Complex system modeling of community displacement in an African American neighborhood in Chicago and a case for policy interventions to support a just transition

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Concepts:

Market - Information, land acquisition, price, Market Power, Asymmetries, Urban Displacement, Dispossession as Gentrification, destabilization, information network, network power, justice transition

Introduction

The ability of railroad companies to shape the development of an urban region through dictating sites of displacement is of concern for urban governance given the question of housing as a human right, the precariousness of housing in urban centers, and uneven burden placed on disenfranchised urban populations. (Ramos; Boyd) The decisions of railroad companies are not simply those of market actors unfettered by policy constraints, but are unique in that they possess state endowed powers of eminent domain. ("Rail Yard Expansion in Englewood Raises Questions of Eminent Domain's Scope"; *610 ILCS 70/ Railroad Powers Act.*; *735 ILCS 30/ Eminent Domain Act.*) Through a large enough acquisition of property, railroad companies could destabilize local housing markets and upend communities using this legal power. (Grinberger and Felsenstein) A better understanding of how these dynamics play out could inform better policy decisions that account for consequences of such developments.

This study explores the impact of rail yard expansion into a Chicago neighborhood, its social cost and policy implications. An interdisciplinary approach was leveraged using ethnography, urban studies and complex system theory to build out a conceptual representation of key drivers of neighborhood change in an agent-based model. The model sought to explore the multi-dimensional nature of decision making among heterogeneous stakeholders and system dynamics that lead to displacement. The basis of the model structure and principles for agent interaction were derived from an analysis of a film titled *The Area* documenting African American residents in a Chicago neighborhood fighting against displacement caused by the expansion of a Norfolk Southern Intermodal Transport Station through their residential community. (*The Area, A Documentary Film About Community and Displacement in Chicago, Illinois*)

The agent-based model borrows from concepts readily available in literature on complexity and urban systems. The representation of resident actions via individual decision-making borrows from Magliocca et al's coupled housing and land market (C.H.A.L.M.S) framework dually exploring micro-economic decisions in relation to a pseudo land market. (Magliocca et al.) Social cohesion is represented in the model through the incorporation of network dynamics. This makes up for the shortcomings of individual decision making models that de-emphasize networked structures and impacts that reverberate through social relations in the real world. (Castells; Watts) The model demonstrates how a formidable destabilizing action in a residential neighborhood impacts the coherence of the community and influences market dynamics. The destabilizing force proceeds to erode networks and the destabilizing actor proceeds to gain market power supporting the case for policy intervention.

The use of ethnography to inform complex systems modeling of urban displacement is not a widespread practice in the shaping of municipal housing and land-use policy. Literature relating complex systems, urban land-use development, and freight logistics is sparse. Chicago's status as a national freight hub, the emerging dominance of online shopping, and the resulting demands placed on local freight logistics centers highlights a critical need for policymakers to make evidence-based ethical and economic decisions regulating land acquisition. (*FHWA Freight Management and Operations - FHWA Freight and Land Use Handbook*; "Freight"; Hesse and Rodrigue) This study adds to existing literature by proposing an expanded integrated approach scaffolded on Watkins et al's ethnographic work linking the methods used in anthropology, complex systems, and urban studies research. It aims to demonstrate an approach that accounts for the needs of urban communities in land-use development. (Zellner et al.)

Conceptual Model

In 2013 the city of Chicago sold close to 550 parcels of land to Norfolk Southern Railway, a company valued at around $50 billion. The purchase laid the groundwork for the $245 million expansion of their intermodal shipping hub situated in the Englewood and New City community areas. The expansion of the yard would displace a large swath of housing and residents of the area. (*The Norfolk Expansion – South Side Weekly*; "Rail Yard Expansion in Englewood Raises Questions of Eminent Domain's Scope") The Scrapper Film group captured the fight of residents to curtail and remediate the actions of Norfolk Southern's plan. The film, titled *The Area*, served as a key document in formulating units of analysis, representations of residents' thinking, and providing insight into localized systems, structures, actions various stakeholders took. This film informed the development of the agent based model used in this study.

The development of this agent based model rests upon a set of assumptions derived from empirical research, including ethnography and literature review. One such assumption is that households are considering selling based on two main considerations, selling price and social cost. Each household considers the then current maximum selling price of their home based on imperfect information within their social network. This same social network is assessed for stability and intrinsic value to determine if selling would be worthwhile. As community members set differing importance on social bonds and stability this valuation varies along with housing current value.

Another assumption is that Norfolk Southern, our destabilizing market actor, is operating with a seemingly infinite budget and can offer multiple bids to any household. This "budget" reflects in the model the fairly intense buying campaign and concentrated deployment of capital that went into the intermodal terminal expansion. Norfolk in the bidding structure has near perfect market information and looks at the aggregate average assessed home value in *The Area* to set the bid. Households can say no to the offer but must consider each offer. This reflects the coercive implication of impending imminent domain action.

Lastly, there is the assumption that created our pseudo housing market. The market is not dynamically responding to fluctuation in supply and demand. This is because the event reflected in this model happened during the financial crisis of 2008 and its aftermath. This community, like many other African American communities, was acutely impacted by the crisis. It's housing market remained "redlined", curtailing any ability to attract new residents or capture any increased assessment in housing value as it related to the citywide housing market.(McKernan et al.; Wolff; Federal Reserve Bank of St. Louis et al.; Herring; University) Through our agent based model, we explore the many ways that decisions situated at the individual, organizational, and policy levels impacted the displacement of residents in *The Area* and make a case for a set of policy heuristics to ensure a more just transition for neighborhoods in similar situations.

Model Components

This model was developed using NetLogo, an agent based modeling software. (Wilensky) This model is composed of two types of agents representing households and the buyer entity (Norfolk) who interact on a matrix of patches representing mortgage values. Household agents are represented by houses on the matrix, and the buyer entity is represented by the Netlogo observer. The patches represent a mortgage market and not a geographic space, though adjacency effects and network links are utilized in this model.

Households

Household agents are displayed as colored homes in the model environment. Each represents one household within the model market. A household agent considers both social and monetary factors into the personal valuation of their household, functioning as an adaptive decision maker. (Payne et al.) A personal valuation is separate from the underlying mortgage value of the home within the market when the house was purchased. Household agents have social preferences, monetary and social valuations, tenure, and network valuations. All of these factor into the personal valuation of their home that determines the amount the buyer entity would have to offer for a successful sale. Each household is initialized with a possibility of being linked to one or more other households, and the direct links held by a household is used to determine the valuation of their property.

The formulation of prices differs from classical economic assumptions of equilibrium modeling and chooses to rely on "decentralized bilateral transactions" between the buyer entity and household agents. (Filatova et al.; Parker and Filatova) Household agents determine their monetary valuation based on the original mortgage value of their home averaged with the values of surrounding occupied properties. Social valuation is determined using the following equation:

*social_valuation =(number of network connections * (tenure + ticks))*

where tenure is a variable randomly assigned to each house between 1 and 70 to represent homes that have lived in the area for varying amounts of time. The final valuation used by households in their decision to sell is a weighted utility function between their social valuation and monetary valuation where the weights are set by a social preference variable assigned at the beginning of the simulation. The final equation for valuation is a normalized utility function that accounts for the entire matrix of mortgages:

*Utility =((1 - social_preference) * monetary_quality) + (social_preference * soc_quality)*[1]

[1]*where social quality and monetary quality are the normalized monetary and social valuations.*

Buyer Entity

The buyer entity is modeled after Norfolk Southern, our destabilizing market actor. It determines its own valuation of properties in the market based on the underlying mortgage of the household it is making an offer to, the offer adjustment is a fixed value set at the beginning of the simulation, the number of failed bids it has made so far, and the averaged valuation of all properties it owns at the time of the offer. This offer uses the following formula based loosely on literature describing historical path dependence: (Arthur)

*(mortgage * (.01 * offer adjustment) * bid failures) + (normalized average value of all owned patches in the market)*

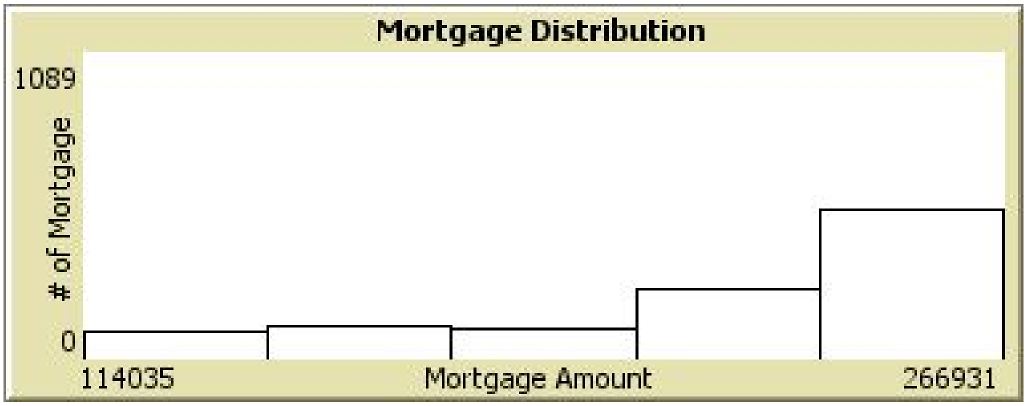
Landscape

The matrix of patches represent mortgage values within the housing market. A patch can be owned by either a household, the buyer entity, or nobody. Patches hold the mortgage value of the lot, whether or not it's owned by the buyer entity, whether or not it's empty, and the number of bid failures that have occurred on that lot.

The mortgage market within the simulation does not behave like an actual market, as it does not fluctuate with the buying and selling of residential properties as you would expect a housing mortgage market to. The "market" is a limited representation during the simulation run and refers to a set of initial conditions for the simulation. It is the total currently available mortgages for residents in *The Area*. The limited dynamism in the mortgage mechanism also reflects the then on-going financial crisis of the time where the housing market collapsed and creditors stopped lending. (University; Olivo et al.)The simulation assumes that homes prices will not exceed mortgages in valuations due to this context.

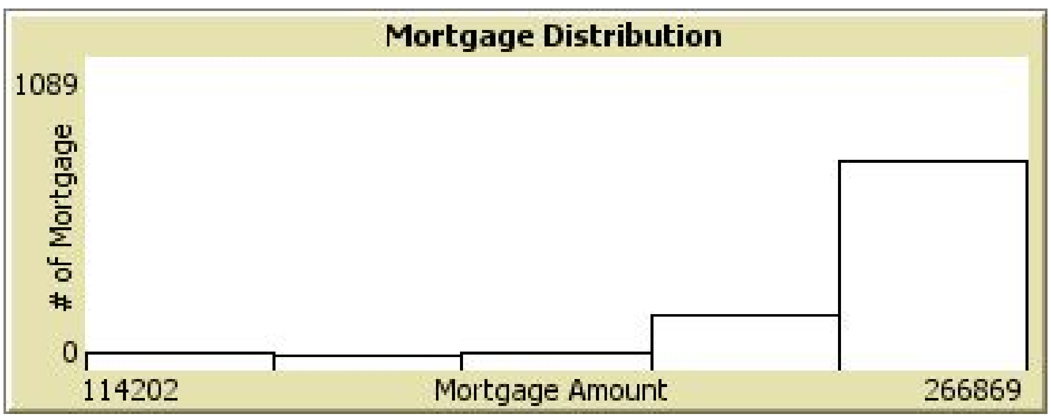
This research is informed by the documentary film *The Area* released in 2012. The film documents a set of major land acquisition and policy actions by Norfolk Southern and local officials in the aftermath of the U.S. Housing crisis. Our model utilized mortgage data from that place and period of time to develop the underlying mortgage distributions for the simulated markets. Analysis was conducted of the housing market from 2008 - 2016 , during the course of events captured in our model. We found that given the collapse of the housing market and protracted marginalization of the neighborhood that the mortgage as residents valuation of their home was a better indicator at the time than the market valuation . The unique situation that residents found themselves in capped all aspiration of windfalls in selling homes due to both historic under-valuations of their homes plus an acute crisis left many with few options. ("Download Historic HMDA Data"; "2018 Community Lending Fact Book")

Englewood Research Area Mortgage Value Distribution c 2013



The Home Mortgage Disclosure Act data served as a foundation for our modeling effort. We replicated the mortgages distribution structure and then extended it through use of a Gamma Distribution function allowing for further modification to test hypotheses on market structures. The distribution of the mortgage value for the research area had a mean of $221,803 with a standard deviation of $42,512. We used this data to generate a similar distribution with a gamma distribution function.

Gamma Distribution Generated Mortgage Value Distribution



This generated distribution allowed us to create a sample set of mortgages during each model run that most closely resembled the observable mortgage distribution of the housing market in the Englewood research area with some random variation. It also allowed us to change the shape of the distribution to impact the distribution of mortgages for further simulate experiments. The gamma distribution function alpha(a) and beta(b) variables were pulled from the real world distribution.

$$\gamma(x;\alpha,\beta) = \frac{\beta^\alpha}{\Gamma(\alpha)} x^{\alpha-1} e^{-\beta x}, x \geq 0,\ \alpha \geq 0,\ \beta \geq 0$$
$$\bar{x} = \frac{\alpha}{\beta}\ ;\ \overline{x^2} - \bar{x}^2 = \frac{\alpha}{\beta^2}$$
$$\alpha = \frac{\text{mean}^2}{\text{variance}}\ ;\ \beta = \frac{\text{mean}}{\text{variance}}$$

(*The AstroStat Slog » Blog Archive » Gamma Function (Equation of the Week)*)

Alpha was derived in the code as (mean_mortgage ^ 2 / mort_stnd_dev ^ 2)
Beta was derived in the code as (1 / ((mort_stnd_dev ^ 2) / mean_mortgage)

Model Process

The general design of the model can be broken down into three phases, initialization, home valuation, and bidding. Setup occurs once per simulation run, assigning each patch a mortgage value, spawning homes, generating network links between homes, which the homes then use to determine their own monetary values. The simulation then cycles between the valuation and bidding processes. In valuation, each home on the matrix updates its monetary valuation. Their valuation strategy can be linear, which sets a value determined as a function of their social and monetary valuations, or nested, which utilizes the same approach as the linear strategy but includes a modifier based on the number of network links the home has. After their individual valuation, the home informs a final valuation in relation to its linked neighbors if any are present. The bidding process follows, with the Norfolk agent selecting a random set of homes to make offers to. The offer for each house is set based on the underlying patch mortgage, the number of previously failed bids, the value of the accumulated portfolio of homes from previous turns, and the offer adjustment variable set by the user. Each house receives an offer, and if that offer is greater than their individual valuation the home is bought and removed from the matrix. This Valuation to Bidding cycle continues until there are no more homes left on the matrix. Each tick represents one bidding cycle and is not associated with any discrete time scale. This process is illustrated in the appendix.

Model Mechanisms

Important mechanisms and interactions within the model are moderated through interactive variables in the model interface. Modifiable variables include those related to agents such as residential density and network type; those related to the buyer entity such as block size and offer adjustment; and variables related to the mortgage market landscape governing the distribution and central tendency of mortgages.

Negative Impacts

When the buyer entity bids on a property, it sets its offer using the home's mortgage value (the underlying patch), the offer adjustment setting, the number of bid failures, and the mean mortgage values of all other homes owned by Norfolk. This value is normalized by the maximum mortgage value in the mortgage universe. The offer adjustment setting allows the user to experiment with the buyer entity's strategy. How aggressively is it willing to bid on these houses, and how feasible is it for them to purchase the entire environment quickly? The inclusion of bid failures as a multiplier to the adjustment ensures that the Norfolk offer doesn't become frozen, resulting in an environment that will never be bought out. Basing the offer valuation off of the underlying mortgage and the already purchased mortgages simulates the effects of mass-purchasing of properties for reconstruction on individual properties. As Norfolk purchased homes it began demolishing them, making the surrounding properties lose value and diminishing the quality of life for nearby residents.

Negative impact effects incorporate model elements from an agent based model simulating land use changes developed by Rand et al. Conceptually, negative impacts in the context of this model simulate the environmental degradation and reduced quality of life associated with housing demolition. This reflects an important aspect of the experiences of residents living in the area purchased by Norfolk in the events of *The Area*. The general, gradual devaluation and destruction of existing housing stock is reflected in declining mortgage values in the model. (Rand et al.; *The Area, A Documentary Film About Community and Displacement in Chicago, Illinois*) When negative impacts occur due to the purchasing of a property through the bidding process, adjacent properties on the matrix have their mortgage value reduced by a percentage set by the user.

The decrease in mortgage values across the entire market can lead to feedback effects where the homeowner's surrounding market diminishes the value of their own home. The loss of equity in a home due to surrounding environmental, social, and economic changes leaves the household agents facing confounding crises of displacement and depleted wealth. One effect of this is the possibility of some homes "holding out" or refusing to take an offer in hopes that the buyer agent will offer them a substantial amount for their home. This was seen in *The Area*, where one final homeowner was refusing to sell their home to Norfolk Southern resulting in an eminent domain filing that halted the progress of Norfolk's intermodal transport hub expansion. These holdout effects are tracked in the model using this formula:

total number of failed bids / total number of remaining houses who have rejected bids

This formula is used in our experiments to capture whether or not there are holdouts within the model, and we couple it with the mortgage buyout ratio, the percentage of the buyer's offer compared to the original mortgage value of the home, to explore these effects.

Network Structure

Network structure offers the choice between a random network and a preferred network at setup. If the network structure is set to random each house will choose a link with a randomly selected house as they populate the neighborhood. If the network structure is set to preferred, each house will choose a link with another house that already has a network link. The difference between these options is subtle, and under the programmed conditions there is no way for the model to begin with any unlinked houses.

Random network link distribution sample

Preferred network link distribution sample

The logic for the network structure options in our model was pulled from the Preferential Attachment model example in the NetLogo Models Library. The model was developed by Uri Wilensky and based on research by Barabasi Albert-Laszlo in *Linked: The New Science of Networks*. Our decision to implement preferential network logic into our model was made on the basis that members of a community often develop relationships with their neighbors through other community members who serve as the “community hub”. While a preferred network model reflects social network formation over time, we also included the option for a random network structure to explore the effects of Norfolk Southern’s purchases on a relatively disjointed community of residents.

The inclusion of social networks and measures of social cohesion serve to capture diffused impacts and information flows that affect decision making for residents. The decision of one resident to sell signals a major change for other connected residents. The resident’s social network erodes as those they have ties with leave and depending on their valuing of those relationships it can add a heavy burden and disincentive to remaining in a rapidly changing area. The model takes these dynamics into account via social quality and social affinity parameters that interact with network degree centrality. (“Social Cohesion and Forced Displacement”) As links to other residents deteriorate each resident takes that into account in their selling price calculation under the “Nested” residential strategy. The “Linear” residential strategy doesn’t take this into account and has residents sell only considering current profit.Regardless of the residents’ motive behind selling social cohesion as represented by the ”link” network degrades as Norfolks acquires more properties in the area.

Model Experiments

Initial parameter settings for each scenario

Category	Parameter	Values	Scenario		
			The Area	Asymmetrical Market	The Affluent Area
Mortgage Distribution	Distribution	Real, Simulated	Real	Simulated	Simulated
	Mean Mortgage	$50,000 - $300,000	NA	$300,000	$300,000
	Mortgage Std Deviation	$5,000 - $90,000	NA	$70,000	$42,500
Resident Characteristics	Residential Density	50 - 1080	540	1000	540
	Resident Strategy	Nested, Linear	Nested	Linear	Nested
	Social Affinity	10% - 100%	90%	5%	90%
	Social Type	Heterogeneous, Homogeneous	Heterogeneous	Heterogeneous	Heterogeneous
	Network Type	Preferred, Random	Preferred	Random	Preferred
Buyer Characteristics	Block Size	1 - 1080	25	1000	25
	Offer Adjustment	1% - 100%	20%	5%	20%
	Impact Effects	On, Off	On	Off	On
	Impact Magnitude	0% - 25%	15%	NA	15%

The Area Scenario

This scenario attempts to simulate the events that inspired the development of this model. To approximate the conditions in the Englewood market at the beginning of Schalliol's film, the residential density is set to 500. The mortgage distribution will be unchanged from the program defaults, since the default distribution is pulled from actual mortgage data in the area. Social affinity will be heterogeneous at 50% to reflect the difficulties the community faced in organizing a collective response to the buyout. The neighborhood in the film was severely affected by the development that occurred on lots where homes had been purchased, and because of this the negative impact setting will be set to 15%. Research states (tk) that human social networks follow a preferred network pattern. Finally, the block size will be set to 20 to reflect the small-scale strategy Norfolk utilized in the film, and the offer adjustment will be set to 10% to reflect Norfolk's buying power and long-term strategizing.

Affluent Area Scenario

This scenario is meant to experiment with an alternative to The Area Scenario in which the residents were more affluent and the mortgages were higher. Aside from this change the settings remain the same.

Asymmetrical Market Scenario

This scenario represents an ultra-dense urban neighborhood with little social cohesion and a competitive housing market. This is reflected by a residential density setting of 1000, a heterogeneous social affinity set at 5%, and a high mean mortgage value with a low standard deviation. Negative impacts will be turned off to reflect a neighborhood with strong redevelopment regulations. The block size will be set to 1000 to reflect a blanket bid strategy, with a low offer adjustment to account for the quantity of bids being made each tick.

Results

Each experiment was run twice, with the data collected into a database file and the variables being aggregated to the bidding cycle count. Analysis was performed using the R programming language. Plots associated with the results can be found in the appendix.

The maximum number of bidding cycles that occurred before the completion of the buyer entity's strategy was not different between The Area and Affluent Area experiments. However, likely due to the larger block size and despite the larger number of residents in the market the Asymmetrical Market experiment had a maximum of 9 bidding cycles before a full buyout. This could be a result of the lack of negative impact effects in the simulation, or it could be a result of the lower social affinity, or through interaction effects between these and other parameters that differed from the Area and Affluent Area experiments.

Holdouts and the Mortgage Buyout Ratio

The holdout ratio trends were similar between the Area and Affluent Area experiments, with a spike occurring in the final bidding cycles. The Asymmetrical Market experiment experienced a higher holdout ratio after half of the bidding cycles had completed for the simulation. Similarities were found between the Area and Affluent Area experiments in mortgage buyout ratio trends as well, with both simulations experiencing above value buyouts until the final bidding cycles where the ratio declined. The Asymmetrical Market experiment experienced high buyout ratios for the first 50% of bidding cycles, but dropped below .5 afterwards.

The relationship between network centrality and hold-out dynamics we saw in our sensitivity test held. In *The Area* and *Area Affluent* scenario experiment, the number of network links a household was connected to increased the likelihood that they would not sell. (See Graph: Social Network, Hold Out Ratio) We sought to better codify this pattern and create a hold-out ratio measure. All simulations will eventually result in all residents selling, so there is no indefinite hold out. We devised a hold out measure counting the number of bids refused as well as refusing to sell. These were the few residents that remained toward the end of a simulation, extending the simulation run until a fair price was reached or network degradation was too great. Both *Area* scenarios continued for the twice the length of the Affluent scenario that did not take into consideration social bonds. The more valued social bonds are and the higher centrality of a household or sub-network of households, the more likely that hold-outs will appear.

Network Breakdown

Average network link degradation in the Area and Affluent Area experiments followed gradual negative slopes, with 50% of the network links eroded within the first half of the bidding process. In the Asymmetrical Market scenario the network link degradation followed a logarithmic trend.

Discussion and Policy Implications

The results of these experiments point towards a dynamic of asymmetrical power between entities using policy levers to acquire properties and those households whose properties are being acquired. In each experiment, the mortgage holders experienced an aggregate loss in wealth from the land acquisition event, leaving them displaced and dispossessed. The contextual setting this model was designed around, *The Area*, documented these events playing out in real life and the ways in which the lives affected were left worse off than when the film began. This model, the film it was based on, and the experiments performed in this paper highlight a need for robust community benefits agreements during large-scale land acquisition, by any entity, that leads to mass displacement. Expanding logistic centers, the creation of new public venues, and any other acquisition of residential land constitute asymmetrical political dealings, and policies providing recourse and mediation for residents during these events should be implemented to prevent undue burden falling upon those most affected.

The unaccounted for social impact of Norfolk Southern rail yard expansion on the residents of this section of Englewood points to a shortcoming by policy actors. The rapid destabilization and predatory acquisition practices left a community reeling and residents struggling to ensure they were compensated enough to find equal and adequate housing. The efforts of residents seeking a fair shake to get redress for being displaced during a global financial crisis points to a world of opportunities for better policy.

One such opportunity is curtailing the imminent domain power granted to railroads companies in Illinois. Norfolk was able to acquire land from the city and place pressure on homeowners to sell. ("Rail Yard Expansion in Englewood Raises Questions of Eminent Domain's Scope") This is a state facilitated distortion of market power. Our simulations showed that regardless of affluence of an individual or set of residents, once a certain threshold of sellers are reached, the forces of displacement grow exponentially if left unchecked. The curtailing of imminent domain should include a mandated Community Benefits Agreement (CBA) process. The CBA should guarantee collective bargaining for residents, home owner, businesses and renters of an area. Our model did not reflect the courageous efforts of many community member who aimed to collectively negotiate with Norfolk Southern with little help from elected officials. The efforts of these residents can serve as a model and mandate to assure other communities when faced with a crisis that a just transition is possible.

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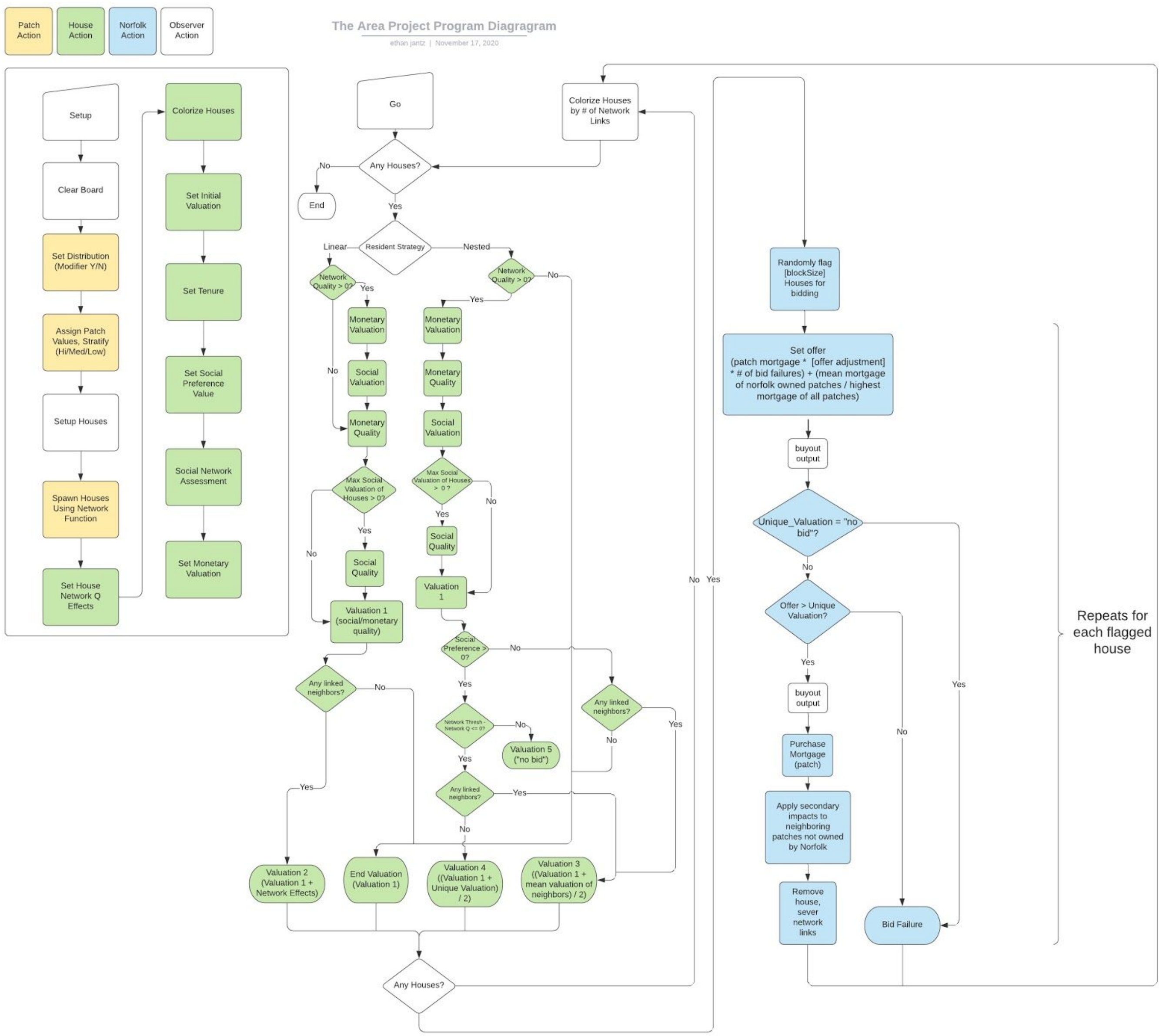
Appendix

Model Process Diagram



Model Interactive Values and Experiment Parameters

Initial parameter settings for each scenario

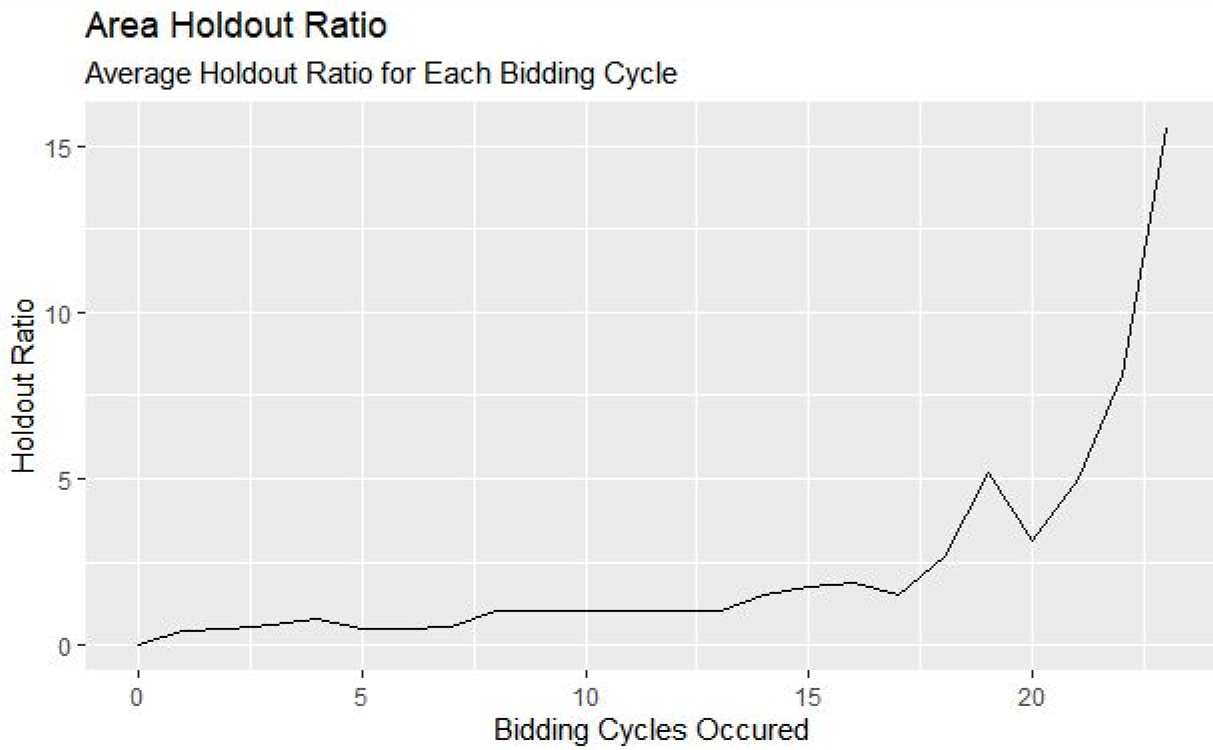
Category	Parameter	Values	Scenario		
			The Area	Asymmetrical Market	The Affluent Area
Mortgage Distribution	Distribution	Real, Simulated	Real	Simulated	Simulated
	Mean Mortgage	\$50,000 - \$300,000	NA	\$300,000	\$300,000
	Mortgage Std Deviation	\$5,000 - \$90,000	NA	\$70,000	\$42,500
Resident Characteristics	Residential Density	50 - 1080	540	1000	540
	Resident Strategy	Nested, Linear	Nested	Linear	Nested
	Social Affinity	10% - 100%	90%	5%	90%
	Social Type	Heterogeneous, Homogeneous	Heterogeneous	Heterogeneous	Heterogeneous
	Network Type	Preferred, Random	Preferred	Random	Preferred
Buyer Characteristics	Block Size	1 - 1080	25	1000	25
	Offer Adjustment	1% - 100%	20%	5%	20%
	Impact Effects	On, Off	On	Off	On
	Impact Magnitude	0% - 25%	15%	NA	15%

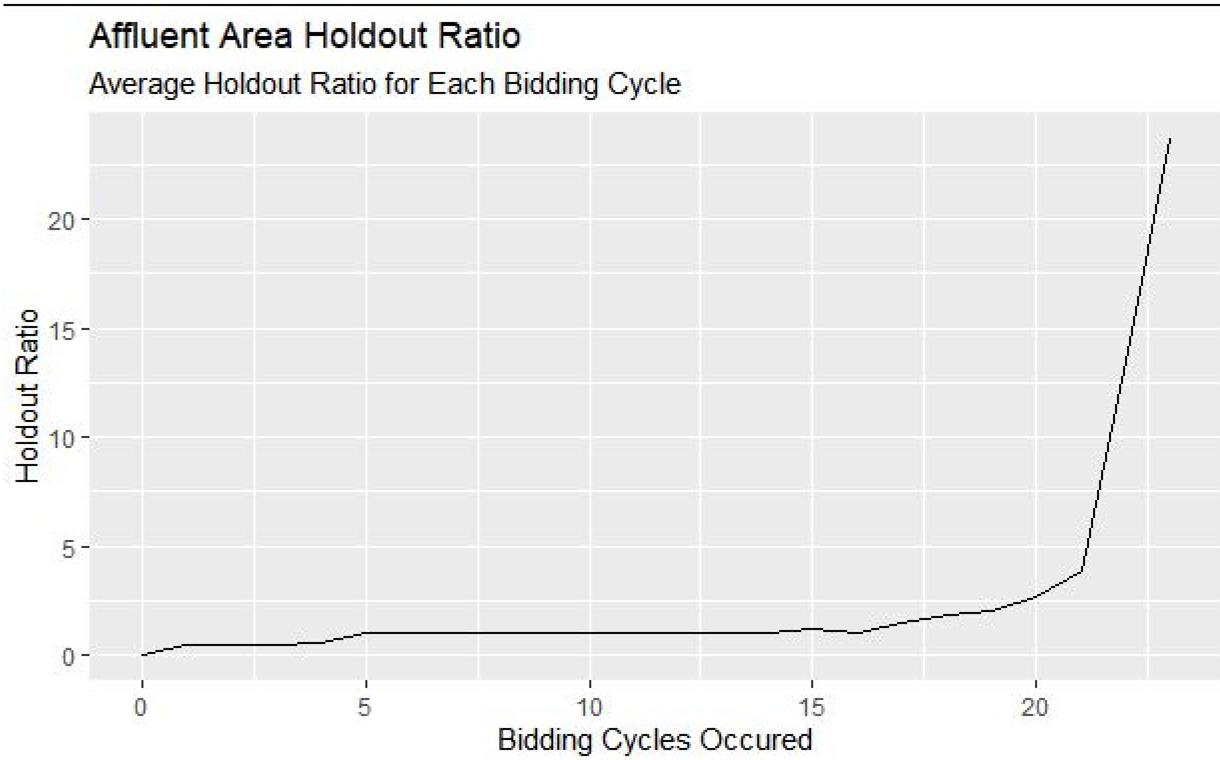
Analysis Data

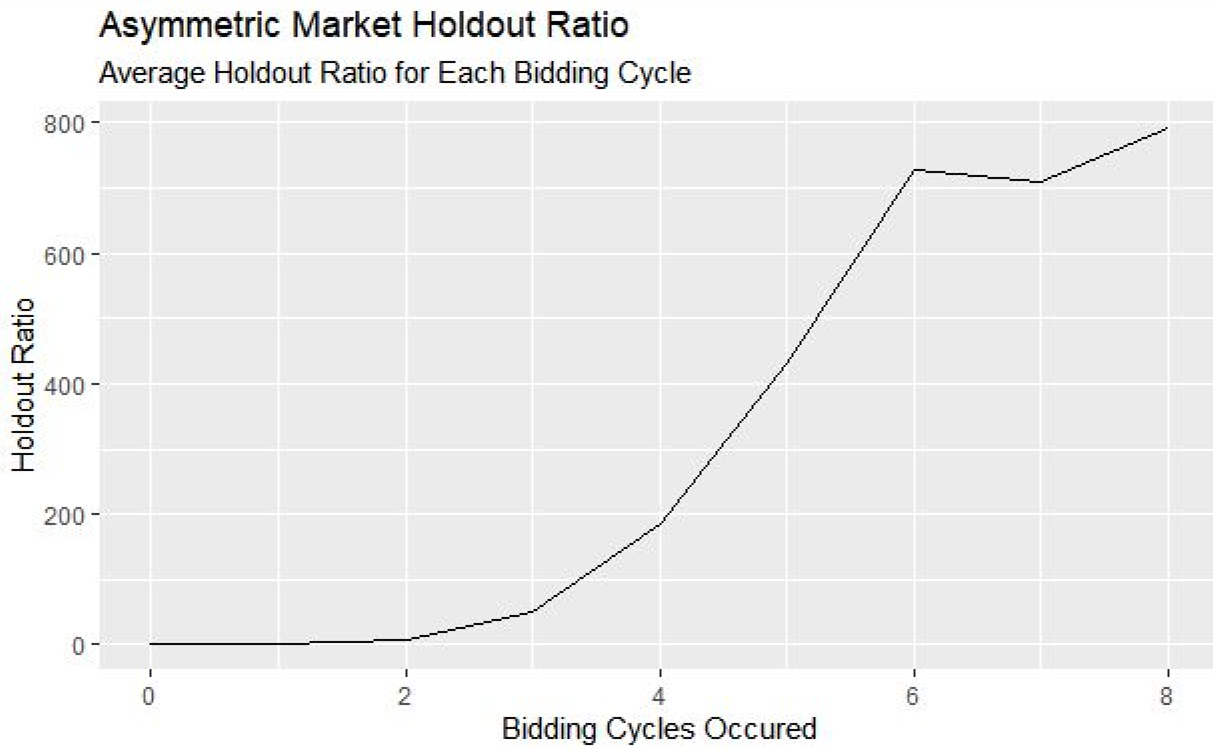
The analysis of this data was performed using output from our NetLogo model. The output was processed into a database file compatible with SQL. Summary tables and graphs were created using R in the R Studio programming environment. The full model, data, and analysis scripts can be found on GitHub at the following link: https://github.com/EthanJantz/The-Area-Project

Analysis Plots

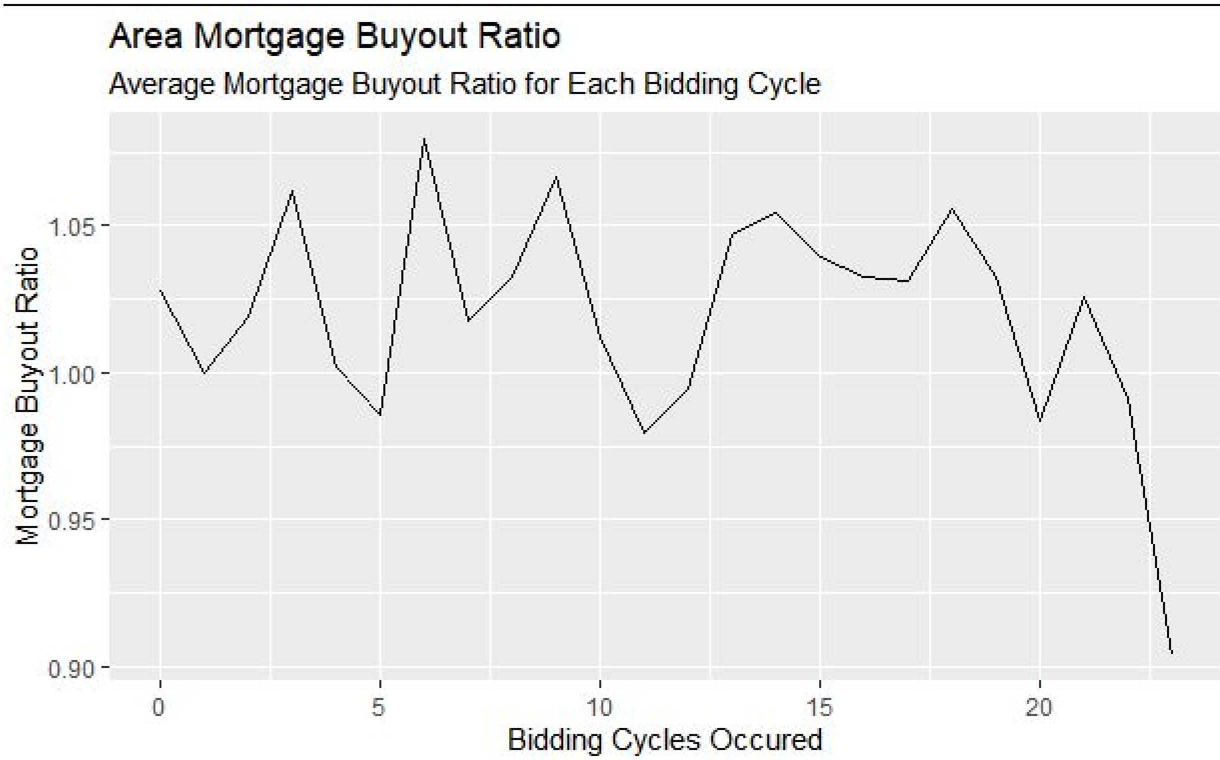
Holdout Ratio

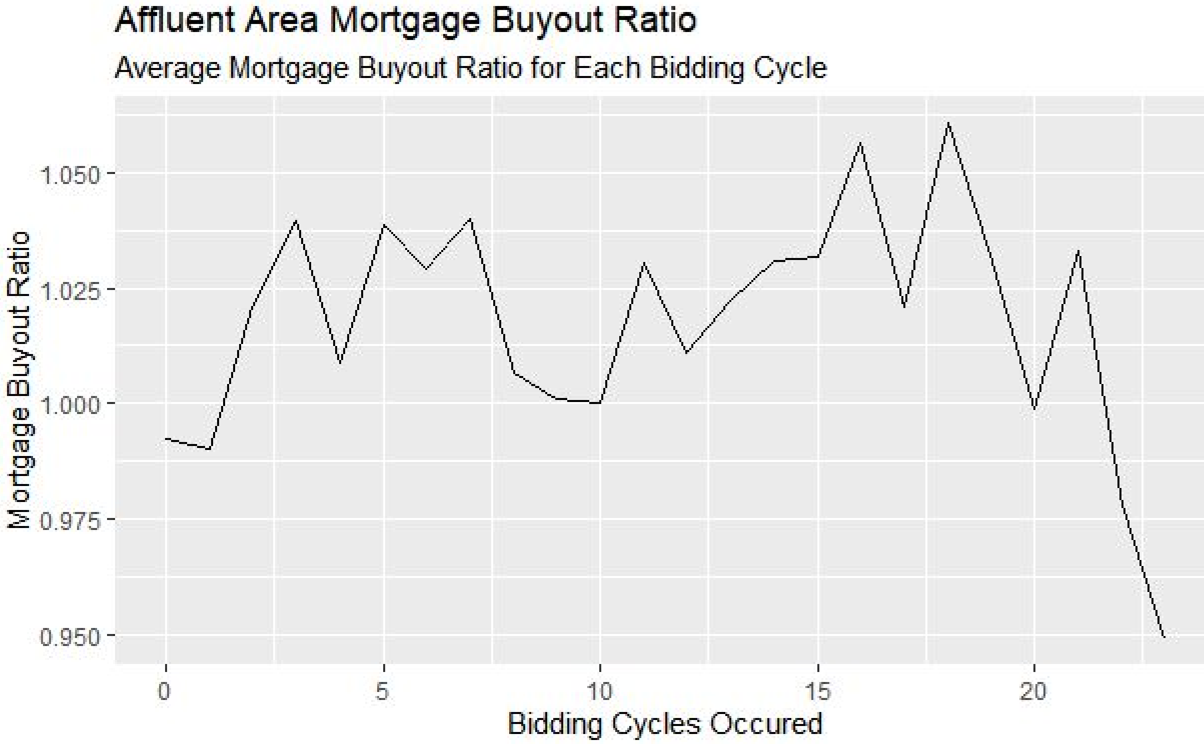


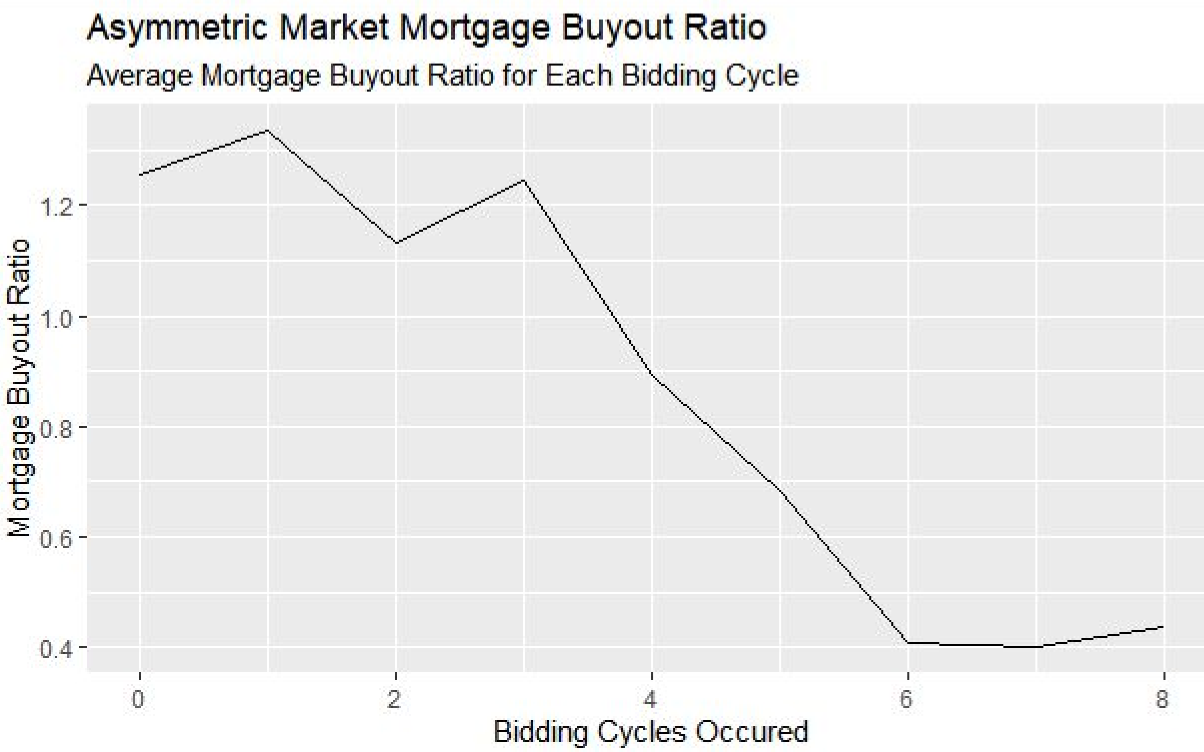




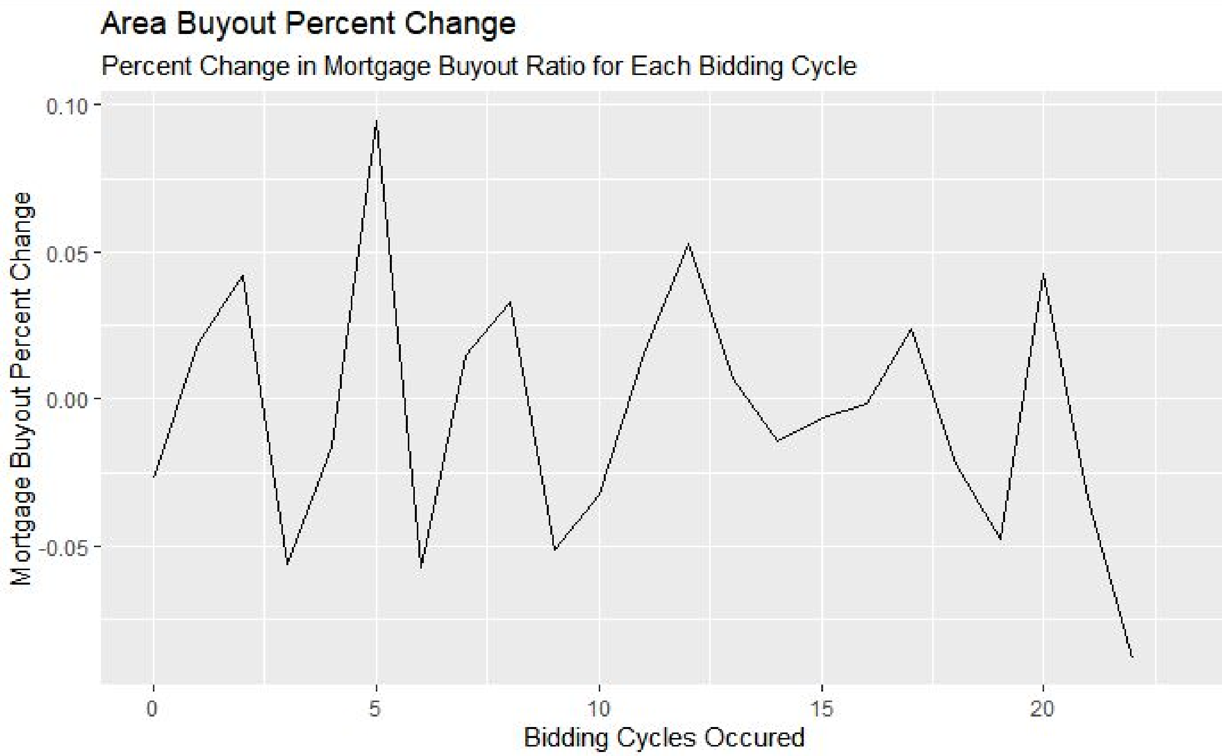
Mortgage Buyout Ratio

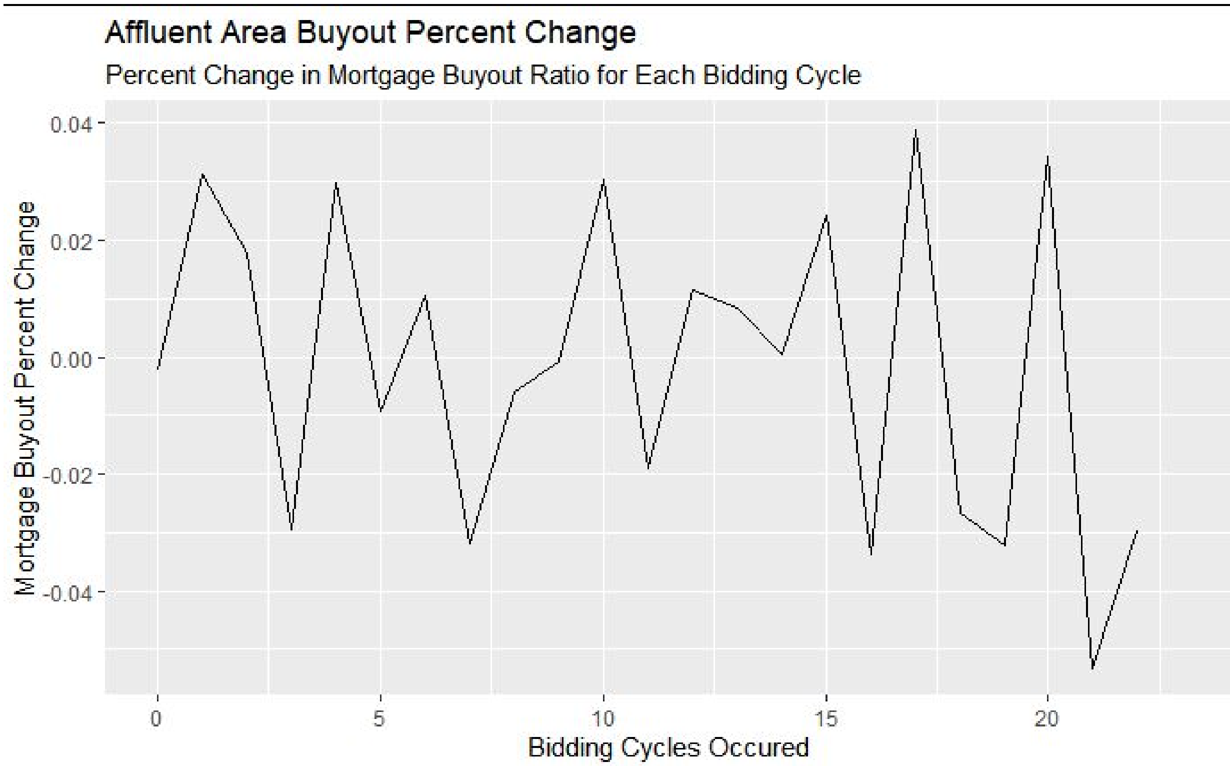


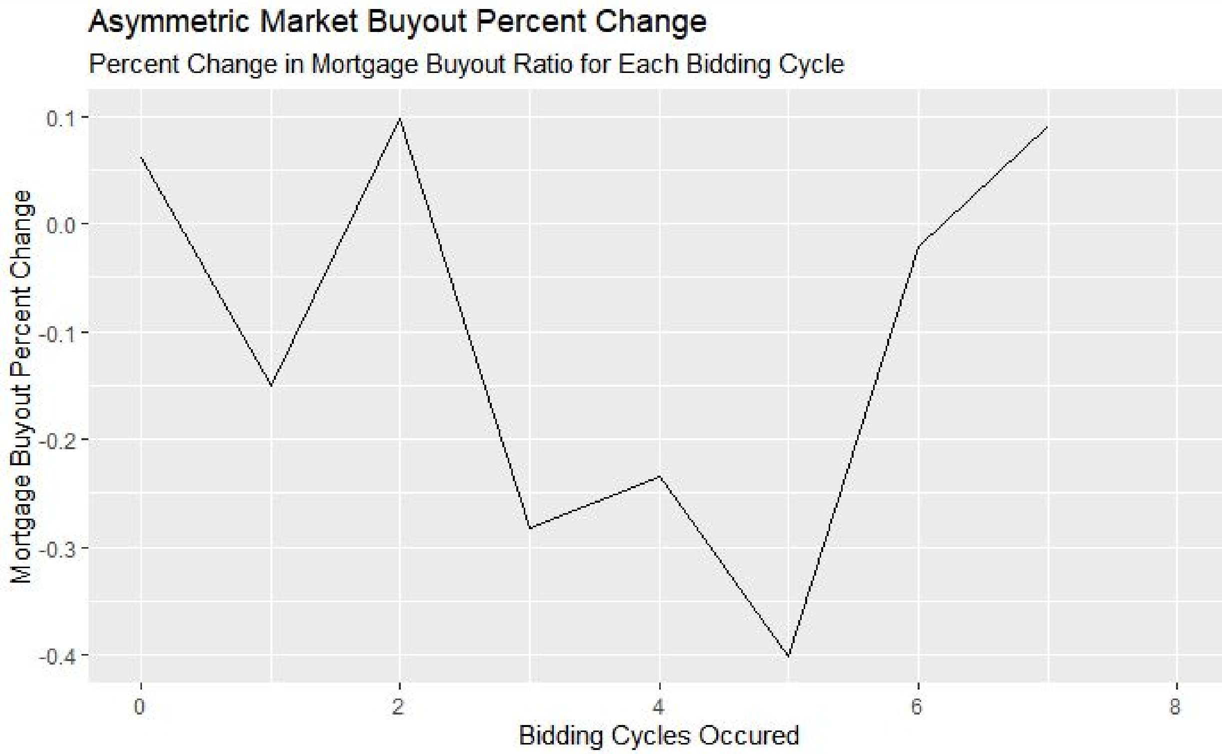

Affluent Area Mortgage Buyout Ratio
Average Mortgage Buyout Ratio for Each Bidding Cycle
Mortgage Buyout Ratio
1.050
1.025
1.000
0.975
0.950
0
5
10
15
20
Bidding Cycles Occured


Asymmetric Market Mortgage Buyout Ratio
Average Mortgage Buyout Ratio for Each Bidding Cycle
Mortgage Buyout Ratio
1.2
1.0
0.8
0.6
0.4
0
2
4
6
8
Bidding Cycles Occured

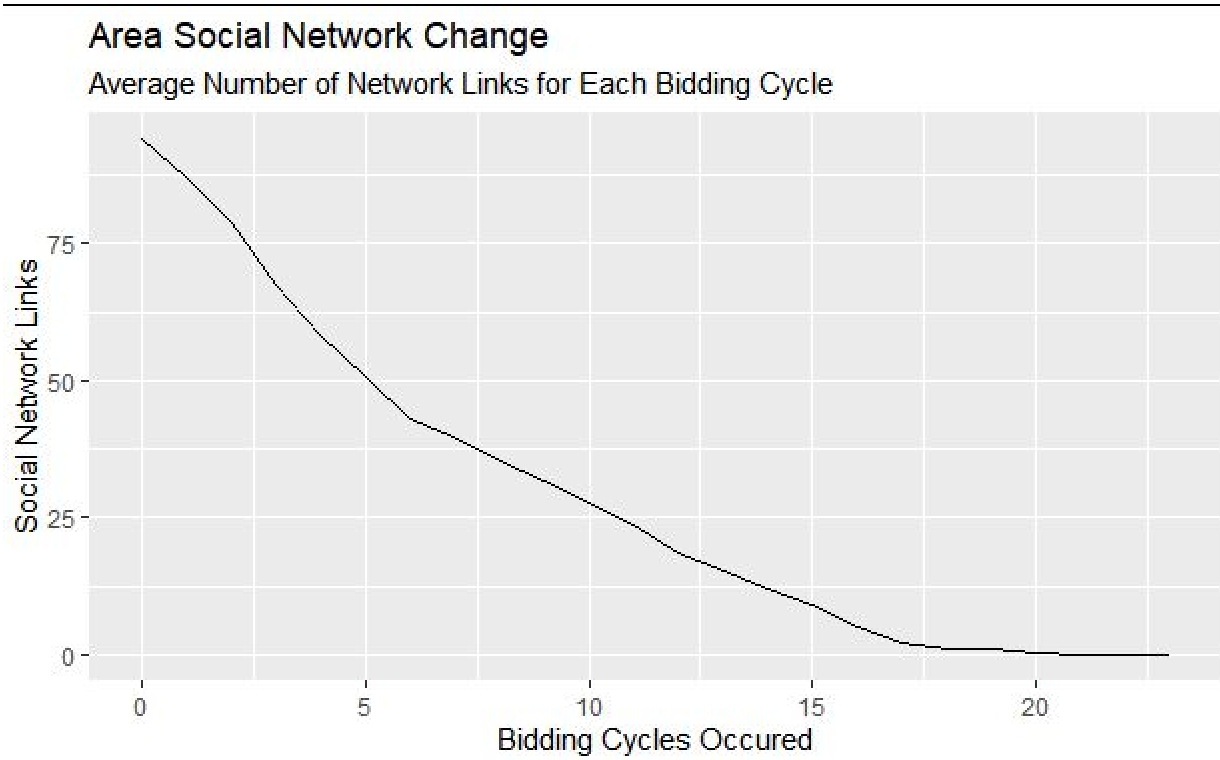
Buyout Ratio Rate of Change

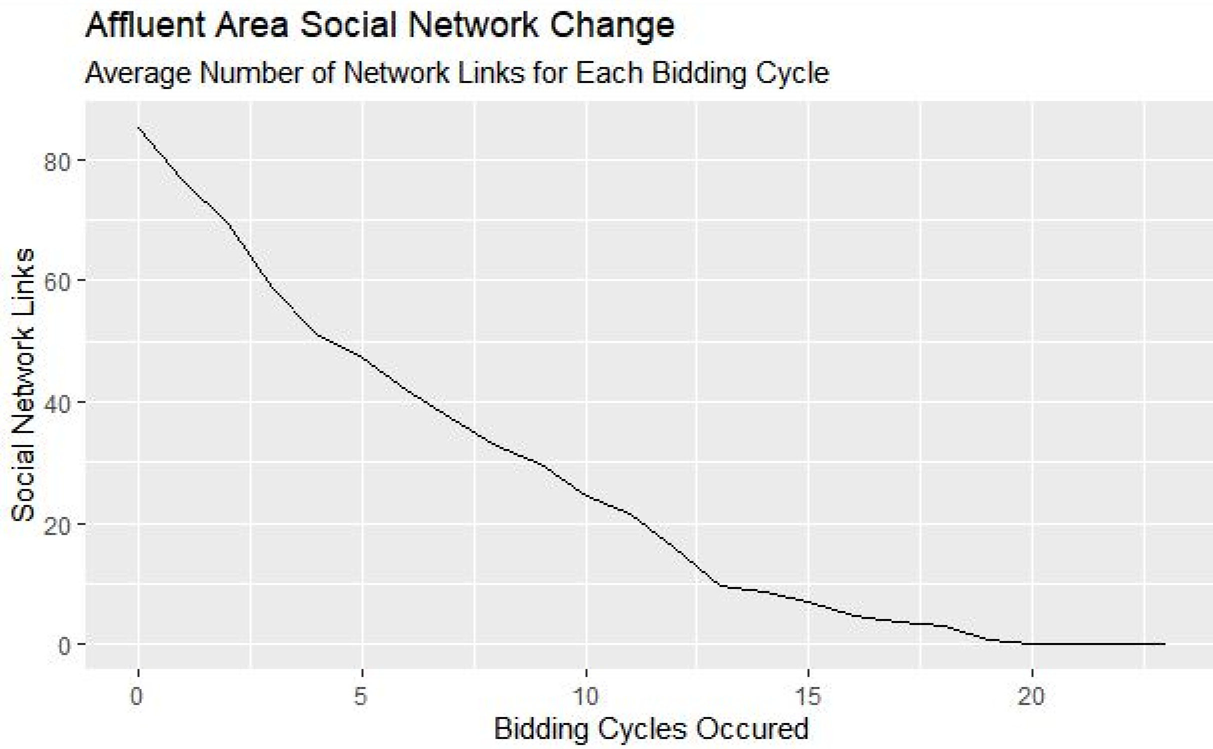


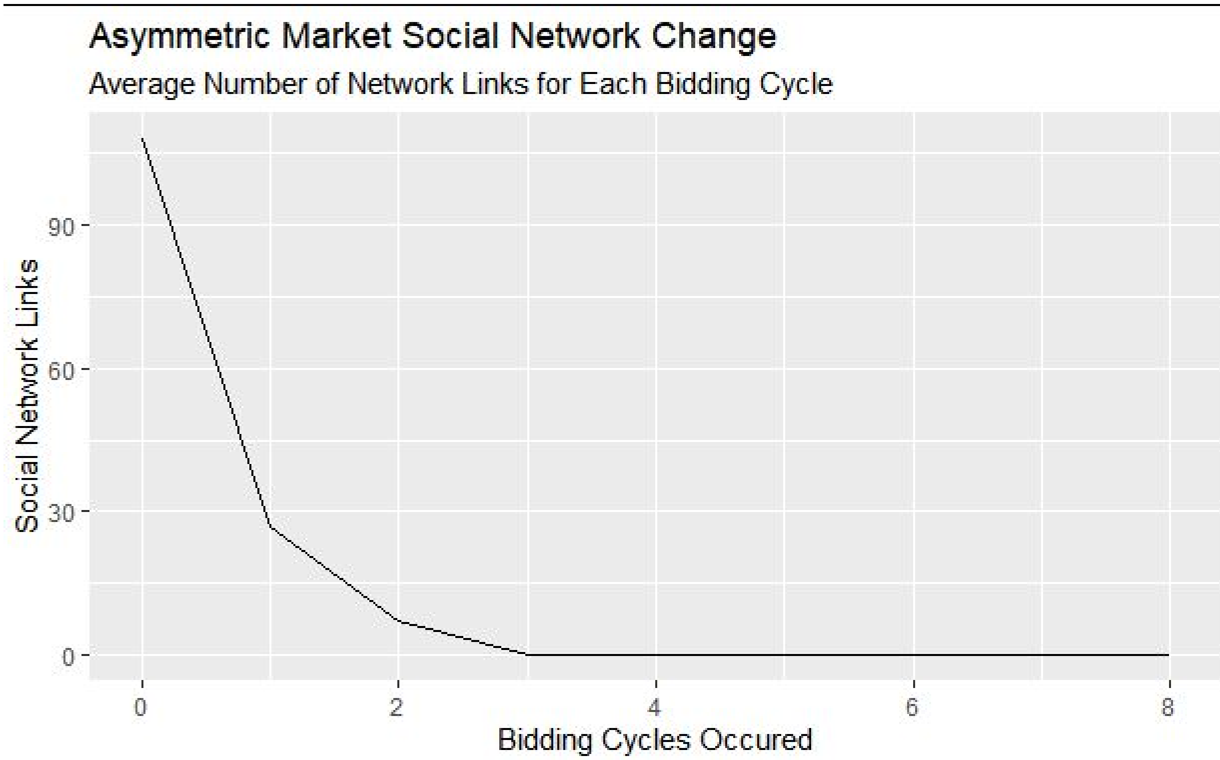




Network Links




Affluent Area Social Network Change
Average Number of Network Links for Each Bidding Cycle
Social Network Links
0
20
40
60
80
0
5
10
15
20
Bidding Cycles Occured


Asymmetric Market Social Network Change
Average Number of Network Links for Each Bidding Cycle
Social Network Links
0
30
60
90
0
2
4
6
8
Bidding Cycles Occured