Policy relevant monetary valuation of flood risk

Policy relevant monetary valuation of flood risk: a review of approaches and estimates.

Andrew Snow^, Angela Connelly, Ian Mell, and Sotirios Thanos

Planning and Environmental Management, School of Environment, Education, and Development, University of Manchester

Abstract

This review provides insights into current methodological approaches to the valuation of flood risk and the conceptualisation of said risk. It reviews 32 papers identified through an extensive literature search. While there seems to be a degree of agreement in using hedonic pricing methods and that the introduction of new flooding information impacts house prices, there is significant variability in the magnitude of this effect. Some markets respond differently to others, with house prices recovering quickly in some instances despite recent instances of flooding. This is further complicated by the spatial dependencies, particularly in coastal locations, and the diverse ways in which flood risk can be framed to affect the price of houses. This is captured in a conceptual overview, where we have produced categorisations for the range of flood risk variables found in the studies reviewed. Potential avenues for further research aiming to experiment with combinations of flood risk variables that can refine valuation models are illustrated in the case of England and Wales, in terms of both geographic and governance particularities.

Key Words: Flood Risk; Hedonic Pricing; Non-market Valuation; Flood Policy; Housing Market; Stated Preference.

^ Corresponding author. Address: Bridgeford Street Building, University of Manchester, M13 9PL, UK. Tel: +44(0) 161 275 2808. Email: andrew.snow@manchester.ac.uk

1. Introduction

There is a tendency within existing literature to approach the valuation of flood risk according to certain models (e.g. difference-in-differences models (DID)) and spatial scale (e.g. the region/city) (Beltrán et al., 2018). This poses the question as to whether it is possible to quantify a more generalised capitalisation of flood risk, or if flood risk is so contextually dependent it is impossible to isolate. Through a review of existing literature, this study has sought to provide a broader review of approaches to the valuation of flood risk than has previously been offered, drawing on literature which employs diverse methodologies and conceptualisations of flood risk (*contra* Beltrán et al. (2018)). Through this review, we aim to better understand the extent of this existing literature and identify gaps within it for further exploration in relation to the question posed above.

In undertaking the review for this study, a series of journals were identified. These journals cover a diverse range of discipline areas, ranging from mainstream economics; environmental/ecological, urban, regional and real estate economics; environmental, urban and real estate policy; and urban, regional and housing studies. To ensure replicability and comprehensive coverage, the search terms inputted into each journal were standardised and searches covered two stages. In the first instance the term '"flood risk" valuation housing' was inputted. Once relevant studies were collated from this search a second term was inputted 'flood risk valuation housing'. The removal of quotation marks around flood risk in the second instance was to ensure that articles which did not contain this exact phrase but did address flood valuation were not omitted. Following the collation of literature across these two phases a forward and backward searching literature search was then performed using Web of Science and Google Scholar to identify relevant articles which were not published in the batch of journals reviewed originally.

The piece is organised as follows. Section 2 reviews differing methodological approaches and draws comparisons between their findings. Section 3 analyses the various approaches within the reviewed literature to conceptualising flood risk and proposes a typology for categorising the diverse variables which have been used in econometric models. This section also seeks to propose analytical criteria for future studies. Section 4 brings the lessons learned from the previous sections together and applies them to England and Wales. Potential problems and avenues for calculating the value of flood risk in the England and Wales housing market are then explored. In order to provide further analytical breadth and depth to any future study. This section also introduces the current policy framework for addressing flood risk within England and Wales. The governance structure and underpinning ideologies are detailed, and the implications of the findings for previous sections are discussed. Section 5 concludes the piece with proposals for future research in England and Wales.

2. Methodological overview

2.1 Hedonic pricing and informational changes

Generally, and particularly with those studies which modelled for the presence of new flood-related information, measurements of the value of flood risk tend to make use of difference-in-difference (DID) models. These approaches typically employ a semi-log regression to model the relationship between dependent and independent variables. Votsis and Perrels (2016: 460) study in Finland utilising a DID approach found that, modelling for properties inside and outside of various flood risk zones and for the introduction of flood risk maps, a property located in a "flood prone area incurs a statistically significant discount in the range of €316-1060 per square meter, depending on flood probability". Atreya and Ferreira's (2015) study of Georgia modelled for similar differences, seeking to understand the effects of floodplain designation and previous inundation, their findings were somewhat different. Through their analysis, Atreya and Ferreria (2016) were able to show that previously inundated properties both within and outside a floodplain were discounted by 48% and 36% respectively, leading them to conclude that the capitalization of flood risk into this localised property market was as a result of "the inundation effect" rather than that of floodplain designation (ibid: 840). This DID approach then enabled the study to draw a broader conclusion that in terms of flood risk discounts "homeowners respond better to what they have visualized ("seeing is believing")" (ibid: 846). This is further supported with results of a DID study performed by Rajapaska et al. (2016) who included two dummy variables in their study for the release of flood maps and for the actual incidence of flooding. They found that the former only had a 1-4% discounting effect whereas the latter was 18-19%.

DID studies have also shown that flood risk has a spatio-temporal impact on property prices. Atreya and Czajkowski (2016) have shown how a distance to the coast variable interacts with a flood return period variable to produce gradated flood discounts and/or price premiums. This found that while properties prices suffer a marginal decay as distance to coast increases, this is also mediated by the risk of returned floods leading the study to conclude that "as the positive amenity value decreases… the remaining designated high flood risk is discounted more severely" (ibid: 23). This is further impacted by the effects of an exogenous source of information in the form of a hurricane, with premiums and discounts both effected in the post-hurricane period. Zhang's (2016) study is also significant in terms of determining the temporal aspects of flood risk. It is shown that although "there is large price drop (17.02%) for houses confronting a flood risk in the year right after the 2009 flood" this "decreases to 9.41% in 2011… while after 2011, the significant price drop induced by the 2009 major flood disappears" (ibid: 15).

Those studies applying a repeat sales model generally use a flooding event as a covariate around which to pair the sales of a property. The flood event acts as an informational update within the market, with the presumption that prices after this update will be impacted by this new information (Hallstrom and Smith, 2005; Carbone et al., 2006; Lamond and Proverbs, 2006). Hallstrom and Smith's (2005: 543) study investigating the effects of Hurricane Andrew, for example, modelled an "exogenous source of information" to distinguish between the distance of a property from the coast as "either a proxy for coastal amenities or for increased risk of damage", makes use of a repeat sales model. Within this model, sales of a property were paired according to their relationship to the hurricane, where one sale was before and the other after. Through this analysis, Hallstrom and Smith were able to show that those properties possessive of this hurricane characteristic appreciated in value at a rate of $598/y compared to $1377/y for those properties where the pair of sales both took place after the hurricane. As part of this study, Hallstrom and Smith were able to show how even in unaffected, 'near miss' areas the hurricane still impacted upon the rate of appreciation of properties, proving that this informational update had a broader effect on the housing market. Carbone et al. (2006) also used a repeat sales model in the Florida area around the time of Hurricane Andrew. This study found that the "hurricane was a statistically significant factor in reducing the rate of increase in housing prices" (ibid: 292) with those properties in the two counties studied experiencing 23-30% reductions.

Lamond and Proverbs (2006) found in their study of a Yorkshire housing market with a major flood acting as the informational event that there was a fast recovery of mean housing prices in flooded and at-risk areas when compared to non-affected areas. While there was an initial fall in the rate of appreciation in the c.2 years following the event, after this appreciation rates recovered and mirrored those of unaffected properties leaving "no significant impact on prices of property" (ibid: 375). They conclude that if this "quick recovery… is common, property owners can take the long view and reinstate their homes with confidence" (ibid).

2 of the 32 studies analysed make use of generalised additive models (GAM) (Hirsch and Hahn, 2018; Rajapaksa et al., 2017). The purported benefit of this methodological approach is that it attempts to model means of evaluating unexpected, nonlinear covariate effects (Hastie and Tibshirani, 1986). This, in theory, then enables "smooth functions describing the relations" between variables (Hirsch and Hahn, 2018: 56). Using this model, Hirsch and Hahn (2018: 57) found that "purchase prices for one square meter of living area are, on average, EUR299 lower if the property is located in the 100-flood risk zone". For rental properties, contra the authors' initial hypothesis, there was also a discount for at-risk properties of –1.88%.

Rajapaska et al. (2017) use a GAM approach to assess the impacts of flood risk in terms of distance to and elevation from a river and its temporal behaviour. Their findings indicate that the "amenity value of being close to the river is higher than risk discount" and that while properties are discounted immediately following a flood, prices do recover in high- and medium-income suburbs. Those properties in low-income suburbs suffered a price slump immediately following the flood and prices continued to decline thereafter, suggesting that income is a determinate variable in assessing the effects of flood on property sub-markets.

2.2 Hedonic pricing and spatial aspects of the data

Clearly studies which incorporate a spatial dimension into their hedonic models are also important (Atreya and Czajkowski, 2016; Bin et al., 2008; de Koning et al., 2017; de Koning et al., 2018; Fu et al., 2016; Meldrum, 2016; Rajapaksa et al., 2016; Zhang, 2016). The use of SARAR and Kriging are helpful in modelling for the spatial dependence of covariates within said frameworks. A noteworthy example of a study employing this method, while also utilising a larger-than-typical sample size (319,507) was that of Fu et al. (2016). This looked specifically at the inundation of coastal properties in Florida combining a spatial lag model with a standard hedonic framework. The aim was to isolate the amenity value of coastal properties which would be lost in the event of sea-level rises due to climate change. While not strictly concerned with the valuation of flood risk, this is a noteworthy study because it pertains to an issue identified by Beltrán et al. (2018) who conclude that it is impossible to dissociate the amenity value(s) attached to coastal properties from the price discounts attached to increased flood risk in these locations. This work by Fu et al. (2016: 13) provides a potential means of conceptualising the loss of coastal amenity value due to flooding by modelling for the "transferred value to inner land properties due to inundation by sea level rise". However, in doing so coastal amenity and flood *risk* remain inextricable, in that the *loss* of amenity is tied to the actual occurrence of a flood rather than the risk of this occurrence which is not necessarily a factor in determining the value of the property. This is where a study by Bin et al. (2008), which was deliberately excluded by Beltrán et al. (2018) based on its coastal location, possesses further potential. As part of their methodological approach, Bin et al. (2008) also make use of a spatial-lag model but further supplement this with remote sensing (LIDAR) and mapping technologies (GIS) to model for a 'view-scape' for each individual property. This encompasses the distance of each property from the coast in addition to its field of view of the coast. In this way characteristics which are likely to be viewed as enhancing the amenity value of a property[1] can be incorporated into a hedonic model and the marginal prices of each calculated. In this way, characteristics relating to coastal amenities can start to be separated from those characteristics which relate to flood risk.

Only 1 of the 32 studies analysed used a fixed/random effects model, but the aggregated findings of this study are significant for future studies who wish to consider the range of variables which might impact upon the capitalisation of flood risk. Atreya et al. (2015) use the combination of fixed and random effects models to analyse the market penetration of flood insurance in the state of Georgia. Their study found that

[1] The proximity of the property to the coast and the extent of its coastal view

the income of residents and the price of houses both “significantly influence the decision to buy flood insurance” (ibid: 159). In addition, and in support of other studies, they also found previous flood damage “up to three years back” (ibid) has a positive influence on the decision to take-up flood insurance, after which the effect vanishes. Race, education and age were also found to have a significant impact, with a unit increase in the African American population accounting for a 1.05% increase in insurance policies per 1000 population, a 1% increase in high school and colleague graduates account for a 4.35% increase, and a 1% increase in 45-64 and 65+ year olds accounting for 4.7% and 5.6% increases respectively (ibid: 160).

2.3 Hedonic pricing combination with survey-based methods

In terms of combining this subjective assessment with hedonic models, de Koning et al. (2017) sought to ‘bridge the gap’ between stated and revealed preferences by comparing their hedonic analysis with the results from an agent-based model. This analysis found large variance in risk perception and loss aversion at the individual level, which de Koning et al. (2017: 7, emphasis added) argue lead to “fundamentally different *market* level outcomes in terms of capitalised risk discounts”. Using four ‘simulated’ markets[2], this study found that the “marginal implicit price of flood risk… strongly depends on framing” (ibid: 6) in that properties which have experienced a single previous flood are more heavily discounted than those which have three previous floods as a reference point. It is argued that this is because “people under-weigh the probability that no flood occurs, making them undervalue the expected utility gain from buying a flood-prone property in this scenario” (ibid).

Zhang et al. (2010) also make use of questionnaires to supplement their study of risk perception, although this did include hurricanes and toxic chemicals as hazard phenomena. In terms of flood and hurricane risk, this study sought to test the hypothesis that “proximity to flood hazard and hurricane hazard will have a direct positive effect on housing value that is independent of risk perception” (ibid: 603). This was disproven, as it was found that for “every mile away from the flood hazard, housing value would increase by 8%” even after controlling for the mediation of flood risk perception (ibid: 611-3).

2.4 Contingent valuation and other survey-based approaches

Of the studies analysed, those using CV approaches make up a relatively small proportion (4 out of 32). Contingent valuation measures a respondent’s willingness to pay (WTP) and/or willingness to accept (WTA) for dis/utility by providing them with scenarios to which they can assign a value. From this, researchers can ascertain a

[2] 1. Negligent risk 2. Expected utility with standard risk of flooding 3. Prospect model where one previous flood is already accounted for and taken as a reference point for expected utility 3. Prospect model where three previous floods are already accounted for and taken as a reference point for expected utility.

value for a number of dis/utilities, and resource management strategies and policies can be devised accordingly. Botzen and van den Bergh's (2012) study of WTP for flood insurance used scenarios based on increasing climate change risks posed by climate change and a risk ladder to enable participants to compare the risks of flooding with the risks of other catastrophes and mishaps (e.g. car-theft and house fires). This study found that as the risk of flooding increased from 1 in 1,250 years to 1 in 400, the WTP for insurance increased, but "few individuals adjust their WTP proportionally or more than proportionally to changes in flood probability" even when risk was communicated using a risk ladder (ibid: 158).

Koetse and Brouwer (2016: 743) sought WTP and WTA estimates through their flood probability choice experiments and found that "WTA values are larger than WTP values for identical changes in flood probability" and that when flood probability reference points are altered "disparity increases when using a lower flood probability reference value, or vice versa the disparity decreases when using a higher reference value". This accords with research from the standard hedonic studies, which also stipulates that flood valuation is a function and time- and place-specific information, meaning that flood risk does not have a uniform effect on WTP across contexts.

Torgersen and Navrud (2018) also used CV to assess urban residents' perceptions and valuation of flood risk. This study found that those participants who had self-identified as being 'close to flooding' had a higher mean WTP per year to avoid insecurity from flooding than those participants who were not 'close to flooding', but within this group those who had identified as 'close to flooding' by way of their 'own experience' had a lower mean WTP than those who had identified as 'very exposed' and '<100m away' from a flood hazard (938NOK compared to 1255NOK and 1200NOK respectively). This has potentially interesting implications for the conclusions of the standard hedonic literature which state that flood discounts are greater in the time immediately after a flood event, but this effect disappears over time. The manifestation of flood experience in the housing market may be mediated by the capacity for those properties to withstand and/or recover from damage which would explain both the lower WTP and the fairly quick recovery of housing prices post-flood. Only a single study of the 32 analysed made use of an inter-rater agreement approach. This study by Bhattacharya-Mis and Lamond (2016) used questionnaires and a Likert scale ranking to measure the preferences of respondents in relation to flood damage and its effects on property value. The use of the inter-rater agreement technique is justified on the basis that a measure is required to ensure that responses "are more similar to each other than would be expected by chance" (Bhattacharya-Mis and Lamond, 2016: 255). In terms of a housing market, this is an important factor, particularly when one is attempting to uncover a generalised market-level flood perception as opposed to atomised, actor-level responses which bear no relation to one another. This study found that "respondents, irrespective of their flood experience, showed a fairly neutral attitude towards vulnerability of value" with regards a number of desirability and marketability variables, including flexible lease terms, higher expected income, historical reduction of property value as a result of flooding, installation of flood protection measures, and easy mortgage availability (ibid: 257).

3. Conceptual overview: flood risk's multiple characteristics

The differentiation between flood risk and coastal amenity within hedonic frameworks is further enhanced in a study by Atreya and Czajkowski (2016: 10). This study utilised a series of flood risk related variables according to floodplain designation (high, moderate or minimal) in addition to an "associated relative flood risk" determined by a property's elevation variance[3]. Through an interaction of this flood risk with a distance-to-coast measurement within a multi-staged hedonic framework, Atreya and Czajkowski (2016) were able to capture the granular effects of flood risk and coastal amenity valuation, even within an ostensibly aggregated food risk zone (i.e. a 100-year or 500-year floodplain). Previous studies by Hallstrom and Smith (2005) and Carbone et al. (2006) adopt a slightly different approach by attempting to model for the presence of additional information – in the form of a hurricane – on coastal property prices. Again, however, this is an attempt to isolate flood risk as an explanatory variable within hedonic frameworks. It pertains to the assumption that the inextricability of flood risk from coastal amenity relates to an information gap which only an "endogenous source of information" in the form of a hurricane can fill (Hallstrom and Smith, 2005: 543). Once the effects of a hurricane (and the associated risk of flooding it poses in coastal locations) are factored into a hedonic framework, it is plausible to argue that those properties most at risk will begin to experience observable price discounts. This would then allow the study to dissociate the effects of flood risk from the amenity premiums on coastal property prices.

This brings discussion on to the more general conceptualisation of flood risk within the econometric models used to calculate the pricing of said risk. As with the previous discussion on coastal properties, there appears to be an acute awareness within the literature of the fact that, as Beltrán et al. (2018: 679) argue, floodplain designation in of and by itself is a "a poor measure of the probability of any individual property flooding". This is supported by the evidence presented in Table 3. A large proportion of the studies analysed (20 out of 32) – even going as far back as Barnard's (1978) – have attempted to incorporate different measures of flood risk to enable more comprehensive and gradated hedonic models. Sensitivity to the multitude of characteristics which make up valuation of both revealed and stated preferences in relation to flood risk (de Koning et al., 2017) is vital if one aims to calculate with accuracy the effects of said risk on property prices. Generally, these attempts can be split into two categories. The first is constituted by studies which have sought to incorporate other observable characteristics of the properties under consideration into their econometric models. Similar to those identified in the previous section, these

[3] Elevation variance: "difference between the elevation of the ground upon which the immediate structure rests and the elevation of the flood plain" (Atreya and Czajkowski, 2016: 10).

characteristics include the distance of the property to the nearest waterbody, river or coastline (Rajapaksa et al., 2017); potential and actual inundation levels (Atreya and Ferreira, 2015); elevation of the property (Atreya and Ferreira, 2015; Rajapaksa et al., 2016); the proximity of the property to an identifiable source of increased flood risk (e.g. the eye of a hurricane) (Carbone et al., 2006); demographic characteristics of the populace in terms of age, race and education (Atreya et al., 2015); and the presence of flood risk information in the form of maps and/or flood history (Eves and Wilkinson, 2014; Rajapaksa et al., 2016; Rajapaksa et al., 2017; Votsis and Perrels, 2016). What is common amongst these studies is the presumption that by building in more and more of the characteristics that relate to flood risk, these models can reveal the nuanced nature of flood risk valuation in housing markets and make policy recommendations attuned to these dynamics (Atreya et al., 2015).

The second category can be said to cover those studies which incorporate the stated preferences of actors within the housing markets towards flood risk. Although these studies constitute a much smaller proportion of the studies analysed (7 out of 32), they do pose questions of the assumptions made by the models within the first category. Pryce et al. (2011) argue that flood risk perception at the individual level is *not* characterised by rational decision-making and perfect information but is instead affected by behavioural traits of myopia and amnesia. Previous floods are quickly forgotten about (supported by results of revealed preference models (e.g. Atreya et al., 2015)) and individuals adopt myopic attitudes to the risk of flooding, resulting in a market failure in the capitalisation of flood risk. Pryce et al. (2011) argue that these myopic and amnesiac behaviours will diminish as floods become more frequent, but with the onset of climate change and the associated increased risk of flooding waiting to do so will incur and inflict unacceptable costs and damages. A later study by O'Neill et al. (2016) sought to adapt its methodological approach to test the rational decision-making hypothesis that distance to a perceived hazard zone has a significant influence on risk perception. This study made use of a cognitive mapping exercise during face-to-face interviews and found that individual perceptions of flood risk are driven by *mis*perceptions of risk reality.

This variation in flood risk conceptualisation is captured in Table 1. The ways in which the literature seeks to model for flood risk can be split into six categories relating to: floodplain designation; demographic characteristics of the study population; topographical characteristics of the case-study area; proximity of properties to waterbodies; the presence (or lack of) information at particular times over the study period; and the physical characteristics of properties. Within each of these categories, the variables used by the studies analysed have been listed. As can be seen in Table 3, these variables are by no means mutually exclusive, with several studies utilising several as part of their price models. In terms of moving towards a replicable conceptualisation of flood risk, it is noteworthy that several of these variables are context specific. For example, the proximity of the property to the eye of a hurricane is obviously dependent on the presence of said hurricane and comes from a study which used this naturally occurring phenomenon as a proxy in their model for the presence of new information (Carbone et al., 2006). As with other studies which include informational variables, the nature and form of this information varies according to time and place.

What this does tell us, however, is that while flood risk may be calculable according to universal, quantifiable measures like floodplain designation its manifestation in a housing market is mediated by these context-specific information variables. Hence, flood risk is possessive of both a differentiating and differentiable character within housing markets. It differentiates between properties based on their exposure to flood hazards as well as being differentiable according to the contextual characteristics which give rise to it (i.e. flood risk manifest itself differently from one context to the next). Accordingly, when attempting to model for flood risk the evidence sourced here suggests that more comprehensive conceptualisations of flood risk which draw on variables from a variety of the categories listed in Table 1 are preferable to those which rely on single, or even multiple, variables from a single category.

Table 1: Flood risk categorisation and variables

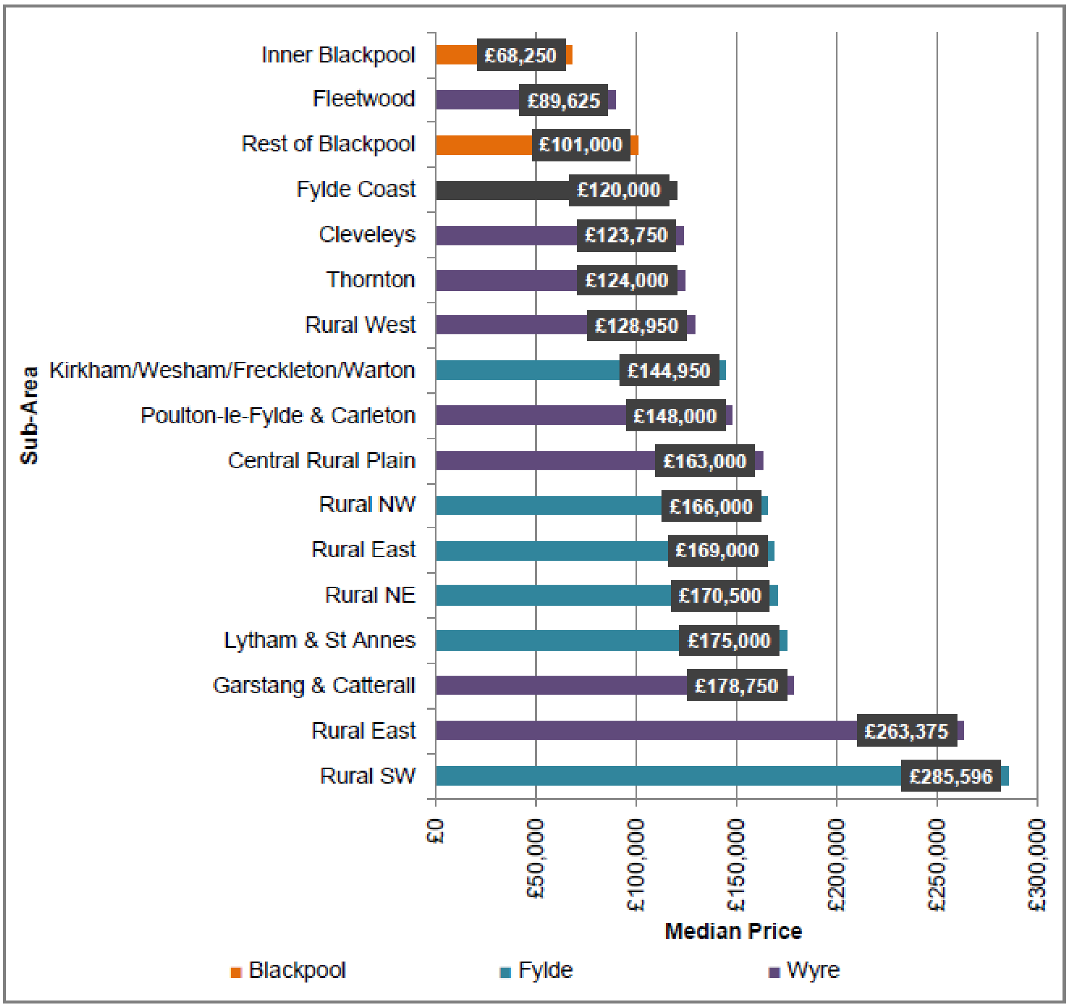
Flood risk category	Variables within the reviewed literature
Floodplain designation	100 100 and 500 merged into one floodplain variable 400 500 1000 1250 1600 2000 5000 10,000 Minimal Moderate High
Demographic characteristics	Educational attainment Ethnicity
Topographical characteristics	Probability that flood waters will reach elevation of home and low point of lot on a given day Inundation levels No shores Shores off the coast Shores next to the dike
Proximity to waterbodies	Hazards associated with storm waves Distance to river Distance to coast Elevation from river Geodesic distance from nearest waterbody
Informational	Frequency of flooding Respondent perceptions of flood risk Recent flood events Previously inundated by flood Previously affected by flood Flood return period Proximity to path of the eye of hurricane Worry Disclosure of flood-risk information Release of flood maps Subjective risk assessment Self-assessment of exposure
Physical characteristics of property	Elevation of property (from base of foundation and from low point on lot) Raised floors Flood defences Coastal location

4. England and Wales' potential as a case-study

An overwhelming majority of the studies performed on flood risk valuation in the housing market are based on data gathered from the US (Beltrán et al., 2018). In particular, work performed on coastal housing markets has led to a generalised assumption within the literature that distance-to-coast and view-perspective are representative of a generalised hedonic valuation of coastal amenity (Fu et al., 2016; Bin et al., 2008). Evidence from the England and Wales context would suggest that these are not necessarily an overriding factor. Some of the most socially and economically deprived towns are found in coastal locations with attendant negative impacts on house prices. This section uses secondary data gathered from the Blackpool and Fylde area to pose questions of these models and explore future avenues for housing research.

Gibbons et al. (2014) use a range of amenity variables, including 'distance to coast', to model for the effects of natural assets on UK house prices in the period 1996-2008. Their calculations found that "increasing distance to natural amenities is unambiguously associated with a fall in prices" (ibid: 190) and that an increasing distance to the coast lowers prices by £140 to £275 per km. While within this particular study this coastal price premium was not statistically significant, it aligns with the findings of previous studies and the metanalysis by Beltran et al. (2018). However, in the context of England and Wales and the high-levels of deprivation in coastal areas (Corfe, 2017), it is pertinent to question whether coastal amenity value is something which is uniformly experienced across housing markets. Secondary data gathered as part of this study would suggest that there is at least some doubt of this. Taking the example of Blackpool and the Fylde Coast, housing market analyses performed by local councils based on land registry data in these areas suggest that those properties located closest to the coast do not necessarily enjoy an aggregated price premium. Distinguishing between 'outer' and 'inner' Blackpool (the purple and green boundaries respectively in Figure 2), this analysis found that the median price of inner Blackpool properties was £68,250, compared to £101,000 for those in the outer region (see: Figure 1). Given that inner Blackpool is the most proximate region to the coast and is likely to be, based on an initial reading of the map (Figure 2),comprised by a larger proportion of properties possessive of a 'coastal' characteristic when compared with the outer region, several issues are raised.

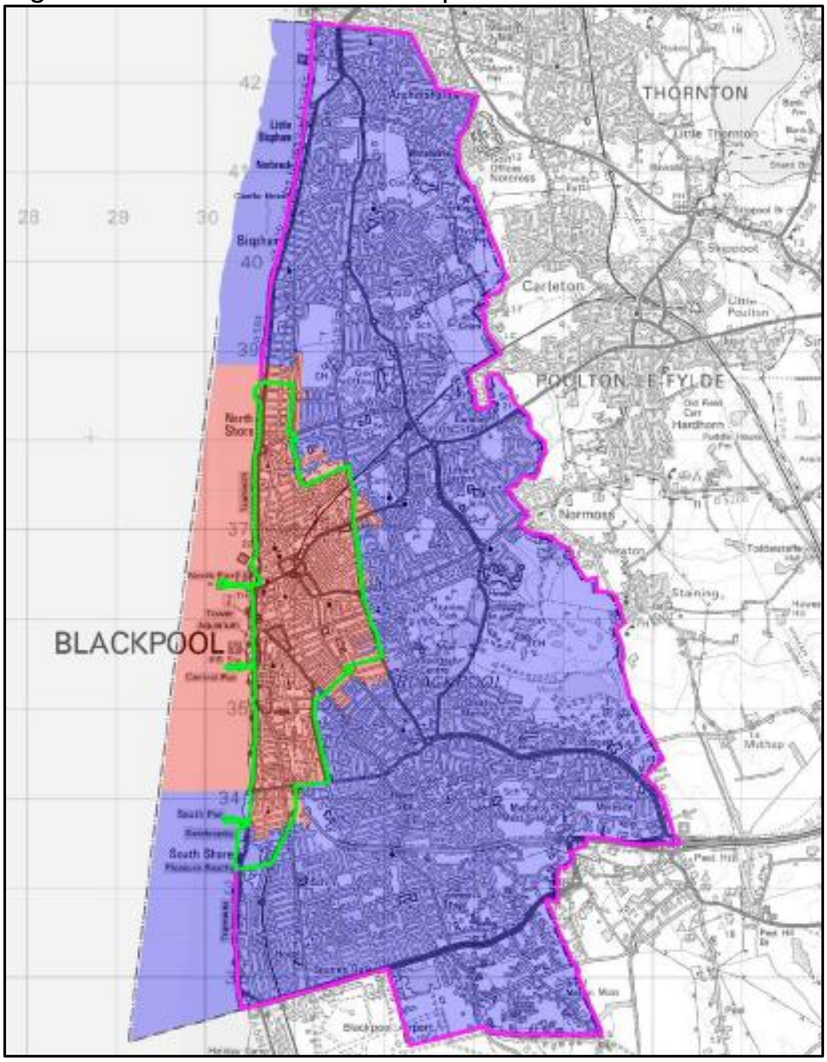
Figure 1: Median prices of properties in various English regions



Source: Blackpool Council et al. (2014)

Firstly, while this unweighted comparison between two median prices obviously does not account for variables such as house quality, bedroom sizes, and garden sizes. The stark difference between regions of the same city suggests that 'distance to coast' is likely to be significantly outweighed by other variables in any willingness-to-pay calculation. As such, a conceptualisation and attendant model for coastal amenity that captures the significance of the coastal variable in relation to other property characteristics is necessary.

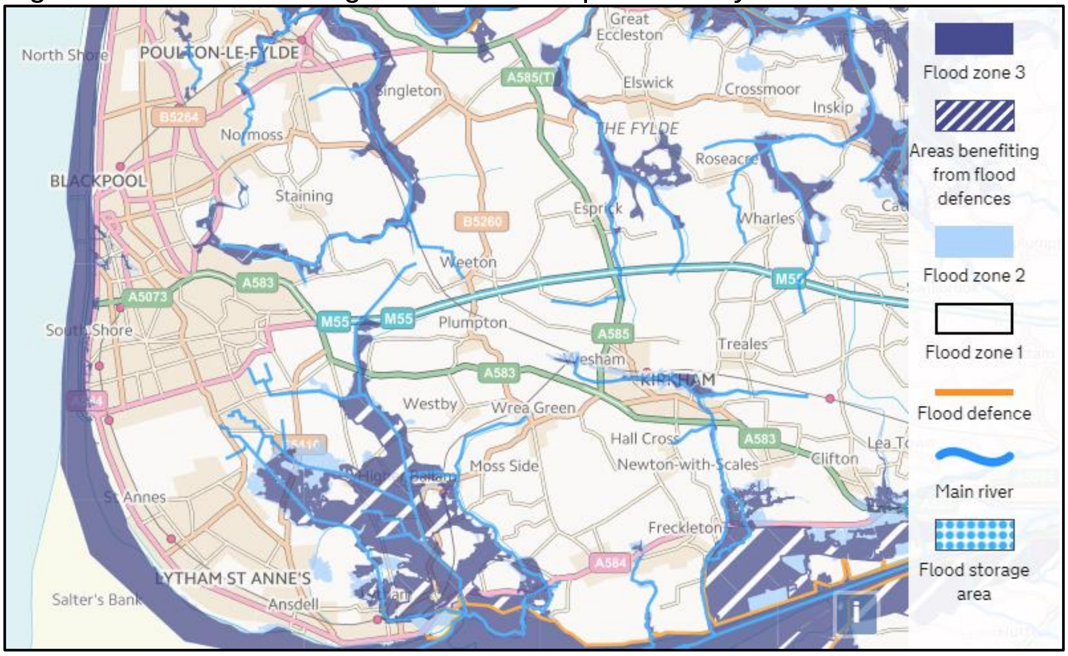
Figure 2: Inner and outer Blackpool



Source: Blackpool Council et al. (2014)

Secondly, there are properties in the example given which lie in the ‘outer’ Blackpool region but which could also be classed as ‘coastal’. This poses the question as to whether there are identifiable characteristics of the ‘outer’ region which distinguishes its properties by way of their coastal amenity. If a model was able to delineate the coastal characteristics of properties, it would be able to identify the covariates which impart price premiums and better explain the nature of coastal amenity and its effects on housing markets within and across specific contexts.

Figure 3: Flood risk designation for Blackpool and Fylde Coast



Source: EA (2020)

Once a conceptualisation of coastal amenity is constructed which reflects these intricacies, ‘flood risk’ can start to be isolated and related to these coastal characteristics. Indeed, an initial reading of the raw, non-regressed data from Blackpool indicates that the properties in its inner region are subject to a significant discount. While this region has not been identified by the EA as at risk of flooding (see: Figure 3 above), as Beltran et al. (2018) argue and as shown in previous studies, floodplain designation is a poor measure in of and by itself of flood risk. The question posed, therefore, is whether proximity to a waterbody can, by itself, become a kind of proxy for flood risk in property price calculation. In addition, taking into consideration the previous stipulations, in coastal locations there is the potential that those coastal characteristics which *do not* impart a price premium could be supplanted by flood risk in property values. Identifying these characteristics which are supplanted would better enable a hedonic model to calculate the effects of coastal location in combination with the effects of flood risk, ensuring that those properties located in coastal locations were included in regression analyses and a nuanced, gradated calculation of flood risk. Conceptualising one’s approach to calculating the price of flood risk in such a way would enable a study to include coastal properties in its regression safe in the knowledge that both ‘coastal amenity’ and ‘flood risk perception’ had been modelled appropriately and accurately.

4.1 England and Wales policy context

This section details the current England and Wales policy context for flood risk management (FRM) and discusses the implications of the previous findings. It is argued that the current emphasis on localised management and subsequent potential for differentiated response to flood risk within and between different housing markets can exacerbate the issues identified. Moving forward, there needs to be appropriate recognition of the fact that, because flood risk is so multifaceted, if responsibility for valuing it continues to take place at an individual level then there is little chance of the ‘true’ cost of flooding being capitalised into housing markets. In the context of a changing climate, and the subsequent increase in incidences of heavy rainfall and pluvial and fluvial flooding, there is an increasing need for a policy framework which recognises this risk and provides a framework for both the management *and* reduction of flood risk. The England and Wales current policy framework, it is argued, reinforces inequality through FRM as well as normalising the acceptance of flood risk (Johnson et al., 2007; Ball et al., 2013; Begg et al., 2015). In terms of housing market studies, the mutual dependencies between policy frameworks and consumer behaviours need to be better recognised in order to better understand, *prima facie*, market dynamics.

FRM in England and Wales, shown in Table 2, is characterised by a multi-actor, multi-levelled system of governance which prioritises cross-level partnerships, evidence gathering, and awareness building. This is emblematic of a shift in ideology following major flooding at the turn of millennium which de-emphasised structural and engineering defence responses and sought to promote the management of risk through strategic decision-making (Johnson et al., 2007). Within this paradigm, FRM is “inherently adaptive, privileging *resilience*, as opposed to outright prevention” (Ball et al., 2013: 266, emphasis in original). Facilitating for the collaboration and multi-directional flows of information between the various institutions, organisations and actors who have both responsibilities and capacities in relation to flood risk should ensure a higher-level of preparedness, adaptability and responsiveness within the FRM system as a whole. This manifests itself in an emphasis on local delivery (see: Table 2). While the EA and the DCLG provide national frameworks for the delivery of FRM, the emphasis is on enabling those local bodies (ordinarily county councils) to provide tailored FRM strategies recognisant of local context.

A major plank of England and Wales’ current FRM approach is individual insurance. The reasons for this are ably explained by Ball et al. (2013) who are argue that the new emphasis on resilience manifests itself in the capacity for “communities to withstand and rapidly recover” from floods (ibid: 267). From a socio-economic perspective, this capacity is tied inextricably to the ability of communities to ‘withstand and rapidly recover’ from the costs of a flood in terms of damage and disruption. Insurance is therefore vital in mitigating these costs and allowing for recovery. Following a period of cross-subsidisation from low-risk to high-risk policy holders (Ball et al., 2013), the current approach to flood insurance in England and Wales is a reinsurance scheme: *Flood Re*. Through a taxation of insurance providers, certain properties built prior to 2009 are able to take out insurance against flooding with contributions and premiums capped at a more affordable level and any excess funded through this tax. Flood Re have found that 295,159 homes in England and Wales are at risk of flooding in high food risk areas (BBC, 2016).

Table 2: England and Wales FRM organisational structure

Operating level	Actors (institutions, organisations or individuals)	FRM responsibilities and capacities
National	Environment Agency	Provide strategic overview Providing evidence to central government Developing capacity at lower levels Providing framework for delivery at lower levels
	Department for Communities and Local Government (DCLG)	Overseeing delivery of flood-risk objectives in NPPF Devising and setting building regulations
Regional	Regional Flood and Coastal Communities	Plans for identifying, communicating and managing flood and coastal erosion risk Investment in flood and coastal erosion risk management Linking FRM authorities and other relevant bodies to develop mutual understanding of flood and coastal erosion risks in their areas
	Water and Sewerage Companies	Managing risks of flooding from sewer systems Providing drainage from buildings and yards
Local	Lead Local Flood Authorities (LLFAs)	Developing, maintaining and applying strategies for FRM in their areas Maintaining registers of flood risk assets Managing risk of flooding from surface water, groundwater and ordinary watercourses
	District Councils	Partners in carrying out FRM works on minor watercourses Development decisions which ensure flood risks are effectively managed
	Internal Drainage Boards	Public authority which manages water levels in places where there is special need for drainage Maintenance of watercourses to reduce and manage flood risk Work in partnership with other bodies
	Highway Authorities	Providing and managing highway draining and roadside ditches Ensure road development does not increase flood risk
Individual	Home-/business-owners	Purchasing flood insurance Property level flood defence measures

Adapted from DEFRA (2014) and EA (2014)

This collaborative, multi-actor, locally- and adaptive-focused approach arguably enables more ‘sustainable’ approaches to FRM, in terms of its current application there are “concerns about equality between areas” (Begg et al., 2015: 697). In the context of localism, an approach to planning which emphasises locally sourced and managed solutions to planning problems with minimal interference(/support) from central government, the capacity to deliver FRM depends on the local availability of resources in terms of funding and motivation. At a time when central government funding for council services is being cut, economic growth in development activity is prioritised, and the "presumption in favour of sustainable development" is enshrined in planning policy, local councils face complex decisions in terms of where FRM ranks in their list of political priorities. Where there *is* local motivation and access to funding, Begg et al. (2015) have found that local FRM delivery can be innovative and effective. On the other hand, however, where motivation and/or funding is lacking, short-term growth-oriented planning may take over. Recent reports have found that 10,000 homes per year, or 7% of total houses, are built on floodplains in England and Wales (The Independent, 2015). While it would be empirically inaccurate to draw a direct causal link between this figure and England and Wales' current approaches to planning and FRM delivery, there is a suggestion that this predilection for housebuilding in at-risk areas is at the very least exacerbated by them. As a result, inequality in the suffering of flood risk between areas where FRM is prioritised and deprioritised respectively becomes more pronounced.

Another implication of the emphasis on local delivery and the inequality that it gives rise to is the ownership of flood risk. In some of the examples provided by Begg et al. (2015), where funding, participation in, and 'ownership' of, a FRM scheme is drawn from a variety of public and private actors and organisations, flood risk is – to a degree – socialised, whereas in those areas where the necessary support is lacking it is privatised. Within an FRM approach where insurance plays such a central role, the capitalisation of flood risk within the housing market can take a number of divergent paths not necessarily representative of the 'true' cost of flooding.

In the first scenario, where local motivation and funding exists, it may be that the risk of flooding to properties is eliminated or reduced to such a degree that it no longer has a marginal effect on property price. Within these areas, however, there is the potential that previous incidences of flooding have elicited funding and/or engendered motivation (Ball et al., 2013). The presence of an effective FRM strategy may induce a reduction in flood risk discount, or even facilitate for premiums depending on the nature of the area. However, the memories associated with previous floods may counteract this, leading to an overvaluation of flood risk in an area with an ostensive reduced flood risk. Further studies into these types of areas in England and Wales would be beneficial in testing this potential.

In those areas with existing socioeconomic deprivation and inequality, however, there is a greater potential for ignorance of flood risks (Walker, 2012), producing a situation where flood risk is significantly undervalued in a housing market. Even where there is take-up of flood insurance by those willing and able to afford it, underpinned by the Flood Re scheme, this will lead to an acceptance of flood risk at a price determined by the scheme. Flood Re may therefore stand accused of normalising the risk of flooding and in doing so undervaluing its costs particularly with regards to social and environmental damage. Concerns over the data used and the transparency of calculations also causes the undervaluation of flood risk through insurance (McAneney et al., 2016).

This is particularly pronounced in those properties which have been built on floodplains in the post-2009 period which are not covered by the Flood Re scheme. In these cases, flood risk is more likely to be ignored if insurance premiums are deemed to be prohibitive, meaning that insurance is likely to be taken up by a smaller proportion of households. In this scenario, the cost of flood risk would also be undervalued at the market level. While it might be argued that the market would eventually 'correct' this imbalance, previous studies (discussed in Sections 2 and 3) have shown that it is only properties that have either been recently damaged by floods or those in areas with a recent history of flooding which more accurately capitalise the risk of flooding. In terms of housing market capitalisation of flood risk, it is argued that the Flood Re scheme can only ever represent an at best partial value of flood risk. While it may be that the take up of flood insurance is how flood risk is ultimately capitalised into a property, the take-up of insurance is dependent on a variety of factors, including recent flooding and characteristics of the property. This means that only certain aspects of flood risk are capitalised at any one time, and that the actual extent of risk may not be accurately reflected.

In terms of the implications for future FRM and housing, an initial reading of England and Wales context in light of existing literature on flood risk capitalisation leads one to conclude that the dynamics within and between housing markets and policy frameworks require careful elucidation. While the current approach to FRM in England and Wales is, to an extent, reflective of the need for responsive and locally-sensitive strategies, in practice the presence of motivation at a local level combined with the ability to access funding means that flood risk is dealt with unequally. The centrality of insurance and the nature of the current Flood Re scheme exacerbates this inequality, and in interaction with current planning ideologies actually serves to encourage the decapitalisation of flood risk from the housing market. To the myopia and amnesia that is said to characterise housing markets' response to flood risk (Pryce et al., 2011), it is argued that one can add *trivialisation*, enabled and exacerbated by FRM which atomises and localises flood risk; depends exclusively on a willingness to make use of resources, if they are available; and assuages concerns regarding flood risk through an insurance scheme which does little to reduce the risk of damage caused by flooding.

While the current emphasis on information provision and increased awareness has the potential to engage citizens, and access to local decision-making and service delivery mechanisms the potential to empower them (Nye et al., 2011), the literature on flood risk argues that 'seeing is believing'. Without the immediate experience of flooding, the likelihood of a consistent and accurate valuation of flood risk is lessened.

Trends in the recovery of property prices in relatively short periods of time following major flood events would suggest that the window for capitalising on flood events to devise and implement FRM strategies is narrow. Only when it is ‘too late’ and flooding has become a regular and/or extremely burdensome phenomenon will the market be able to ‘correct’ the undervaluation of risk. Until then, prospective homebuyers are unlikely to be put off buying homes in at-risk areas for long, and even where there is a knowledge and understanding of these risks the ability to purchase insurance “mitigates worries about flood risk, as well as, for those affected, the psychological effects of past flood experiences” (Ball et al., 2013: 269). This is where arguments for locally-sensitive but socialised responses to FRM which take the valuation of flood risk out of the housing market’s hands are necessary. Sustainable FRM is ideally iterative, adaptive and collective, but the capacity to elicit this type of response is weakened by the combination of a policy framework and housing market response which embeds forgetfulness, rigidity and individuality.

5. Conclusion

There are key convergences and divergences in the methodological approach to the valuation of flood risk. As identified by Beltrán et al. (2018), US-based studies dominate. While this is not unexpected, this does lead to a heavy reliance within the literature on assumptions which accord with characteristics of US housing markets and hydrology. A prominent example of this is the use of hurricanes as flood hazard phenomena. In other countries where the risk of flooding is more pluvial in nature, models which rely on these large-scale, extreme weather events as information reference points are not necessarily applicable. Similarly, a preponderance of studies rely on regional or city-scale study areas for their data, with the notable exception of Belanger and Bourdeau-Brien (2017). Again, this may relate to the dominance of US sources. While US flood-risk management, policy-making and -implementation is addressed at the state-level within a federalised governmental system, those countries with centralised approaches to flood-risk will require models which have some cross-regional validity.

This is further problematised by the varying ways in which flood-risk is perceived at both the market and individual actor level. Those studies which have employed methods to obtain data on subjective flood-risk perception have identified divergences between perceptions of risk and its reality. This is further complicated by the abundance of variables which can affect flood risk capitalisation at a market level, with some recent studies incorporating broader and wider-ranging demographic and socio-economic characteristics into their models. This would suggest that any attempts to measure the value of flood risk require at the very least a multi-levelled approach, combining data from traditional sources (e.g. estate agents, land registries) with data obtained from individual actors. Finally, the spatialised nature of house prices and the attendant spatial dependencies between key explanatory variables within hedonic models would suggest that any econometric model adopted to measure the price of flood risk necessitates the use of mapping and remote sensing techniques. The aforementioned complexity and nature of the data required to ascertain the “best estimate” (Beltrán et al., 2018: 669) of flood-risk valuation demands that its spatial dependencies are recognised and accounted for. To better understand the various ways flood risk can be conceptualised, this piece has proposed a typology of five flood-risk categories within which the multitude of flood risk variables can be organised. It is argued that future research seeking to more accurately measure for the effects of flood risk should draw on variables from a range of these categories as opposed to using one or more from a single category.

England and Wales provide a complex yet potentially fruitful case-study for exploring and developing these findings. In terms of the current policy approach to FRM, while attempts have been to localise strategies and make communities more ‘resilient’ the material effects have been divergent, with some areas being able to develop innovative and effective FRM strategies compared to other areas where flood risk has clearly been deprioritised. An initial reading of the Blackpool and Fylde Coast region poses some particularly pertinent questions surrounding the value of coastal amenity and its relationship with flood risk. The use of such a case-study in a comparative analysis with other coastal and non-coastal regions would allow for a housing market analysis to disentangle the various characteristics which make up flood risk and give them marginal values which are applicable across and within different local contexts. From this, there is further potential for developing an evidence base for this review’s initial proposal for a more sustainable approach to FRM in England and Wales which recognises the root causes of flood risk (mis)perception, explores locally specific means of alleviating it, and socialises responsibility for devising and implementing prevention and/or reduction measures.

Table 3: Methodological review of selected flood risk valuation studies

Study ID	Author	Year	Country (region)	Estimation period	Year last flooded	Flood risk (floodplain/ other)	Average sample	Hedonic spec.	Functional form of dependent variable	Econometric model	Notes
1	Barnard	1978	US (Iowa)	1950-1977	1972	100/elevation of property (from base of foundation, from low point on lot)/probability that flood waters will reach elevation of home and low point of lot on a given day	1,364	Standard (?)	Linear	OLS	
2	Schaefer	1990	Canada (Ontario)	1977-1988	1954	100	93 transactions	Standard (?)	Linear/Semi-log/Double-log		Property prices before and after floodplain designation and before and after adoption of locally specific official plans relating to flood risk
3	Tobin and Montz	1994	US (California, Pennsylvania, Illinois)	1967-1989	1986, 1972, 1987	Frequency of flooding/inundation levels	1,075	Standard (?)	Linear		
4	Hallstrom and Smith	2005	US (Florida)	1980-2000	1992	≤100	5,212	DID/repeat-sales	Semi-log		Hurricane Andrew in 1992 was considered a “near-miss” for the study area. Sought to investigate whether this risk information was factored into property prices. Argue that “in property value studies to evaluate the risks of damage due to coastal storms, the distance to the coast can serve as either a proxy for coastal amenities

Study ID	Author	Year	Country (region)	Estimation period	Year last flooded	Flood risk (floodplain/ other)	Average sample	Hedonic spec.	Functional form of dependent variable	Econometric model	Notes
											or for increased risk of damage. Under these conditions, an exogenous source of information is needed to distinguish the two effects. For our application, this new information is provided by a record-setting hurricane" (p543).
5	Bin and Kruse	2006	US (North Carolina)	2000-2004	1999	500, 100, 100 with additional hazards associated with storm waves	4,342	Standard (?)	Semi-log	Least squares	Different from previous studies in attempting to capture flood-risk from different source (waves from coastal location). Concludes that "location within such a coastal flood zone is so tightly interconnected with proximity to coastal water that it is not possible to separate the two effects on property values" (p143).
6	Carbone et al.	2006	US (Florida)	1983-2000	1992	≤100 Proximity to path of the eye of hurricane	5,212	DID	Semi-log (?)	OLS	Use of repeat sales Time between sales Special Flood Hazard Areas = 1% or greater chance of flooding in any given year

Study ID	Author	Year	Country (region)	Estimation period	Year last flooded	Flood risk (floodplain/ other)	Average sample	Hedonic spec.	Functional form of dependent variable	Econometric model	Notes
7	Lamond and Proverbs	2006	UK (Yorkshire)	2000-2006	2000	100 (moderate)/flood defences/raised floors	159	Repeat-sales	Semi-log		Shows how in short-term prices of at risk and/or flood-affected properties did not "keep up with the growth in value of the rest of the market" but "after two years this shortfall dissipated and the previously flooded property caught up" (p375)
8	Lamond et al.	2007	UK (Worcestershire)	2000-2005	2002	1000	41 pairs of sales (16 within 1000-year profile)	Repeat-sales	Semi-log		
9	Bin et al.	2008	US (North Carolina)	1995-2002	1999	≤100	1,075	Spatial-lag	Semi-log	Spatial	Using LIDAR and GIS this study creates a diagrammatic 'view-scape' for each property (one-mile distance from the coast + field of view). Uses this to try and separate 'risk' from 'coastal amenities'.
10	Zhang et al.	2010	US (Texas)	2002	2001	100, 500/distance-to-river/respondent perceptions of flood risk	200	Standard (?)	Box-cox/Semi-log	OLS	Utilised identifiable characteristics of study area and houses and questionnaires to model for risk perceptions against hazard proximity (including hurricanes and toxic chemicals).
11	Ponce et al.	2011	Chile (Aysen region)				485	CV	Linear	Parametric and nonparametric models	

Study ID	Author	Year	Country (region)	Estimation period	Year last flooded	Flood risk (floodplain/ other)	Average sample	Hedonic spec.	Functional form of dependent variable	Econometric model	Notes
12	Pryce et al.	2011	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Work from behavioural economics perspective that flood risk perception is characterised by myopia and amnesia, but that these will diminish as floods will become more frequent.
13	Botzen and van den Bergh	2012	Netherlands		2003	1/1250/1/600, 1/400	982	CV	Double-log	Standard Tobit model	Bayesian model of updating risk "In summary, few individuals adjust their WTP proportionally or more than proportionally to the changes in the flood probability mentioned in the survey. This is in accordance with several other studies, suggesting that individuals are insufficiently sensitive to probability changes" (p158)
14	Eves and Wilkinson	2014	Australia (Brisbane)	2011-2012	2011	Effect of flood event in 2011 on property prices	48 suburbs (24 subject to extensive flooding and 24 of similar property characteristics but not flood-affected)	N/A	N/A	N/A	Looks at change in no. of average weekly residential property sales listings; change in no. of average residential property listings; volume of residential property sales; and comparison of

Study ID	Author	Year	Country (region)	Estimation period	Year last flooded	Flood risk (floodplain/ other)	Average sample	Hedonic spec.	Functional form of dependent variable	Econometric model	Notes
											median price trends between flood-affected and non-flood-affected suburbs. "after 2–3 months, the number of homes being listed for sale in the flood-affected suburbs increases in a similar trend to the non-flooded suburbs, although volumes remain lower" (p1534). No "immediate impact on the rental property market in all of the study suburbs" (ibid).
15	Atreya and Ferreira	2015	US (Georgia)	1985-2007	1994	100 merged with 500/inundated or non-inundated by 1994 flood	2,685	DID	Semi-log	OLS/SARAR	Use inundated statistics to model for effects of past flood on individual house prices
16	Atreya et al.	2015	US (Georgia)	1978-2010	1994	Recent flood/100/elevation/ education/race	153 counties	Fixed effects/random-effects	Log-log	Hausman	Uses data on take-up of NFIP to draw conclusions on flood risk perception. Finds that demand for flood insurance fairly inelastic. Recent flood events important in determining demand for insurance, but this effect "vanishes after 3 years" (p161).
17	Atreya and Czajkowski	2016	US (Texas)	2001-2010	2008	High (≤100), moderate or	35,586 property sales	Standard/DID	Natural log	SARAR/GS2SLS (Generalised	Utilises standard, DID and spatial

Study ID	Author	Year	Country (region)	Estimation period	Year last flooded	Flood risk (floodplain/ other)	Average sample	Hedonic spec.	Functional form of dependent variable	Econometric model	Notes
						minimal/coastal or non-coastal/distance-to-coast/flood return period				spatial two-stage least square)	hedonic to test for the effects of amenity and different conceptualisations of flood-risk.
18	Bhattacharya-Mis and Lamond	2016	UK (Yorkshire)		2007	≤100, 100-1000, >1000	213	r_{wg} (inter-rater agreement)	N/A	N/A	Sought to investigate the perception of commercial property holders towards flood risk. Used surveying and ARC-GIS to map changes in vulnerability according to scale.
19	Fu et al.	2016	US (Florida)	2014	N/A	≤100/Inundation	319,507	Standard/Spatial lag	Semi-log	Spatial regression	Investigates the effects of inundation on coastal amenity valuation
20	Koetse and Brouwer	2016	Netherlands (Ijsselmeer)			500, 1,000, 2,000 5,000, 10,000 No shores, shores off the coast, shores next to the dike	1, 208	WTP/WTA		Random Utility Model (RUM)	"we find that WTA values are larger than WTP values for identical changes in flood probability" (p743) "we find that the WTA–WTP disparity increases when using a lower flood probability reference value, or vice versa the disparity decreases when using a higher reference value." (ibid) "In order to reliably assess the welfare consequences

Study ID	Author	Year	Country (region)	Estimation period	Year last flooded	Flood risk (floodplain/ other)	Average sample	Hedonic spec.	Functional form of dependent variable	Econometric model	Notes
											of specific environmental changes, time- and space-specific research is therefore required.”
21	Meldrum	2016	US (Colorado)	1995-2012	1969	100	59,929	Spatial-lag	Log-linear/Box-cox	Spatial weights matrix/maximum likelihood estimation code	Looks at difference between property types – standalone homes and condominiums. Implicit discount rate of 5.7% was found for condominiums but no consistent one for standalone homes. Looks at how the National Flood Insurance Program (NFIP) has been internalised into these markets.
22	O’Neill et al.	2016	Ireland (Co. Wicklow)	2011	1986	100/proximity/’worry’	304 interviews	Standard (?)	Linear (?)	OLS	Using face-to-face interviews and a cognitive mapping exercise, the study aimed to investigate the hypothesis that distance to a perceived hazard zone has a significant influence on risk perception. Findings suggest that individual worries about flood risk are driven by misperceptions of risk reality.

Study ID	Author	Year	Country (region)	Estimation period	Year last flooded	Flood risk (floodplain/ other)	Average sample	Hedonic spec.	Functional form of dependent variable	Econometric model	Notes
23	Rabassa and Zoloa	2016	Argentina (La Plata)	2004, 2006-7	2013	20-100	1,969 single-family homes 679 vacant plots	DID(?)	Linear	OLS/SARAR	
24	Rajapaska et al.	2016	Australia (Queensland)	2006-2013	2011	20, 100, 500 or 1000/distance and elevation from river/disclosure of flood risk information	2,345	DID	Semi-log	OLS/LM/spatial	Australian flood risk is quantified and mapped according to the probability of a flood occurring in an average time period *and* as a percentage within a single 70-year period (i.e. a 'lifetime')
25	Votsis and Perrels	2016	Finland (Helsinki, Pori, Rovaniemi)	2000-2011	2005, 2007, 2004	5, 20, 50, 100, 250, 1000/flood-maps	1,471	DID	Linear	Additive	Used control and treatment groups within each city (in and out of flood prone areas). Pre- and post-treatment groups refer to transactions that took place prior to and after introduction of flood-risk maps.
26	Zhang	2016	US (North Dakota & Minnesota)	2000-2013	2009	100	28,154	DID	Linear-log (?)	OLS/spatial/2SLS	
27	Belanger and Bourdeau-Brien	2017	England (multiple regions)	1995-2006	2005	≤100/geodesic distance between each property and nearest waterbody	608,095 dwellings 1,042,244 transactions	DID	Linear-log	WLS/M-estimation/LMM	Distance from water both outside and within floodplain results in a premium (approx. 5% and 3% respectively)
28	de Koning et al.	2017	US (North Carolina)	1992-2002	1999	100/subjective risk assessment	9,793 actual properties 1,954 flood-affected properties 5 for agent-based model	ABM	Semi-log (?)	Kriging	Uses subjective risk assessment model to compare results with hedonic pricing model. Found large variance in risk

Study ID	Author	Year	Country (region)	Estimation period	Year last flooded	Flood risk (floodplain/ other)	Average sample	Hedonic spec.	Functional form of dependent variable	Econometric model	Notes
											perception and loss aversion at the individual level which lead to "fundamentally different *market* level outcomes in terms of capitalised risk discounts" (p7, emphasis added)
29	Rajapaska et al.	2017	Australia (Queensland)	2006-2013	2011	Previously flood-affected/floodplain location/distance-to-river/elevation	3,154	Generalised additive model (GAM)	Natural log/Linear	Semi-parametric regression	
30	de Koning et al.	2018	US (North Carolina)	1992-2002	1999	100 and 500 merged into one floodplain variable	4,779	DID (?)	Semi-log	OLS(?)/Kriging	Attempts to show how different hedonic models vary in quality when different sample sizes are inputted (RMSE, MAE, SDE, Adjusted R-squared)
31	Hirsch and Hahn	2018	Germany (Bavaria)	2012-2015	2013	100/inundation depths/distance-to-river	16,811 (7,777 for sale, 9,034 for rent)	Generalised additive model (GAM)	Linear-log(?)		Used price/rent per square metre as the dependent variable. Found that discounts for flood-risk are built into asking prices, rather than being dependent on buyers possessing flood-risk information. Also found that, in contrast to initial assumptions, rental prices also carry a flood-risk discount.
32	Torgersen and Navrud	2018	Norway (multiple areas)	2016	N/A	Participant self-assessment of	643 respondents in net sample	CV (WTP)	Semi-log (?)	OLS	Sought to test a series of

Study ID	Author	Year	Country (region)	Estimation period	Year last flooded	Flood risk (floodplain/ other)	Average sample	Hedonic spec.	Functional form of dependent variable	Econometric model	Notes
						exposure to urban floods			NB: log-transformation of two WTP variables		hypotheses regarding flooding: that WTP for avoiding insecurity from urban floods increases with income; increases with more experience or exposure to flooding; and whether WTP is higher for more inclusive goods (those that prevent flooding rather than those which insure against losses).

References

Atreya, A. & Czajkowski, J. 2016. Graduated Flood Risks and Property Prices in Galveston County. *Real Estate Economics*, 47, 807-844.

Atreya, A. & Ferreira, S. 2015. Seeing is Believing? Evidence from Property Prices in Inundated Areas. *Risk Analysis,* 35, 828-848.

Atreya, A., Ferreira, S. & Michel-Kerjan, E. 2015. What drives households to buy flood insurance? New evidence from Georgia. *Ecological Economics,* 117, 153-161.

Ball, T., Werritty, A. & Geddes, A. 2013. Insurance and sustainability in flood-risk management: the UK in a transitional state. *Area,* 45, 266-272.

Barnard, J. R. 1978. Externalities from Urban Growth: The Case of Increased Storm Runoff and Flooding. *Land Economics,* 54, 298-315.

BBC. 2016. *New flood insurance scheme to cut bills by hundreds of pounds* [Online]. Available: http://www.bbc.co.uk/news/business-35944397. Accessed 24th April 2018.

Begg, C., Walker, G., and Kuhlicke, C. 2015. Localism and flood risk management in England: the creation of new inequalities? *Environment and Planning C: Government and Policy* 33: 685-702.

Belanger, P. & Bourdeau-Brien, M. 2017. The impact of flood risk on the price of residential properties: the case of England. *Housing Studies*, 1-26.

Beltrán, A., Maddison, D. & Elliott, R. J. R. 2018. Is Flood Risk Capitalised Into Property Values? *Ecological Economics,* 146, 668-685.

Bhattacharya-Mis, N. & Lamond, J. 2016. Risk perception and vulnerability of value: a study in the context of commercial property sector. *International Journal of Strategic Property Management,* 20, 252-264.

Bin, O., Crawford, T. W., Kruse, J. B. & Landry, C. E. 2008. Viewscapes and Flood Hazard: Coastal Housing Market Response to Amenities and Risk. *Land Economics,* 84, 434-448.

Bin, O. & Kruse, J. B. 2006. Real Estate Market Response to Coastal Flood Hazards. *Natural Hazards Review,* 7, 137-144.

Blackpool Council, Fylde Council & Wyre Council 2014. *Fylde Coast Strategic Housing Market Assessment,* Manchester, Turley Associates.

Botzen, W. J. W. & van den Bergh, J. C. J. M. 2012. Risk attitudes to low-probability climate change risks: WTP for flood insurance. *Journal of Economic Behavior & Organization,* 82**,** 151-166.

Carbone, J. C., Hallstrom, D. G. & Smith, V. K. 2006. Can Natural Experiments Measure Behavioral Responses to Environmental Risks? *Environmental and Resource Economics,* 33**,** 273-297.

Corfe, S. 2017. *Living on the edge: Britain's coastal communities,* London, Social Market Foundation.

De Koning, K., Filatova, T. & Bin, O. 2017. Bridging the Gap Between Revealed and Stated Preferences in Flood-prone Housing Markets. *Ecological Economics,* 136**,** 1-13.

De Koning, K., Filatova, T. & Bin, O. 2018. Improved Methods for Predicting Property Prices in Hazard Prone Dynamic Markets. *Environmental and Resource Economics,* 69**,** 247-263.

Department for Environment, Food, and Rural Affairs (DEFRA) and The Environment Agency (EA). 2014. *Flood risk management: information for flood risk management authorities, asset owners and local authorities* [online]. Available at: https://www.gov.uk/guidance/flood-risk-management-information-for-flood-risk-management-authorities-asset-owners-and-local-authorities#overview. Accessed on 17 February 2020.

Environment Agency (EA). 2020. Flood Map for Planning app [online]. Available at: http://apps.environment-agency.gov.uk/wiyby/37837.aspx. Accessed on 17 February 2020.

Eves, C. & Wilkinson, S. 2014. Assessing the immediate and short-term impact of flooding on residential property participant behaviour. *Natural Hazards,* 71**,** 1519-1536.

Fu, X., Song, J., Sun, B. & Peng, Z.-R. 2016. “Living on the edge”: Estimating the economic cost of sea level rise on coastal real estate in the Tampa Bay region, Florida. *Ocean & Coastal Management,* 133**,** 11-17.

Gibbons, S., Mourato, S. & Resende, G. M. 2014. The Amenity Value of English Nature: A Hedonic Price Approach. *Environmental and Resource Economics,* 57**,** 175-196.

Hallstrom, D. G. & Smith, V. K. 2005. Market responses to hurricanes. *Journal of Environmental Economics and Management,* 50**,** 541-561.

Hastie, T. & Tibshirani, R. 1986. Generalized Additive Models. *Statistical Science,* 1**,** 297-318.

Hirsch, J. & Hahn, J. 2018. How flood risk impacts residential rents and property prices: Empirical analysis of a German property market. *Journal of Property Investment & Finance,* 36**,** 50-67.

Johnson, C., Penning-Rowsell, E. & Parker, D. 2007. Natural and imposed injustices: the challenges in implementing 'fair' flood risk management policy in England. *The geographical journal,* 173**,** 374-390.

Koetse, M. J. & Brouwer, R. 2016. Reference Dependence Effects on WTA and WTP Value Functions and Their Disparity. *Environmental and Resource Economics,* 65**,** 723-745.

Meldrum, J. R. 2016. Floodplain Price Impacts by Property Type in Boulder County, Colorado: Condominiums Versus Standalone Properties. *Environmental and Resource Economics,* 64**,** 725-750.

McAneney, J., McAneney, D., Musulin, R., Walker, G., & Crompton, R. 2016. Government-sponsored natural disaster insurance pools: A view from down-under. *International Journal of Disaster Risk Reduction* 15: 1-9.

Nye, M., Tapsell, S. & Twigger-Ross, C. 2011. New social directions in UK flood risk management: moving towards flood risk citizenship? *Journal of Flood Risk Management,* 4**,** 288-297.

O'Neill, E., Brereton, F., Shahumyan, H. & Clinch, J. P. 2016. The Impact of Perceived Flood Exposure on Flood-Risk Perception: The Role of Distance. *Risk Analysis,* 36**,** 2158-2186.

Pryce, G., Chen, Y. & Galster, G. 2011. The Impact of Floods on House Prices: An Imperfect Information Approach with Myopia and Amnesia. *Housing Studies,* 26**,** 259-279.

Rabassa, M. J. & Zoloa, J. I. 2016. Flooding risks and housing markets: a spatial hedonic analysis for La Plata City. *Environment and Development Economics,* 21**,** 464-489.

Rajapaksa, D., Wilson, C., Managi, S., Hoang, V. & Lee, B. 2016. Flood Risk Information, Actual Floods and Property Values: A Quasi-Experimental Analysis. *Economic Record,* 92**,** 52-67.

Rajapaksa, D., Zhu, M., Lee, B., Hoang, V.-N., Wilson, C. & Managi, S. 2017. The impact of flood dynamics on property values. *Land Use Policy,* 69**,** 317-325.

Schaefer, K. A. 1990. The effect of floodplain designation/regulations on residential property values: A case study in North York, Ontario. *Canadian Water Resources Journal,* 15**,** 319-332.

The Independent. 2015. *10,000 UK homes built on flood plains each year* [Online]. Available: https://www.independent.co.uk/news/uk/home-news/10000-uk-homes-built-on-flood-plains-each-year-a6788816.html [Accessed 25th April 2018].

Tobin, G. A. & Montz, B. E. 1994. The flood hazard and dynamics of the urban residential land market. *JAWRA Journal of the American Water Resources Association,* 30**,** 673-685.

Torgersen, G. & Navrud, S. 2018. Singing in the rain: Valuing the economic benefits of avoiding insecurity from urban flooding. *Journal of Flood Risk Management,*11, 1-12.

Votsis, A. & Perrels, A. 2016. Housing Prices and the Public Disclosure of Flood Risk: A Difference-in-Differences Analysis in Finland. *Journal of Real Estate Finance and Economics,* 53**,** 450-471.

Walker G. 2012. *Environmental justice: concepts, evidence and politics*, London: Routledge.

Zhang, L. 2016. Flood hazards impact on neighborhood house prices: A spatial quantile regression analysis. *Regional Science and Urban Economics,* 60**,** 12-19.

Zhang, Y., Hwang, S. N. & Lindell, M. K. 2010. Hazard Proximity or Risk Perception? Evaluating Effects of Natural and Technological Hazards on Housing Values. *Environment and Behavior,* 42**,** 597-624.