An Exploration of the Effect of Buyer Preference and Market Composition on the Rent Gradient using the ALMA Framework

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INTRODUCTION

Urban land markets exhibit complex emergent behaviors that have yet to be fully explained by the microeconomic decision-making which constitutes the market. The Agent-based Land MArket (ALMA) framework has been introduced to simulate a bilateral agent-based land market that produces a rent gradient. In this paper, we extend the ALMA framework by introducing two new parameters, heterogeneity, and stochasticity which allow us to explore how the rent gradient is affected by buyers with diverse preferences and a range of market compositions.

THE RENT GRADIENT

Bid Rent Theory is a geographical economic theory that describes how demand and price for land changes as distance from a Central Business District (CBD) changes. It suggests that we would observe "rent gradients" in which prices and demand for real estate increases as proximity to the CBD increases creating concentric circles of land use.

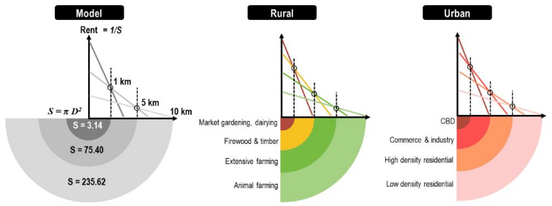


Image Source: https://doi.org/10.1007/978-3-030-26626-4_16

While Bid Rent Theory makes sense economically, the real world is often more complicated. Below is a map of median rent prices in Chicago with darker shades being high prices. We do not observe a clear-cut rent gradient.

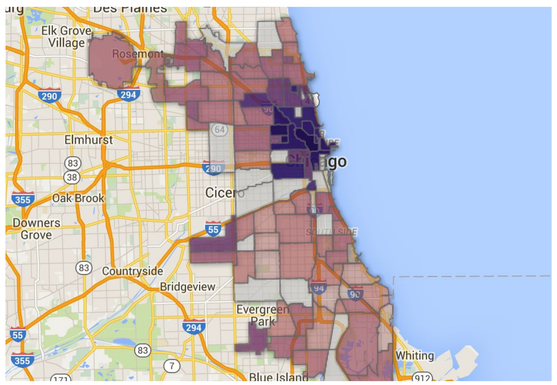
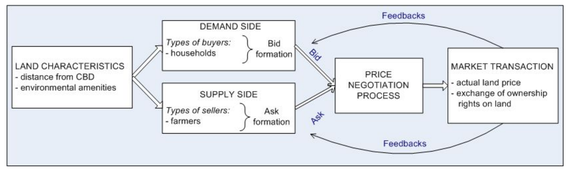


Image Source: Chicago Tribune using data from City of Chicago and Zillow: https://www.chicagotribune.com/business/ct-chicago-neighborhood-rent-20150507-htmlstory.html

THE MODEL

Our agent-based model is based on the work of Parker and Filatova who developed the Agent-based LAnd Market (ALMA) framework for exploring rent gradients.



Conceptual Scheme of ALMA. Image from Filatova, Parker and van der Veen.

In the ALMA model, the utility of a cell of land is described by the equation to the right.

$$U = A^{\alpha} \times P^{\beta}$$

Utility (Usefulness) = U; Green Amenities = A^{α} (Preference for Green Amenities = α); Normalized Proximity = P^{β} (Preference for Proximity = β)

where $\alpha + \beta = 1$

The ALMA model makes a lot of constrictive assumptions. All agents have the same preferences and budgets and all cells have the same level of amenities. Thus every buyer is identical and buyers never face a tradeoff between amenities and proximity. Our goal is to see if the ALMA model works while loosening these assumptions!

To produce a more realistic model, we worked to weaken these assumptions by adding heterogeneity and randomness to the model:

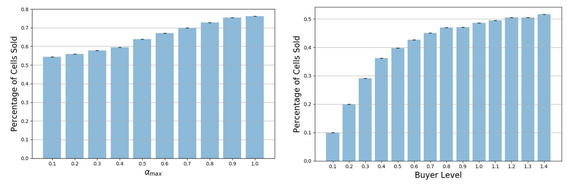
- Buyer preference for amenities (α) is now drawn from a uniform distribution [0, α_{max}] as opposed to being 1 for all agents. $\boldsymbol{\alpha_{max}}$ is a new parameter of the model.
- Buyer housing budgets are now drawn from a uniform distribution [800, 1000] as opposed to be 800 for everyone.
- Cell amenity levels are now uniformly distributed [0,1] instead of being 1 for all cells.
- We tested a wider variety of market compositions by parameterizing the ratio between buyers and sellers. This new parameter is called **Buyer Level.**

A Python implementation is available on CyberGISX!

https://cybergisxhub.cigi.illinois.edu/notebook/agent-based-land-market/

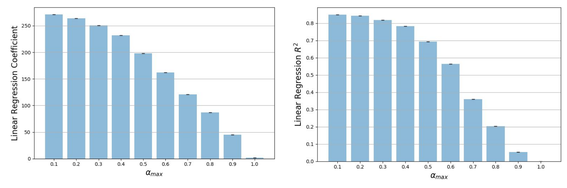
RESULTS

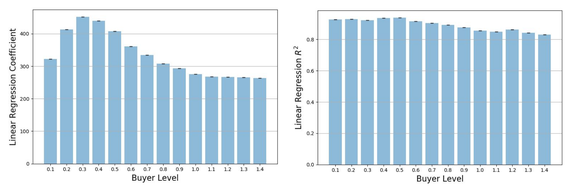
Our results show that the ALMA model is able to produce a rent gradient even under more realistic conditions and explores how the rent gradient is affected by a wide variety of parameter settings which represent buyer preference and market composition.



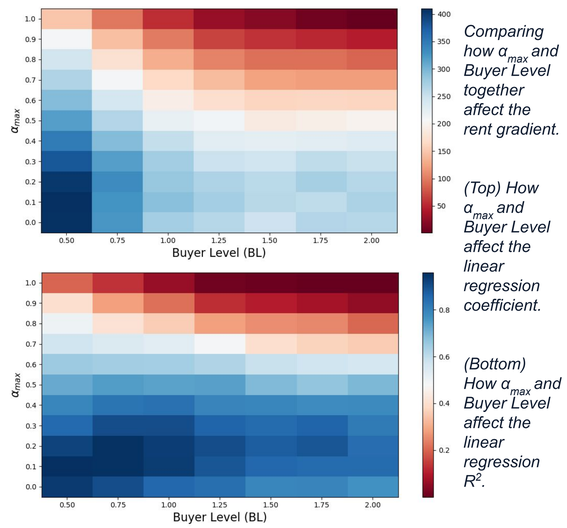
(Above) Percentage of Cells/Homes Sold as a function of α_{max} (left) and Buyer Level (right).

(Below) Linear Regression coefficient (left) and R^2 (right) of α_{max} vs. sale price.





(Above) Linear Regression coefficient (left) and R2 (right) of Buyer Level vs. sale price.



Comparing how α_{max} and Buyer Level together affect the rent gradient.

(Top) How α_{max} and Buyer Level affect the linear regression coefficient.

(Bottom) How α_{max} and Buyer Level affect the linear regression R^2.

CONCLUSION

This work has accomplished replicating the model and results as described in Filatova and Parker's work under more diverse and realistic settings and analyzed how diverse parameter sets affect the rent gradient. However, more work needs to be done for the model to describe real-world scenarios. The first of these improvements is to allow for a polycentric model of cities. It may be difficult to adapt this model to allow for multiple business districts, but we believe that the presence of multiple business districts and Buyers having preferences between these business districts is necessary to model the complexities of the geography of real-world cities. Additionally, we propose considering multiple green amenities and spatially autocorrelated green amenities to better reflect geographic realities.

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