The Impacts of Climate Change on the Dynamics of Housing Market

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Abstract: In this paper we developed a simulation of the impact of climate change in residential property markets. In developed countries, major portions of the residential property market are well formalized with established investment mechanisms. Equilibrium prices are determined through the interaction of demand and supply. However, disruptions such as the increasing risk of bushfires in California and Australia are changing the market behavior. In this paper, we simulate the impacts of these disruptions on the housing price dynamics, and consequently, the change in the number of owner-occupied versus rental units in residential areas. We captured the effects of climate change on housing demand by increasing home insurance costs as well as increasing the public awareness of bushfire risk.

Introduction: With the growing concerns over the impact of climate change, the impact of vulnerability of residential areas to disasters is increasingly observed in the housing market (Baldauf et al. 2020). One of the mechanisms for such impacts is through increased insurance premiums. Higher insurance premiums can increase the annual costs of home ownership and may even force a portion of the homeowners to terminate their ownership (Dumm et al. 2015) or make low-income families move to sub-standard housings (Al-Homoud et al. 2009). This phenomenon is known as climate gentrification, implying that climate change can lead to the unaffordability of living in one area and forcing individuals to move to another area (Keenan et al. 2018). The dynamic is shaped through different mechanisms, for example, information on flood zone designation impacts insurance rates and the price of the housing market (Meldrum 2016). More informed public perception on the risks associated with natural hazards can shift the market demand towards a safer area (Erdik and Durukal 2008). With potential threat to properties, individuals are likely to pay less for the housing units, therefore, driving down property values in hazard-prone areas (Zhang et al. 2010).

Several classic economics models aim to determine the long-run equilibrium for the housing market based on factors including population, disposable income, macro-economic conditions, and rate of construction (Wheaton 1999, Miles 2012). Furthermore, hedonic models have been developed to explore the impact of hazard proximity on the property values (Bin and Kruse 2006). However, such studies do not differentiate between the hazard proximity and perceived risk (Zhang, Hwang et al. 2010), while the perceived risk is a mediating factor between hazard proximity and property value. In addition, hedonic pricing models do not capture the dynamics of the supply and demand in the housing markets considering the risk perception of the market actors. Therefore, there is a need to study dynamics of the housing market based on the impact of climate change, while considering the behavior of the individuals in response to increased insurance premiums, associated increase in home ownership costs, as well as changes in their behavior due to enhanced risk perceptions. In this paper, we address this gap by developing a system dynamics model to explore the impact of multiple hypothetical scenarios reflecting potential dynamics in the housing market in response to climate change impacts. Scenarios included a range of dynamics that simulate the status quo, without the impact of climate change, as well as the impact of climate change through the increasing cost burden and increasing risk perception of the residents.

Methodology: The proposed system dynamics model builds on the existing models in the housing markets literature (Mashayekhi et al. 2009). We additionally consider: (i) the role of individuals' risk perception; and (ii) separating the vacant and rented stocks. A major focus within previous housing market models is on the impact of initial investment and its interplay with market dynamics, while the operating costs including insurance rates are often neglected as it does not impact the market dynamics in normal situations.

However, these costs are the major venues through which climate change impacts the dynamics of the housing market. Therefore, our proposed first step in this research stream is to model the impact of operating costs in market entry/exit, to model the fundamental mechanism for the impact of climate change in the housing market. In addition, we consider the role of individuals' subjective risk assessment on their behavior in the market. The three pre-defined behaviors considered for each individual in the model are: (i) keeping the status quo, (ii) changing the occupancy type (from renting to owning or vice versa), or (iii) moving out from the neighborhood due to high costs. The first two decisions are derived based on the Expected Utility Theory (Morgenstern and Von Neumann 1953) and the third decision is characterized by the affordability of the housing units. The causal loop diagram, shown in Fig. 1, is discussed in this section.

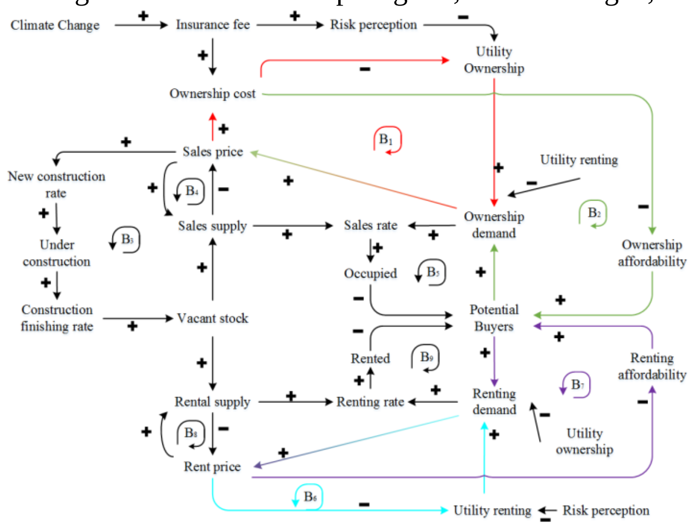

Fig. 1. The model causal loop

Loop B_1: as stated in the introduction section, an increase in the disruptions as a result of climate change can increase the insurance rates of more vulnerable housing units, thus increasing the ownership costs, and driving down the prices through two mechanisms (DiPasquale and Wheaton 1996). First, the ownership costs get too high and it is no longer the best choice for the buyers to own a house. Therefore, a portion of the owners may prefer renting a housing unit. This preference is captured by the comparison between the expected utility of owning and renting a house. The Expected Utility Theory assumes that individuals behave rationally in the face of uncertainty and prefer the choice with the highest expected utility. The utility of each possible outcome for an action is determined based on the adjustments of that outcome for the wealth of the decision-makers. The expected utility of an action is obtained by weighting the utility of the outcomes by their associated probabilities. Therefore, the expected utility of the action a , $EU(a)$ that can lead to outcome, x_i, each with the corresponding probability of occurrence of, $P(x_i)$, and utility function, $u(x_i)$, can be calculated using Eq. (1) (Morgenstern and Von Neumann 1953):

$$EU(a) = \sum_{i=1}^{N} P(x_i) \times u(x_i) \tag{1}$$

We can calculate the utility of owner-occupied housing units based on the present value of the costs, assuming a 30-year period for the mortgage and the fact that the insurance only covers the economic losses sustained by the disruption such as a bushfire or flood.

$$EU_{Ownership} = \pi(p,\gamma) \times U(SP - LL - m - I) + \big(1 - \pi(p,\gamma)\big) \times U(SP - m - I) \tag{2}$$

Where LL is the life loss sustained by the residents in the face of bushfires, m is the present value of the mortgage paid in the long-term, I is the present value for the paid insurance premium, SP is the sales price, and $\pi(p,\gamma)$ is the subjective probability of being impacted by bushfires (Morshedi and Kashani 2020):

$$\pi(p,\gamma) = S^{2\gamma-1} \times p \qquad (3)$$

Where p is the probability of the occurrence of bushfire, S is the subjective risk factor, which is assumed to be equal to 10 (Botzen et al. 2009), and γ is the average level of public risk perception. Risk perception is defined as individuals' perception about the frequency and severity of uncertain situations (Hallowell 2010, Kashani et al. 2019). Based on Eq. (3), when the risk perception is zero, the objective probability of the bushfire is equal to S times the subjective probability. When risk perception is equal to 0.5, the subjective and objective risks are equal. In the case that the risk perception gets its highest value of one, the objective risk is perceived higher by a factor of S (Botzen, Aerts et al. 2009). Using the utility function used by Shan et al. (2016) the ownership utility based on the net present value of the expenses is:

$$EU_B = S^{2\gamma-1} \times p \times (1 - e^{-\lambda(SP-LL-\sum_{t=0}^{t=T/2}(\frac{m}{(1+i)^t}+\frac{I_t}{(1+i)^t}))}) + (1 - S^{2\gamma-1} \times p) \times (1 - e^{-\lambda(SP-\sum_{t=0}^{t=T/2}(\frac{m}{(1+i)^t}+\frac{I_t}{(1+i)^t}))}) \qquad (4)$$

Where λ is the risk-aversion factors that can vary between 0.00015 and 0.00045 with a mean value of 0.00003 (Shan, Peng et al. 2016), I_t is the insurance premium at year t and i is the interest rate. In addition, since there is uncertainty regarding the time of bushfire incident, the economic and life losses may be sustained at an unknown time t^*. We assume that the chances of bushfires follow a Poisson distribution, which means that the incident of a bushfire this year is independent of its occurrence in the past years. This is the most common assumption with disruptions such as earthquakes.

$$\mathrm{LL} = \mathrm{LL}' \times \sum_{t=1}^{t=T/2}(\frac{(p^*) \times (1-p^*)^{t-1}}{(1+i)^t}) \qquad (5)$$

Where LL' is the life loss sustained by the residents of the building per the incidence of the bushfire, which has an annual probability of occurrence, p^*. Similarly, the renting utility can be determined:

$$EU_R = S^{2\gamma-1} \times p \times (1 - e^{-\lambda(A\times DI-R-LL)}) + \left(1 - S^{2\gamma-1} \times p\right) \times (1 - e^{-\lambda(A\times DI-R)})) \qquad (6)$$

Where DI is the disposable income, A is a constant, and R is the price of renting the housing unit.

Loop B_2: When the ownership costs increase over time due to climate change, a portion of the owners may no longer be able to afford the recurring ownership costs. Such owners might decide to move to rental units if the utility of renting is higher than owning a house and they can afford the rent. Otherwise, they might decide to leave the neighborhood altogether. As a result, the potential buyers that seek to buy housing in that neighborhood will reduce, and the reduction in demand leads to lower prices.

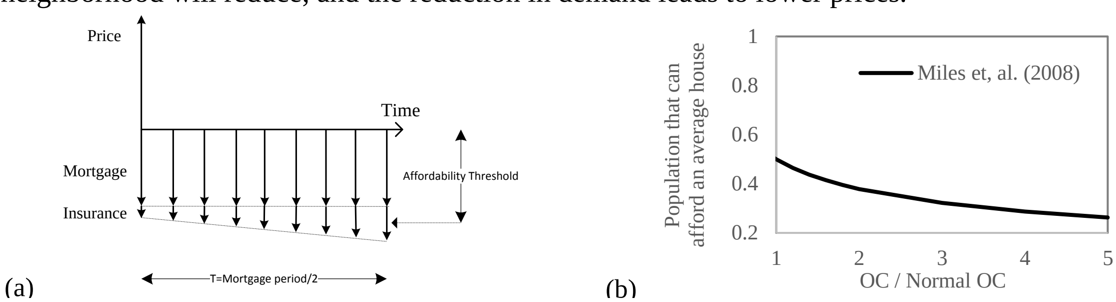

Fig. 2. Affordability of houses: (a)-the cash flow diagram for owners, (b)- the impact of higher ownership costs on the demand for housing units (Miles and Pillonca 2008)

The cash flow diagram, shown Fig. 2(a), is a sample that is used to represent the decision making of the owners. As shown in Fig. 2(a), there is an affordability threshold for the ownership cost (OC) of the houses, which can be determined using Fig. 2(b). The affordability curve can vary significantly form one society to another and it is highly related to the level of disposable income and living expenses. Therefore, it should be calibrated to better represent the behavior of an average person for each community.

Loop B$_3$: the new demand and prices influence the market supply in the long term. A reduction in the price of the housing units that are susceptible to the impacts of climate change reduces the construction of new housing units. This can prevent a significant fall in the prices of the housing units as they have shown to be derived by the gap between the demand and supply (Sterman 2000, Mashayekhi and Ghili 2012).

Loop B$_4$: as the prices increase, the number of vacant buildings that go for sales increases. However, the increase in supply is limited as an oversupply prevents a significant rise in prices.

Loop B$_5$: loop B$_5$ captures the satisfaction of the demand for housing units from potential buyers. With increasing occupation or rent rates, the number of potential buyers in the neighborhood will decrease. As the feedback loops for the rental units are similar to owner-occupied units, they are not discussed.

Results: The following scenarios have been tested and compared to each other in Fig. 3. Under the base scenario, there is an initial 6.3% vacancy rate (oversupply). Under scenario (I), the insurance premium gradually increases from 0.5% to 0.7% after 25 years from the start of the simulation. Under scenario (II), the insurance premium trend is the same as scenario (I), while this scenario also captures the impact of elevated insurance premiums on the public risk perception about bushfire risk. The base scenario, scenario (I), and scenario (II), are represented by black, red, and blue colors, respectively in the figures. The results suggest that an increase in the insurance premium leads to a shift from owner-occupied to rental housing units. This trend drives down the price of the owner-occupied housing units in the short term. But the price decline is recovered to a great extent after 25 years. On the other hand, the price of the rental units elevates sharply due to the new demand from the owners who have decided to rent a house instead of owning one. The increase in the vacancy rates show that a portion of the residents of the neighborhood decide to migrate to other neighborhood due to high costs of rental units, as well as high vulnerability of owner-occupied units (they see their lives and their house as their long-life investment at risk).

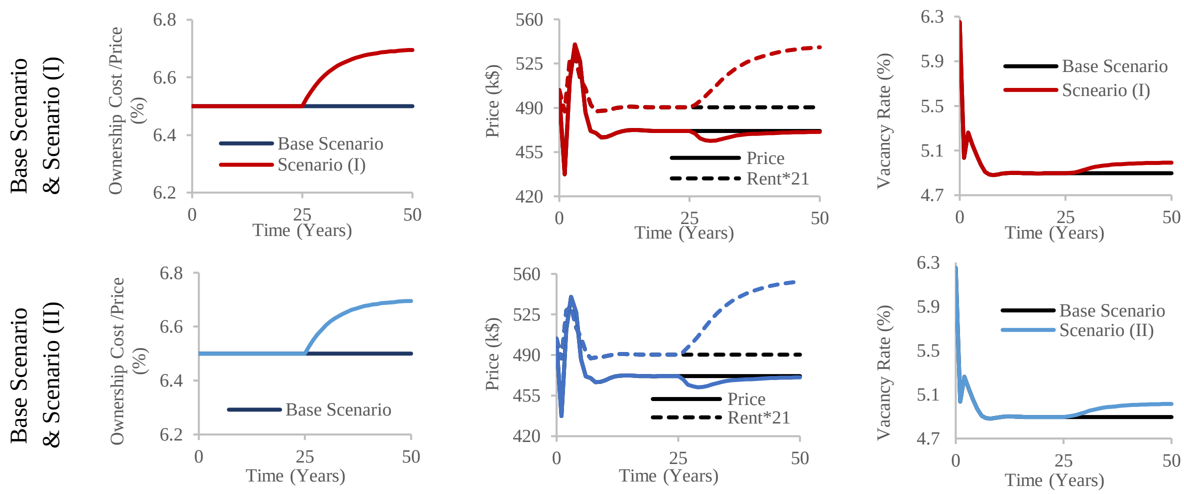

Fig. 3. The housing market response to the described scenarios

A comparison between the model response under scenarios (I) and (II) is made in Fig. 4.

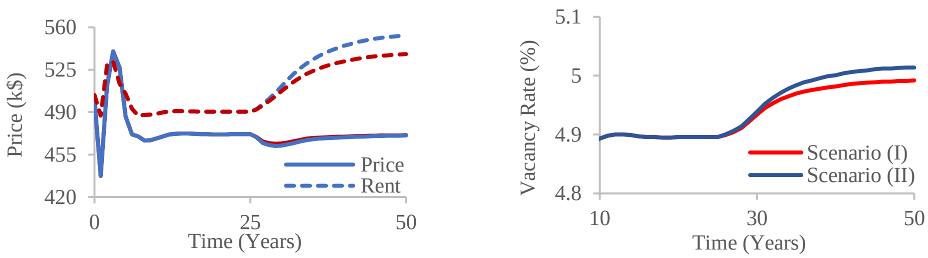

Fig. 4. The amplifying impact of the risk perception (Comparison scenario (I) & (II))

According to Fig. 4, the impact of enhanced risk perception caused by elevated insurance premiums increases the shift from owner-occupied to rental units. In addition, the number of residents who decide to leave the neighborhood for safer ones increases when the subjective perception of individuals about the risks associated with climate change are considered.

Conclusions: In this paper, we established a baseline model to integrate the impact of dynamics associated with climate change into the housing market. The initial results indicate that a portion of the residents move out from the neighborhood either due to enhanced risk perception about the bushfire risk and its consequences or the fact that they can no longer afford the elevated ownership costs and rental fees. Analysis of the model outcomes reveals that considering individuals' risk perception intensifies the climate change-induced gap between the price and rental fees, as well as the vacancy rates. The findings of this study can be expanded to include the potential impacts of climate change on the regime shifts between the owner-occupied and the rental housing market. This line of research can provide valuable insights for decision-makers and policymakers to enhance the equity among societies through the implementation of insurance plans, awareness programs, and financial support when necessary.

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