The impact of flooding on property prices

Beltran Hernandez, Allan; Maddison, David; Elliott, Robert

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The impact of flooding on property prices: A repeat-sales approach

Allan Beltrán, David Maddison, Robert Elliott[*]

University of Birmingham

Abstract

In this paper we use a repeat-sales model to analyse the price path of properties affected by flooding in England between 1995 and 2014. Our dataset contains information on 4.8 million houses with at least one repeat-sale. This database is merged with high-definition GIS data delineating the spatial extent of all recorded flood incidents in England covering a total area of 2,654km^2. Our results show that immediately after a flood event the price of property in a postcode entirely inundated by inland flooding is on average 24.9% lower than non-flooded property, whereas for property in a postcode entirely inundated by coastal flooding the price reduction is 21.1%. Nonetheless, we find that this discount is short-lived and the discount is no longer statistically significant for properties affected by inland flooding after 5 years, which falls to just 4 years for properties affected by coastal flooding. For lower-priced properties however, the post-flood price discount can be observed up to 6-7 years for both inland and coastal flooding. The magnitude of the impact also depends on the characteristics of the properties, the characteristics of the flood and the existence of flood protection assets.

Keywords: Flood risk, house prices, repeat-sales, hedonic valuation

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* Corresponding author: Robert Elliott (r.j.elliott@bham.ac.uk). Address: The Department of Economics, JG Smith Building, University of Birmingham, B15 2TT. United Kingdom.

1. Introduction

Flood risk is a serious policy issue globally and particularly in the United Kingdom (UK). It is estimated that 2.8 million properties in England alone are exposed to some risk of flooding of which 690 thousand are properties at very significant risk (75-year return period or less). The expected annual damage to residential properties alone amounts to £270m, although even this considers only the direct damages (Sayers *et al*., 2015). Projections of future flood risk by Sayers *et al*. (2015) produced for the UK Climate Change Risk Assessment 2017 suggest that even in a scenario without population growth the number of properties in England exposed to very significant risk would increase by 43-130 percent by 2080. The UK Committee on Climate Change (2015) notes that each year 4,600 new homes are built in areas exposed to significant flood risk, and almost 50 percent of these are constructed in areas at very significant risk.

The current prevalence of flooding, with major UK flood events occurring in 1998, 2000, 2007, 2012, 2013, 2014, 2015 and 2016, together with continuous development on floodplains and the expected increase in flooding due to climate change means that it is important to understand the implications of flooding for households. Samwinga *et al*. (2004) and Lamond *et al*. (2010) state that one of the major concerns of households affected by flooding is the financial impact in terms of the insurability and saleability of their property. Brignall and Jones (2016, *The Guardian*) document the fear of households that their properties have been permanently blighted and in some cases become virtually unsaleable after the recent floods in the north of England in December 2015.

A significant body of literature now examines the effect of a flood on the price on properties located in floodplains. Importantly however, many of these studies fail to distinguish between properties merely situated in the floodplain and those which were actually *inundated* resulting in a major problem of interpretation. Furthermore, most of these studies were undertaken in the United States (US). With the exception of Atreya and Ferreira (2015) for the US and Daniel et al (2009) for the Netherlands there are no other studies into the effect of flooding on the price of *inundated* properties, something ascribable to missing information regarding those properties that were located within the inundated area.

The purpose of this paper is to analyse the immediate impact on and the subsequent recovery of the price of inundated properties in England using a repeat-sales Hedonic Price Model

(HPM). More specifically we analyse the price of property in postcodes that were either partially flooded (where we know the precise extent of flooding) and in postcodes that were entirely flooded. Furthermore unlike Atreya and Ferreira (2015) and Daniel et al (2009) we explain the heterogeneity of flooding impacts by reference to property characteristics (type and price), flood type (coastal, inland or sewer), duration and frequency, and location characteristics (rural versus urban) and presence of flood defence infrastructure. Our dataset includes information on over 12 million individual property transactions and about 4.8 million houses with at least one repeat-sale during the period of analysis. Central to our work is the use of recently-released high-resolution Geographical Information Systems (GIS) data delineating the area maximally affected by each individual flood event on record in England. This evidence is generally based on aerial photographs taken at 'peak flooding'. Together, these flood events represent a total flooded area of 2,654 km^2 during the period 1995-2014.

Apart from being one of only two others to investigate the impact of inundation on property values our paper also makes several further contributions to the literature. We present the first study to use information on all repeat sales within an entire country to measure the impact of all recorded flood events over a 20 year period. All other studies of which we are aware consider the impact of flooding on specific regions or the impact of single flood events which may be atypical. However, our national dataset includes multiple flood events in numerous locations representing the entire 'population' of floods. Furthermore, only one other study has used information on 'actual' inundation revealed through observation rather than through flood simulation (Daniel et al. 2009). Likewise, only one other paper has examined the impact of flooding on the price of flats (Meldrum 2015) and only one other paper has used a semi-parametric representation of the recovery in prices post flooding (Atreya *et al*. 2013).

To anticipate our main findings, in the immediate aftermath of inland flooding the average price of property in a postcode entirely inundated is 24.9% lower. For incidents of coastal flooding the corresponding figure is 21.1%. These results moreover emerge from a comparison of inundated and non-inundated properties all within the floodplain. Such discounts are however short-lived; property affected by inland flooding typically recovers after 5 years and in just 4 years for coastal properties. The time for price recovery differs markedly for properties in different price-quartiles. For properties affected by coastal flooding in the highest price-quartile, the property price discount disappears after only 1 year whereas for properties in the lowest price-quartile the discount remains statistically significant for up to 6-7 years.

The remainder of this paper is organised as follows. Section 2 presents a review of the literature on the use of the HPM to estimate the effect of flooding on property prices. Section 3 provides the theory underlying HPM applied to flooding and section 4 describes our identification strategy. Section 5 describes the data and the econometric model upon which our analysis is built. Section 6 presents our results and section 7 discusses their implications. Section 8 concludes.

2. Literature Review

The standard approach to analysing the impact of flooding is to use HPM.[1] One can classify empirical applications of the HPM to the issue of flooding into four groups. The first group of studies uses a standard representation of the HPM to compare the prices of properties located inside and outside the floodplain. The resulting price differential is interpreted as the implicit price of flood risk in the housing market. Studies adopting this approach include for example, MacDonald *et al.* (1987), Donnelly (1989), Speyrer and Ragas (1991), Bin (2004), Bin and Kruse (2006), Rambaldi *et al*. (2012) and Meldrum (2015).

The second group of studies analyses the effect of a flood event on the price of properties located inside the floodplain, an unknown number of which might have been inundated. This literature is based on the work of Bin and Polasky (2004) who argue that previous studies finding an association between property prices and the existence of flood risk actually analyse locations with recent experience of flooding, whereas results from floodplains with no recent flood experience do not show a significant price discount. They suggest that the occurrence of a flood provides new information to households changing their perception of flood risk. These studies use a Difference-in-Differences (DID) variant of the HPM to analyse the price differential for floodplain location before and after a flood.[2] The coefficient

[1] Beltran et al. (2018) provide a meta-analysis of the hedonic flood risk literature. An alternative approach is taken by Fan and Davlasheridze (2016) who present a sorting model incorporating flood risk. With a sorting model it is possible to analyse how a household's characteristics affect its valuation of flood risk and to value discrete changes in a way that would be nigh impossible with the hedonic technique. The authors find that willingness to pay (WTP) for flood protection measures varies with prior experience of flooding and that water-based amenities are more important than flood risk.

[2] Note that following Kuminoff and Pope (2014) with a DID design strictly-speaking what is measured is capitalisation rather than the WTP. For a more recent discussion see Banzhaf (2015).

on the post-flood variable is interpreted as the information update on the price of properties in the floodplain. Such studies include Bin and Polasky (2004), Hallstrom and Smith (2005), Kousky (2010) and Atreya, *et al.* (2013). More recent applications investigate not only how the price of property changes immediately after a flood event but also track the subsequent recovery in prices. Atreya and Ferreira (2015), Atreya *et al*. (2012, 2013) and Bin and Landry (2013) all find that the immediate post-flood discount for properties inside the floodplain diminishes with time.[3]

The third group of studies, unlike those which analyse the effect of flooding on the price of properties in the floodplain *whether directly affected or not,* analyse the effect of flooding on the price of properties in the *inundated* area. In these studies, information on the inundated area is used to identify the effect of flood damages on the price of affected properties. Such studies are far fewer in number, including only Daniel *et al.* (2009) and Atreya and Ferreira (2015).

Daniel *et al.* (2009) use a DID HPM to analyse the price of properties in seven municipalities in the Netherlands affected by flooding from the Meuse River in 1993 and 1995, using the observed price of houses between 1990 and 2004. The sample includes over 9,500 transactions, of which 313 concern houses that aerial photographs revealed were either flooded or surrounded by floodwater in at least one of the events. The results indicate that after the first flood affected properties were sold at a discount of 4.6 percent. The figure increases to 9.1 percent after the second flood.

The study by Atreya and Ferreira (2015) uses a DID HPM to identify the effect of flooding on inundated properties after a flood in 1994 caused by tropical storm Alberto in Albany, Georgia, US. The sample is restricted to an area in the vicinity of Flint River which includes around 3,000 single-family residences. Results indicate that immediately after the flood properties in the inundated area suffered a price fall of 33-48% depending on the precise econometric specification and whether the inundated property was inside or outside the floodplain. Interestingly, after controlling for being within the inundated area, there is no significant additional discount associated with being in the floodplain. The authors suggest that the post-flood discount is therefore mainly driven by damages rather than an information

[3] Other authors, for instance Harrison *et al*. (2001), Troy and Romm (2004), Pope (2008), Samarasinghe and Sharp (2010), and Rajapaksa *et al*. (2016), use DID hedonic price models to analyse the effect of changes in regulations, such as floodplain zoning, on the price of properties in the floodplain.

effect, and that previous studies not accounting for inundation hugely overestimate the information effect of a flood on properties merely located in the floodplain. In all cases results indicate that the discount on inundated properties is relatively short lived, decreasing at a rate of around 6 percent per year and lasting, therefore, about 8 years. One possible shortcoming of this study however, is that the identification of the inundated area is based on geospatial simulations of the flood event not on actual observations of the inundated area.

The final set of studies includes Beltran *et al*. (2018), Dundas (2017), McNamara *et al*. (2015) and Qiu and Gopalakrishnan (2018). These studies consider the effect of constructing flood defences and beach nourishment on property prices.

We now turn briefly to prior applications of the HPM to the issue of flooding in the UK. Lamond and Proverbs (2006), Lamond *et al.* (2007) and Lamond *et al*. (2010) all analyse the effect of the 2000 floods in England on the price of properties in the floodplain. Lamond and Proverbs (2006) use a standard HPM with a sample of 159 properties in Barlby, North Yorkshire, that were sold during 2000-2006. The authors conclude that after the flood properties in the floodplain were sold at a discount of 17.5%. This discount however, is significant only for the two years following the event. Lamond *et al*. (2007) use a repeat-sales approach to analyse the change in the price of 32 properties with sales before and after a flood in Bewdley, Worcestershire, during the period 2000-2005. Finally, Lamond *et al*. (2010) use a repeat-sales model to analyse the effect of the 2000 flood on the growth rate of the price of properties in the floodplain. Using a sample containing 1,303 properties with transactions before and after the flood the authors conclude that the price of properties in the floodplain grew at a rate 9% below that of properties outside the floodplain. Apart from the fact that these UK studies rely on small samples to identify the effect of flooding on floodplain designated properties, none distinguish between properties merely situated in the floodplain and those which were actually inundated.

3. The Hedonic Price Model for Flood Risk Valuation

Leaving aside those studies looking at the effect of flood defences the HPM has, as discussed, been used to evaluate three slightly different cases: (1) the effect on property prices of location within the floodplain, (2) the effect of a flood on the price of property situated in the floodplain and (3) the effect of flooding on the price of property actually inundated. Below, we present a theoretical analysis of these with the third case the one relevant to our research.

The theoretical model is based on the characterisation of the hedonic price function (HPF) by Rosen (1974) and its extension to the flood risk literature by MacDonald *et al.* (1987), Carbone *et al*. (2006), Bin *et al.* (2008), Kousky (2010) and Bin and Landry (2013). The HPF describes the price of a quality-differentiated commodity (residential property) as a function of its multiple attributes. When a household decides where to live this decision also includes the level of flood risk and this can be regarded as one more characteristic of a property.

Let $\boldsymbol{S}$ represent the set of structural characteristics of a house such as age, number of bathrooms and plot size; $\boldsymbol{N}$ is the neighbourhood / locational characteristics such as crime rates, distance to the city centre or to a major motorway, and $\boldsymbol{E}$ environmental characteristics such as the level of pollution. We define $Z = \boldsymbol{S}, \boldsymbol{N}, \boldsymbol{E}$. Furthermore, let the subjective probability of flooding be a function $p(i, r)$ of the set of information, i, the household holds about flood risk in the location of the property and r which represents those site attributes related to flood risk e.g. proximity to water bodies or elevation. The HPF describing the price of a property, P, is written as:

$$P = P\big(Z, r, p(i, r)\big) \qquad (1)$$

P is exogenous to buyers and sellers, but reflects subjective risk perception $p(i, r)$. Prices are assumed to be market clearing, given the stock of residential property and its characteristics. The property market is assumed to be in equilibrium, which requires that households optimise their choice based on prevailing prices in all alternative locations. It is further assumed that households are able to adjust the different levels of each characteristic by moving. No transaction costs are considered.

It is important to distinguish the subjective assessment of the probability of flooding, p, from the objective measure of flood risk, π. This distinction implies three things: (1) perceived risk is not necessarily equal to objective risk, (2) changes in objective risk are not necessarily perceived and (3) changes in perceived risk do not necessarily arise from changes in objective risk. In areas where flood risk disclosure is mandatory or public information about flood risk is available, the set of information, i, may include the objective probability of flooding, π.

The HPM uses an expected utility (EU) framework that incorporates any risk factors associated with a property. The household's decision is modelled using the following state dependent utility function:

$$EU = p(i,r) \cdot U^F[Z,r,Q] + \big(1 - p(i,r)\big) \cdot U^{NF}[Z,r,Q] \tag{2}$$

where $U^F(\cdot)$ is the utility of the homeowner in a state where a flood occurs and $U^{NF}(\cdot)$ is the utility of the homeowner when there is no flood. The budget constraint (M) for the household in state F is given by equation (3) and in state NF by equation (4):

$$F: \quad M = P\big(Z,r,p(i,r)\big) + Q + L(r) \tag{3}$$

$$NF: \; M = P\big(Z,r,p(i,r)\big) + Q \tag{4}$$

Note from equations (3) and (4) that the level of consumption Q is different across states. The conditional loss $L(r) \in (0,\bar{S})$, is a function of r and represents the magnitude of the loss should state F occur where $\bar{S}$ represents the cost of structural replacement. At this point it is possible to explain the main differences between the aforementioned three different sets of applications of the HPM to the flood risk literature. In all three cases the decision of the household is modelled using the expected utility framework in equation (2).

The first case corresponds to the effect of floodplain location on property prices. In this case, the expected utility of the household, depends on the subjective perception of flood risk ($p(i,r)$) and the conditional loss ($L(r)$) should state F occur. The implicit price of flood risk in the housing market is then given by:

$$\frac{\partial P}{\partial p} = \frac{U^F - U^{NF}}{p(i,r)\frac{\partial U^F}{\partial Q} + \big(1 - p(i,r)\big)\frac{\partial U^{NF}}{\partial Q}} \tag{5}$$

Note that this model can be readily extended to account for flood insurance.[4]

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[4] Following Bin and Landry (2013) assume the insurance cover on the property is given by $C \in (0,\bar{S})$, where $\bar{S}$ is as before. The insurance premium $I(\pi(r),C)$ is assumed to be a function of the objective probability of flooding $\pi(r)$ rather than $p(i,r)$. The household's decision is modelled using the same state dependent utility function as in equation (2). The budget constraint for the household in state FI (flooded with an insurance policy) and NFI (not flooded and with an insurance policy) is given by equations (6) and (7), respectively:

$$FI: \quad M = P\big(Z,r,p(i,r)\big) + Q + L(r) + I(\pi(r),C) - C \tag{6}$$

$$NFI: \; M = P\big(Z,r,p(i,r)\big) + Q + I(\pi(r),C) \tag{7}$$

Formally the household maximises the expected utility in equation (2) with respect to p, subject to the state dependent budget constraint of the household with flood insurance in equations (6) and (7). This yields:

The second case corresponds to the effect of a flood on the price of properties located in the floodplain. In this case, the occurrence of a flood is considered to provide new information (i) to homeowners in the floodplain who update their subjective assessment of the probability of flooding ($p(i,r)$). This increase in the perceived probability of a flood is reflected in property prices and the corresponding price update is given by:

$$\frac{\partial P}{\partial i} = \frac{\frac{\partial p}{\partial i}(U^F - U^{NF})}{p(i,r)\frac{\partial U^F}{\partial Q} + \left(1 - p(i,r)\right)\frac{\partial U^{NF}}{\partial Q}} \tag{9}$$

Notice carefully that this effect represents only the change in prices due to the information conveyed by the flood and excludes the value of any realised flood damages.

The third set of applications of the HPM to flood risk refers to the effect of the inundation of properties, which is the focus of this paper. The price of an inundated property is, we argue, likely to reflect three things: (1) the price discount for being located in a floodplain, (2) the informational update conveyed by the flood itself and (3) the cost, $L(r)$, of restoring the property to its former condition. But whereas it is easy to separate out the first of these components, even if attention is focussed only on those properties already in the floodplain, as Atreya and Ferreira (2015) and Hallstrom and Smith (2005) point out, in order to identify the 'pure' information effect of a flood it is necessary in some way to isolate the effect of flood damages.[5] In what follows we estimate the combined effect of the informational update and flood damages.

4. The Empirical Hedonic Model

Typical applications of the HPM within the flood risk literature address the issue of floodplain location and its capitalisation in property prices using an additive representation of the HPF in equation (1) as follows:

$$\frac{\partial P}{\partial p} = \frac{U^{FI} - U^{NFI}}{p(i,r)\frac{\partial U^F}{\partial Q} + \left(1 - p(i,r)\right)\frac{\partial U^{NF}}{\partial Q}} - \frac{\partial I}{\partial \pi} \tag{8}$$

[5] If flooding alters the objective risk of further flooding then there is likely to be a fourth component: changes in flood insurance premiums.

$$lnP_i = \beta_0 + \sum_{j=1} \beta_j Z_{ij} + \gamma r_i + \phi p_i + \varepsilon_i \quad (10)$$

Where i denotes a specific property and j represents specific characteristics of property i; P, Z, r and p are as previously defined. Common practice is that p is a dummy variable representing location within the floodplain. β_0, β_j, γ and ϕ are estimated coefficients; ϕ is the coefficient on the risk variable as denoted in equation (5). ε_i is the house-specific error term to which the usual assumptions apply i.e. $\varepsilon_i \sim N(0, \sigma^2 I)$.

More recent applications of the HPM to flood risk examine the information effect of a flood on the price of floodplain designated properties using a quasi-experimental design with a DID approach. The rationale for the use of this methodology is to help address any potential bias in the identification of the information effect of a flood in standard hedonic models due to unobserved characteristics. For an overview of the use of quasi-experimental methods in hedonic models see Parmeter and Pope (2013). The strategy for identification relies on the occurrence of floods as a source of exogenous variation in the sale price of a house, via a before and after approach. Thus, there are two dimensions distinguishing the structure of a quasi-experiment: the group assignment for each property, i.e. whether it is inside the floodplain and the timing (t) of the potential outcome that is observed. The extended empirical model is represented as follows:

$$lnP_i = \beta_0 + \sum_{j=1} \beta_j Z_{ij} + \gamma r_i + \phi p_i + \alpha Flood_i + \psi(Flood_i \times p_i) + \varepsilon_{it} \quad (11)$$

The treatment group is distinguished by the dummy variable indicating floodplain location (p_i) and the treatment refers to the occurrence of a flood. The timing is the date of the sale in relation to the flood event and this is represented by the variable $Flood$, which is a dummy variable equal to one for sales occurring after the flood event. The parameter ϕ represents the group effect, i.e. the pre-flood relative price differential between the control group (outside the floodplain) and the treatment group (inside the floodplain); α captures the time effect, i.e. the relative price difference for all properties that were sold after the flood; and ψ represents the treatment response, i.e. the incremental effect of the flood on properties in the floodplain.

The key assumption for identification is that $E[\varepsilon_{it}|Flood_i] = 0$. Previous studies by Bin and Polasky (2004), Kousky (2010), Atreya *et al.* (2013), Bin and Landry (2013), and Rajapaksa *et al.* (2016) among others, use this strategy to identify the information effect of a flood on properties located in the floodplain. Atreya and Ferreira (2015) and Hallstrom and Smith (2005) however argue that results from these studies provide biased estimates of the information effect as the authors fail to disentangle the effect of flood damages on flooded properties. Hallstrom and Smith (2005) suggest analysing the information effect of the flood by focusing on properties in the floodplain that were not hit by the flood.

The econometric approach so far described in this section uses a pooled cross-section of property prices over time and is therefore conditioned on values of the other covariates Z_{ij} and r_i. A shortcoming of this approach is the amount of information required on all the major structural and locational characteristics (Z_{ij} and r_{i}) to ensure unbiased estimates (Palmquist 1982, 2005). An alternative way to address this issue is the use of the repeat-sales model.

4.1. A Repeat-sales Model to Identify the Effect of a Flood on Inundated Properties

The repeat-sales model is derived from the standard HPM described above, but using panel data. We consider the sale price of properties sold multiple times over a given period. In between sales, there are changes in some characteristics of the properties such as age, environmental quality and the real price whereas many other characteristics of the house remain the same. Therefore, by considering two sales of the same property it is possible to control for time-invariant characteristics and recover estimates for the effects of those things that do change over time.[6] Essentially, the repeat-sales specification allows us to evaluate the price effect of an environmental change which is not uniform across properties (Kousky 2010, Palmquist 1982, 2005).

Consider the additive representation of the HPF in equation (12). This is similar to the DID representation in equation (11), but with two important changes. First, it has now been indexed by t to identify the timing for the sale of each house i, and k now identifies the county in which property i is located. Second, since now we are interested in the effect of the flood on inundated properties, the group assignment for each house is given by the variable IND which although normally a dummy variable, here represents the proportion of the postcode area in which the property is situated, that was actually flooded; this variables

[6] We are assuming that the structural attributes of a property do not change following flooding. This seems a reasonable assumption in the context of the UK where it would be extremely unusual for a property to require rebuilding and where it is anyway impossible to change important structural attributes without obtaining planning permission which is an involved process.

ranges from 0-1 in every postcode affected by flooding during the period of analysis, 1995-2014.

$$lnP_{it} = \beta_0 + \sum_{j=1} \beta_j Z_{ij} + \gamma r_i + \phi p_i + \theta IND_{it} + \alpha Flood_{ikt} + \psi(Flood_{ikt} \times IND_{it}) + \varepsilon_{ikt} \quad (12)$$

The dependent variable, lnP, is now the natural logarithm of the property sale price adjusted to July 2014 GBP. Z, r and p are as previously defined. ε_{ikt} is the house-specific error term to which the usual assumptions continue to apply i.e. $\varepsilon_{ikt} \sim N(0, \sigma^2 I)$. Similar to equation (11), we define the timing of the potential outcome that is observed for each unit using the variable $Flood$, which is a dummy variable equal to unity for sales occurring after the time of the flood. However, the construction of the variable $Flood$ in equation (12) is more involved. We keep the comparison of price differentials for properties before-and-after a flood within the geographical borders of the county in which the flood occurred. Therefore, the variable $Flood$ in equation (12) takes the value unity for sales within county k that occur after a flood event. Notice that in locations that experienced repeated flooding during the period of analysis the time of the sale after a flood is restricted by the time of the occurrence of the second flood. Therefore $(Flood_{ikt} \times IND_{it})$ is a variable indicating the proportion of the postcode flooded for sales that occur after a flood event (or between floods in locations with repeated flooding).

As the repeat-sales model requires at least two sales of each property, there are two sales periods, t and s. P_{it} denotes the outcome observed after the flood and P_{is} identifies the outcome prior to the flood. Thus, for property i there is an earlier sale in time period s for which the price is explained by an equation similar to (12) but where the variable $Flood$ takes the value of zero. Considering the difference in sales prices for the same property $(lnP_{it} - lnP_{is})$ and assuming all structural, locational and neighbourhood characteristics of the property (Z_i, r_i, p_i) remain constant between the two sales, t and s, as do the parameters of the HPF, yields equation (13).

$$\Delta ln(P_{its}) = \alpha Bracket_{ikts} + \psi(Bracket_{ikts} \times IND_i) + \lambda_0 Year_{is} + \lambda_1 Year_{it} + \Delta\varepsilon_{ikts} \quad (13)$$

Constant characteristics of the property Z_i, r_i, p_i then drop out of the equation and the term identifying properties that were sold after the flood, $Flood_i$, now translates into a dummy variable that we call $Bracket_{its}$, which identifies properties with sale transactions before and after the flood, i.e. sales that *bracket* the flood. Following Kousky (2010) and Phaneuf and Requate (2017), the variables $Year_{is}$ and $Year_{it}$ are introduced in equation (13) to control for appreciation and age effects. The coefficient α represents the time effect, i.e. the relative price differential for all properties whose repeat-sales *bracket* the occurrence of a flood, and ψ represents the treatment response, i.e. the price discount for properties located within postcode areas that were directly affected by flooding.

Note that the repeat-sales specification in equation (13) does not yet take account of other potential factors that might differentially impact the market prospects of affected properties. To address this issue we add three additional sets of variables to the basic repeat-sales specification in equation (13).

The first set of variables (*recovery*) corresponds to post-flood dummy variables that take the value unity to identify the number of years elapsed since the occurrence of a flood to the time when we observe the second sale of each property. We use these variables to track the evolution of property prices after a flood. The second set of variables controls for differences in property characteristics (*house_type*). We hypothesise that heterogeneity in the type of property might affect its vulnerability to flooding. For instance, detached, semi-detached and terraced houses might be more exposed to flood damages than flats (other than ground floor and basement flats). Likewise, differences in the location of the property might influence the extent of the discount after a flood. This could be due to differences in the characteristics of urban and rural properties, and exposure to subtly different types of flooding. We also allow for possible differences related to the price of properties, as these might be associated with differences in the quality of the construction and therefore with the damages. There is significant policy-maker interest in whether people living in lower-value properties are differentially impacted by flooding.

The final difference concerning property characteristics relates to the availability of flood insurance at the time of the transaction.[7] Unfortunately, information on specific conditions or availability of flood insurance for the properties considered in the sample is not available. Therefore we are unable to disentangle the effect of flood damages and information effects from a potential increase in insurance premiums in the event of a flood. However, we include

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[7] No home in the UK is required by law to have flood insurance. It might be however, that some mortgage lenders will only lend on properties having comprehensive insurance policies.

a dummy variable to control for potential price effects arising from changes in the insurance industry's willingness to provide flood insurance to households. Historically, since the late 1960s flood insurance cover in the UK was included within the standard general household insurance cover at a subsidised rate as a result of a gentlemen's agreement between the Association of British Insurers (ABI) and the UK Government (Lamond *et al*. 2009). After widespread floods in the country during 1998 and 2000 however, the conditions of this agreement were revised and a new statement of principles agreed in 2002 (ABI, 2002, 2005, 2008). This changed the conditions of flood insurance for properties exposed to high levels of risk. Under the new agreement, insurers were allowed to price flood insurance policies based on risk and to refuse to issue a policy to households with an annual flooding probability greater than 1 in 75 years if there were no plans to improve flood defences in the area within the next 5 years (Lamond *et al*. 2009; ABI, 2008). Lamond *et al*. (2009) and Lamond and Proverbs (2008) suggest that this led to various kinds of difficulties for those living in floodplains especially for anyone recently flooded, including: increased premiums, an increase in policy excess, flooding being excluded from policies, a refusal to quote and a refusal to renew. These changes might result in different rates of capitalisation for a flood event for properties occurring after the policy change took place (we return to this point below).

Given these considerations the set of variables *house_type* in equation (14) includes one categorical variable identifying the price-quartile of the property and three dummy variables to control for different types of properties (detached, semi-detached, terraced and flats). Also included are dummy variables identifying freehold properties, the rural / urban classification of the property and properties sold after the change in flood insurance regulations in 2002.

The third set of variables in equation (14) control for differences in the characteristics of the flood (*Flood_type*). Our sample includes properties affected by inland and coastal flooding. Different sorts of floodwater might affect the post-flood price of the property. For instance, sewer flooding might require additional cleaning and disinfection, and could cause health issues whereas seawater flooding might also imply additional cleaning costs due to salt water, or additional damages due to wave action. We also identify those properties affected by flooding in locations where flood defences are already in place because existing flood defences might help to reduce the extent of flood damages.

Finally, a fourth set of variables concerns differences in the flood history of the properties (*Flood_history*). The first variable represents the duration of the flood in days. Two dummy variables identify properties in postcodes that were affected by flooding multiple times during the period of analysis. One of these variables takes the value unity if the sale occurs after a second flood whilst the other takes the value unity if the sale is after three or more floods.

Equation (14) below describes the final specification of the repeat-sales model that we use to identify the effect of flooding on property prices:

$$\begin{aligned}\Delta ln(P_{its}) &= \alpha_1 Bracket_{ikts} + \alpha_2(Bracket_{ikts} \times house\_type_i) \\ &+\psi_1(Bracket_{ikts} \times IND_i) + \psi_2(Bracket_{ikts} \times IND_i \times recovery_i) \\ &+\psi_3(Bracket_{ikts} \times IND_i \times house\_type_i) + \psi_4(Bracket_{ikts} \times IND_i \times F\_type_i) \\ &+\psi_5(Bracket_{ikts} \times IND_i \times F\_history_i) + \lambda_0 Year_{is} + \lambda_1 Year_{it} + \Delta\varepsilon_{ikts}\end{aligned} \tag{14}$$

Notice that equation (14) includes as the second term on the RHS a set of variables controlling for property type *without* the interaction with the group assignment variable, IND, identifying the 'treated' observations. The purpose of including the *house_type* variable without the interaction with the group variable IND is to allow for different rates of property price inflation across the different types of properties, given that the property price trend is not specific to particular types of properties.

Although the repeat-sales model allows one to exclude data on those characteristics that are assumed time-invariant, thereby avoiding possible omitted variable bias, it brings with it certain complications. Previous studies suggest that the use of repeat-sales models might induce a bias due to the subset of repeat-sales being unrepresentative of the market as a whole (Steele and Goy, 1997 and Lamond *et al.* 2007). However, it has been argued by Clapp *et al.* (1991) that in the long run there should be no systematic differences between the repeat-sales sample and the full sample, and Nagaraja *et al.* (2014) maintain that as the sample period increases, the efficiency of the repeat-sales method increases faster than that of the standard HPM. In what follows we address the issue of sample selection in two ways. First, we try to minimise a potential selection bias by using a large sample of properties that spans over almost 20 years. Second, we follow Carbone *et al*. (2006) in using a two-step Heckman (1979) selection specification to estimate equation (14) to take account of any remaining selection effect associated with using repeat sales. The Heckman selection approach first considers the probability of observing a property with repeat-sales and corrects the results of our main econometric model for potential selection bias by using the inverse Mills ratio of the selection equation.

5. Data and Econometric Methodology

Data on prices arising out of arms-length property transactions are taken from the England and Wales Land Registry (EWLR). This dataset is publicly available and includes all residential property sales in England and Wales going back to 1995. The data includes information on sale price, date of transaction (DD/MM/YYY), address and the most basic property characteristics.[8] It also includes information on whether a property is new or second-hand and whether it is sold on a freehold or leasehold bias.

The complete dataset consists of over 19 million observations for properties sold in England and Wales. However, since our focus is on analysing the price of properties affected by flooding in England, all observations corresponding to Wales were dropped. The remaining dataset still includes over 18 million transactions.

As noted, the use of the repeat-sales model requires a panel data structure for properties that have been sold multiple times over the period of analysis. Housing units with repeat-sales were identified by matching: the full postcode, street, primary house number and secondary house number (for buildings divided into flats). Over 6 million observations for properties with only a single sale were dropped, as well as over 12,000 observations with a missing postcode.[9]

The final dataset includes over 12 million transactions corresponding to 4.8 million properties in England. All sale prices were adjusted to July 2014 values using the all-property county-specific monthly House Price Index (HPI) available through the EWLR thereby allowing for differential price trends. On average, a property was sold 2.5 times between January 1995 and July 2014, with a minimum of 2 and a maximum of 29 sales. The average transaction price for a property was £234,129, with a minimum of £4,742 and a maximum of £44.2 million.

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[8] Authors such as Case and Quigley (1991) and Shiller (1993) suggest the use of 'hybrid models' combining repeat sales data and the property characteristics included in standard hedonic analyses. Unfortunately, property characteristics are not available in our data.

[9] In practice the full postcode (postcode unit level) of a property in the UK can range between six and eight alphanumeric characters. Throughout this paper we use the term '*six-digit postcode*' to refer to the full postcode of the property. According to Ordnance Survey there are 1.7 million postcodes in the UK. The mean area covered by each postcode is 0.14km^2.

Lastly, the between-sales growth rate for the price of each property was calculated as the first difference of the logged price, as shown in equation (13). Thus, the final dataset consists of over 7 million observations representing the between-sales growth rate of approximately 4.8 million properties.

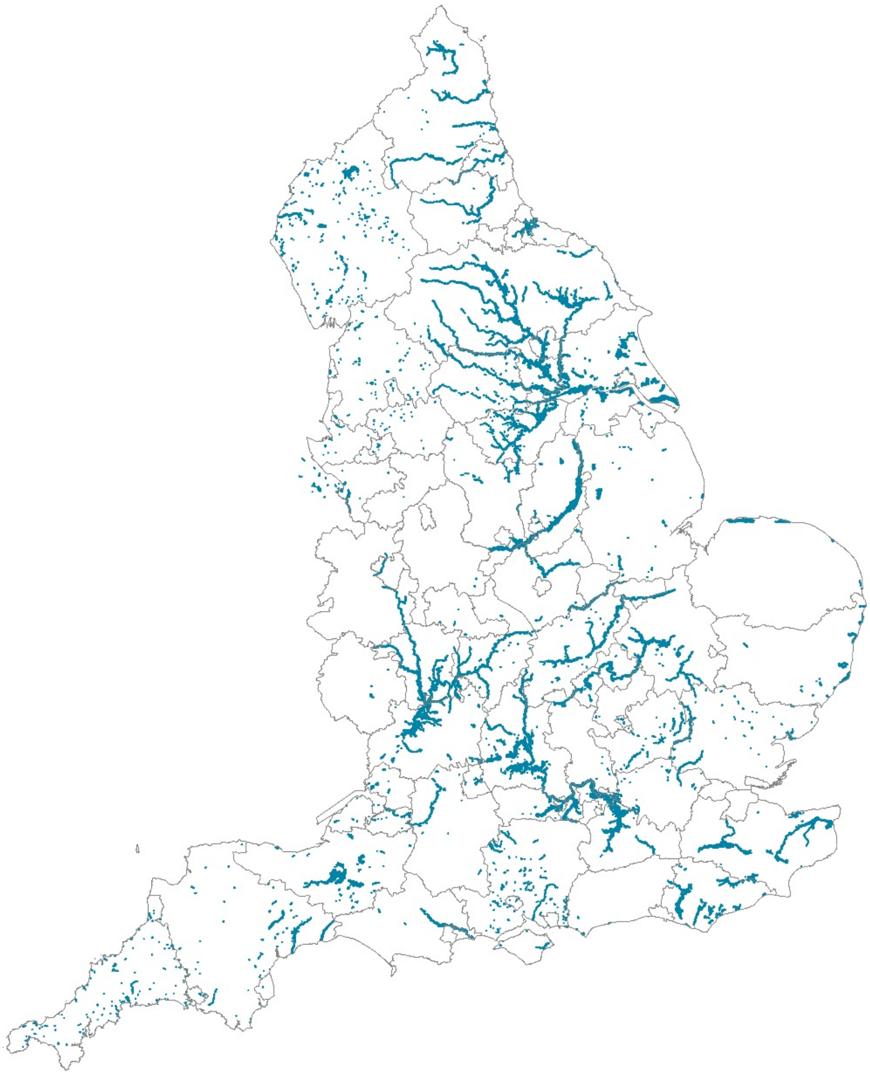
We use GIS data from the Environment Agency (EA) recently made publicly available to identify the area affected by each individual flood. The dataset contains polygons showing the Recorded Outlines of Individual Flood Events (ROIFE) in England. The data also includes important characteristics of the floods such as the start and end date of the flood (DD/MM/YYY), the source of the flood (inland or coastal) and the cause of the flood (e.g. channel capacity exceeded). We adopt the Environment Agency definitions of inland and coastal flooding. This information is collected by the EA from diverse sources although all are obtained through actual observation and refer to the flood at its maximal extent.

The dates of the floods recorded in the ROIFE data are available up to February 2014. Due to the design of the analysis and the fact that the information on property prices is only available since 1995, our final dataset includes only those flood events occurring after 1995.[10] The ROIFE identifies a total of 141,841 polygons delineating the areas affected by individual flood events in England, which represents a total flooded area of 2,654 km^2 during the period of analysis.

The total flooded area includes two types of flooding: inland (95 percent) and coastal (5 percent). For the case of inland flooding, we further differentiate between fluvial and sewer flooding. Whilst both are likely to result from a prolonged period of heavy rain, fluvial flooding is caused by an overflow of rivers, or other secondary watercourses, whereas sewer flooding occurs when surface water run-off exceeds the capacity of the drainage system. Sewer flooding represents only a small fraction (0.6 percent) of the total inland flooded area. Figure 1 below shows the flooded area considered in the analysis. A summary of the data on flood polygons from different sources is presented in Table 1.

[10] We discuss the consequences of omitting flooding events prior to 1995 later in the paper.

Figure 1. Recorded outlines of individual flood events in England, 1995-2014



Source: Own elaboration based on data from the ROIFE dataset, UK Environment Agency.

Table 1. Summary of flood incidents from different sources in England, 1995-2014

Source of flooding	Number of polygons	Area (km^2)
Inland	134,807	2,558
Fluvial	133,119	2,543
Sewer	1,688	15
Coastal	7,034	96

Total	141,841	2,654

Source: Based on data from the ROIFE dataset, UK Environment Agency.

The GIS flooded areas data is then merged with GIS full postcode data from the Ordnance Survey (available through the Digimap Resource Centre of the University of Edinburgh), to identify at the 6-digit level those postcodes that were affected by flooding during the period of analysis. More specifically, for each postcode and flood event we identify the *proportion* of the postcode that was inundated on a 0-1 scale. We likewise merge the GIS postcode data with the EWLR data to determine the location of properties. Finally, comparing the dates of floods with the dates of property transactions allows us to identify those properties with transactions that *bracket* the occurrence of a flood.

The ROIFE data allows us to identify with a high degree of accuracy those properties located in postcodes that were affected by flooding. Full-postcodes in the UK consist of an average of 15 houses grouped together, so that properties that we identify as affected by flooding were either flooded or largely surrounded by water during the event. Figure A1 in the appendix shows an example of the flood outlines and affected postcodes for an area in Oxford flooded multiple times during the period of analysis. Note the existence of some postcodes that were partially inundated. For properties in these postcodes it is uncertain whether or not a property was actually penetrated by floodwater although such properties might yet be impacted because of e.g. damage to neighbourhood infrastructure. We cannot disentangle damage to neighbouring infrastructure from damage to the property itself.

Although we do not have information on either flood depth or the speed of the flood water we use the duration of the flood, measured as the number of days that the area remained flooded, as a proxy for the ‘intensity’ of the flood.

Other GIS datasets used by this analysis include a flood map for England from the EA that shows the spatial delineation of the 100-year floodplain for inland flooding and 200-year floodplain for tidal flooding, and a rural-urban classification of land from the Department for Environment, Food and Rural Affairs (DEFRA).

Table 2 describes the variables included in the model together with the usual summary statistics. On average, the price of a property in the sample is £234,130 (July 2014 prices), with a price increase of 7.8 percent during an average period between sales of five years. The sample includes over 7 million properties with at least one repeat-sale, out of which 1.8 million (25 percent) have sales that *bracket* the occurrence of a flood in the county where they are located. Of these, 14,206 properties represent treated observations, i.e. properties whose sales bracket the occurrence of a flood and are located within a postcode that was affected by flooding according to the ROIFE database. The main difference encountered between panels 2 and 3 is that both detached and rural houses are more likely to be affected by flooding. The latter may reflect the better flood defences in urban areas.

Table 2. Summary statistics

	Variable	Description	No. Obs.	Mean	S.D.	Min.	Max.
	Price	July 2014 GBP	12,012,455	234,130	259,475	4,742	44,200,000
	Δln(Price)	House-specific first-difference of the logged real price	7,222,401	0.078	0.252	-6.28	4.17
	Bracket (B)	Dummy=1, sale before and after a flood		0.247	0.431	0	1
	Lyear (s)	Year of first sale		2001	3.901	1995	2014
	Year (t)	Year of second sale		2006	4.465	1995	2014
Bracket Sample [1]							
House_type[2]	B*sdetached	Dummy=1, semi-detached	1,787,079	0.277	0.447	0	1
	B*terraced	Dummy=1, terraced		0.329	0.469	0	1
	B*flat	Dummy=1, flat		0.184	0.388	0	1
	B*free	Dummy=1, freehold		0.769	0.421	0	1
	B*rural	Dummy=1, rural		0.176	0.380	0	1
	B*quartile 2	Dummy=1, if price-quartile =2		0.262	0.071	0	1
	B*quartile 3	Dummy=1, if price-quartile =3		0.260	0.068	0	1
	B*quartile 4	Dummy=1, if price-quartile =4 (highest)		0.233	0.083	0	1
	B*after2002	Dummy=1, sale after 2002		0.695	0.460	0	1
Bracket-Flooded Sample [3]							
	B*IND	Proportion of the inundated postcode, 0-1 scale	1,787,079	0.158	0.063	0	1
	B*Any Flooding (AF) [5]	Dummy=1, if located in a postcodes with IND > 0		0.008	0.0889	0	1
House_type	B*AF*sdetached		14,206	0.255	0.436	0	1
	B*AF*terraced			0.312	0.463	0	1
	B*AF*flat			0.163	0.369	0	1
	B*AF*free			0.801	0.399	0	1
	BF*AF*rural			0.311	0.463	0	1
	BF*AF*quartile 2			0.225	0.092	0	1
	BF*AF*quartile 3			0.278	0.083	0	1
	BF*AF*quartile 4			0.316	0.107	0	1
	BF*AF*after2002			0.689	0.462	0	1
F_type [4]	B*AF*sea	Dummy=1 if Coastal flood	14,206	0.186	0.389	0	1
	BF*AF*sewer	Dummy=1 if Sewer flood		0.023	0.149	0	1
	BF*AF*defence	Dummy=1 if existing flood defence		0.076	0.264	0	1
F_history	BF*AF*dur	Duration of last flood (days)	14,206	5.6	42.9	0	364
	BF*AF*2F	Dummy=1 if 2dn time flooded		0.135	0.341	0	1
	BF*AF*3F+	Dummy=1 if 3rd time flooded or more		0.064	0.245	0	1

Notes:
[1] The summary statistics under this title correspond to the 25 percent of the sample with repeat-sales that *bracket* the occurrence of a flood in the affected county.
[2] Omitted categories are dummy variables for detached property, urban location and properties sold on leasehold.
[3] The summary statistics under this title correspond to the 1 percent of the sample with repeat-sales that *bracket* the occurrence of a flood and are located within a postcode affected by flooding.
[4] The omitted category is a dummy variable for fluvial.
[5] In practice, this variable takes the value of one for properties located in a postcode that was affected by flooding to any extent (proportion). We use this variable only for this table to present informative summary statistics for the sample of properties located in affected postcodes.

6. Results

Table 3 displays the results of the repeat-sales model in equation (14) using a two-stage Heckman selection model to account for potential selection bias. Table A1 in the appendix shows the results of the selection equation for each of the specifications in Table 3. The identifying restriction for the selection equation is a dummy variable indicating if a property is new or second-hand, all other characteristics of the properties are also included in the equation. The coefficients on the inverse Mills ratio for the selection models in Table A1 range between 0.06 – 0.15 and are all statistically significant. This demonstrates the relevance of using a Heckman selection approach to correct for selection bias in our repeat-sales specification.

The results in Table 3 show six alternative specifications with different samples and control groups. Column (1) considers the full sample, including all properties affected by different sources of flooding. Dummy variables identify each different type of flooding, where the omitted category is fluvial flooding. The assumption underlying this specification is that the effect of all other variables is invariant with respect to different types of flooding. Note that although the data includes information from properties in postcodes some of which were only partially flooded the results in column (1) and elsewhere correspond to a situation in which IND=1. The results in column (1) are very similar to the results obtained from analysing only those postcodes that were between 90-100% flooded.

Columns (3) and (5) divide the sample according to the different types of flooding. By running separate regressions we allow the parameters in the equation to differ across different types of flooding. This is potentially important as different types of floods possess different characteristics so their potential impacts are also different. Thus, in column (3) the treatment group corresponds to all properties affected by inland flooding between sales, while the control group includes those properties with repeat-sales that *bracket* the occurrence of inland flooding in the county where they are located. A similar definition follows for the sample in column (5), but there the treatment group includes properties affected by coastal flooding, and the control group is those properties that *bracket* the occurrence of a coastal flood in the county where they are located. This distinction is especially relevant in those counties affected by more than one type of flooding during the period of analysis.

One possible criticism of our identification strategy is that it relies on a quasi-experimental design where the random assignment of the treatment is not guaranteed. More specifically, flooding occurs mostly in locations which are exposed to flood risk and it can be argued that the property market in such regions might already possess some special characteristics and attracts households with distinctive preferences. Therefore, comparing the price change of properties affected by flooding against the price change of all other properties might lead to misleading conclusions. To address this issue, columns (2), (4) and (6) show the results of regressions with the relevant sample defined as above i.e. full sample, inland flooding and coastal flooding, respectively, but now the control group is restricted to properties located *inside* the floodplain. In this way, we compare the price change of properties affected by flooding, against that of properties exposed to a similar risk but which were not affected by flooding during the period of analysis. An implication of restricting the sample to include only properties in the floodplain is that we exclude flooded properties located outside of the floodplain which represents 12 percent of the total sample of treated observations. This reduces the total number of observations from 7,222,401 down to 1,137,605.[11]

Our discussion of results presented in Table 3 focuses on Columns (4) and (6) as our preferred specifications. The results are however, fairly robust across different specifications. All specifications include county level fixed-effects to control for between county heterogeneity. Heteroscedasticty-robust standard errors (Huber, 1967; White, 1980) appear in parentheses.

[11] Although we have not done so here it is possible to go even further e.g. by making a comparison between flooded and non-flooded properties enjoying water-based amenities as defined e.g. by distance from a water body or having a view of a water body. The existence of water amenities is an enduring problem in hedonic analyses of flooding but one better addressed in the context of a single water body providing both water-based amenities as well as a risk of flooding.

The top panel in Table 3 (*Bracket sample*) includes the coefficients of the variables that control for differential price trends across different types of properties. These variables include the type of property (*B*sdetached, B*terraced, B*flat*), the type of contract (*B*free*), the rural / urban classification of land (*B*rural*), the price-quartile of the property (*B*q1-4*) and a dummy variable to identify the properties that were sold after the change in flood insurance practices in 2002 (*B*after2002*). The omitted categories are detached properties, leasehold contract, urban locations and properties sold before the change in flood insurance practices. In general, all the variables included in the model to control for differences in price trends across different types of properties are highly significant. This indicates that, regardless of the occurrence of a flood, properties with different characteristics had different price trends over the period of analysis. Relative to detached houses, the price increases for semi-detached, flats and terraced houses has been slower. For example, from Column (1) semi-detached house prices grew 2.3% faster than the all-property price index.[12]

The second panel from the top in Table 3 (*Bracket-Flooded Sample*) shows the main results. We deal first with the results for inland flooding in Column (4).

6.1. Results for Inland Flooding

The effect of a flood on the price of inundated properties with the characteristics of the omitted categories is captured by the coefficient on the variable *B*IND*. This coefficient in Column (4) suggests that inland flooding reduces the price of such properties by 31.3% corresponding to the coefficient -0.375. Note that this price change is measured relative to what would otherwise have occurred for non-flooded property of the same type. This does not preclude the possibility that prices for flooded properties will be higher in nominal terms 1 year after flooding, given that property prices are generally rising anyway and that prices for some sorts of properties are rising faster than the all-property price index. Notice too that this figure represents the price discount for a property sold *immediately* after a flood. Property sold immediately after a flood may not have been restored to its former condition. According to the Association of British Insurers however, the majority of flooded property is at least made habitable within 6-9 months. A report by the Royal Institute of Chartered Surveyors suggests that the average cost of repairing a 3 bedroom property in 2014 was

[12] As noted by Halvorsen and Palmquist (1980) the coefficient on a dummy variable cannot be interpreted as indicating a percentage change. Using the formula $e^{\gamma} - 1$ taken from that paper the coefficient 0.0228 translates into a 2.31% change.

£30,000. Repairs generally include drying out the property and replacing the plaster and electrics. Floor coverings and décor will be changed. Chattels will be replaced although these are not typically included in property sales. The effects of inland flooding on properties with different characteristics, subjected to different types of flooding, and possessing a different flood history, are measured over and above this baseline figure.

The other results in Column (4) point to different effects across different types of properties. The coefficient on the variables *B*IND*sdetached*, *B*IND*terraced* and *B*IND*flat* indicate the differential effect of a flood on the price of different types of properties relative to detached properties. Thus inland flooding reduces the price of semi-detached properties by 29.9% (by applying the formula to -0.375 + 0.0187). As expected, flats experience the smallest discount (-0.375 + 0.184) of 17.4%, nevertheless it is still surprising to find such a high discount for properties where the majority are unlikely to be directly damaged by flooding (although as already noted we are not able to distinguish the effect on flats located on the ground floor or basement from those located in upper floors).

The next set of variables indicates what happens to the price of property sold one year after being flooded through to 15 years after being flooded. For the results in Column 4 it is clear that there is a steady recovery in prices. For example the coefficient on *B*IND*+1 year* demonstrates that one year after flooding prices are 4.3% higher relative to a property that has *just* been flooded. This gradually increases until years 8-9 after flooding when, at least for the benchmark property, the effect of past flooding has all but disappeared i.e. the coefficient on *B*IND*+8-9 years* is virtually the same as the coefficient on *B*IND*. After that point the coefficients continue to become increasingly less precise and it becomes harder to say how the price of once-flooded property fares compared to equivalent property that has never flooded. The reason for this is simply that we observe more properties with a repeat sale one or two years after the flood than 13-15 years after the event.

Whether the property is leasehold or freehold does not appear to influence the impact of flooding on the price of properties. The coefficient on the variable *B*IND*rural* indicates that flooding has an impact on the price of properties in rural areas that is insignificantly different to that in urban areas. Evidently property in rural areas has no features that make it especially susceptible to flooding.

The coefficients on the dummy variables *B*IND*q2-4* indicate that the immediate price discount on affected properties is greater for properties in the lowest price-quartile. Note however, that this coefficient refers only to the percentage discount and it does not necessarily mean that the loss in monetary terms is greater. We discuss this issue in more detail below.

The coefficient on the variable *B*IND*after2002* indicates that the discount is not significantly different for those properties sold after the change in the flood insurance regulations in 2002. This is somewhat unexpected; authors such as Lamond *et al*. (2009) and Lamond and Proverbs (2008) have suggested that the change in the flood insurance regulations in 2002 resulted in difficulties for owners of properties in the floodplain, especially for those recently flooded. One possibility is that the change in the regulations was anticipated by households and in the end turned out to be not as bad as expected. According to Lamond *et al*. (2009) and Lamond and Proverbs (2008) the policy debate on the need to change flood insurance regulations and to adopt a new scheme that priced flood insurance more according to risk started soon after the widespread floods of 1998. The majority of those in high risk properties were, it turned out, still able to obtain flood insurance at standard rates following these regulatory changes. Nevertheless the effect of changes in flood insurance on the price of properties remains an area of further research.[13]

Table 3. Repeat-sales model. Semi-parametric post-flood recovery

	Variables	(1) All estimates	(2) All estimates FP	(3) Inland	(4) Inland FP	(5) Coastal risk	(6) Coastal risk FP
	Bracket Sample						
House_type	Bracket (B)	-0.0433***	-0.0438***	-0.0393***	-0.0463***	0.0181	0.0215**
		(0.0010)	(0.0028)	(0.0011)	(0.0031)	(0.0140)	(0.0103)
	B*sdetached	0.0228***	0.0197***	0.0231***	0.0219***	0.0167***	0.0070**
		(0.0005)	(0.0014)	(0.0006)	(0.0016)	(0.0013)	(0.0033)
	B*terraced	0.0478***	0.0456***	0.0473***	0.0470***	0.0274***	0.0268***
		(0.0005)	(0.0014)	(0.0006)	(0.0015)	(0.0013)	(0.0033)
	B*flat	0.0167***	0.0179***	0.0174***	0.0333***	-0.0259***	-0.0412***
		(0.0010)	(0.0029)	(0.0011)	(0.0032)	(0.0025)	(0.0072)
	B*free	0.0078***	0.0114***	0.0077***	0.0174***	0.0191***	0.0454***
		(0.0008)	(0.0025)	(0.0009)	(0.0028)	(0.0020)	(0.0062)
	B*rural	0.0024***	0.0066***	0.0007	0.0021	0.0162***	0.0311***
		(0.0005)	(0.0012)	(0.0006)	(0.0013)	(0.0013)	(0.0033)
	B*q2	0.0046***	0.0101***	0.0049***	0.0120***	-0.0290***	-0.0250***
		(0.0005)	(0.0012)	(0.0005)	(0.0012)	(0.0029)	(0.0066)
	B*q3	-0.0381***	-0.0357***	-0.0373***	-0.0356***	-0.0763***	-0.0503***
		(0.0005)	(0.0012)	(0.0005)	(0.0012)	(0.0032)	(0.0075)

[13] We also divided the dataset at the point where the changes were made. The results point to no marked difference in the coefficients of interest i.e. those indicating the impact on flooding of particular property types.

	B*q4	-0.0792***	-0.0826***	-0.0778***	-0.0838***	-0.1080***	-0.0926***
		(0.0005)	(0.0011)	(0.0005)	(0.0011)	(0.0044)	(0.0098)
	B*after2002	0.0043***	0.0030***	0.0029***	0.0003	-0.0193***	-0.0274***
		(0.0004)	(0.0011)	(0.0005)	(0.0012)	(0.0018)	(0.0055)
	Bracket-Flooded Sample						
	B*IND	-0.371***	-0.390***	-0.344***	-0.375***	-0.487***	-0.513***
	(Percentage Flooded)	(0.0346)	(0.0387)	(0.0375)	(0.042)	(0.0935)	(0.0970)
Semi-parametric recovery	B*IND*+1 year	0.0515***	0.0452**	0.0504**	0.0423**	0.1204*	0.1010**
		(0.0186)	(0.0196)	(0.0208)	(0.0215)	(0.0624)	(0.0489)
	B*IND*+2 years	0.1320***	0.1390***	0.1230***	0.1310***	0.1550***	0.1900***
		(0.0196)	(0.0207)	(0.0214)	(0.0223)	(0.0535)	(0.0567)
	B*IND*+3 years	0.1670***	0.1660***	0.1540***	0.1550***	0.2090***	0.1950***
		(0.0222)	(0.0236)	(0.0242)	(0.0255)	(0.0585)	(0.0619)
	B*IND*+4 years	0.2580***	0.2500***	0.2560***	0.2520***	0.2620***	0.2450***
		(0.0240)	(0.0256)	(0.0262)	(0.0277)	(0.0617)	(0.0643)
	B*IND*+5 years	0.3110***	0.2940***	0.3080***	0.2890***	0.2950***	0.2950***
		(0.0271)	(0.0290)	(0.0298)	(0.0316)	(0.0685)	(0.0728)
	B*IND*+6-7 years	0.3510***	0.3400***	0.3360***	0.3260***	0.4030***	0.3800***
		(0.0232)	(0.0248)	(0.0256)	(0.0271)	(0.0575)	(0.0616)
	B*IND*+8-9 years	0.4060***	0.4050***	0.3540***	0.3580***	0.5580***	0.5330***
		(0.0697)	(0.0718)	(0.0869)	(0.0883)	(0.1210)	(0.1229)
	B*IND*+10-12 years	0.3950***	0.3690***	0.2550*	0.2340	0.4690***	0.4571***
		(0.0901)	(0.0926)	(0.1410)	(0.1430)	(0.1260)	(0.1290)
	B*IND*+13-15 years	0.3710**	0.3710**	0.2600	0.2470	0.4930**	0.4880**
		(0.1650)	(0.1690)	(0.2810)	(0.2830)	(0.2090)	(0.2100)
House_type	B*IND*sdetached	0.0264	0.0501***	-0.0021	0.0187	0.0893*	0.1169**
		(0.0177)	(0.0186)	(0.0192)	(0.0199)	(0.0472)	(0.0487)
	B*IND*terraced	0.0291*	0.0655***	0.0061	0.0455**	0.1170**	0.1537***
		(0.0165)	(0.0174)	(0.0180)	(0.0187)	(0.0457)	(0.0470)
	B*IND*flat	0.1530***	0.1890***	0.1430***	0.1840***	0.2450***	0.2623***
		(0.0295)	(0.0336)	(0.0316)	(0.0360)	(0.0858)	(0.0887)
	B*IND*free	-0.0043	-0.0120	0.0316	0.0231	-0.0655	-0.0804
		(0.0257)	(0.0298)	(0.0277)	(0.0322)	(0.0730)	(0.0756)
	B*IND*rural	0.0268**	0.0115	0.0344**	0.0177	-0.0257	-0.0266
		(0.0130)	(0.0138)	(0.0144)	(0.0150)	(0.0322)	(0.0336)
	B*IND*q2	0.0987***	0.0933***	0.0714***	0.0666***	0.1570***	0.1442***
		(0.0167)	(0.0177)	(0.0188)	(0.0198)	(0.0380)	(0.0394)
	B*IND*q3	0.0847***	0.0861***	0.0607***	0.0589***	0.1710***	0.1634***
		(0.0166)	(0.0176)	(0.0183)	(0.0194)	(0.0451)	(0.0461)
	B*IND*q4	0.1440***	0.1600***	0.1100***	0.1190***	0.3840***	0.2840***
		(0.0180)	(0.0192)	(0.0196)	(0.0208)	(0.0544)	(0.0556)
	B*IND*after2002	0.0222	0.0304*	0.0138	0.0281	0.0489	0.0317
		(0.0157)	(0.0167)	(0.0178)	(0.0187)	(0.0380)	(0.0395)
F_type	B*IND*sea	-0.0541***	-0.0621***				
		(0.0174)	(0.0184)				
	B*IND*sewer	-0.1630**	-0.2280***	-0.1660**	-0.2270***		
		(0.0700)	(0.0866)	(0.0700)	(0.0855)		
	B*IND*defence	0.1160***	0.1050***	0.1240***	0.1120***	0.0481	0.0065
		(0.0227)	(0.0237)	(0.0353)	(0.0359)	(0.0351)	(0.0368)
F_history	B*IND*dur	-0.000278***	-0.000293***	-0.000287***	-0.000304***	-0.000451	-0.00043
		(5.60e-05)	(5.84e-05)	(5.78e-05)	(5.98e-05)	(0.00068)	(0.00069)
	B*IND*2F	-0.0709***	-0.0778***	-0.0810***	-0.0902***	0.0157	0.0225
		(0.0164)	(0.0169)	(0.0179)	(0.0183)	(0.0442)	(0.0448)
	B*IND*3F+	-0.068500***	-0.069200***	-0.0626***	-0.0638***	-0.0626	-0.0462
		(0.0201)	(0.0209)	(0.0216)	(0.0222)	(0.0593)	(0.0599)
	Lyear (s)	-0.0040***	-0.0044***	-0.0039***	-0.0042***	-0.00359***	-0.00297***
		(2.96e-05)	(7.7e-05)	(3.00e-05)	(7.70e-05)	(0.00022)	(0.00053)
	Year (t)	0.0041***	0.0044***	0.0039***	0.0042***	0.00341***	0.01137***
		(2.95e-05)	(7.6e-05)	(2.98e-05)	(7.67e-05)	(0.00023)	(0.00075)

Observations	13,229,034	2,119,595	12,653,951	1,802,297	575,083	317,298
Treated Obs.	14,206	12,488	11,561	10,096	2,645	2,392
County FE	YES	YES	YES	YES	YES	YES

Notes: Robust standard errors in parentheses. ** and *** means rejection of the null hypothesis at the 5% and 1% significance level.
[1] Omitted categories are dummy variables for detached property, urban location and properties with repeat-sales before change in the flood insurance regulation in 2002.
[2] The omitted categories are dummy variables for fluvial flooding and for those properties affected by flooding in locations without flood defences.
[3] The omitted category represents properties with repeat-sales before and after the first flood, during the period of analysis, in the postcode where they are located.

Regarding differences in the type of flooding, the coefficient on the variable *B*IND*sewer* in Column (4) indicates the discount on the price of properties affected by sewer flooding is around 20.3% greater compared to the discount for properties affected by other types of inland flooding. This is as discussed, likely to be due to additional cleaning and disinfection costs, and potential health issues. Floods can also occur in locations with standing flood defences due to overtopping or a failure of the defences. The coefficient on the variable *B*IND*defence* indicates that the price discount for affected properties is 11.8% less in locations where flood defences are in place. We believe that this reflects the fact that flood damages might be lower where there are flood defences – even if on this occasion they have been breached.

Finally, the variable *B*IND*dur* controls for differences in flood history in terms of the duration of the previous flood. As expected, the negative coefficient in Column (4) points to a greater price discount for affected properties in areas where the period of inundation lasted longer (although the magnitude of the effect is small). The coefficients on the variables *B*IND*2F* and *B*IND*3F+* identifying properties with a history of repeated flooding during the period of analysis are also significant. The implication is that properties with a prior history of flooding suffer a greater fall in prices. The coefficient of -0.0902 on the first of these two variables suggests that when a property has been flooded before the relative impact of further flooding serves to reduce prices by 8.6% relative to those properties flooding for the first time.[14]

[14] It has been pointed out to us that the coefficients on these two variables might be biased due to them not including flood events occurring prior to 1995. Although there were far fewer flood events we explored this issue by dividing the data into two equal time periods and examining the coefficients. No significant differences were observed between 2005-2014 (where the prior flood events of 1995-2004 are recorded) and 1995-2014.

The final two variables in the model, *Lyear (s)* and *Year (t),* control for appreciation and age effects. The significant effect of these variables across all specifications highlights the importance of controlling for these effects for the purposes of identifying the impact of inundation on property prices.

6.2. Results for Coastal Flooding

We now briefly investigate the results for coastal flooding referring to Column (6) of Table 3. The interpretation of the coefficients is identical to the case of inland flooding. Most of the variables have the same sign and significance although a few important differences related to the magnitude of the coefficients are worth highlighting. As before, the effect of coastal flooding on the price of detached properties, with a leasehold contract, in urban locations and sold before the change in the flood insurance regulation is captured by the coefficient on the variable *B*IND*. This coefficient suggests that coastal flooding now reduces the price of detached properties by 40.1%. We suggest that this more sizeable discount is related to the greater potential for damages and cleaning costs due to the intrusion of sea water and the effect of wave action. Other sorts of properties also attract larger a discount for coastal flooding compared to inland flooding.

As for the case of inland flooding, there is also strong evidence of a recovery in property prices. The coefficients on the variables B*IND*+1 years through to B*IND*+8-9 years increase monotonically until the coefficient reaches 0.533 at which point the effect of past-flooding is eliminated. Beyond that point moreover, it appears as if prices stabilise at the levels they would have been in the absence of flooding at least for the case of the benchmark property (the coefficients on B*IND*+10-12 years and B*IND*+13-15 years are little changed). The only difference is that post-flood property prices in coastal areas fall further and recover faster. One suspects that some individuals view flood events as an opportunity to buy a sea front property at a knock-down price; recent research by estate agents Knight Frank (2016) confirms that over the last two decades high demand for coastal properties in the south of England has driven up the price of properties in that region.[15]

[15] Knight Frank (2016) use the same publicly available data from the Land Registry going back to 1995. Their results suggest that, the average annual growth rate of the price of coastal properties, in 35 cities included in the analysis, was 2.7 percent higher than comparable non-coastal properties during the period of analysis. The authors conclude that by 2016, this annual premium has resulted in prices of waterfront properties being as much as 71 percent higher than comparable properties located just a mile inland.

Similar to the case of inland flooding, differences in the type of contract given by the coefficient on the variable *B*IND*free* in Column (6) are not significant. The coefficient on the variable *B*IND*rural* indicates that the discount on rural properties affected by coastal flooding is insignificantly different to that experienced by comparable properties in urban areas.

The coefficients on the variables *B*IND*q2-4* in Column (6) indicate that the price discount on properties affected by coastal flooding is once more greater for properties in the lowest price-quartile. This result is similar to the one observed for inland flooding, however the coefficients on properties affected by coastal flooding is far larger. This difference might be driven by the high demand for luxury properties along the coast. The coefficient on the variable *B*IND*after2002* that identifies affected properties sold after the change in the flood insurance regulations in 2002 is once again statistically insignificant.

Interestingly the coefficient on the variable *B*IND*defence* for properties affected by coastal flooding suggests that the price discount of an affected property is not statistically different to that experienced in locations with a flood defence. This is different to the case of inland flooding.

The coefficient on the variable *B*IND*dur* in Column (6) suggests that the duration of coastal flooding does not have a significant effect on the post-flood discount. Despite its insignificance the coefficient is nonetheless similar in terms of magnitude to the one that we observe for the duration of inland flooding in Column (4). The interpretation of the coefficients on the variables *B*IND*2F* and *B*IND*3F+* suggest that the extent of the post-flood discount on properties which are flooded repeatedly is not significantly different from the discount on properties which suffer only one flood during the period of analysis. The variables *Lyear (s)* and *Year (t)* are significant and have the expected sign.

Additional robustness tests referring to all specifications are relegated to section A1 of the appendix. These include first removing observations with extreme values of the dependent variable from the sample and second undertaking a quasi-placebo test to ensure that our results are indeed capturing the effect of flooding. We also analyse the data according to NUTS1 statistical regions in order to assess the geographical stability of the coefficients

(Michaels and Smith, 1990). The results reveal the existence of the same patterns observed in the national dataset i.e. a large, immediate impact from flooding followed by a swift recovery in prices, although the statistical significance of the effect varies across regions (unsurprisingly so since some regions have experienced more flood events than others). Finally, using OLS we examine the effect of removing influential outliers using Cook's d-statistic.

7. Discussion

In this section we investigate what the coefficients contained in Table 3 imply about the size of the immediate post-flood discount for affected properties and the subsequent speed of recovery of prices. Once more we deal separately with inland and coastal flooding using the coefficients in Columns (4) and (6) of Table 3. We present Tables distinguishing the impacts for properties in different price-quartiles. Also included in these tables are χ^2 tests used to test the null hypothesis that prices are back to where they would have been but for the flooding. Following all this we discuss what our results might mean in policy terms.

Table 4 shows the evolving post-flood price discount for properties affected by inland flooding. The estimates therein reflect the average composition of housing in inland floodplains and a typical first time flood in a location not already protected by flood defences. The results in Table 4 suggest that the immediate discount for properties affected by inland flooding is between -27.9% (corresponding to the coefficient -0.327) and -18.4%. Regarding the persistence of the post-flood discount however, the results suggest that after 6-7 years the price discount has all but disappeared for property in the lowest price-quartile. The price discount from flooding disappears even faster for property in the highest price-quartile where after 3 years the difference between high-value property that has flooded for the first time and that which has not is no longer statistically significant at the 5% level of confidence. Furthermore, there is even some evidence to suggest that in the medium term such property might even be worth more, overshooting its final value before settling back.

Table 4. Effect of inland flooding on property prices: per price-quartile[1]
(*Inland flooding; Column (4) of Table 3*)

	Inland (*percentage*)			
	Q1	**Q2**	**Q3**	**Q4**
Initial discount	-0.327 [83.67]***	-0.261 [51.64]***	-0.268 [54.40]***	-0.208 [30.81]***

+1 year	-0.285 [79.13]***	-0.218 [44.96]***	-0.226 [47.85]***	-0.166 [23.63]***
+2 years	-0.195 [34.82]***	-0.129 [14.90]***	-0.136 [16.94]***	-0.076 [4.73]**
+3 years	-0.171 [21.33]***	-0.105 [7.78]***	-0.112 [8.97]***	-0.050 [1.67]
+4 years	-0.073 [7.98]***	-0.004 [0.01]	-0.012 [0.10]	0.047 [0.01]
+5 years	-0.034 [5.88]**	0.034 [1.24]	0.027 [0.60]	0.081 [2.67]
+6-7 years	0.004 [0.01]	0.067 [1.99]	0.061 [1.10]	0.120 [7.81]***
+8-9 years	0.037 [0.45]	0.100 [0.95]	0.091 [0.75]	0.153 [2.41]
+10-12 years	-0.088 [0.39]	-0.021 [0.02]	-0.028 [0.04]	0.033 [0.10]
+13-15 years	-0.075 [0.08]	-0.007 [0.00]	-0.014 [0.00]	0.047 [0.03]

Note: [1] Considering the average composition of the housing market in floodplain areas.
The figures in parentheses refer to χ^2 tests.

Table 5 shows the immediate discount and recovery for properties affected by coastal flooding. Once more the table reflects the average composition of properties in the floodplain subjected to a flood for the first time and without any flood protection.

The time taken to eliminate the price discount from flooding appears to vary markedly across different price-quartiles. For properties in the lowest price-quartile the immediate impact of flooding is a -31.4% reduction in prices. But after 6-7 years there is no longer any discernible impact from coastal flooding for properties in the lowest price-quartile. This is identical to the impact from inland flooding. Turning to property in the highest price-quartile the immediate impact from flooding is only a -10.1% fall in prices. In addition, as we consider properties in higher price-quartiles the speed of recovery increases markedly and for properties in the highest price-quartile the price discount for flooding disappears after only 1 year. And there is even evidence that after 5 years the price of such property exceeds the price of non-flooded property.

Table 5. Effect of coastal flooding on property prices: per price-quartile[1]
(*Coastal flooding; Column (6) of table 3*)

	Coastal *(percentage)*			
	Q1	**Q2**	**Q3**	**Q4**
Initial discount	-0.377	-0.245	-0.218	-0.105

	[24.77]***	[15.78]***	[13.73]***	[16.18]***
+1 year	-0.280 [11.31]***	-0.143 [3.90]**	-0.124 [3.33]*	-0.006 [0.00]
+2 years	-0.201 [4.94]**	-0.056 [3.18]*	-0.036 [0.09]	0.084 [0.69]
+3 years	-0.196 [4.07]**	-0.051 [2.23]	-0.032 [0.06]	0.088 [1.22]
+4 years	-0.143 [3.56]**	-0.002 [0.00]	0.017 [0.01]	0.142 [2.08]
+5 years	-0.096 [3.38]*	0.047 [0.09]	0.065 [0.03]	0.191 [5.93]**
+6-7 years	-0.011 [0.01]	0.137 [2.35]	0.158 [4.67]**	0.275 [9.40]***
+8-9 years	0.146 [1.25]	0.292 [6.25]**	0.314 [5.28]**	0.439 [11.97]***
+10-12 years	0.069 [0.17]	0.216 [2.63]	0.238 [2.62]	0.364 [6.01]**
+13-15 years	0.105 [0.01]	0.249 [1.70]	0.271 [2.16]	0.397 [3.55]*

Note: [1] Considering the average composition of the housing market in floodplain areas. The figures in parentheses refer to χ^2 tests.

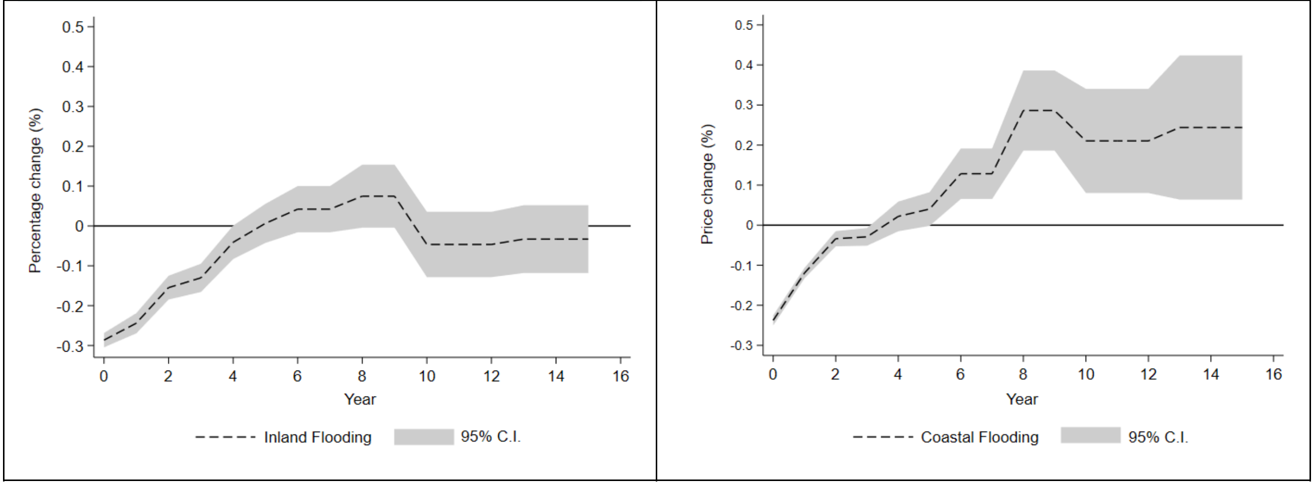
Figure 2 below illustrates the different price paths to recovery for the average property affected by inland and coastal flooding. Once more, we examine the case of a first time flood in an area not protected by flood defences. For inland flooding the immediate impact of flooding is a price discount of -24.9%. This price discount continues to be statistically significant up until year 5. For coastal flooding by contrast, the immediate price impact from flooding is -21.1% with a statistically significant price impact up until 4 years after flooding.[16] The case of coastal flooding is however more interesting since it appears that after 6 years the price of flooded property actually exceeds that of non-flooded property. There are various explanations for this finding. One possibility is of course, that properties affected by coastal flooding are following a different underlying price trend arising out of e.g. the presence of water-based amenities which we have failed to control for merely by focussing on properties in the floodplain. Another possibility is that property owners are using the opportunity to upgrade their properties rather than return them to their original state pre-flooding. A further possibility is that the rapid price increases that occur post flooding result in property price speculation. It has also been suggested to us that, insofar as flooding triggers

[16] These impacts are larger than those reported in Daniel et al. (2009) who find that there is a discount of 4% and 9% following the first and second flood of the Meuse river as it flows through the Netherlands. By contrast Atreya and Ferreira (2015) find a much larger immediate impact of 33% to 48% for one in 100 year flood in Albany, Georgia.

the construction of flood defences, the increase in property prices might indicate a reduction in the perceived risk of further future flooding. This remains an area of future research.

Figure 2. Mean effect of flooding on property prices: per type of flooding

A. Inland Flooding	B. Coastal Flooding



Source: Own elaboration based on results from Table 3.

As noted, a fear expressed by many homeowners is that once a property has been flooded there may be a permanent reduction in its value. Depending on the extent of the reduction such households could fall into negative equity. For this reason mortgage lenders need to know whether the effects of inundation on property prices are temporary or permanent. A permanent decline in the price of flooded property also presents a challenge for policy-makers intent on protecting households, especially those inhabiting properties in the lowest price-quartile, from a sharp reduction in their wealth. The impermanence of the effects of flooding might also have implications for what is viewed as a proper apportionment of the costs of flood defences between the owners of properties situated in the floodplain and others. In particular, if property prices rebound swiftly following flooding then there may seem less justification for those located outside the floodplain to pay for flood defences. But when for particular sorts of properties the process of price recovery is slow or absent this might suggest that policy-makers should prioritise the protection of such properties.

According to our findings the immediate reduction in property prices that follows flooding does not appear to herald a permanent reduction. The understandable concern expressed by households affected by flooding therefore appears unfounded. And owners of flats in flooded areas might even find themselves at an advantage. There is only a modest period of time to wait before prices recover even for properties in the lowest price-quartile.

Despite the transient effects some households might still be forced to sell up whereas others might be able to sit it out thus avoiding having to sell at a loss. Many households are of course renting in which case the impact of flooding is borne mainly by the owner. At the other end of the spectrum are those households owning property in the highest price-quartile and yet affected by coastal flooding. For such properties the recovery in property prices appears to be almost immediate. No help beyond the assistance of emergency services during the event itself seems warranted for such households. This makes sense because if property is promptly reinstated following inundation and if the objective risk of flooding has not altered there is no reason for the price of the property to change either; it does so only because the subjective evaluation of recent flood events leads to an overestimation of future risks. The losses sustained by the household following a flood event will be in the form of uninsured or uninsurable intangible damages and not in the form of a permanent reduction in the value of the property once reinstated.

8. Conclusions

During recent years the UK has experienced a sequence of costly flood events. However, whilst a large body of literature looks at the effect of a flood on the price of properties located in the floodplain, there is a lack of research on the effect of flooding on the price of inundated properties, presumably due to missing information regarding precisely which properties are directly affected by particular floods.

Our findings suggest that the average post-flood price discount of flood-affected properties is substantial yet relatively short-lived for most sorts of property. Even flood-affected properties in the lowest price-quartile seem to recover after 6-7 years. The recovery time appears shorter still for properties in higher price-quartiles.

Currently, greater weight is attached to flood relief projects benefitting deprived areas. This appears to be because of the view that low-value properties are more seriously and enduringly affected. Our results, pointing as they do to a swift recovery in the price of flooded property, therefore have important implications for those planning flood defences.

We suggest three important areas for future research into flooding of which the first is to investigate risk-based sorting. With a sorting model it should be possible to analyse how household characteristics affect the valuation of flood risk as well as to value discrete changes in flood risk. The second area for future research is to distinguish the 'pure' informational update from flooding from actual flood damages. This might be approached by examining the effect on prices for those properties subject to a 'near-miss' from flooding. The final area for research is to identify the effect of changes in flood insurance premiums on the price of properties situated in the floodplain. At present we are unable to disentangle the effect of flood damages and any informational update from the effect of any ensuing change in insurance premium. This is however important, particularly in light of ongoing attempts in the UK to provide flood insurance at an affordable price for properties in flood-prone areas.

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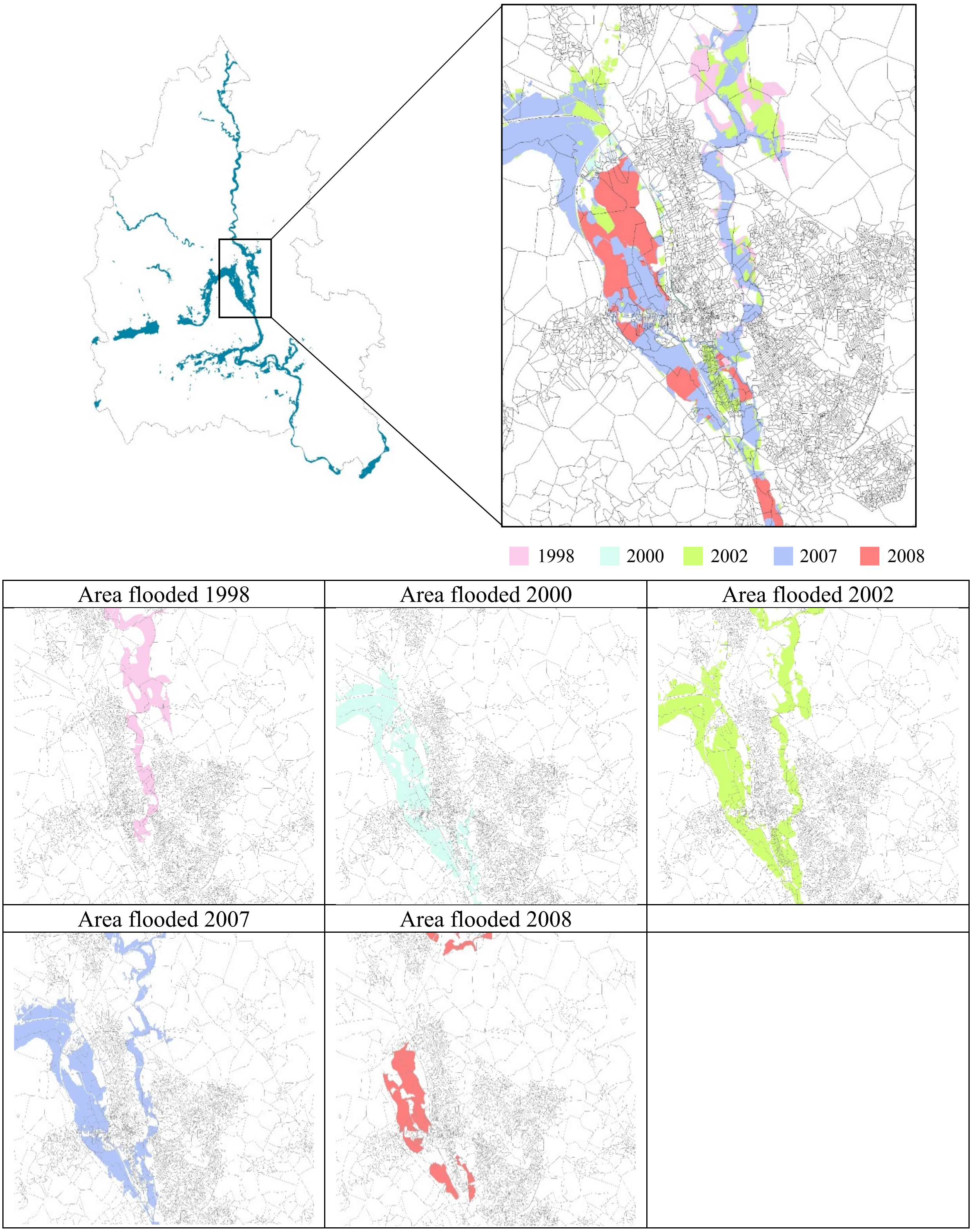
Appendix

Figure A1. Example: Area affected by inland flooding in Oxfordshire

A. Area flooded 1995-2014 **B. Area flooded by year 1998-2008**
(*6-digit postcode area*)



Source: Own elaboration based on data from the ROIFE dataset, UK Environment Agency.

Table A1. Results Heckman selection equations (Table 3)

Variables	(1) All estimates	(2) All estimates FP	(3) Inland	(4) Inland FP	(5) Coastal risk	(6) Coastal risk FP
new_dummy	-2.461***	-2.549***	-2.453***	-2.611***	-2.184***	-2.775***
	(0.0032)	(0.0078)	(0.0033)	(0.0086)	(0.0395)	(0.0216)
year	0.0235***	0.0246***	0.0212***	0.0238***	0.0740***	0.0593***
	(0.0001)	(0.0003)	(0.0001)	(0.0004)	(0.0010)	(0.0005)
sdetached	-0.0505***	0.0103***	-0.0499***	0.0050	-0.1120***	0.0141**
	(0.0012)	(0.0028)	(0.0012)	(0.0031)	(0.0087)	(0.0067)
terraced	0.1460***	0.1970***	0.1500***	0.2220***	0.1070***	0.1830***
	(0.0012)	(0.0030)	(0.0013)	(0.0033)	(0.0086)	(0.0063)
flat	0.2620***	0.3070***	0.2800***	0.4600***	0.2935***	0.3287***
	(0.0021)	(0.0057)	(0.0022)	(0.0064)	(0.0166)	(0.0142)
freehold	-0.0570***	-0.0447***	-0.0585***	-0.0394***	-0.0559***	-0.0614***
	(0.0016)	(0.0047)	(0.0017)	(0.0052)	(0.0124)	(0.0141)
q2	-0.0706***	-0.0675***	-0.0758***	-0.0764***	0.0503***	0.0679***
	(0.0012)	(0.0030)	(0.0012)	(0.0035)	(0.0033)	(0.0078)
q3	-0.2310***	-0.2120***	-0.2410***	-0.2390***	-0.1030***	-0.1030***
	(0.0013)	(0.0034)	(0.0014)	(0.0038)	(0.0084)	(0.0084)
q4	-0.3950***	-0.3760***	-0.4080***	-0.4150***	-0.5220***	-0.5220***
	(0.0016)	(0.0040)	(0.0017)	(0.0045)	(0.0092)	(0.0092)
rural	-0.0384***	-0.0897***	-0.0564***	-0.1570***	-0.0459***	-0.1157***
	(0.0011)	(0.0025)	(0.0011)	(0.0027)	(0.0071)	(0.0085)
100 year floodplain	0.0248***		0.2230***		0.4841***	
	(0.0011)		(0.0012)		(0.0930)	
after2002	0.3070***	0.2890***	0.3350***	0.3040***	0.3705***	0.3329***
	(0.0013)	(0.0032)	(0.0013)	(0.0037)	(0.0106)	(0.0227)
flooded postcode	-0.0078***	0.0141***	-0.0120***	-0.0382***	0.0549***	0.0549***
	(0.0027)	(0.0031)	(0.0029)	(0.0033)	(0.0111)	(0.0111)
Lambda	0.1219***	0.1502***	0.1114***	0.1544***	0.0570***	0.0866***
(Mills ratio)	(0.00057)	(0.0014)	(0.0008)	(0.0014)	(0.0092)	(0.0065)
Constant	-47.14***	-49.14***	-42.45***	-47.43***	-39.1***	-48.0***
	(0.246)	(0.621)	(0.252)	(0.701)	(0.452)	(0.830)
Observations	13,229,034	2,119,595	12,653,951	1,802,297	575,083	317,298
County FE	YES	YES	YES	YES	YES	YES

Notes: Robust standard errors in parentheses. *, ** and *** means rejection of the null hypothesis at the 10%, 5% and 1% significance level.

Appendix. Section A1

Robustness Tests

In this appendix we present the results of two additional robustness tests, once more estimated using Heckman sample-selection techniques. The first test consists of removing the outlier observations from the sample. We run this test to ensure that our results are not driven by a specific set of properties with extreme prices. More specifically, we exclude from our sample the 1 percent of properties with the highest and lowest prices. The results of this test appear in Table A2 along with the sample selection equations. The control and treatment groups through columns (1) to (6) are specified as in Table 3. There is no difference to report between our main results contained in Table 3 and the results of the robustness test in Table A2.

The second robustness test is a quasi-placebo test. The objective is to test for the possibility that the significant capitalisation of flood events that we observe in our results in Table 3 might be driven by different local characteristics not associated with the occurrence of a flood. In other words, we want to ensure that our identification strategy is really capturing the effect of flooding on property prices and not something else. Our quasi-placebo test consists in a 'false' experiment where the 'treatment' group is now formed by properties located in areas that were directly affected by flooding but involving repeat-sales occurring either both before or both after the flood. The econometric model for the quasi-placebo test appears in equation (A1) below.

$$\begin{aligned}\Delta ln(P_{its}) = {} & \alpha_1 \overline{Bracket}_{ikts} + \alpha_2\left(\overline{Bracket}_{ikts} \times house\_type_i\right) \\ & +\psi_1\left(\overline{Bracket}_{ikts} \times IND_i\right) + \psi_2\left(\overline{Bracket}_{ikts} \times IND_i \times recovery_i\right) \\ & +\psi_3\left(\overline{Bracket}_{ikts} \times IND_i \times house\_type_i\right) + \psi_4\left(\overline{Bracket}_{ikts} \times IND_i \times F\_type_i\right) \\ & +\psi_5\left(\overline{Bracket}_{ikts} \times IND_i \times F\_history_i\right) + \lambda_0 Year_{is} + \lambda_1 Year_{it} + \Delta\varepsilon_{ikts}\end{aligned} \quad \text{(A1)}$$

Equation (A1) is similar to the econometric specification in equation (14), but in this case $\overline{Bracket}_{ikts}$ is a dummy variable which takes the value unity if the two sales of the property, at time *t* and *s*, occur either both before or both after a flood event in county *k* where they are located. Hence the variable $\left(\overline{Bracket}_{ikts} \times IND_i\right)$ identifies our 'false' treatment group; it takes the value unity if the property is located in a postcode that was affected by flooding during the period of analysis, but for which the two sales are either both before or both after the event.

As in equation (14), the set of variables $house\_type_i$ in equation (A1) controls for different characteristics of the properties. However, it is important to note a slight change that we make to define the values for the variables controlling for differences in the type of flooding (F_type_i) and differences in flood history ($F\_history_i$). Although our 'false' treatment group of properties is located in areas that were affected by a flood, their repeat-sales do not *bracket* (occur before and after) the occurrence of the flood. Therefore the values for the set of variables F_type_i and $F\_history_i$ in our quasi-placebo regression correspond to the characteristics of the previous flood in the postcode where they are located. In practice, this restricts our sample of 'false' treated observations to properties with the two sales after the occurrence a flood during the period of analysis, or between floods for properties in locations that were flooded more than once. That is, our false treatment group in equation (A1) looks at the change in the price of properties with two sales during the recovery period after a flood.

The results of our quasi-placebo regression appear in Table A3 below starting with the sample selection equations. As with Table 3, the control group for the regressions in Table A3 changes across Columns (1) to (6). The first section in Table A3 (*Bracket sample*) includes the coefficients of the variables that control for difference in price trends across different types of properties. In general, all the variables included in the model to control for differences in price trends across different types of properties are highly significant. This is similar to what we observe in Table 3 and is itself unremarkable.

The second panel in Table A3 (*Bracket placebo flooded sample*) shows the main results of our quasi-placebo experiment. The variable $\bar{B}$*Inundated* shows the price growth rate differential for properties located in postcodes affected by flooding but for which the repeat-sales are both after a flood, or between floods for postcodes affected more than once, with respect to the price growth rate of the properties in the control group. The coefficient is highly significant across specifications and has a positive sign, opposite to the sign of the coefficient that we found in Table 3. This positive coefficient indicates that the prices of properties in areas affected by flooding, but for which repeat-sales do not bracket the occurrence of a flood, grew at a faster rate than the price of properties in each corresponding control group. This result is as expected and wholly consistent with the idea of post-flood price recovery for properties located in affected areas. The coefficient is moreover consistent across different types of flooding.

There are several other important points to note from the results of the quasi-placebo test in Table A3. For the case of inland flooding in Columns (3) and (4), the negative and significant coefficient on the variables $\bar{B}$*IND*sdetached* and $\bar{B}$*IND*terraced* suggest that the speed of recovery for semi-detached and terraced properties is slower than that of detached houses. For the case of coastal flooding (Columns (5) and (6)) there appears no significant difference across different types of properties. All the other variables associated with the characteristics of the properties or flood are insignificant.

Table A2. Repeat-sales model. Robustness test: Excluding extreme values

(Excludes top 1% and bottom 1% of observations)

	Variables	(1) All estimates	(2) All estimates FP	(3) Inland	(4) Inland FP	(5) Coastal risk	(6) Coastal risk FP
	Bracket Sample						
House_type	Bracket (B)	-0.0435***	-0.0444***	-0.0392***	-0.0464***	0.0190	0.0218**
		(0.0010)	(0.0028)	(0.0011)	(0.0032)	(0.0140)	(0.0104)
	B*sdetached	0.0224***	0.0201***	0.0233***	0.0214***	0.0174***	0.0066**
		(0.0005)	(0.0014)	(0.0007)	(0.0016)	(0.0013)	(0.0033)
	B*terraced	0.0475***	0.0455***	0.0474***	0.0471***	0.0273***	0.0262***
		(0.0006)	(0.0013)	(0.0006)	(0.0015)	(0.0014)	(0.0033)
	B*flat	0.0164***	0.0177***	0.0178***	0.0336***	-0.0264***	-0.0411***
		(0.0010)	(0.0029)	(0.0011)	(0.0032)	(0.0025)	(0.0072)
	B*free	0.0074***	0.0118***	0.0081***	0.0174***	0.0189***	0.0446***
		(0.0009)	(0.0025)	(0.0010)	(0.0028)	(0.0020)	(0.0062)
	B*rural	0.0017***	0.0063***	0.0005	0.0024*	0.0166***	0.0301***
		(0.0005)	(0.0012)	(0.0005)	(0.0014)	(0.0013)	(0.0034)
	B*q2	0.0041***	0.0101***	0.0057***	0.0117***	-0.0284***	-0.0252***
		(0.0005)	(0.0012)	(0.0005)	(0.0012)	(0.0029)	(0.0066)
	B*q3	-0.0373***	-0.0354***	-0.0377***	-0.0356***	-0.0768***	-0.0511***
		(0.0004)	(0.0012)	(0.0005)	(0.0011)	(0.0032)	(0.0074)
	B*q4	-0.0793***	-0.0829***	-0.0783***	-0.0838***	-0.1081***	-0.0929***
		(0.0005)	(0.0012)	(0.0005)	(0.0010)	(0.0043)	(0.0098)
	B*after2002	0.0045***	0.0036***	0.0036***	0.0008	-0.0190***	-0.0432***
		(0.0004)	(0.0011)	(0.0005)	(0.0012)	(0.0018)	(0.0055)
	Bracket-Flooded Sample						
	B*IND	-0.3713***	-0.3960***	-0.3322***	-0.3858***	-0.4940***	-0.5069***
	(Percentage Flooded)	(0.0346)	(0.0388)	(0.0376)	(0.0418)	(0.0935)	(0.0972)
Semi-parametric recovery	B*IND*+1 year	0.0542***	0.0414**	0.0490**	0.0447**	0.1267**	0.0946*
		(0.0187)	(0.0196)	(0.0207)	(0.0214)	(0.0624)	(0.0489)
	B*IND*+2 years	0.1279***	0.1414***	0.1203***	0.1295***	0.1507***	0.1951***
		(0.0196)	(0.0208)	(0.0216)	(0.0223)	(0.0535)	(0.0567)
	B*IND*+3 years	0.1702***	0.1703***	0.1498***	0.1462***	0.2116***	0.1944***
		(0.0222)	(0.0236)	(0.0243)	(0.0254)	(0.0585)	(0.0619)
	B*IND*+4 years	0.2585***	0.2465***	0.2545***	0.2523***	0.2685***	0.2409***
		(0.0240)	(0.0256)	(0.0262)	(0.0276)	(0.0616)	(0.0643)
	B*IND*+5 years	0.3163***	0.2937***	0.3113***	0.2838***	0.2934***	0.2998***
		(0.0271)	(0.0290)	(0.0299)	(0.0316)	(0.0685)	(0.0727)

	B*IND*+6-7 years	0.3499***	0.3422***	0.3425***	0.3329***	0.4081***	0.3860***
		(0.0233)	(0.0248)	(0.0257)	(0.0270)	(0.0576)	(0.0616)
	B*IND*+8-9 years	0.4058***	0.4008***	0.3587***	0.3554***	0.5555***	0.5372***
		(0.0697)	(0.0718)	(0.0870)	(0.0881)	(0.1209)	(0.1230)
	B*IND*+10-12 years	0.4031***	0.3638***	0.2508*	0.2350*	0.4674***	0.4629***
		(0.0903)	(0.0925)	(0.1410)	(0.1430)	(0.1260)	(0.1289)
	B*IND*+13-15 years	0.3692**	0.3677**	0.2634	0.2430	0.4960**	0.4931**
		(0.1650)	(0.1690)	(0.2820)	(0.2819)	(0.2090)	(0.2100)
House_type	B*IND*sdetached	0.0263	0.0501***	-0.0021	0.0189	0.0895*	0.1151**
		(0.0177)	(0.0187)	(0.0192)	(0.0198)	(0.0471)	(0.0490)
	B*IND*terraced	0.0282*	0.0652***	0.0023	0.0484***	0.1160**	0.1485***
		(0.0165)	(0.0174)	(0.0180)	(0.0188)	(0.0457)	(0.0470)
	B*IND*flat	0.1530***	0.1881***	0.1433***	0.1893***	0.2455***	0.2592***
		(0.0295)	(0.0336)	(0.0318)	(0.0359)	(0.0858)	(0.0887)
	B*IND*free	-0.0041	-0.0118	0.0323	0.0246	-0.0658	-0.0809
		(0.0257)	(0.0298)	(0.0277)	(0.0321)	(0.0730)	(0.0757)
	B*IND*rural	0.0276**	0.0115	0.0351**	0.0170	-0.0259	-0.0276
		(0.0130)	(0.0138)	(0.0144)	(0.0151)	(0.0321)	(0.0336)
	B*IND*q2	0.0983***	0.0929***	0.0713***	0.0659***	0.1568***	0.1440***
		(0.0168)	(0.0177)	(0.0188)	(0.0197)	(0.0379)	(0.0394)
	B*IND*q3	0.0845***	0.0860***	0.0602***	0.0581***	0.1709***	0.1642***
		(0.0166)	(0.0175)	(0.0184)	(0.0193)	(0.0450)	(0.0461)
	B*IND*q4	0.1452***	0.1599***	0.1101***	0.1178***	0.3836***	0.2844***
		(0.0179)	(0.0192)	(0.0196)	(0.0208)	(0.0543)	(0.0556)
	B*IND*after2002	0.0215	0.0306*	0.0127	0.0295	0.0490	0.0308
		(0.0157)	(0.0167)	(0.0178)	(0.0186)	(0.0381)	(0.0397)
F_type	B*IND*sea	-0.0536***	-0.0621***				
		(0.0174)	(0.0184)				
	B*IND*sewer	-0.1643**	-0.2262***	-0.1733**	-0.2260***		
		(0.0701)	(0.0867)	(0.0701)	(0.0854)		
	B*IND*defence	0.1079***	0.1092***	0.1271***	0.1151***	0.0509	0.0068
		(0.0227)	(0.0236)	(0.0353)	(0.0358)	(0.0351)	(0.0368)
F_history	B*IND*dur	-0.0004***	-0.0003***	-0.0005***	-0.0004***	0.0003	-0.0001
		(7.36E-05)	(7.37E-05)	(1.14E-05)	(9.05E-05)	(6.39E-04)	(6.43E-04)
	B*IND*2F	-0.0709***	-0.0777***	-0.0808***	-0.0903***	0.0146	0.0222
		(0.0165)	(0.0169)	(0.0180)	(0.0184)	(0.0443)	(0.0450)
	B*IND*3F+	-0.0683***	-0.0690***	-0.0638***	-0.0624***	-0.0624	-0.0466
		(0.0201)	(0.0209)	(0.0216)	(0.0221)	(0.0593)	(0.0599)
	Lyear (s)	-0.0031***	-0.0037***	-0.0045***	-0.0042***	-0.0038***	-0.0023***
		(7.21E-05)	(9.71E-05)	(8.93E-05)	(9.20E-05)	(2.81E-04)	(5.74E-04)
	Year (t)	0.0041***	0.0045***	0.0046***	0.0040***	0.0029***	0.0116***
		(7.31E-05)	(1.14E-04)	(3.02E-04)	(1.33E-04)	(2.10E-04)	(7.51E-04)
	Observations	12,964,453	2,077,203	12,400,872	1,766,251	563,581	310,952
	Treated Obs.	14,035	12,335	11,425	9,972	2,610	2,363
	County FE	YES	YES	YES	YES	YES	YES

Notes: Robust standard errors in parentheses. *, ** and *** means rejection of the null hypothesis at the 10%, 5% and 1% significance level.

[1] Omitted categories are dummy variables for detached property, urban location and properties with repeat-sales before change in the flood insurance regulation in 2002.

[2] The omitted categories are dummy variables for fluvial flooding and for those properties affected by flooding in locations without flood defences.

[3] The omitted category represents properties with repeat-sales before and after the first flood, during the period of analysis, in the postcode where they are located.

Table A2 (continued). Robustness test. Heckman selection equations

Variables	(1) All estimates	(2) All estimates FP	(3) Inland	(4) Inland FP	(5) Coastal risk	(6) Coastal risk FP
new_dummy	-2.4614***	-2.5712***	-2.4077***	-2.5490***	-2.2275***	-2.7153***
	(0.0116)	(0.0163)	(0.0051)	(0.0086)	(0.0422)	(0.0257)
year	0.0230***	0.0244***	0.0211***	0.0241***	0.0732***	0.0597***
	(0.0006)	(0.0006)	(0.0010)	(0.0011)	(0.0011)	(0.0010)
sdetached	-0.0504***	0.0109***	-0.0497***	0.0043	-0.1121***	0.0136**
	(0.0020)	(0.0032)	(0.0019)	(0.0036)	(0.0096)	(0.0071)
terraced	0.1481***	0.1965***	0.1533***	0.2234***	0.1122***	0.1877***
	(0.0017)	(0.0037)	(0.0014)	(0.0039)	(0.0092)	(0.0071)
flat	0.2620***	0.3034***	0.2775***	0.4602***	0.3022***	0.3200***
	(0.0025)	(0.0061)	(0.0031)	(0.0069)	(0.0166)	(0.0150)
freehold	-0.0566***	-0.0432***	-0.0586***	-0.0401***	-0.0554***	-0.0617***
	(0.0023)	(0.0051)	(0.0022)	(0.0056)	(0.0127)	(0.0148)
q2	-0.0707***	-0.0676***	-0.0755***	-0.0759***	0.0511***	0.0683***
	(0.0020)	(0.0035)	(0.0013)	(0.0045)	(0.0038)	(0.0085)
q3	-0.2253***	-0.2149***	-0.2403***	-0.2320***	-0.1023***	-0.0986***
	(0.0023)	(0.0041)	(0.0023)	(0.0048)	(0.0085)	(0.0089)
q4	-0.3914***	-0.3799***	-0.4085***	-0.4111***	-0.5187***	-0.5304***
	(0.0025)	(0.0042)	(0.0026)	(0.0046)	(0.0100)	(0.0094)
rural	-0.0260***	-0.0905***	-0.0533***	-0.1526***	-0.0459***	-0.1151***
	(0.0011)	(0.0028)	(0.0021)	(0.0030)	(0.0080)	(0.0088)
100 year floodplain	0.0225***		0.2211***		0.4841***	
	(0.0016)		(0.0019)		(0.0935)	
after2002	0.3111***	0.2830***	0.3380***	0.3111***	0.3765***	0.3339***
	(0.0017)	(0.0034)	(0.0017)	(0.0037)	(0.0109)	(0.0231)
flooded postcode	-0.0127***	0.0202***	-0.0112***	-0.0122***	0.0549***	0.0549***
	(0.0027)	(0.0029)	(0.0028)	(0.0031)	(0.0112)	(0.0112)
Lambda	0.1274***	0.1567***	0.1110***	0.1524***	0.0142***	0.1641***
(Mills ratio)	(0.0007)	(0.0016)	(0.0008)	(0.0015)	(0.0097)	(0.0091)
Constant	-47.070***	-49.566***	-42.910***	-47.540***	-38.980***	-47.778***
	(0.2957)	(0.6913)	(0.3031)	(0.7477)	(0.5006)	(0.8755)
Observations	12,964,453	2,077,203	12,400,872	1,766,251	563,581	310,952
County FE	YES	YES	YES	YES	YES	YES

Notes: Robust standard errors in parentheses. *, ** and *** means rejection of the null hypothesis at the 10%, 5% and 1% significance level.

Table A3. Repeat-sales model. Robustness test: Placebo regression

	Variables	(1) All estimates	(2) All estimates FP	(3) Inland	(4) Inland FP	(5) Coastal risk	(6) Coastal risk FP
	Bracket Sample						
House_type	Bracket (B)	-0.0433***	-0.0438***	-0.0393***	-0.0463***	0.0181	0.0215**
		(0.0010)	(0.0028)	(0.0011)	(0.0031)	(0.0140)	(0.0103)
	B*sdetached	0.0255***	0.0178***	0.0256***	0.0214***	0.0224***	0.0075***
		(0.0013)	(0.0016)	(0.0014)	(0.0021)	(0.0015)	(0.0025)
	B*terraced	0.0469***	0.0462***	0.0485***	0.0460***	0.0261***	0.0333***
		(0.0014)	(0.0019)	(0.0012)	(0.0019)	(0.0016)	(0.0033)
	B*flat	0.0228***	0.0143***	0.0118***	0.0328***	-0.0284***	-0.0436***
		(0.0012)	(0.0032)	(0.0019)	(0.0041)	(0.0031)	(0.0077)
	B*free	0.0077***	0.0086***	0.0085***	0.0177***	0.0255***	0.0473***
		(0.0018)	(0.0026)	(0.0010)	(0.0029)	(0.0021)	(0.0062)
	B*rural	-0.0038***	0.0064***	-0.0007	0.0035	0.0155***	0.0309***
		(0.0005)	(0.0012)	(0.0060)	(0.0026)	(0.0052)	(0.0054)
	B*q2	0.0032***	0.0068***	0.0048***	0.0102***	-0.0312***	-0.0262***
		(0.0008)	(0.0015)	(0.0007)	(0.0015)	(0.0037)	(0.0072)
	B*q3	-0.0369***	-0.0309***	-0.0389***	-0.0383***	-0.0783***	-0.0503***
		(0.0013)	(0.0018)	(0.0007)	(0.0012)	(0.0036)	(0.0076)
	B*q4	-0.0784***	-0.0800***	-0.0764***	-0.0860***	-0.1085***	-0.0929***
		(0.0012)	(0.0013)	(0.0010)	(0.0020)	(0.0046)	(0.0098)
	B*after2002	-0.0027***	-0.0036***	0.0067***	-0.0023*	-0.0190***	-0.0273***
		(0.0007)	(0.0011)	(0.0005)	(0.0012)	(0.0018)	(0.0055)
	Bracket-Flooded Sample						
	B*IND	0.0799***	0.0770***	0.0694***	0.0629***	0.0904***	0.1080***
	(Percentage Flooded)	(0.0205)	0.0197	(0.0171)	(0.0162)	(0.0233)	(0.0271)
Semi-parametric recovery	B*IND*+1 year	-0.0278***	-0.0239**	-0.0318**	-0.0471**	-0.0723**	-0.0919**
		(0.0103)	(0.0112)	(0.0157)	(0.0226)	(0.0354)	(0.0450)
	B*IND*+2 years	-0.0544**	-0.0736***	-0.0532***	-0.0642***	-0.0747	-0.0918*
		(0.0214)	(0.0276)	(0.0205)	(0.0234)	(0.0694)	(0.0520)
	B*IND*+3 years	-0.0416	-0.0446	-0.0633*	-0.0515	-0.0937	-0.1096
		(0.0293)	(0.0335)	(0.0359)	(0.0347)	(0.0636)	(0.0774)
	B*IND*+4 years	-0.0572	-0.0743	-0.0863	-0.0634	-0.0905	-0.1117
		(0.0478)	(0.0662)	(0.0737)	(0.0529)	(0.0794)	(0.0944)
	B*IND*+5 years	-0.0700	-0.0836	-0.0643	-0.0438	-0.1114	-0.1289
		(0.0581)	(0.0727)	(0.0536)	(0.0376)	(0.1068)	(0.1143)
	B*IND*+6-7 years	-0.0636	-0.0525	-0.0600	-0.0548	-0.0866	-0.1098
		(0.0489)	(0.0411)	(0.0475)	(0.0484)	(0.0765)	(0.0891)
	B*IND*+8-9 years	-0.0820	-0.0785	-0.0668	-0.0753	-0.1035	-0.1019
		(0.0934)	(0.0817)	(0.0649)	(0.0831)	(0.1051)	(0.1009)
	B*IND*+10-12 years	-0.0554	-0.0657	-0.0755	-0.0605	-0.1037	-0.0944
		(0.0530)	(0.0596)	(0.0679)	(0.0620)	(0.0960)	(0.0838)
	B*IND*+13-15 years	-0.0732	-0.0838	-0.0705	-0.0745	-0.0928	-0.1164
		(0.0957)	(0.0999)	(0.0739)	(0.0829)	(0.1129)	(0.1352)
House_type	B*IND*sdetached	-0.0291*	-0.0203***	-0.0207*	-0.0336**	-0.0149	-0.0274
		(0.0170)	(0.0075)	(0.0106)	(0.0162)	(0.0106)	(0.0173)
	B*IND*terraced	-0.0169	0.0045	-0.0454***	-0.0263*	0.0090	0.0167
		(0.0133)	(0.0030)	(0.0172)	(0.0137)	(0.0071)	(0.0118)

	B*IND*flat	0.0160	0.0147	0.0228	0.0268	0.0357	0.0366
		(0.0188)	(0.0189)	(0.0277)	(0.0305)	(0.0418)	(0.0392)
	B*IND*free	-0.0102	-0.0187	-0.0014	0.0134	-0.0166	-0.0144
		(0.0110)	(0.0208)	(0.0017)	(0.0160)	(0.0203)	(0.0187)
	B*IND*rural	0.0036	0.0036	0.0021	0.0124	-0.0193	-0.0264
		(0.0042)	(0.0046)	(0.0028)	(0.0151)	(0.0225)	(0.0319)
	B*IND*q2	-0.0132	-0.0110	-0.0280	-0.0101	-0.0159	0.0171
		(0.0101)	(0.0078)	(0.0196)	(0.0076)	(0.0110)	(0.0121)
	B*IND*q3	0.0102	0.0132	0.0216	0.0194	-0.0192	-0.0170
		(0.0125)	(0.0168)	(0.0238)	(0.0225)	(0.0217)	(0.0186)
	B*IND*q4	0.0034	0.0016	0.0133	0.0146	0.0144	0.0140
		(0.0036)	(0.0020)	(0.0151)	(0.0157)	(0.0177)	(0.0168)
	B*IND*after2002	0.0054	0.0005	0.0155	0.0036	0.0188	0.0176
		(0.0046)	(0.0004)	(0.0124)	(0.0032)	(0.0182)	(0.0159)
F_type	B*IND*sea	0.0169	0.0163				
		(0.0172)	(0.0136)				
	B*IND*sewer	-0.0181	-0.0157	0.0074	-0.0085		
		(0.0166)	(0.0135)	(0.0059)	(0.0149)		
	B*IND*defence	0.0179	0.0182	0.0203	0.0232	0.0350	0.0310
		(0.0124)	(0.0127)	(0.0157)	(0.0165)	(0.0322)	(0.0261)
F_history	B*IND*dur	7.47E-05	9.92E-05	1.96E-05	4.76E-05	1.43E-04	1.20E-04
		(1.03E-04)	(1.59E-04)	(2.46E-05)	(4.14E-05)	(1.59E-04)	(1.14E-04)
	B*IND*2F	0.0153	0.0136	0.0161	0.0113	0.0153	0.0115
		(0.0176)	(0.0143)	(0.0176)	(0.0120)	(0.0101)	(0.0076)
	B*IND*3F+	0.0083	0.0049	0.0123	0.0150	0.0117	0.0178
		(0.0102)	(0.0060)	(0.0161)	(0.0186)	(0.0080)	(0.0120)
	Lyear (s)	-0.0040***	-0.0044***	-0.0039***	-0.0042***	-0.0036***	-0.0029***
		(1.79E-04)	(2.86E-04)	(4.00E-04)	(4.71E-04)	(9.89E-04)	(5.09E-04)
	Year (t)	0.0040***	0.0045***	0.0039***	0.0043***	0.0035***	0.0025***
		(6.02E-05)	(6.26E-04)	(2.21E-04)	(5.07E-04)	(4.62E-04)	(8.29E-04)
	Observations	13,229,034	2,119,595	12,653,951	1,802,297	575,083	317,298
	Treated Obs.	66,602	58,077	61,112	52,677	5,490	5,400
	County FE	YES	YES	YES	YES	YES	YES

Notes: Robust standard errors in parentheses. ** and *** means rejection of the null hypothesis at the 5% and 1% significance level.

[1] Treatment group: properties in postcodes affected by flooding but with the two sales after the flood (recovery period).

[2] Omitted categories are dummy variables for detached property, urban location and properties with repeat-sales before change in the flood insurance regulation in 2002.

[3] The omitted categories are dummy variables for fluvial flooding and for those properties affected by flooding in locations without flood defences.

[4] The omitted category represents properties with repeat-sales before and after the first flood, during the period of analysis, in the postcode where they are located.

Table A3 (continued). Robustness test. Heckman selection equations

Variables	(1) All estimates	(2) All estimates FP	(3) Inland	(4) Inland FP	(5) Coastal risk	(6) Coastal risk FP
new_dummy	-2.461***	-2.549***	-2.453***	-2.611***	-2.184***	-2.775***
	(0.0032)	(0.0078)	(0.0033)	(0.0086)	(0.0395)	(0.0216)
year	0.0235***	0.0246***	0.0212***	0.0238***	0.0740***	0.0593***
	(0.0001)	(0.0003)	(0.0001)	(0.0004)	(0.0010)	(0.0005)
sdetached	-0.0505***	0.0103***	-0.0499***	0.0050	-0.1120***	0.0141**
	(0.0012)	(0.0028)	(0.0012)	(0.0031)	(0.0087)	(0.0067)
terraced	0.1460***	0.1970***	0.1500***	0.2220***	0.1070***	0.1830***
	(0.0012)	(0.0030)	(0.0013)	(0.0033)	(0.0086)	(0.0063)
flat	0.2620***	0.3070***	0.2800***	0.4600***	0.2935***	0.3287***
	(0.0021)	(0.0057)	(0.0022)	(0.0064)	(0.0166)	(0.0142)
freehold	-0.0570***	-0.0447***	-0.0585***	-0.0394***	-0.0559***	-0.0614***
	(0.0016)	(0.0047)	(0.0017)	(0.0052)	(0.0124)	(0.0141)
q2	-0.0706***	-0.0675***	-0.0758***	-0.0764***	0.0503***	0.0679***
	(0.0012)	(0.0030)	(0.0012)	(0.0035)	(0.0033)	(0.0078)
q3	-0.2310***	-0.2120***	-0.2410***	-0.2390***	-0.1030***	-0.1030***
	(0.0013)	(0.0034)	(0.0014)	(0.0038)	(0.0084)	(0.0084)
q4	-0.3950***	-0.3760***	-0.4080***	-0.4150***	-0.5220***	-0.5220***
	(0.0016)	(0.0040)	(0.0017)	(0.0045)	(0.0092)	(0.0092)
rural	-0.0384***	-0.0897***	-0.0564***	-0.1570***	-0.0459***	-0.1157***
	(0.0011)	(0.0025)	(0.0011)	(0.0027)	(0.0071)	(0.0085)
100 year floodplain	0.0248***		0.2230***		0.4841***	
	(0.0011)		(0.0012)		(0.0930)	
after2002	0.3070***	0.2890***	0.3350***	0.3040***	0.3705***	0.3329***
	(0.0013)	(0.0032)	(0.0013)	(0.0037)	(0.0106)	(0.0227)
flooded postcode	-0.0078***	0.0141***	-0.0120***	-0.0382***	0.0549***	0.0549***
	(0.0027)	(0.0031)	(0.0029)	(0.0033)	(0.0111)	(0.0111)
Lambda	0.1219***	0.1502***	0.1114***	0.1544***	0.0570***	0.0866***
(Mills ratio)	(0.00057)	(0.0014)	(0.0008)	(0.0014)	(0.0092)	(0.0065)
Constant	-47.14***	-49.14***	-42.45***	-47.43***	-39.1***	-48.00***
	(0.246)	(0.621)	(0.252)	(0.701)	(0.452)	(0.830)
Observations	13,229,034	2,119,595	12,653,951	1,802,297	575,083	317,298
County FE	YES	YES	YES	YES	YES	YES

Notes: Robust standard errors in parentheses. *, ** and *** means rejection of the null hypothesis at the 10%, 5% and 1% significance level.