HOMELESSNESS AND THE LOW INCOME HOUSING RATIO: AN AGENT-BASED MODEL EXPLORING SYSTEMATIC HOMELESSNESS

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ABSTRACT

HOMELESSNESS AND THE LOW INCOME HOUSING RATIO:
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This study aimed to create a theory-testing tool for three factors of systematic homelessness, including the low-income housing ratio, buying-down, and income restricted mobility. In order to test these features, the researcher created three separate agent-based models. The agent-based modeling approach effectively models the dynamic systematic factors of homelessness, by using agents to model the interactions between low-income families and housing market. Preliminary results of models are presented. These models are an important step in the development of relevant housing policy. In addition, future models of gentrification and urban decay are discussed.

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KEY TO ABBREVIATIONS

HUD	Department of Housing and Urban Development
ABM	Agent-Based Model

INTRODUCTION

According to the Department of Housing and Urban Development (HUD), over 500,000 people experience homelessness on any given night in the United States (Henry, Shivji, de Sousa, Cohen, Khadduri, & Culhane, 2015). The damaging impact of homelessness on both children and adults has been well documented in the past few decades. Long-term, or chronic, homelessness may lead to increased risk for both serious mental illness and substance abuse. Individuals often endure an extensive sum of physical conditions, including an increased risk of experiencing physical or sexual violence.

In recent years a growing number of cities in the United States began adopting laws making the experience of being homeless illegal. Policy makers in some communities have criminalized pan-handling, loitering, sleeping in a public space or car, and some have gone so far as to make it illegal to sit or lie down in particular public places (Bauman, 2014). Policies such as those may lead one to believe that homelessness is a choice, an outcome based solely on poor decisions, or a state experienced by those with major deficits, and therefore something to be punished. Alternatively, various scholars have seen the issue of homeless within the United States as rooted in structural conditions. Not a choice, but an outcome based on circumstance over which he or she has little control.

Using this frame, homelessness has been described as a game of musical chairs by scholars such as McChesney (1990) & Shinn (1992). In this game, the players are low-income households, and the chairs are housing units that they can afford. If there are more low-income households than affordable housing units, this means some families will be left without affordable housing when the music stops. Personal issues, such as substance addiction, do not affect the number of housing units, and have only a marginal effect on the number of low

-income households. Thus, they do not cause homelessness, but rather determine vulnerability in a difficult housing market.

This study focuses on two primary research questions. First, the study examines how the relationship between income distribution and home price distribution in a community impact rates of homelessness. Second, the study explores the added effect of both the process of buying-down and income restricted mobility on the rate of homeless.

This paper is organized into six sections. Starting with a discussion of the definition and quantification of homelessness, I present evolving perceptions of homelessness, as well as statistics and methods used for national data collection. Next, I briefly describe the negative impacts of homelessness on children, youth and adults. The third section outlines the factors affecting homelessness, focusing on the spatial mismatch between household income and housing costs. In the fourth section, I briefly introduce agent-based model methodology, including its epistemological framework, key concepts needed to interpret and understand the model, and the use of agent-based modeling in community-based research. I then describe the models of the low-income housing ratio, buying down, and income restricted mobility, and their corresponding analysis and findings. I conclude with limitations of the current models as well as future direction.

DEFINITION AND QUANTIFICATION OF HOMELESSNESS

What does it mean to be homeless in America? Defining homelessness does not come without controversy or disagreement. Lawmakers, advocates, and researchers often do not agree on who is or is not homeless (Rossi & Wright, 1987). Over the past century, the definition of homelessness has shifted and stretched covering an abundance of housing situations.

The public's understanding of homelessness has moved from a post-World War II definition, whereby homeless individuals were those without social relations or those characteristics that would distinguish a house from a home, to a more recent account of homelessness, which focuses on an individual's ability to maintain stable and safe housing (Rossi, 1994). This conceptual change originated from the visible shift of accommodations for those individuals and families experiencing homelessness in America between 1950 and 1980. Comparatively, an increase in the mid-1970s and 1980s of individuals and families living on the street, in parks, bus stations, and other very observable locations, created a different understanding of homelessness, and rising concern among the general public.

Literal Homelessness v. Precariously Housed

Prominent definitions of homelessness arose out of the 1980s, included a distinction between what researchers called *literal homelessness* and persons who are *precariously housed*. Literally homeless individuals, or "those who obviously have no access to a conventional dwelling unit and who would be considered homeless in any conceivable definition of the term" are differentiated from the marginally housed, or "persons with tenuous or very temporary claims to a more or less conventional dwelling or at least a stable housing situation" (Rossi & Wright, 1987, p.21). This distinction not only effects the way we understand the experience of

homelessness, but also affects an individual's or family's eligibility for supportive services (Grant, Gracy, Goldsmith, Shapiro & Redlener, 2013).

HUD Homeless

With a surge in public outrage about this social issue at the end of the 20th century, came the subsequent demand for government action and thus a need for a clear definition of homelessness. Traditionally, The United States Department of Housing and Urban Development (HUD) defined homelessness in two categories. The first category includes those who lack a fixed, regular, and adequate nighttime residence, or literally homeless individuals. The second category includes individuals whose primary nighttime residence is a publicly operated shelter designed for temporary living, an institution that provides temporary residence for individuals intended to be institutionalized, or a public or private place not designed for or ordinarily used as human accommodations (Stewart B. McKinney Homeless Assistance Act, 1987). However in recent years, HUD offered a more inclusive definition of homelessness. The HEARTH Act, passed in May 2009, amended the McKinney-Vento Homeless Assistance Act and included a revised definition of homelessness that could then be applied to HUD's Homeless Assistance Programs. From this modification, homelessness was categorized into four distinct groups (Grant et al, 2013; Changes in the HUD Definition of, 2012).

Core Definition. Category one describes literal homelessness. Included within this group are individuals and families who lack a regular and adequate nighttime residence. According to HUD guidelines, this also includes those who are exiting institutions where they resided for 90 days of less, including emergency shelter or a place not meant for human habitation immediately before entering the institution (Changes in the HUD Definition of, 2012).

Imminently Losing Primary Nighttime Residence. Category two has been expanded to include individuals and/or families being evicted within 14 days from their primary nighttime residence. This includes individuals who have no current subsequent housing, or those who lack the resources and support needed to obtain other permanent housing. Importantly, this definition of homelessness also applies to persons who are "doubled-up", which refers to individuals unable to maintain their own housing and those who are forced to stay with a succession of friends, or extended family (Changes in the HUD Definition of, 2012).

Persistent Housing Instability. Traditionally, individuals with persistent housing instability were not considered homeless by the United State government. However, category three includes individuals with chorionic disability or illness, or people/families with multiple barriers to employment (i.e. illiteracy, history of unstable employment, and low English proficiency). In addition, persons who have not had a lease, ownership interest, or occupancy agreement in permanent housing in the past 60 days, or individuals and families who have moved two or more times in the 60 days immediately prior to applying for assistance are categorized within group three. Unaccompanied youth and families with children are identified as a special sub-group as part of category three. Those youth and families who are defined as homeless under other federal statues, but not otherwise qualifying as homeless under the first and second category definition, would be included in this third group (Changes in the HUD Definition of, 2012).

Fleeing Domestic Violence. Lastly, the passage of the HEARTH Act included a more comprehensive recognition of individuals and families who are fleeing domestic violence. Category four includes those who are attempting to flee domestic violence, dating violence,

sexual assault, stalking, or dangerous or life-threatening situations related to violence against either an individual or family member (Changes in the HUD Definition of, 2012).

Time-based Definition of Homeless

In addition to the above categories of homelessness, individuals and families are often grouped based on the span of time they have experienced homelessness. Most often, a distinction is made between those who are temporarily homeless and those who experience chronic homelessness. Persons experiencing chronic homeless, according to HUD, or persons who have either been continuously homeless for a year or more, or have experienced at least four episodes of homelessness in the last three years.

Prevalence of Homelessness In The United States

According to the National Alliance to End Homelessness and the Department of Housing and Urban Development, as of January 2014, there were 578,424 people experiencing homelessness on any given night in the United States. Of the total population of individuals experiencing homelessness, 216,197 were people in families and 362,163 were individuals. The vast majority were persons experiencing temporary homelessness or housing instability, with only 15 percent of the homeless population considered chronically homeless (Snapshot of Homelessness, 2015). In addition, there was a notable difference between the frequency of homelessness experienced in large urban areas, as compared to both suburban and rural communities in the United States, with nearly 20 percent, or one in five, people reporting homelessness located in either New York City or Los Angeles (Henry, Shivji, de Sousa, Cohen, Khadduri, & Culhane, 2015).

The statistics released by HUD are based on a Point-In-Time (PIT) count, in which each Continua of Care report nationally on the number of sheltered (residing in emergency shelter or

transitional housing) and unsheltered individuals (those living on the street, abandoned building or other locations not seen fit for human habitation). Continua of Care are geographical domains varying in size and composition, which sanction efforts to address homelessness at a city, county, multi-county or state level. Therefore, within these geographical bounds families and singles are counted on a single designated night in January to measure the occurrence of homelessness for that community. Because these counts only happen once per year, seasonal changes in the homeless population may also not be captured in those communities with harsh or deterring weather during the month of January.

PIT count estimates have been critiqued because they may underestimate or misrepresent segments of the homeless population, specifically the experience of housing instability and homelessness of families in the United States. Notably, these numbers do not include those doubled-up, and therefore represent the number of people considered literally homeless, and exclude all those precariously housed (Henry, Shivji, de Sousa, Cohen, Khadduri, & Culhane, 2015). In addition, some communities believe a PIT count tends to over-represent chronically homeless individuals and under-represent those for whom the experience of homelessness is brief (Smock, 2009). Moreover, critics of PIT count methodology have noted the difficulty in locating the 'visibly' homeless, noting the likelihood for skewed statistics based on counters assumptions about where homeless persons are living and who "looks homeless" (Hopper, Shinn, Laska, Meisner & Wanderling, 2008). These critiques may lead to a systematic suppressing estimated of homelessness among families.

IMPACTS OF HOMELESSNESS ON FAMILIES

Experiencing homelessness, particularly for families who experience multiple episodes or chronic homelessness, may precede some outcomes associated with housing instability, such as substance related disorders and mental health issues (Castellow, Kloos, & Townley, 2015). Living in nontraditional residences or maintaining unstable housing situations can cause considerable problems related to an individual's mental and physical health. These potential harmful outcomes further emphasize the importance of understanding the underlying mechanisms of homelessness.

Mental Health and Substance Abuse

Destabilization, stress, and trauma associated with homelessness can result in multiple poor mental health outcomes in both children and adults (Bassuk, 2010; Zeger, 2008). Children experiencing homelessness show higher rates of behavioral problems, issues related to emotion regulation, attachment disorders, delayed neurological development, and increased risk for both anxiety and depression (Bassuk, 2010; Saade & Winkelman, 2002). Multiple studies have documented negative mental health outcomes in adults, namely major depression, post-traumatic stress disorder (PTSD) and emotional distress (Bassuk, 2010). Additionally, the use and abuse of substances is shown to be associated with homelessness, for both chronically homeless men and women **(**Castellow, Kloos, Townley, 2015; Edens, Kasprow, Tsai & Rosenheck, 2011). And self-reported increase in both drug and alcohol use has been documented as a result of becoming homeless (O'Toole et al, 2004).

Physical Health & Exposure To Violence

According to the Institute of Medicine (1998), adults in homeless families are in poorer overall health than those in the general population. Homeless adults reportedly experienced

asthma, anemia, HIV/AIDS and chronic ulcers at higher rates than the general population (Min-Park, 2011; Magnus et al, 2014). Similarly, children experiencing homelessness are at higher risk of teen pregnancy, contracting sexually transmitted illnesses, and experiencing respiratory condition than the general population Kulik, Gaetz, Crowe, & Ford-Jones, 2011). Although few studies have systematically documented the occurrence of sexual and physical abuse of homeless young adults, experts agree it is not uncommon (Zerger, Strehlow & Gundlapalli, 2008).

STRUCTURAL FACTORS' INFLUENCE ON HOMELESSNESS

The housing literature sometimes explains homelessness as a manifestation of personal factors unique to the individual. Personal traits, namely mental illness, substance abuse, and exposure to violence, are thought to render an individual unable to obtain or maintain housing. However, Sosin (2003) argues that pathways into homelessness are complicated and may be due less to individual attributes and more to transitions, resources, and events. Further, an explanation of homelessness as a product of individual incompetence, including behavioral disorders such as SMI and substance abuse, runs contrary to several studies documenting the dynamics of behavioral disorder and homelessness (Montgomery, Matraux & Culhance, 2013), which conclude that although behavioral disorder increases the risk of becoming homeless, it is neither essential nor adequate as a sole cause of homelessness (Sullivan, Brunam & Koegel, 2000).

For the purpose of this study, family homelessness will be framed as a breakdown of structural factors as opposed to a failure of individual families. Structural factors, including national patterns of poverty and housing markets may better describe the driving force behind homelessness as a broad social phenomenon. More specifically, homelessness described as product of a mismatch between income and home prices or income-housing ratio McChensney (1990).

Income-Housing Ratio

McChensney (1990) describes homelessness as a result of an unbalanced low-income housing ratio. This ratio is defined as "the number of households living below the poverty line divided by the number of affordable housing units available" (p. 191). Therefore, when the number of poor households exceeds the number of low-income housing units low-income

families are often left with three options. Families that can pay more for their housing do so; those who cannot pay more double up with family and friends; and those who can do neither become homeless. She contends that only programs, which target the reduction of poverty or the increase supply of affordable housing, will effectively decrease the total number of homeless families.

The income-housing ratio theory was used to frame a review of data collected focused on the distribution of poverty and inadequate and unaffordable housing (Shinn & Gillespie, 1994). This data emphasized the experience of families using information collected in New York from 700 families requesting shelter and 524 families randomly selected from public assistance. Interview and archival data collected supported a structural, as opposed to individual deficit, model of homelessness for those families sampled.

The first component of the Income-Housing Ratio is the number of low-income households, or the experience of finical hardship or poverty. According to census figures released in September 2013, 46.5 million people are estimated to be living in poverty in the United States. Those whose income is 50% below the poverty line, commonly referred to as living in deep poverty, made up 6.6% of the American population (National Center for Law and Economic Justice, 2015). A large body of research provides evidence of adverse effects from living in neighborhoods of concentrated poverty on a family's health, education, and long-term economic prospects (Massey, 2015).

In addition to numerous negative outcomes, poverty and homelessness are also inextricably linked. Families living in poverty must make hard choices about spending money on food, childcare, health care, education and/or housing. Results from one study of welfare reform, suggests that limiting the financial supports to families in poverty increases the rates of family

mobility, evictions, and the likelihood of sharing housing (Nicholos, 2003). Also, despite an 18 percent increase in the number of families in deep-poverty from 15.9 million in 2007 to 18.5 million in 2013, funding for the largest HUD programs remain below 2008 levels (Joint Center For Housing Studies, 2015).

The second key component of the Income-Housing Ratio is the availably of affordable low-income housing**.** Affordable housing refers to housing for which the residents are paying no more than 30 percent of their income toward total housing costs (Affordable Housing –CPD – HUD, 2014). However it should be noted that some jurisdictions define affordable housing based on other locally determined criteria. Numerous studies have found significant negative association between affordable housing supply and the size of the homeless population, as well as positive associations between increasing housing prices and the size of the homeless population (Bohanon, 1991; Burt, 1992; Eliot and Krivo, 1991; Honig and Filer, 1993).

This relationship was prominent during the economic downturn and housing crisis over the last decade. More than 12.8% of the nation's supply of low-income housing has been permanently lost since 2001 (Bauman, 2014). The shortage of affordable housing is particularly difficult for extremely low-income renters who, in the wake of the foreclosure crisis, were competing for fewer and fewer affordable units.

Housing burdens have increased in the past decade as rentable housing costs and income have diverged. According to a report issued by the Joint Center For Housing Studies of Harvard University, the number of renters burdened with housing costs has reached a new high of 21.3 million in 2014. This includes, 11.4 million renters households with severe cost burdens (2015). In addition, low-income householders are experiencing almost universal cost-burdens, with extremely low-income renters facing an absolute shortage of affordable units. This is especially

true for those looking for housing in the private market (Joint Center For Housing Studies, 2015).

Buying-Down

McChenseny makes a strong case for the low-income housing ratio, however this ratio is also believed to underestimate the actual shortage of low-cost housing. The number of low-cost units occupied by residents who are not low-income also exacerbates the shortage of affordable housing. The process of living in housing units whose cost is well below one's income, also known as "buying down" or "renting down," increases the shortage of affordable housing beyond what the ratio would suggest. Buying down, in fact, can be also caused by a shortage of affordable homes, then causing not only an imbalance in the income-housing ratio, but also gentrification of the neighborhoods depleted of affordable housing (McChesney, 1990). Gentrification, consequently, will be addressed further as a systematic process thought to contribute to the rise in homelessness among low-income families.

Poverty and Residential Mobility

McChesney (1990) argued that income and other individual traits do not describe the cause of homelessness, but rather determine a family's vulnerability. One aspect of this vulnerability can be explained by a family's limited access to the housing market based solely on their income. Multiple studies of national residential mobility have found that those living in poverty are more likely to move frequently (Crowley, 2003; Petttit & McLanahan, 2003), and importantly, these families move in small distances (Schaft, 2006). For those families living below the poverty line, the process of finding affordable housing may pose a challenge. Low income families may not only have less income to spend on housing, but may not be able to drive around looking for a new house, and may have more restricted social networks thus

providing less information about the housing market. Although the limited distance in residential mobility associated with a family poverty was not explicitly stated as a direct cause for systematic homelessness among low-income families, this too will be explored within the presented model.

RESEARCH QUESTIONS

In order to further explore the structural factors influencing homelessness and housing instability, this study aims to answer two primary research questions. First, the study looks to examine how the relationship between income distribution and home price distribution impacts rates of homelessness. Second, the study explores the added effect of both the process of buying-down and income restricted mobility on the rate of homeless. Answering these questions is important for gaining a better understanding of the primary structural factors that may underlie the pervasive issue of homelessness.

METHODS

Agent-Based Model (ABM)

The low-income housing ratio is a theory cannot be tested using traditional research methodology. The structural factors involved in the ratio – income distribution and home prices – cannot, and arguably should not, be experimentally manipulated for the purposes of research. Therefore, in order to examine the effects of poverty and affordable housing on the rate of homelessness, a computer-simulation method, agent-based modeling, was used. By using a computer model, I further explore large-scale phenomena, including the effects of systematic buying-down, and poverty restricted mobility on general rates of homelessness.

An ABM is a system science method designed to replicate the behaviors and interactions of agents, often representing people, within a given setting. Emerging from an epistemological position known as methodological individualism, ABMs look to explain how individual behaviors, as well as contextual factor create a macroscopic social phenomenon. These models provide a researcher with a single analytical tool to investigate a social problem or pattern holistically, by incorporating both an individual's behavior as well as the contextual factors influencing their decisions and actions (Neal & Lawlor, 2015).

ABMs and Community Based Research. Using an ABM, one is able to explore social issues in a manner that may otherwise be impossible within a real community. It is an ABM's flexibility or ability to test and simulate what-if scenarios that increases its utility for community research. Implementation of housing policy interventions can be costly, time intensive, requiring substantial investment by the community. In comparison, the creation and testing of an ABM is cost effective and requires far less time and resources.

Using this methodology, one may also test an intervention or collect pilot data prior to a larger and more resource intensive project. Given that the field of community psychology often works with and for marginalized populations, the ability to anticipate possible harm to a community or population is of the utmost importance (Neal & Lawlor, 2015). For example, experimentally introducing a restricted number of affordable housing units into a community would be improbable and, more importantly, unethical. Therefore, ABMs allow the researcher to better understand the mechanisms behind these systematic changes without imposing negative consequences into the community. Or alternatively, a model can be used to test positive interventions and policies designed to reduce homelessness.

Importantly, ABMs also allow us to explore mechanisms and processes for complex social issue, constructs, or observed patterns (Macy & Willer, 2002). For the purpose of the present model, this bottom-up approach can be used to enrich understanding of underlying factors related to the occurrence of homelessness.

Basic Assumptions Of An Agent-Based Model. ABMs are created around a set of underlying assumptions, which guide the process of model development. As described by Epstein (1999), ABMs "situate an initial population of autonomous heterogeneous agents in a relevant spatial environment; allow them to interact according to simple local rules, and thereby generate – or 'grow' – the macroscopic regularity from the bottom up" (p 42). In order for the model to meet these assumptions, the agents in the model must move and make decisions autonomously. In addition, following the epistemological stance presented above, the agents should act following relatively simple behavioral rules. These simple rules ultimately create the anticipated macro phenomenon. For the purpose of the current model, this means families act

independently according to basic decision making criteria, in order to simulate larger shifts in housing markets and prevalence of homelessness.

Model Development. The development of an ABM takes place over several repetitions of the modeling cycle**.** According to Railsback & Grimm (2012), the modeling cycle begins with the formation of a question and hypothesis, which will dictate the purpose of the project. Next, based on the existing literature, the modeler must make a decision about the construction of the model, whereby the modeler must identify the significant characteristics, entities and variables to include. In terms of an ABM, these fundamental factors will be represented as the structural assumptions, relevant agents, the parameter that will guide the behaviors of agents, and the appropriate time scale for each run of the model.

After the model structure is determined, the implementation phase of the modeling cycle begins. Implementation refers to the transition of the purposed structure into a computer-generated representation. The modeler develops computer programs that follow the process defined by the model structure to demonstrate the construct of interest. The final phase of the modeling cycle is to analyze the model. Based on the presented research questions and hypotheses, the modeler will choose from a number of possible analytic methods. The analysis phase is also important for the refinement of the model and revisions as necessary.

Model 1: Low Income Housing Ratio

This study begins with a relatively simple initial model designed to replicate the most basic principles of the income-housing ratio, and in turn answer research question 1: what is the relationship between the *level of poverty* and *availability of affordable housing* on the rate of homelessness and housing instability in a community. In this initial model, both income and home prices are held constant. In efforts to adopt an inclusive description of homelessness, for

the purpose of this model, both precariously housed and literally homeless families will be measured across time (Rossi & Wright, 1987). In other words, families' who meet HUD's category 1 definition of homelessness, those who lack a regular and adequate nighttime residence including the use of emergency shelter, will be described as homeless. Additionally, families who meet HUD's category 2 definition, or those in imminent threat of losing primary nighttime residence, will be counted as unstably housed (Changes in the HUD Definition of, 2012).

Model Setup. Using Netlogo software, the model is arranged within a 32 x 32 area. This simulated environment is unwrapped, meaning the world is one where the patches on the left side of the grid do not extend to the right, and the top row does not meet the bottom row of the grid.

Agents. The agents used within Model 1 represent the important entities identified during the initial stages of the modeling cycle. Based on the described intention of the model, the Netlogo environment will contain two agents: *families* and *houses*.

The entire world consists of 1,024 homes situated in a grid formation of a 32 X 32 area. From the beginning, all of the patches have one attribute, *cost* (C), which is captured by a continuous variable ranging from 0 to 10. A housing *cost* of 0 represents the lowest priced home in the community and 10 represents the highest priced home in the community.

The second type of agent within this model is a family. Each agent is located on a unique patch, representing an assumption that only one family can reside in each house. Each family has two distinct values: *income* (I) and *savings* (S). The family's *income* is a ratio variable, which can vary from 0 to 10, with 0 representing a low-income family and 10 representing a high-income family. A family's *savings* represents their saved surplus income. Every family starts with a *savings* value equal to their *income*, thus a family's *savings* value begins with a range of 0 to 10.

Ticks. Each iteration, or tick of the model represents a period of time passing. For the purpose of the Poverty, Affordable Housing, and Homelessness model, each tick represents a 4-month period. In other words, every 4 months families reassess their current living situation and undergo a possible process of eviction from their current residence.

Parameters. In addition to the previously stated values, the model contains the capabilities to adjust two parameters using sliders found on the Netlogo interface. First, one can adjust the mean income of the population in a range of 0 to 10. Each family's income is assigned as a random draw from a truncated normal distribution with a range of 0 to 10, and the specified mean. Thus, a community with a mean income of 1 contains families who are generally low-income, while a community with a mean income of 9 contains mostly high-income families. When the model is initialized, these families are distributed randomly throughout the grid. Second, the mean cost can be altered, whereby the users can set the mean cost anywhere from 0 to 10. Each patch's value is assigned as a random draw from a truncated normal distribution with a range of 0 to 10, and the specified mean. Thus, a community with a mean value of 1 contains mostly inexpensive houses, while a community with a mean value of 9 contains mostly expensive homes. When the model is initialized, these patches are distributed so that patches with similar values are spatially clustered. In addition, the house with the lowest cost is defined as a shelter. Unlike all other patches, more than one family may occupy the shelter patch.

Model Implementation. Once the model has been initiated and all parameters and agents are set within the fixed grid, the model is ready to run. With every model tick (T), each family follows a set of rules. A flow chart provided in *Figure 1* portrays the process described below.

First, each family calculates their total wealth, by adding their savings (S) and income (I). After which they determine whether or not they are satisfied with their current residence.

Satisfaction is based off of three factors: (1) the family must not be living in a shelter, (2) they must be able to afford the home long-term, which is determined by comparing their income (I) to the cost (C) of the house (I> C), and (3) the house must not be far below their income:

$C + 0.1 \geq I \geq C$	(1)

If all three of those criteria are met, then a family is considered satisfied and they remain in that house, whereby the family pays cost (C) of the current residence, from its income (I), adding any surplus income to savings, or subtracting any shortfall from savings:

$S_T = S_{T-1} + I - C$	(2)

If one of the three previously stated criteria is not met than the family is considered dissatisfied, and begins the process of looking for a new home. Dissatisfied families examine the patches within the community, to determine whether any available homes would lead them to be satisfied. If a house is available and satisfies criteria, the family moves into the new home, making their old home available and paying the new cost of the home (i.e. equation 2).

If no home in the community is both available and affordable, the family must determine whether or not they can afford the current home for the time being. To do so, the families compare their total wealth (W) to the cost (C) of the home ($W \geq C$). If a family cannot afford the current home and has determined there is no other affordable houses, they are evicted from their home and are moved into the shelter space.

Model 2: Buying – Down

The second model builds on the Low-Income Housing Ratio Model, described above, by adding more nuanced view of housing selection by each of families in the model. This version of

the model adds a component of "buying-down" or "renting-down". Buying-down, as described previously, is process whereby families live or move to housing units whose cost is well below their given income (McChesney, 1990).

Model Modification. A third parameter, represented by a switch, was added to the interface in order to incorporate the process of buying-down. The *buying-down* switch can be turned on or off before the model begins to run. This switch effects the computation of the satisfaction variable for families within the model. When the *buying-down* switch is turned off, a family will be satisfied with their home given the satisfaction guidelines described in the previous model. However, if the *buying-down* switch is turned on, the satisfaction variable is expanded to include families residing in houses significantly less expense than what can afford (2.0 units below their given income). Meaning a family with an income of 5.0 can be *satisfied* in a home with a cost of 3.0, if there are no other houses of higher in which they can afford.

$C + 2.0 \geq I \geq C$	(3)

Model 3: Income Restricted Mobility

The third model looks to simulate another aspect of housing choice by families within the model. More specifically, a family's ability to move is often restricted or expanded by their income. Low-income families are limited in their ability to move far from their current residence, whereas those with very high income may not be limited at all by distance from their current neighborhood or residence.

Model Modification. Adding another switch to the interfaced allowed for the fifth parameter, *mobility*, to be added to previous versions of the model. When the mobility switch is turned off, and in all previous versions of the model, families are able to assess the prices of all available houses in the community and move to any of those houses. Or in other words, they

have limited mobility and are no confined by any spatial barrier. However, for model 3, when the mobility switch is turned on, the families relative wealth, calculated by adding their income and savings, dictates the distance in which they can move. Scaled on a 10-point hierarchy, the richest families are given unlimited movement, whereas the poorer families are given significantly less mobility.

ANALYSIS

Analysis took place in four stages. First, experimentation with model 1 was used to answer the first research question, by examining the relationship between the *level of poverty* and *availability of affordable housing* on the rate of homelessness and housing instability. Next, analysis of model 2 examined the effect of buying-down on the rate of homelessness. Third, an examination of model 3 identified the effect of income-restricted mobility on the occurrence of homelessness and housing instability. Finally, a more focused analysis of all models 1-3 was conducted to explore each parameter in communities where both low-income families and low value homes were prevalent.

To test each of the models, Low-Income Housing Ratio Model, Buying-Down Model, and Income Restricted Model, experiments were conducted using Netlogo's BehaviorSpace tool. For the initial model, the relationship between the housing-income ratio and prevalence of homelessness were examined. Additionally, subsequent models tested parameters of buying-down and restricted mobility. First, values of mean-income were examined from 1 to 9 in increments of 0.5. Starting mean-land-value was varied, similarly from 1 to 9 in increments of 0.5. In addition, percent occupancy rate was tested 93%, based on average rental vacancy rates within the United States (Census Bureau, 2015). Each combination of adjusted parameters was simulated until the homelessness became stable. Different combinations of parameters ran between 10 and 141 ticks.

In order to test more precise variations in the low-income housing ratio, a second set of analysis was done specifically focused on communities with low incomes and home values. Both buying-down and income-restriction parameters were tested in a second set of analysis where income and home value range from 1 to 4 in increments of 0.075. The occupancy rate was set at

93% and simulations were completed once homelessness became stable within the model. Models within this set of analysis stabilized after 10 to 119 ticks.

RESULTS

Results for both initial and secondary analysis of models 1-3 are compiled and displayed using heat maps. The provided heats maps indicate the percentage of average homelessness given the tested parameters of both mean-income and mean-land-value (See Figures 2-7). The x-axis provides the mean-income and y-axis the mean-land-value parameter used during the run of the model. Color variations in the diagram represent the average percent of families that were homeless over 100 realizations of the model, with dark blue indicating lowest rates of homelessness and red highest rates of homelessness.

Model 1

Model 1 was designed to simulate the effects of the housing-income ratio on homelessness. Within this model, one distinct pattern was observed. Notably, homelessness occurred when mean land-value exceeded mean income. When mean land value > mean income, mean homeless is high (mean = 69.76%, SD= 1.45). When mean land value = mean income, homelessness is low (mean= 1.84%, SD= 1.51). When mean land value < mean income, homelessness is almost absent (mean = 0.03%, SD=0.05).

This pattern can be observed in Figures 2 & 3. Figure 2 displays findings from initial analysis of model 1. The level of homeless, as stated above, is indicated by the color. The diagonal division running from the bottom left corner to the top right refers to observed homelessness when income and land-value are matched. The dark blue color in the bottom right half of the figure indicates low homelessness (<10%). In this case, this level of homelessness occurs when income is lower than land-value. Whereas, increased levels of homelessness are indicated from light blue (20%) to dark red (100%) as the ratio increase. Or in other words,

colors shift from dark blue to dark red when homelessness increases and where the difference between income and land-value becomes larger.

Figure 3 presents secondary analysis findings, which focused specifically on low income and land-value simulations. Furthermore, findings from both sets of analysis support patterns presented by McChesney (1990), or those following the understanding of homelessness using the low-income housing ratio.

Model 2

An additional parameter to the low-income housing ratio, specifically the effect of buying-down (or renting-down) on the rate of homelessness, was simulated in Model 2. Importantly, the patterns of homelessness in Model 2 looked somewhat different from those found in Model 1. In Model 2 homelessness occurs when mean land-value matches income. In fact, homelessness is seen when mean income exceeds mean-land value.

In comparison to homelessness observed in model 1, rates of homelessness in model 2 were markedly higher under all conditions. Figures 4 display the provided findings. When mean land value > mean income, mean homeless is higher than in model 1 (mean = 72.56%, SD= 1.35). When mean land value = mean income average homelessness was observed at 15.05% (SD= 1.51). And when mean land value < mean income, homelessness is at it's lowest rate (mean = 0.51%, SD=0.15).

In further analysis of Model 2, focusing specifically on simulations where the model had both low average income and land-value, the effect of buying-down on homelessness was even more prominent. Notably, this pattern was observed under conditions where income exceeded mean land-value. In these circumstances, when mean income > mean land-value, a mean homelessness was 1.97% (SD= 1.35). Patterns presented in Figure 5 reflect these data.

Moreover, McChesney (1990) suggests that the process of buying-down would exacerbate the rate of homelessness beyond what is seen by modeling the low-income housing ratio. And therefore homelessness would be seen in communities where income and land-value are matched. McCheseny also stated that the process of buying-down would be most detrimental to those with low-income or in poverty.

Model 3

Model 3 was designed to simulate the effect of income-restricted mobility in addition to the process of buying-down on the rate of homelessness. Homelessness occurs, during this model, even when income exceeds land-value. Markedly, this difference between Models 1 and 3, exhibited in Figure 6, is most noticeable when mean income is low. This is represented in further analysis of Model 3, which focused on communities with both low mean income and land-value (See Figure 7).

In comparison to homelessness observed in models 1 and 2, rates of homelessness in model 3 were again higher under all conditions. Observing both processes of income-restricted mobility and buying down, when mean land value > mean income, mean homeless is at it's highest (mean = 73.83%, SD= 1.33). When mean land value = mean income average homelessness was observed at 20.11% (SD= 1.51). And when mean land value < mean income, homelessness is relatively high compared to the first two models (mean = 1.94%, SD=0.55).

A more focused analysis of model 3, looking specifically at simulations where the model had both low average income and land-value, exhibited significant effects on income-restricted mobility on rates of homelessness under these conditions. In particular, when mean income > mean land-value, average rates of homelessness were observed at 9.52% (SD= 2.34). Given the

reported effect of income on mobility for low-income families, one would expect to see rates of homelessness increase in simulations where average income and land-value are low.

DISCUSSION

Low-Income Housing Ratio Simulations

McChesney (1990) suggested that the homeless rate is best described by the relationship between the *number of low-income families* within a community and the *number of low-income houses* within that community. This ratio was tested with both the exclusion and inclusion of buying down properties also considered by McChesney. *Model 1: Low-Income Ratio* and *Model 2: Buying-Down* displayed the expected relationship, given McChesney's theory, between the proportion of low-income families and low-income housing on the rate of homelessness within the simulated community. Simulations in Model 1 observed rates of homelessness that reflected the Low-Income Housing Ratio, that is to say when average housing cost was lower than or equal to the average income of the community, homelessness was not observed. In addition, moderate increases in homelessness rates were detected when buying-down/renting-down was included in Model 2. As predicted by McChesney, the process of buying-down exacerbated the shortage of affordable housing, as middle-income families in the model began to occupy low-cost housing.

However, when aspects of income-restricted mobility were added in to *Model 3*, rates of homelessness became even higher than the Low-Income Housing Ratio would have projected. As compared to the results of Model 1, the increase of homelessness across all simulations of Model 3 was seen to be higher than the noted differences in homelessness of Model 2. The effect of income-restricted mobility was most influential in communities where high poverty was present even under circumstances where the ratio was the same across simulations. For example, in Model 3 when average income and housing value were matched, homelessness rates for individual simulations ranged from 12.74% in communities with average income of 4.0 to

47.17% in communities where average income was 0.25.

Notably, the additional parameter in Model 3 were based on proposed difficulties that low-income families face when searching for affordable housing, including having limited ability and time to look for a new homes, as well as more restricted social networks that may provide less information about the housing market. These assumptions were supported by multiple studies, which found that those living in poverty were more likely in small distances (Schaft, 2006). The provided results of Model 3 suggest that barriers for finding housing may have an additional impact on rates of homelessness beyond the processes of buying-down.

Ratio Model & Community Psychology

Researchers can use ABMs as a theory-testing tool. The existing models use a bottom-up approach to understand fundamental features related to the incidence of homelessness. The presented models depict situations where four mechanisms are tested to understand their affect on homelessness: housing price, income, restricted mobility, and buying-down. All tested features take a system-level approach to understanding the issue of homelessness, as outlined by McCheseny (1990). The low-income housing ratio has not been used or tested a great deal outside of a few notable researchers, namely Shinn and her colleagues (Shinn, 1992; Shinn & Gillespie 1994; Shinn, Gottlieb, Wett, Bahl, Cohen, & Ellis, 2007). By and large, a more person-centered approach has been used to understand the development of homelessness. For this reason, models 1-3 present a much-needed tool to further understand this social issue using a system-level perspective.

Limitation

Moving forward, it's important to interpret the presented findings with consideration to the studies limitations. Most relevant to this study are challenges associated with using models to

represent complex human behavior. Simulations, including agent-based models are always a flawed representation of social issues and other complex phenomena. However, models can be used as tools for expanding knowledge on these topics. In this study, the models were simplifications of an everyday process and therefore they did not include all potential contextual factors that may be a part of transpiring homelessness. The available model only looked to better understand a theoretical framework for homelessness, namely the low-income housing ratio. However, there are a few ways that the model could be further enhanced and tested to better represent the systematic occurrence of homelessness.

Further, the model only represents one piece of a more complex relationship that low-income families have with housing. It was outside the scope of this work to explore processes of land change as it relates to housing lost. Nevertheless, the model may benefit from the addition of other parameters. Other factors may better contextualize the issue of homelessness including: increase in land-value representing gentrification, or decrease in land-value signifying urban decay. In addition, individual factors may have further and possibly unique contribution to the rate of homelessness within a specific population. For example, simulations of person-centered factors such as disparities in serious metal illness may create a more accurate representation of the low-income housing ratio

A common concern with the use of a simplified model such as the one presented is the happenstance that multiple mechanisms may create outcomes similar to those patterns observed by the present model (Helbing, 2012). That is to say, the patterns observed in the model may not be truly representative of the underlying mechanisms involved in the theory being tested. Instead, a variety of other parameters may be used to create the low-income housing ratio. For example, simulations of person-centered factors such as housing disparities due to serious mental

illness may lead to similar patterns of homelessness.

Future Directions

Application to Cities in the United States. As a basis for understanding issues of homelessness and housing instability in a real-world context, the presented models may be applicable to multiple cities across the United States. Each model can be adjusted to imitate communities with varied occupancy rates, availability of affordable housing, and income within an individualized simulation. Hence, replication can be done to compare and further test the model's accuracy. In order to test varying accounts of the Low-Income Housing Ratio, communities such as the following may be used.

San Francisco County, CA. San Francisco County could be used to test the affect of the low-income housing ratio on a community with relatively high cost of living. According to Untied State census data from 2010-2014, San Francisco County has a population of 864,816, the median value of owner-occupied housing units was $765,700, the mean gross rent per month was $1,533, and the median household income was $78,378. San Francisco represents a community who is both high income and has a relatively low rate of poverty, 12.1% (United States Census, 2014). The 2015 HUD Point-In-Time count of homeless individuals, concluded that on any given night 7,539 adults and children were homeless. Additionally, 3,505 individuals were considered to not have permanent shelter, including those unstably housed and doubled up.

Maricopa County, AZ. In comparison, Maricopa County Arizona may be considered a community with relatively low cost of living. The total population of this community was 4, 167,947, the median income of residents in Maricopa County was $53,689, where the median value of a housing unit was $175,600 and the median gross rent from 2010-2014 was $952. The poverty rate is higher, 17.1%. According to data collected in the 2015 Point-In-Time count,

5,631 people experienced homelessness on any given night within that region.

Ingham County, MI. Lastly, Ingham County Michigan may be used to better understand the applicability of models 1-3 to communities with a neutral Low-Income Housing Ratio. The population of this region is the smallest, with a total population of 280,895. The poverty rate is also higher than the other two communities discussed, according to the 2015 census, was 20.1%. The median household income is $45,278, median value of owner-occupied housing unit is $117,700, and the median gross rent from 2014-2015 was $790 in the Ingham County area. Based on HUD required Point-In-Time counts in January 2015, 430 individuals were homeless on any given night.

Dynamic Land-Values. Aspects of the current three models fall short in representing some important features of the Low-Income Ratio. Important to this discussion is the part that dynamic and fluctuating cost of housing. If one considers the Low-Income Housing Ratio as malleable, than one most think of its responsiveness to both changes in occupancy and resident demographics. Most obviously, changes in household incomes affect the ratio; as household incomes rise, housing becomes more affordable. However, changes in home prices also affect the ratio. In the following section, two broad changes in the housing market – vacancy-driven decay and occupancy-driven gentrification –are discussed.

Urban Decay. Urban decay is defined as the process whereby a previously functioning city, or part of a city, falls into disrepair. The process of urban decay has been linked to multiple factors including deindustrialization, depopulation (Hollander, 2011), high local unemployment, segregation, white flight (Geronimus, 2000), political disenfranchisement and crime (Andersen, 2003). Although urban decay can have multiple causes, future studies will focus on decay arising from depopulation and home vacancy. One consequence of the rise of housing abandonment

was a decrease in property value. Not only does the abandoned property lose its value as it lay empty, but the houses and community around it also began to lose value. In future proposed models the effects of vacancy-driven decay could be considered as a process related to the experience of homelessness and housing instability. These patterns are seen as a stark contrast to another important phenomena, gentrification (Hartley, 2013).

Gentrification. Gentrification is a process defined as much by its effect on the physical landscape as its impact on low-income residents. A strictly economic explanation of gentrification is one that focuses on both the state of the housing market as well as the economic state of the current community. This rationalization of gentrification describes *a process*, which includes but is not limited to, cycles of disinvestment or reinvestment in urban area or innercity, as well as neoliberal policies, or those driven by laissez-faire economics (Harvey, 1989; Wyly & Hammel, 2002). The rent-gap hypothesis suggests that gentrifiers, individuals who promote gentrification of an area, and investors take advantage of a gap between the present and potential housing value (Smith, 1979). Not only does Smith describe this process as a political, urban economic, and geographic restructuring, but ultimately the hallmark of the new global city and a product of the new global housing market (Brown-Saracino, 2009). And as communities grow and change in a new urban landscape, gentrification as well as housing instability and homelessness, has been observed throughout the United States. For this reason, the process of gentrification may be an important part of an extended model.

CONCLUSION

Multiple theoretical conclusion regarding the formation of homelessness have been considered within academic literature, including those who describe homelessness as both an issue of individual achievement as well as a structural failure. Those theories, namely the low-income housing ratio, that focus on system level forces, has not received ample attention of researchers studying this social issue. However, the presented model gives a glimpse into how this theory may look in real-world communities across the United States. At its face, the three models represent a starting point for breaking down the different contextual factors, which led to homelessness. In addition, with further calibrations of the model, it may be used as a tool to test housing interventions related to multiple components.

APPENDICES

APPENDIX A

Flow Chart

Figure 1: Decision Tree for Family Housing Choice

APPENDIX B

Data

Figure 2: Heat map of percent homeless using low-income housing ratio model

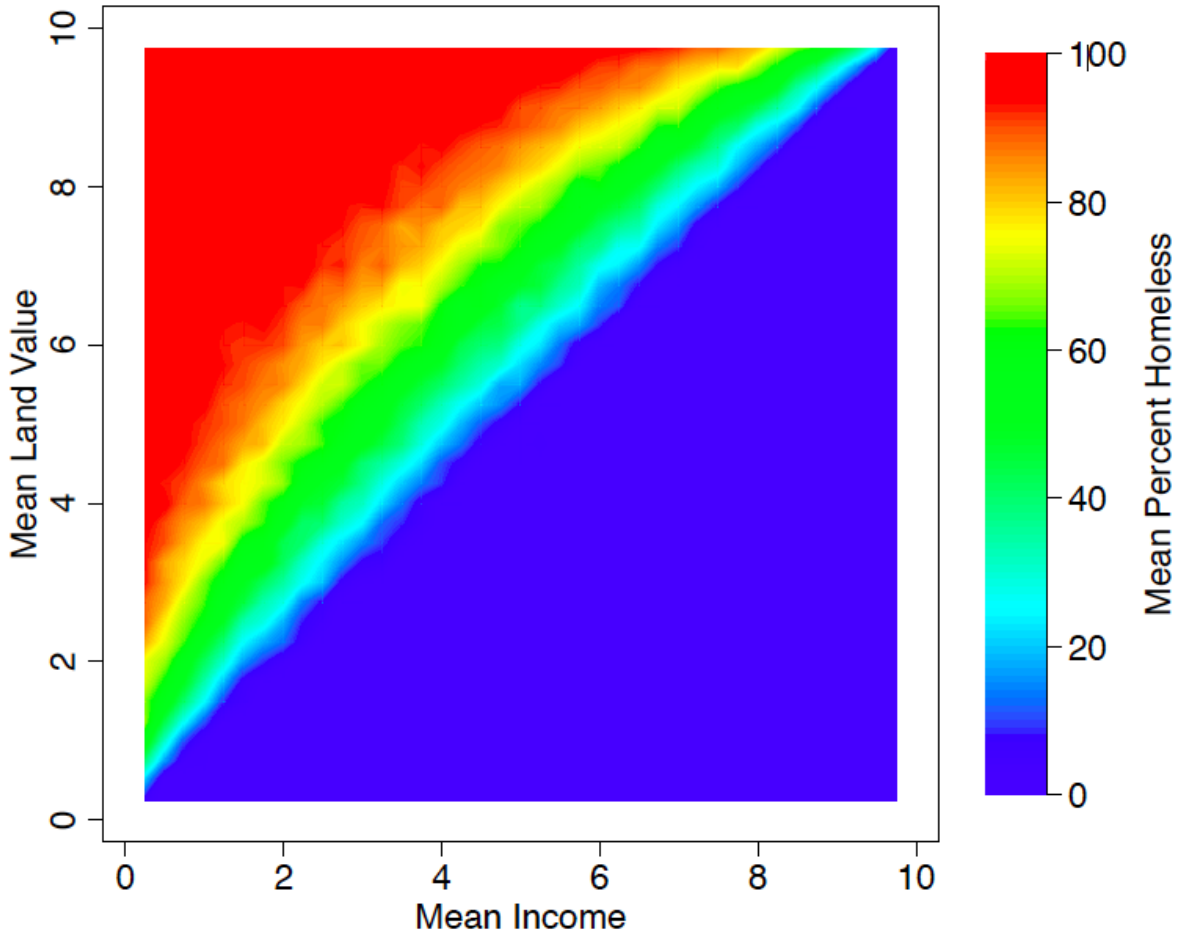


Figure 3: Heat map for percent homeless using zoomed version of low-income housing ratio model

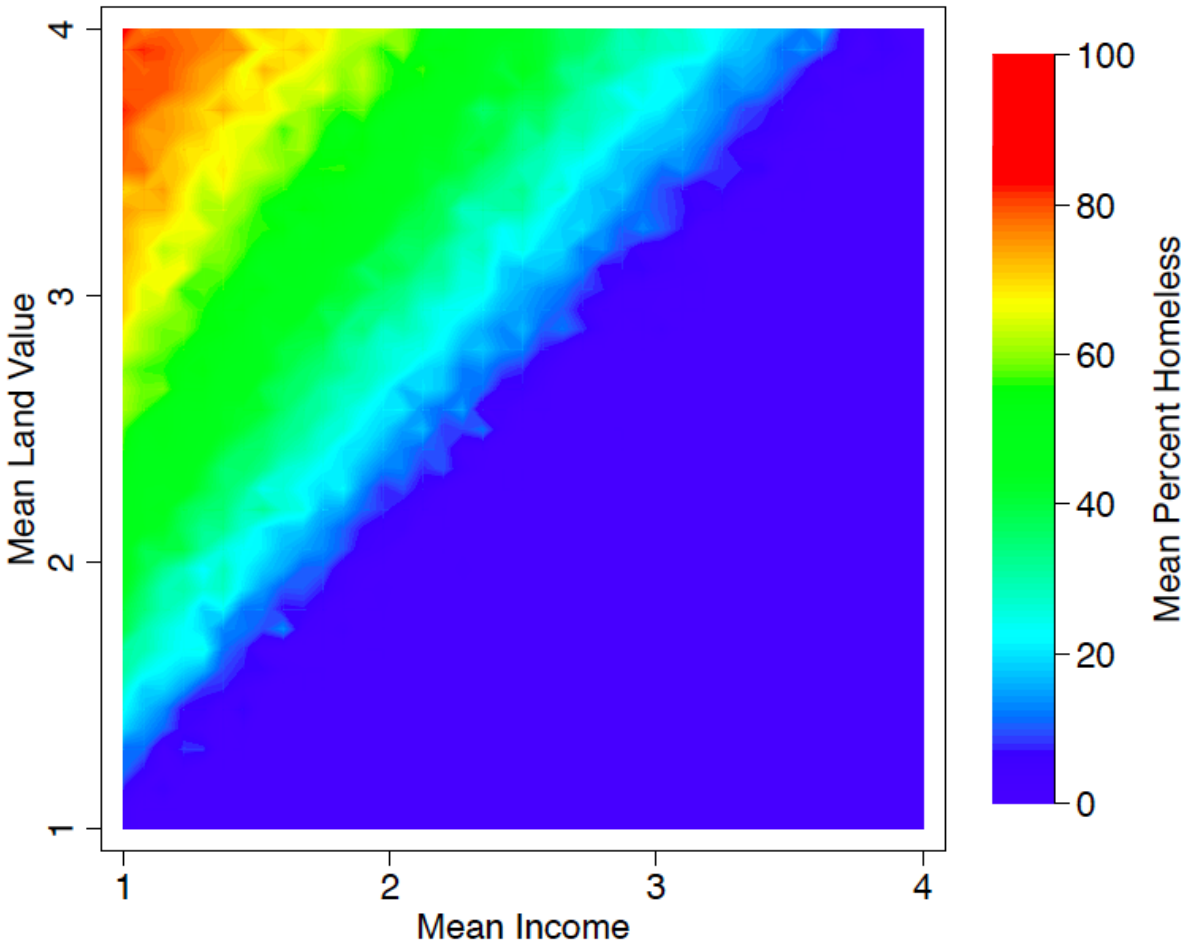


Figure 4: Heat map for percent homeless using buying-down model

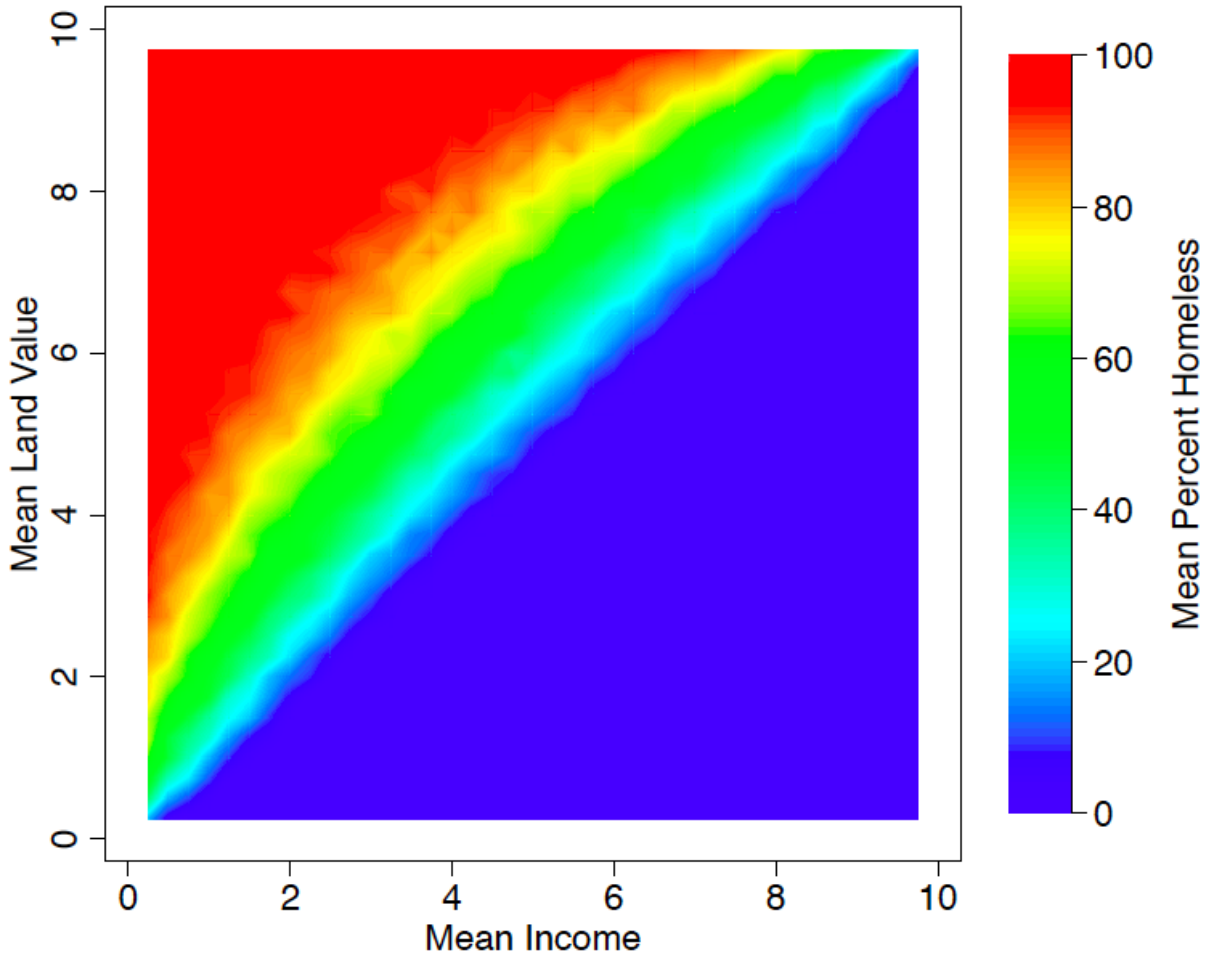


Figure 5: Heat map for percent homeless using zoomed version of buying-down model

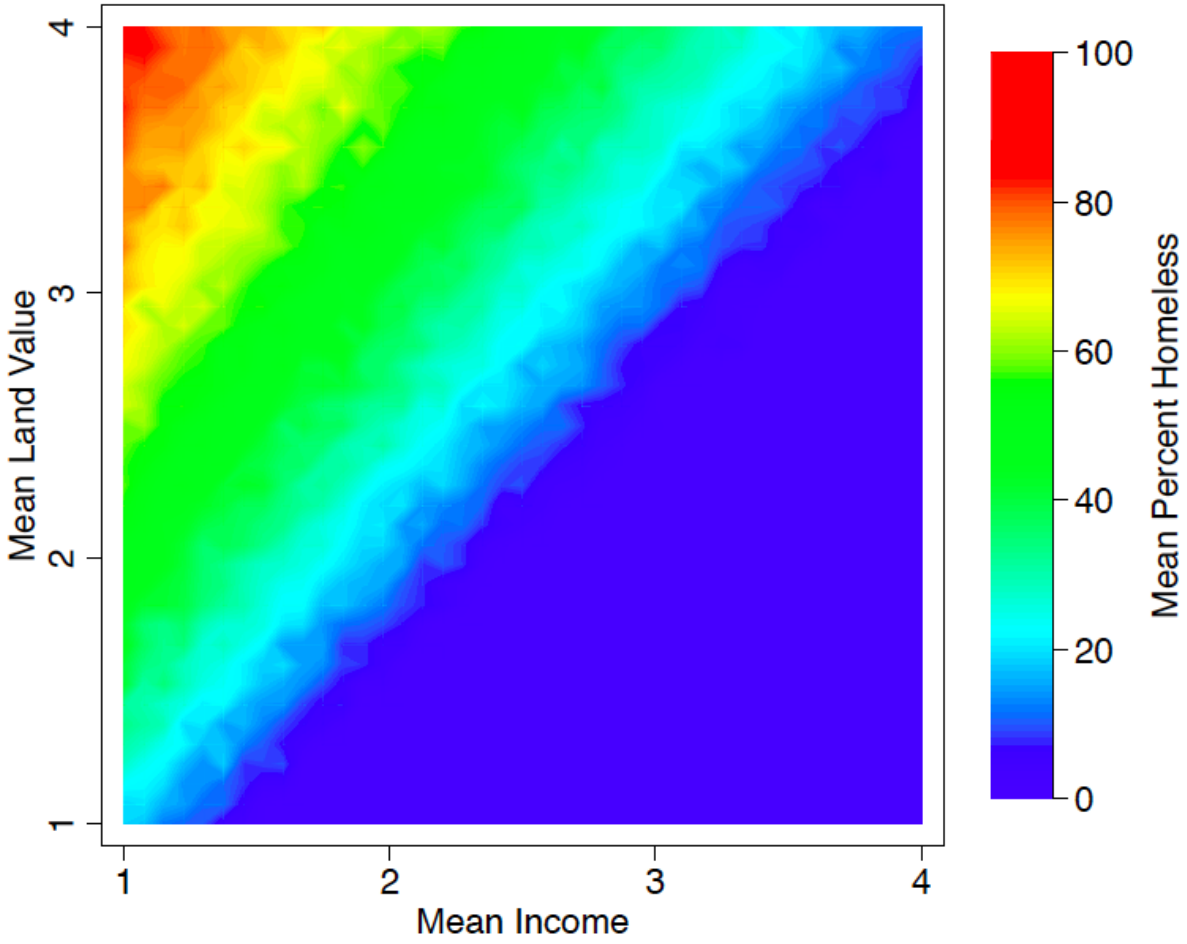


Figure 6: Heat map for percent homeless using income-restricted mobility model

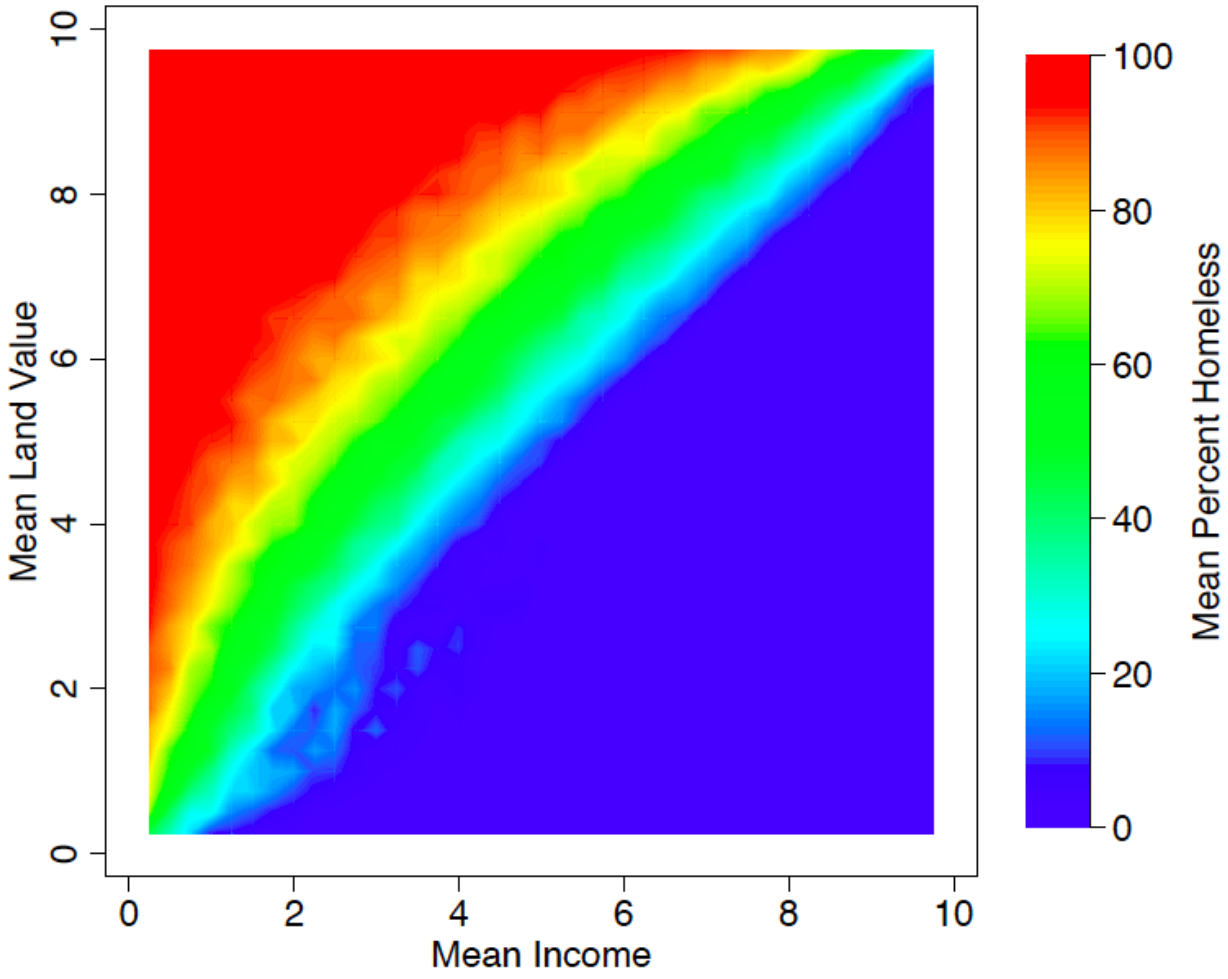
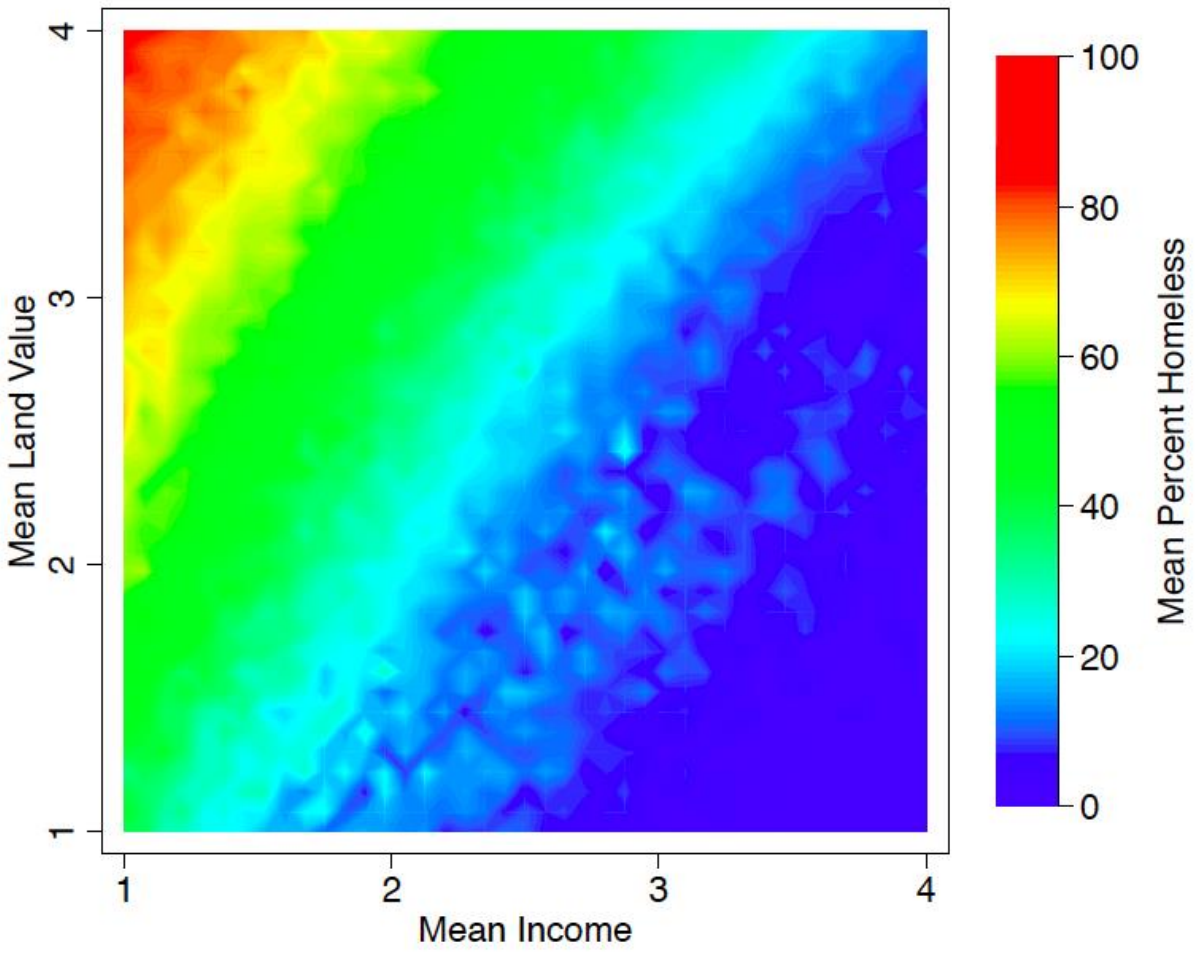


Figure 7: Heat map for percent homeless using zoomed version of income-restricted mobility model



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