices quickly adjust downwards towards their risk-adjusted level. If myopia is particularly strong and the local media particularly sensationalist in their exaggeration of future flood risk, actors may systematically *overestimate* local scientific flood estimates in the aftermath of a flood. If so, this would produce a fall in P_A below P_{RA} that would be in excess of that associated with short-term damage repairs.

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



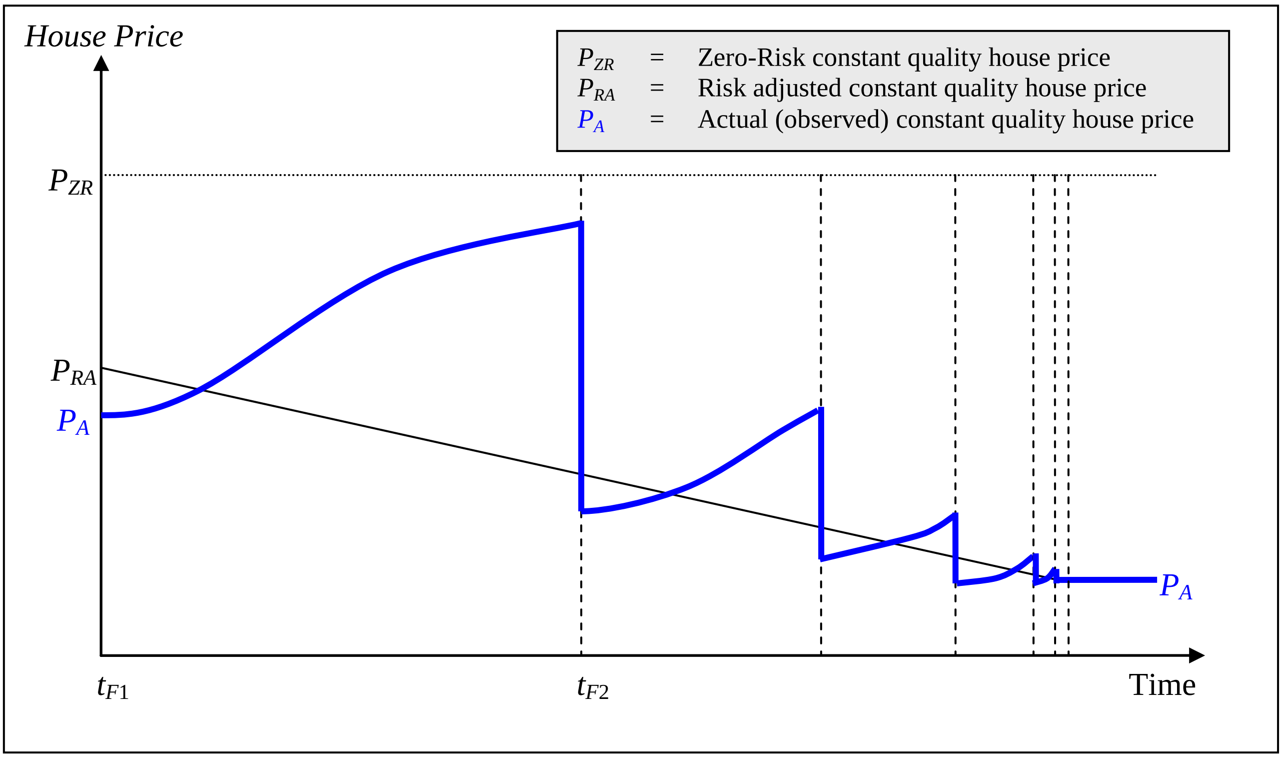
In the case of high-risk flood areas – ones that flood frequently – the difference between P_{ZR} and P_{RA} is greater than for low-risk areas (illustrated in Figure 2). Of more interest to us, the observed market price may rarely have the opportunity to deviate significantly from the risk-adjusted price because floods occur often enough to remind buyers and sellers of the true risk of flooding. Any deviation that does occur may be too small to be distinguishable from the white noise associated with house trading. Thus, on average, the difference between P_A and P_{RA} is lower than for low-risk areas and the bias of $P_A > P_{RA}$ is less. This situation is depicted in Figure 3.

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



Finally, consider the regime of increasingly frequent floods in an area. This scenario is depicted in Figure 4 where P_{RA} falls over time, instead of remaining constant as in Figures 2 and 3. In this case, actual house prices drift away from the risk-adjusted price following a similar drift-trajectory to that which occurs in constant flood risk world. When a flood occurs, therefore, prices fall even more sharply than before, adjusting not only to the flood risk level that characterised the housing market at the time of the previous flood t_{F1}, but to the new, higher flood risk level. As risk of flooding rises, the increased frequency of floods cuts short a prolonged price drift away from P_{RA}, but myopia means that current prices P_A are always drifting due to out-of-date flood risk estimates produced by this more dynamic regime.

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



3.2. The Effects of Amnesia and Myopia on Patterns of Home Prices and 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 varying flood risk.

In general, we would expect to find a non-linear, non-monotonic relationship between *average* constant quality house prices (signified by $\underline{\mathrm{P}}$ hereafter) and flood risk at a given time when measured across a large cross section of areas. The hypothesised relationship is depicted in 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}. This is because, in low flood risk areas floods are infrequent, and so observed prices in most such areas, at a given snapshot in time, will have drifted close their zero-risk price, as we explained above in the context of Figure 2. In moderate-risk areas like at ϕ_2, the associated average prices observed $\underline{\mathrm{P}}_{\mathrm{A2}}$ will be somewhat less than the zero-risk price but nevertheless diverge substantially from the risk-adjusted prices due to amnesia and myopia effects, as we explained above in the context of Figure 3. As flood risk rises to higher levels, the observed average house price converges towards the risk-adjusted house price because, as the frequency of flooding rises, the scope for amnesia to effect transacted prices is reduced. So, the difference between $\underline{P}_{A2}$ and $\underline{P}_{A3}$ observed average house prices across areas with low and high flood risk, respectively, is comparatively large. Eventually, the frequency of floods is so large that observed average prices converge to risk-adjusted prices.[2]

[2] 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 ϕ.

This $\underline{P}_A$ graph has a number of important implications. First, consider a subset of areas currently experiencing low flood risk but in the near future will experience significantly increasing flood risk because they are affected most by rising sea levels, precipitation and/or storminess associated with climate change. 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 of the observed average price $\underline{P}_A$ curve 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. Selling prices will steadily adjust downwards as flood risk rises, allowing for a relatively gradual and panic-free market accommodation to climate change. 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 Risk, ϕ

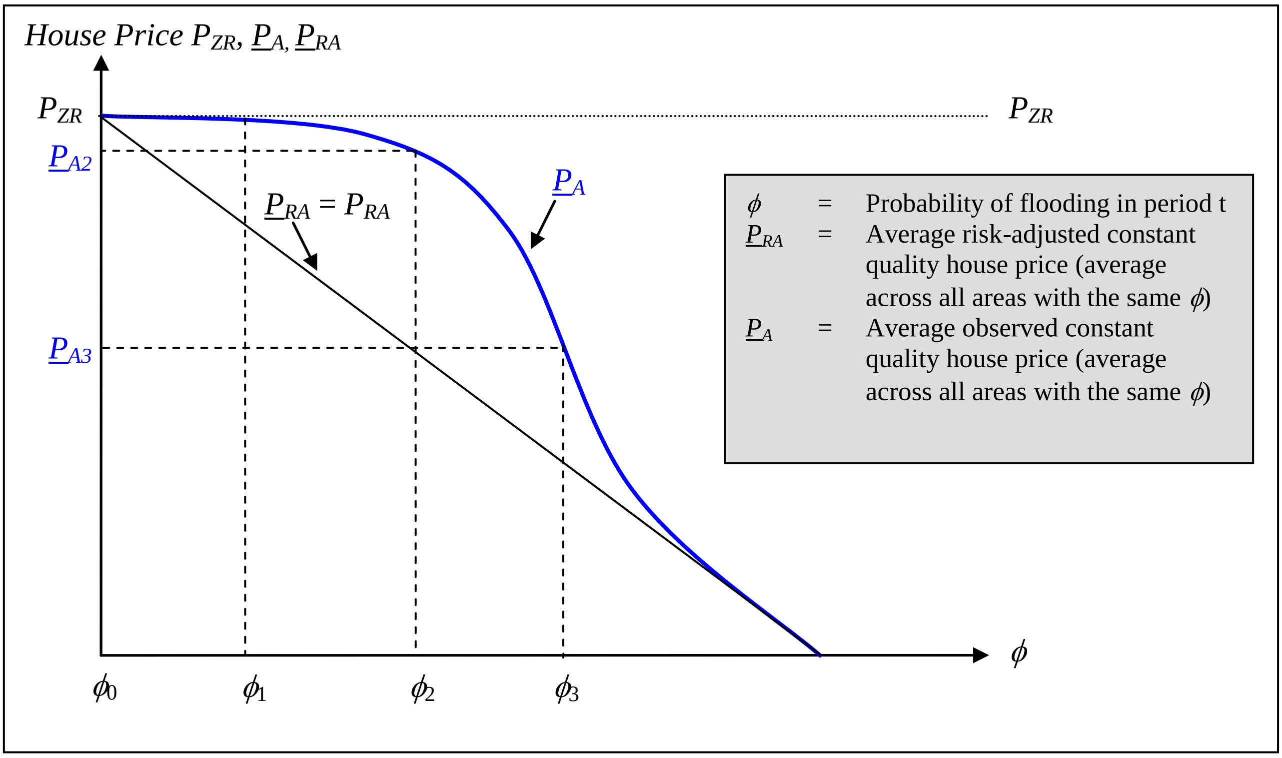
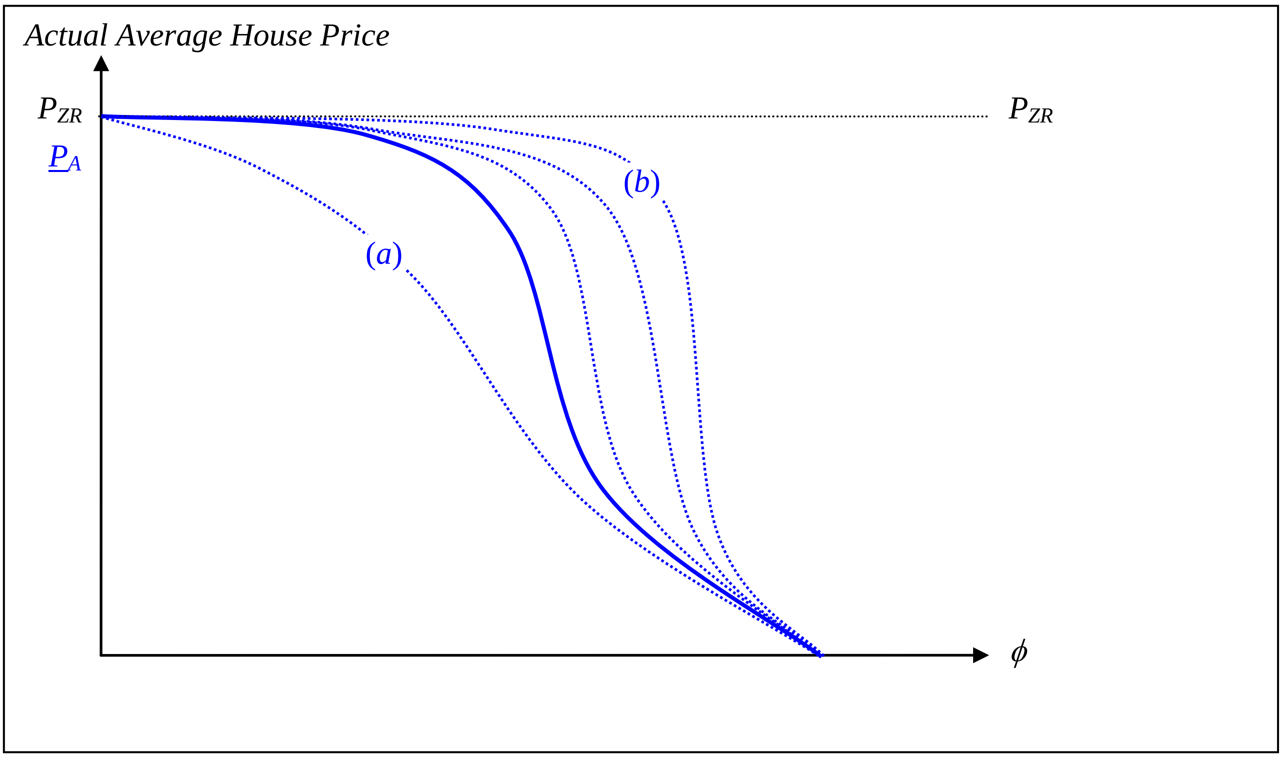


Figure 6. Potential Tipping Points in the Updating Process of Average Housing Prices



3.3. The Spill-over Effects of a Flood Event

We have hypothesised that market adjustment to flood risk at the local level will not be a continuous, gradual process, but an erratic one, punctuated and catalysed by actual flood incidents. Such events bring households face to face with the true risk of flooding that the location of their dwelling entails. However, the “realisation” effect of a flood event is unlikely to be limited only to those dwellings actually flooded. Those unaffected dwellings in close proximity will also receive a wake-up call -- perhaps not quite so potent as that experienced by households who actually experienced flooding, but a wake up call nonetheless. It seems reasonable then to assume that the extent to which a flood event causes the prices of unaffected houses to shift towards their risk-adjusted price will decline with distance.

To illustrate this variable spatial effect on housing price adjustments caused by a flood, consider the hypothetical, pre-flood house price surface plotted in geographical space presented in Figure 7. This is how house prices are distributed across space before flooding occurs. Now assume that a flood occurs in period *t*=2, the severity of which (in terms of where flooding of various depths occurs) is depicted in Figure 8.

Figure 7 Hypothetical House Price Surface Pre-Flood (t=1)

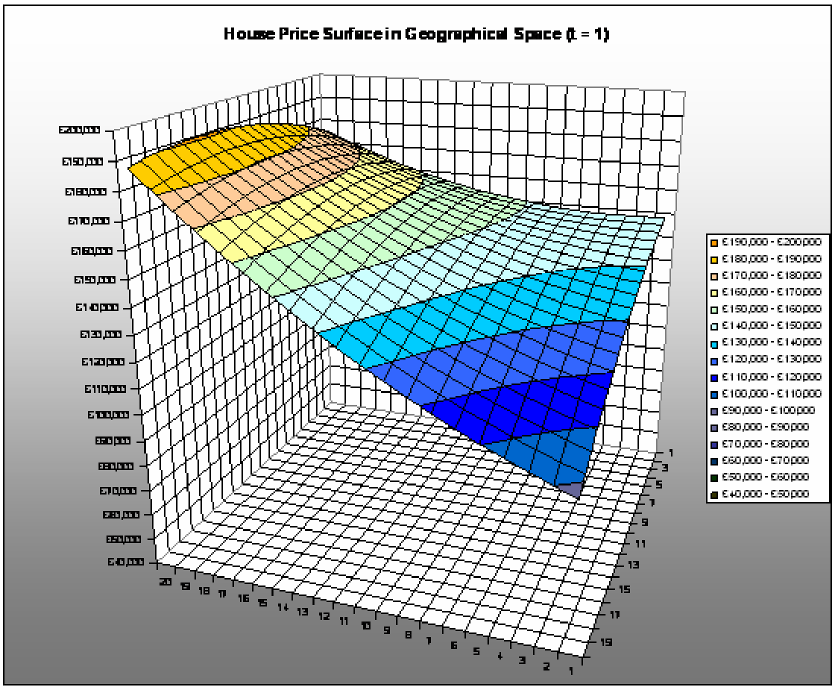


Figure 8 Flood Severity in period t=2 (1 = worst flooding, 0 = no flooding)

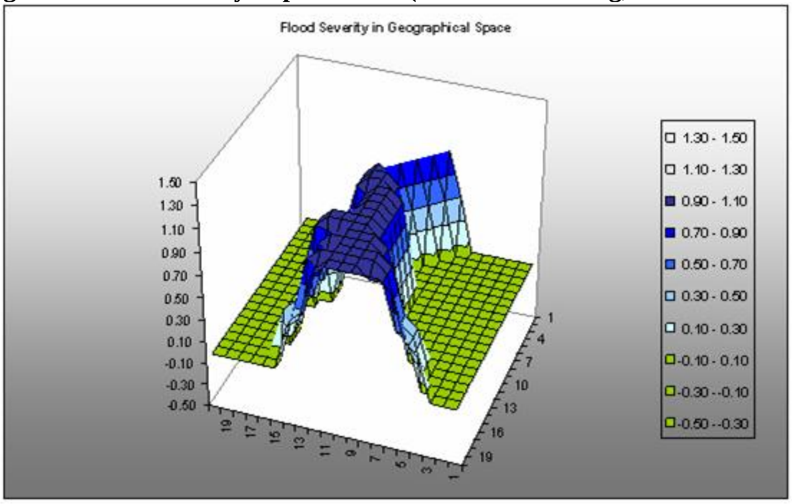
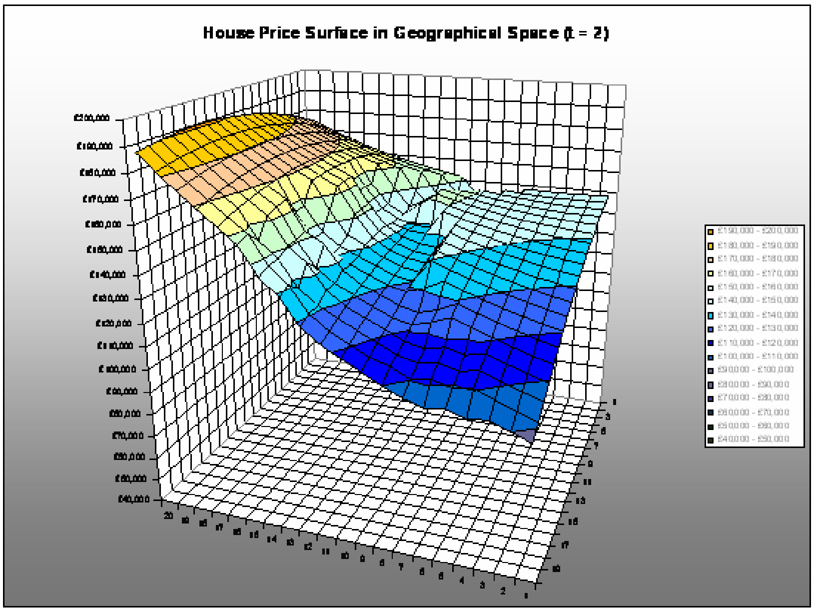
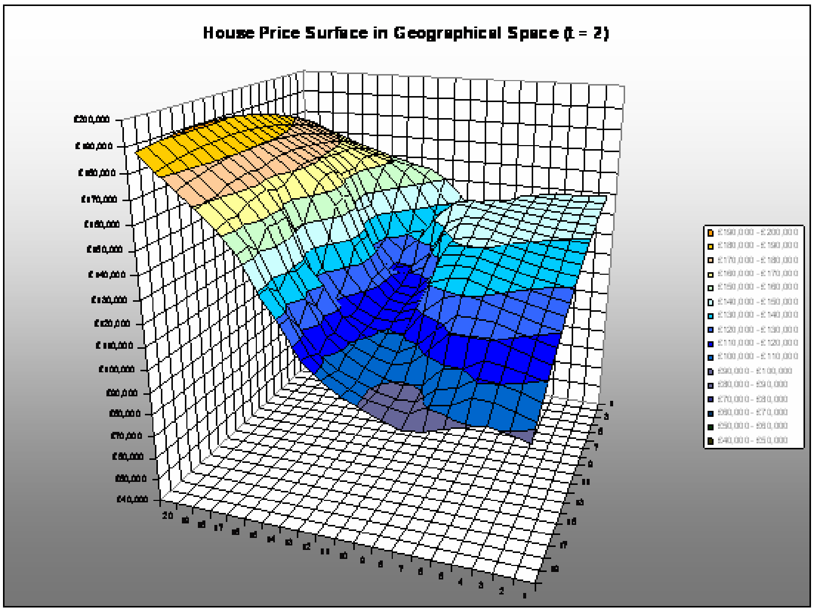


Figure 9 Hypothetical House Price Surface Post-Flood (t=2) with No Spatial Effects



Parameter on spatial lag 1 = 0.0; Parameter on spatial lag 2 = 0.0;
Flood impact parameter = 0.1

Figure 10 Hypothetical House Price Surface Post-Flood (t=2) with Spatial Effects



Parameter on spatial lag 1 = 0.3; Parameter on spatial lag 2 = 0.2;
Flood impact parameter = 0.1

Figure 9 shows the immediate impact of the floods on the house price surface assuming no spatial effects – in other words, only those postcodes directly affected by the floods experience a fall in house prices. The spatial spill-over effects are displayed in Figure 10, where the degree of downward price adjustment is inversely related to distance to the nearest flooded areas.

4. The Role of Flood Insurance

A potentially complicating factor in our analysis that thus far has not been considered is the role of insurance. If insurance premiums on homes and their contents reflected the true risk of floods, and insurance premiums were fully capitalized into actual home prices, it may not be important that home buyers and sellers do not accurately assess flood risk. If true, this would suggest that our hypothesized temporal drift of P_A away from P_{RA} will be dampened and our worry over amnesiac-myopic markets obviated thereby.

Of course, the veracity of the two prior assumptions may be questioned on analogous grounds of imperfect information. Moreover, there are at least two additional ways in which the insurance market can deviate from the efficient market archetype. Firstly, as is still the case in the U.S., U.K., and elsewhere, insurance companies may not fully price flood risk. In other words, households in low-risk areas effectively cross-subsidise those located in high-risk areas. Subsidised insurance does not, however, entirely insulate households in risky locations, even in the short run. Flood insurance does not typically compensate households for inconvenience and trauma, which can be the most potent aspects of extreme weather events. Also, it is unlikely that all households, particularly in poorer neighbourhoods, will have insurance.

Secondly, while insurers may not fully price risk, they may well ration insurance coverage, i.e., policies may be offered that exclude coverage for damage caused by flooding. This possibility has major implications, even for households willing to accept the loss and inconvenience of flooding, because mortgage lenders may, as a consequence, refuse to offer mortgage finance for dwellings in high flood risk areas, either because insurance is not currently available or because there is risk that in the future. The risk of insurance rationing is likely, therefore, to increase the risk 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 not be able to sell the house.

The inconvenience and trauma caused by flooding, combined with uncertainty about future insurance and mortgage provision, are likely to imply that, in the aftermath of a flood, observed market prices will tend towards their risk-adjusted price, even when current insurance is subsidised. Perhaps even more critically, subsidised (as opposed to full-cost) insurance should exacerbate the concavity of the price-risk adjustment curve, making a catastrophic tipping point all the more likely, insofar as it artificially encourages the pre-flood divergence between actual and risk-adjusted prices.

5. Implications

Our theoretical framework for understanding the relationship between floods and housing prices has implications both for future housing research and for public policy. As for the former, our framework suggests empirically testable hypotheses for assessing market efficiency in flood pricing. In an efficient market, house prices in a locality should decline only slightly for a short period following damage from a flood, regardless of the time since the prior flood. In an amnesiac-myopic market, house prices in a locality should decline substantially and for an extended period following damage from a flood, the decline directly related to the elapsed time since the prior flood and the distance to previously flooded areas.

From a public policy perspective, our framework suggests the possibility of grim adjustment processes. We have argued that a world of strongly amnesiac and myopic flood risk assessment by market actors, exacerbated by subsidized flood insurance, is a world ripe for catastrophic property value 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 demonstrated, where a comparatively small number of defaulting loans brought the world financial system to the brink of systemic failure.

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. Until relatively recently, changes to the world climate were assumed to occur over prolonged periods, but recent analysis of ice cores has uncovered evidence that historical shifts in climate have occurred very rapidly – shifting from an ice age to a Mediterranean climate within a single lifespan [refs]

6. Conclusion

One of the most material implications of climate change is increased flood risk in many of the world's most densely populated countries [refs]). How will housing markets respond to this intensified risk? Will households have perfect foresight regarding the changing risks and will their decisions reflect rational calculation based on such an epistemological utopia?

This interpretation of an efficient market with full information is not consistent with evidence on housing price responses to floods, and a broader theoretical and empirical literature emerging from behavioural economics. We posit that in estimating the monetary risk of flood damage to a particular property, market actors evince *amnesia* (progressively discount information from more past periods) and *myopia* (progressively discount information expected from more future periods) and *spill-over effects.* As a result, perceived flood risk (and home prices) may diverge considerably from actual risk (and risk-adjusted prices), particularly if a long period has passed since the last flood occurred or the location is far from any previous floods. In the event that market actors behave in ways characterised by amnesia and myopia, 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, step-change declines. Given the huge potential dislocations associated with these catastrophic adjustments, it behoves urban economists to conduct the sorts of empirical tests that would clearly identify the underlying market processes at work.

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