Long term divergence between ex-ante and ex-post hedonic prices of the Meuse River flooding in The Netherlands [*]

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Abstract

Hedonic pricing methods have been widely used to value flood risk, especially in the United States. It is well documented that housing prices are reactive to flood risk, and that devaluation of housing prices due to flood risk is greater after a recent flood experience. This has, for instance, been documented for Maastricht, The Netherlands, where it appeared that ex-post valuations of flood risk were twice as high as before the 1993 Meuse River flooding. Earlier work showed that selling prices of houses located in a location that was flooded in 1993 were ex-ante 7% lower than a similar house located in a safe zone, and were about 14% lower after the event. The present paper aims at exploring in more details the dynamics of the variations in housing prices due to flood risk and experience. A central question is whether the high ranges of ex-post flood risk valuations are due to temporary overreactions or whether they disclose long term effects. This question is addressed by making use of a hedonic price model for different cities along the Meuse River, considering house sales that occurred between 1990 and 2004. The model is estimated with appropriate econometric tools taking into consideration the potential presence of spatial dependence and spatial heterogeneity in the data. We find that the total impact of flood on house values in the municipalities affected by the recent high tide events is substantial with a decrease between about 7 and 13%. We find that this devaluation does not disappear after some years, probably because of the increasing attention paid to flood risks in the media.

Key words: river flooding, hedonic pricing, spatial econometrics

JEL Codes: C31, D81, H54, Q51, Q54

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1. Introduction

Among the natural disasters, floods are in fact the most frequent, lethal and expensive incidents occurring in the world. Contrary to other types of natural disasters, such as earthquakes or volcano outbursts, flooding constitutes a hazard with a ubiquitous prevalence throughout the world (Faure 2004). In The Netherlands, the concern for flooding is particularly relevant as 70 percent of the real estate properties are at risk, since they are situated below either sea or river level. Sources of floods are widespread and include local heavy rainfall, dam failure, and river or sea flooding frequently associated with the impact of climate change (Kok et al. 2003).

The value of river flooding hazard can be evaluated using stated as well as revealed preference techniques (see for instance Freeman (2003) for a complete review of non market valuation techniques). We prefer using the revealed preference technique because it has the advantage of avoiding potential biases in stated preference techniques resulting from the possible mismatch between respondent's statements and their actual behaviour. In addition, the revealed preference technique allows for the investigation of consumer behaviour in the case where the risk of river flooding is accounted for on the basis of subjective perceptions. In stated preference techniques flood hazards are typically presented in terms of specific scenarios accounting for climate variables (including up-stream conditions) and the associated risks of dike overtop or failure. The overall outcomes of these scenarios, together with the a-priori expected damage resulting from the occurrence of the disaster, are important inputs for flood risk reduction plans as they are presented to respondents. However, the costs associated with the *perception* of risk are typically left aside. These costs can, for instance, be related to psychological harm, to stress or to individual valuation of time lost for recovering material damage. We pay particular attention to the valuation of the cost associated with risk perception because such costs are expected to be non-negligible and they have generated little awareness in policymaking. A recent government white paper in The Netherlands observes that feelings of desperation and social disruption due to the occurrence of a flood have hitherto not been investigated (Ministerie van Verkeer en Waterstaat 2005).

This paper investigates the assessment of households of the risk of river flooding by means of a hedonic property value or pricing model (HPM). The HPM model is set up in an econometric framework that accounts for the spatial features of the data. The model accounts for spatial heterogeneity as well as spatial dependence, and we empirically estimate the economic valuation of risk experience using the 1993 and 1995 Meuse river high tides. The availability of data is such that we can assess the shadow price of being in a river flood zone before and after the disastrous event.

The organization of the remainder of this paper is as follows. We start by describing flood risk in The Netherlands and discuss the difficulties associated with defining flooding hazards appropriately. Subsequently, we provide a description of the property value database and the additional variables we collected. Methodological issues are also discussed, paying specific attention to the use of spatial econometrics and its implementation in the context of a hedonic pricing model. Finally, we present and examine the empirical results.

2. Flood risk in The Netherlands

The Netherlands is world renowned for its water management capabilities, which is partly induced by the fact that substantial parts of The Netherlands are below sea or river level. The Technical Advisory Committee on Water Defences (1998) identifies three reasons why flood risk in The Netherlands needs to be subject to prolonged analysis and evaluation. First, flood risk is typically *a dynamic process*. Risk levels are naturally affected by variations in water levels and sedimentation, and hence levels of protection are not even constant in the case of a status quo because flood defences are worn by time. We will illustrate this feature by a short discussion of the uncertainties associated with future developments, including climate change. Second, the constituent components of the *costs and benefits* of flooding can change as illustrated by the important capital investment in many polder areas and by the increase in the number of residents and workers in these areas. We will address this point by a discussion of different approaches towards tailoring flood defence policies in The Netherlands. Finally, the *evaluation* of sacrifices in itself can change, for instance, because of apparent changes in social conceptions and norms.

The abovementioned issues are obviously related to the perception of river flooding hazards in The Netherlands, and we will discuss them consecutively below.

2.1 Climate change and flooding risk

Climate change can affect The Netherlands in two distinct ways, either by changing prevalent weather conditions, or by affecting the sea level. The latter is usually of the greatest concern to the Dutch.

Verhagen (2002) presents two scenarios describing changes in weather conditions due to *climate change*. One scenario is based on a model from the Royal Netherlands Meteorological Institute (KNMI) for the period 2050–2100; the other scenario is based on a model from the Hadley Centre in England and covers the period 2020–2100. The consequences of climate change are summed up as follows by the respective institutes. The expected increase in temperature ranges from 0.5 to 2°C in 2050 and from 2.5 to 4°C in 2100. Precipitation is expected to increase by 3 to 6% in 2050, and by 6 to 12% in 2100 according to KNMI. The Hadley Centre predictions are fuzzier, ranging from a 5% decrease to a 10%

increase in the coming century. Both institutes state that winters will become wetter, and that summers will either be drier or they will remain the same. Although the Hadley Centre does not predict dramatic changes in terms of extreme precipitation, this is not the case for KNMI. The latter expects extreme winter precipitations to rise by 40%, and extreme summer precipitations to rise by 4%, both referring to 2100.

Concerning *sea level rise*, Verhagen (2002) reminds us that since the beginning of the twentieth century, the sea level has already risen by 10 to 20 cm. Projections for the twenty-first century range from a 10 to 90 centimetres additional rise. The strength of sea waves appears to be higher nowadays than it has been before, even without a claim on climate change. In the past century, the sea level increased with a decrease in storm tide levels on which dike-rings were designed. It is already expected that discharge of the rivers Rhine and Meuse is going to increase with climate change, and this phenomenon may already be taking place. This would lead to an increase in the pressure on river dikes, and induce the necessity of periodical adaptation of dikes and/or of the streambed of rivers. Because the increase in the discharge of the rivers may occur before further protection is in place, it is not unlikely that the risk of river flooding at some point in time will be higher than the expected level (RIVM 2004).

2.2 Flood defence infrastructure

The Dutch were strongly impressed by the spring tide drama that occurred in 1953, causing the death of almost 2000 persons in the south-west of the country. Since then, sea or river flooding has fortunately not instigated more human losses in The Netherlands, but flooding risk remains a highly visible issue as a result of financial losses caused by river flooding. In 1993, river flood cost amounted to 0.1 billion Euros along the Meuse, and two years later, 200,000 people had to be evacuated along the Rhine and the Meuse with material losses evaluated to be 0.28 billion Euros (Kok et al. 2003). Extreme rainfall, constituting another source of flooding, has also been very costly. The associated cost has been estimated to be half a billion Euros in 1998.

The above shows that flooding can result from river overflow or dike failure. Concerning river overflow, two rivers are especially under scrutiny in The Netherlands, the river Meuse and the river Rhine. For the river Rhine a substantial share of its water source stems from melting snow and glaciers, so that its discharge is rather constant. The volume of the river Meuse on the other hand is mainly determined by rainfall, and thus the Meuse has a much more variable discharge. In case of rainfall, flood risk depends on the speed of the increase in the water level. Extreme rainfalls present a risk because they can lead to overflows of rivers, to overtopping of dikes, or to an increase in pressure on dams, eventually leading to failure. The latter concerns both rivers. In addition, the river Rhine also presents a risk in terms of sudden flows, because the river is surrounded by a number of polders protected by dikes. For coastal areas, an increase in sea level obviously leads to a higher risk of flooding.

Given these different sources of risk, the Netherlands is protected by an extensive network of sea and river dikes. However, legal safety norms, which were last set in 1996 in the so-called “Wet op de Waterkering” (Flood Defences Act) on the basis of advice of the Delta Commission, are currently based on the land use that was prevalent in the 1960s. In fact, soon after the spring tide disaster of 1953, safety norms were established on the basis of the economic and demographic situation at that time. Current economic conditions and human settlements are very different, effectively making the actual level of risk much higher than originally envisaged. Safety norms of dikes along the coasts and the estuaries were based on the works of the so-called Delta Commission. Later on, River Commissions, following up on the work of the Delta Commission, set norms for river dikes. In 1996, the norms for the coast, the estuary and the rivers, as well as the norms for the transition plains, were established in the abovementioned act on flood defences. The current safety policy is still based on these norms. Article 21 of the act promotes the achievement of a sustainable, safe and liveable country in terms of economic interests and human lives.[1] In detail, the implemented risk levels resulting from the work of the Delta Commission are as follows: a risk of 1/1,250 per year for rivers, 1/10,000 for the Central Holland and North Holland coasts, and 1/4,000 for other coastal zones (RIVM 2004). It is at this stage important to stress that regardless of the flooding source, households would be the first victims in economic terms, ahead of firms (Rijkswaterstaat 2003). Approximately half of The Netherlands is situated in a location that would be flooded in case of major dike failures, hosting 9 million people and contributing 65 percent of the country’s GNP (RIVM 2004). In comparison to other countries, where the extent of the area at risk usually represents only a small proportion of the land, the Dutch national government applies rather stringent norms. Individual risk, which has a time dimension in relation to a given point in space, is very low in comparison to other countries, including the US. However both economic and group risks are relatively high (group risk results from a statistical distribution of the frequency per year and from the magnitude of the adverse event).

[1] The Flood Defences Act, issued on December, 21, 1995 states: “We have considered that it is desirable that protection against flooding by external water – in particular in the case of high storm surges, high surface water in the major rivers or high water in the IJsselmeer or a combination thereof – is an essential requirement for the habitability of the Netherlands; and that it is desirable to lay down general rules concerning the extent of the protection which must be guaranteed in different areas, and to take procedural measures to ensure that new or reinforcement works can be rapidly implemented, with a view to achieving this degree of protection as quickly as possible” (see Technical Advisory Committee on Water Defences 1998).

2.3 Concerns of the general population

It is commonly understood that the level of acceptability of risk exposure is constantly decreasing. Nowadays, potential victims do not seem to accept fatal accidents and they expect to be compensated for their losses in case of a disaster (Faure 2004). Whereas flooding was until recently considered an exogenous natural disaster, it is now increasingly being considered an external risk associated with human activities that should not happen anymore. This is specifically true with respect to dike failures. Uncertainty related to the abovementioned climate change is likely to increase the individual perception of risk even more. It is well documented that people prefer certain rather than uncertain situations. The Dutch population seems confident that the risk of flooding risk is under control, because it is appropriately managed by decentralized Water Boards and the Ministry of Transport and Public Works (RIVM 2004). Their confidence is probably enhanced by the country's long history of successful water management, the reclaiming of land from the sea and rivers (polders), and a general feeling of trust in authorities. The latter is considered an important factor influencing one's perception of risk (Berg et al.2002).

A good illustration of the confidence of Dutch citizens is found in the study carried out by Berg et al. (2002). The study shows that coastal residents have great confidence in authorities, such as the coast safety guard. People feel safe and do not think about the possibility of a dike failure. Most of the coastal area residents do not seem to have extensive knowledge of developments that can influence coast safety (such as an increase in sea level and soil dive). People often undervalue the magnitude, and do oftentimes not perceive the relevance of the way in which coastal safety is guaranteed. Berg et al. (2002) conclude that measures that remain in line with the actual situation are the most acceptable, but one is willing to think about alternative solutions. Measures that would directly harm financial and safety interests of coast inhabitants are in general not acceptable. Measures that do not directly harm interests of coast inhabitants can be acceptable if people trust the efficiency of such measures.

Flooding risk, as far as it is associated with the coast, is apparently not considered to be much of an issue by the inhabitants concerned, which contradicts what we discussed in the beginning of this section. We therefore also consider a study dealing with people's perception of the 1993 flood of the river Meuse (Ministerie van Verkeer en Waterstaat 1994), supported by Commissie Watersnood Maas (Commissie Boertien II) and Commissie Klankbordgroep. This survey, directed to 500 households and 200 businesses in the areas immediately affected by the flood, focuses on immaterial effects of floods of the river Meuse, such as feeling of safety, stress, sickness, or psychological distress associated with loosing personal belongings. This study confirms that protection from flood risk is in general considered a public good for which the national government has a certain responsibility. In particular, failure to disclose information related to the possibility of flooding (for instance, when applying for settlement) is considered by households an important shortcoming of the legislature. It appears that a great majority of households, about 80%, did not receive information about flood risk, while a 65% claims that they were not conscious of the risk.

This section has shown that the analysis of flooding risk should consider two types of determining factors. One derives from geophysical and chemical laws related to the response sensitivity to climate conditions of the earth, the other relates to human perception of risk and uncertainty. In addition to 'objective' engineering-type assessments of protection infrastructure, 'subjective' assessments of the value of flood defence infrastructure based on individual perception and experience cannot be discarded. In the next section we introduce a method to assess the economic value of the perception of flood defence infrastructure reliability.

3. Valuation of perceived reliability of flood defence infrastructure

River flooding is an inherently spatial phenomenon that is particularly suitable for exploratory and confirmatory spatial data analysis because floods tend to cover a substantial spatial range, and they oftentimes cause enormous financial and material damages. There is an impressive literature that uses non-market valuation techniques, specifically revealed preference methods. Among the non-market goods that have been studied, environmental risk constitutes the most frequently studied area. For instance, Boyle and Kiel (2001) provide a comprehensive review of willingness-to-pay valuations of environmental goods using hedonic pricing models. They review studies concerning air quality, water quality, and undesirable land use related to proximity to electrical power plants, nuclear plants, hazardous waste sites, landfills, petroleum refineries, incinerators or superfund sites. In addition to environmental hazards caused by human activity, natural hazards constitute another source of environmental risk. Hedonic pricing methods have been used to study natural hazards as well. Earthquake risk valuation is analyzed in, for instance, Kawawaki and Ota (1996), and Kurt et al. (1997), and also the valuation of flood risk has been extensively studied in the United States (see Daniel et al. (2007), for a comprehensive overview).

The assumption underlying revealed preference studies based on housing market prices is that the choice of buying a dwelling is shaped by its structural characteristics as well as by characteristics related to the property's location. The hedonic price method, initially presented by Rosen (1974), regards a dwelling as a differentiated market good representing a bundle of quantitative and qualitative characteristics. Each of these characteristics has a value, and these values sum up to the observed transaction price. By controlling for these characteristics we are able to infer their corresponding implicit shadow prices.

Analytically, considering a single housing market in equilibrium, we can estimate the relationship $p_i = p(s_i, n_i, r_i)$ in a stochastic setting, as:

$$\ln(p_i) = \alpha + s_i' \beta + n_i' \gamma + \delta r_i + \varepsilon_i, \tag{1}$$

where i indexes dwellings, s_i is a (row) vector of structural characteristics of the dwelling, n_i of neighbourhood characteristics related to the location of the house, and r_i is the spatial risk of the particular dwelling. The implicit marginal price of any characteristic of the dwelling can be expressed as the partial derivative of this expression to the characteristic of interest, and amounts to the monetary value associated with a housing bundle with a higher level of that characteristic, *ceteris paribus*.

In our empirical analysis we use a price vector comprising transaction prices observed between 1990 and 2004. We have at our disposal a comprehensive dataset made available by NVM, of observations geo-coded at the PC-6 level, with about half the observations referring to single family houses and the other half representing apartments. In the current analysis we use part of this dataset, specifically single family homes along the river Meuse. Flood experience is identified as follows. We make use of aerial photos of the river Meuse showing the zones under water during the December 1993 – January 1994 or during the January 1995 – February 1995 episode. It appears that most zones have been flooded during both events, and that some zones were not flooded but surrounded by water. By visually identifying flooded places and their respective location close to roads, rivers, channels, and residential areas, we are able to geo-code our dataset at the PC-6 level.

An important drawback in the use of hedonic price models in the context of economic flood risk valuation is caused by the coincidence of river-related amenities and flood risk. It is possible that the risk associated with a location inside the flood plain is (partly) compensated by the amenities represented by the presence of water, such as the presence of open-space, or the possibility to practice water sports. As a result, failing to control for the presence of water amenities, will lead to a biased estimate of the implicit price of flooding risk. For that reason we explicitly include a variable indicating proximity to the river and proportion of water in land surface (eg. lakes, canals or river branches) at the level of the neighbourhood. This enables us to distinguish between the level of risk related to the proximity of the river Meuse, and the positive amenities related to this proximity (for instance, sightseeing).

[Figure 1 about here]

Data is sufficient to run the analysis in the following 7 municipalities: Boxmeer, Bergen, Cuijk, Maasbracht, Roermond, Maastricht and Meerssen. These municipalities are spread along the Meuse River in three non connected groups labeled for convenience A, B and C from North to South.

Table 1 provides and overview of the variables that we use in the analysis, and includes some descriptive statistics.

[Table 1 about here]

Our sample is made up 9505 observed transactions, among which 246 concern houses located in a zone that has been flooded at least once, and 67 are surrounded by water during both events.

We can note that dwellings are in equivalent proportion town houses and halves of double houses (together 61% of all observations). The proportion of monuments is rather low (only 501 dwellings built between 1500 and 1905), and about 6% of the dwellings were built in the few years preceding the transaction. The overall quality of houses is good: central heating is present in 92% of the houses, and the average number of isolation layers is greater than one and a half. We can note that the range of neighbourhood variables is rather high: average income can be twice and a half higher among neighbourhoods. In order to control for positive amenities related to water, we account for the distance to the closest segment of a river and for the proportion of water in the total neighbourhood land surface. The latter has a maximum of 52%; 8% of houses are located within 500m from the river. Accessibility to highway is rather high in the whole sample as 92% of houses are located within 4500m of an entrance point of highway.

We estimate several models in order to detect the presence of ex-ante house prices variations, related to a consciousness of the risk before experience took place. If ex-ante and ex-post effects would be similar, it would mean that risk level was perfectly known before hand and that the risk premium did not need to be reassessed after experiencing a flood. We also want to explore whether the first event only had an impact, or if both floods had a cumulative influence on house prices. It could also be that prices react to the second flood only if the first flood fell into the expectations of concerned inhabitants, not revealing any additional risk to what they knew before hand. Finally we want to check if effects on prices, if present, went down after a few years, as the event's remembrance would die out in memories.

We first estimate the hedonic price equation by OLS. Table 2 reports summary estimation results for the simplest specification: ex-ante and ex-post effects are supposed to be equal, and we consider houses located in zones that were flooded once or twice without distinction. Before drawing any conclusions based on the reported coefficients estimates, we investigate whether the residuals are spatially correlated.

[Table 2 about here]

In order to check for the presence of spatial correlation we use Moran's *I* statistic. The presence of a positive spatial autocorrelation reveals that spatial clusters consist of similar values, whereas a negative spatial autocorrelation reveals that spatial clusters are made of high and low values together. The Moran's *I* statistic is defined as follows (Cliff and Ord, 1981):

$$I = \frac{N}{S_0} \frac{e'We}{e'e}, \tag{2}$$

where W is the spatial weight matrix, e regression residuals obtained using the OLS estimator, N the number of observations, and S_0 the sum of the elements of the spatial weight matrix.

We design the spatial weight matrix such that every house within an 1808 metres band is designated as a neighbour, and subsequently row-standardize the matrix. This distance ensures that every house has at least a neighbour. Moran's *I* statistic shows extremely low values (0.038).

However the presence of spatial dependence in the OLS-based residuals is confirmed by performing Lagrange Multiplier diagnostics, which are based on restricted versions of the following ARAR(1, 1) model:

$$\ln(p) = \alpha + \rho W \ln(p) + S\beta + N\gamma + \delta R + (I - \lambda W)^{-1} \mu, \tag{3}$$

where μ is an iid error term. This general model includes two different types of spatial process models, which can be derived by putting restrictions on the parameters: the spatial lag model is obtained in the case where $\rho \neq 0$, and $\lambda = 0$; and the spatial autoregressive error model incorporates the restrictions $\lambda \neq 0$, and $\rho = 0$. Multi-directional Lagrange Multiplier tests on $\rho = 0$ and $\lambda = 0$, respectively, indicate that the spatial ARAR(1, 1) model is the appropriate specification (see Anselin and Florax 1995, for details).

The size of the dataset hampers computation; we make use of the fact that the three groups of municipalities are not geographically connected and write the weight matrix as a block diagonal matrix made up sub matrices of each sub groups. Off diagonal elements are then 0 matrices. This allows splitting the dataset per region and compute spatial lags separately.

$$W = \begin{bmatrix} W_A & 0 & 0 \\ 0 & W_B & 0 \\ 0 & 0 & W_C \end{bmatrix}$$

The estimation procedure is based on the work of Kelejian and Prucha (1998) and the related Stata routine; it refers to the generalized spatial two-stage least squares. The model is first estimated by 2SLS using set of instruments consisting of the covariates, and spatially lagged (once and twice) covariates. The obtained residuals are used to estimate a GM autoregressive error parameter. A Cochrane Orcutt transformation is applied to the model, which is estimated by 2SLS. Table 3 presents some key results.

[Table 3 about here]

All coefficients show the expected signs. The results for the distance variables reveal that proximity to the river is appreciated, whereas proximity to a highway is undesirable (coefficient estimate -0.036). The later catches negative externalities related to traffic noise. However, the distance to an entrance point to the highway has a positive influence on prices (0.057).

Characteristics of the dwelling are also well valued. The presence of a garage is highly appreciated. Bad maintenance, both inside and outside the dwelling, or the presence of a gas or a coal heating show negative signs. The quality of the house (isolation, central heating), however, is positively reflected is transaction prices. Proxies for the presence in the city (shared houses, houses in a row, corner houses, half houses, as opposed to detached houses) are devalued. Finally, the level of income per inhabitant is associated with a positive coefficient estimate (0.039).

The most striking results concern the variables associated with flood characteristics. This deserves special attention and is to be discussed in the following section, together with concluding remarks.

4. Discussion on the effects of flood on house prices and concluding remarks

The estimation results in Table 3 show that local housing markets in the Netherlands are sensitive to flood risk. To our knowledge, this is the first time that such a study, based on revealed preference techniques, with such a detailed and comprehensive data set, is carried out in the Netherlands.

In order to obtain the marginal effect related to the location in a flooded zone, the coefficient estimates need to be corrected for the spatial multiplier. Formally, the spatial lag model (i.e., the model in (3), with $\lambda = 0$) can be rewritten as:

$$\begin{aligned} \ln(p) &= \alpha + \rho W \ln(p) + S\beta + N\gamma + \delta R + \mu \\ &= (I - \rho W)^{-1}(\alpha + S\beta + N\gamma + \delta R + \mu). \end{aligned} \tag{4}$$

As a result, the marginal effect related to the location in a flooded zone on the selling price is not simply δ, but rather:

$$\frac{\partial \ln(p)}{\partial R'} = (I - \rho W)^{-1}\delta\ , \tag{5}$$

where $(I - \rho W)^{-1}$ is the spatial multiplier. Due to the semilog specification, this marginal effect is expressed in terms of relative change in selling price. The marginal effect consists of three elements (Abreu et al. 2005): the direct impacts of the location in a flooded zone on the selling price of a given house, the indirect effects due to the impact of location on the selling prices of neighbouring houses which are spillovers related to the direct effects, and the induced effects which are spillovers related to direct and indirect effects on all neighbours. The direct effect due to the location in a zone that was flooded is the coefficient estimate associated with the flood risk variable, and amounts to –7.8% when considering the effects of the second flood. This refers to the difference in prices between dwellings that were affected by the flood and dwellings that were not affected. In order to compute the total effect, we sum the elements of the spatial multiplier matrix over its columns. The total effect due to the location in the flooded zone, taking into account the spatial multiplier process, varies between –11.4% and –7.9%.

We do not find significant ex-ante impacts across specifications, neither impacts between both floods. It may be that the occurrence of the first flood met the expectations of concerned inhabitants. The fact that a house was surrounded by water during one of the events also does not seem to be reflected in its selling price.

We explored whether this devaluation varies over time. We tried different periods with increments of 6 months, and obtain significant results when accounting for periods of 2 years following the second flood. It seems that the decrease in house values does not disappear after some years. During the two years following the second flood, devaluation in prices lies between 7.3 and 10.7%; this value seems to decrease in the following period and ranges between 6.3 and 9.2%. But it remains at a high level and in the last period, this devaluation still amounts to 8.4 to 12.3% of house selling prices. It is interesting to note that perception of recent floods remains persistent; a possible explanation is the increased communication on flood risk related themes in the media in the last decade.

We conclude that the total impact of flood on house values in the municipalities affected by the recent high tide events is substantial with a decrease between about 7 and 13%. These values are rather high, although not exceptional if compared with the meta-analysis we carried out on this subject (Daniel et al., 2007). We also note that the government compensated the victims in a rather generous way for the damage costs. Hence, our estimates do not in the first place reflect the direct damages to the dwellings, but a broader range of costs including various inconveniences and feelings of stress for being at risk.

It should be emphasised that water does not only have a negative impact on house prices, but that there may also be positive effects, because water is the source of several positive amenities. For example, we find that a dwelling located within 500 metres of the river Meuse are worth up to 3.8% higher as compared to a similar dwelling located further than 500 metres away. Thus, the areas affected by the floods are to a certain extent compensated by positive amenities. The reason why we can disentangle these effects is of course, that there is a sufficient number of houses that combine the best of both worlds: proximity to water and absence of flood risks, for example because they are located on hills near the river.

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Table 1. Descriptive statistics of the property value dataset

	Group A	Group B	Group C	Total
Flooded anytime	28	89	129	246
Surrounded by water anytime	0	67	0	67
Flooded anytime and sold before the first flood	3	22	16	41
Flooded anytime and sold between the two floods	2	3	5	10
Flood anytime and sold after the second flood	23	64	108	195
Number of observations	3406	2663	3436	9505

Municipality		Number of observations
Group A		
	Boxmeer	1306
	Bergen	483
	Cuijk	1617
Group B		
	Maasbracht	369
	Roermond	2294
Group C		
	Maastricht	2812
	Meerssen	624

		Minimum	Maximum	Sum	Mean	Std. Deviation
Flood patterns						
	Flooded anytime	0	1	246	0.026	0.159
	Surrounded by water	0	1	67	0.007	0.084
	Flooded anytime and sold before the first flood	0	1	41	0.004	0.066
	Flooded anytime and sold between the two floods	0	1	10	0.001	0.032
	Flood anytime and sold after the second flood	0	1	195	0.021	0.142
House characteristics						
	Transaction price	17697	1077728		166066	93992
	Log surface in square meters	3.912	6.25		4.974	0.276
	Built recently	0	1	603	0.063	0.244
	Townhouse	0	1	2876	0.303	0.459
	House in a row	0	1	376	0.040	0.195
	Corner house	0	1	1321	0.139	0.346
	Half of a double house	0	1	2933	0.309	0.462
	Detached house (*)	0	1	1981	0.208	0.406
	Simple house	0	1	444	0.047	0.211
	Single-family house	0	1	6634	0.698	0.459
	Canal house	0	1	6	0.001	0.025
	Manor house	0	1	1170	0.123	0.329
	Farmhouse	0	1	175	0.018	0.134
	Bungalow	0	1	443	0.047	0.211
	Villa	0	1	208	0.022	0.146
	Country house (*)	0	1	423	0.045	0.206
	Parking lot	0	1	284	0.030	0.170
	Carport	0	1	692	0.073	0.260
	Garage	0	1	4583	0.482	0.500
	Both carport and garage	0	1	200	0.021	0.144
	Garage adapted to several cars	0	1	394	0.041	0.199

L-living room	0	1	2549	0.268	0.443
T-living room	0	1	495	0.052	0.222
Z- or U-living room	0	1	106	0.011	0.105
Through-living room	0	1	2912	0.306	0.461
Room and suite	0	1	445	0.047	0.211
Gas or coal heating	0	1	259	0.027	0.163
Central heating boiler. central heating. district heating	0	1	8741	0.920	0.272
Construction year 1500-1905	0	1	501	0.053	0.223
Built-in parking possibility	0	1	1120	0.118	0.322
Number of isolation layers	0	5		1.803	1.419
Number of bathrooms with shower and/or bath	0	3		0.854	0.442
Number of balconies	0	2		0.074	0.269
Number of sculleries	0	1		0.276	0.447
Number of dormer windows	0	2		0.055	0.229
Number of terraces	0	3		0.026	0.166
Number of floors	1	7		3.138	0.741
Index of inside maintenance	1	9		3.112	1.191
Index of outside maintenance	1	9		3.106	1.133
Index of practice possibility	0	3		0.027	0.213
Index of practice presence	0	3		0.025	0.201
Garden oriented to south. southeast or southwest	0	1	3648	0.384	0.486
Attic	0	1	4110	0.432	0.495
Presence of stairs	0	1	2336	0.246	0.431
Attic, elder	0	1	898	0.094	0.293
First sale (no public notary charges)	0	1	43	0.005	0.067
Neighborhood characteristics					
Index of urban density	1	5		3.296	1.178
Average income per inhabitant	7.7	18.6		12.720	1.790
Proportion of single-person households	5	73		30.6303	12.167
Proportion of households with no children	15	49		31.645	5.527
Proportion of water in land surface	0	52.41		4.197	8.652
Distance to the closest segment of the highway <500m	0	1	1118	0.118	0.322
Distance to the closest point of entrance to the highway <4500m	0	1	8758	0.921	0.269
Distance to the closest segment of the river <500m	0	1	764	0.080	0.272

(*) reference cases

Table 2. Estimation key results (OLS); spatial diagnostics on the residuals

Variables/diagnostics	Est	se	p-value
Intercept	9.682	0.511	0
Flooded anytime	–0.064	0.012	0
Dist to river <500m	0.024	0.007	0
Dist highway <500m	–0.048	0.006	0
Dist entrance to highway <4500m	0.034	0.009	0
Urban density index	–0.018	0.003	0
Average income	0.045	0.001	0
Proportion of water in land surface	0.001	0.000	0
Residual standard error	0.1595		
Adj R^2	0.9050		
Moran's I[a]	0.0382		
LMerr	378.3		
RLMerr	139.6		
LMlag	1965.8		
RLMlag	1727.1		
SARMA	2105.3		

[a] All the spatial diagnostics are significant at the 0.01 level or below.

Table 3. Estimation key results (generalized spatial 2SLS)

	Coef. Est	Std error	P-value	Marginal effects	
<u>Similar ex-ante and ex-post effects on prices</u>					
Root MSE	0.1565				
Autoregressive error term	0.5568				
Spatial lagged dependent variable	0.236	0.027	0.00		
Proximity to the river	0.025	0.007	0.00	0.025	0.038
Flooded anytime	–0.050	0.013	0.00	–0.051	–0.076
<u>Accounting for the effects of the second flood</u>					
Root MSE	0.1564				
Autoregressive error term	0.5812				
Spatial lagged dependent variable	0.219	0.028	0.00		
Proximity to the river	0.025	0.007	0.00	0.025	0.036
Before the second flood	0.023	0.023	0.31	0.024	0.034
After the second flood	–0.078	0.017	0.00	–0.079	–0.114
Surrounded by water (ex-ante)	0.009	0.068	0.89	0.010	0.014
Surrounded by water (ex-post)	–0.018	0.023	0.43	–0.018	–0.026
<u>Accounting for the effects of the first flood</u>					
Root MSE	0.1564				
Autoregressive error term	0.5761				
Spatial lagged dependent variable	0.232	0.028	0.00		
Proximity to the river	0.026	0.007	0.00	0.026	0.039
Before the first flood	0.014	0.026	0.58	0.015	0.022
After the first flood	–0.065	0.014	0.00	–0.066	–0.098
Surrounded by water (ex-ante)	–0.027	0.075	0.71	–0.028	–0.041
Surrounded by water (ex-post)	–0.022	0.023	0.32	–0.023	–0.034
<u>Accounting for both floods separately</u>					
Root MSE	0.1564				
Autoregressive error term	0.6077				
Spatial lagged dependent variable	0.222	0.029	0.00		
Proximity to the river	0.025	0.007	0.00	0.025	0.037
Before the first flood	0.017	0.026	0.50	0.018	0.025
Between both floods	0.049	0.050	0.33	0.050	0.072
After the second flood	–0.078	0.017	0.00	–0.079	–0.115
Surrounded by water (before the first flood)	–0.020	0.075	0.79	–0.020	–0.029
Surrounded by water (between both floods)	0.145	0.157	0.36	0.147	0.214
Surrounded by water (after the second flood)	–0.017	0.023	0.44	–0.018	–0.026
<u>Accounting for the effects of the second flood, non constant ex-post effects</u>					
Root MSE	0.1565				
Autoregressive error term	0.5590				
Spatial lagged dependent variable	0.224	0.027	0.00		
Proximity to the river	0.024	0.007	0.00	0.024	0.035
Before the second flood	0.024	0.023	0.31	0.024	0.035
Within 2 years after	–0.072	0.033	0.03	–0.073	–0.107
Between 2 years and 4 years after	–0.062	0.035	0.07	–0.063	–0.092
Between 4 years and 6 after	–0.088	0.028	0.00	–0.089	–0.130
Between 6 years and 8 after	–0.072	0.032	0.03	–0.073	–0.106
Remaining period	–0.083	0.030	0.01	–0.084	–0.123

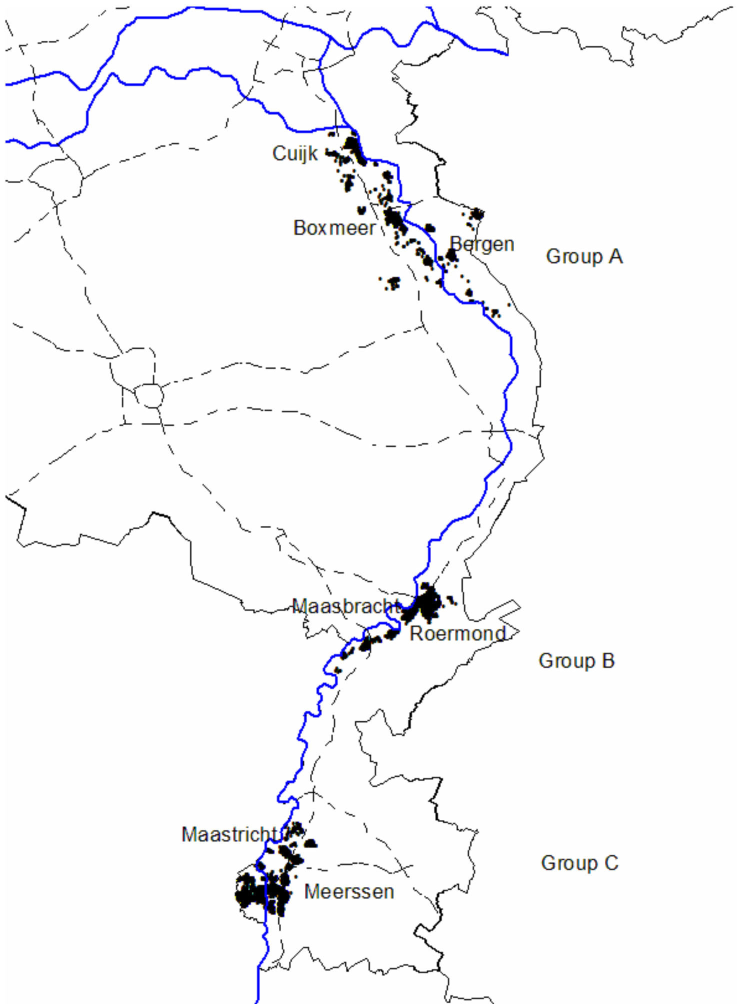

Figure 1. Municipalities along the Meuse River