Mandatory Flood Insurance and Housing Prices: An Empirical Agent-Based Model Approach

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Abstract

Federally regulated or insured lenders in the United States are mandated to require flood insurance on properties that are located in areas at high risk of flooding. Despite the existence of this mandatory flood insurance requirement, take-up rates for flood insurance have been low and the federal government's exposure to uninsured property losses from flooding remains substantial. The Biggert-Waters Flood Insurance Reform Act of 2012 addressed the lack of enforcement of the mandatory insurance requirement by increasing penalties on noncompliant lenders. In this paper we employ an empirical adaptive agent-based model to simulate the impacts of such mandatory flood insurance requirement on a housing market. Our approach combines the empirical hedonic analysis with the computational economic framework to examine capitalization of insurance premiums in housing prices. A bilateral housing market allows exploring a shift between simulated hedonic equilibria while directly tracing the dynamics of implicit prices of flood risk over time. Results indicate that the mandatory flood insurance requirement would have a detrimental effect on housing prices in flood-prone areas. The effect is more pronounced for the Special Flood Hazard Areas than for the less risky areas.

Keywords: NFIP, Biggert-Waters, agent-based model, flood risk differential, housing price

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1. Introduction

Floods are one of the most common and widespread natural disasters in the United States, and yet the damage from flood events is often not covered by homeowner's insurance policies.[2] Flood coverage is offered federally through the National Flood Insurance Program (NFIP), established by the National Flood Insurance Act of 1968. Under current provisions, if communities choose to adopt minimum floodplain management policies, their residents become eligible for this insurance backed by the federal government. The goal of the NFIP is to provide an insurance alternative to disaster assistance to meet the escalating costs associated with floods. The NFIP is currently managed by the Federal Emergency Management Agency (FEMA) within the Department of Homeland Security.

The success of the NFIP depends on making the flood insurance widely available to homeowners and protecting communities from potential damage through floodplain management without adverse selection and information asymmetry. The Flood Disaster Protection Act of 1973 directed regulated lenders to require flood insurance on properties located in Special Flood Hazard Areas (SFHAs) that have a federally backed mortgage. This mandatory requirement was strengthened by the National Flood Insurance Reform Act of 1994 which required recipients of certain flood disaster assistance to purchase and hold flood insurance to protect against future flood losses, under the penalty of receiving no federal disaster aid in subsequent floods. Despite the existence of this mandatory purchase requirement, take-up rates for flood insurance have been very low (Kriesel and Landry 2004; Kousky 2011). A recent study of the NFIP's market penetration rate indicated that only about 49% of single-family homes in SFHAs are covered by flood insurance (Dixon et al. 2006).

The Biggert-Waters Flood Insurance Reform Act of 2012 (Biggert-Waters) addressed the lack of enforcement of the mandatory insurance requirement by increasing the amount of civil penalties that can be imposed against regulated lending institutions that fail to require flood insurance. Subsequently, several federal regulatory agencies issued a joint notice of proposed rulemaking to amend regulations pertaining to loans secured by property

[2] Alternatively, flood insurance is usually included in homeowners' insurance policies and provided by private insurers in the U.K. and France. In Germany, flood insurance is also provided by private insurers as a supplement to homeowners' insurance coverage. In the Netherlands, a private insurance option is being considered although the homeowners rely entirely on government relief after the disaster (Michel-Kerjan, 2010).

located in SFHAs.[3] The proposed rule would implement certain provisions of the Biggert-Waters Act with respect to private flood insurance, the escrow of flood insurance payments, and the forced-placement of flood insurance.[4]

The goal of this paper is to explore and quantify the effects of such mandatory flood insurance on a residential housing market. Specifically, we address whether the mandatory flood insurance has a profound effect on housing values and whether this effect differs across risky zones. Our approach combines an empirical hedonic analysis (HA) with an agent-based computational economics (ACE) model to examine capitalization of insurance premiums in housing prices. ACE models study economies as evolving systems of many interacting heterogeneous agents, which follow simple behavioral rules (Axtell 2005; Tesfatsion and Judd 2006). Such computer-enabled simulations offer a virtual laboratory where emergent outcomes of many instructing agents can be tested under various policies. ACE models have been widely applied to a variety of market settings, including financial, electricity, commodity, and labor markets (Arthur et al. 1997; Kirman and Vriend 2001; Tesfatsion 2006). Agent-based methodology is also actively used to study the dynamics of coupled human-environment systems (Parker et al. 2002; An 2012; Filatova et al. 2013). At the same time, their use in environmental and spatial economics is becoming increasingly popular (Nolan et al. 2009; Irwin 2010; Filatova et al. 2011). Previous spatial ACE models applied to housing markets generally either tend to use an empirical landscape setting to lay foundations for agents' behavior omitting theoretical assumptions about economic processes (Benenson 1998; Brown and Robinson 2006; Dawson et al. 2011), or use a stylized landscape and little empirical micro-foundations of agents' behavior with theoretically-elegant economic solutions (Filatova et al. 2009; Ettema 2011; Magliocca et al. 2012). Huang et al. (2013) provides a comprehensive review of spatial agent-based models applied to study urban phenomena and identifies the current frontiers of the method. To the best of our knowledge, an empirical ACE model of housing markets, which is well grounded in economic theory and could use readily available spatial data and empirical analysis, is not available yet.

The innovativeness of this approach is twofold. Firstly, in comparison to other economic methods studying a proposed policy change, our approach explicitly simulates the emergence of property prices under adaptive price expectations of heterogeneous agents in rich spatially explicit settings. Our integrated HA-ACE model allows

[3] The proposed rule was issued by the Board of Governors of the Federal Reserve System, the Farm Credit Administration, the Federal Deposit Insurance Corporation, the National Credit Union Administration and the Office of the Comptroller of the Currency (source: http://www.federalreserve.gov/newsevents/press/bcreg/20131011a.htm).

[4] The proposed rule would require that regulated lending institutions accept private flood insurance as defined in Biggert-Waters to satisfy the mandatory purchase requirements. In addition, the proposal involves regulated lending institutions to escrow payments and fees for flood insurance for any new or outstanding loans secured by residential improved real estate or a mobile home.

exploration of fluctuations in implicit prices of risks or amenities as a balance between aggregated demand and supply driven by changing individual willingness to pay (WTP) and willingness to accept (WTA). This may lead to the emergence of cardinally new trends in prices and spatial development patterns making this approach potentially suited to study non-marginal changes in economic systems. Secondly, in comparison to other ACE property markets which are stylized abstract models (Parker and Filatova 2008; Gilbert et al. 2009; Ettema 2011; Magliocca et al. 2012), the current model makes step forward towards empirical modeling of ACE property markets by using empirical hedonic analysis, GIS data, and distribution of households preferences and incomes while maintaining a fully modeled housing market. In particular, our integrated HA-ACE model utilizes rich GIS data on the NFIP flood maps and residential property sales from mainland Carteret County, North Carolina. In examining the housing market responses to the proposed mandatory flood insurance, we differentiate between the 100-year flood risk zones and 500-year flood risk zones. At the same time, we frame theoretical micro-foundations of residential household agents' behavior within urban economics theory (Alonso 1964; Frame 1998; Wu 2001) and use adaptive price expectations.

Our results indicate that the mandatory flood insurance requirement would have a detrimental effect on housing price in risky areas over time. With high valuation of coastal amenities, the housing price in the 100-year floodplain increases by about 51% without the insurance requirement as compared to only 39% with the mandatory insurance over the next 30 years. The effect for the 500-year floodplain is less pronounced, with about a 20% increase without the insurance requirement but only a 13% increase with the mandatory insurance over the next 30 year period. The next section of the paper offers background on the NFIP relevant to understanding the effects of mandatory insurance requirement. Section three presents our methods while the fourth section discusses the study area and data. The results are summarized in section five. We conclude with a discussion of our findings and some important caveats.

2. Mandatory Flood Insurance Requirement of the NFIP

The NFIP was created in 1968 as a result of the passage of the National Flood Insurance Act. Prior to this legislation, the federal government routinely paid large sums for disaster relief after floods. The NFIP is a Federal program enabling property owners in participating communities to purchase insurance as a protection against flood losses in exchange for local floodplain management regulations that reduce future flood damages. This program intends to provide an insurance alternative to disaster assistance and reduces the rising costs of repairing damage to buildings and their contents caused by floods. The NFIP has three components: to provide flood insurance, to improve floodplain management and to develop maps of flood hazard zones. Homeowners can purchase up to $250,000 of building coverage and up to $100,000 of contents coverage. Business-owners can purchase up to $500,000 each of both building and contents coverage. Excess flood insurance can be purchased, but they must be covered by NFIP flood insurance first.

Concerns about the costs of flooding and low take-up rates led Congress in 1973 to make the purchase of flood insurance mandatory for property-owners in 100-year floodplains with a mortgage from federally backed lenders. Take-up rates remained low in the early years of the program, but have grown steadily over the decades. Still, concern is often expressed following major flood events that many at-risk homeowners remain without coverage. Focusing on barrier islands, Kriesel and Landry (2004) estimate that only 49% of coastal households maintain flood insurance, despite mandatory requirements for those households that hold a federally-backed mortgage. Kousky (2011) examines the demand for flood insurance using data from St. Louis County, Missouri, and finds that take-up rates are very low, and risk drives demand but not always as predicted. An estimate of take-up rates in 100-year floodplains by RAND Corporation finds high regional variation, with the South and West having the highest take-up rates of around 60%, while in the Midwest, take-up rates are only around 20-30% (Dixon et al. 2006). As of September 2013, about 5.54 million policies were in-force nationwide, representing just under $1.29 trillion in coverage (Kousky and Kunreuther 2013).

After Hurricane Katrina in 2005, the NFIP paid out more in claims than had previously been paid over the entire life of the program (Hayes and Neal 2009).[5] In October 2012, Hurricane Sandy caused widespread flood-related property damage in coastal areas of states throughout the Northeast and the mid-Atlantic region, raising the prospect that NFIP would not be able to pay all the resulting claims without borrowing additional funds from the Treasury. In January 2013, Congress passed legislation to temporarily increase NFIP's borrowing authority by $9.7 billion, from $20.7 billion to $30.4 billion to address these claims. The significant NFIP debt generated broad interest in reforming the program.

The Biggert-Waters Flood Insurance Reform Act reauthorized the NFIP for five more years until 2017, and made a number of reforms aimed at making the program more financially and structurally sound. A few of the

[5] These are payments for insured properties. Congress also appropriated over $60 billion in disaster relief for Hurricane Katrina. Some of this money does go into grants for individuals (who may be uninsured) but the amount is limited to just over $30,000.

provisions of Biggert-Waters have been implemented, while others are being phased in over time. Several federal agencies are proposing to amend their regulations regarding loans in areas having special flood hazards to implement provisions of Biggert-Waters. The proposal would clarify that regulated lending institutions have the authority to charge a borrower for the cost of force-placed flood insurance coverage beginning on the date on which the borrower's coverage lapsed or became insufficient and would stipulate the circumstances under which a lender must terminate force-placed flood insurance coverage and refund payments to a borrower. Penalties on noncompliant lenders have been increased as well. As these reforms are put in place, it is essential to understand their potential impacts on housing markets in risky areas. In particular, assuming that the mandatory flood insurance is fully enforced, how would such program impact households' demand for properties in floodplain and how it would capitalize in property prices, and thus, influence potential direct damage at stake.

3. Methods

3.1 Model assumptions

Hedonic analysis (HA) has been successfully used to understand how various spatial and structural property characteristics contribute to its value (Rosen 1974). The spatial econometric models successfully accommodate heterogeneity of the 2D landscape usually using rich GIS datasets. Yet, conventional HA models reflect only a snapshot of a market, as they are estimated using transaction prices, which represent the net results of bargaining between buyers (based on their WTP) and sellers (based on their WTA). This implies that predictions from a regression model based on past transactions may not be robust when underlying behavior or economic conditions change, altering WTP and WTA (Bockstael 1996). The statistically estimated demand curve or the probability of choosing a location by a representative agent based on historic data are static, once estimated, while individual location choices may change with time (e.g. because of changing preferences, budget constrains or macroeconomic conditions).

ACE approaches to modeling property markets represent a practical and flexible alternative (Nolan et al. 2009; Parker et al. 2011). A review by Irwin (2010) provides a detailed analysis of the strengths and limitations of traditional economic modeling methods and those of agent-based models. Economic agents in ACE models are usually heterogeneous, involved in interactions with each other and their environment, boundedly rational and able to learn and adapt to the behavior of other traders and aggregated market conditions. These aspects of ACE models make them well suited to the modeling of property markets. ACE models replace a centralized price determination mechanism (i.e., equilibrium conditions motivated by a story of a Walrasian auctioneer) with decentralized bilateral trading among agents (Tesfatsion and Judd 2006). Due to this flexible model structure, ACE models provide a platform for wider exploration of out-of-equilibrium dynamics (Arthur 1999), agent heterogeneity (Kirman 1992), bounded rationality (Simon 1997), and interaction between agents (Axtell 2005). ACE markets often use straightforward microeconomic assumptions for agents' behavioral rules, which drive such emergent outcomes as prices and trade volumes. Property markets are special types of markets (Parker and Filatova 2008; Irwin 2010; Magliocca et al. 2012). Not only traders – including residential buyers and sellers, developers, and rural landowners – have heterogeneous preferences, resources, and knowledge; spatial goods are also highly heterogeneous. Property market participants have imperfect information when forming expectations about property values because each spatial good has unique characteristics in space and time, and because housing market goods are infrequently purchased. Thus, modeling of price expectations is a core issues in ACE models for property markets (Ettema 2011; Magliocca et al. 2012).

Our integrated HA-ACE model combines the strengths of two methodologies. Namely, we use ACE to trace changes in aggregated housing market dynamics endogenously as new economic agents appear in a market, and as a mandatory flood insurance changes their budget constrains and, thus, their WTP for properties in a flood plain. HA offers a reliable estimate of marginal WTP for highly heterogeneous spatial goods, which is easily matched with the rich GIS data. When ACE and HA combined, a bilateral housing market allows exploring a shift between simulated hedonic equilibria while directly tracing the dynamics of implicit prices of flood risk.

The HA-ACE model to study the impacts of the mandatory flood insurance is implemented in Netlogo software using GIS and R extensions (Wilensky 1999; Thiele and Grimm 2010). Our ACE model combines the microeconomic demand, supply, and bidding foundations of spatial economics models with the spatial heterogeneity of HA models in a single methodological platform. We model a coastal town where both recreational amenities and flooding disamenities drive housing market outcomes, facilitating separate analysis of the effects of each driver on property values and their spatial distribution. We start with a conventional urban economics model and gradually relax the assumptions of perfect rationality and homogeneity among households as well as the assumption of an instantly equilibrating housing market. Heterogeneous household agents (buyers and sellers) exchange heterogeneous spatial goods (houses) via simulated bilateral market interactions with decentralized price determination (Figure 1). The model is run for 30 years with each simulation period equal to six months.

3.2 Buyers' behavior

At the beginning of a trading period all active buyers search for a property that maximizes their utility. Following Alonso (1964), we assume that household's utility depends on a combination of composite (*z*) and housing (*s*) goods which is affordable for her budget (*Y*) net of transport costs (*T(D)*), where *D* is a distance from the central business district. The Cobb-Douglas utility function also depends on environmental amenities provided by a location (*A*), as in Wu and Plantinga (2003) and Wu (2006):

$$U = s^{\alpha} z^{1-\alpha} A^{\gamma}$$

$$\text{or } U = s^{\alpha}(Y - T(D) - k_H H_{ask})^{1-\alpha} A^{\gamma} \quad (1)$$

where $0 < \alpha < 1$ and $\gamma > 0$. Here k_H is a coefficient to translate the asking price of a seller (H_{ask}) into an annual payment. Preferences for housing good (α) and amenities (γ) as well as exogenous incomes (*Y*) are heterogeneous across household agents (Table 1).

When choosing a location in a coastal town with designated flood zones, a household operates under the conditions of uncertainty. Thus, following Frame (1998), we assume that she maximizes her expected utility (*EU*):

$$EU = P_i U_F + (1 - P_i) U_{NF} \quad (2)$$

where U_F is household's utility in case flood event occurs, U_{NF} is utility in the case of no flood, and P_i is a subjective flood probability as perceived by a buyer.[6] After Bin, Kruse, Landry (2008) we assume that households may be required to pay an annual flood insurance premium (*IP*) and will receive an insurance coverage (*IC*) in the case of a flooding:

$$U_F = s^{\alpha}(Y - T(D) - k_H H_{ask} - L - IP + IC)^{1-\alpha} A^{\gamma} \quad (3)$$

$$U_{NF} = s^{\alpha}(Y - T(D) - k_H H_{ask} - IP)^{1-\alpha} A^{\gamma} \quad (4)$$

Here *L* is the damage in the case of flood. It is assumed that housing search is costly, thus, households search for a local maximum: from a subset of properties they select the one that delivers highest utility. After a buyer has found the property that gives her maximum utility, she submits her bid price to a seller. Buyers bid differently depending on how long a property is on a market and on their relative market power. Real estate guidelines suggest that buyers

[6] In the current paper it is assumed that buyers have perfect information, i.e. perceive flood risk probability objectively.

bid within a range of -/+ 3-5% of an ask price depending on the excess of demand or supply and on how long a property has been on market. Our ACE model assumes that the bid price is a random number within the (-5%; +5%) interval of the ask price of a property of interest. However, in any case buyer's bid price should not exceed her reservation price, which is when translated into annual payment should not exceed 40% of her annual income.

3.3 Sellers' behavior

At the model initialization stage some properties are for sale, i.e. each property has a seller (Figure 1). As simulation goes on, settled households may decide to sell their property. At the beginning of a trading period, active sellers announce their ask prices. They do so by requesting regression coefficients from the hedonic analysis of the current period and applying them on their property. At the initialization stage this hedonic function and coefficients come from Bin, Kruse, Landry (2008). As model runs and new transactions occur real, estate agents are rerunning hedonic analysis. Regression coefficients may change as for example housing costs in safe and risky areas change or new households with different preferences for locations are arriving to the city.

After buyers make their choices, all sellers check how many bid-offers they received. They choose the highest bid to engage in price negotiations (Figure 2 and section 3.4). The transaction price is defined through a price negotiation procedure, which is based on bid and ask prices and relative market power of traders.

3.4 Price negotiation

Multiple interactions between buyers and sellers affect future trades and property values (Figure 1). Bilateral price negotiations constitute one of the innovative aspects of this ACE model. If a seller has at least one bid submitted he engages in price negotiations with the buyer who offered the highest bid price. Naturally, if her bid price is higher than the seller's ask price, then the trade is successful and final transaction price is equal to this bid (box 1, Figure 2). If the highest bid is below the original ask price, then the market power of agents plays a role (box 2, Figure 2). Specifically, if the seller has more than one bid offered, then the highest-bid buyer is the first one to reconsider his bid price. The highest-bid buyer checks if the opportunity costs of waiting another period for another trade attempt (her *OC*) are comparable to the difference between the bid and ask prices (box 3, Figure 2).

Here *OC* of a buyer is operationalized as one period of renting an average house in the city,[7] which is updated with time as residential housing prices change. If it is beneficial for the buyer to accept the ask price instead of waiting another period for a trade attempt, then she accepts the ask price and trade is successfully registered. A consequence of this competition among buyers and stronger market power of sellers of the most demanded properties is that the latter are likely to be sold at sellers' ask prices or even above (box 2 and 1 correspondingly). However, if the seller receives only one offer-bid, then he is the one to reconsider his ask price (box 4, Figure 2). In particular, he compares the difference between the bid and ask prices to the opportunity costs of waiting another period (his *OC*) and accepts the bid price, if comparison is in its favor. The *OC* of a seller is operationalized as one period of mortgage for his property at the start of sellers trading history and gets updated with every unsuccessful trade attempt. Thus, it adapts to changing endogenous variables and interactions leading to the outcome when less demanded properties gradually fall in price. If the seller and the buyer do not agree on a price the negotiation fails.

3.5 Adaptive versus static price expectations: behavior of a real estate agent

It is challenging to model price expectations in the property markets characterized by high heterogeneity of goods, which are infrequently traded. While ACE has made a major progress on modeling markets of homogeneous goods (Arthur et al. 1997; Kirman and Vriend 2001; Tesfatsion and Judd 2006), housing goods have very diverse attributes. The same house in a different location may have a disproportionally different price as do two houses with different structural characterizes in the same neighborhood. Modeling price expectations in housing markets needs an introduction of mediator who learns the efficient price of any unique house and who participates often in transactions of such infrequently-purchased good (Parker and Filatova 2008; Ettema 2011; Magliocca et al. 2012). We build upon the previous research on urban ACE markets and introduce real estate agents who observe successful transactions and form price expectations. As a realtor engages in many transactions, the society of agents relies on the collective information about recent transaction prices. Thus, adaptive expectations about property prices are implemented as a collective learning process.

Adaptive price expectations realized through a re-estimation of hedonic coefficients to trace housing price changes accounting for spatial goods heterogeneity and market dynamics. Residential property is a bundle of

[7] Our housing market ACE model does not simulate a residential renting market explicitly. Thus, the average rent in the city is equal to average mortgage payment in this city and is the same for all buyers. In case a rental market is modeled explicitly in parallel to the ownership market, the monthly rent would be heterogeneous across households.

quantitative and qualitative characteristics (Rosen 1974). Thus, a price of a residential parcel can be expressed as a function of those attributes – presented as 14 GIS attributes (Table 2). Marginal implicit prices can be interpreted as marginal WTP of a representative household for specific housing attributes. Our ACE adopts the hedonic function estimated for the area based on the GIS data used to initialize the landscape:

$$ln\, H_{tran} = \beta_0 + \sum_{i=1}^{n} \beta_i\, x_i + \varepsilon. \quad (5)$$

Here lnH_{tran} is the log of transaction price, x_i is a variable for the i^{th} housing attribute (structural, neighborhood and environmental), β are regression coefficients, and ε is the error term. At initialization realtors are endowed with coefficients of the original hedonic analysis of Bin, Kruse, Landry (2008, Model 4). At the end of each time step during the simulation all successful transactions get registered in a file together with all the attributes of traded agents and properties. Each period a real estate agent runs a HA on the new transactions from the last 6 months re-estimating new hedonic equilibria. Eventually, the new coefficients got recorded into realtor's memory.

In addition to adaptive price expectations we also employ so-called 'static' price expectations. In this case the hedonic model based on the initial empirical analysis will be used throughout the whole simulation. The outcomes of the integrated HA-ACE model in the case of static expectations would resemble the predictions of a price trend, which HA alone would produce. In this case a snapshot of a market that is an outcome of the equilibrium allocation of the initial traders with their preferences and budget constrains (which the mandatory flood insurance was not part of) would be extrapolated for the 30 years of simulations. Housing price predictions of realtors in this case do not reflect falling or growing demand for certain safe or risky areas as the mandatory flood insurance gets introduced.

4. Study Area and Data

The model is applied to the coastal town of Beaufort in Carteret County, North Carolina (Figure 3). The area is in general low lying and is prone to flooding with varying risks. For the model initialization we employ spatially referenced data from multiple GIS datasets on the locations of residential housing, coastal amenities (measured in terms of distance from coastal water and sound, and a binary measure of waterfront), flood probabilities, distances to the CBD and national parks, and data on structural characteristics of properties including age, structure square footage, lot size, number of rooms, etc. Those include property parcel data from Carteret County Tax Office, NFIP digital flood maps and other GIS layers from North Carolina Floodplain Mapping

Program, and county/coastline boundary data from North Carolina Center for Geographic Information and Analysis. Data from these sources are merged so that each parcel had information on flood hazard and coastal amenities as well as standard structural and neighborhood attributes. Sales prices were inflation-adjusted using a Consumer Price Index to report figures in September 2004 dollars. The attributes of the average home in the data set are listed in Table 2.

The NFIP digital flood maps are obtained from the North Carolina Floodplain Mapping Program and used to identify properties within flood zones. Flood zone maps provide the location and extent of floodplains in the county. We denote two major categories based on the recurrence interval. A 100-year floodplain (or A-zone) corresponds to an area that has a 1% annual probability of flooding. Due to the relatively high risk of flooding in this area, flood insurance is mandatory for homeowners who finance their purchase through federally regulated lenders. A 500-year floodplain (or X-zone) is an area outside the 100-year floodplain, but associated with a lower level of flood risk (annual probability 0.2%). The case-study area in our GIS dataset contains 7,106 parcels, 3,588 of which are residential. Among residential parcels 50% are located in the zone with zero flood occurrence, 27% and 23% of residential properties are in 100-year and 500-year floodplains, respectively.

Amenities such as the proximity to coastal water (i.e., ocean, sound, and Intracoastal waterways), water frontage, and boat access are highly valued in the coastal housing market. In order to account for these amenities, we measure the distance to nearest coastal water for each residential property. The distance is measured as the Euclidean distance in feet from the centroid of each property to the nearest coastal water.[8] The average distance to nearest coastal water is less than one mile in our data set. A binary indicator for first row from coastal water is created to proxy for water frontage and access. About 11% of homes sold during the period of our analysis have water frontage. We also control for neighborhood characteristics using distance to nearest central business district (downtown Morehead City), nearest highway, and nearest park, forest, or game land.

In addition to the comprehensive spatial dataset, our residential market ACE model uses other data affecting agents demand for housing (Table 1). Specifically, to parameterize agents' preferences for amenities and housing versus non-housing consumption we employ values used in other economic papers (Wu and Plantinga 2003; Wu 2006), which rely on for example in 2003 consumer expenditure survey data of the US Bureau of Labor

[8] An alternative to the approach reported here is to construct an objective measure representing the "view" amenity. Constructing a view variable within GIS requires detailed data on the location and physical dimensions of coastal structures. These data were not available for the mainland of Carteret County at the time of this study.

Statistics. To endow agents with heterogeneous incomes we use 2011 income distribution for Carteret County from the US Census Bureau.[9] To match the hedonic price function we deflated the incomes to 2004 dollars using Consumer Price Index from the US Bureau of Labor Statistics. While in the ideal case one would use location-specific risk-based insurance premiums and actual insurance coverage in the case of a disaster, the estimation of both could become quite complicated and would depend on various policies. For the illustrative case of this paper we employ empirically-based average insurance premiums and insurance claim payments.[10]

5. Results

The simulation results of the mandatory flood insurance requirement on housing prices are presented in Figure 4. Figure 4a captures the dynamics of the average price for properties located in the 100-year floodplain, and Figure 4b in the 500-year floodplain. For each flood risk zone, we experimented with four different models: (1) a status-quo model with static expectations, (2) a mandatory flood insurance model with static expectations (with the assumption of full participation in the NFIP), (3) a status-quo model with adaptive expectations, and (4) a mandatory flood insurance model with adaptive expectations (with the assumption of full participation in the NFIP). In order to provide robust results, the estimated price dynamics are based on the average of 25 simulations for each of the four experiment settings over 30 years.

It appears that a market with static expectation produces quite stable price trends over the whole simulated period while a market with adaptive expectation produces significant price increase, especially for properties in 100-year floodplain. Under the static expectation, we find no difference between the status-quo and the mandatory insurance purchase. Interestingly, with the adaptive expectation, we find a significant gap between the price dynamics for the status-quo and the mandatory insurance requirement scenarios. The models with adaptive expectation allow to update the demand for housing each period, and to adjust the housing price formation in response to changes in the demand. Changes in the housing market demand are an aggregated outcome of changes in individual demands driven by incomes and other variables impacting budget constrains, such as a mandatory insurance premium to be paid, by households' preferences for coastal amenities and share of income they like to

[9] Available online: http://factfinder2.census.gov/faces/nav/jsf/pages/index.xhtml

[10] Insurance premium is based on the NFIP's Flood Insurance Manual (May 2004 Edition). Insurance claim payment is based on the historical data (Bin, Bishop, Kousky 2012). The average premium per policy between 1980 and 2006 is about $432, and the average claim per policy during the period is approximately $368. Thus, we use a 76.3 percent of the insurance premium as our estimate for insurance claim. Note that there are other aspects such as operating expenses and floodplain management costs to understand the financial operation of NFIP.

spend on housing good versus a composite good, as well as of the rate of population growth in the area. Market supply depends on the number of active sellers and the type of properties – in terms of their location in the floodplain, availability of coastal amenities and structural and neighboring characteristics – being offered each period. Thus, adapting housing prices are an emergent outcome of changes in aggregated demand and supply of housing goods with heterogeneous amenities and risk attributes and corresponding changes in price expectations. Conventional HA is based on the assumption of the market equilibrium, and thus may omit or underestimate the effects when a market is not in equilibrium.[11] Moreover, being a snapshot of a market at a certain moment HA may omit changes in demand (due to changing housing costs for property owners in risky areas) and supply (due to changing price expectations), and how they cumulatively endogenize in housing prices over time. Our further interpretation of the results will be mainly based on the adaptive expectation models to demonstrate price capitalization effects of the introduction of mandatory flood insurance over time.[12]

We find that the mandatory insurance requirement have a detrimental effect on housing prices in a floodplain over time. In the 100-year floodplain the housing price increases by about 51% without the insurance requirement as compared to only 39% with the mandatory insurance. As property values are the main component of expected direct damage, and thus potential disaster relief payments and flood protection investments, this outcome implies that the costs associated with flooding in general are transferred to the owners of risky properties (Filatova 2013). The effect for the 500-year floodplain is less pronounced, with about a 20% increase without the insurance requirement but only a 13% increase with the mandatory insurance. This could be due to the fact that probabilities as well as insurance premiums are much lower for the properties in the 500-year floodplain than for homes in the SFHAs, usually the 100-year floodplain. Lower probabilities, premiums, and insurance coverage to be paid lead to less significant differences in expected utility between with and without the insurance scenario. It is important to highlight, that this is assuming that households have perfect information about flood hazard and insurance policies. In the real world people have low flood risk perceptions, information asymmetry between buyers and sellers is present, and insurance policies change. Thus, the effects of the mandatory insurance introduction might be even less pronounced if these biases are accounted for. In fact, previous studies have shown that the 500-year flood zone

[11] There have been recent efforts to analyze the housing market within the hedonic framework during a distinctly "non-equilibrium" period (Coulson and Zabel 2013, Kuminoff and Pope 2012). The quasi-experimental approach uses an exogenous shock to a public good to identify the hedonic implicit price in a difference-in-differences framework. The key consideration is that one is estimating a movement between two hedonic equilibria, not a movement along a single equilibrium.

[12] As of 2006-2010, the median price of a house in Carteret County was $207,500 indicating its increase by 67.47% since 2000. It appears that adaptive expectation is closer to the actual price dynamics.

designation often does not convey the risk to potential buyers and results in no significant risk premiums (Bin, Kruse, Landry 2008; Kousky 2011; Bin and Landry 2013). It is important to note that the properties in the 500-year floodplain are not intended for mandatory purchase of insurance under Biggert-Waters.

On average the level of amenities (measured as proximity to the coast and availability of the coastal front) in the 100-year floodplain are 45% higher than in the safe zone while in 500-year floodplain amenity levels constitute only 48% of amenity levels in the safe zone. As preferences for coastal amenities are quite strong, the demand for these areas is higher, and the market constantly adjusts by pushing prices up. One may also notice that price trends in the 500-year floodplain have an initial downward trend in market with static expectations. Properties in the 500-year floodplain have lower expected utility than comparable properties in safe zone and at the same time the level of environmental amenity is low, which makes them less attractive than the properties in the 100-year floodplain. In line with the economic equilibrium models (Frame 1998), a decrease in housing prices is due to relatively low demand for those areas, and implies that households are compensated for bearing risks of living in a floodplain with a greater non-housing consumption. The price trend differs from the one in a 100-year floodplain where risks and additional insurance costs property owners face are compensated by a higher quality of housing good, namely through the high level of coastal amenities.

Table 3 shows the dynamics in the coefficients of the hedonic price function and the standard errors, which are the results of the housing market with adaptive price expectations**.** With the mandatory flood insurance, the location within a 100-year floodplain lowers the property values between 4.7% and 9.1% while the location within a 500-year floodplain lowers the property values between 5.3% and 9.4%. For the initial year, the average sales price in the 100-year floodplain was $169,392 and the average sales price in the 500-year floodplain was $151,481. The average price discount for being in a flood zone is estimated to be $12,807 and $9,351 for the 100-year and 500-year flood risk areas, respectively. Thus, results indicate that the price discount from locating within a higher flood risk area is larger than the price discount from a lower risk area. The dynamics of the flood risk coefficients are displayed in Figure 6. We estimate the implicit prices of flood risks under the mandatory flood insurance program in Table 4. We use three housing values: low ($75,000), average ($150,000), and high ($225,000). As expected, the risk premiums for the properties within a 100-year flood plain weaken over time due to the strong preference for coastal amenities. On the other hand, the risk premiums for the properties within a 500-year flood plain do not fade during the period.

In addition to reporting the average of 25 simulations for each of the four experiments, we have performed several sensitivity analysis including varying key assumptions in the model. We experimented with varying insurance premiums, preferences, and incomes, but found that the trends shown in Figure 4 remain qualitatively the same. In all cases, there is a difference between the static vs. adaptive expectation described earlier. An average trend over multiple simulations runs under the same settings demonstrates that the trend for the mandatory insurance model with adaptive expectation is below the trend for the status-quo model.[13]

6. Discussion

This study examines the effects of the mandatory flood insurance requirement on housing prices in a coastal real estate market. The simulation results indicate that the mandatory flood insurance requirement would have a detrimental effect on the property price within a floodplain. In the 100-year floodplain the housing price increases by about 51% without the insurance requirement but increases by only 39% with the mandatory insurance. The effect for the 500-year floodplain is less pronounced, with about a 20% increase without the insurance requirement but only a 13% increase with the mandatory insurance. Such negative effects on property values would imply lower property tax revenue for local governments and loss in wealth for current property owners. However, the latter may be compensated through governmental support of the program that may cost taxpayers much less than paying for repetitive losses (Bagstad et al. 2007; Filatova 2013).[14] Moreover, the mandatory insurance program may result in less capital at stake and less incentives for developers to build in the risk area (Kousky and Kunreuther 2010; Kousky and Kunreuther 2013). The net effect of the mandatory insurance program would require the comprehensive cost benefit analysis of flood protection which beyond the scope of this study.

Several caveats are in order for our analysis. First, our initial hedonic analysis is based on two townships in Carteret County while the income variable comes from general Carteret County and the preference variable represents general US public. That is, the simulated demand in our model is not of exactly the same population as the empirical demand function from the hedonic analysis of Bin, Kruse, Landry (2008). Second, the penetration rate of flood insurance has grown but still low in this area. Table 5 shows the number of NFIP policy in Carteret County between 2000 and 2008. Our simulation is based on the assumption of full compliance, but some homeowners still

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[13] This is common to do for ACE models to control for random seed effects.

[14] In the U.S., taxpayers will bear the costs of returning the NFIP to solvency if Congress should forgive the program's debt to the Treasury.

would choose not to be covered by the insurance. The net effect of such program should depend on the enforcement effort and the compliance to the proposed change. Third, as for any computational model, the results of the ACE model presented here would depend on settings, e.g. agents' preferences and incomes, frequency of market interactions, rate of population growth in the area. While we tried to rely on empirical data and other literature sources as much as possible here, the results presented in this paper should not be taken literary for a policy analysis. This should rather be considered as an illustrative case, which shows that possibilities of the method that combines traditional empirical HA and computational simulation models to directly trace market impacts of a policy intervention under adaptive market dynamics. By combining the strengths of two methodologies we are able to grow price trends in this housing market assuming agents heterogeneous in preferences and incomes and housing goods heterogeneous in structural, neighborhood, environmental and flood-risk attributes, when quantifying the impacts of the Biggert-Waters policy intervention which alters households' budgets constrains. The benefits of methodological innovation of tracing the price trends in safe and risky zones with and without the mandatory flood insurance under adaptive price expectations are visible in comparison with static price expectations, which is close to what a hedonic model alone would predict.

This work could be extended in several directions. Firstly, a realistic policy analysis requires more precise data on insurance premiums and coverage as well as projections of population growth in the area, and distribution of preferences for amenities and housing goods. Secondly, as discussed by Viscusi (1985) and Smith and Desvousges (1988) people constantly learn about risks they face. Individual risk perception changing over time as people forget or get reminded about a specific hazard such as flood in our case can seriously alter their locations choices and WTP for safety. Empirical research on housing markets in flood-prone areas captures that there is indeed a dynamics of flood risk perceptions, which get exacerbated just after a disaster and get forgotten over time, as reflected in price discounts changing dramatically over time (Bin and Landry 2013). An integrated HA-ACE model could be used to study how flood risk capitalization in housing prices changes over time as people's risk perceptions get updated or vanish. Thirdly, as such changes in individual behavior could be captured and parameterized with data, one may explore non-marginal effects, which are anticipated in economic systems in climate change world (Stern 2008). As opposed to majority of economic tools that are designed to study gradual changes along the same trend, computational economics models are not bounded to such marginal dynamics. This could potentially open new methodological opportunities and shift frontiers of economic discipline into quantitatively studying non-marginal changes as well.

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References

Alonso, W. (1964). Location and Land Use. Cambridge, MA: Harvard University Press.
An, L. (2012). "Modeling human decisions in coupled human and natural systems: Review of agent-based models." Ecological Modelling 229: 25-36.
Arthur, W. B. (1999). "Complexity and the economy." Science 284(5411): 107-109.
Arthur, W. B., S. N. Durlauf and D. Lane (1997). The economy as an evolving complex system II. Santa Fe Institute Studies in the Science of Complexity, Vol. XXVII, Addison-Wesley.
Axtell, R. (2005). "The Complexity of Exchange." The Economic Journal 115(June): F193-F210.
Bagstad, K. J., K. Stapleton and J. R. D'Agostino (2007). "Taxes, subsidies, and insurance as drivers of United States coastal development." Ecological Economics 63(2-3): 285-298.
Benenson, I. (1998). "Multi-Agent Simulations of Residential Dynamics in the City." Computers, Environment and Urban Systems 22(1): 25-42.
Bin, O., J. B. Kruse and C. E. Landry (2008). "Flood hazards, insurance rates, and amenities: Evidence from the coastal housing market." The Journal of Risk and Insurance 75(1): 63-82.
Bin, O. and C. E. Landry (2013). "Changes in Implicit Flood Risk Premiums: Empirical Evidence from the Housing Market." Journal of Environmental Economics and Management 65(3): 361–376.
Bin, O., J. Bishop, and C. Kousky (2012). "Redistributional Effects of the National Flood Insurance Program." Public Finance Review 40(3): 360-380.
Bockstael, N. E. (1996). "Modeling economics and ecology: The importance of a spatial perspective." American Journal of Agricultural Economics 78(5): 1168-1180.
Brown, D. G. and D. T. Robinson (2006). "Effects of heterogeneity in residential preferences on an agent-based model of urban sprawl." Ecology and Society 11(1): art.46.
Coulson, N. E. and J. Zabel (2013). "What Can We Learn from Hedonic Models When Housing Markets Are Dominated by Foreclosures?" Annual Review of Resource Economics *5:* 261-279.
Dawson, R. J., R. Peppe and M. Wang (2011). "An agent-based model for risk-based flood incident management." Natural Hazards 59: 167–189.
Dixon, L., N. Clancy, S. A. Seabury and A. Overton (2006). The National Flood Insurance Program's Market Penetration Rate: Estimates and Policy Implications. Santa Monica, California, RAND Corporation. Availablae online: http://www.rand.org/pubs/technical_reports/TR300.html. Accessed: January 6, 2014.
Ettema, D. (2011). "A multi-agent model of urban processes: Modelling relocation processes and price setting in housing markets." Computers, Environment and Urban Systems 35: 1–11.
Filatova, T. (2013). "Market-based instruments for flood risk management: A review of theory, practice and perspectives for climate adaptation policy." Environmental Science & Policy November.
Filatova, T., D. C. Parker and A. van der Veen (2011). "The Implications of Skewed Risk Perception for a Dutch Coastal Land Market: Insights from an Agent-Based Computational Economics Model." Agricultural and Resource Economics Review 40(3): 405-423.
Filatova, T., A. van der Veen and D. Parker (2009). "Land market interactions between heterogeneous agents in a heterogeneous landscape—tracing the macro-scale effects of individual trade-offs between environmental amenities and disamenities." Canadian Journal of Agricultural Economics 57(4): 431-459.
Filatova, T., P. H. Verburg, D. C. Parker and C. A. Stannard (2013). "Spatial agent-based models for socio-ecological systems: Challenges and prospects." Environmental Modelling & Software 45: 1-7.

Frame, D. E. (1998). "Housing, natural hazards, and insurance." Journal of Urban Economics 44(1): 93-109.
Gilbert, N., J. C. Hawksworth and P. A. Swinney (2009). An Agent-Based Model of the English Housing Market. Association for the Advancement of Artificial Intelligence Spring Symposium Series, March 23–25, 2009, Stanford, California, The AAAI Press, Menlo Park, California.
Hayes, T. L. and D. A. Neal (2009). Actuarial Rate Review: In Support of the Recommended May 1, 2009, Rate and Rule Changes. Washington, D.C., Federal Emergency Management Agency.
Huang, Q., D. C. Parker, T. Filatova and S. Sun (2013). "A Review of Urban Residential Choice Models Using Agent-based Modeling." Environment and Planning : B 40.
Irwin, E. G. (2010). "New Directions For Urban Economic Models Of Land Use Change: Incorporating Spatial Dynamics And Heterogeneity." Journal of Regional Sience 50(1): 65–91.
Kirman, A. P. (1992). "Whom or what does the representative individual represent?" Journal of Economic Perspectives 6(2): 117-136.
Kirman, A. P. and N. J. Vriend (2001). "Evolving Market Structure: An ACE Model of Price Dispersion and Loyalty." Journal of Economic Dynamics and Control 25: 459-502.
Kousky, C. and H. Kunreuther (2010). "Improving Flood Insurance and Flood-Risk Management: Insights from St. Louis, Missouri." Natural Hazards Review 11(4): 162-172.
Kousky, C. (2011). "Understanding the Demand for Flood Insurance." Natural Hazards Review 12(2), 96–110.
Kousky, C. and H. Kunreuther. (2013). "Addressing Affordability in the National Flood Insurance Program." Resources for the Future Issue Brief 13-02, August.
Kriesel, W. and C. Landry. (2004). "Participation in the National Flood Insurance Program: An Empirical Analysis of Coastal Properties." The Journal of Risk and Insurance 71: 405-420.
Kuminoff, N. V. and J. C. Pope (2012). "A novel approach to identifying hedonic demand parameters." Economics Letters 116(3): 374-376.
Magliocca, N., V. McConnell, M. Walls and E. Safirova (2012). "Zoning on the urban fringe: Results from a new approach to modeling land and housing markets." Regional Science and Urban Economics 42: 198–210.
Michel-Kerjan, E. O. (2010). "Catastrophe Economics: The National Flood Insurance Program." Journal of Economic Perspectives 24(4): 165-186.
Nolan, J., D. Parker, G. C. van Kooten and T. Berger (2009). "An Overview of Computational Modeling in Agricultural and Resource Economics." Canadian Journal of Agricultural Economics-Revue Canadienne D Agroeconomie 57(4): 417-429.
Parker, D. C., T. Berger and S. M. Manson, Eds. (2002). Agent-Based Models of Land-Use and Land-Cover Change: Report and Review of an International Workshop, October 4-7, 2001. LUCC Report Series Bloomington, LUCC.
Parker, D. C., D. G. Brown, T. Filatova, R. Riolo, D. T. Robinson and S. Sun (2011). Do Land Markets Matter? A Modeling Ontology and Experimental Design to Test the Effects of Land Markets for an Agent-based Model of Ex-urban Residential Land-use Change. Agent-based Models of Geographical Systems. A. J. Heppenstall, A. T. Crooks, L. M. See and M. Batty. Dordrecht. Available onlne: http://www.casa.ucl.ac.uk/ABM.pdf Accessed: January 6, 2014, Springer: 525-542 pp.
Parker, D. C. and T. Filatova (2008). "A conceptual design for a bilateral agent-based land market with heterogeneous economic agents." Computers, Environment and Urban Systems 32(6): 454–463.
Rosen, S. (1974). "Hedonic prices and implicit markets: product differentiation in pure competition." Journal of Political Economy 82(1): 34–55.
Simon, H. (1997). Models of Bounded Rationality. Vol 3: Emperically Grounded Economic Reason, MIT Press.
Smith, V. K. and W. H. Desvousges (1988). "Risk Perception, Learning, and Individual Behavior." American Journal of Agricultural Economics 70(5): 1113-1117.
Stern, N. (2008). The Economics of Climate Change: The Stern Review. Cambridge, Cambridge University Press.
Tesfatsion, L. (2006). Agent-Based Computational Economics: A Constructive Approach To Economic Theory. Handbook of Computational Economics Volume 2: Agent-Based Computational Economics L. Tesfatsion and K. L. Judd. Amsterdam, Elsevier B.V.: 831-880.
Tesfatsion, L. and K. L. Judd (2006). Handbook of Computational Economics Volume II: Agent-Based Computational Economics Elsevier B.V.
Thiele, J. C. and V. Grimm (2010). "NetLogo meets R: Linking agent-based models with a toolbox for their analysis." Environmental Modelling & Software 25(8): 972-974.
Viscusi, W. K. (1985). "A Bayesian Perspective On Biases In Risk Perception." Economics Letters 17: 59-62.
Wilensky, U. (1999). NetLogo. http://ccl.northwestern.edu/netlogo/. Center for Connected Learning and Computer-Based Modeling, Northwestern University. Evanston, IL.

Wu, J. (2001). "Environmental Amenities and the Spatial Pattern of Urban Sprawl." American Journal of Agricultural Economics 83(3): 691-697.
Wu, J. and A. J. Plantinga (2003). "The influence of public open space on urban spatial structure." Journal of Environmental Economics and Management 46(2): 288-309.
Wu, J. J. (2006). "Environmental amenities, urban sprawl, and community characteristics." Journal of Environmental Economics and Management 52(2): 527-547.

Tables

Table 1 Key model parameter values

Parameter	Value	Source
Preferences for housing good (the mean of normal distribution)	0.4	Wu 2006
Preferences for amenities (the mean of normal distribution)	0.5	Wu and Plantinga 2003; Wu 2006
Percent of population in each income (Y) category, 2004 $, Carteret county		US Census Bureau [15]
< 8361.8	7.6	
8361.8 - 12542.7	10.1	
12542.7 - 20904.4	10.8	
20904.4 - 29266.2	9.3	
29266.2 - 41808.8	17.9	
41808.8 - 62713.2	16.9	
62713.2 - 83617.7	11.6	
83617.7 - 125426.5	10.3	
125426.5 - 167235.3	2.0	
> 167235.3	3.4	
Annual travel costs per mile (T)	$ 1500	Wu and Plantinga 2003; Wu 2006
Insurance premium (IP)	equation	NFIP 2004[16]
Insurance coverage (IC)	equation	Bin, Bishop, Kousky 2012

[15] Available online: http://factfinder2.census.gov/faces/nav/jsf/pages/index.xhtml

[16] Insurance premium is based on the NFIP's Flood Insurance Manual (May 2004 Edition).

Table 2 Summary Statistics of the spatial data

GIS parcel attribute	Min	Average	Max
Number of bathrooms	0.5	1.69	6
House age	31	68.14	217
Sq. footage of a house	160	1563.8	4072
Lot size	0.005	0.9	42.39
Whether a house is in 1:100 flood zone	0	0.27	1
Whether a house is in 1:500 flood zone	0	0.23	1
Whether a property is at coastal front	0	0.11	1
Distance to intracoastal waterways	1.8	1597.3	8445.6
Distance to CBD	7552.7	22692.1	46516.4
Distance to highway	50.7	2609.3	14007.3
Distance to parks	4331.9	14390.9	32221.2

Table 3 Dynamics in the Coefficients of the Hedonic Price Function

Period	**Bath**	**Std.err**	**Age**	**Std.err**	**Sqft**	**Std.err**	**Lot**	**Std.err**	**FP100**	**Std.err**	**FP500**	**Std.err**	**Front**	**Std.err**	**Dist**	**Std.err**	**CBD**	**Std.err**	**Hwy**	**Std.err**	**Parks**	**Std.err**
1	0.109	0.015	-0.010	3.31E-04	0.001	1.29E-05	0.032	0.002	-0.079	0.004	-0.064	0.004	0.314	0.005	-0.108	0.002	0.000	0.008	0.004	0.002	-0.006	0.006
2	0.114	0.013	-0.010	3.68E-04	0.001	1.51E-05	0.032	0.002	-0.082	0.004	-0.063	0.005	0.311	0.005	-0.109	0.002	-0.009	0.009	0.006	0.002	0.004	0.007
3	0.125	0.011	-0.009	2.80E-04	0.001	1.36E-05	0.035	0.001	-0.084	0.003	-0.069	0.004	0.326	0.005	-0.108	0.002	-0.014	0.008	0.005	0.002	0.002	0.006
4	0.123	0.012	-0.009	3.15E-04	0.001	1.44E-05	0.035	0.001	-0.078	0.004	-0.068	0.004	0.334	0.006	-0.109	0.002	-0.024	0.009	0.005	0.002	0.005	0.006
5	0.132	0.012	-0.010	3.54E-04	0.001	1.41E-05	0.037	0.001	-0.074	0.004	-0.066	0.004	0.342	0.006	-0.105	0.002	-0.028	0.009	0.007	0.002	-0.003	0.006
10	0.100	0.015	-0.010	3.98E-04	0.001	1.88E-05	0.057	0.002	-0.079	0.004	-0.056	0.005	0.396	0.006	-0.110	0.002	-0.071	0.010	0.005	0.002	0.019	0.007
15	0.076	0.016	-0.009	0.001	0.001	1.76E-05	0.070	0.002	-0.089	0.005	-0.059	0.006	0.431	0.007	-0.115	0.003	-0.047	0.012	-0.004	0.002	0.002	0.009
20	0.066	0.021	-0.009	0.001	0.001	2.35E-05	0.085	0.002	-0.073	0.005	-0.076	0.006	0.469	0.007	-0.110	0.003	-0.129	0.012	-0.001	0.002	0.019	0.008
25	0.188	0.019	-0.007	0.001	0.001	2.03E-05	0.099	0.002	-0.080	0.006	-0.075	0.006	0.508	0.007	-0.117	0.003	-0.147	0.012	-0.003	0.002	0.017	0.009
30	0.222	0.018	-0.006	0.001	0.001	2.07E-05	0.111	0.001	-0.077	0.006	-0.084	0.006	0.531	0.008	-0.119	0.003	-0.203	0.013	-0.002	0.003	0.021	0.009
35	0.232	0.013	-0.007	0.001	0.001	1.95E-05	0.142	0.002	-0.062	0.006	-0.062	0.006	0.573	0.009	-0.132	0.003	-0.290	0.015	-0.006	0.003	0.044	0.009
40	0.294	0.011	-0.007	0.001	0.001	1.78E-05	0.147	0.001	-0.048	0.005	-0.068	0.006	0.596	0.006	-0.140	0.003	-0.310	0.011	-0.011	0.002	0.039	0.008
45	0.314	0.016	-0.008	0.001	0.001	2.33E-05	0.172	0.003	-0.053	0.006	-0.077	0.006	0.632	0.007	-0.144	0.003	-0.354	0.012	-0.015	0.002	0.043	0.008
50	0.347	0.016	-0.006	0.001	0.001	1.64E-05	0.187	0.002	-0.065	0.005	-0.092	0.006	0.662	0.007	-0.155	0.003	-0.366	0.011	-0.014	0.002	0.037	0.008
55	0.324	0.015	-0.005	0.001	0.001	1.60E-05	0.194	0.002	-0.054	0.005	-0.082	0.006	0.697	0.007	-0.159	0.002	-0.407	0.011	-0.011	0.002	0.030	0.008
60	0.326	0.017	-0.002	0.001	0.001	1.70E-05	0.207	0.002	-0.055	0.005	-0.080	0.006	0.747	0.007	-0.149	0.003	-0.387	0.014	-0.012	0.003	-0.009	0.010

Table 4 Estimated Implicit Prices of Flood Risks

Properties within a 100-year Floodplain					
House Value	**Year 1**	**Year 5**	**Year 10**	**Year 20**	**Year 30**
Low ($75K)	-$5,671	-$5,673	-$5,315	-$3,494	-$4,001
Avg. ($150K)	-$11,341	-$11,347	-$10,629	-$8,108	-$8,003
High ($225K)	-$17,012	-$17,020	-$15,944	-$10,481	-$12,004
Properties within a 500-year Floodplain					
House Value	**Year 1**	**Year 5**	**Year 10**	**Year 20**	**Year 30**
Low ($75K)	-$4,630	-$4,065	-$5,463	-$4,927	-$5,793
Avg. ($150K)	-$9,260	-$8,131	-$10,925	-$9,065	-$11,586
High ($225K)	-$13,890	-$12,196	-$16,388	-$14,780	-$17,378

Table 5 NFIP in Carteret County 2000-2008

Year	Policy in Force	Coverage ($million)	Premium ($thousand)	Payment ($thousand)
2000	13247	$1,750	$4,795	$34
2001	13359	$1,847	$4,727	$5
2002	13328	$1,941	$4,937	$41
2003	13777	$2,094	$5,455	$16,400
2004	14370	$2,313	$5,956	$330
2005	15119	$2,588	$6,440	$8,730
2006	15968	$2,943	$7,170	$62
2007	16285	$3,151	$7,886	$0
2008	15797	$3,166	$8,291	$4

Figures

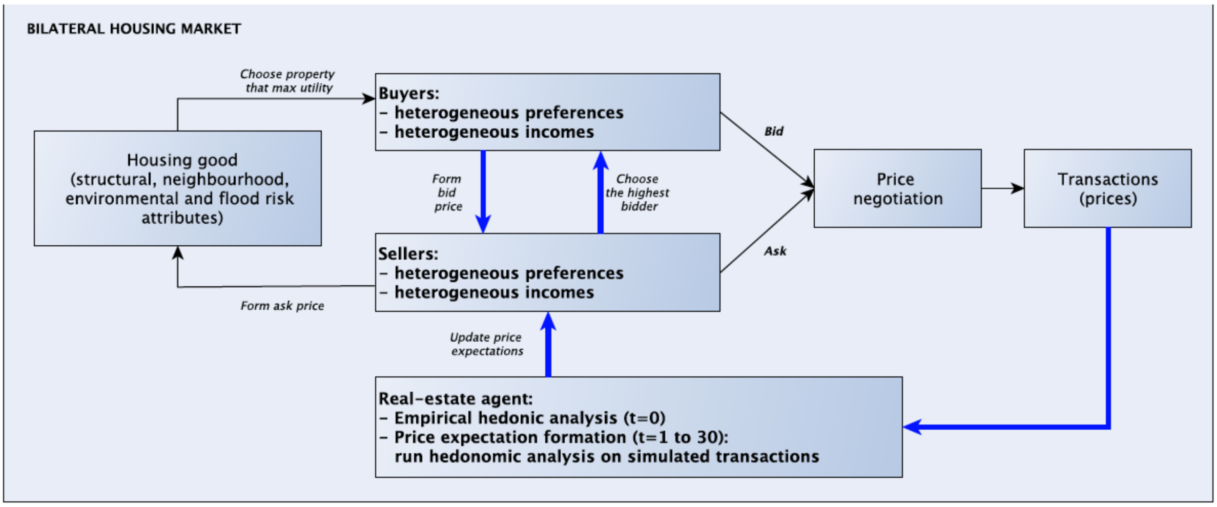

Figure 1 Flow Chart Diagram of an ACE Housing Market Model

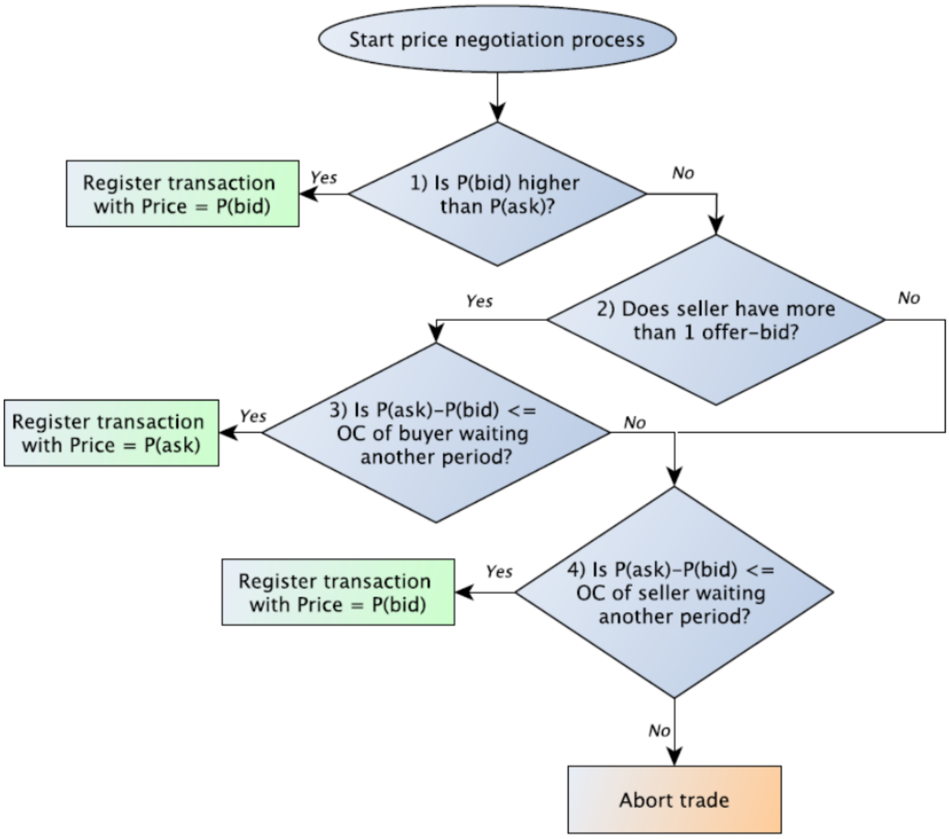

Figure 2 The Simulation Flow of the Negotiation Process

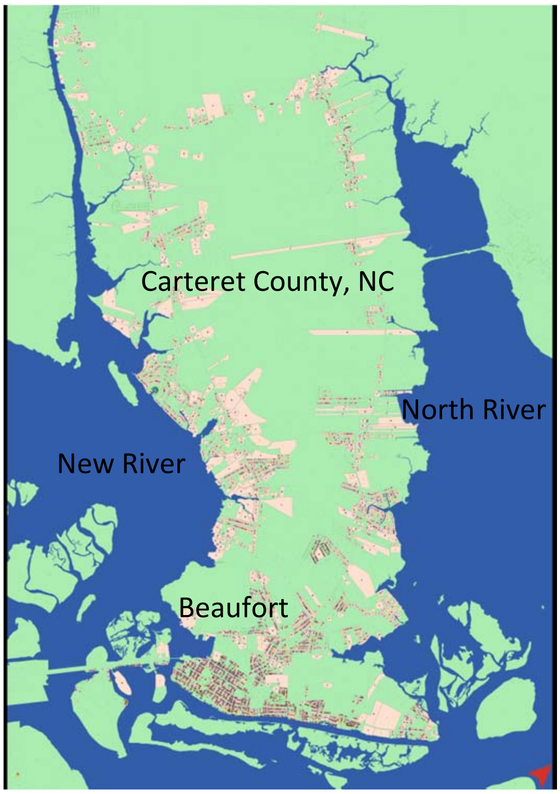

Figure 3 Map of the Study Area

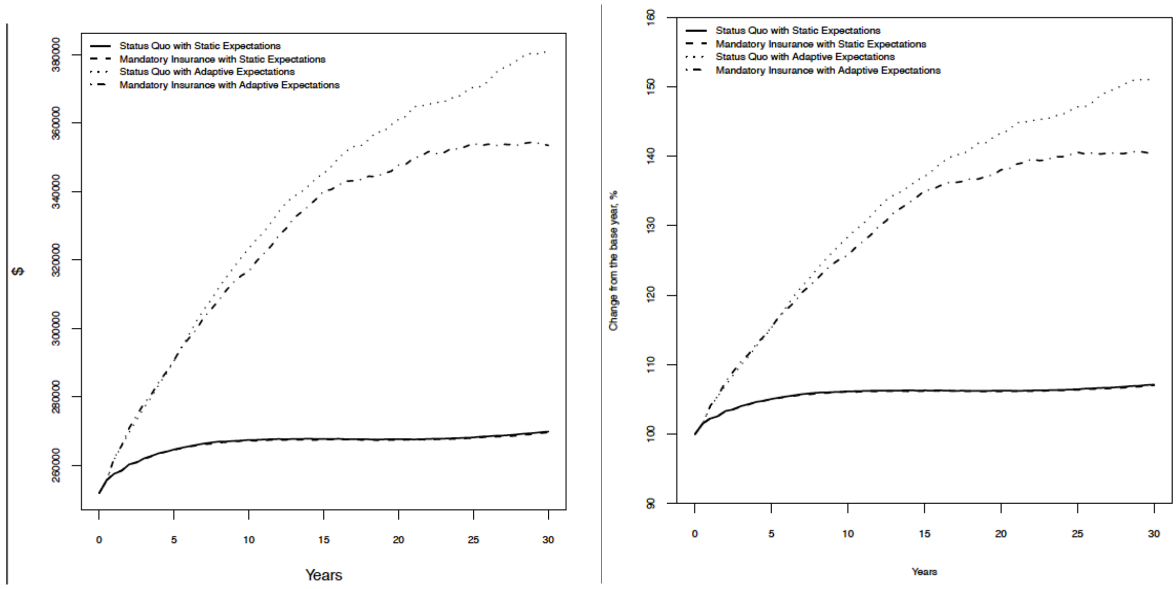

Figure 4a Price Changes for the 100-year Flood Risk Zone ($ and %)

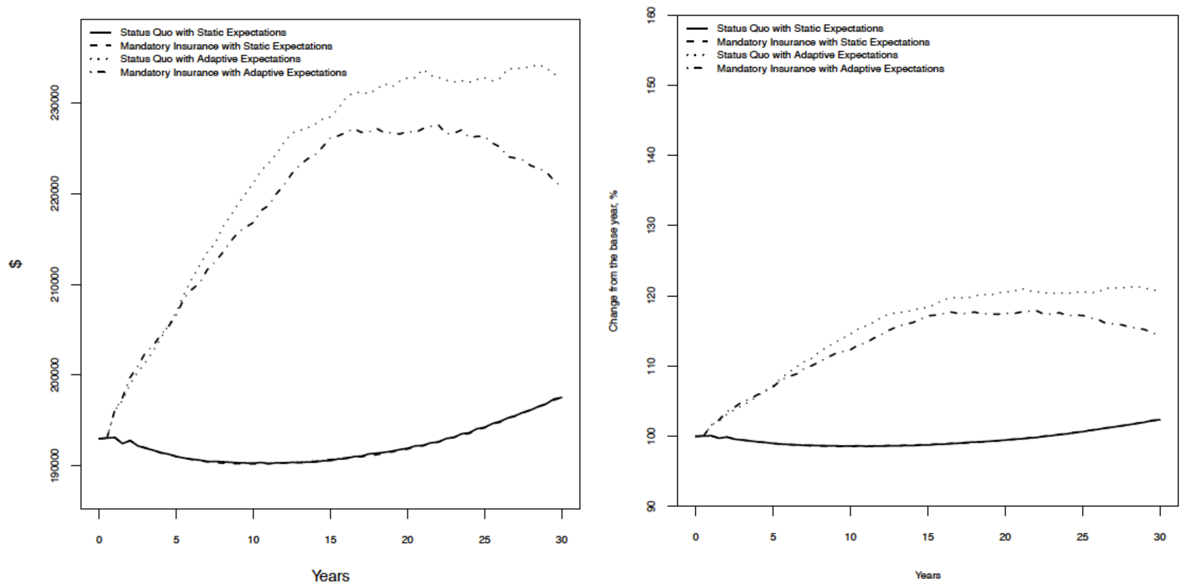

Figure 4b Price Changes for the 500-year Flood Risk Zone ($ and %)

Figure 4 Impacts of the Mandatory Insurance Requirement on Housing Prices

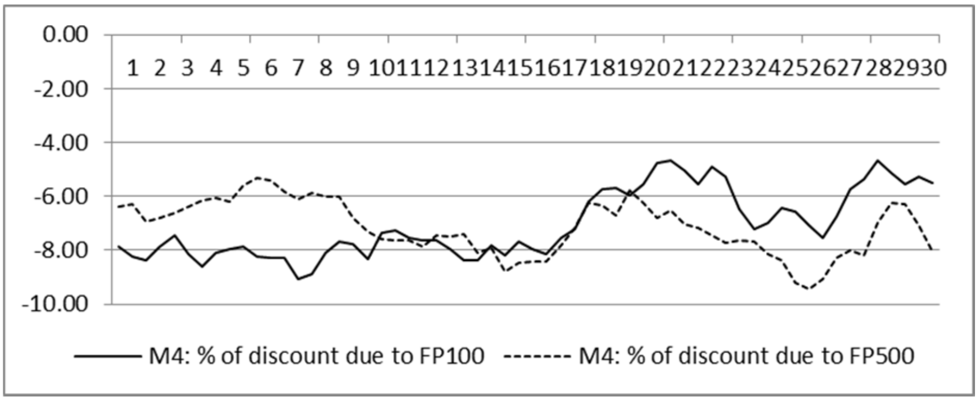

Figure 5 Dynamics in the Flood Risk Coefficients under Adaptive Price Expectations with Mandatory Flood Insurance over 30 Years.