Information Matters: Evidence from flood risk in the Irish housing market

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Abstract: In this paper, we test the effect of new information about flood risk on housing prices in Ireland. Our core finding is that information matters. Sales prices responded dramatically to the release of flood risk maps in 2011, with the emergence of a 3.1% price discount for dwellings at risk of flooding. This flood discount is not observed prior to the release of the new risk information, for dwellings defended by flood relief schemes, or for rental dwellings. We also document public attitudes to flood risk through survey findings that suggest a continuing information deficit in relation to flood risk.

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1. Introduction

Flood risk is the most pervasive and costly natural hazard, with an estimated one billion people in 155 countries exposed worldwide (JRC, 2017). With the prospect of rising sea levels and more intense rainfall events due to climate change, flood risk is expected to increase in many locations over coming decades. Projections of the future costs of flooding depend not only on the risk of flood events but also on societies' exposure to those events. Changing exposure to flood risk alone is projected to result in a near ten-fold increase in the global costs of flooding between 2005 and 2050, from US$6 billion per year to US$52 billion, while adding in the increased risk due to climate change could see those costs rise to as much as US$1 trillion per year, in the absence of further measures to manage flood risk (Hallegatte et al., 2013). This underlines the importance of the extent to which flood risk is taken into account in private decisions, especially where the costs are borne, at least in part, by taxpayers in the form of various subsidies to flood risk such as subsidised insurance, flood relief schemes and disaster assistance.

Due to the immobile nature of real estate and its prevalence in the typical household's balance sheet, the housing market represents a unique and important window into how private actions reflect flood risk. Theory would suggest a price discount for dwellings at risk of flooding, given the associated costs. The standard methodology in this literature builds on Rosen's (1974) theoretical framework of hedonic prices. However, individual households may lack good information on flood risk, and there is also the issue of moral hazard. In their Nobel Prize-winning contribution, Kydland & Prescott (1978) highlighted the problem of over-exposure to flood risk, in settings where taxpayers bear some of the costs of flooding. Husby et al (2014) show that flood defences built after major flooding in the Netherlands in 1953 had a positive effect on long-run population growth in protected areas. In short, where market signals are weak, there may be a tendency towards over-exposure to flood risk.

These issues have meant that the true welfare costs of flooding are not always reflected in private individuals' willingness to pay to avoid flood risk. There are also numerous empirical challenges to estimating flood discounts, for example there may be highly correlated positive amenities, such as sea-views or access to the coast or river walks, which make it challenging to convincingly identify the value of households' willingness to pay to avoid flood risk. A recent review of the literature on flood risk and housing prices finds widely varying results, with estimates of the price effect ranging from -75% to +61% (Beltran et al. 2018a). While a meta-analysis in the same study suggests a much tighter range of -7% to +1%, the review also highlights the limitations of the existing literature.

In general, the existing literature estimating the effect of flood risk on housing prices, hereafter the 'flood discount', can be divided into two broad strands. The first strand estimates flood discounts by comparing the value of dwellings within hazard risk zones to those elsewhere, controlling for a range of dwelling attributes (e.g. MacDonald et al., 1990 and Bin et al., 2008a,b). However, interpreting the results of such studies as causal depends on the strong assumption that hazard risk is exogenous, conditional on other observable determinants of housing prices. The second strand of the literature tests the effects of specific flood events on housing prices. A common finding in these studies is that there are significant discounts after flood events, which fade over time; see, for example, Bin & Polasky (2004), Bin & Landry (2013), Atreya et al. (2013) and Beltran et al. (2019). A similar finding in Gallagher (2014) shows a spike in demand for flood insurance following flood events, at county level in the US, an effect that declines with time since the flood. Identification in these studies relies on the timing of events, which is more plausibly exogenous. Nonetheless, as noted by Bosker et al. (2018), this strand of the literature identifies changes in households' risk perceptions following a recent flood event, rather than directly identifying their level of risk perceptions.

In this paper, we examine the relationship between flood risk and both sale and rental prices for housing in Ireland. Our empirical approach combines elements from the two strands of literature noted above. We exploit spatially and temporally precise official data for Ireland, on flood risk, historical flood events and flood defences, to identify the level of flood discounts – i.e. households' willingness to pay to avoid flood risk – as well as *changes* in flood discounts in response to the publication of flood risk information, flood events and flood mitigation measures.

Specifically, we test the effect on housing prices of the release of highly detailed scientific assessments of flood risk in the form of new risk maps. This information has been made widely and easily available online and our findings indicate that it has led to the emergence, for the first time, of an observable price signal on flood risk in the Irish housing market. In our preferred specification, the estimated flood discount is 3.1%. A simple illustrative exercise shows that our estimate of the flood discount corresponds closely to the appropriate flood discount based on expected damages, for reasonable parameter values, albeit the estimated market discount is slightly lower.[1]

We also report on a survey of public attitudes to flood risk, which finds that the general public in Ireland is concerned about flooding, that those concerns have increased for many over the last 10 years, and that a large majority of people expect the problem to get worse in the coming decades. Recent flooding in Ireland has been costly, with roughly €1bn, or close to €800 per household, in insured losses over the period 2000-2014. Moreover, the Irish government has committed to spending large sums on flood relief schemes: the 68 schemes in our analysis cost €226.6 million in

[1] A recent British government report on flooding during the winter of 2015/16 found the average claim per residential property flooded was GBP50,000 (report available at https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/672087/Estimating_the_economic_costs_of_the_winter_floods_2015_to_2016.pdf , last accessed July 2020). Taking average damages per flood of €60,000 for an individual dwelling, a 3% discount rate, and a 30-year time horizon, the capitalized value of flood risk with a 1% probability of occurrence per year is €12,360 in present value terms, equivalent to a flood discount of 4.1% for a dwelling valued at €300,000.

total, with an additional €1 billion of planned public expenditure, or roughly 0.5% of national income, on flood relief schemes over the next 10 years (OPW, 2018).[2]

In spite of these costs and the apparent concerns about flood risk, our survey results also reveal a continuing information deficit in relation to flood risk. A quarter of those surveyed said they didn't know if flood risk was relevant for the areas in which they were looking. Of those who said they thought it was relevant, more than a third said they weren't aware of the risk in the specific areas in which they were looking to buy or rent. This finding indicates that the availability of scientifically assessed information on flood risk, while creating an important price signal, on its own may not be sufficient to ensure a well-informed public (see also McDermott and Surminski, 2018).

Our survey also asked about the appropriate price discount for dwellings at risk of flooding. The results indicate a stated preference flood discount that is an order of magnitude larger than revealed preferences, at around 31% compared to 3.1% in our hedonic price models. The larger stated preference discount might partly reflect the nature of the methodology, for example in relation to salience of flood risk. But it could also be that the full welfare costs of flooding are still not reflected in Irish housing prices. In particular, there is suggestive evidence in our data that

[2] The stated intention is that these schemes will provide protection to 80% of the 34,500 dwellings in Ireland assessed as having a 1% chance of experiencing a significant flood event in any year. In scaling by national income, the measured used in Ireland is modified Gross National Income (GNI*), which was valued at €197.5 billion in 2018, according to data from the Central Statistics Office (CSO), available here https://www.cso.ie/en/releasesandpublications/ep/p-nie/nie2018/ (last accessed in May 2020).

perceptions of the probability of flooding are much higher than the scientifically assessed risk presented in official flood risk maps, particularly for relatively low risk areas.[3] Indeed, the larger stated preference flood discount corresponds closely to the value that emerges from an expected damages calculation, if survey respondents are implicitly applying the highest risk category (a 10% probability of flooding per year) to dwellings at risk of flooding, regardless of the information about risk provided in the question. This interpretation is supported by the similarity of the average discount across respondents who were asked about dwellings with a 10%, 1% or 0.1% probability of flooding per year, and by the stated expectation of a large majority of respondents that flood risk will get worse in the coming decades.

Our flooding data include official nationwide maps of scientifically assessed coastal and fluvial flood risk, released in the middle of our study period, an official dataset of 2,031 historical flood events, and information on the spatial extent of 68 public flood defence schemes implemented during our period. By exploiting the timing and spatial extent of these different 'treatments' relating to flooding – events, assessed risk and flood defences – our set-up is similar to difference-in-differences, as we compare, for example, dwellings at risk to otherwise similar dwellings not at risk,

[3] For example, we observe a relatively large flood discount of 1.1% for dwellings located inside low risk flood zones – i.e. those with a 0.1% probability of flooding per year – and also for dwellings located outside of, but within 100m of, these low risk zones, where the assessed risk must be less than 0.1% per year. The magnitude of the estimated discount in these locations implies very large damages per flood, if we take the low probability of flooding literally. A more plausible interpretation of this finding might be that the market is overestimating the probability of flooding, for these relatively low risk locations.

before and after the release of information on risk. Our housing data come from three extremely rich datasets, comprising a total of over one million observations of sales and rental listings from the real estate website daft.ie, with national coverage over the period 2006-2018, supplemented by a bespoke dataset of nearly 46,000 sales transactions in Dublin over the period 2010-2018.

We have three principal findings from the hedonics. Our headline finding, as already noted, is that exposure to flood risk brings a substantial discount – by an average of 3.1% in our preferred specification. This discount emerges only after the release of information on flood risk, providing reassurance that we are identifying the effects of exposure to flood risk, and not the effects of unobservable correlated factors. This result also provides our second major finding – that information matters. Third, we find no equivalent flood discount on rental prices, suggesting that flood risk is somehow less relevant or less salient in rental markets. This is also reflected in the findings from our survey. Respondents who were looking to rent a home were about half as likely to rate avoiding flood risk as very important in deciding where to live, compared with those looking to buy, and renters were about five times more likely than buyers to rate avoiding flood risk as not at all important in their decision.

There are three additional findings, in relation to flood defences, market memory of flood events, and the distribution of the flood discount. First, flood defences work: the discount for flood risk disappears after the construction of defences. In fact, we document a short-lived premium for dwellings defended by new flood relief schemes in the period immediately after their installation. Secondly, the market's memory of flood events is short: on average, we observe a 4.3% price discount for being within 100 metres of a flood event but also that this largely disappears after two years. And thirdly, flood risk is borne unequally: dwellings in the lowest two quintiles of value suffer a 6-7% discount, compared to no statistically significant discount across most of the upper half of the value distribution.

A causal interpretation of our results relies on our various treatments, such as being in a flood risk zone or the timing of new information on flood risk, being uncorrelated with other factors not included in our analysis that may affect housing prices and rents. Identification rests ultimately jointly on the timing and spatial extent of three flood-related phenomena – flood events, defences, and information release. At a basic level, we are able to estimate flood discounts while simultaneously controlling for historical flood events and the (time-varying) installation of flood defences. The richness and spatial precision of our data further allows us to show robustness to the inclusion of very localised spatial fixed effects and clustering within spatial units to account for unobserved spatial heterogeneity, as well as trends in housing prices specific to the local market. It also allows us to include a large suite of additional control variables in our analysis, including potentially important factors plausibly correlated with flood risk, such as a continuous measure of sea views. Collectively, these controls should maximise the comparability of treated and untreated groups.

Our results build on a number of recent contributions to the literature. The most closely related research to this paper is Gharbia et al (2019), who compare directly the effects of assessed risk and a large flood event for the case of Dublin, Ireland, after severe flooding in 2011. They find evidence that flood events had a bigger impact on housing prices than assessed flood risk. This reinforces the idea that actors in housing markets are not always well informed about flood risk. Similarly, Gibson et al. (2018) and Timar et al. (2018) find that flood risk perceptions update following flood events, suggesting incomplete information on existing flood risk. Ortega and Taspinar (2018) show a large discount on dwellings damaged by Hurricane Sandy that declines over time, but also evidence of updating of risk perceptions, with a growing discount for dwellings located in the flood zone that were not damaged.

Two recent studies have assessed the flood discount using national datasets, for the Netherlands (Bosker et al. 2018) and the U.S. (Hino and Burke 2020). Bosker et al. (2018) use a border discontinuity design to identify the effect of flood risk on housing values in the Netherlands, where flood risk and defences are both prominent. They find that housing prices are on average 1% lower in places at risk of flooding but with flood protections in place, suggesting that perceived flood risk is higher than official protection levels. Hino and Burke (2020) use a panel set-up, exploiting the updating of flood risk maps in the U.S., to identify the flood discount. Their findings suggest that housing markets in the U.S. do not fully price flood risk in the aggregate. Our results are complementary to these recent contributions, given that we estimate the flood discount for undefended properties (as well as the effect of installing new defences). We also study market responses to information updating, and present evidence suggesting that markets continue to under-price flood risk, even following the release and widespread availability of highly detailed scientific risk assessment.

Our principal contribution to the literature is to estimate the effect on the flood discount of new information about risk. Whereas most of the existing literature focuses on updating of risk perceptions following flood events, our analysis differs in that we assess the effects of the release of new information, in the form of detailed scientific assessment of flood risk, while simultaneously controlling for historic flood events, and flood defences. Indeed, ours is also the first paper that we know of to examine housing prices before and after each of three relevant dimensions of flood risk: flood events, scientifically-assessed flood risk, and the construction of flood defences. We also exploit timing (of new flood risk information in particular) to obtain clean identification of the willingness to pay to avoid flood risk in the Irish housing market. Other contributions include a direct comparison of both stated and revealed preferences of the flood discount and of sale and rental price effects on a like-for-like basis. We also show that, on a like-for-like basis, list prices can act as a good proxy for transaction prices, where those are unavailable, which is often the case in lower-income countries. Lastly, we document the effects on estimated flood discounts of important choices in empirical specifications, including the appropriate choice of spatial fixed effect, and the inclusion of specific controls, in particular blue space amenities.

Our findings have rich implications for policymakers, including relating to flood risk management, insurance and flood defences, as well as for projections of future flood losses. Our results present compelling evidence on the effectiveness of public investments in flood mitigation – both in terms of information provision and flood defences. But these two types of investments might be expected to have very different effects on future costs of flooding. Better information results in more awareness and a clear price signal, which should translate into less exposure to flooding in future, albeit our survey findings suggest there is still work to be done to translate scientific assessment of risk into public awareness. Moreover, the provision (and dissemination) of risk information is important to protect the integrity of public investments in flood relief schemes (to create a price signal on risk and protect taxpayers from escalating future costs). In contrast, flood defences – and the expectation of future investments in defences – might encourage development of flood-prone areas, with important implications for the future costs of flooding in a world with increasing flood risk.

The rest of the paper is structured as follows. The next section describes the data used in our analysis, in particular the data relating to flood risk, flood defences and flood events. Section 3 outlines our empirical framework and our rationale for interpreting the analysis as causal, while the results of our empirical analysis are presented in Section 4. In Section 5 we briefly discuss some of the main findings from our survey of public attitudes towards flood risk in Ireland, before the final section concludes.

2. Data

2.1 Flood data

The principal source of information related to flooding in Ireland is the Office of Public Works (OPW), the principal agency with responsibility for flood risk management in Ireland. The OPW provided us with data on past flood events, on scientifically assessed risk, and on flood defences, as detailed below.

Flood risk

In the early 2010s, the Irish government began publishing new flood risk maps, to comply with EU Directive 2007/60/EC, which requires all member states to assess and manage flood risk. Preliminary Flood Risk Assessment (PFRA) maps were published in 2011 and made widely available by early 2012 with the launch of myplan.ie, a central repository for spatial information related to planning. While the most detailed map resolutions were not provided online at this point, individual dwellings could still be identified as being within the risk zones (see PFRA map example in Appendix A, Figure A.3), thus representing an information shock in terms of newly available information on officially assessed flood risk for the entire country. Previous to the release of the PFRA maps in 2011, there were no detailed maps available on flood risk in Ireland.[4] This preliminary mapping exercise was used to identify Areas of Further Assessment (AFAs). The 300 AFAs identified became the focus of more detailed engineering analysis, risk assessment and extensive public consultation (see Figure A.1 in Appendix A,).[5] According to the OPW, approximately 80% of the dwellings at risk of flooding in Ireland are within an AFA. The geographic distribution of flood risk is illustrated in Figure A.6 in Appendix A.

The flood risk maps that we use in our analysis come in the form of high resolution flood polygons depicting both fluvial and coastal flood risk zones at three levels of risk probability. For fluvial flood risk, these levels are 0.1% (1-in-1000 year flood), 1% (1-in-100 year flood), and 10% (1-in-10 year flood); for coastal flood risk, the low and high risk categories are the same, but the middle category is 0.5% (1-in-200 years). To identify the effect of being within a flood risk area, we define a categorical variable based on a dwelling's location with respect to the officially assessed flood risk zones, as follows: a base (excluded) category greater than 500m from any flood risk zone; categories for intervals of 500-200m, 200-100m, and 100-0m from any flood risk zone; within the low-risk zones but not medium/high risk; and lastly, one combining

[4] Previously, official Ordnance Survey of Ireland (OSi) maps had areas denoted as "flood plain" but the resolution was coarse and these were neither comprehensive nor probabilistic assessments of flood risk.

[5] There are, thus, two maps of flood risk for Ireland: one based on the PFRA and the other based on the AFAs. The latter is the most detailed and up-to-date assessment of flood risk available in Ireland and is used as our principal measure of flood risk. As a robustness check, we also replicate our main results using the PFRA risk maps, which cover the entire country without restriction by area.

medium and high risk zones.[6] We describe this latter category as 'flood risk' in headline results. We also distinguish between dwellings at risk of flooding but protected by flood defences, and dwellings at risk of flooding and not protected by flood defences. The distinct categories of risk in our data allows us to estimate the effects of exposure to risk of different severity, as well as proximity to those risks.

Flood defences

The OPW also provided us with polygon data related to 68 existing flood defence schemes completed between 1996 and 2017. Attributes include the date of completion, spatial extent of protection, whether the defence was permanent or demountable, and the cost of each scheme. The categorical variable capturing flood risk, described above, was interacted with flood defences to enable an empirical examination of the flood discount before and after the construction of a flood defence and to ensure that our estimate of the flood discount is based on dwellings at risk of flooding and not protected by flood defences at the time of their listing or sale. In addition to a control group (dwellings more than 500m away from any flood risk), this gives ten categories of treatment by flood risk and defences. Descriptive statistics for these categories are in Table 1, for sale listings, sale transactions and rental listings datasets, described further in Section 2.2.

[6] Inequalities are strict for the lower bounds, both in this instance and in other cases (such as time since last flood event). The combination of medium and high risk categories is due to the small number of observations in the high-risk (10%) category.

[Table 1 here]

Flood events

Our data on flood events are drawn from an extensive archive of historical flooding in Ireland, compiled by the OPW.[7] Information in the archive is drawn from various sources, such as reports by local authorities, engineers' reports, newspaper articles, and photos. This archive is the most comprehensive and complete collection of data on past flood events available in Ireland, with new information verified and checked for duplication before addition to the archive. We extract location and timing information from this archive. The vast majority of reported flood events include point location and peak flood time, while flood polygons (showing areas inundated) are available for a relatively small number of events. The dated flood points were defined based on a named location in the report related to the particular flood, while polygon flood event data were compiled using aerial photography. The dataset contains a total of 1,947 dated flood points and 84 dated flood polygons dating from 1763 to 2016.[8]

Given that most of the flood events data are in point format, we construct indicators for dwellings affected by each event based on the distance of the dwelling from the

[7] These data were provided to us directly by the OPW, in the form of dated flood points and polygons (as described further here in the text), and are based on the archive of past flood events, which is publicly available at www.floodmaps.ie (last accessed May 2020).

[8] Roughly 90% of these events occurred since 1980. There is also an extensive collection of recurring flood points in the data. These were dropped from the analysis, as they are highly correlated with assessed flood risk. In versions of the analysis where we included these recurrent flood points as separate controls, not reported here, our estimates of the flood discount were essentially unchanged.

event, as well as the timing of the event. We construct two distance categories: dwellings within 100m of a flood event (or within a flood event polygon), and dwellings between 100m and 250m from a flood event. Only the most recent flood event, relative to the date of sale or listing, in the 100 (or 250) meter radius was used. The time since the most recent flood within a 100 (or 250) meter radius of a dwelling was modelled as a categorical variable of which there were four categories: >30 years since a flood, 10-30 years, 2-10 years, and <2 years, with a base of no flood event recorded. With a reference category of no recorded flood event within 250m of a dwelling, this gives 10 measures of treatment by flood event, details in Appendix A, Table A.1.

2.2 Dwelling & Location data

Our housing data come from three rich datasets. Firstly, we use a national dataset of listings from the real estate website daft.ie, the leading real estate website in Ireland. The daft.ie listings dataset is long, covering the period from early 2006, at the height of a real estate boom, through to the end of 2018, and broad, covering the national market in its entirety. It is also deep, with an estimated coverage of over 90% of all listings in the Irish market, and rich, in terms of the information available for each listing. This includes dwelling attributes such as type and number of bedrooms and bathrooms, and an estimate of its location based on the dwelling's address. The full daft.ie archive includes over 800,000 residential sale listings between 2006Q1 and

2018Q4. Excluding dwellings that are either outliers or errors in size and price and restricting to those mapped to the exact building (rather than street or area) reduces the available dataset to 426,035.[9] Focusing on dwellings within the AFAs described in Section 2.1 gives a final listings sample of 284,963, of which 190,785 are listed in 2011 or later, the focus of some specifications in Section 4.

In addition to detailed systematic information on dwelling attributes such as size and type, a large number of other attributes were also available from the text of the ad; more details are provided in Appendix A, Table A.3. A limitation of the listings dataset is, by its nature, that it does not contain the ultimate transaction price.[10] To complement our listings dataset, we use a supplementary dataset of housing transactions taking place in Dublin (the largest city in Ireland). This dataset is smaller, with some 40,000 observations, and covers a shorter time period (2010-2018), but also has some notable advantages, aside from the inclusion of transaction prices, which we fully exploit in our analysis. Full details of this dataset and how it was constructed are included in the Data Appendix A.

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[9] The raw sales listings dataset has 814,635 observations. Restricting the dataset to building level accuracy only results in a sample of 514,726. Removing price outliers <€30,000 and >€2million and also removing observations outside of the range of 1-5 bedrooms and 1-7 bathrooms reduces the sample to 426,035. The geographic coverage of these data are illustrated in Figure A.5 in Appendix A.

[10] The use of listed prices is well established in the literature. In Ireland, listed prices are based on estate agent assessment, rather than an owner's valuation; estate agents have local market knowledge, including the price of dwellings recently transacted in the area. Research exploring the relationship between list and transaction prices in Ireland during this period finds a very strong correlation between the two, once hedonic methods are used, both over time and across space (Lyons 2018).

The third source of housing data is based on listed rental prices. This dataset is similar to the sale listings dataset, in that it is sourced from daft.ie, with nationwide coverage from 2006-2018, and with similar dwelling attributes included. Rental price is aggregated up to an annual level allowing for weekly and monthly rent collection periods to be synchronised. There are 514,000 observations (within AFA, 2006-2018) in the rental listings dataset.

The listings datasets have at least four substantial features of value, compared to the transactions dataset. Firstly, they offer like-for-like data across both sale and rental segments, something unique in the flood discount literature. Secondly, the long time-span allows the estimation of flood risk discounts before and after the release of new information on flood risk. Thirdly, they cover all markets across the country, rather than just the largest urban market. Lastly, the larger size of the two datasets, relative to transactions, allows for greater within-unit variation. In addition to the greater accuracy of the prices measured, the transactions dataset offers greater precision of location as well as some additional important control variables (as detailed in the Data Appendix A).

Dwelling-level location information in each dataset is used in the calculation of not only distance to relevant measures of flood risk, as described above, but also a variety of other location-specific amenities. These include nearest city centre, transport facilities, schools, and natural amenities; a full list is given in Appendix 2. Nonetheless, despite these inclusions, there are always likely to be some spatial processes or location attributes that remain unobserved in the data.[11] For this reason, spatial fixed effects (SFEs) are included, to capture the impact on housing prices of factors that are not included in a given specification, including location-specific and population-specific attributes. Four options are considered: local markets, 'micro-markets', Electoral Divisions, and Small Areas. Full details of these different spatial partitions of the sample are included in the Data Appendix A. Table 2 outlines the number of spatial units in the samples and the mean and median number of observations per unit.

[Table 2 here]

3. Empirical Framework

3.1 Baseline specification

The standard methodology in this literature builds on Rosen's (1974) theoretical framework of hedonic prices (see also the recent review of best practice in using hedonic property value models in Bishop et al. 2019). Conceptually, the value of a dwelling takes the following form:

$$\mathrm{Price} = \mathrm{f}(\mathrm{S}, \mathrm{L}, \mathrm{F}) + \varepsilon, (1)$$

[11] Omitted variable bias is a pervasive issue in hedonic models of housing prices and there are many unobservable spatial processes that can influence the price function of housing. Von Graevenitz and Panduro (2015) provide a useful discussion of alternative approaches used to minimise the influence on identification. We detail our strategies for dealing with this important identification challenge in Section 3 below.

where the logged sale/rental price of the dwelling is a function of its structural characteristics (S; such as number of bedrooms, bathrooms, or the presence of a garden), its location and environmental characteristics (L; including the spatial unit fixed effect, proximity to CBD, to the coast and to green spaces, access to transport networks, and socio-economic factors), and flood-related variables (F; flood risk, past flood events, flood defences). The error term, ε, reflects the gap between the predicted value and the actual value. The dwelling price is thus a function of all of the attributes relating to the dwelling and the resulting coefficients are the implicit marginal prices of the attributes.

More specifically, this analysis uses ordinary least squares and a semi-log or log-log specification (depending on the variable), as is typical in this type of study. Allowing for the long duration of the sample, and the focus on flooding, the baseline specification is, therefore, as follows:

$$\log(\mathrm{price}_i) = \beta_0 + X'_{1i}\beta_1 + X'_{2i}\beta_2 + X'_{3i}\beta_3 + X'_{4i}\beta_4 + X'_{5i}\beta_5 + \varepsilon_i \quad (2)$$

Where: price_i refers to the transacted or listed sale/rental price (depending on the sample); X'_{1i} to a vector of dwelling-specific attributes; X'_{2i} to the time period (quarterly fixed effects); X'_{3i} to spatial fixed effects; X'_{4i} to a vector of location-specific amenities and controls; and X'_{5i} represents our regressors of interest, a vector of variables capturing flood-related effects. The vectors of dwelling- and location-specific controls, and spatial fixed effects, are as discussed in Sections 2.2 and 2.3, with the exact set of dwelling attributes varying across the three datasets.

3.2 The identification challenge

The key identification challenge for estimating the value of flood risk, or willingness to pay to avoid flood risk in a hedonic housing price regression framework, is the possibility that proximity to a given (dis)amenity may be correlated with other relevant dwelling attributes or with other spatial processes related to the location of the dwelling that affect its market value. The richness of our data and some unique features allow us to exploit spatial precision and timing to identify the causal effect of flood risk on housing prices. Our set-up is similar to difference-in-differences, as we compare, for example, dwellings at risk to otherwise similar dwellings not at risk, before and after the release of information on risk.

One basic concern for a hedonic model of flood risk and housing prices relates to controlling for the attributes of the dwellings themselves. If dwellings "exposed" to flood risk are somehow different from those not exposed, then the *ceteris paribus* condition in the regressions does not hold; we could be comparing flood-exposed 'apples' with non-exposed 'oranges'. We exploit the richness of information in our datasets on dwelling attributes, to minimise the concern that omitted variables related to the dwelling itself may be driving results. For example, the two listings datasets include 30 variables based on the text of the ad, including indicators for wide range of dwelling attributes, such as "jacuzzi" and "garage". The transactions dataset includes attributes from the dwelling's official energy efficiency assessment. In addition, the large size of the dataset enables us to restrict the sample by dwelling type, to focus on dwellings that are more likely to be homogenous on unobservables.

Nonetheless, there remains the concern that factors other than the individual dwelling's attributes that affect its value could still be correlated with flood risk – in particular spatial processes, related for example to other amenities and neighbourhood characteristics. As a first step in addressing these concerns, in all our specifications we control for a range of location-specific attributes, including distance to nearest city centre, transport facilities, schools, and natural amenities (see full list in Appendix 2). We also include Census-based measures of neighbourhood quality, in particular educational attainment and unemployment rates at the SA level.[12]

However, without further strategies, identification would depend on the strong assumption that flood risk is exogenous, conditional on the included observable housing price determinants (dwelling-level attributes and location-specific amenities). Omitted variable bias is a pervasive issue in hedonic models of housing prices, and there are many unobservable spatial processes that can influence the price function of housing (see Von Graevenitz and Panduro, 2015, for a discussion of alternative approaches used to address this problem). To capture unobservable

[12] Such controls could be considered as "bad controls" (Angrist and Pitschke 2008). In Section 4.4, we show how inclusion of these controls affects our main results. Excluding these neighbourhood quality controls leads to a *larger* estimated flood discount, which suggests that flood risk is correlated with lower neighbourhood quality in our data. We also present results using SA fixed effects, such that these neighbourhood attributes get absorbed by the spatial fixed effect.

spatial processes, we include highly localised spatial fixed effects in all our main specifications, and test the sensitivity of the findings on our main variables of interest to controlling for different levels of spatial fixed effects (see Von Graevenitz and Panduro, 2015; Bosker et al. 2018).[13]

The unique nature of our datasets allows us to exploit timing for cleaner identification. In particular, the timing of the release of new information on flood risk, which occurred during the middle of the listings datasets, allows us to estimate the before-and-after effect of flood risk on housing prices. The contrasting findings we report below for the effect of flood risk on sale prices before and after the release of the information provides reassurance that we are estimating the causal effect of flood risk on housing prices (conditional on the availability of quality information on flood risk), and not some other unrelated spatial process that happens to be spatially correlated with flood risk.

Our identifying assumption is therefore that flood risk is exogenous to housing prices, conditional on the timing of the release of new information on flood risk. The concern might remain, though, that there are confounding factors that could be both spatially correlated with flood risk and temporally correlated with the release of the

[13] Von Graevenitz and Panduro (2015) argue that the use of spatial (parametric) econometric models to address omitted spatial processes would be inappropriate in this context. Spatial lag models imply spillovers between prices of nearby dwellings, an interpretation that would not seem appropriate for many of the dwelling attributes and location amenities included in our analysis. The spatial error model, on the other hand, assumes that omitted spatial processes causing correlated residuals are uncorrelated with the regressors included in the model, which is unlikely to hold if the regressors include spatially varying characteristics, as in the models we estimate.

new information on flood risk, and that affect sales but not rental markets.[14] One candidate could be local trends in the housing market, if these happened to correlate with areas at risk of flooding, and also differ by sales and rental segments of the market. Given that Ireland has experienced a very pronounced housing market cycle during our sample period, this might add further to this concern. However, our standard specifications always include time period (year-quarter) fixed effects, to control for the national housing market cycle. Furthermore, as a robustness check, we add spatio-temporal fixed effects to control for regional/local market trends and find that our estimation of the flood discount is essentially unaffected.

There may be other factors that affect the *salience* of flood risk during our sample period, and we may be confounding these with the information shock, if they happen to correlate with the timing of new information. Flood events, in particular, might be a relevant source of changes in flood *salience* or flood risk perceptions. In all our main specifications, we control for past flood events (timing and location, as discussed previously in the data section, and further below). We also show that the result that the flood discount exists after information is released, but not before, is unaffected by the inclusion or exclusion of events in the same regression. We also check the robustness of our main findings to exclusion of dwellings that were affected by a particularly large flood event that occurred in the same year as the information release.

[14] We find a significant flood discount for sales, after the release of information about flood risk, but no equivalent discount for rentals.

One final concern, in relation to identification, is that selection effects may exist, both with AFAs and with flood defences. The selection of AFAs involved prioritising scientific assessment in flood risk areas considered most likely to be impacted by future flooding, which in general meant areas with a relatively large amount of development, rather than all areas at risk of flooding.[15] The selection of AFAs is thus clearly not random. In our main analysis we restrict the sample to only include dwellings in AFAs, rather than all dwellings, so that dwellings designated at risk are being compared to other dwellings in AFAs not at risk (with both sets of dwellings having received the same information shock). We also check the robustness of our main findings using the PFRA maps of flood risk, which covered the entire country, rather than restricting the sample to dwellings in AFAs, and find a very similar pattern of results. Selection issues might be a more serious concern with the allocation of flood defences, given the relatively small number of schemes, the potential for political considerations to affect their prioritization, and the relatively small share of the housing stock affected.[16] For this reason, we are cautious in interpreting the magnitude of the estimated effect of installing new defences on the value of protected dwelling, given that the estimated effects are unlikely to be

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[15] The AFAs include all large urban areas in Ireland, as well as many smaller agglomerations. Of the 300 AFAs, approximately one quarter had populations of less than 500 people and half had less than 2,000 people.

[16] As per Table 1 in Section 2, just 1,375 dwellings out of ~190,000 (or less than 1%) in our *listings data* (listed in 2011 or later) are protected by the 68 flood relief schemes for which we have detailed information.

representative of the value of reducing flood risk for *the average at-risk dwelling* in Ireland.

3.3 Variations to the specification

Our main specification, as outlined above and in Equation (2), is the basis of our estimate of the flood discount and provides us with our three main findings – the sale flood discount, the impact of new information on it, and how it differs from the rental flood discount. In our main specification, we also estimate the effect of distance from flood risk zones, of flood defences and of past flood events. Flood risk and flood defence variables are as described in Section 2.1, with ten categories of flood risk/defence, in addition to the not-at-risk control.

To estimate the effect of the information shock, we implement two variations on the main specification; first we split the sample into pre information shock (2006-2010, inclusive) and post-information shock (2011-2018, inclusive) sub-periods, and run the analysis separately on the two subsamples; and, separately, we interact the flood risk indicator (within medium-to-high risk zones) with the year of the dwelling's listing to show how the flood discount has varied over time. The results of the latter exercise, shown in Figure 2 in Section 4, illustrate the dramatic change in the price effect of flood risk after the release of the flood risk maps in 2011.

In Section 4.4 below, we present three main sets of robustness checks of our main findings. The first of these is to show how estimates of the flood discount are affected by inclusion of various sets of controls. We begin with the most parsimonious model possible, with only the flood risk indicators included as explanatory variables, gradually adding in groups of controls in a step-wise fashion until we arrive at the fully specified model as per our headline results. This process allows us to isolate the effect and importance of various groups of controls, including for example spatial controls and those that capture "blue space" amenities.

A second set of robustness tests involves variation to the level of the spatial fixed effects that we include. As outlined in Section 2.3, four different levels of spatial fixed effect are considered. The trade-off between different scales of fixed effect is that larger spatial units allow more variation within the spatial unit for the regressors of interest, while smaller units minimise the potential for unobserved spatial processes correlated with the error term leading to omitted variable bias and unreliable estimates. Our preferred specification includes ED fixed effects, balancing the trade-off of capturing unobserved spatial factors and reliable estimation of location effects, as outlined in Table 2.

As recommended by Von Graevenitz and Panduro (2015), we report variations on our main specification using each of the four available levels of spatial fixed effects. Observing the sensitivity of the estimated coefficient on the variable of interest to changes in the level of spatial fixed effect can give an indication as to whether there is some omitted spatial process influencing the variables of interest. This set of robustness tests also includes versions of our main specifications with spatio-temporal fixed effects added to control for regional/local market trends, and clustering errors within spatial fixed effects units to capture any remaining spatial correlation in the error term. The results of these checks both support the choice of ED fixed effects and demonstrate the robustness of our findings to variation in the level of spatial fixed effects, to clustering, and to the inclusion of spatio-temporal fixed effects on top of location fixed effects.[17]

A third set of robustness tests involves comparison of results using our main listings dataset with the alternative transactions price dataset, described previously in Section 2. We present results using a matched sample that allows for direct comparison of transaction and list prices. Aside from comparing transactions and list prices as the dependent variable, there are a number of other distinctions between the two datasets. We present results in a step-wise fashion, allowing us to isolate in turn: the effects of the additional dwelling-level attributes available in the transactions data, the different measures of dwelling location across the two datasets, and the obvious difference in sample and geographic coverage. These results indicate that our headline finding likely represents a lower bound on the true value of the flood discount.

[17] As an additional robustness test, we also implement a border-discontinuity-design (BDD) style analysis, where we restrict the comparison group to dwellings within a set distance from the boundary of the flood risk area. Our data allow us to mimic the three-step estimation strategy in Bosker et al. (2018): controlling for highly localized fixed effects, restricting the sample by dwelling type, and implementing a border-discontinuity-design type restriction on the comparison group. Results of these specifications are included in the Appendix B, Table B.3.

A final variation on our main specification involves estimation of the flood discount across the value distribution of housing prices. Flood risk may be borne unequally in the housing market for several reasons. Estimations are based on unconditional quantile regressions (UQR) (Peeters et al., 2017). The advantages of the UQR, relative to (conditional) quantile regressions, are that its coefficients are directly interpretable as marginal effects (Firpo et al., 2009) and are consistent under alternative sets of covariates or specifications of the hedonic function (Maclean et al., 2014). Results are then interpretable in a policy or population context (Borah and Basu, 2013).

4. Results

In this section we present findings from a range of empirical analysis, as described in the previous sections. We open with the estimated impact on housing prices of the release of information regarding flood risk in 2011, and related results on the relationship between distance to flood risk and housing prices. Our headline results are shown in Figure 1. Until the publication of information about which locations are scientifically assessed to be at risk of flooding, there is no statistically significant impact of flood risk on housing prices, either sale or rental. When that information is made publicly available, dwellings with at least a medium risk of flooding have sale prices that are on average 3.1% lower than those with no assessed risk of flooding. For rental prices, there is no effect of the publication of flood risk information on dwellings within the medium and high risk zone.

[Figure 1 here]

We also present additional results related to flood defences, flood events, and the flood discount across the housing value distribution, as well as a range of robustness checks. Our results show that the headline finding is robust to the use of different samples (nationwide, or restricting to Dublin only), transaction prices as the outcome, and to different model specifications (including varying the level of spatial FE, inclusion of spatio-temporal FE, and a border-discontinuity-style analysis). We also show how our estimate of the flood discount varies with the inclusion of different groups of controls. If anything, the additional specifications presented suggest that our headline finding likely represents a lower bound on the flood discount.

4.1 Information and the flood discount

Table 3 shows coefficients for various measures of flood risk, for both sale and rental listings, for two periods: prior to 2011, and from 2011 on, reflecting the release of information about flood risk.[18] The regressor of particular interest is for dwellings inside zones assessed by the CFRAM exercise to be at medium or high risk of flooding, as revealed in 2011. Prior to the release of this information on flood risk, there is no housing price discount for either sale or rental dwellings located within

[18] The reported coefficients are for dwellings not protected by flood defences at the time of their listing.

what were later revealed to be areas at risk of flooding (the coefficient on 'Inside medium/high' in the first and third columns of Table 3).

After the release of the information in 2011, we see the emergence of a significant flood discount of 3.1% for dwellings for sale with at least a medium risk of flooding (the second column of Table 3). However, there is no equivalent discount for rental dwellings in flood risk zones (the final column of Table 3). The specifications reported in Table 3 include controls for various dwelling and neighbourhood attributes, past flood events, as well as time (year-quarter) and location (ED) fixed effects. The empirical specification that gives the 3.1% result above is referred to hereafter as our preferred specification.

[Table 3 here]

The timing of the emergence of the flood discount is further illustrated in Figure 2. This shows coefficients, and associated confidence intervals, from regressions similar to those reported in Table 3 (for sale and rental listings) but using the full time period available (2006-2018) and with the indicator for dwellings inside a medium to high risk zone (and not protected by flood defences) interacted with year dummies. It shows a clear change in the relationship between sale prices and flood risk, after the release of the new flood risk information in 2011. This pattern is far less evident in the rental segment, where the estimated coefficient is smaller in magnitude. In addition to our baseline specification, which includes year-quarter fixed effects, our headline finding is robust to the inclusion of local market trends, as described in Section 4.4.

[Figure 2 here]

4.2 Variation in the flood discount

(i) By distance to risk

The second main result from Table 3 is the relationship between distance and the flood discount for sale dwellings, once flood risk is published. Figure 3 shows the point estimates for each of the five flood risk categories by distance, for the pre-2011 and post-2010 samples of sale listings data, as reported in Columns (1) and (2) of Table 3. For sale listings after the release of flood risk information (solid black line; second column of Table 3), there is a clear negative relationship between proximity to flood risk and housing prices. The emergence of a statistically significant discount on flood risk after the release of information applies to all dwellings within 200 metres of the flood risk zone, and grows from 0.7% for dwellings 100m-200m away from the low flood risk zone to 1.1% for dwellings either within the low flood risk zone or within 100m of it and to 3.1% for dwellings inside the medium and high flood risk zone. Beyond 200 metres from a low risk zone there is no statistically significant flood discount for sale dwellings in the post-2010 sample.

[Figure 3 here]

(ii) Across the price distribution

Figure 5 graphs the marginal effects of flood risk on housing prices across the price distribution. We estimate these using unconditional quantile regressions and the post-2010 sale listings dataset. The figure shows a larger flood discount at the lower end of the price distribution: the bottom decile experiences a 7.2% discount for flood risk, compared to an estimated discount for the upper half of the distribution that is for the most part not statistically different from zero.

[Figure 4 here]

4.3 Events, defences and the flood discount

(i) Past flood events

In this subsection, we examine how both flood events and flood defences are reflected in housing prices. Gharbia et al (2019) show the relative impact on housing prices of a major 2011 flood event in the Dublin housing market. We use a database of over 2,000 flood events to examine whether this finding extends to other events and is persistent. To do this, we include flood events by date and location in all our main specifications. For each dwelling, our two treatments of interest are the time since the most recent flood event within 100 meters and the most recent event between 100 and 250 meters from that dwelling. These are categorized into five time intervals, as shown in Figure 5.

Full regression output for the relevant variables, across all three datasets, is given in Appendix B, Table B.1. For sale listings, dwellings within 100 meters of a flood event that took place less than two years ago are subject to a discount of 4.3%. This discount disappears after two years. There is a smaller effect for recent flood events slightly further from the dwelling (100-250 meters away): 2.7% for an event within the last two years. As shown in Figure 5, there is some evidence of an effect of major past floods. Relative to properties with no history of flood events nearby, dwellings where the most recent flood event was more than thirty years ago are subject to a discount of 2.4%.

[Figure 5 here]

(ii) Flood defences

Flood defences have a big effect on the sale price of housing (in line with the findings in Beltran et al. 2018b). Full results are shown in extended regression output for Table 3, in Appendix B, Table B.1. Compared to dwellings with a similar exposure to flood risk before the construction of flood defences, being within the area protected by flood defences once they are constructed is associated with a significant price premium. This price premium is estimated to be close to 10% – but only for dwellings within the medium/high risk zone. For dwellings at lesser risk, there is no positive effect on prices after the construction of flood defences. Similarly, there is only modest evidence of any effect on rental dwellings in the medium/high risk zone (2.3%, with a t-statistic of 2.1) and no other statistically significant effect for other risk categories. This pattern of results holds in a specification with even more granular fixed effects, as reported in Table 5.

[Figure 6 here]

The finding of a price premium in defended areas is consistent either with an otherwise omitted variable making dwellings in these locations particularly attractive once the flood risk has been mitigated or with the market over-reacting to the installation of flood defences, perhaps due to pent up demand for those locations. Exploiting information on the timing of flood defence installation, we further investigate the reported premium, by looking at how the effect of flood defences on housing prices varies with time since installation. The results are illustrated in Figure 6 and show that the premium is in fact short-lived, consistent with the 'pent up demand' hypothesis, rather than an OV bias story. Within five years, the premium has disappeared and housing prices for dwellings located in areas assessed as at risk of flooding, but protected by flood defences, are not statistically different from housing prices in areas not at risk of flooding.

As noted earlier, it is likely that there are strong selection effects in the location of flood defence schemes, and so it is possible that these are locations of particular (idiosyncratic) value. For that reason, the estimated premium reported in Table 3 should not be interpreted as representing the value of installing flood defences for the *average dwelling* at risk of flooding, even over the short-run.

4.4 Robustness of the flood discount

Here, we discuss various robustness checks to the results presented in Sections 4.1-4.3. Below we provide details on three sets of robustness checks: (i) a presentation of the estimated flood discount for various subsets of controls, (ii) varying the level of spatial fixed effects, and (iii) using a dataset of transaction prices, rather than listed prices, for the sale segment.

In additional robustness checks, we also find that our headline finding is essentially unaffected by: the inclusion or exclusion of past flood events as additional controls; the exclusion of dwellings affected by a particularly large flood event that occurred in the same year as the information release; the use of the nationwide PFRA maps (and nationwide housing sample), rather than the CFRAM maps (and the sample restricted to AFAs only); restricting the sample to similar property types only; and to the use of a border-discontinuity-design style approach where we restrict the control group to dwellings within a fixed distance of a flood risk zone.[19]

(i) Step-wise inclusion of controls

As discussed in Section 1, a growing literature examines the relationship between flood risk and housing prices. Not all studies include the same controls, however, and in Table 4, we present the results of eight empirical specifications, which vary by the sets of controls they include. We add controls sequentially, building up the

[19] All of these additional robustness checks are detailed in Appendix B, Table B.2.

model from the most parsimonious to the most comprehensive, showing in turn how the addition of each set of controls affects the estimated flood discount. The first column presents a naïve regression, where housing prices are a function of flood risk only. The large negative coefficient on being within the medium/high flood risk zone implies that, all else equal, dwellings at risk of flooding have lower-value attributes than those not at any risk. Adding spatial FEs at the Census ED level in Column (2) leads to a substantial fall in the estimated flood discount, and a big increase in the R-squared. Adding time period fixed effects, to control for aggregate market conditions, in Column (3) has a relatively small effect on the estimated discount.

The addition of dwelling attributes in Column (4) leads to a further substantial decline in the estimated flood discount, suggesting that dwellings exposed to flood risk are on average of lower quality. The estimated flood discount of -1.4% in Column (4) is less than half the discount of -3.1%, in our preferred specification. This implies that even where empirical specifications include controls for market conditions, a detailed set of dwelling attributes, and local area controls for unobserved spatial attributes, the potential remains for significant OV bias.

The addition of a range of location-specific amenities, such as distance to CBD and transport facilities, in Column (5) does increase the estimated flood discount, from roughly 1.4% to 2%. It is the inclusion of 'blue space' controls in Column (6) – specifically distance to the coast and other water bodies and an estimate of sea views

– that has a far larger impact on the flood discount, which increases to almost 4% (see Gillespie et al, 2018, for more on calculation of sea views).

The addition of neighbourhood quality, through use of Census Small Area measures of educational attainment and unemployment in Column (7), reduces the estimated flood discount. This implies that flood risk and neighbourhood quality are negatively correlated in our dataset. As discussed in Section 3.2, it is possible that these are 'bad controls' and the true effect of flood risk is larger than in what we have termed our preferred specification. Given the effect of including SA fixed effects (discussed below), we err on the side of these slightly smaller magnitudes.

Finally, Column (8) adds controls for historical flood events, reproducing the results from our preferred specification. This leads to a slight reduction in the estimated flood risk discount, which is not a surprise given the likely correlation between past flood events and assessed flood risk. But perhaps more surprisingly, this effect is not large. This last set of results underlines the idea that information about flood risk matters, and this effect is distinguishable in our data, and using our estimation strategy, from the effects of direct experience of flooding.

[Table 4 here]

We take from this exercise an important finding for the flood discount literature, namely that due to the high correlation between 'blue space' amenities and flood risk disamenities, any estimate of the flood discount that does not explicitly control for 'blue space' amenities is likely to underestimate that discount.

(ii) Varying the level of spatial fixed effects

Our results directly speak to the issues raised by Von Graevenitz and Panduro (2015) regarding the importance of the choice of spatial unit when attempting to control for omitted location-specific factors. In Table 5, we present additional specifications showing how our results vary firstly with four different levels of spatial fixed effects (in Columns 1-4) and secondly when we add spatio-temporal market-by-year fixed effects on top of location fixed effects, to allow for market-specific trends or shocks. In all specifications reported in Table 5, t-statistics are shown for standard errors that cluster at the level of the spatial unit used as the fixed effect.

The most obvious difference across the first four columns of Table 5 is between Local Market fixed effects (in Column 1) and the other three levels (Columns 2-4). The magnitude of the coefficient for dwellings located within a medium/high flood risk zone, when using market-level fixed effects (in Column 1), at -8.1%, is more than double that of the any of the other specifications. As discussed in Section 3.3, the trade-off in choosing the SFE is between capturing spatial processes that might happen to correlate with flood risk and allowing enough within-unit variation for identification. There are 54 'Local Markets' within our sample, with an average 37,000 households per market. Our results suggest that, even with other area features included as controls, this level of aggregation is insufficient to capture location-specific features that may be correlated with flood risk. Again, this finding is important for the flood discount literature, where often spatial fixed effects cover geographical units with tens of thousands of households.

Among the other three specifications, the estimated flood discount is similar in order of magnitude, ranging from 1.6% with micro-markets (in Column 2) to 3.1% for ED fixed effects (in Column 3). As discussed in Section 3.3, it is likely that the use of Small Area fixed effects may suffer from limitations in relation to statistical power, with an average of just 18 listings per Small Area in the listings sample (2011-2018), as well as potential correlation between the Small Area, which may be as granular as an apartment block, and the regressor of interest. Census EDs are our preferred specification, with an average of 185 listings per ED in the post-2010 sample.

The results in Columns 5 and 6 replicate those in Columns 3 and 4 but with the addition of market-by-year spatio-temporal fixed effects. The results are qualitatively and quantitatively very similar in these more-demanding specifications. It is also worth noting, following the discussion in Section 4.2, that the premium on defended dwellings is reduced in magnitude and statistical significance in these last two specifications. Overall, we conclude that these additional specifications reinforce the robustness of our estimate of the flood discount and highlight the importance of including highly localised spatial fixed effects.

[Table 5 here]

(iii) Using transaction prices rather than list prices

We next investigate the extent to which the price effects found using a detailed dataset of list prices (as reported in Table 3) are reflected in a smaller database of transaction prices, which offers additional controls and more precise measures of location. Table 6 shows the results for a number of specifications, comparing results using transaction and list prices as the outcome.

Column 1 of Table 6 reports a specification similar to our preferred one (Column 2 of Table 3) but with four notable differences. Firstly, the outcome is the natural log of the dwelling's *transaction* price, as recorded in Ireland's Residential Property Price Register, rather than its listed price. Secondly, the geographic scope of sample differs, as the sample of 36,000 includes only dwellings sold in Dublin (as discussed in Section 2.2). Thirdly, the exact empirical specification includes some additional dwelling attributes, available through the linking of transactions with official energy performance certificates, including the overall energy efficiency assessment, exact size in square meters and building age, which were not available for the listings data. Finally, the transactions data use location information based on Eircodes, which may be more precise than the (building-level) location information generated algorithmically by daft.ie using the address entered by the advertiser.

The result, as reported in Column (1) of Table 6, is a substantially larger price discount of 6.2% for dwellings located within medium to high risk zones, as opposed to the 3.1% estimated discount from our preferred model with the sales listings data reported previously. In the remaining columns of Table 6, we investigate the source of this difference in estimated flood discount, by isolating in turn the effect of each of the four differences between Column (1) here and the main results from Table 3.

First, in Columns (2) and (3), we replicate the specification in Column (1), but this time on a matched sample of just under 30,000 dwellings for which we have both transaction and list prices. Column (2) reports the effect on transactions prices, for the matched sample, while Column (3) reports the effect on the list price, for the same sample. In both cases, the specification and controls included are identical to those used in Column (1). Use of the matched sample narrows the gap significantly, with a flood discount in transaction prices of 5.7% compared to one in list prices of 4.8%. Thus, the use of transaction prices, as compared to list prices, leads to a higher estimate of the flood discount (+0.9pp). Nonetheless, the difference is not statistically significant and lends support to the use of listed prices in settings where transactions data are not readily available, such as lower-income countries.

[Table 6 here]

Column (4) replicates Column (3), but excluding the additional dwelling-specific controls available through the BER database of energy performance certificates, such as dwelling age, exact size in square meters, and energy efficiency, which were included in Columns (1)-(3) here, but not available for the listings dataset used in Table 3. Compared to Column (3), the flood discount increases from 4.8% to 6.9%. Of the additional controls, it is exact floor area in square metres that has by far the largest impact on the estimated the flood discount. Without this, the flood risk discount may be overstated, at least in the case of Dublin.

Lastly, in Column (5), we examine the extent to which exact measures of location are important in determining the magnitude of the flood risk discount. As noted in Section 2.3, the exact coordinates of the dwelling are measured in two different ways across listing and transaction datasets. Of the two measures, the Eircode measure of location used in the transaction dataset is official and thus likely to be the more accurate. The specification in Column (5) is identical to Column (4), except now using the dwelling locations from the listings data, as opposed to the locations from the transactions data. The result shows that this makes a substantial difference to the estimated flood discount, which drops to 2.6% in Column (5) compared with 6.9% in Column (4). The lower degree of precision of dwelling location in the listings data is a form of measurement error, thus resulting in an bias attenuating the coefficient towards zero.

Column (5) of Table 6 is the most directly comparable to the results presented previously in Table 3, as both use an identical specification, with the only difference being the sample of dwellings included. Comparing the estimated flood discount of

2.6% from Column (5) of Table 6, with our headline finding of 3.1%, indicates that if anything the flood discount is lower for this smaller Dublin-only sample of dwellings, compared to the national sample used previously, when comparing like-for-like specifications. In all, the results of this table support the hypothesis that our headline result – of a flood discount estimated at 3.1% – represents a lower bound on the true figure. Both the use of transactions prices and of more precise location information result in a larger estimated flood discount.

5. Comparing market outcomes with stated preferences

Our empirical analysis on preferences as revealed by market outcomes is supplemented by an online survey on public perceptions and awareness of flood risk in Ireland. The survey was hosted on daft.ie, the most popular real estate website in Ireland, with a link to the survey in the strapline of the home page for approximately three weeks in June 2019. The survey attracted a total of 837 respondents, 36% of whom said they were interested in buying a home and 26% in renting a home.[20] There was no mention of floods in the title or description of the survey to avoid self-selection of respondents with a particular interest in the topic, with the aim of gaining insight on the wider public's perception and knowledge of flood risk.

[20] Some respondents left questions blank, such that we do not have 837 responses for every question in the survey. There were also some questions on the survey that only appeared in logical sequence depending on the answer to the previous question. Further detail on the survey, including the full list of survey questions, are included in Appendix C.

5.1 Attitudes to flood risk

When asked to rank various amenities and disamenities in terms of their importance in choosing where to live, on a Likert scale where 1 is 'not important' and 5 'very important', 54% of respondents ranked "no risk of flooding" as "very important" (n=802). This was the joint highest (in terms of frequency of respondents choosing "very important") along with neighbourhood quality (54%, n=816), and ahead of proximity to other amenities including transport networks, central business district, green spaces and schools.

A large share of respondents (45%) also said that flood risk had become more of a concern for them in the last 10 years, as against just 4% who said it had become less of a concern for them (n=758). Looking to the future, 81% of respondents expect flood risk in Ireland to increase by the year 2050 (n=633). In terms of direct experience of flooding, 12% of respondents said they had directly experienced flooding of a dwelling they were living in at some point in the past (n=633).

Concern about flood risk was notably different among those looking to buy compared with those looking to rent. Of those looking to buy a home, 58% rated avoiding flood risk as very important, while just 5% said it was not important (n=298). In contrast, of those looking to rent, similar fractions rated avoiding flood risk as very important (32%) and not important (25%) (n=202). Buyers were almost twice as likely to state that flood risk was relevant to their search, relative to renters (35% vs 19%; n=305 and n=216 respectively), and about half as likely to say they didn't know if flood risk was relevant (18% vs 35%). A similar proportion of respondents in each category (48% of buyers and 46% of renters) stated that flood risk wasn't relevant in the areas they were looking at.

5.2 Awareness of flood risk information

In spite of concern about flood risk, the responses to the survey also indicate a continuing information deficit among the general public. Of those who said that flood risk was relevant for their search, over a third (37%) said they weren't aware of the risk for those areas (n=217). Fewer than one in five respondents (17%) said they knew where to find flood risk information, while the majority (61%) said they didn't know, and 22% said they thought it would be difficult to find (n=643). When asked about official flood risk maps, only 22% said they were aware of the existence of these maps (n=758).

These findings have important implications for policy as well as for the results presented above. Firstly, the results of this survey imply that the availability of scientifically assessed risk information on its own appears insufficient to ensure a well-informed public, even when the stakes are relatively high and when respondents report high levels of concern. Greater efforts at information dissemination and communication to the public may be required; see McDermott and Surminski (2018) for a related discussion on translating scientific assessment of flood risk for local decision-making.

Secondly, if only one in five respondents say they are aware of the official risk maps, it also raises the question as to whether it is plausible that the release of these maps had the significant effect on the market that we observe in the data. Clearly, even a fraction of market participants being well informed could still be sufficient to move the marginal price. Moreover, it is likely that more sophisticated market participants – including various agents working on behalf of buyers and sellers – would be well informed and their assessments would affect both ask and bid prices.[21] As discussed by Stein (2009) in a different setting, where concerns around crowding or leverage are absent, the presence of well-informed traders would be expected to ensure that prices represent fundamental values, even when unsophisticated buyers still represent a significant fraction of the overall market.

5.3 Willingness to pay to avoid flood risk

A willingness-to-pay question was included in the survey, relating to people's perception of flood risk discounts on housing prices. Respondents were asked to imagine two identical houses, that differ only in that one is at risk of flooding and the other is not. Each respondent was randomly assigned one of six versions of the question: two versions for each of three levels of flood risk (0.1%, 1% and 10%), where one version for each level of risk included an illustration of the risk in terms of

[21] Indeed, the results from our hedonics show a significant flood discount for list prices (asking prices), and a slightly larger discount for transaction prices (the price actually paid). See Table 6 above.

the probability of being flooded over the course of a 30 year mortgage. The exact wording of the questions is included in Appendix C.

The mean flood discount across all responses was 31.4% (sd 21%, n=629). The mean shows little variation across the three different levels of risk specified in different versions of the question: 29% for a 0.1% risk of flooding (n=195), 31% for a 1% risk (n=210), and 34% for 10% risk (n=224).[22] This may indicate some issue with the interpretation or assessment of flood risk probabilities. On the other hand, within each risk category, the inclusion of the mortgage illustration creates no statistically significant difference in means, which would suggest the opposite, i.e. statistical literacy.

These stated-preference results suggest a much larger flood discount – indeed, an order of magnitude larger – than the discount that emerges from the revealed preferences as quantified in our hedonic housing price analysis. The large gap between the two is consistent with a number of different narratives. One explanation could be salience: flood risk was listed in the survey and willingness to pay specifically elicited, unlike in the housing market. A second and potentially related explanation is that, in line with 'talk is cheap' criticisms of stated-preference methods, known as the hypothetical bias, respondents substantially over-state the

[22] The difference between mean discounts for 0.1% and 1% risk is not statistically significant at conventional levels (one sided p-value=0.26); while the differences in mean between 1% and 10% risk, and between 0.1% and 10% risk are significant (one sided p-values for these differences are 0.03 and 0.009, respectively).

true value to them of avoiding flood risk (Murphy et al, 2005). A third explanation is that the full costs of flood risk to housing market participants are still not fully captured in housing prices, perhaps in part as a result of a continuing information deficit amongst the public in relation to flood risk. There is also the related issue of implicit or explicit subsidies to flood risk, for example in the form of public investment in flood defences, paid from general taxation. As our results on defences demonstrate, these public investments eliminate the flood discount for protected dwellings. There is also substantial new investment in flood defence schemes planned in Ireland over the coming years, and the expectation of future protection may have an effect on market outcomes that would not necessarily show up in the survey findings.

The fact that we find no statistically significant flood discount for most of the upper half of the value distribution of housing in Ireland, would seem to support the idea that the welfare costs of flooding are still not fully reflected in Irish housing prices. It seems unlikely that the true welfare cost for higher-value dwellings is zero. If higher-value dwellings tend to be in areas that will attract future public investment in defences – for example, denser locations, where presumably proposed flood relief schemes are more likely to meet benefit-cost requirements for investment – this may partly explain the lack of a discount for higher-value dwellings. The allocation of flood defence investments and its distributional effects is an important outstanding question for future research.

The large majority of respondents to our survey expect flood risk to get worse in the coming decades. They also value flood risk of very different magnitudes (in terms of the probability of flooding per year) at roughly the same level of flood discount. This points to what is perhaps the most plausible way to reconcile these seemingly disparate estimates of the flood discount: that respondents to our survey are implicitly attaching substantially larger probabilities to flood risk than the scientifically assessed level of risk. Indeed, the larger stated preference flood discount corresponds closely to the value that emerges from an expected damages calculation, if survey respondents are implicitly applying the highest risk category (a 10% probability of flooding per year) to dwellings at risk of flooding, regardless of the information about risk provided in the question.[23] This interpretation is supported by the similarity of the average discount across respondents who were asked about dwellings with a 10%, 1% or 0.1% probability of flooding per year, as well as by the finding from our hedonics that dwellings in areas with relatively low risk (0.1% probability of flooding per year) and dwellings located just outside these areas (with presumably even lower risk) still attract relatively large flood discounts.

[23] Based on average damages per flood of €60,000 for an individual dwelling, a 3% discount rate, and a 30-year time horizon, the capitalized value of flood risk with a 10% probability of occurrence per year is €123,600 in present value terms, equivalent to a flood discount of 41% for a dwelling valued at €300,000. In contrast, based on the same set of parameter values and a 1% probability of occurrence per year, average damages per flood of close to €500,000 for an individual dwelling would be required to justify a flood discount of over 30%. Similarly, for flood risk with a 0.1% probability of occurrence per year, damages per flood of close to €5M per individual dwelling, would be required to justify a flood discount of 30%.

On the one hand, this over-weighting of the risk, particularly for lower risk areas, may reflect problems with risk information and its communication to the public – although as noted, this is not what is suggested by the results from our survey on the mortgage illustration. Alternatively, this may reflect a conscious choice by respondents to treat the scientific assessments as underestimates of the true risk. These rival hypotheses constitute an important open question for future research in this area.

6. Concluding remarks

In this paper, we examine the relationship between flood risk and housing market outcomes, using the case of Ireland since 2006. In particular, we exploit rich housing data – including a dataset of almost 800,000 listings and 36,000 transactions in areas at risk of flooding – and detailed official data relating to flood risk, previous flood events, and completed flood defences. We find clear evidence of a flood discount in the housing market, with the emergence of a 3.1% price discount for dwellings in medium to high flood risk zones, after the publication of flood risk information in 2011. We also find evidence that flood defences work in reversing this discount, that flood risk is borne disproportionately by dwellings in the lowest quartile of value, and that the market's memory of flood events is short.

Because we take advantage of the fact that new information about flood risk was released in the middle of the sample period, our estimates are unlikely to be biased by some unobserved process that is correlated with flood risk *and* the severity of flood risk. In addition, a number of robustness checks – including varying the level of spatial fixed effect, clustering the error terms, and comparing estimates from different samples – largely confirm the reliability of our estimates for willingness to pay to avoid flood risk zones. Nonetheless, our results have limitations. While the volatility in the housing market during the years analysed may help internal validity and robustness of the results, they may also limit the external validity, as housing systems with less dramatic mismatches between supply and demand may exhibit different relationship between (dis)amenities and housing prices than a system like Ireland's. Also, the datasets used have significant strengths and are largely consistent with each other but ultimately findings for the full period from 2006 rely on listings, while transactions data are limited to one city.

Nonetheless, we believe that our findings are identifying the causal effect of flood risk on housing prices. They have important policy implications for flood risk management, insurance and flood defences, as well as for projections of future flood losses in a world of increasing flood risk. The point estimates and frequencies presented here can be used in combination with other information to give a preliminary estimate of the aggregate effect of flood risk on Irish housing wealth. As of 2020, Ireland had roughly 1.75m occupied dwellings. According to our listings data, roughly two-thirds of Irish homes are located in areas potentially at risk of flooding. All dwellings within 200 metres of flood risk are, according to our preferred specification, subject to a statistically significant discount, implying a total of just over 420,000 affected dwellings. Applying these discounts and frequencies to a system with an average dwelling value of €300,000 gives a total effect of flood risk on housing of approximately €1.35bn, compared to an overall stock of wealth in residential real estate of approximately €520bn. As discussed in Section 4.4, this is likely a lower bound to the true flood discount and this figure also does not take into account other costs of flooding, such as damage to public infrastructure or commercial real estate. For that reason, this is perhaps best thought of as an attempt to reflect usually more hidden costs of flooding, such as the effect on households of disruption, including mental health costs.

Perhaps most importantly for policymakers, however, our results present compelling evidence on the effectiveness of public investments in flood mitigation – both in terms of information provision and flood defences. But these two types of investments might be expected to have very different effects on future costs of flooding. Better information results in more awareness and a clear price signal, which should translate into less exposure to flooding in future, albeit our survey findings suggest there is still work to be done to translate scientific assessment of risk into public awareness. In contrast, flood defences – and the expectation of future investments in defences – might encourage development of flood-prone areas, with important implications for the future costs of flooding in a world with increasing flood risk.

Lastly, we believe our research has at least four important findings for the growing literature in this area, beyond those specific to the market analysed. Firstly, we document that the sale price effect is substantively larger than the rental price effect. Secondly, we document the importance of appropriate choice of spatial fixed effect, when attempting to estimate the flood discount. Specifically, spatial units with tens of thousands of dwellings may give biased estimates of the flood discount, even when rich dwelling and other location controls are included. Thirdly, we show the importance of including specific controls, when estimating the flood discount. In particular, while the omission of exact floor area may exaggerate the flood discount, the omission of 'blue space' amenities – in particular sea views/distance to beaches – may create a downward bias in estimated flood discounts. These controls have often been omitted from previous empirical analysis of flood discounts, but our results suggest their inclusion in future studies should be standard. Finally, we show that, on a like-for-like basis, list prices act as a good proxy for transaction prices, where those are unavailable. Given the prevalence of flood risk in lower-income settings, where formal housing statistics are typically weaker, this is a useful finding for both researchers and policymakers.

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Table 1. Frequency of flood risk and defence variables

Flood risk and defences measure		Sales Listings	Sales Transactions	Rentals Listings
No flood defences	More than 500m away	98,390	21,122	163,480
	500m-200m away	84,938	9,004	136,869
	200m-100m away	40,521	3,576	70,146
	<100m from low risk	47,538	4,414	97,633
	Inside low risk	6,773	741	23,302
	Inside medium/high	5,289	296	19,032
After flood defences	500m-200m away	54	24	104
	200m-100m away	20	3	81
	<100m from low risk	388	60	1,327
	Inside low risk	762	297	2,390
	Inside medium/high	209	106	412
Total		284,882	39,643	514,776

Note: The table shows the frequency of observations for each of the 11 categories of exposure to flood risk and flood defences, as described in the text, for three samples: sale listings (2006-2018), sale transactions (2010-2018) and rental listings (2006-2018).

Table 2: Spatial fixed effects by number of units/observations within units

Sales listings sample, 2006-2018 (national)

Fixed Effect	Number of spatial units in sample	Mean Number of Observations	Median Number of Observations
Local Market	54	7,847	6,874
Micro-Market	377	1,891	1,427
Electoral Division	1,027	768.9	519
Small Area	10,875	40	34

Sales transactions sample, 2010-2018 (Dublin)

Fixed Effect	Number of spatial units in sample	Mean Number of Observations	Median Number of Observations
Local Market	26	2,241	1,990
Micro-Market	118	576	435
Electoral Division	322	242	145
Small Area	4,558	11.8	11

Rental listings sample, 2006-2018 (national)

Fixed Effect	Number of spatial units in sample	Mean Number of Observations	Median Number of Observation
Local Market	54	15,302	13,454
Micro-Market	382	4,584	3,177
Electoral Division	1,002	1488	1215
Small Area	10,702	177.3	87

Note: The above table displays the number of units of spatial fixed effects as well as the mean and median number of observations per unit of fixed effect. All of the above samples are within AFAs, as discussed in the text.

Table 3: The flood discount before and after information

Sample	Sale listings		Rental listings	
	2006-2010	**2011-2018**	**2006-2010**	**2011-2018**
500m-200m away	-0.006	-0.001	0.001	0.003
	-2.5	-0.3	0.5	3.2
200m-100m away	-0.001	-0.007	0.000	0.005
	-0.2	-2.9	-0.1	4.3
<100m from low risk	-0.014	-0.011	0.005	0.008
	-4.1	-4.2	2.0	6.2
Inside low risk	-0.007	-0.011	-0.013	0.009
	-1.0	-2.1	-3.3	4.5
Inside medium/high	0.001	-0.031	0.003	-0.002
	0.1	-4.9	0.8	-1.0
Observations	94,172	190,635	124,408	390,301
R-squared	0.788	0.842	0.841	0.878
RMSE	0.222	0.263	0.154	0.169
Spatial units	955	1,020	931	1003

Notes: Regression results show coefficients on various measures of flood risk, as discussed in the text, where the dependent variable is the natural log of the dwelling's listed price. Robust t-statistics are shown underneath each coefficient. Different columns show results across sale and rental listing datasets, before and after the release of flood-risk information. Controls include Census ED fixed effects, dwelling attributes, location amenities, and market conditions, as discussed in the text.

Table 4: Step-wise adding groups of controls

	No controls	+ ED fixed effects	+ Time controls	+ Dwelling attributes	+ Proximity to amenities	+ Blue space controls	+ Neighbourhood 'quality'	+ Flood Events
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	lnprice	lnprice	lnprice	lnprice	lnprice	lnprice	lnprice	lnprice
No flood defences								
500m-200m away	-0.220	-0.0208	-0.0205	0.00556	0.00348	-0.000137	-0.000576	-0.000666
	-60.5	-6.45	-6.68	2.83	1.77	-.0665	-.289	-.335
200m-100m away	-0.275	-0.0390	-0.0422	0.00391	0.000549	-0.00604	-0.00745	-0.00744
	-59.1	-9.67	-10.9	1.55	.217	-2.26	-2.87	-2.87
<100m from low risk	-0.323	-0.0816	-0.0853	0.00312	-0.00158	-0.0130	-0.0118	-0.0113
	-72.9	-19.8	-21.6	1.22	-.611	-4.67	-4.35	-4.16
Inside low risk	-0.238	-0.125	-0.129	0.00598	-0.000470	-0.0164	-0.0119	-0.0106
	-21.2	-16	-17.2	1.19	-.0933	-3.15	-2.31	-2.05
Inside medium/high risk	-0.399	-0.161	-0.164	-0.0137	-0.0197	-0.0389	-0.0320	-0.0311
	-35.9	-17.5	-18.6	-2.23	-3.2	-6.08	-5.08	-4.88
Spatial fixed effects	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time controls	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Dwelling attributes	No	No	No	Yes	Yes	Yes	Yes	Yes
Proximity to amenities	No	No	No	No	Yes	Yes	Yes	Yes
Blue space controls	No	No	No	No	No	Yes	Yes	Yes
Neighbourhood quality	No	No	No	No	No	No	Yes	Yes
Flood events	No	No	No	No	No	No	No	Yes
Observations	190,704	190,704	190,704	190,704	190,704	190,704	190,635	190,635
R-squared	0.043	0.575	0.613	0.834	0.834	0.835	0.842	0.842
RMSE	0.645	0.431	0.411	0.270	0.269	0.269	0.263	0.263

Note: The results in this table are based on the listings data (2011-2018) and are similar to those reported in Table 3. The dependent variable in each case is the natural log of the dwelling's listed sale price. The first column reports a specification with flood risk categories as the only explanatory variables (no other controls added). Each subsequent column adds a set of controls in sequence as per the column headings. Column 8 replicates Column 2 from Table 3 with the full set of controls included. In all but the first column, there are 1,020 spatial units

Table 5: The flood discount, for different spatial fixed effects

Level of Fixed Effect	Sale listings (2011-2018)					
	Local Market	**Micro-market**	**Census ED**	**Census Small Area**	**Census ED**	**Census Small Area**
					+ Spatio-temporal FE	
No flood defences						
500m-200m away	-0.020	-0.001	-0.001	-0.001	-0.003	-0.002
	-2.2	-0.2	-0.1	-0.2	-0.6	-0.4
200m-100m away	-0.037	-0.012	-0.007	-0.004	-0.011	-0.003
	-3.3	-1.5	-0.9	-0.6	-1.4	-0.5
<100m from low risk	-0.046	-0.013	-0.011	-0.002	-0.015	-0.003
	-3.8	-1.4	-1.2	-0.3	-1.7	-0.3
Inside low risk	-0.067	-0.012	-0.011	-0.012	-0.014	-0.011
	-3.2	-1.0	-0.8	-1.1	-1.2	-1.0
Inside medium/high	-0.081	-0.016	-0.031	-0.018	-0.032	-0.016
	-4.3	-0.9	-1.9	-1.5	-2.0	-1.3
After flood defences						
Inside medium/high	-0.030	0.072	0.097	0.118	0.06	0.056
	-0.9	1.9	2.7	3.2	1.9	1.5
Controls	YES	YES	YES	YES	YES	YES
Observations	190,635	190,635	190,635	190,635	190,644	190,644
R-squared	0.808	0.834	0.842	0.874	0.852	0.883
RMSE	0.289	0.269	0.263	0.241	0.254	0.233
Spatial units	54	375	1,020	10,809	1,020	10,809

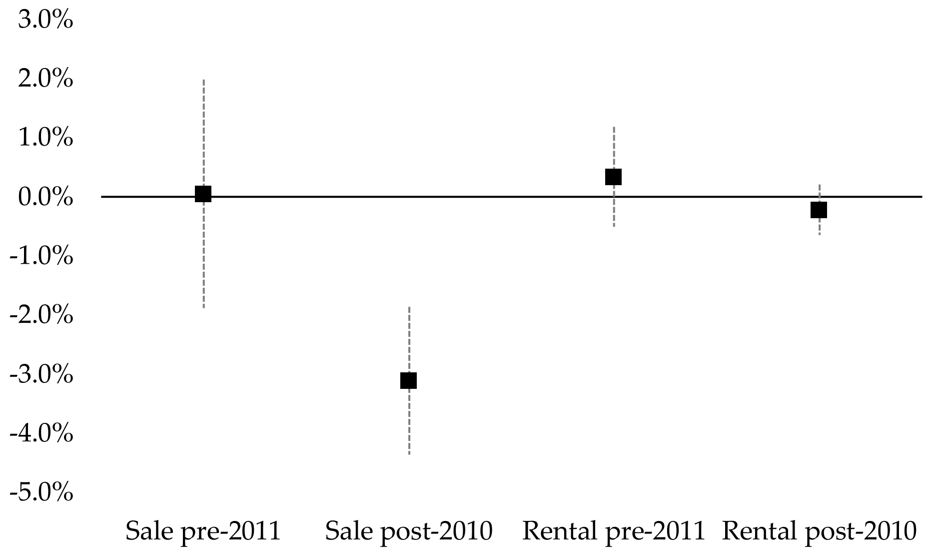
Notes: Regression results show coefficients on various measures of flood risk, as discussed in the text, where the dependent variable is the natural log of the dwelling's listed price. t-statistics are shown underneath each coefficient, based on standard errors that are clustered within the spatial unit in each case. Different columns show results using different fixed effects. Controls include dwelling attributes, location amenities, and market conditions, as discussed in the text.

Table 6. Flood discount across transaction and list prices

	Transaction Prices (1)	Matched: Transaction Prices (2)	Matched: List Prices (3)	As per (3) No BER controls (4)	As per (4) Locations from listings (5)
No flood defences					
500m-200m away	0.003	-0.002	0.001	-0.000	0.001
	0.9	-0.5	0.4	-0.1	0.2
200m-100m away	-0.003	-0.004	-0.003	-0.009	-0.007
	-0.6	-0.8	-0.6	-1.7	-1.4
<100m from low risk	-0.012	-0.016	-0.008	-0.018	-0.012
	-2.4	-3.0	-1.6	-3.1	-2.2
Inside low risk	-0.027	-0.034	-0.025	-0.033	-0.021
	-2.7	-3.1	-2.6	-3.0	-2.0
Inside medium/high	-0.062	-0.057	-0.048	-0.069	-0.026
	-4.2	-3.7	-3.4	-4.4	-2.0
After flood defences					
Inside medium/high	0.027	0.040	0.049	0.049	0.077
	1.0	1.6	2.1	1.8	2.9
Controls	YES	YES	YES	YES	YES
Observations	35,922	29,253	29,253	29,253	29,253
R-squared	0.897	0.896	0.909	0.886	0.883
RMSE	0.172	0.173	0.159	0.178	0.180
Spatial units absorbed	322	316	316	316	318

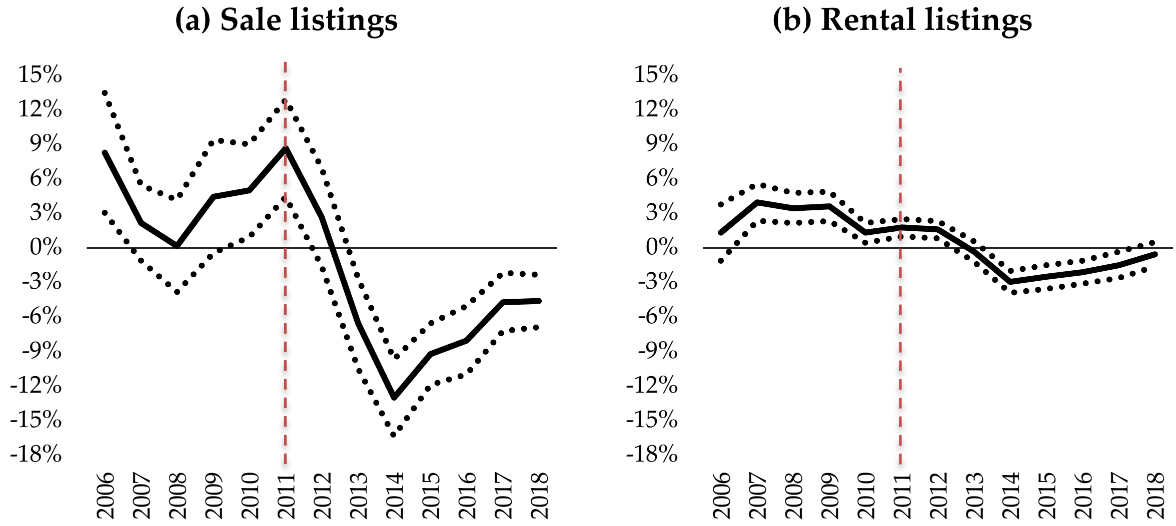
Notes: Regression results presented in this table show coefficients on various measures of flood risk, as discussed in the text, where the dependent variable is the natural log of the dwelling's transaction price. The results in this table are based on the transactions price data. Robust t-statistics are shown underneath each coefficient. Column (1) uses the full transactions dataset. Columns (2) and (3) use a restricted version of the transactions data where each observation is matched to the listings data. Column (4) replicates Column (3) but omits additional BER controls. Finally, Column (4) replicates Column (3) but using location information from the listings data. Controls include Census ED fixed effects, dwelling attributes, location amenities, and market conditions, as discussed in the text.

Figure 1: Estimated flood discount, by segment and sample



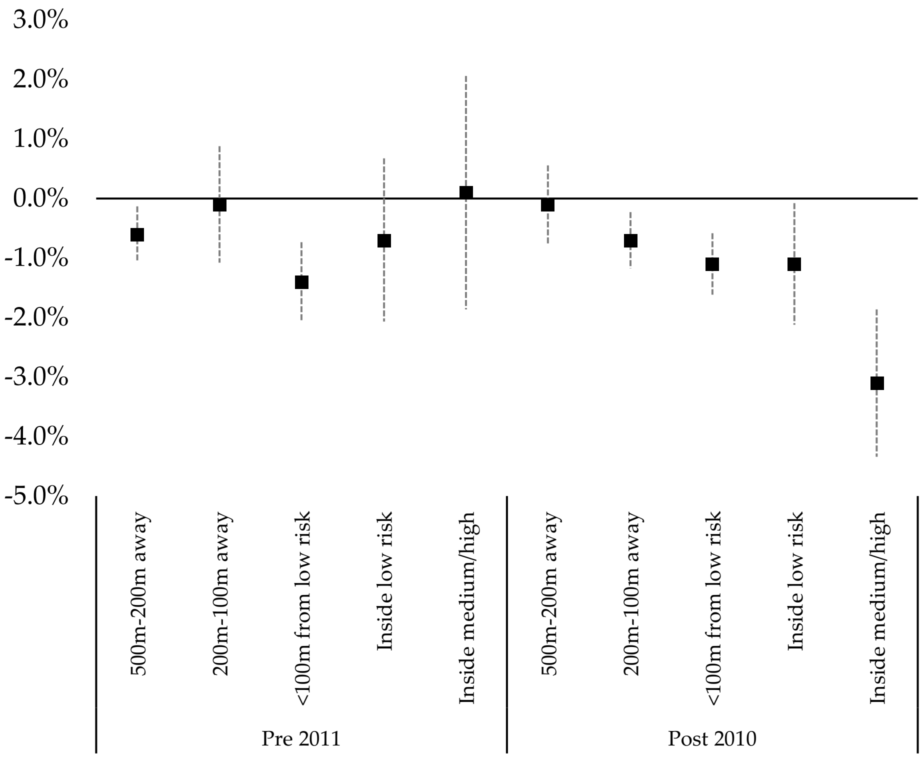
Note: the figure shows the estimated coefficients and confidence intervals for being inside the medium flood risk zone published in 2011, based on our preferred specification for sale and rental listings before and after this information is released; see Table 3.

Figure 2: Estimated flood discount, by year and segment



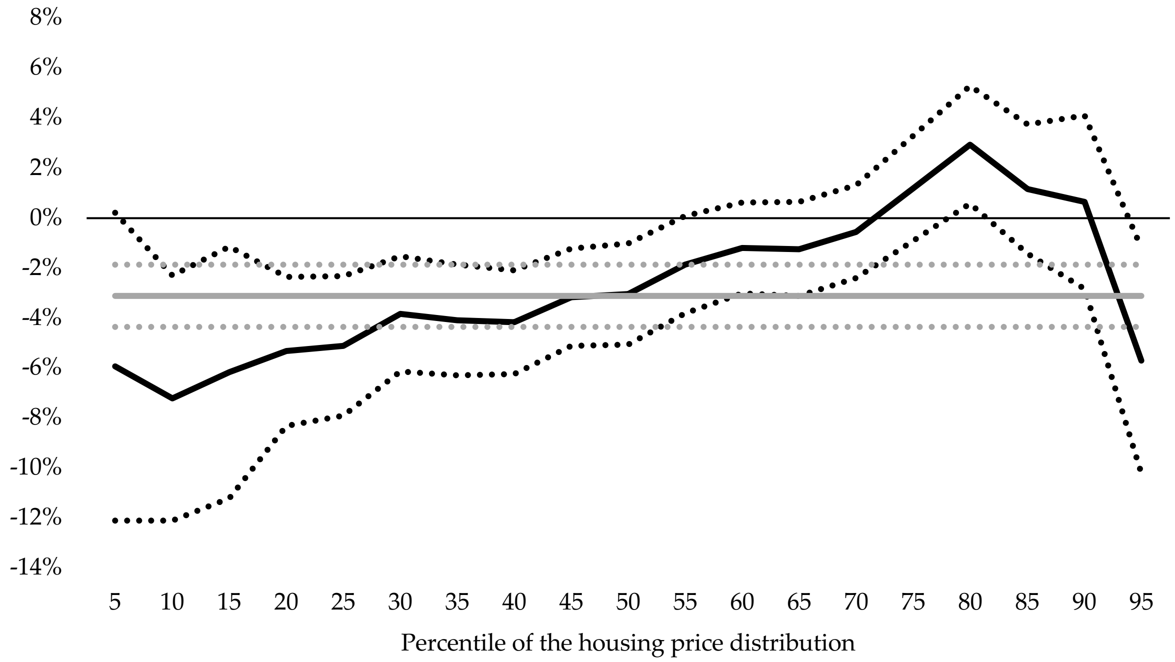
Note: The figures show the time-varying estimated flood discount (with 95% confidence interval) for dwellings within a medium to high flood risk zone, based on specifications similar to those reported in Table 3, but with the 2006-2010 and 2011-2019 samples combined and the flood risk indicator interacted with year. The red dashed vertical line in each panel indicates the release of the new information on flood risk (in 2011).

Figure 3: Estimated effect of flood risk on housing prices, by distance categories and segment



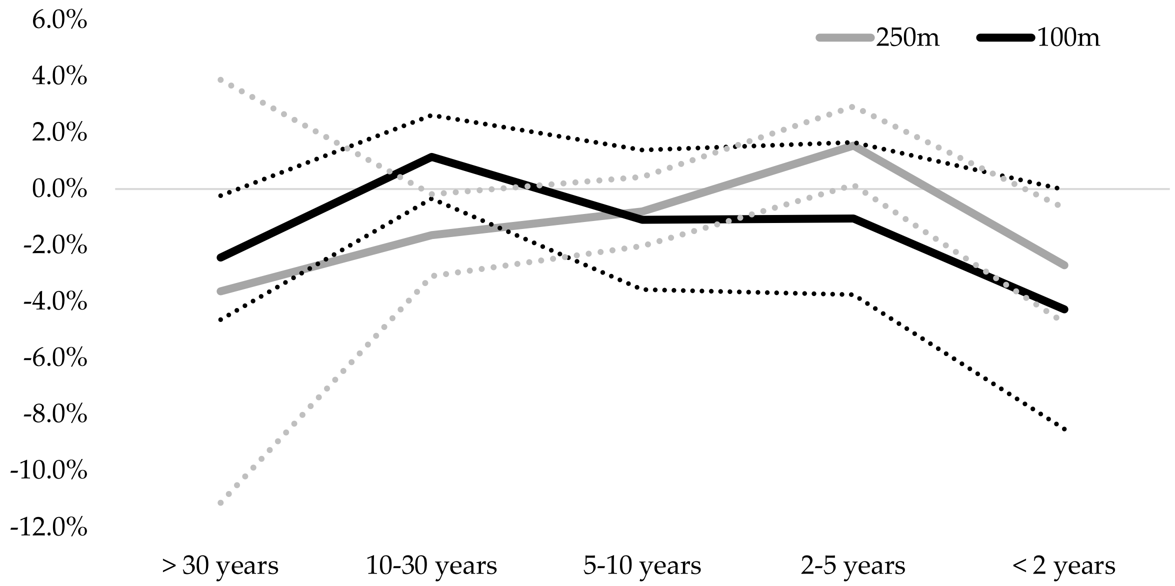
Note: The figure illustrates the magnitude of the estimated flood discount for each distance category (without flood defences) for the pre-2011 and post-2010 samples of sale listings data, as presented in Table 3.

Figure 4: Estimated flood discounts over the price distribution, sale listings dataset



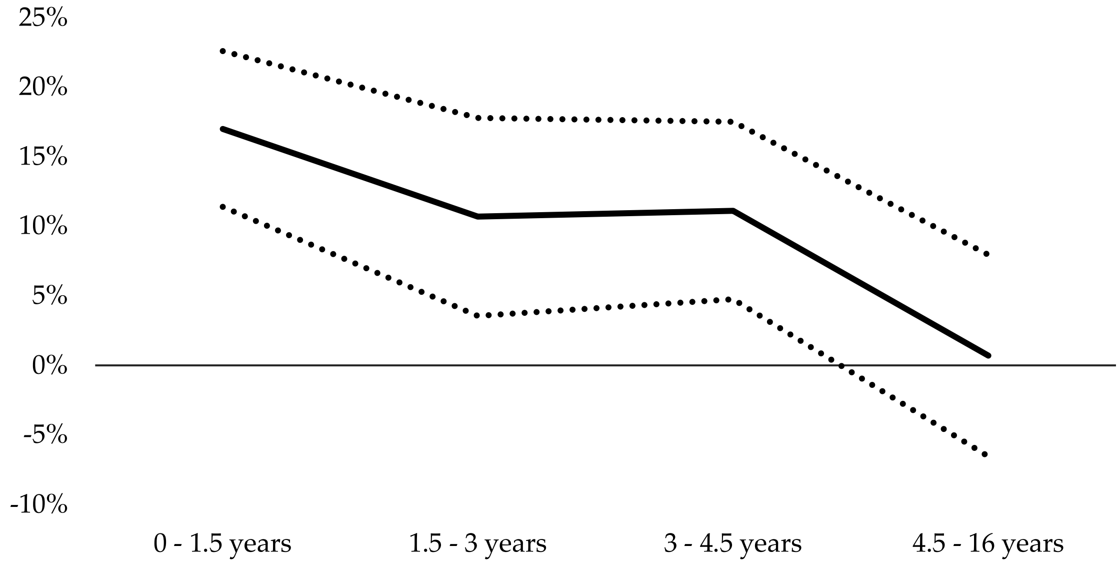
Note: This figure shows the flood discount for dwellings located within the medium/high flood risk zone on the y-axis and the price ventiles on the x-axis, based on the 2011-2018 sale listings sample. The solid black line indicates the point estimates from unconditional quantile regressions, with the corresponding 95% confidence intervals shown in dashed black lines. The solid grey line indicates the OLS estimate of the flood discount (from Table 3), with corresponding confidence intervals given by grey dashed lines. In all cases, the same controls as Table 3 are included, with ED locational fixed effects.

Figure 5. Estimated effect of recent flood events on housing prices, by time distance, sale listings dataset



Note: *The figure illustrates the magnitude of the estimated effect of past flood events that occurred within 100m of a dwelling (black line) or 100m-250m from a dwelling (grey line), along with 95% confidence intervals, by intervals of time elapsed since the most recent flood event in each category. The specifications are as per those reported in Table 3. See Appendix B, Table B.1, for full regression results.*

Figure 6: Estimated flood defence premium, by time since scheme construction



Note: The figure reports coefficients (and confidence intervals) for the time-varying effect of flood defences on housing values, for dwellings within a medium to high risk zone. The specification is similar to that reported in Column 2 of Table 3.

Appendices

(Online supplementary material – not for publication)

Appendix A: Data

A.1 Flood events

Table A.1. Frequency of flood event variables

Flood events measure		**Sales Listings**	**Sales Transactions**	**Rentals Listings**
Flooding within 100-250m of dwelling	None	269,726	37,216	463,904
	More than 30 years	302	41	2,277
	10-30 years	2,425	318	8,848
	5-10 years	2,614	522	6,568
	2-5 years	2,523	468	6,110
	Less than 2 years	1,291	167	5,779
Flooding within 100m of dwelling	More than 30 years	1,665	293	5,023
	10-30 years	2,460	329	8,359
	5-10 years	907	140	3,924
	2-5 years	686	118	2,297
	Less than 2 years	283	31	1,687
Total sales		284,882	39,643	514,776

Note: The table shows the frequency of observations in each of the 11 categories related to exposure to past flood events, as described in the text, for three samples: sale listings (2006-2018), sale transactions (2010-2018) and rental listings (2006-2018).

A.2 Housing data

As noted in Section 2.2 in the paper, our housing data come from three rich datasets, including a national dataset of listings from the real estate website daft.ie. In addition to detailed systematic information on dwelling attributes such as size and type, a large number of other attributes were also available from the text of the ad placed on daft.ie for each dwelling. This includes a vector of categorical variables for specific features (such as "built-in wardrobes", "patio", "red brick" or "balcony"), as well as information relating to the age or condition of the property; full details are provided in Appendix Table A.2 and A.3 below.

To complement our listings dataset, we use a supplementary dataset of housing transactions taking place in Dublin, Ireland (the largest city). The underlying data relate to property transactions, recorded on Ireland's official Residential Property Price Register (PPR).[24] This register is a comprehensive database of all property transactions in Ireland since 2010, based on transaction tax returns made by solicitors. The register only contains the property's address as entered by the solicitor, the date of its transfer, its contractually agreed price, whether the dwelling is newly built, and whether the price is a full market price or not (i.e. whether the transaction is arm's length).

In order to accurately map these transactions, and to add the dwelling characteristics needed for hedonic housing price regressions, transactions for Dublin were mapped to Ireland's official Eircode dwelling-level identifiers. This was undertaken by daft.ie, using an iterative process of automatic scripts, reviewed manually to ensure accuracy. Successful matches between the PPR and Eircodes enabled the identification of the exact dwelling, based on its location. Dwelling characteristics were added using Eircode matches with the database of Building Energy Ratings (BERs), which is maintained by the Sustainable Energy Authority of Ireland (SEAI). In accordance with EU regulations, since 2007 for new dwellings, and since 2009 for existing dwellings, it has been mandatory for all dwellings sold to have a standardized energy rating, on a scale from A1 to G. The only exceptions are for protected structures, although in some instances these will still have BERs for marketing purposes. BER certificates include rich property-level information entered

[24] The data are available at www.propertypriceregister.ie (last accessed July 2020).

by registered assessors, including the age, exact floor area in square meters, type of the dwelling, and number of storeys, as well as a variety of attributes used to calculate its overall energy rating, such as glazing and fuel type.

These PPR-BER matches were then reviewed for timing also. Where the date of the BER was either a month after the transaction, or a year before, this match was excluded as in either case the property attributes measured in the BER may differ from those reflected in the PPR, due to renovations. PPR-BER matches through Eircodes form one transactions-level dataset, the 'double match' transactions dataset. An additional 'triple match' transactions dataset was also constructed, containing those properties that are on PPR, BER and daft.ie databases (as measured by their Eircodes). To do this, the daft.ie database was also mapped to Eircodes. This enables important robustness checks, including both a direct comparison between the properties included in both datasets and the inclusion in specifications of transactions prices of all property-level information available from daft.ie. Of 108,005 transactions at full market price in Dublin 2010-2018, it was possible to match 71,850 to an Eircode, and 64,432 to a BER cert matching the timing criteria. This is the 'double match' transactions dataset. Of these, a total of 39,789 were additionally matched to daft.ie listings, the 'triple match' transactions dataset used as our baseline sale transactions dataset.

A.3 Treatment of location

Location was calculated by daft.ie using a quasi-official mapping of addresses to coordinates known as Geodirectory. This process is necessarily imprecise, as addresses are often non-unique or entered with error. The script used to map addresses to exact location returns a confidence level, to which the location is mapped (e.g. 'street-level' or 'building-level'). Given the subject of our analysis, we use only listings with the highest level of location accuracy (building-level) in our analysis. In the transactions dataset, all dwellings are mapped using the newly established official Eircode dwelling-level identifiers, providing precise location information for each dwelling. Given the manual reviews of the matching process, the exact locations in the transactions dataset come with a very high degree of confidence. Having exact coordinates allows the calculation of not only distance to relevant measures of flood risk, as described above, but also a variety of other location-specific amenities. These include nearest city centre, transport facilities, schools, and natural amenities; a full list is given in Appendix Table A.2 and A.3 below.

Nonetheless, despite these inclusions, there are always likely to be some spatial processes or area attributes that remain unobserved in the data. For this reason, spatial fixed effects are included, to capture the impact on housing prices of factors that are not included in a given specification, including location-specific and population-specific attributes. Four options are considered: local markets, 'micro-markets', Electoral Divisions, and Small Areas. The first two are based on daft.ie's breakdown of real estate markets nationwide. Local markets refer to cities, postal districts (within Dublin city), and counties elsewhere in the country; there are a total of 54 markets in Ireland and 25 within Dublin. Micro-markets refer to collections of named areas on the daft.ie system. They are aggregated up from approximately 2,500 areas around the country into micro-markets, based on the volume of market activity, and geographical and socio-economic coherence. There are 375 micro-markets included in the dataset, of which 118 are in Dublin.

The latter two options for spatial fixed effects are based on Census divisions of the country, and use the coordinates of the property, rather than the named area in the listing. There are just over 3,500 Electoral Divisions (EDs) in the country. Reflecting the focus of the analysis on AFAs, the nationwide listings sample cover 1,028 EDs, while the Dublin transactions sample covers 322. Lastly, Census 'Small Areas' (SAs) are a new spatial categorization of Ireland, introduced in the 2011 Census and with an average of 180 dwellings per SA. Of 18,641 SAs in the country, 10,815 are covered in the sale listings dataset and 4,557 in the transactions dataset. The rentals listings dataset includes 1,002 ED's and 10,702 SA's. Table 3 in the main paper outlines the number of spatial units in the samples and the mean and median number of observations per unit.

A.4 Dwelling attributes

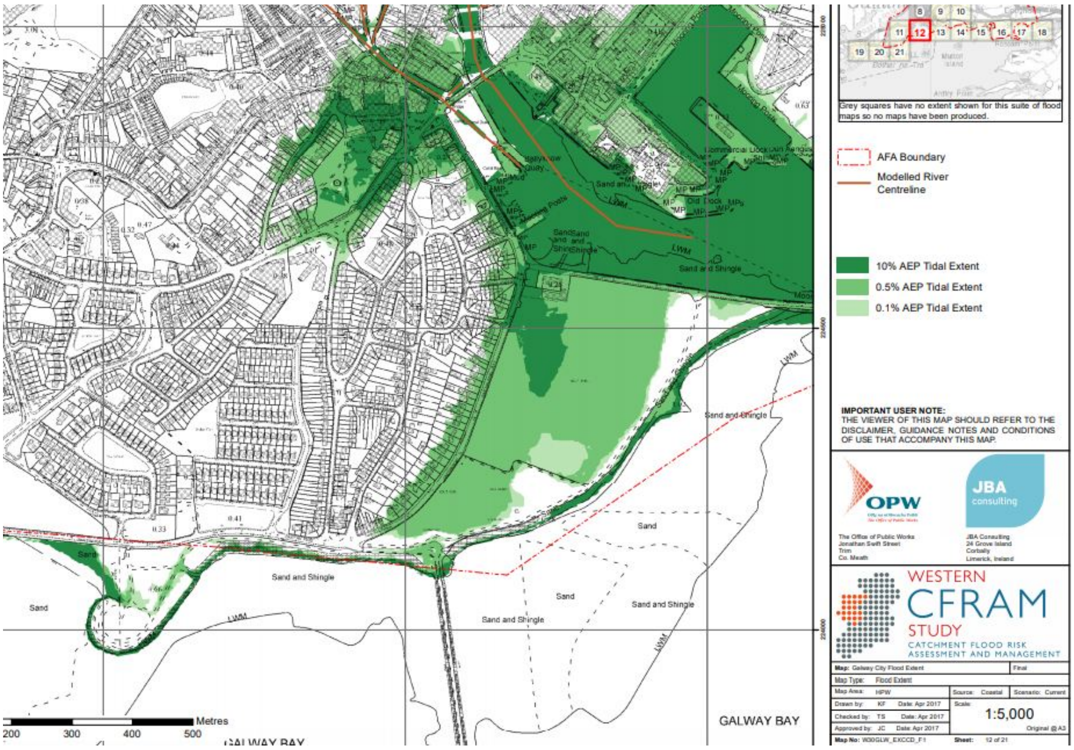
Key property-level attributes for inclusion in a hedonic housing price model include the property's type and size. In our data, we distinguish between apartments and houses dwelling types, with apartments further segmented between duplexes and regular apartments. For houses, there are additional distinctions in the data between terraced, semi-detached, detached and bungalow houses. These distinct property types are captured in our regressions using categorical variables.

Floor area (in square metres) is not a widely used size metric by consumers in Ireland and consequently, the majority of sale listings do not include this information. To capture a property's size in the listings data, indicator variables are included for number of bedrooms (one to five) and for number of bathrooms (one to seven) relative to number of bedrooms. The sale transactions dataset includes floor area in exact square metres, based on information from official energy efficiency assessments of each individual dwelling, as well as other attributes including its year of construction and the number of floors in the dwelling.

In terms of other property-level characteristics, the sale and rental listings datasets include a large range of other attributes, including those mined from the text of the ad, which gives an indication of dwelling amenities and features. A full list of these dwelling attributes, and their summary statistics, is given in Appendix Table A.2 and A.3 below.

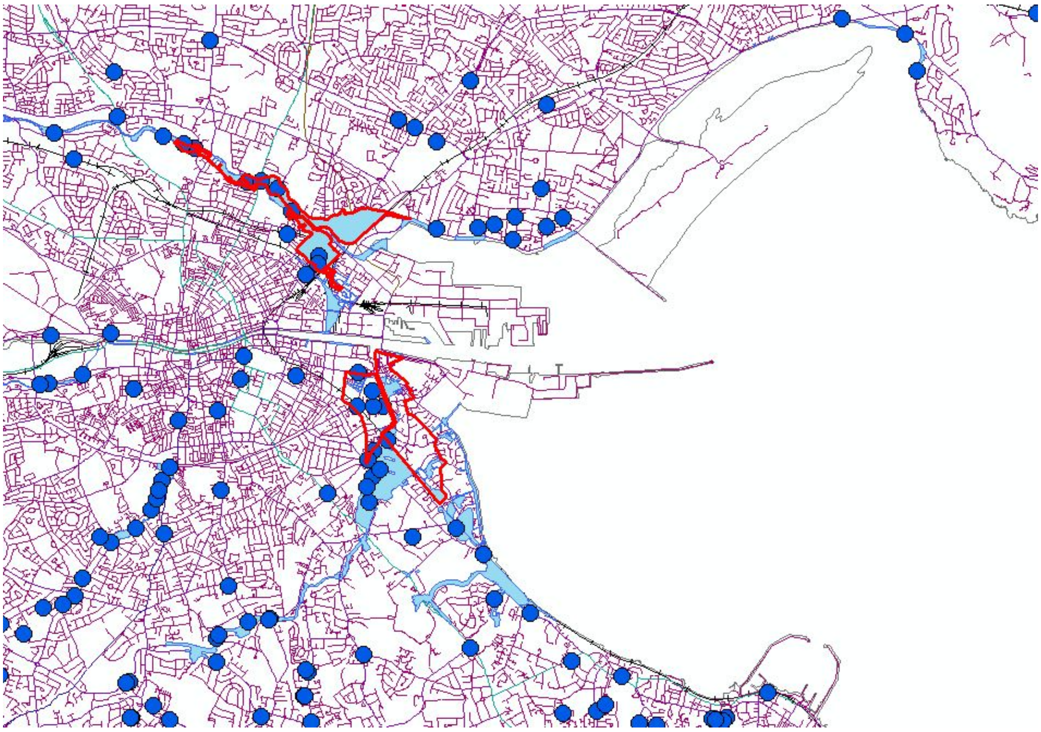
A.5 Figures

Figure A.1: CFRAM example



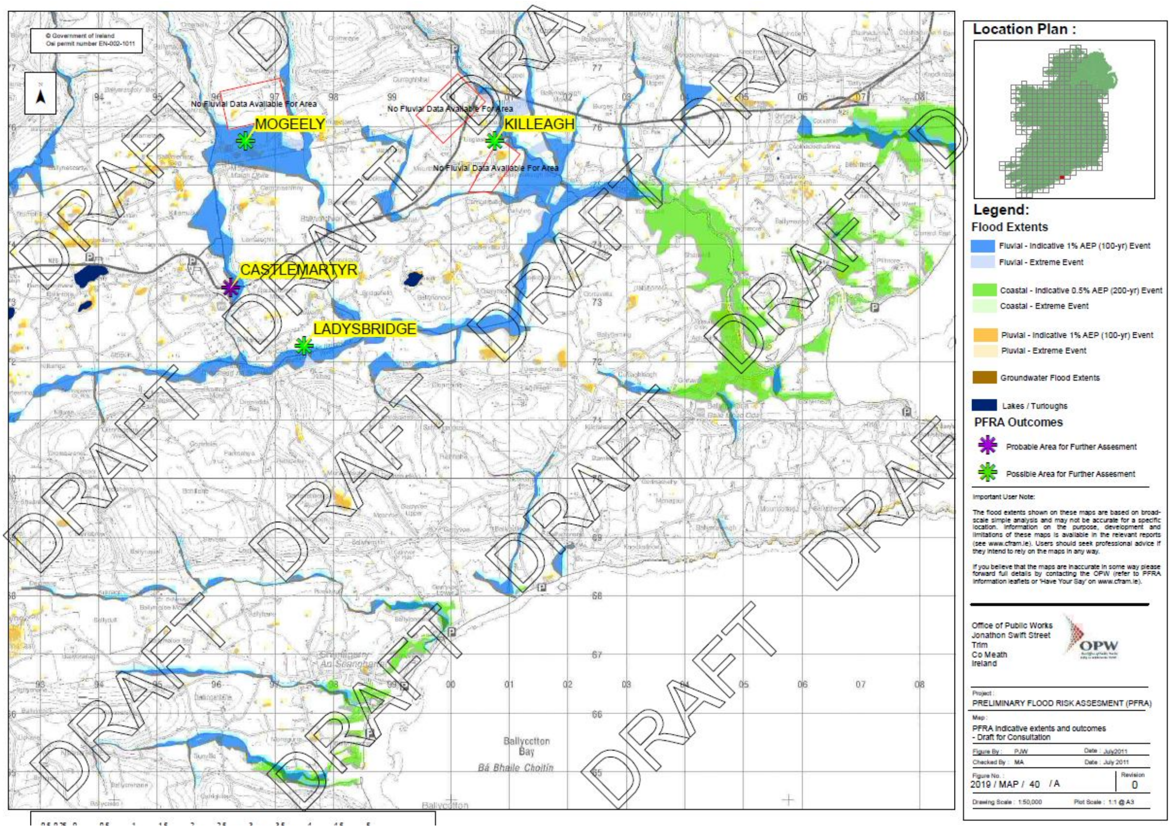
Note: The above figure is an example of the publicly available CFRAM maps which can be accessed at floodinfo.ie. The CFRAM maps are of the highest precision at 2 meter resolution making it possible to ***distinguish e.g. individual dwellings at risk and not at risk on the same street or in the same housing estate.***

Figure A.2: Flood events and flood defences



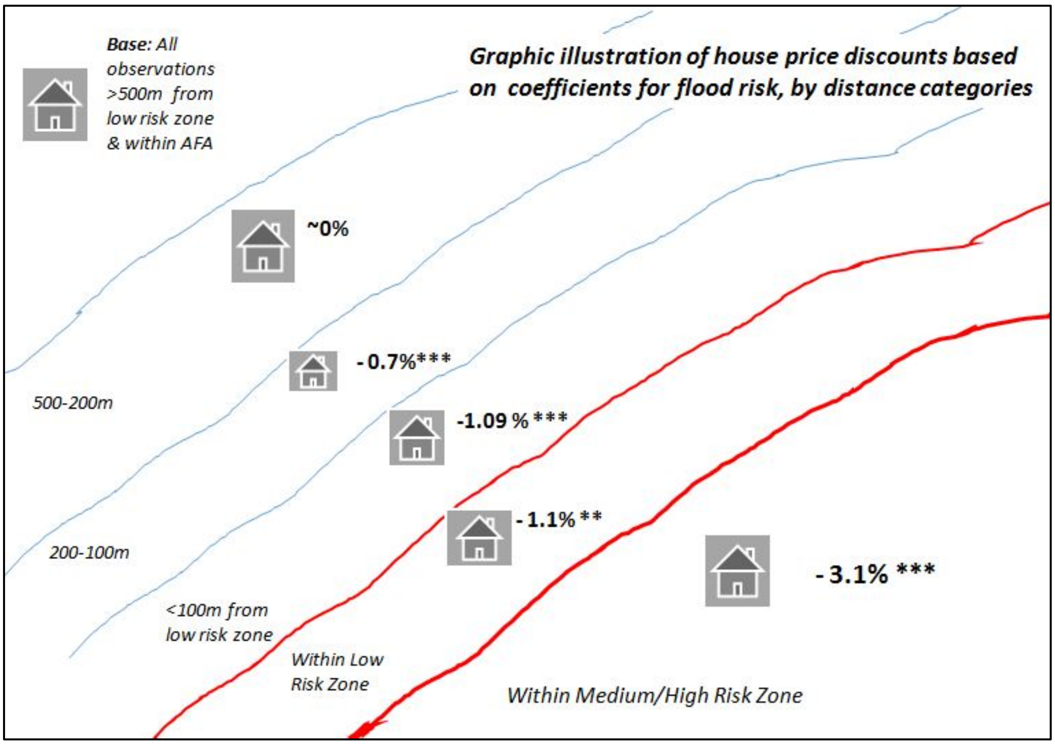
Note: The above figure displays flood event points (blue dots), flood event extents (blue polygons), and areas protected by flood defences (red outlines) for the Dublin area.

Figure A.3: PFRA map example



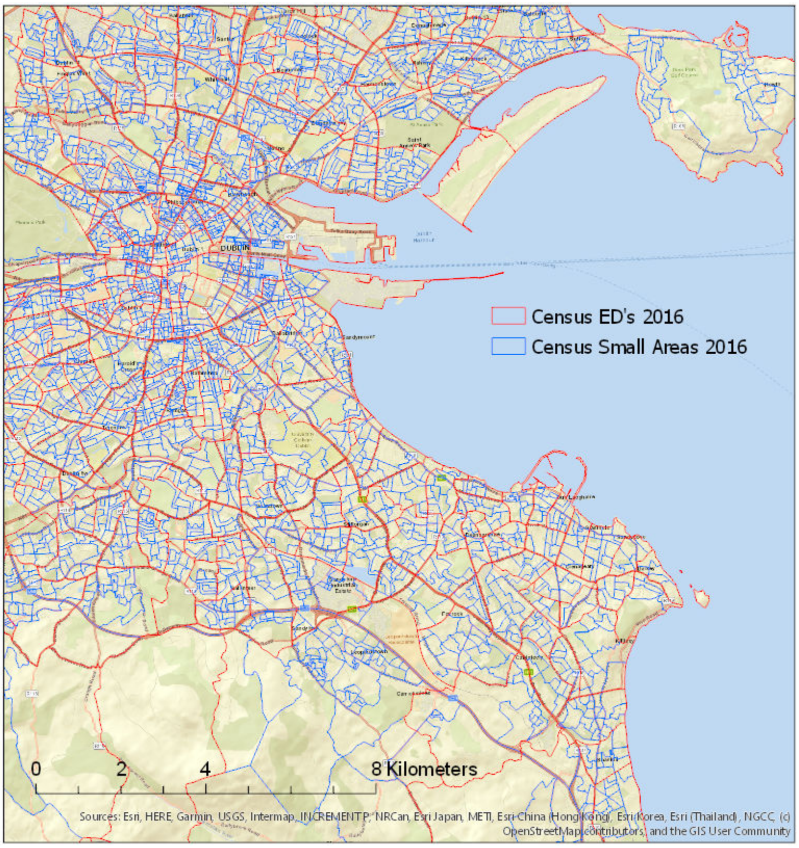
Note: The above figure displays the extent of the PFRA flood risk areas as described in the text. These maps were made publicly available in 2011 at a high enough resolution to identify individual dwellings. PFRA maps had a national coverage but with varied levels of resolution. These were then replaced by the CFRAM maps in 2014, an example of which can be seen in Figure A.1.

Figure A.4: Illustration of flood discount by distance



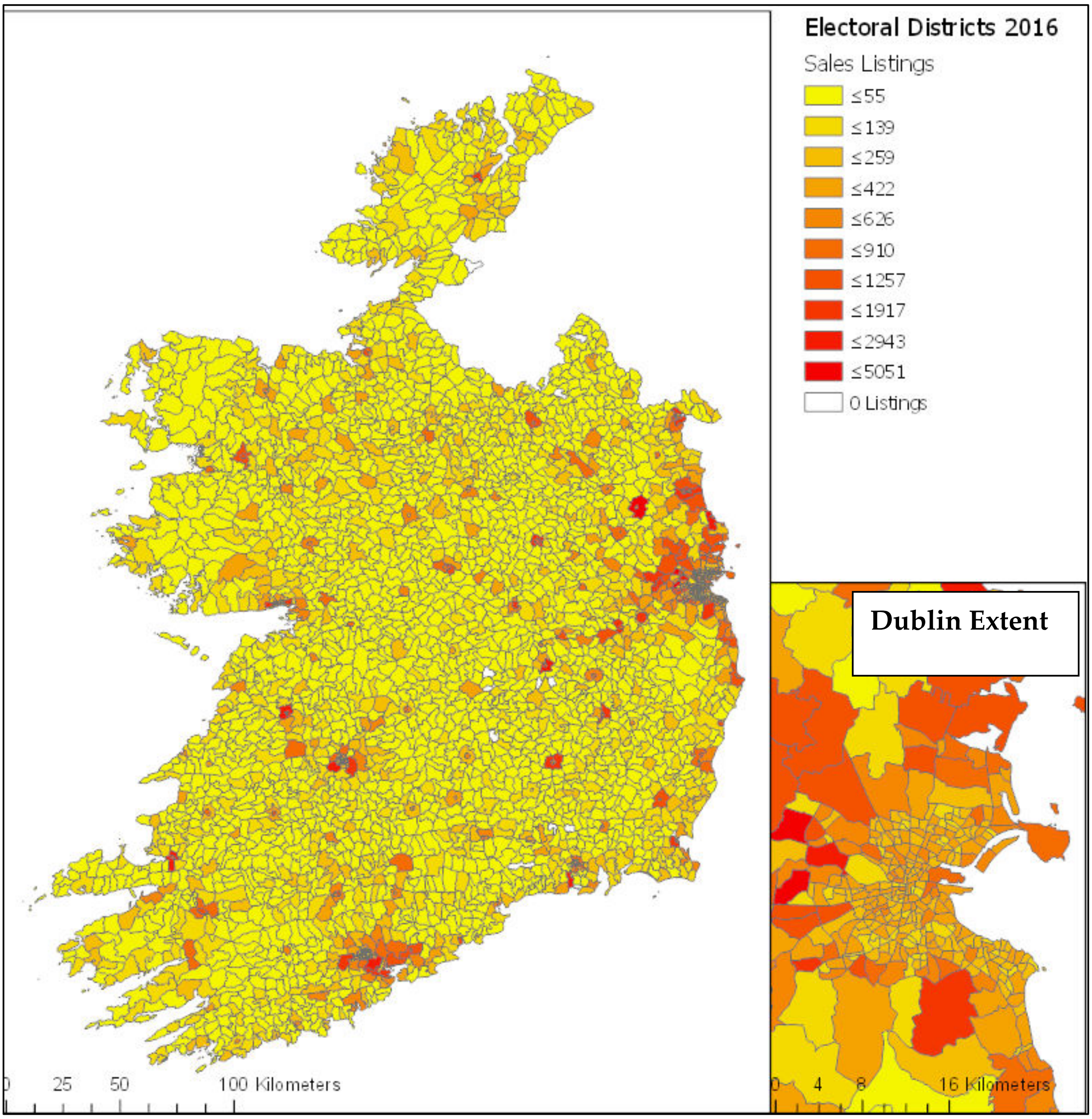
Note: The above figure spatially illustrates the results of the main specification for flood risk from the sales listings sample from Table 4 in the main text.

Figure A.5: Census 2016 ED and small area boundaries for Dublin area



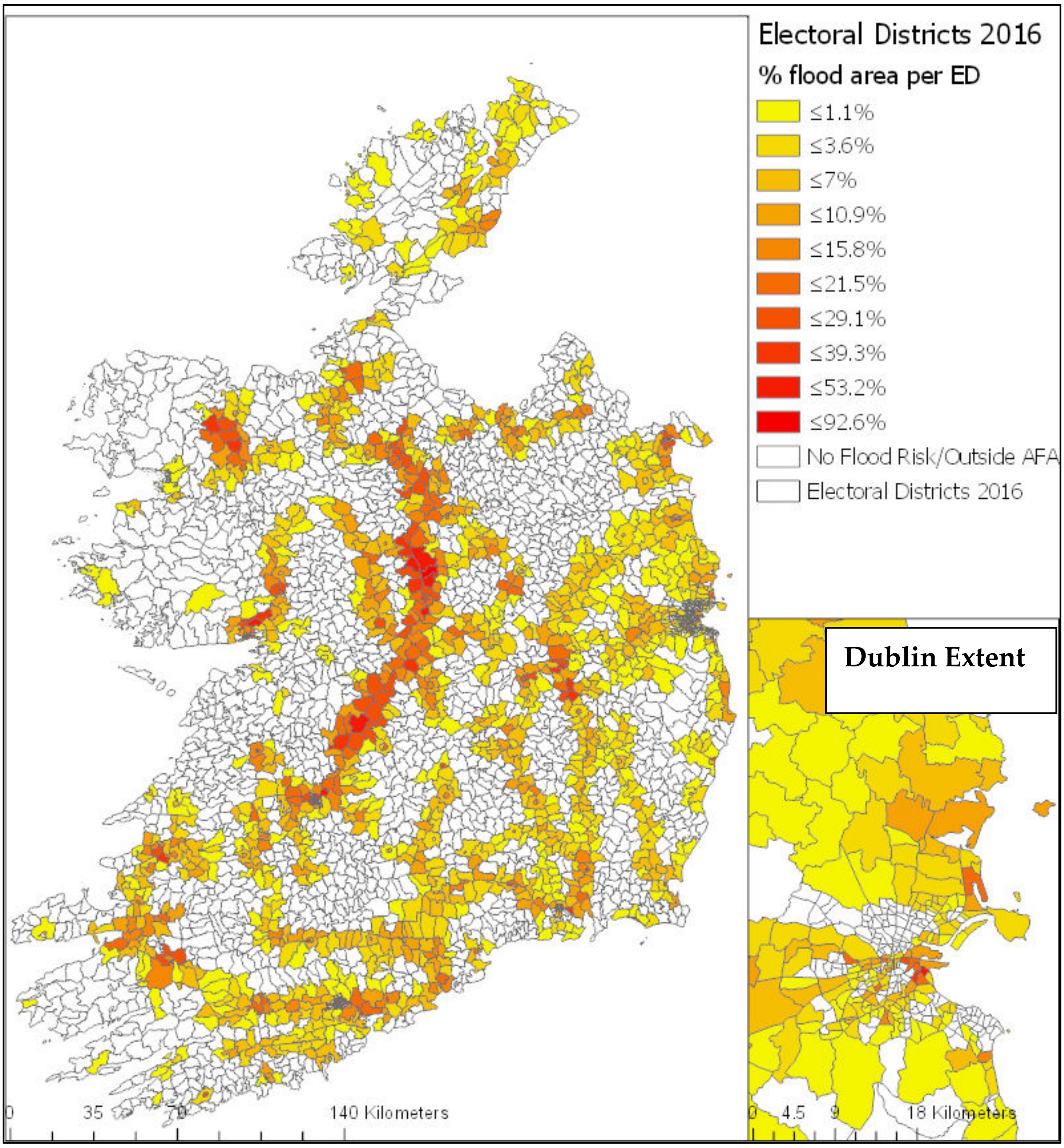
Note: The above figure shows boundary outlines for electoral districts and small areas, the primary levels of spatial fixed effects used in the analysis.

Figure A.5: Distribution of sales listings per ED



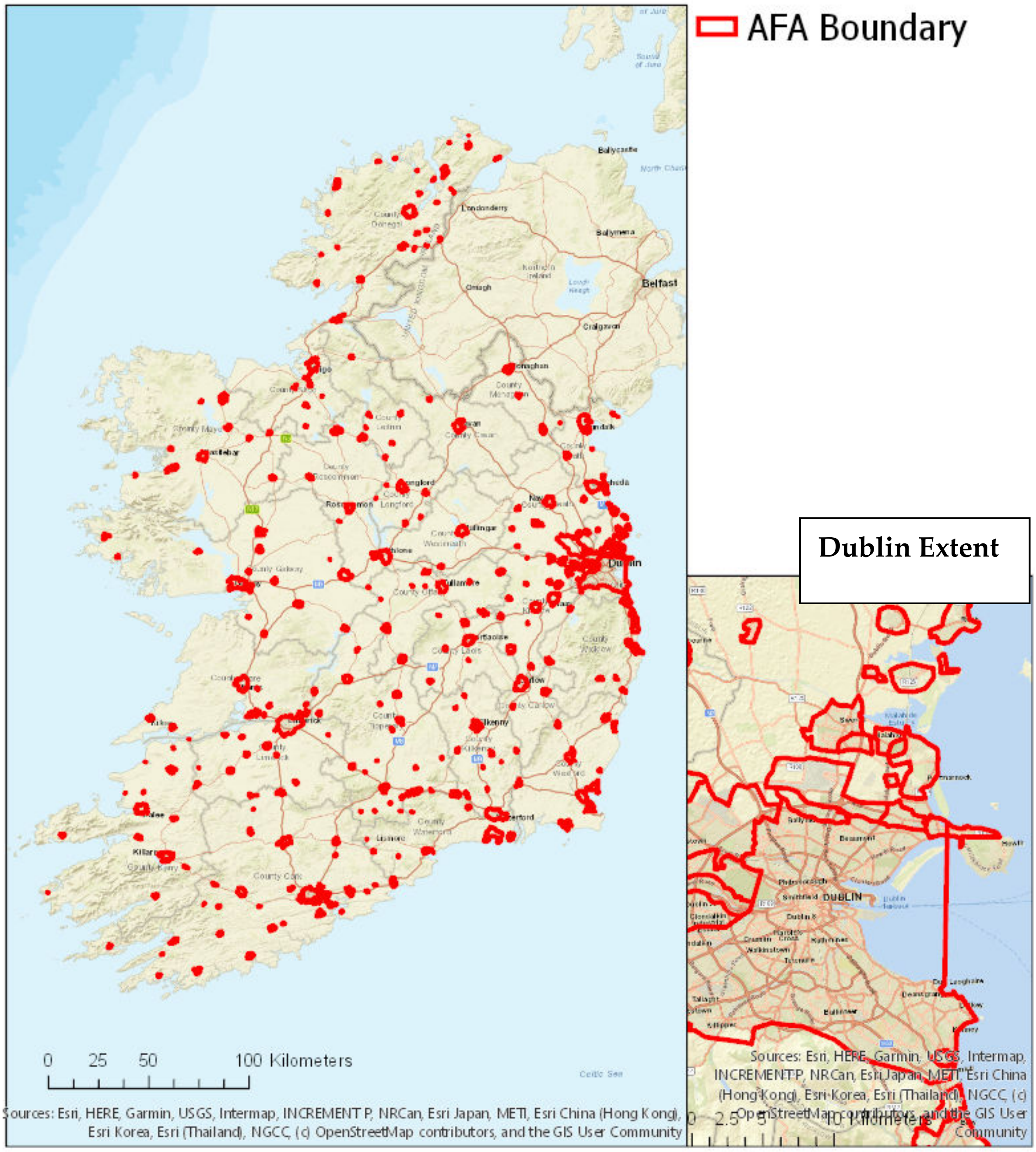
Note: The above figure displays the number of sales listings per electoral district.

Figure A.6: Distribution of flood risk per ED



Note: The above figure displays the percentage of electoral district area which is classified as a medium/high coastal/fluvial flood risk zone from the CFRAM dataset. Blank ED's either have no flood risk or are outside AFA boundaries.

Figure A.7: AFA boundaries



Note: The above figure displays boundaries of the "Areas of Further Assessment" (AFAs), which define the geographic scope of the samples used in our baseline (preferred) specifications.

A.6 Frequencies of variables

Table A.2: Continuous Variables frequencies

	VARIABLES	N	mean	sd	min	p25	p50	p75	max
Sales Listings 2006-18	Price	284,954	276,167	195,393	30,000	158,000	235,000	335,000	2.00E+06
	primary school	284,954	587	409.1	0.414	297.4	483.7	759.8	6,306
	secondary school	284,954	1,150	1,621	2.578	446.4	733.7	1,210	19,887
	distance to CBD	284,954	28,930	29,039	0.393	5,110	15,409	44,046	130,428
	distance to major road	284,954	1,466	2,103	0.0177	345.5	798.5	1,684	29,257
	% unemployed	284,936	11.55	6.05	0	6.993	10.73	15.06	56.28
	% with degree	284,861	11.07	6.914	0	5.882	10	15	50
	Distance to coastline	284,954	19,546	23,123	0.226	2,756	8,964	29,075	91,916
	Dist. trans. waters	284,954	12,633	19,080	0	1,085	3,844	15,380	85,652
	Sea view	284,954	0.00637	0.0371	0	0	0	0	0.544

	VARIABLES	N	mean	sd	min	p25	p50	p75	max
Sales Transactions 2011-18	Sale price	36,341	361,951	218,513	31,276	222,000	305,000	435,000	2.00E+06
	Floor area	36,341	99.22	41.88	11.59	72.18	91.46	116.4	726.3
	Main water heating efficiency	36,070	82.76	14.89	30	75.4	79.4	90.5	417
	Main space heating efficiency	36,070	82.57	19.39	30	75	79.2	90.4	566
	Building age	36,341	41.61	32.3	-4	15	32	61	258
	Building area	36,341	151.4	670.1	0	50.22	64.34	86.46	45,141
	distance to CBD	36,341	1,184	1,226	0.0968	377.3	856.8	1,610	8,942
	distance to major road	36,341	7,998	5,395	72.93	4,069	7,156	10,969	31,226

primary school	36,341	470.9	272.7	10.42	274.2	424	611.7	3,075
secondary school	36,341	754.1	597.8	34.58	400.5	622.4	895.6	8,778
% unemployed	36,341	8.845	5.012	0	5	7.975	11.73	40.86
% with degree	36,341	14.51	8.247	0	8	13.79	19.79	45.45
Distance to coastline	36,341	5,138	4,216	5.713	1,734	4,000	7,162	20,947
distance transitional waters	36,341	4,048	2,930	6.859	1,475	3,356	6,556	15,419
Sea view	36,338	0.0101	0.0452	0	0	0	0	0.613

Rental Listings 2011-18

VARIABLES	N	mean	sd	min	p25	p50	p75	max
Rent (annual)	390,353	13,269	7,804	2,086	8,340	11,400	15,642	108,000
primary school	390,353	523	362.7	1	264.9	440.6	680.3	6,298
secondary school	390,353	879.7	1,171	2.51	370.3	606.8	972.1	19,836
distance to CBD	390,353	20,477	26,670	3.47	2,350	7,361	29,757	130,386
distance to major road	390,353	1,062	1,512	0.00102	253.2	618.8	1,254	29,256
% unemployed	390,353	10.85	6.227	0	6.04	9.836	14.43	56.28
% with degree	390,322	14.43	8.408	0	7.826	13.19	19.88	66.67
Distance to coastline	390,353	14,139	19,980	0.0637	2,014	5,170	14,318	91,823
Dist. trans. waters	390,353	8,577	15,859	0	642.1	2,021	7,152	85,802
Sea view	390,353	0.00614	0.035	0	0	0	0	0.551

Table A.3: Frequency of categorical variables

		Sales Listings 2011-18		Sales Transactions 2011-18		Sales Listings 2006-18		Rental Listings 2011-18	
Property Type									
Apartment		30,039	15.75%	7,681	21.14%	33,231	11.66%	193,220	49.50%
Terraced		34,871	18.28%	8,531	23.47%	53,907	18.92%	N/A	
End-of Terrace		13,346	7.00%	3,456	9.51%	19,336	6.79%	N/A	
Bungalow		7,351	3.85%	836	2.30%	10,678	3.75%	N/A	
Detached		34,243	17.95%	2,829	7.78%	51,901	18.21%	N/A	
Duplex		2,664	1.40%	853	2.35%	3,029	1.06%	N/A	
Townhouse		3,490	1.83%	438	1.21%	5,550	1.95%	N/A	
Semi-Detached		64,772	33.95%	11,717	32.24%	107,322	37.66%	N/A	
House		N/A		N/A		N/A		13,536	3.47%
Flat		N/A		N/A		N/A		182,689	46.80%
Studio		N/A		N/A		N/A		908	0.23%
Total		**190,776**	**100%**	**36,341**	**100%**	**284,954**	**100%**	**390,353**	**100%**
Property Size (Bedroom:Bathroom)									
	11	6,898	3.62%	2,039	5.61%	8,146	2.86%	69847	17.89%
	12	202	0.11%	41	0.11%	249	0.09%	1391	0.36%
	13	17	0.01%			31	0.01%	48	0.01%
	14	5	0.00%			17	0.01%	12	0.00%
	15	1	0.00%			1	0.00%	1	0.00%

16	0	0.00%			0	0.00%	1	0.00%
21	23,317	12.22%	6,030	16.59%	31,869	11.18%	83049	21.28%
22	15,482	8.12%	3,875	10.66%	18,131	6.36%	67889	17.39%
23	1,213	0.64%	205	0.56%	1,565	0.55%	3456	0.89%
24	13	0.01%	3	0.01%	18	0.01%	29	0.01%
25	0	0.00%			0	0.00%	2	0.00%
26	1	0.00%			1	0.00%	1	0.00%
27	0	0.00%	0		0	0.00%	2	0.00%
31	35,435	18.57%	7,987	21.98%	61,424	21.56%	36358	9.31%
32	29,235	15.32%	5,457	15.02%	44,635	15.66%	43270	11.08%
33	18,066	9.47%	2,904	7.99%	26,248	9.21%	25534	6.54%
34	635	0.33%	126	0.35%	803	0.28%	889	0.23%
35	18	0.01%	3	0.01%	21	0.01%	20	0.01%
36	3	0.00%			3	0.00%	7	0.00%
37	2	0.00%			2	0.00%	2	0.00%
41	7,238	3.79%	1,163	3.20%	14,301	5.02%	6987	1.79%
42	18,001	9.44%	2,526	6.95%	27,788	9.75%	19330	4.95%
43	19,569	10.26%	2,288	6.30%	28,016	9.83%	19096	4.89%
44	3,891	2.04%	389	1.07%	4,883	1.71%	3183	0.82%
45	492	0.26%	50	0.14%	588	0.21%	473	0.12%
46	50	0.03%	6	0.02%	66	0.02%	30	0.01%
47	1	0.00%			4	0.00%	6	0.00%
51	829	0.43%	103	0.28%	1,919	0.67%	545	0.14%
52	2,840	1.49%	385	1.06%	4,391	1.54%	2812	0.72%
53	4,111	2.15%	462	1.27%	5,741	2.01%	3586	0.92%
54	2,265	1.19%	218	0.60%	2,942	1.03%	1767	0.45%
55	718	0.38%	63	0.17%	875	0.31%	565	0.14%
56	199	0.10%	15	0.04%	243	0.09%	139	0.04%
57	29	0.02%	3	0.01%	33	0.01%	26	0.01%

Phrase (Dummy)								
”balcony”	16,816	8.81%	5,208	14.33%	18,543	6.51%	56,497	14.47%
”bay_window”	23,122	12.12%	4,204	11.57%	33,402	11.72%	3,765	0.96%
”conservatory”	5,202	2.73%	1,266	3.48%	8,041	2.82%	3,802	0.97%
”deck”	14,269	7.48%	3,447	9.49%	23,394	8.21%	10,720	2.75%
”double_glaze”	46,892	24.58%	9,650	26.55%	73,574	25.82%	17,105	4.38%
”edwardian”	418	0.22%	154	0.42%	535	0.19%	234	0.06%
”ensuite”	56,845	29.80%	9,623	26.48%	81,595	28.63%	81,701	20.93%
”fireplace”	86,136	45.15%	18,233	50.17%	125,783	44.14%	24,959	6.39%
”frenchdoors”	13,462	7.06%	2,692	7.41%	18,400	6.46%	3,749	0.96%
”garage”	24,914	13.06%	5,224	14.37%	36,429	12.78%	11,926	3.06%
”garden”	125,408	65.74%	27,462	75.57%	188,785	66.25%	126,964	32.53%
”georgian”	1,159	0.61%	186	0.51%	1,641	0.58%	2,765	0.71%
”granny_flat”	944	0.49%	162	0.45%	1,323	0.46%	395	0.10%
”highceilings”	4,156	2.18%	1,227	3.38%	5,064	1.78%	4,127	1.06%
”jacuzzi”	3,808	2.00%	642	1.77%	5,449	1.91%	2,955	0.76%
”mews”	1,247	0.65%	274	0.75%	1,543	0.54%	2,422	0.62%
”patio”	57,123	29.94%	10,563	29.07%	83,819	29.41%	36,588	9.37%
”period”	5,637	2.95%	1,713	4.71%	7,340	2.58%	7,732	1.98%
”redbrick”	5,226	2.74%	1,881	5.18%	7,361	2.58%	1,737	0.44%
”sash”	1,610	0.84%	406	1.12%	2,027	0.71%	1,210	0.31%
”securitygates”	729	0.38%	214	0.59%	940	0.33%	2,182	0.56%
”solar”	2,351	1.23%	249	0.69%	2,617	0.92%	989	0.25%
”sunroom”	7,760	4.07%	1,505	4.14%	11,067	3.88%	3,199	0.82%
”terrace”	41,326	21.66%	9,724	26.76%	62,384	21.89%	39,934	10.23%
”tripleglaze”	1,102	0.58%	229	0.63%	1,136	0.40%	524	0.13%
”underfloor”	2,675	1.40%	663	1.82%	3,313	1.16%	4,466	1.14%

”utility”	54,966	28.81%	7,998	22.01%	79,798	28.00%	39,760	10.19%
”victorian”	1,769	0.93%	507	1.40%	2,273	0.80%	1,553	0.40%
”walkinwardrobe”	6,602	3.46%	939	2.58%	8,585	3.01%	4,688	1.20%
”wetroom”	4,330	2.27%	1,201	3.30%	4,914	1.72%	1,626	0.42%
river_views (<75m &"views"==1)	1,367	0.72%	212	0.58%	1,632	0.57%	2,606	0.67%
lake_views (<75m &"views"==1)	233	0.12%	74	0.20%	255	0.09%	834	0.21%
Golf Course								
>1k (Base)	151,366	79.34%	27,792	76.48%	226,827	79.60%	320,861	82.20%
500m-1k	23,645	12.39%	4,908	13.51%	35,146	12.33%	43,280	11.09%
250m-500m	8,988	4.71%	2,080	5.72%	13,379	4.70%	15,455	3.96%
100m-250m	4,518	2.37%	1,073	2.95%	6,472	2.27%	7,228	1.85%
<100m	2,259	1.18%	488	1.34%	3,130	1.10%	3,529	0.90%
Powerlines								
>1k (Base)	157,827	82.73%	29,631	81.54%	232,872	81.72%	337,335	86.42%
500m-1k	18,320	9.60%	3,521	9.69%	28,794	10.10%	29,882	7.66%
250m-500m	7,414	3.89%	1,593	4.38%	11,868	4.16%	11,821	3.03%
100m-250m	4,556	2.39%	1,004	2.76%	7,165	2.51%	6,888	1.76%
<100m	2,659	1.39%	592	1.63%	4,255	1.49%	4,427	1.13%
Mixed Woodlands								
>1k (Base)	167,044	87.56%	29,581	81.40%	250,241	87.82%	350,272	89.73%
500m-1k	14,918	7.82%	4,508	12.40%	21,823	7.66%	25,257	6.47%
250m-500m	5,508	2.89%	1,442	3.97%	8,216	2.88%	8,544	2.19%
100m-250m	2,198	1.15%	547	1.51%	3,184	1.12%	4,212	1.08%
<100m	1,108	0.58%	263	0.72%	1,490	0.52%	2,068	0.53%
Deciduous Woodlands								
>1k (Base)	140,184	73.48%	27,502	75.68%	208,752	73.26%	300,226	76.91%
500m-1k	29,975	15.71%	5,856	16.11%	45,429	15.94%	52,248	13.38%
250m-500m	12,743	6.68%	1,853	5.10%	19,294	6.77%	22,552	5.78%

100m-250m	5,361	2.81%	878	2.42%	7,736	2.71%	10,348	2.65%
<100m	2,513	1.32%	252	0.69%	3,743	1.31%	4,979	1.28%
Conifer Woodlands								
>1k (Base)	160,897	84.34%	34,236	94.21%	240,350	84.35%	344,510	88.26%
500m-1k	17,947	9.41%	1,253	3.45%	27,161	9.53%	27,881	7.14%
250m-500m	6,848	3.59%	508	1.40%	10,179	3.57%	10,355	2.65%
100m-250m	3,563	1.87%	236	0.65%	5,121	1.80%	5,142	1.32%
<100m	1,521	0.80%	108	0.30%	2,143	0.75%	2,465	0.63%
Nature Reserve								
>1k (Base)	183,935	96.41%	32,782	90.21%	276,333	96.97%	372,875	95.52%
500m-1k	3,719	1.95%	1,964	5.40%	4,693	1.65%	9,246	2.37%
250m-500m	1,799	0.94%	962	2.65%	2,272	0.80%	4,764	1.22%
100m-250m	944	0.49%	483	1.33%	1,221	0.43%	2,407	0.62%
<100m	379	0.20%	150	0.41%	435	0.15%	1,061	0.27%
Canals								
>1k (Base)	162,436	85.14%	27,746	76.35%	244,472	85.79%	302,209	77.42%
500m-1k	13,599	7.13%	4,214	11.60%	20,185	7.08%	39,562	10.13%
250m-500m	7,734	4.05%	2,333	6.42%	10,872	3.82%	25,226	6.46%
100m-250m	4,804	2.52%	1,414	3.89%	6,626	2.33%	15,468	3.96%
<100m	2,203	1.15%	634	1.74%	2,799	0.98%	7,888	2.02%
Rivers								
>1k (Base)	97,061	50.88%	24,098	66.31%	144,400	50.67%	184,762	47.33%
500m-1k	40,773	21.37%	6,077	16.72%	63,254	22.20%	81,476	20.87%
250m-500m	27,316	14.32%	3,377	9.29%	40,834	14.33%	57,796	14.81%
100m-250m	16,442	8.62%	1,818	5.00%	24,146	8.47%	38,784	9.94%
<100m	9,184	4.81%	971	2.67%	12,320	4.32%	27,535	7.05%
Lakes								
>1k (Base)	166,383	87.21%	30,931	85.11%	249,200	87.45%	322,861	82.71%
500m-1k	16,216	8.50%	3,748	10.31%	24,408	8.57%	41,193	10.55%
250m-500m	5,255	2.75%	1,064	2.93%	7,444	2.61%	16,208	4.15%

100m-250m	2,195	1.15%	402	1.11%	3,061	1.07%	6,860	1.76%
<100m	727	0.38%	196	0.54%	841	0.30%	3,231	0.83%
Flood Variables								
Risk								
0	65,210	34.18%	19,322	53.17%	98,418	34.54%	124,943	32.01%
Before defence or no defence								
1. (500-200m)	55,160	28.91%	8,236	22.66%	84,961	29.82%	100,400	25.72%
2. (200-100m)	27,032	14.17%	3,300	9.08%	40,529	14.22%	53,967	13.83%
3. (<100m from low risk)	33,182	17.39%	4,079	11.22%	47,546	16.69%	76,704	19.65%
4. (inside low risk)	4,792	2.51%	663	1.82%	6,776	2.38%	15,292	3.92%
5. (inside med or high)	4,025	2.11%	268	0.74%	5,290	1.86%	15,130	3.88%
After defence								
6. (500-200m)	54	0.03%	24	0.07%	54	0.02%	104	0.03%
7. (200-100m)	20	0.01%	3	0.01%	20	0.01%	81	0.02%
8. (<100m from low risk)	373	0.20%	57	0.16%	388	0.14%	958	0.25%
9. (inside low risk)	720	0.38%	287	0.79%	763	0.27%	2,365	0.61%
10. (inside med or high)	208	0.11%	102	0.28%	209	0.07%	409	0.10%
Events								
0	178,891	93.77%	34,075	93.76%	269,795	94.68%	352,412	90.28%
250 m radius from listing (base								

= no floods < 250m)								
1. (>30years)	92	0.05%	23	0.06%	302	0.11%	1,075	0.28%
2. (10-50 years)	1,854	0.97%	294	0.81%	2,426	0.85%	5,147	1.32%
3. (5-10 years)	1,993	1.04%	489	1.35%	2,614	0.92%	4,583	1.17%
4. (2-5 years)	2,059	1.08%	450	1.24%	2,524	0.89%	5,607	1.44%
5. (<2 years)	1,078	0.57%	145	0.40%	1,291	0.45%	5,250	1.34%
100m radius from listing (including polygon data)								
6. (>30years)	1,340	0.70%	283	0.78%	1,665	0.58%	3,998	1.02%
7. (10-50 years)	2,043	1.07%	301	0.83%	2,461	0.86%	6,354	1.63%
8. (5-10 years)	633	0.33%	134	0.37%	907	0.32%	2,595	0.66%
9. (2-5 years)	548	0.29%	117	0.32%	686	0.24%	1,896	0.49%
10. (<2 years)	245	0.13%	30	0.08%	283	0.10%	1,436	0.37%
Year Quarter								
2006Q1	0		0		1,252	0.44%	0	
2006Q2	0		0		2,830	0.99%	0	
2006Q3	0		0		4,663	1.64%	0	
2006Q4	0		0		4,613	1.62%	0	
2007Q1	0		0		7,787	2.73%	0	
2007Q2	0		0		7,849	2.75%	0	
2007Q3	0		0		8,098	2.84%	0	

2007Q4	0		0		6,255	2.20%	0	
2008Q1	0		0		6,450	2.26%	0	
2008Q2	0		0		6,537	2.29%	0	
2008Q3	0		0		5,518	1.94%	0	
2008Q4	0		0		3,159	1.11%	0	
2009Q1	0		0		3,514	1.23%	0	
2009Q2	0		0		3,953	1.39%	0	
2009Q3	0		0		3,710	1.30%	0	
2009Q4	0		0		2,405	0.84%	0	
2010Q1	0		0		3,232	1.13%	0	
2010Q2	0		0		4,345	1.52%	0	
2010Q3	0		0		4,890	1.72%	0	
2010Q4	0		0		3,118	1.09%	0	
2011Q1	4,506	2.36%	20	0.06%	4,506	1.58%	18,813	4.82%
2011Q2	4,957	2.60%	138	0.38%	4,957	1.74%	20,878	5.35%
2011Q3	4,559	2.39%	319	0.88%	4,559	1.60%	22,384	5.73%
2011Q4	2,822	1.48%	422	1.16%	2,822	0.99%	15,628	4.00%
2012Q1	3,836	2.01%	333	0.92%	3,836	1.35%	17,476	4.48%
2012Q2	3,982	2.09%	445	1.22%	3,982	1.40%	18,934	4.85%
2012Q3	3,832	2.01%	549	1.51%	3,832	1.34%	18,817	4.82%
2012Q4	3,214	1.68%	796	2.19%	3,214	1.13%	13,054	3.34%
2013Q1	3,774	1.98%	397	1.09%	3,774	1.32%	14,657	3.75%
2013Q2	5,140	2.69%	584	1.61%	5,140	1.80%	13,547	3.47%
2013Q3	4,695	2.46%	902	2.48%	4,695	1.65%	14,466	3.71%

2013Q4	3,440	1.80%	1,076	2.96%	3,440	1.21%	10,000	2.56%
2014Q1	4,481	2.35%	666	1.83%	4,481	1.57%	10,361	2.65%
2014Q2	6,549	3.43%	860	2.37%	6,549	2.30%	11,463	2.94%
2014Q3	6,102	3.20%	1,228	3.38%	6,102	2.14%	11,865	3.04%
2014Q4	4,924	2.58%	1,420	3.91%	4,924	1.73%	8,871	2.27%
2015Q1	6,759	3.54%	1,242	3.42%	6,759	2.37%	10,535	2.70%
2015Q2	8,028	4.21%	1,224	3.37%	8,028	2.82%	10,419	2.67%
2015Q3	7,229	3.79%	1,556	4.28%	7,229	2.54%	10,831	2.77%
2015Q4	4,735	2.48%	1,541	4.24%	4,735	1.66%	8,384	2.15%
2016Q1	6,463	3.39%	1,122	3.09%	6,463	2.27%	9,069	2.32%
2016Q2	8,177	4.29%	1,268	3.49%	8,177	2.87%	9,612	2.46%
2016Q3	7,235	3.79%	1,721	4.74%	7,235	2.54%	9,924	2.54%
2016Q4	4,911	2.57%	1,776	4.89%	4,911	1.72%	8,537	2.19%
2017Q1	7,112	3.73%	1,254	3.45%	7,112	2.50%	9,210	2.36%
2017Q2	8,405	4.41%	1,379	3.79%	8,405	2.95%	9,334	2.39%
2017Q3	8,500	4.46%	1,770	4.87%	8,500	2.98%	9,480	2.43%
2017Q4	6,865	3.60%	1,960	5.39%	6,865	2.41%	8,261	2.12%
2018Q1	7,567	3.97%	1,515	4.17%	7,567	2.66%	8,609	2.21%
2018Q2	10,385	5.44%	1,566	4.31%	10,385	3.64%	8,982	2.30%
2018Q3	10,257	5.38%	1,902	5.23%	10,257	3.60%		2.48%

							9,680	
2018Q4	7,335	3.84%	2,020	5.56%	7,335	2.57%	8,272	2.12%
2019Q1	0	0.00%	1,285	3.54%	0	0.00%	0	0.00%
2019Q2	0	0.00%	31	0.09%	0	0.00%	0	0.00%
Total	190,776	100%	36,341	100.00%	284,954	100.00%	390,323	100%

BER Data

New or Second-hand		
New Dwelling	435	1.20%
Second-Hand Dwelling	35,906	98.80%
stories		
0	3	0.01%
1	8,830	24.30%
2	24,031	66.13%
3	3,408	9.38%
4	64	0.18%
5	5	0.01%
Insulation Type		
Masonry	21,954	60.41%
Mixed Masonry/Timber	13,626	37.49%
Timber	751	2.07%
Glazing		
Double/Triple	521	1.43%
Double	24,467	67.33%
None	1	0.00%
Single/Double/Triple	116	0.32%
Single/Double	8,564	23.57%

Single/Triple			30	0.08%
Single			2,468	6.79%
Triple			174	0.48%
Fuel type				
Electricity			5,483	15.09%
Gas			27,199	74.84%
Oil			3,159	8.69%
Solid Fuel			229	0.63%
BER rating				0.00%
A2			39	0.11%
A3			242	0.67%
B1			185	0.51%
B2			855	2.35%
B3			2,116	5.82%
C1			2,803	7.71%
C2			3,457	9.51%
C3			3,896	10.72%
D1			4,756	13.09%
D2			5,050	13.90%
E1			3,392	9.33%
E2			3,112	8.56%
F			3,351	9.22%
G			3,087	8.49%
Total	0	0%	36,341	100.00%

Rental Data

Rental Dummy Variables

	Garden	263,416	67.48%

Parking	251,114	64.33%
Central heating	80,358	20.59%
House alarm	167,746	42.97%
Cable television	231,959	59.42%
Washing machine	134,083	34.35%
Dryer	104,626	26.80%
Dishwasher	202,119	51.78%
Microwave	172,476	44.18%
Pets allowed	229,718	58.85%
Wheelchair access	369,677	94.70%
Internet	281,559	72.13%
Lettings agent		
Yes	118,168	30.27%
Lease (months)		
0	17,141	4.39%
3	4,568	1.17%
6	21,178	5.43%
9	4,582	1.17%
12	341,686	87.53%
24	779	0.20%
36	419	0.11%
Rent allowance		
0	254,399	65.17%
1	110,890	28.41%
2	25,064	6.42%
Furnished		
0	1,491	0.38%

1	354,649	90.85%
2	15,342	3.93%
3	18,871	4.83%

Bed single

10	67,556	17.31%
11	3,744	0.96%
20	126,621	32.44%
21	26,410	6.77%
22	1,397	0.36%
30	28,442	7.29%
31	72,806	18.65%
32	4,198	1.08%
33	634	0.16%
40	13,244	3.39%
41	24,361	6.24%
42	10,323	2.64%
43	805	0.21%
44	372	0.10%
50	3,192	0.82%
51	3,578	0.92%
52	1,902	0.49%
53	495	0.13%
54	134	0.03%
55	139	0.04%

Appendix B: Additional results

Table B.1: Main specification on all three datasets

	Sale Listings **Post-2010**	Rental Listings **Post-2010**	Sale Transactions **Post-2010**
Level of Fixed Effect	**Census ED**	**Census ED**	**Census ED**
No flood defences			
500m-200m away	-0.001	0.003	0.003
	-0.3	3.2	0.9
200m-100m away	-0.007	0.005	-0.003
	-2.9	4.3	-0.6
<100m from low risk	-0.011	0.008	-0.012
	-4.2	6.2	-2.4
Inside low risk	-0.011	0.009	-0.027
	-2.1	4.5	-2.7
Inside medium/high	-0.031	-0.002	-0.062
	-4.9	-1.0	-4.2
After flood defences			
500m-200m away	-0.041	0.065	-0.068
	-1.2	4.2	-1.4
200m-100m away	-0.011	0.004	0.060
	-0.2	0.3	1.1
<100m from low risk	-0.011	-0.011	-0.037
	-0.7	-1.8	-1.4
Inside low risk	-0.024	0.002	-0.042
	-1.7	0.3	-2.3
Inside medium/high	0.097	0.023	0.027
	4.9	2.1	1.0
Last flood event 100-250 meters from the dwelling			
More than 30 years	-0.036	-0.061	-0.052
	-0.9	-10.0	-0.9
10-30 years	-0.016	0.011	0.017
	-2.2	4.1	1.6
5-10 years	-0.008	-0.003	0.012
	-1.3	-1.0	1.6
2-5 years	0.015	0.015	0.013
	2.2	5.5	1.4
Less than 2 years	-0.027	-0.008	-0.036
	-2.6	-3.0	-1.6
Last flood event within 100 meters of the dwelling			
More than 30 years	-0.024	-0.002	-0.026
	-2.2	-0.6	-1.6
10-30 years	0.011	0.028	-0.010
	1.5	10.2	-0.6
5-10 years	-0.011	0.009	0.046
	-0.9	2.3	3.2
2-5 years	-0.011	-0.008	0.032
	-0.8	-2.0	1.7
Less than 2 years	-0.043	-0.004	-0.011
	-2.0	-1.0	-0.2
Controls	YES	YES	YES

Observations	190,635	390,301	35,922
R-squared	0.842	0.878	0.897
RMSE	0.263	0.169	0.172
Spatial units	1,020	1,003	322

Notes: Regression results show coefficients on various measures of flood risk and flood events, as discussed in the text, where the dependent variable is the natural log of the dwelling's listed sale price, listed rental price, and transacted sale price, respectively. Robust t-statistics are shown underneath each coefficient. Different columns show results using different samples as discussed in the text. Controls include dwelling characteristics, location amenities, and market conditions, as discussed in the text. Columns (1) and (2) here report extended results from the same specifications as reported in Columns (2) and (4) of Table 4 in the main text. Column (3) here reports extended results from the same specification as reported in Column (1) of Table 7 in the main text.

Table B.2: Additional robustness checks

Specification	(1)	(2)	(3)	(4)	(5)	(6)
No flood defences						
500m-200m away	-0.001	-0.001		-0.001	-0.007	-0.010
	-0.3	-0.3		-0.3	-4.2	-5.3
200m-100m away	-0.007	-0.007		-0.007	-0.008	-0.016
	-2.9	-2.9		-2.8	-3.4	-6.2
<100m from low risk	-0.011	-0.012		-0.010	-0.013	-0.019
	-4.2	-4.4		-3.7	-5.8	-7.1
Inside low risk	-0.011	-0.012		-0.010	-0.009	-0.017
	-2.1	-2.3		-1.8	-1.7	-2.9
Inside medium/high	-0.031	-0.032		-0.029	-0.026	-0.034
	-4.9	-5.1		-4.3	-7.7	-9.1
After flood defences						
500m-200m away	-0.041	-0.058		-0.042	-0.072	-0.088
	-1.2	-1.7		-1.2	-2.0	-2.7
200m-100m away	-0.011	-0.010		-0.008	-0.095	-0.079
	-0.2	-0.2		-0.2	-2.0	-1.7
<100m from low risk	-0.011	-0.013		-0.009	-0.046	-0.060
	-0.7	-0.9		-0.6	-2.5	-3.4
Inside low risk	-0.024	-0.026		-0.038	-0.095	-0.085
	-1.7	-1.9		-2.6	-4.6	-4.0
Inside medium/high	0.097	0.097		0.093	-0.014	-0.026
	4.9	4.9		4.2	-1.4	-2.6
Last flood event 100-250 meters from the dwelling						
More than 30 years	-0.036		-0.038	-0.038	-0.055	-0.034
	-0.9		-1.0	-1.0	-1.4	-0.9
10-30 years	-0.016		-0.018	-0.018	-0.015	-0.014
	-2.2		-2.5	-2.4	-2.1	-1.9
5-10 years	-0.008		-0.010	-0.027	-0.010	-0.007
	-1.3		-1.7	-2.9	-1.7	-1.2
2-5 years	0.015		0.014	-0.006	0.021	0.016
	2.2		1.9	-0.6	3.0	2.3
Less than 2 years	-0.027		-0.029	-0.028	-0.037	-0.027
	-2.6		-2.8	-2.1	-3.7	-2.6
Last flood event within 100 meters of the dwelling						
More than 30 years	-0.024		-0.029	-0.027	-0.003	-0.019
	-2.2		-2.6	-2.4	-0.3	-1.7
10-30 years	0.011		0.009	0.010	0.011	0.016
	1.5		1.2	1.3	1.5	2.1
5-10 years	-0.011		-0.014	-0.037	-0.015	-0.009
	-0.9		-1.1	-2.1	-1.2	-0.7
2-5 years	-0.011		-0.014	-0.054	-0.017	-0.008
	-0.8		-1.0	-2.9	-1.3	-0.6
Less than 2 years	-0.043		-0.047	-0.054	-0.053	-0.043
	-2.0		-2.2	-1.8	-2.6	-2.0
Controls	YES	YES	YES	YES	YES	YES
Observations	190,635	190,635	190,635	188,132	299,070	190,635
R-squared	0.842	0.842	0.842	0.841	0.798	0.842
RMSE	0.263	0.263	0.263	0.263	0.294	0.263
Spatial units absorbed	1,020	1,020	1,020	1,020	3,395	1,020

Notes: Regression results show coefficients on various measures of flood risk and flood events, as discussed in the text, where the dependent variable is the natural log of the dwelling's listed sale price. Robust t-statistics are shown underneath each coefficient. Different columns show separate specifications as discussed in the text. Controls include dwelling characteristics, location amenities, and market conditions, as discussed in the text. Column (1) here is the same as Column (1) of Table B.1 above, for ease of comparison. The second and third columns here replicate Column (1) but omitting events (Column 2), or omitting flood risk (Column 3). Column (4) drops all observations that were affected by a major flood event in 2011. Approximately 2,500 observations were removed from the sample that were within 250m of that particular flood event based on flood event points, or observations that were within a flood event polygon related to that flood. The specifications reported in Columns (5) and (6) use flood risk data from the Preliminary Flood Risk Assessment (PFRA) maps. The variables are calculated in exactly the same way as described previously. Column (5) uses the full nationwide sample of sale listings, as the PFRA maps were not restricted to the AFA boundaries. Column (6) reports a specification where flood risk is defined using the PFRA maps, but restricting the sample to dwellings within AFAs.

Table B.3: Border Discontinuity style analysis

	Baseline model	500m	Terraced and semi-detached	Terraced and semi-detached 500m
	(1)	(2)	(3)	(4)
No flood defences				
500m-200m away	-0.001		-0.005	
	-0.3		-2.3	
200m-100m away	-0.007	-0.007	-0.014	-0.008
	-2.9	-3.3	-4.6	-3.0
<100m from low risk	-0.011	-0.012	-0.012	-0.005
	-4.2	-4.9	-3.7	-1.8
Inside low risk	-0.011	-0.012	-0.012	-0.005
	-2.1	-2.3	-1.7	-0.7
Inside medium/high	-0.031	-0.034	-0.021	-0.016
	-4.9	-5.5	-2.3	-1.7
After flood defences				
Inside medium/high	0.097	0.096	0.144	0.149
	4.9	4.7	5.9	5.9
Controls	YES	YES	YES	YES
Observations	190,635	125,478	112,929	70,286
R-squared	0.842	0.828	0.865	0.849
RMSE	0.263	0.276	0.235	0.249
Spatial units absorbed	1,020	887	943	808

Notes: Regression results show coefficients on various measures of flood risk, as discussed in the text, where the dependent variable is the natural log of the dwelling's listed sale price. Robust t-statistics are shown underneath each coefficient. Different columns show separate specifications related to the border discontinuity style analysis, as discussed in the text. Controls include dwelling characteristics, location amenities, and market conditions, as discussed in the text. Column (1) replicates our baseline model, as reported in Column (2) of Table 4 in the main text. Column (2) restricts the control group to dwellings no more than 500m away from a flood risk zone. Column (3) restricts the sample to terraced and semi-detached dwellings only. Column (4) restricts the sample both by dwelling type and by distance of control group dwellings from flood risk zones.

Appendix C: Survey

C.1 Survey Description

An online survey on public perceptions and awareness of flood risk in Ireland was carried out in June 2019. The survey was hosted on daft.ie, the most popular property website in Ireland, with a link to the survey in the strapline of the home page for approximately 3 weeks in June 2019. The survey attracted a total of 837 respondents.[25] There was no mention of floods in the title or description of the survey to avoid self-selection of respondents with a particular interest in the topic, with the aim of gaining insight on the wider public's perception and knowledge of flood risk. The full list of survey questions is included below.

In brief, the survey included a range of non-flood-related questions, including standard demographic questions, such as the respondent's age, gender and education, their reason for visiting the site, and questions on the budget and risk aversion of the respondent. Of those who indicated their age, the median response was the 40-44 age bracket (n=552), while of those who indicated their gender, 57% were female (n=525). Out of 837 respondents, 36% said they were interested in buying a property and 26% said they were interested in renting a property.

Further questions asked about the locations/markets of interest, and the importance of location characteristics, including amenities like green space and schools and disamenities like the crime rate. Flood risk was listed as one of these disamenities and additional questions (which followed later in the survey) asked respondents about their awareness of information about flood risk and of the availability of flood risk information, their concern about and experience of flooding, their perception of flood defences, and their willingness to pay to avoid flood risk.

[25] Some respondents left questions blank, such that we do not have 837 responses for every question in the survey. There were also some questions on the survey that only appeared in logical sequence depending on the answer to the previous question.

C.2 Perceptions of flood risk and flood defences

In addition to results discussed in the main paper, the survey also probed the sources of flood risk salience. In particular, for those who indicated that their concern about flood risk had increased in the last 10 years, we asked about the reasons for their increasing concern: 38% cited coverage of flooding in the media, 27% cited increased awareness of climate change, while 12% chose "release of new information on flood risk" (n=351).

The survey also asked respondents about their attitudes towards flood defences. 18% of respondents said that flood defences had been constructed in or were planned for their area, while another 34% said they didn't know (n=632). The majority (59%) agreed (or strongly agreed) with the statement that "Man-made flood defences provide an adequate protection against flood risk" (n=632). Half disagreed (or strongly disagreed) with the statement "Man-made flood defences reduce your enjoyment of an area, either visually or otherwise", with 18% stating they didn't know (n=626). And finally, a large majority (70%) agreed (or strongly agreed) with the statement "flood defences should be funded by general taxation" (n=632).

C.3 Willingness to pay to avoid flood risk

As discussed in the paper, a willingness-to-pay question was included in the survey, relating to people's perception of flood risk discounts on property values. Each respondent was randomly assigned one of six versions of the question. The six versions were based two versions for each of three levels of flood risk (0.1%, 1% and 10%), where one version for each level of risk included an illustration of the risk in terms of the probability of being flooded over the course of a 30 year mortgage. Two of the six examples (the other four are identical but at the 0.1% and 10% level of risk) are given below, with the additional text in italics (added here for clarity):

- "Consider two houses that are identical in every respect, including size, location, access to amenities etc. The only difference is that one house is in a flood risk zone, with a 1% (one in a hundred) chance of flooding per year and the other is not at risk of flooding. If the house which is not at risk of flooding is valued at €300,000, what price do you think the house in the flood risk zone should be?"

- "Consider two houses that are identical in every respect, including size, location, access to amenities etc. The only difference is that one house is in a 1% (one in a hundred) flood risk zone, *roughly similar to a 25% chance of being flooded at least once over the course of a 30-year mortgage*, and the other is not at risk of flooding. If the house which is not at risk of flooding is valued at €300,000, what price do you think the house in the flood risk zone should be?"

Results from this question are reported in the paper.

C.4 Complete copy of survey (full list of survey questions)

1. Which of the following best describes the reason you visited daft.ie today?

   Interested in buying a property
   Interested in renting a property
   Looking to sell or rent out my property or my client's property
   Other, including general browsing or market research

2. What area(s) are you looking in?

   Drop down menu of 54 local markets

3. When choosing where to live, how important are the following factors:

   1 to 5 number scale very important to not important

   Proximity to Central business district of nearest city/town
   Proximity to Schools
   Proximity to Coastline
   Neighbourhood quality
   Proximity to Transport network (train stations etc)
   Proximity to Mountains
   No risk of flooding
   Proximity to Sports facilities (football pitch, golf course, etc)
   Proximity to Green spaces (parks, fields, etc)
   Proximity to Other inland blue spaces (rivers, lakes, canals, etc)

Proximity to Forestry
Proximity to Hospitals

4. Specifically thinking about the areas you are looking at, do you think flood risk is relevant to those areas?

   Yes
   No
   Don't know

5. (Logical if yes to 4) Are you aware of the flood risk in the area in which you are searching, and for the properties you may be interested in?
   Yes
   No

6. (Logical if yes to 5) Please check the box which indicates the source from which you obtained the flood risk information

   Local knowledge
   Online resource
   Ordinance survey maps
   Property agency
   Bank
   Other (you may specify if you wish)

7. [logical yes to 5] Was it straightforward to find out the flood risk information for that particular location?

   Straightforward
   Somewhat straightforward
   Difficult

8. [seen only if they answer no or dont know to 4 OR no to 5] Would you know where to look for flood risk information?

   I know where the information is available.
   I do not know where the information is available but I assume it would be easy to find.
   I think it would be difficult to find.

9. [seen only if they answer no or dont know to 4 OR no to 5] Where would you look for flood risk information?

   I would ask in the locality

I would look online
I would ask my estate agent
Other (optional specify)

10. Are you aware of the existence of publicly available flood risk maps for Ireland?

Yes
No

11. In the last 10 years has flood risk become:

More of a concern for you
Unchanged
Less of a concern for you
Not relevant

12. (Logical if answered less to 11)Please indicate the reasons why flood risk has become less of a concern for you.

I moved away from flood risky areas
Flood defences were installed
Flooding is less likely
I have new information
Other (specify optional)

13. (logic if answered "more" to 11) Please select the reasons for which flood risk has become more of a concern:

Flooding near me
Flooding near a friend or relative
Increased awareness of climate change
Flooding coverage in the media
Release of new information on flood risk in Ireland/locally
Other reason(s) (you may specify)

14. Split survey with 6 separate versions:

    1. Consider two houses that are identical in every respect, including size, location, access to amenities etc. The only difference is that one house is in a flood risk zone, with a 1% (one in a hundred) chance of flooding per year and the other is not at risk of flooding. If the house which is not at risk of flooding is valued at €300,000, what price do you think the house in the flood risk zone should be?

Scale bar 0 - €300,000

2. Consider two houses that are identical in every respect, including size, location, access to amenities etc. The only difference is that one house is in a 1% (one in a hundred) flood risk zone, roughly similar to a 25% chance of being flooded at least once over the course of a 30 year mortgage, and the other is not at risk of flooding. If the house which is not at risk of flooding is valued at €300,000, what price do you think the house in the flood risk zone should be?
Scale bar 0 - €300,000

3. Consider two houses that are identical in every respect, including size, location, access to amenities etc. The only difference is that one house is in a flood risk zone, with a 0.1% (one in a thousand) chance of flooding per year and the other is not at risk of flooding. If the house which is not at risk of flooding is valued at €300,000, what price do you think the house in the flood risk zone should be?
Scale bar 0 - €300,000

4. Consider two houses that are identical in every respect, including size, location, access to amenities etc. The only difference is that one house is in a 0.1% (one in a thousand) flood risk zone, roughly similar to a 3% chance of being flooded at least once over the course of a 30 year mortgage, and the other is not at risk of flooding. If the house which is not at risk of flooding is valued at €300,000, what price do you think the house in the flood risk zone should be?
Scale bar 0 - €300,000

5. Consider two houses that are identical in every respect, including size, location, access to amenities etc. The only difference is that one house is in a flood risk zone, with a 10% (one in ten) chance of flooding per year and the other is not at risk of flooding. If the house which is not at risk of flooding is valued at €300,000, what price do you think the house in the flood risk zone should be?
Scale bar 0 - €300,000

6. Consider two houses that are identical in every respect, including size, location, access to amenities etc. The only difference is that one house is in a 10% (one in ten) flood risk zone, roughly similar to a 96% chance of being flooded at least once over the course of a 30 year mortgage, and the other is not at risk of flooding. If the house which is not at risk of flooding is valued at €300,000, what price do you think the house in the flood risk zone should be?
Scale bar 0 - €300,000

15. Do you expect flood risk in Ireland to change by the year 2050?

Flood risk will increase

Flood risk will remain the same as today
Flood risk will decrease

16. Have you ever experienced flooding in a property you lived in, in the past?

Yes
No

17. Please rate the following types of flood in terms of their potential for property damage.

Highly Damaging, Somewhat Damaging, Not Damaging, Don't know

Coastal Flooding (Storm surge and high tides)
Fluvial Flooding (River bursting its banks)
Pluvial Flooding (Heavy accumulations of water due to rainfall)

18. Have flood defences been constructed/planned to be constructed in your area?

Yes
No
Don't know

19. To what extent to you agree/disagree with the following statements?

- "Man-made flood defences provide an adequate protection against flood risk."

  Strongly agree, agree, disagree, strongly disagree, don't know

- "Man-made flood defences reduce your enjoyment of an area, either visually or otherwise."

  Strongly agree, agree, disagree, strongly disagree, don't know

- "Flood defences should be funded by general taxation."

  Strongly agree, agree, disagree, strongly disagree, don't know

Risk and budgetary related questions

20. If you are considering buying a property, what type of buyer best describes you?

First time buyer
Upsizing
Downsizing
Looking for an investment property
Other

21. If you are considering buying a property, will you be paying in cash or will you be getting a mortgage from a bank?

    Cash buy
    Mortgage

22. If you are planning to purchase a property, please indicate the price category which most closely corresponds to your available budget:
    (Edit to homogenise with daft version)

    30-100k
    100-200k
    200-300k
    300-400k
    400-500k
    500-600k
    600-700k
    700-800k
    800-900k
    >900k

23. Considering the following periods, relative to today's house prices, do you think, in Ireland: (edit so same as daft survey.)

    In 1 years' time (prices will be: higher than today, the same as today, lower than today)
    In 5 years' time (prices will be: higher than today, the same as today, lower than today)
    In 10 years' time (prices will be: higher than today, the same as today, lower than today)

24. Do you have any of the following types of insurance? (Please check the box)

    Yes, No, Don't know

    Life insurance
    Health insurance
    Dental insurance
    Income protection cover
    Mobile phone insurance

25. If you were to receive one of the following payouts, which would you rather receive?

€45 in three days' time.
€70 in three months' time.

Demographics questions

26. Including you, how many people are in your household in the following age groups:

Below 5 years
5-15 years
Between 16-60 years old
Over 60 years old

27. What age are you?
28. What gender are you?
29. Which of the following best describes your level of education?

Primary level
Secondary level
Third level
Post-graduate education

30. Which category best describes your current work status?

Working full time
Working part time
Student
Home maker
Retired
Unemployed
Unable to work due to sickness or disability
Other