Financialization of the Housing Market: A Contribution to Modern Urban Rent Theory

by

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Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Abstract

A great deal of wealth is produced through the economic activity of cities. There is a gap, however, in the formal apparatus in standard economic theory for analyzing the distribution of this enormous value created in cities.

In the context of a widely-felt housing crisis, we explore how the capture of urban value by financial actors through the financialization of the housing market affects ownership patterns in urban areas, and the ultimate implications of these processes for urban productivity. We hypothesize that financialization induces a shift towards tenancy among the urban workforce that is likely to result in decreased urban productivity through a range of channels. To examine this hypothesis, we construct an agent-based model with a land market and production sector in which productivity scales superlinearly with city population. This work brings together urban agglomeration effects, Ricardian rent theory and a spatially explicit land market model in a novel way.

In our model, transportation costs determine the size of the city, and the available locational rents. Rising productivity increases wages and urban land values, so the value of increased productivity is transferred to land owners. Investors attempt to capture these productive gains by purchasing land. These financial actors can bid against residents to purchase urban land. The interaction of agents determines the distribution of property ownership, city size, and wages. City size and wages provide a measure of urban productivity. The evolving pattern of property ownership tells us how residents are distributed between the tenant class and the owner class.

We then explore a range of channels through which financialization might result in decreased urban productivity. When we add this link in the model, we see that financialization not only transforms the class structure of the city and the distribution of urban wealth, it disrupts the relationship between population growth and productivity, reducing the wealth and resilience of the urban system. To illustrate the uses of this kind of computational model for economic policy analysis, we run six policy experiments with and without the productivity link.

Contributions of this work include: *integrating classical rent theory into an agent-based urban model; linking urban rent dynamics with urban productivity, and population growth; incorporating urban scaling literature into the model framework; examining the impacts of financialization on wealth distribution and urban productivity; creating a framework for a broader understanding of public policies in an urban system; and examining the qualitative effects of various public policies on wealth distribution, productivity, and class.*

Acknowledgments

If is an organizing logic for my work, it may be the tagline for the Systems Design Engineering department: 'systems is how we understand the world and design is how we change it.' I feel enormous gratitude to Waterloo for the chance it has offered to engaged with both how to understand systems and how to transform them. My first job was at Blackberry, in the building with Mike Lazaridis and the early engineering team. In early engineering projects, I got to work on clocks for the Long Now Foundation, sculptures with Philip Beesley and Rob Gorbet, underwater robots, light based communication protocols, and reverse engineering the Canada arm.

Then I had the good fortune of getting to join Frances Westley's team working on Social Innovation and participating in development of The Waterloo Institute for Complex Systems (WICI). WICI gathered people like Lee Smolin, Brian Arthur, Roberto Unger, Doyne Farmer, Jaron Lanier and so many others to work on how our understanding of complex systems translates to the beneficial transformation of social and ecological systems.

The dissertation began before we had our two children, and we've entered a much more interdependent world. In a way feel like everyone in my family has done it single handedly: my husband Jason by insisting I go away over March break while he had the stomach flu, was working full-time, and watching our two little kids; my sister who let me stay at her house and helped edit; my parents who insisted I come for weeks to finish draft, fed me and took me snowshoeing every day; and especially my father who talked worked through so much of the economic theory with me. I told my daughter, Jackie, now 6, that I had to go to work on my thesis. She patted me and said 'at least you have your sister and your dad to help you.' She is right.

I am grateful I've had the chance to work with this committee. I'm grateful to Frances and Terry for staying a part of this work as it's evolved, Chrystopher for the inspiration and careful editing; Sean for all our collaborations over the years, and Jangho. I never expected to find a supervisor whose work connected with so many of the pieces of this work, let alone to find one in the Engineering Faculty at Waterloo. It has been wonderful to get the chance to work with all of you. Although there have been challenges, it is hard to imagine a more engaging or stimulating project to get to work on.

Dedication

To Wyatt, Jackie, and Jason.

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Chapter 1

Introduction

> Cities are the crucible of civilization, the hubs of innovation, the engines of wealth creation and centers of power, the magnets that attract creative individuals, and the stimulant for ideas, growth, and innovation.
>
> Geoffrey West [204]

Since the industrial revolution, widely distributed property ownership, particularly in North America, has contributed to the wide and relatively equal distribution of wealth [159, 98, 42, 13].[1] However, property ownership is now going through a great transformation in structure, with financial capital coming to own a larger share of the urban land and housing stock [71, 153]. For the first time in Canadian history the rate of home ownership has declined, falling from 69% in 2011 to 66.5% in 2021 [33]. In Ontario, 70% of new condo units are owned by investors not residents [157] and asking rent in Canada increased by 10% over last year, as of February 2024 [196].

This process of shifting ownership into the hands of financial actors has been called financialization [71, 96, 193, 153, 175, 150]. Financialization of the housing market refers to the growth in the share of the housing stock controlled by financial institutions and

[1] The role of housing in wealth accumulation is well known. After a detailed examination of data from the US Survey of Consumer Finance (SCF) and the Panel Study of Income Dynamics (PSID), Herbert et al. concluded that "there continues to be strong support for the association between owning a home and accumulating wealth." The effect persists even among minorities and lower-income households. In lower-income minority households, on average, renters do not see any gains in wealth [107].

investors and the overall effect this has on the outcomes of the system [71, 96]. Financialization is not neutral. It is increasingly associated with declining affordability and rising homelessness in Canada. These issues have become so extreme in recent years that Canada is now widely understood to be in a housing crisis. The Ontario Housing Affordability Task Force, for example, reported that home ownership is now "beyond the reach of most first-time buyers across the province ... Housing has become too expensive for rental units ... The system is not working as it should." While discussions about whether and how financialization affects affordability are becoming more prevalent, what has not been explored as thoroughly are the systemic effects of financialization on ownership patterns and urban growth. Our model is an attempt to fill this gap.

Financialization is one of two major transformations changing society discussed in this thesis. The other is urbanization. We are concerned, in particular, with how these processes are beginning to interact. To explore this matter, we have built a model of an urban system to explore financialization in the context of housing markets. Specifically, we look at the systemic effects of the shifting ownership of property in cities on the distribution of wealth and the potential that this shift can actually change the ability of cities to grow, thrive, and produce wealth.

1.1 A modern theory of urban rent

There's now a compelling understanding of the value that is created by cities, both empirically and theoretically [111, 182, 26]. It is well established that when people concentrate in cities, it increases productivity across a range of measures of output including gross domestic product (GDP) and gross national product (GNP) [26]. There is a feedback loop[2] between city growth and productivity and there's never been a rapidly developed urban city where the growth in population was not accompanied by growing productivity [14]. The effects of this relationship are so profound that people in cities now produce most of the wealth of society [26].

To analyze the distribution of the value created in the city, we employ the idea of spatial rent and put it into a model that allows for the financialization of the urban housing market.

[2]Work on feedback loops emerged largely as the result of WWII work on electronic and mechanical feedback controls for military purposes. Researchers across many fields quickly recognized that feedback mechanisms were a fundamental feature of systems and found examples in social science, engineering, biology, and brain science, among others. Enthusiasm for the concept was supported by a series of conferences supported by the Macy Foundation between 1946 and 1953 [161]. Systems Dynamics, associated with Jay Forrester emerged as more systematic offspring of this work [77, 78].

The underlying dynamic driving spatial rents is that people come to cities for higher wages, amenities, and opportunities that arise because cities enhance overall productivity. New arrivals need places to live, so land close to the concentration of jobs becomes valuable. This means that whoever owns the land can charge for its use and capture what are called locational rents. Owning urban land is therefore a claim on the productivity of the city, just as owning agricultural land entitles the owner to the productivity of that land.

The ultimate goal of this work is to develop a modern urban theory of rent, linking spatial rent, housing markets, and urban production. Figure 1.1 illustrates both the synthetic aspect of our analysis and the direction in which we develop existing work. The following sections introduce how this work fits in the literature and the basic structure of the core model, then list its main contributions, and, finally, outline the structure of the thesis.

Our work draws together insights from urban economics, geography, and planning. A central, shared concern in all three fields is geographic space: in all three, locational value gives rise to locational rents,[3] explaining the dynamics of economic development, and the spatial distribution of human activities, respectively.

1.2 Theoretical background

To model the distribution of locational rents in an urban system, we go back to the classical theory of rent. The concept of economic rent was developed by the classical economists of the late eighteenth and early nineteenth centuries to explain how wealth was created and distributed in an agricultural society. David Ricardo [165] elaborated the classical theory of land rent and the distribution of wealth, to explain economies dominated by agricultural production in 1815. Johann von Thünen [199] produced the first formal treatment of spatial economics and economic geography in 1826.

Much later, in 1961, William Alonso (and others) [8] applied the Ricardian and von Thünen theory to the urban system, launching modern urban rent theory. The spatial implications of the classical analysis were brought forward into modern urban theory, but the distributional implications were not. Our work is designed to integrate the two.

Since an essential feature of cities is that they grow, we also draw on growth theory that looks at agglomeration effects and scaling laws to account for how distribution is affected by scale. As Alonso and others were developing urban rent theory, the economist

[3] See Sprung-Keyser and Porter [183] for a recent paper confirming that location wage premia are heavily capitalized into rents.

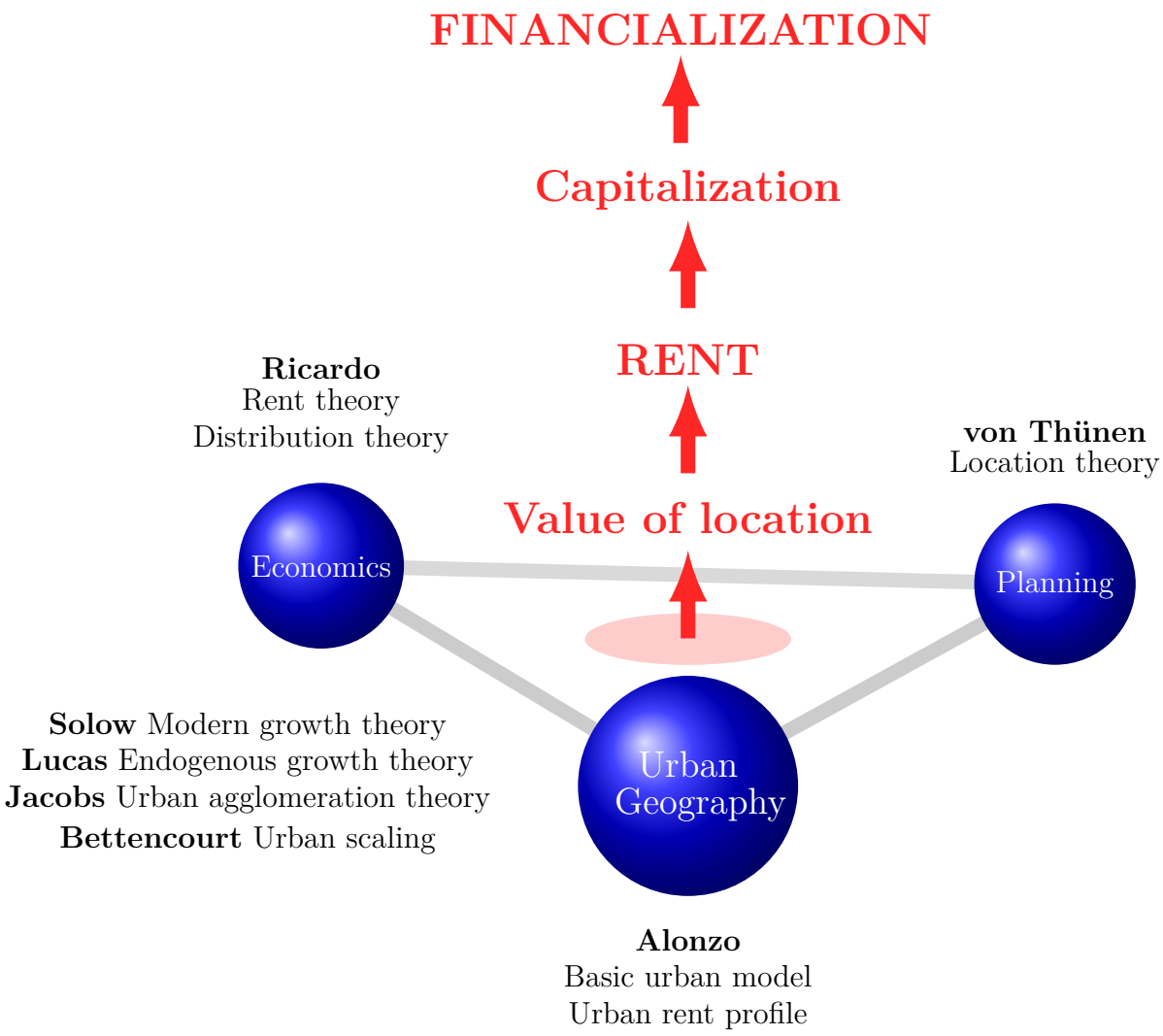


Figure 1.1: Space and urban rents play a foundational role in urban economics, geography, and planning. We extend the analysis of urban rents to model the effects of financialization.

Robert Solow [180] proposed a theory of economic growth that set off a flood of work. The new field spilled into urban theory and connected with a rich body of work on economic development and the value created in cities, including work by Jacobs [111], Lucas [131], Bettencourt [27], and others. We draw on this body of work to account for the scaling of productivity with population. We also draw on neoclassical economic theory for its explanations of how the value of production in firms is shared among the owners of various

resources. Our work brings these traditions together into an integrated picture that allows us to look at wealth distribution within a spatial model that includes productivity and growth.

What has been missing until now is a detailed account of who gets the land rents in the modern urban system. Our contribution is to extend the analysis of urban rents to take into account the effects of financialization, which is fundamentally a distributional process. This is a significant step because, while classical rent theory is the foundation for urban rent theory, the distributional aspects of the classical theory have not been applied, which makes it inadequate for understanding the distribution of wealth over individuals or over space. Meanwhile, standard models of financial operations are spaceless[4] focusing on distribution to assets rather than to classes of persons.

Our solution is to explicitly embed the normally spaceless analysis of investment decisions in a spatial model with locational rents. We bring together three theoretical elements: an urban spatial model, an agglomeration-augmented model of wealth production in urban centers, and a financialized land market model built on top of the first two. We call the combination of the spatial and production models the Alonso-Jacobs model, recognizing the sources of the two elements.

The model makes it possible to analyze the potential macro effects of financial capital capturing spatial urban rents. Our focus is on changes in who captures these rents, and how that affects the productivity of the city. The distribution of locational rents, we believe, goes some distance to explaining core social issues like class structure, inequality, and political power.

1.3 Modelling financialization of urban housing markets

The goal of building our model is to bring the aforementioned elements into one combined model that allows us to explore the distributional effects of the financialization of a housing market. We generate the value created in the city with a model of firm production that generates an equilibrium wage target. A wage offer is passed to a spatial model of the city where agents choose whether or not to participate base on the wage, transportation costs,

[4]Financial analysis theorizes assets, debts, flows of revenue and costs, and the rates of change or exchange of these quantities over time. These are inherently spaceless because they are accounting entities, independent of location. It matters where a worker or a farm is, but it does not matter where and dollar or a rouble is in the same way.

and their location. The model generates Ricardian rents which accrue to property owners. Owners and rent seeking investor agents compete in the housing market for the rents.

We develop a model with three components: an urban housing market, a financialization process, and an urban production system. The housing market sub-model distributes the ownership of the housing stock that comes up for sale in each period based on bids. The market determines the price for each unit. The price may depart from the market value of the services that each unit provides, providing the opportunity for speculative gains. Finally, the financial model determines the size of bids for investors based on the availability of capital and estimates of rental income and capital gains.

Figure 1.2 shows the logic of the first component, the housing market model. It shows two primary effects financialization has on the housing market: how it allocates the housing stock, and how it allocates the rents generated by the urban system. The first effect of financialization, on housing allocation, arises because tenants replace owners. While owner-occupiers share in the growing land rents generated by urban agglomeration effects, tenants do not. As a result, a declining fraction of urban residents accumulate capital through their participation in the housing market, and therefore fewer enter the class of workers with both wage and capital income defined by John Roemer [168].

The second effect of financialization on the market is in the allocation of spatial rents, generated in part by the growing productivity of cities. Rents generated by the agglomeration economies in the urban system are diverted to largely non-resident owners, away from investment in local production or amenities, as tenants replace owner-occupiers.

Figure 1.3 illustrates the second component of our model, the financialization process. We develop an explicit model of investor behaviour to explain the market decisions of buyers and the role of financial capital. Investors enter the housing market and, in doing so, they drive up prices by increasing total demand. The rising price generates an expectation of capital gains, which enter the investors' calculations. Investors have, as research shows, better access to capital than most new entrants to the housing market. When the financial sector, the bank in the model, makes more capital available, the pattern of ownership shifts, as illustrated above.

Figure 1.4 illustrates the third component, the feedback between population and productivity. The green blocks represent the theory linking the relevant variables. On the lower right, "Scaling" refers to the literature on agglomeration effects. On the upper right, neoclassical distribution theory provides a model linking productivity with wages. On the left, the bid rent function links wages and population.

A fundamental feature in recent empirical work on scaling laws is the persistent relationship between population and productivity. The productivity of cities increases su-

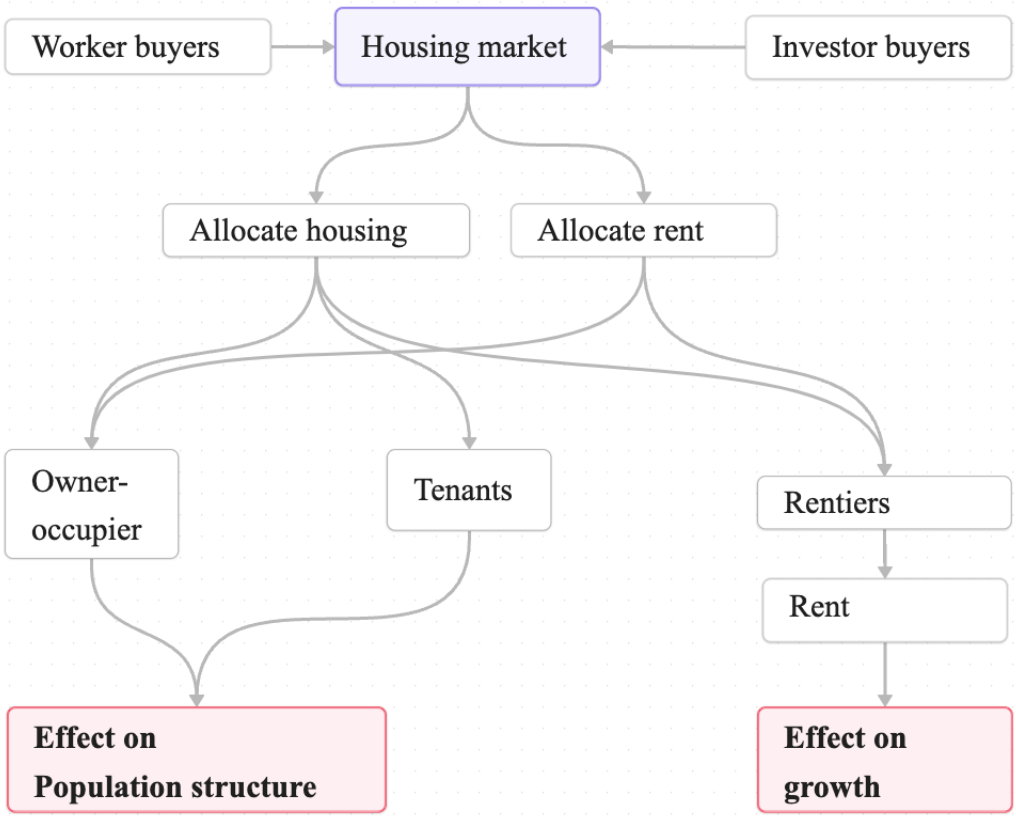


Figure 1.2: The housing market component. Financialization affects both the allocation of housing and its allocation of rents.

perlinearly with population. Cities are the locus of a positive feedback loop with rising populations raising productivity, and rising productivity attracting more people and resources, a theoretical argument associated with the work of Jane Jacobs [111], with strong empirical support from recent work on the scaling of urban productivity [27, 25, 61, 129].

Combining these three components, we have an extended theory of urban rent built on a foundation of theory that goes back to the classical economics around the beginning of the 19^{th} century and incorporating modern growth theory and modern urban theory.

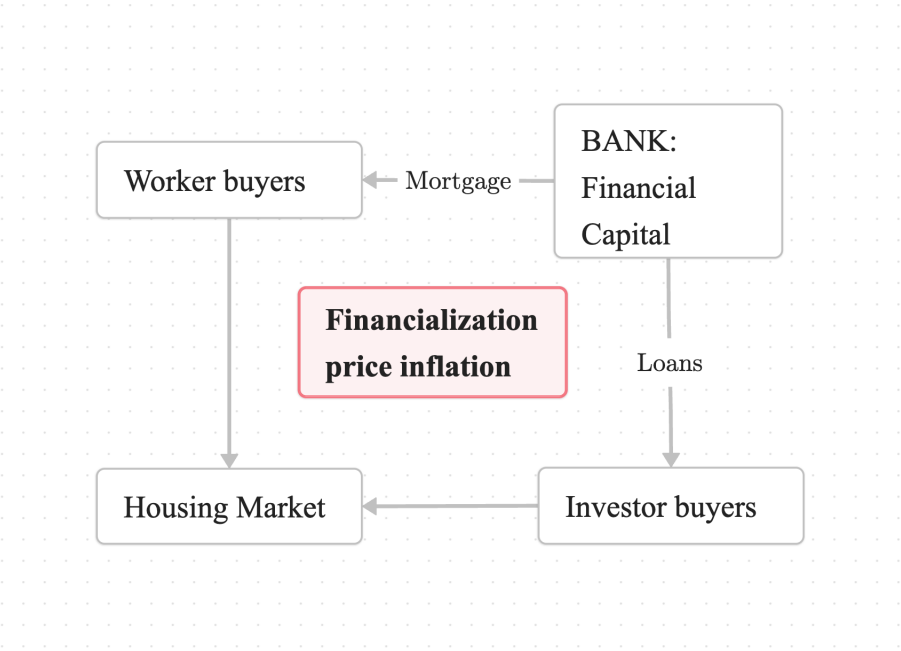


Figure 1.3: The financialization component. There is a feedback loop in which new investors drive up demand and thus drive up prices.

The resulting model suggests two basic hypotheses:

1. Financialization of the housing market will result in the tenantization of the urban middle class as financial capital acquires more of the housing stock.
2. Financialization of the housing market will result in reduced growth of urban productivity as the flow of rents is diverted from real investment to the financial sector.

1.4 Contributions

The overall goal is to provide a theoretically grounded model of the relationship between financialization and urban productivity. The main contributions towards achieving this goal are:

1. Incorporating classical rent theory into an agent-based urban model. This requires modelling how Ricardian rent theory, a theory of the distribution of wealth based on

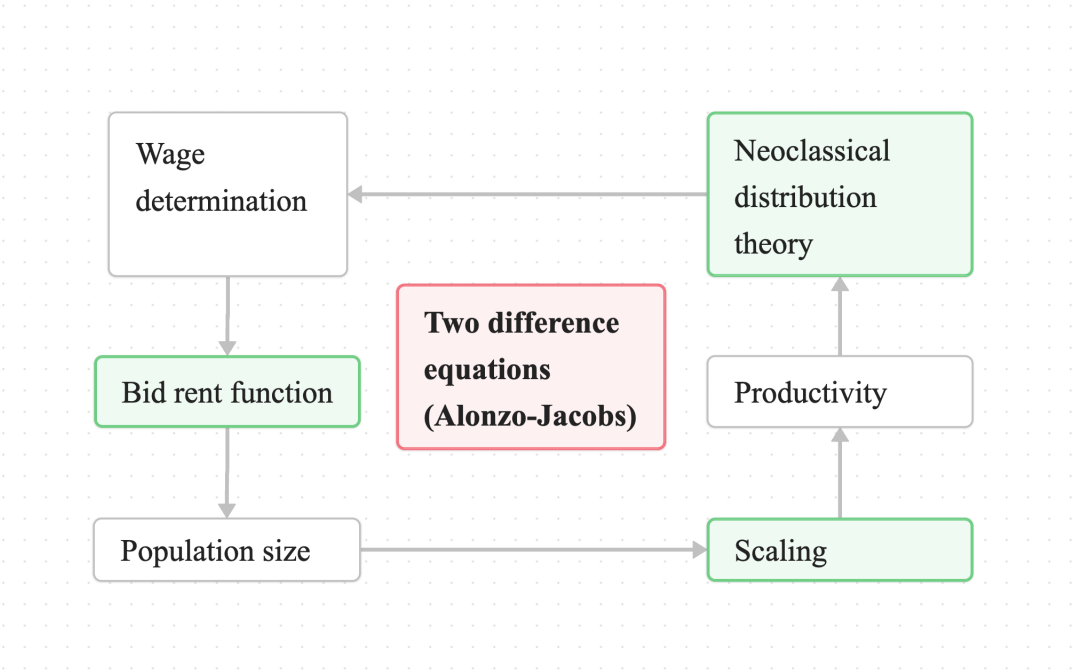


Figure 1.4: The production system component, incorporating the urban scaling of wealth in the urban spatial model. We refer to this coupling of two different equations as the Alonso-Jacobs cycle.

an agricultural economy, applies in an economy driven by human capital agglomeration effects within the urban system.

2. Allowing the creation and distribution of rents to influence urban growth, productivity and population structure. This requires articulating the links between the wealth production of cities and how the urban system evolves.

3. Incorporating current research on urban scaling into the core spatial urban model. This requires drawing on empirical work to formalize the scaling relationship, which embeds productivity in an urban model.

4. Constructing an urban agent-based model that is consistent with neoclassical growth theory. We show how the neoclassical framework can be implemented in the agent-based framework, and make a case for the usefulness of the approach in linking urban rents and productivity.

5. Integrating financial capital into a standard spatial model of the urban system, making an explicitly spatial model of the financial structures, which have traditionally been formalized in a spaceless way.

6. Integrating financial capital into an overlapping generations population model of the urban system and articulating the movement of financial capital though the urban land market.

7. Using an agent-based model to examine how financial markets impact urban land markets, producing a formal simulation model that illustrates the process of housing financialization.

8. Building a model that can be easily extended to explore a range of additional issues, and used to evaluate a variety of policy options. The model combines clear and explicit theoretical assumptions with careful and transparent implementation of the logic. We have taken care to allow for both theoretical and policy-relevant extensions in the simulation, building a base model that aims to be as simple as something like Alonso's urban model [10], but simulates the relevant system features and can incorporate a range of intervention types.

1.5 Document overview

There are three parts in the dissertation. Part I gives the background and introduces the theoretical framework for the analysis, linking financialization with classical rent theory, neoclassical production theory, neoclassical growth theory, the scaling literature, and urban spatial models.

- Chapter 2 discusses financialization.
- Chapter 3 reviews the literature on rent and introduces the approach to modeling rent.
- Chapter 4 develops the urban model of space drawing on the basic Alonso model.
- Chapter 5 introduces growth theory, showing how our model is directly connected with this broad collection of linked theories.
- Finally, Chapter 6 discusses the potential feedback by which financialization, can affect the productivity of the urban system.

Part II describes the methodology, model, and results.

- Chapter 7 examines some of the broader methodological issues involved in bringing together theoretical frameworks for locational value, the structure of the city, how productivity scales with wealth, and financialization of the urban system.
- Chapter 8 details the economic model of the urban system. This model has three parts: first, a production function, modelling how urban regions generate wealth; second, a model of an urban housing market; and, finally, a financial sector that can participate in the market.
- Chapter 9 documents the implementation of the core agent-based model using the 'Overview, Design concepts, and Details' (ODD) standard [93].
- Chapter 10 introduces the results, including the basic ownership result The experiments explore the static and dynamic effects of interventions in each case.

Part III concludes.

- Chapter 11 discusses a variety of extensions that the model has been designed to support, including adding housing production, allowing for varying density and building types, introducing amenity and locational preference, allowing for more complex transportation cost functions, incorporating zoning or other regulations, introducing multiple cities, incorporating multiple firm types, varying the land tax structure, ownership structures.
- Finally, Chapter 12 draws attention to the most dramatic implications of the work and reiterates the main theoretical contributions.

Part I

Background and Theoretical Development

Chapter 2

Financialization

> Financialization occurs when housing is treated as a commodity—a vehicle for wealth and investment—rather than a social good.
>
> Special UN Rapporteur on the right to adequate housing, Leilani Farha [71]

This thesis is a study of the financialization of the urban housing market, and particularly the system-level effects of financialization on distribution and urban productivity. In recent years financialized ownership of housing has increased in Canada while homeownership rates have declined [33]. 70% of new condo units in Ontario are purchased by investors [157]. About a third of the value of owner-occupied homes in Canada is mortgaged, which essentially means owned by lenders. In other words, about a third of the net land rents associated with owner-occupied housing accrues to the financial sector. Since 66% of Canadian homes are owner-occupied, roughly 5/9th of the Canadian housing stock is currently owned as assets of the financial sector. [150] The fraction is increasing. To understand how these trends represent a systematic transformation, one must first understand what financialization is and the financial tools that form its building blocks.

Financialization is, in a broad sense, the capture by financial actors of streams of surplus generated by society.[1] Economists distinguish between productive and financial

[1] There is a difference between investment in productive capital and investment in financial assets. The first contributes to total social output while the second is simply a transfer of ownership. The traditional distinction between capitalists and rentiers pivots on this distinction. Capitalists invest in creating pro-

capital where the the fundamental nature of productive capital is that the value of output generated is greater than value of the inputs, with the difference being called a surplus. Financial capital, on the other hand, is capital applied to capturing surplus for the owners of the capital rather than producing a surplus. Financial actors are persons or institutions in the economy focused on using capital to capture surplus from production. Thomas Palley [153] describes financialization as "a process whereby financial markets, financial institutions, and financial elites gain greater influence over economic policy and economic outcomes." The accumulation of economic power and has been associated with a profound shift in the distribution of wealth and political power.

In urban housing markets, the value of land in a city arises from its (indirect) role in production. Owning the land and housing in a city is therefore a way of capturing the flow of value produced by the city itself. Financialization of the housing market happens as land and property are represented by financial instruments and bought and sold on financial markets[2].

At the micro level, financialization is achieved through the development of legal and financial instruments that allow for exchange. These instruments become the building blocks enabling the process of financialization. They allow financial actors to focus on capturing the future value produced by real assets through trading instruments that represent that value.[3]

In this chapter, we will explain financialization beginning with an analogy with digitization to illustrate how the process works at the micro and macro level. We will then briefly discuss financial instruments such as stocks, mortgages, and Real Estate Investment Trusts, give historical context for financialization both as a broader trend and within the housing market, and then discuss potential systems-level effects of financialization on urban systems.

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ductive assets while rentiers live off the income generated by productive assets previously created. At the level of the economy as a whole, financialization can be seen as diverting savings from capitalist investment to rent-seeking investment. The economic system that emerges as the process continues is sometimes described as rentier-capitalism [44, 184]. In this thesis we are not concerned with the issues around the emergence of rentier capitalism, but mention it here to acknowledge the connection of this work to another literature.

[2]The process of financialization has a long history. Moreno [145] points to Zola's 1872 novel *The Kill*, which "offers a vivid account of the marauding social and cultural forms finance-capital assumes in the process of urbanisation." where "mortgage-loan machine[s]" yield "useless luxury and real penury." The pattern that Zola observes is underway in modern cities.

[3]Financial instruments, like the shares issued by a joint stock company, have been used to facilitate productive investments. Financial instruments are not in general tied to productive activity, however.

2.1 Financialization is a process like digitization

We can see in the financialization of the urban system an emergent phenomenon, analogous to the emergence of ubiquitous digitization. In both transitions, emergent social processes are driven by individual micro-level actions that interact to produce new and unexpected outcomes at the macro-level and have much larger, often unexpected effects at a system level.

Digitization is the replacement of analog processes and tools with digital versions. Through the late 20^{th} century to the present, activities have increasingly shifted from being analog operations on material and mechanical systems to digital content manipulated on microelectronic devices. This revolution happened at different scales. At the micro-level, there was the development of technologies, such as transistors, integrated circuits, and the wide array of products built from them, including mainframe computers, laptops, and smartphones. These micro-level innovations interact to form emergent systems-level changes.

At the macro-level, digitization represented a fundamental system change, reducing transaction and transformation costs, and creating a vast array of digital products that are almost costless to reproduce and distribute. Digitization created huge new industries like video streaming, electronic monies, and coding. It has also vastly expanded other industries, cut costs, expanded consumer choice, and hugely increased the dissemination of intellectual content through electronic publishing and in movie and music creation.

Digitization was not and is not a planned process, but rather the result of millions of individual decisions, each in pursuit of specific, local, individual goals, and ideas about what is happening in the system. The pursuit of these goals supported the development of new supply chains and institutions. The cumulative effect is a systems-level change with wide-ranging effects.

Like digitization, financialization is an emergent and transformative feature of the economy. It happens at the microeconomic level, where individual decisions are made, financial instruments are created and real assets are bought by individuals and institutions. It also has system-level effects as markets become financialized and wealth is diverted to financial actors. Ultimately, financialization transforms the functioning of economic systems at both the micro and macro levels [153].

2.2 Instruments of financialization

To financialize something requires a financial instrument with two primary features: first, it represents something of value, and second, it can be bought and sold as an investment. These instruments represent rights to packages of surplus value that can be redeemed in the future, converting the product of real-world activities into financial assets that can be traded easily. There are many different legal and financial instruments among the building blocks of a financialized system.

The most well-known and quintessential financial instrument is a stock which represents the share of the profit or loss of an enterprise that the stockholder has claim to. Stocks form the basis of the modern stock market. They originally acted as a mechanism for channelling investment into risky productive activity and perfectly illustrate the core features of financial instruments as a class.

Stocks have their roots in the European colonial period and are among the most important financial instruments in the modern economy. They originated as a financing mechanism for a joint-stock company, which facilitates the pooling of investor funds with specific legal protections. It provides a powerful example of a financial instrument that ultimately transformed the economy.

There are records of joint-stock companies being formed in Europe as early as the 13^{th} century. At this time, the basic features of stocks as financial instruments were already in place. They represented ownership of a future flow of profit or loss. This is what you purchase when you buy a stock still today. Originally a tool to allow a group of investors to pool their money, take on large projects, and share the risks, stocks themselves rapidly became objects of trade and speculation with the formation of the first stock market in Amsterdam in 1611. A stock market allows promoters to sell shares in new companies and allows stockholders to buy and sell existing stocks. Because stocks allow for speculation based on hopes of rising prices, their existence very quickly gave rise to the emergent phenomena of financial bubbles which still plague modern markets.

Joint-stock companies multiplied beginning in the 16^{th} century, providing a mechanism for channelling investment into colonial projects. The Virginia joint-stock company was chartered in 1607, not only to create new trading opportunities but also to establish colonies in the acquired lands of North America. It was the Virginia Company's London branch that established the first permanent English settlement in the New World. The East India Company was founded in 1600 to trade in the Indian Ocean region, initially with the East Indies and later with East Asia. The company funded armies, seized control of large parts of the Indian subcontinent, and colonized parts of Southeast Asia and Hong Kong. At its

peak, the company was the largest corporation in the world.

The development of the joint-stock company, a financial tool, enabled both political takeovers and a vast expansion of global markets, which in turn helped drive economic growth and technical innovation, changed wealth flow at a global level, and changed ecosystems, power structures, cultural practices, and even what languages people spoke. The financial instrument enabled investors to capture the wealth of less developed regions, and that shift had a permanent impact on systems at a global level.

2.3 Financialization globally

Just as digitization occurs through the development of many small technologies and this results in broader shifts of processes and production from analogue or digital, financialization happens as instruments of financialization are created and at a broader level there is a shift from productive capital to financial capital like the shift from analog to digital.

One can think of productive versus financial capital as two classes of capital or two ways capital functions, with productive capital being related to increasing productivity and financial capital being related to capturing the surpluses from productivity. This is not a discrete separation. The two types are interrelated, For example, investment in the stock market, which is allocating capital as a financial asset, puts money into companies that are engaged in production. [4] Although the two classes of capital are interrelated and

[4]There is disagreement about how much stock market investment is simply speculation on potential price changes and how much creates productive real assets. Mork et al. identify four theories that attempt to explain the correlation between stock returns and subsequent investment [144].

> The first says that the stock market is a passive predictor of future activity that managers do not rely on to make investment decisions. The second theory says that, in making investment decisions, managers rely on the stock market as a source of information, which may or may not be correct about future fundamentals. The third theory, which is perhaps the most common view of the stock market's influence, says that the stock market affects investment through its influence on the cost of funds and external financing. Finally, the fourth theory says that the stock market exerts pressure on investment quite aside from its informational and financing roles because managers have to cater to investors' opinions in order to protect their livelihood. For example, a low stock price may increase the probability of a takeover or a forced removal of top management. If the market is pessimistic about the firm's profitability, top management may be deterred from investing heavily by the prospect of further erosion in the stock price.

None of these point to a direct connection between stock market investment and real investment.

not entirely distinct, the distinction matters because it captures a notable difference in the way capital can grow.

In financialization, there is a shift from productive to financial capital, meaning more of the active capital in the system/market becomes financial capital. For example, as stock markets become more significant in an economy, more money is invested in financial instruments than in production. In the analogy with digitization, this is the equivalent to more transactions being completed through digital means.

Financialization is a global phenomenon that can be measured as an increase in the stock of financial assets associated with a stock of some set of real assets. For this reason, the term is often used as a collective noun for the growth in the number and/or size of transactions, creating or transferring financial assets to financialized ownership. It is this sense of the word that Tomaskovic-Devey and Lin use when they wrote in 2013 "[t]he U.S. is now a financialized economy, where the financial sector and its priorities have become increasingly dominant in all aspects of the economy" [193]. Christophers argued in 2015 that approximately 40% of the economy was financialized. Aalbers, however, points out that, since many financialized firms are classified as part of the real economy, 40% may be a substantial underestimate [2]. The global financial services market size grew at a compound annual rate of 8.8%. According to the International Monetary Fund, the global real economy has been growing at between 2% and 3%.

While there is not a single point at which financialization began, it has arguably become increasingly significant because of the expansion of financial capitalism during the period from 1970 to the present. Over that period, debt-to-equity ratios increased and financial services accounted for an increasing share of national income relative to other sectors. Thomson and Dutta [191], suggest that August 15^{th}, 1971, when American President Richard Nixon announced that the United States would unpeg its currency from gold, marks a turning point in the financialization of the economy. This accelerated growth in global liquidity and prompted a surge of financial liberalisation and deregulation and undermined the Bretton Woods System. Synthetic derivatives were created soon after: The Chicago Mercantile Exchange launched futures contracts written on financial instruments the following year and the Chicago Board of Trade introduced the first interest rate future contracts three years later. Arbitrage, options trading, and various other activities grew exponentially. By 2011 the over-the-counter (OTC) and exchange-traded derivatives market amounted to almost $800 trillion.

Markets in different jurisdictions are regulated differently, so the effects of financialization vary across countries. There is, however, a 'common trajectory' [103] [4] in which local economies evolve from different starting points subject to similar economic pressures

as more and more wealth is diverted from production to capital.

2.4 Financial Instruments in the housing market

Several financial instruments are specific to the housing market. The familiar home mortgage, for example, makes it possible for persons without sufficient saving to gain ownership of a property by drawing on the financial assets of third parties. Real Estate Investment Trusts (REITS) pool financial assets to allow their owners to capture returns on land and housing. We will describe both, although only the mortgage market plays a direct role in our model.

2.4.1 Mortgages

The financial instrument that changed the structure of the housing market most dramatically is the personal mortgage. Mortgages began as contracts that enabled individuals to make purchases larger than their savings, enabling mainly property purchases. They have become a financial asset that can be bought and sold as property in themselves. This allows investors to purchase mortgages as assets when they think the return is higher than the return on other assets. When mortgages become an easily exchanged financial asset, they begin to serve as a channel for money to move into the housing market, not to produce additional housing for the market, but to capture value from the market. The two uses of mortgages demonstrate two distinct uses of financial instruments.

Mortgages have always allowed lenders to participate in housing purchases in the present in exchange for a future flow of payments. The mortgage does not by itself create housing, but it enables a prospective buyer to become the nominal owner of an asset that produces a stream of benefits that may include a place to live, proximity to work or services, natural features, or other amenities. The value of housing is set by the market to factor in not just the features of the home itself, but the locational value of the property based on the stream of benefits provided.

Because the value of the stream of benefits from secure housing near a source of income generally exceeds a buyer's current assets, mortgages enable the transfer of ownership by making it possible to transfer the rights to a substantial fraction of the future income of the mortgagee to the mortgage-holder. A mortgage gives the mortgage holder a right to the title until the terms of the mortgage are fulfilled. If the mortgagee fails to make those payments, the mortgage-holder can repossess the asset. The security provided by

this instrument "de-risks" the transaction, making it safer and therefore easier to achieve the mutual benefits of the sale.

The additional step of making these mortgages tradable on a market is required to create a financialized market. Originally mortgages were an arrangement between just the buyer and the seller, but in the 1870s in the USA, insurance companies stepped into these transactions, paying off the seller and then collecting the principal and interest payments on behalf of the bank's shareholders. This innovation was an example of financialization in that it made it possible for financial actors, in this case, insurance companies, to profit by providing money to buyers. It also had systemic effects, one of which was making homeownership accessible for more people. When mortgage lending was regulated and insured by the American government during and after the great depression it facilitated a further massive increase in home ownership in the USA and contributed to the post-war construction boom and the suburbanization of American cities.

The housing market was thus initially financialized by the market for insurance-backed mortgages, but these mortgages were still agreements between individual lenders and buyers. When financial institutions later developed markets that let them buy and sell bundles of mortgages among themselves, we say the mortgage market itself was financialized. This added a secondary market for the promises to pay that every mortgage represents on top of the market for housing financed by mortgage-type loans.

The addition of new levels of financialization does not necessarily affect the functioning of the lower-level financial instruments. Buying and selling packages of mortgages does not directly affect the condition of the individual mortgages—they simply add a new product for investors or banks to buy and sell.

Introducing such markets can have an effect at another level, however. The new market in bundled mortgages, for example, was thought to further reduce the risk for lenders, but between 2007 and 2010 in the USA the sub-prime mortgage crisis destabilized the financial institutions that were playing this new market.[5] This is an example of a cross-scale effect of the type that we are exploring in this thesis.

[5]Arguably, that crisis resulted from overselling risky and predatory mortgages by lenders with more money to lend than the market could absorb. Eager investors seeking higher or more secure returns were willing to buy bundles of mortgages that were in theory de-risked. Pooling uncorrelated individual risk, as the insurance industry does, produces lower overall risk. (The instruments that enabled the speculative bubble were mortgage-backed securities (MBSs) and collateralized debt obligations (CDOs).) Pooling does not reduce systemic risk, however. As it turned out, the mortgage default rate rose, lenders' liquidity fell, mortgage rates were pushed up, defaults increased, and the market for the new instruments collapsed, taking down major financial institutions and providing a cautionary tale about the potential dangers of financialization.

If financialization is understood as the increase in the share of surpluses claimed by investors, not all financial instruments are instruments of financialization. Financial instruments can feed into production and mortgages have clearly facilitated home construction. However, the financialization of mortgages led to to expanded mortgage debt on the consumer side, higher home prices, higher mortgages, and ultimately an increase in the share of the benefits produced by the housing stock going to financial actors.

2.4.2 Investment trusts

The process of financialization of the housing market has also involved the development of new financial instruments, that are specifically suited to financialized ownership of housing. An example of a financial instrument designed specifically to support rent extraction and which increases the degree of financialization of the housing supply is the Real Estate Investment Trust (REIT). Other large owners of residential real estate such as life insurance companies and pension plans behave similarly, but REITs are a relatively new financial instrument, the use of which is expanding rapidly and attracting political attention for their effect on housing markets.

A REIT is a company that owns, operates, or finances income-generating real estate and distributes the income to shareholders. While the company itself is a management system, the shares are simply financial assets that are sold to individuals and organizations that want to share in real estate revenues and capital gains. Like mortgages, REITS are financial instruments, but, unlike mortgages, they directly expand the financialization of the housing market by buying housing on behalf of financial actors.

Developed in the USA in 1960 (as an amendment to the Cigar Excise Tax Extension) and introduced in Canada in 1993 [22], REITs are similar to mutual funds in that they make it possible for an individual, often small investors, to earn dividends from real estate investments without having to buy, manage, or finance any properties themselves. A variety of market advisors have pointed out that REITs have outperformed stocks, bonds, and commodities over the last fifty years [40, 29, 39]. One of the reasons REITs can offer high rates of return is because they actively push up rents [18, 71]. Because they have outperformed competing investments they have attracted capital from other uses, particularly during the recent period of low interest rates.[6] For the purpose of this thesis, REITs are among the mechanisms enabling the financialization of housing.

[6]There are questions about preferential tax treatment, and whether some REITs are essentially inappropriately sheltered real-estate corporations.

REITs have system-level effects. According to a paper [203] on REITS in the Irish housing market, "REIT successfully reconnected the international financial market and the Irish real estate market." In other words, in Ireland, REITs have made it easier for international capital to buy Irish land. The entry of outside investors has affected the resident population: "the large-scale acquisition of Irish real estate by REITs and other real estate buyers has also caused some new problems. First, the active management of assets by REITs and other investors has led to a rapid increase in rents."[203][7]

There is evidence that REITs affect real estate markets in other ways. Bat et al. [22] report that "they are actually financial actors that aggressively buy up property assets and manage them to extract wealth at taxpayers' expense." and "they have expanded the pool of capital available for transactions that monetize real property and turn it into tradable assets—financial widgets with little or no connection to the real purpose of the productive enterprises that occupy the properties they own."

In this section, we have called attention to the development of several important financial instruments—stocks, stock markets, derivatives, mortgages, and REITs—with the intention of disentangling the concept of financial instruments from the term "financialization." To illustrate the potential for systemic shifts, we have described some of the system-level effects of the widespread adoption of the two instruments for the financialization of housing described earlier, mortgages and REITs.

2.5 Financialization of the urban system

Financialization of housing is one expression of the broader financialization of the economy. Wijburg et al. [207] argue that rapid financialization of housing markets in Germany, Spain, the US and elsewhere took place in the seven years before the global financial crisis of 2007.

In this thesis, we focus on the distributional and productivity effects of the financialization of housing underway in the Canadian urban system in particular. Housing is a major feature of the urban system. Housing reflects locational decisions and the majority of housing is in urban areas, so housing is, to a large extent, a spatial and urban phenomenon. It follows that the financialization of housing is also a spatial and urban phenomenon that should be analyzed in an economic–geographic framework [2]. We will develop the spatial framework in the next two chapters.

[7] In IMF working paper "Capital Account Liberalization and Inequality" [84] Furceri and Loungani reported that that for 149 countries from 1970 to 2010, "after countries take steps to open their capital account, an increase in inequality in incomes within countries follows." The observation is consistent with our argument that domestic rent-seeking in housing markets will increase inequality.

There are two traditions in urban studies. In economics and geography, the spatial features of the housing market are well-developed, but these 'mainstream' literatures largely ignore the distributional aspects of the housing market, focusing largely on locational decisions. Another tradition, with its roots in Classical economics and Marxist theory, focuses on distributional questions and the financial integration of the urban housing market in the broader capitalist system. This Marxist analysis has done substantial work describing the financial phenomenon but has not developed the kind of formal modeling tools characteristic of the mainstream tradition. This thesis works to bridge that gap. Because we are looking at distribution and productivity, we incorporate both mainstream and Marxist approaches to directly explore these matters.

While the Marxist approach has a long history, including some of Marx's own discussion and the work of Henry George, Henri Lefebvre [123, 124] deserves specific credit for reintroducing the analysis of financial capital in urban systems within a Marxist framework in 1970. Lefebvre argued that instead of passively following the growth of industrial capital, which had historically been the site of capital expansion, owning property had become the site of capital expansion. He wrote:

> 'Real property' (along with construction) is no longer a secondary form of circulation, no longer the auxiliary and balanced branch of industry and financial capitalism that it once was. Instead, it has a leading role.

Through the 1970s and 1980s, David Harvey [100] developed and expanded Lefebvre's hypothesis about the role of the urban system in financial capital accumulation by showing how rent-seeking and finance capital merge in the urban process. The fifty-year-old Lefebvre-Harvey analysis lingers in some academic circles but has no noticeable impact on policy in Canada or the USA.[8]

2.6 Summary

Financialization of the housing market is the increasing control of the stock of urban land and housing by investors in order to capture the scarcity rent generated by the people of the

[8] On the recent history of the term "financialization," Aalbers observes that, "[t]he concept of financialization has been used for a couple of decades by a small group of academics and other intellectuals, for example in the circle surrounding the Marxist Monthly Review (e.g. Sweezy, 1995), but it is only since the global financial crisis that started in 2007, that the term has acquired the status of a popular concept in a range of literatures spanning the different social sciences and the humanities" [3].

city, and the system-level effects of that increasing control. In this chapter, we've discussed what this means at the level of finance and the development of particular financial and legal instruments, at the micro-economic level as these instruments are taken up, and we've introduced some of the broader macro system effects of this process of financialization. The rest of the dissertation is a further exploration of the systemic effects of this process.

Chapter 3

Antecedents of Modern Urban Rent Theory: Rent and Production

> Of the concrete forms of income that have usually been classed as surplus, the rent of land was the earliest to be defined; and so prominent a position has been given to it that the terms 'rent' and 'surplus' have come to be used interchangeably.
>
> Alvin Saunders Johnson, 1902 [113]

> The law of rent has become an obstacle to scientific progress: it has retarded the attainment of a true theory of distribution ... The principle that has been made to govern the income derived from land actually governs those derived from capital and from labor.
>
> John Bates Clark, 1891 [45]

In an urban economy, land provides benefits in the form of housing, and places for work, storage, commerce and recreation. Location matters in an urban economy because value is generated by bringing people and activities together. The value of a piece of land in a city derives, not from the richness of the soil, but from the richness of the activities it supports and because of the people and activities it provides access to. A range of theorists

have struggled to use the classical theory of rent developed by classical economists in the 19^{th} century to explain the problems and crises of the modern city, its form, and even its future [95, 112, 101]. This thesis extends that work.

The economist's notion of rent overlaps with, but is not identical with common usage. Rent, in economic theory is not the amount a tenant pays a landlord every month, nor is it simply a payment for using land or another facility. Originally the term was applied to the payments landowners collected, but in classical theory the concept was modified to mean payment for "the indestructible qualities of the productivity of land" [91]. The economic value of land naturally depends on its location—without nearby buyers, the product of the land has no market value at all—so while the term rent was used to refer to the payment itself, it was actually referring to locational value of the land.

For modern economists, the word, initially developed to understand the income of landowners, extends to include the surplus income produced by any scarce factor of production that is created by nature. People pay a high price for housing near the center of a city because there is a limited amount of land close to the center, and being close to urban jobs and amenities is valuable. The extra payment for being close to the center is an economic rent. Land with natural resources like mineral deposits, similarly generates locational rents.

Economists also talk about scarce talents using the concept of rent. The natural talents of a sports star like soccer player Lionel Messi have substantial market value and also generate rents, since people like Messi are very scarce. It may not be obvious to think of Messi as having a locational value, but if his services cannot be delivered to a market willing to pay to watch football, his services as a footballer have little or no economic value.[1]

In this thesis, we use the concept of rent to model how financialization allows for the capture of a growing share of urban productivity. If financialization of the urban housing market is directed to capturing the stream of economic surpluses generated by the city, the theory of rent provides a basis for understanding the allocation of surpluses.

In this chapter, we build a bridge from classical rent theory to the modern theory of urban rent, which this thesis works to develop. To do this, we discuss classical and neoclassical theories of rent and production.[2]

[1]The market model of football has become almost an inversion of the agricultural market. Stadiums served as the market place where buyers and sellers met, but television now delivers Messi to global market, greatly expanding the rents he can bargain for.

[2]Political traditionally distinguished (1) absolute rent, (2) monopoly rent, (3) extensive differential rent and (4) intensive differential rent [112]. Our exposition deals almost entirely with the third category. To

3.1 The classical theory of rent and distribution

Cultivated land provides a stream of benefits in the form of agricultural products. Prior to the industrial revolution, most people in Europe lived on and worked the land, primarily producing food, with ownership concentrated in the hands of a few landowners. Agricultural production played such a central role in the economy that landownership was the basis of wealth, political power, and social distinction.

For early economists, all wealth appeared to come from the land. The Physiocrats in particular, a school of political economy in 18^{th} century France, emphasized that land is the source of all wealth, that only agricultural labour was genuinely productive.[3] They argued that tradespeople, professionals, clergy, and aristocrats were nonproductive. Rent theory originated in this land-based agricultural society. Landowners controlled access to the means of production and charged for access. The income landowners extracted was what economists called economic rent, or land rent. Given the importance of land to overall economic productivity, the theory of rent emerged as a primary way of understanding the economy, and therefore the distribution of wealth in this period.

3.1.1 Historical development of classical rent theory

Alvin Saunders Johnson wrote in 1902 "[o]f the concrete forms of income that have usually been classed as surplus, the rent of land was the earliest to be defined; and so prominent a position has been given to it that the terms 'rent' and 'surplus' have come to be used interchangeably" [113].

David Ricardo provided the canonical presentation of the classical theory of rent [165] in 1815.[4] Ricardo defines rent in relation to who claims the surplus productivity of the land, saying "[b]y rent I always mean the remuneration given to the landlord for the use

deal with the others would require minor extensions of our model but relatively large additions to our text.

[3]They argued, based on the productivity of land, that government policy should not interfere with the operation of natural economic laws. Within this framework, they were the first to frame labour as the source of value. Marx, extending the approach to the industrial economy, generalized the analysis, treating industrial labour as generating a surplus as well, but excluding other workers.

[4]Classical rent theory originated with thinkers such as Richard Cantillon (1680s–1734), François Quesnay (1694–1774), the Marquis de Mirabeau (1715–1789), Anne-Robert-Jacques Turgot (1727–1781) and Adam Smith (1723–1790), and received its classic statement in Ricardo (1772–1823). Nearly contemporaneous thinker, Johann Heinrich von Thünen (1783–1850) developed a planning model to guide the location of economic activities for an urban-agricultural society. A version of that model was reinvented in urban geography by William Alonso.

of the original power of the land" [165]. The key term in that definition is "the original power of the land." In the classical tradition, rent is the surplus produced by labour, using land, that is claimed by landowners by virtue of their ownership of the land. The price of the corn would include payment for working the land and for transporting, storing, and selling the product, but the residual that was rent was a payment for the virtue of the land not the contribution of the landlord.

For Ricardo, land rent is thus a kind of surplus value, that is, an amount available after the costs of production have been paid, the term rent came to be used interchangeably with this more general concept in much of the classical work on rent and the term rent has been used in a more general sense to other kinds of surplus value, as well as land rents.

In Ricardo's time, economic rent and the rent paid by farmers to use the land were almost interchangeable. Landowners 'rented out' land. The level of rent charged might not be exactly the economic rent, but in a labour-surplus economy[5] landlords had enormous bargaining power, and charged tenant farmers rents that tended to approximate the value of the surplus.[6]

Ricardo was interested, in particular, in the division of the surplus among the classes of society: which is to say, to the owners of land, labour, and capital.

> "The produce of the earth—all that is derived from its surface by the united application of labour, machinery, and capital, is divided among three classes of the community; namely, the proprietor of the land, the owner of the stock or capital necessary for its cultivation, and the labourers by whose industry it is cultivated ... But in different stages of society, the proportions of the whole produce of the earth which will be allotted to each of these classes, under the names of rent, profit, and wages, will be essentially different" [165].

Ricardo's concern with the distribution of the surplus in an agricultural economy reflected the social concerns of his time. Primarily agricultural, the increasing globalization of trade

[5]Between 1604 and 1914 over 5,200 enclosure Bills were enacted by Parliament which related to just over a fifth of the total area of England, amounting to some 6.8 million acres. From the 1750s enclosure by parliamentary Act became the norm. In Scotland between 1750 to 1860 the Highland Clearances evicted a significant number of tenants in the Scottish Highlands and Islands, mostly in two phases from 1750 to 1860. Enclosures and clearances created a large pool of essentially minimum wage labour that supported industrialization and drove British migrations to the colonies.

[6]It is important to remember that there was always a conventional level of rent reflecting the power relations between the classes and anchoring the level of rent extraction that was possible.

in the early stages of the industrial revolution,[7] was driving both rising overall wealth and greater poverty for many in the working class.

Understanding rent was essential for policy analysis. The physiocrats focused on land and on the rents to understand tax policy. Ricardo applied rent theory to explain the effect of tariffs. For Ricardo this theory provided insight into whether Britain should open its doors to corn from the colonies.[8]

3.1.2 Locational value in agricultural markets

Location is at the center of the classical theory of rent. The role of locational value in the theory of rent can be illustrated with the story of a carter. The carter transports agricultural products such as potatoes from farms to sell in town. There is a price for potatoes in town and a lower price at the farm gate. The carter buys potatoes from farmers at the cost of production, transports them to town, and resells them at the higher price in the urban market. What remains of the price gap, after subtracting labour and vehicle costs, is profit.

The cost of transporting the potatoes depends on how close farms are to market. The net return thus declines with distance from town. Beyond a certain distance, the costs of the trip will eat up all profit. That is the farthest distance the carter will travel to purchase potatoes. It marks the extensive margin of agriculture.

Figure 3.1, shows the total transportation costs as the darker, grey area. The lighter, yellow triangle is profit for the carter. The carter makes a 'profit' on the trip to the farm nearest to town, a smaller profit farther from town, and no profit on any farms beyond this point.[9] Together these two triangles represent the value of the 'product of the earth,' but only the upper triangle is a social surplus. The lower triangle is the amount of value expended on transportation. The social surplus was termed the 'produit net' by the Physiocrats. This surplus may go to the landlord, the carter, the merchant or the consumer,

[7] The Industrial Revolution is usually described as beginning around 1760 and having significantly transformed society by about 1820–1840.

[8] This was the debate over the Corn Laws (1794-1846), a set of duties on grain imports into Britain to protect British agriculture from outside competition. In Britain, "corn" was the generic name for cereal crops. The full title of Ricardo's essay explains his purpose "*An Essay on the Influence of a Low Price of Corn on the Profits of Stock, Showing the Inexpediency of Restrictions on Importation: With Remarks on Mr Malthus' Two Last Publications: 'An Inquiry into the Nature and Progress of Rent,' and 'The Grounds of an Opinion on the Policy of Restricting the Importation of Foreign Corn.*"

[9] Note the similarity between Figure 3.1 here and Alonso's urban model, illustrated in Figure 4.1, in Chapter 4.

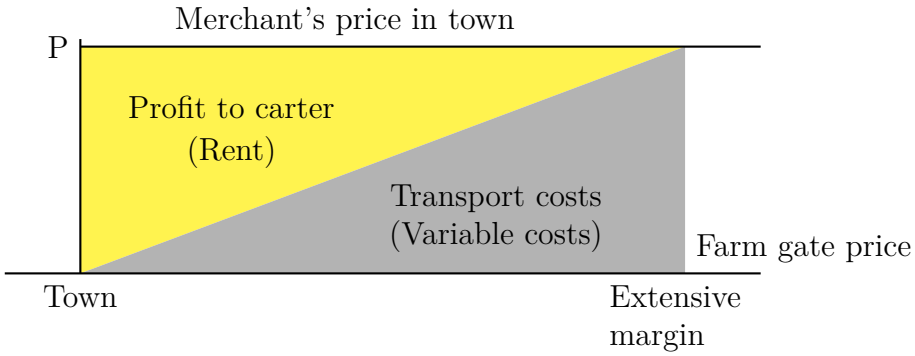


Figure 3.1: Ricardo's theory of the extensive margin using transportation costs to illustrate the similarity between rent in classical theory and in the Alonso model (developed in Chapter 4). Transport costs, the darker, gray area, take a share of the value of vegetables sold in the town.

depending on their relative power. If the carter has a transportation monopoly—owning the only suitable wagon in the region, the carter may claim the profit. The surplus is called rent if it's captured by the landowner. If goes to the carter, it's usually called profit. In modern supply and demand analysis it would be recognized as 'producer surplus,' which is the difference between what a producer gets for a good and what they would be willing to accept.

Differential rents

Differential rent is the difference in earnings between the poorest land in production and a more fertile or better-located field. Ricardo explained differential land rent, focusing on fertility rather than distance to market. The key concept in his explanation was the margin of production. At the margin, whether in fertility or in distance, land rent falls to zero. The margin represents the limit of the economically productive region. Before that limit is reached, on inframarginal lands, rents are positive. In this concept, Ricardo laid the foundation of the neoclassical school of economics that would emerge later, although it would take the application of calculus to make is insights into a general methodology

Ricardo carefully distinguished the intensive margin and the extensive margin. The extensive margin is where the most distant land worth cultivating is found given the cost of transportation. Farmers will not cultivate land beyond the extensive margin, because

there is no profit. The intensive margin, on the other hand, can be seen as the limit to increasing the economic return from a particular piece of land by applying fertilizer, draining, or paying more workers. In modern, marginalist terms, the intensive margin is reached when the revenue generated by an additional amount of fertilizer on a plot of land just begins to exceed the marginal cost of fertilizer. If the merchant's price goes up, or costs go down, the extensive margin moves farther out, and more land comes into production.[10]

We can use the story of the carter introduced above to illustrate how land rents are locational rents, derived from both the proximity of land to the market and the productivity of the land. Just as there is more surplus for land closer to market, there is more surplus for land that is more productive. Good land produces more market value for the same cost as the poorest land in production. The poorest land in production just barely justified the cost of production. If farming did not justify the costs, the farmer would not cultivate the land.

The concepts that made up 'Ricardian rent theory'—surplus, differential rent, intensive and extensive margins, the class basis of distribution—provided a foundation that later economists built on. Marx explored the concept of surplus and applied it to an industrial economy, George applied rent theory in an urban context, and Carl Menger, William Stanley Jevons, Léon Walras, John Bates Clark, and Alfred Marshall expanded on Ricardo's concept of the margin so much that "marginalism" emerged as the main stream of economics analysis.

3.1.3 Surplus in the industrial age

Even as Ricardo was writing, the Industrial Revolution was already changing what Marx would soon call the mode of production. As the economy shifted from overwhelmingly agricultural to largely industrial, through the 18^{th} and 19^{th} centuries, more and more of society's wealth came from factories and the influence of landowners declined, while that of the owners of reproducible capital grew. A theory of value in which only land-produced value was no longer sufficient, even as an approximation. It became increasingly important for economists to theorize industrial production.

Marx, (1818–1883), was born three years after Ricardo published his *Essay on the Price*

[10] Our examples illustrate the principle with uniformly productive land and a single product. Johann Heinrich von Thünen, in *The Isolated State* (*Der isolierte Staat*) [199], provided a more complex analysis based on the same principles in 1826.

of Corn. By the time Marx began writing his economic ideas for *Rhineland News* in 1842,[11] Ricardo had been dead 19 years, the Industrial Revolution had been underway for almost a century, and European economies were largely structured around manufacturing. Marx's *Capital: A Critique of Political Economy* (1867) [138] reshaped the discussion of rents and brought into focus the distribution of the new surplus generated by industrial production. The lynchpin of his analysis involved a redefinition of 'capital.'

For earlier seventeenth-century economists such as Cantillon and Quesnay, money was nothing but a means of exchange and a convenient store of value. Writing in a predominantly agricultural society, they had seen capital as the fund of money needed to finance the lag between expenditure on inputs and return on output in agricultural production [34, 172]. Capital was not productive in itself. Later, the major classical economists like Smith, Ricardo, and Mill began to focus on the role of inputs to the production process that were themselves produced goods—the machinery, the factories, the tools and transportation equipment—in their conceptions of capital. They continued to intermix ideas of these "produced means of production." or capital goods, with the more familiar notion of money as capital [172].

Marx, writing in the crucial period of transition from classical to Neoclassical economics, offered a synthesis. He emphasized that the control of money also provided control of production and the ability to claim all of the residual after all the real inputs had been paid for [172]. For Marx, the different forms of capital were aspects of the same social relation. Capital took different forms in different stages of production, but they were all representation of power over resources. Only owners of capital could build factories, buy supplies, and hire workers.

In his analysis, money capital brought together machinery, buildings, etc. (which he called 'fixed' or 'produced capital') with labour (which he called 'variable capital'). According to Marx, it was the variable capital that was productive and created a surplus. This formulation suggests that labour should receive that surplus or most of it. For Marx, a core flaw of capitalism (his term for this system of production) lay in the excessive share of the surplus value taken by privately owned capital. The appropriation of that surplus by capital was a form of class exploitation analogous to the capture of rents by landlords. This analysis of capital and surplus value was the foundation of his enduring political and intellectual impact. [12]

[11] *Rhineland News* (*Rheinische Zeitung*) was a radical newspaper, terminated by Prussian state censorship just a year later in March 1843.

[12] While the classical 'fund' concept of capital is inherent in the Marxian concept of capital, it becomes a stage in circular reproduction of capital in which 'physical capital' is another stage represented in his

Marx also called attention to a dynamic feature of capitalist systems that would become an ongoing theme in of economic thinking: productive capital is not fixed as land is, but expands as surplus is reinvested. At any rate of return, this growth of capital is exponential and tends to outrun demand. For Marx, it followed that with insufficient demand the rate of profit had to fall, leading to a capitalist crisis.[13] Marx's critiques of the way that the social product was distributed and its tendency to generate periodic crises represented serious challenges for social theorists.[14] Neoclassical economists like Alfred Marshall, looking at the same patterns, concluded that competition among capitalists would indeed drive profits to zero, but he argued the result would not be a crisis, but instead would improve efficiency. Other economists would find ways to normalize the excessive returns to capital.

3.2 Neoclassical theory

Alfred Marshall (1842–1924) was one of the most influential economists of his time and one of the founders of the school of neoclassical economics. His book *Principles of Economics* (1890) [136] was the dominant economic textbook in England, and its approach dominated economic thinking until the 1940's.[15] It brought the ideas of supply and demand, marginal utility, and costs of production together in a coherent whole and contributed many new theoretical insights. The "neoclassical revolution" in economics, which Marshall helped launch, was a movement that extended and corrected classical theory while at the same time introducing the extensive use of mathematics to the discipline. Marshall made significant contributions on both these fronts.

In contrast to Marx, Marshall saw the competition among capitalists as a positive force. Rather than focusing on potential crisis, he argued that competition among capitalists would result in economic efficiency. The presence of higher-than-normal profits would lead new firms to enter an industry, increasing supply, driving down prices, and eliminating

writings as part of 'constant capital.' The physical capital, separated from Marx's ideas of circulation and surplus, would become the central form for neoclassical economics, Marx (1867) was also perhaps one of the very first economic thinkers to underline the demarcation between produced and financial capital [172].

[13] In some analyses, the financialization of housing emerges from investors seeking to invest capitalist surplus value as profit rates fall, for instance David Harvey's work on the second circuit of capital [100].

[14] Marx was far from being the most influential critic of the system. Henry George, whom we discuss below was far more widely known and influential at the end of the 19^{th} century.

[15] Von Neumann and Morgenstern's Theory of Games and Economic Behaviour [198] and Samuelson's Foundations of Economic Analysis [173] introduced new techniques and dramatically shifted the focus of the profession.

the higher profits.[16] Marshall argued that eliminating excess returns would help bring prices down. It would not eliminate the return to capital, rather investors would only receive a 'normal' rate of return, which is usually defined as the average rate of return on all investments. It was exactly this 'normal' profit that Marx and many others saw as exploitative.

To emphasize that the temporary profits from being the first with a new technology or a new product innovation were both a form of rent and also temporary, Marshall introduced the term quasi-rents [113]. He argued that quasi-rents play an important short-run role in attracting existing capital to projects where it is most productive—such as setting up the railroads or building new steel factories—making even excess profit a positive feature of industrial capitalism. By pointing to their transitory nature, Marshall seems to imply that there is a normal and acceptable rate of return on capital and that any profit over and above the normal rate of return on capital, is unimportant in the long run.

Treating capital as a factor of production exactly like labour and concluding therefore that the owners of capital are entitled to the money value of its marginal product just as the owners of labour are entitled to their marginal product is central to neoclassical analysis.

Marginalism is a style of economic analysis that emphasizes marginal values as opposed to total values or average values. The significance of the distinction lies in the fact maximizing a function like the profit function or utility gives rise to expression in terms of marginal quantities like marginal cost, marginal revenue, and marginal utility. It is then possible to say a person wishing to maximize their profit or utility should want to satisfy the derived conditions on marginal values (prescription). Another step allows economists to assume that those conditions are likely to be satisfied (description). The style of argument generally relies on the use of calculus. The systematic shift to marginalist analysis is seen as the dividing line between classical and modern economics.

Marginalism is thus the approach that focuses on looking at effect of a small change in some variable, such as a small increase in output. It falls out naturally from calculus. The marginal product is the amount that the last unit of any factor adds to output while holding all other factors constant. The marginal product of labour (MPL) is the amount that the last worker adds to output without changing the quantities of other inputs used.

[16] To understand how competition would eliminate quasi-rents, we can go back to the story of the carter who was capturing the agricultural rents. Since carts are a form of reproducible capital, there would always be another potential carter who could have a cart built and enter the market to claim a share of the surplus. In this newly competitive market, both would have to offer better prices to the farmers. Profits in carting would fall to zero and the landlords would again capture the land rents. After paying farmers, and paying off the loan to buy their carts, carters would eventually earn just a competitive wage.

The firm's demand function for labour in a competitive market is identically the marginal product of labour function, represented as a downward sloping curve due to the diminishing marginal productivity of labour.

Marginalist techniques provided increased precision, power and elegance to economic theory. They made economics less a collection of thoughts about the economy and more a mathematical edifice that embodied those thoughts in a rigorously consistent way. Though marginalism shifted attention away from questions of class and distribution, the neoclassical economists did not see themselves as overthrowing the insights of the classical economists. Marshall in particular emphasized this point: in the introduction to his *Principles of Economics* he wrote "Some of the best work of the present generation has indeed appeared at first sight to be antagonistic to that of earlier writers; but when it has had time to settle down into its proper place, and its rough edges have been worn away, it has been found to involve no real breach of continuity in the development of the science."

An illustration of the marginalist approach

To illustrate how the marginalist approach both contributes new insights and shifts the emphasis of economic theory, we can look at how the concept of a production function brought Ricardo's notions of intensive and extensive margins to the centre of economic theory. Ricardo has a clear understanding of how the output, for instance of a farm, depended in a tight way on the land and labour used. Later economists would represent this type of relationship between inputs and outputs with a mathematical expression called a production function. Ricardo's description of the production process may be written in mathematical form as:

$$Y = F(K, L, N). \tag{3.1}$$

where Y is output, K is capital invested, L is labour and N is the natural resource land.[17] [18]

Ricardo never wrote a mathematical function for the production function. Writing the production formally like this is an innovation of the neoclassical economists. Ricardo described a production function and gave numerical examples for one case. Writing it down formally like this opens the analysis to a set of new insights.

[17] This makes it a three-factor model of production. In principle, any number of factors can be included.
[18] Ricardo assumes diminishing returns to all factors.

With a function, it is possible to apply calculus and to study precisely the integrals and rates of change. Calculus lets us extract from Equation 3.1 additional expressions for the effect of a small change in one of the variables in the parenthesis on the right on the value on the left. For example, if we differentiate the output function F with respect to labour L we get an expression called the marginal product of labour. It is the amount that adding one more worker would add to total output. The argument that this derivative might also tell us what the new worker should be or would be paid formed the basis of what became the marginalist theory of distribution.

More generally, the introduction of functions and the use of calculus made it much easier to derive what came to be called the 'marginal conditions,' which can serve as rules for efficient management. The results of this new style are analytically more precise than the verbal statements they replace, and more easily communicated accurately to those with mathematical skill. The approach also tended to lay bare the precise conditions, i.e. background assumptions, that must hold for results to be true. It also allowed economists to analyze complex cases that were difficult to state verbally. A cost of this approach is that economics focused more on those questions calculus could solve, and the field became less accessible to those outside the discipline.

3.2.1 The neoclassical theory of distribution

American economist, John Bates Clark (1847-1938), a near contemporary of Marshall and one of the founders of the American Economic Association, was among of the most influential American economists of the day. Like Marshall, Clark was a major contributor to the development of neoclassical economics. Clark developed the essential link between distribution and the emerging understanding of production in an industrial economy by linking the production function directly to distribution.[19]

His 1891 *Distribution as Determined by a Law of Rent* [45] argued that, given competition and homogeneous factors of production labour and capital, the division of the social product will be according to the productivity of the last (or marginal) physical input of units of labour and capital.[20] Knowing how factors contribute to production, this relationship makes it possible to compute how they will be paid, giving a theory of distribution

[19] Clark was not alone in this work. Marshall apparently derived the results independently; Philip Wicksteed proved a crucial product exhaustion theorem in 1894; and others proposed that some, but not all, factors would receive their marginal products.

[20] Clark's work engaged with both foundational economic principles and with the ethical and distributional implications of those principles. His other works include: *The Philosophy of Wealth* (1886), *The Distribution of Wealth* (1899) and *Essentials of Economic Theory* (1907).

grounded in the theory of production. This solved a core puzzle that was increasingly important to understanding the industrial economy.

Clark argued that the distributional pattern that he saw emerging under capitalist industrialization was fair. Responding to the Marxists and what he described as the "indictment that hangs over society" that the wage system involves "exploiting labour," Clark wrote in his 1899 *Distribution of Wealth*:

> It is the purpose of this work to show that the distribution of the income of society is controlled by a natural law, and that this law, if it worked without friction, would give to every agent of production the amount of wealth which that agent creates. However wages may be adjusted by bargains freely made between individual men i.e., without labour unions and other "market imperfections," the rates of pay that result from such transactions tend, it is here claimed, to equal that part of the product of industry which is traceable to the labour itself; and however interest, i.e. profit, may be adjusted by similarly free bargaining, it naturally tends to equal the fractional product that is separately traceable to capital.

He argued, as Marshall did, that in most cases competitive forces were strong enough that the power of the owners of companies, capital, or resources would not matter much. Clark emphasized that land and capital were factors of production logically and morally equivalent to labour.[21] With this development, the notions of surplus and rent were pushed off center stage for mainstream economists.

3.3 Surplus and the city

Henry George (1839–1897) returned to the theory of land rent with a new insight based on the emergence of the capitalist city. Although the neoclassicists appeared to have dispensed with rent and downplayed the importance of economic surplus, neither problem had gone away. With industrialization, economic activity was increasingly centred on cities. The owners of urban land, said George, extract surplus in the same way that owners of agricultural land do in Ricardo's analysis: "[w]ith the growth of population, land grows in value, and the men who work it must pay more for the privilege." Where Marx saw

[21] In doing so, he obscured the fact that it was not the capitalist or the landowner that contributed to production but rather the land or the socially produced purchasing power they held legal ownership rights over.

the extravagant productivity of capital as the source of capitalist rent, George saw the extraction of wealth by land speculators as the mechanism that let owners claim surplus value.

Since land rent is not created by its owners, George argued that land rent should be seen as a social income—that it could be used to pay for the needs of the community.[22] He argued for a single tax on land to finance all public needs. The logic behind the single tax approach is fairly simple: if a public good increases productivity land rents rise. Investment in the public good should proceed until the marginal cost of the public good is equal to the increase in land rent it brings. This is an application of the neoclassical theory of distribution that identifies public investment as a factor of production like capital and labour.[23] Flatters et al. [72] and Stiglitz [186] later identified conditions in which Henry George's single tax is the only tax necessary to finance public expenditures using Alonso's relatively new urban model. This result is now called the Henry George Theorem. George's work represents an important development in the theory of rent [15].

George published his most famous work, *Progress and Poverty* in 1879 [87]. It sold millions of copies worldwide, and its publication is often cited as marking the beginning of the Progressive Era[24], and it launched the single tax movement, which sought to shift all taxation to land and resource rents.

The classical economists agreed that rents are unearned income. They did not emphasize, as George did, that land rents arise from labour's proximity to urban population and production. To be fair, the exclusion makes sense, given that understanding industrial production would naturally be a lower priority in a primarily agricultural economy. In explicitly examining urban land rent from residential or even industrial purposes George added a link to cities and distribution that this thesis takes up.

[22] George's emphasis on land rents parallels the view of the Physiocrats, who concluded that agricultural ground rents should be the source of most or all taxes. They defined ground rent as that portion of all rent that is attributable only to the size and location of the parcel.

[23] Among the most prominent economists who have spoken in favour of a version of George's single tax are Alfred Marshall [136], Arthur Pigou [158], Milton Friedman, (he called it "the least bad tax" [80] (a view he repeated in an interview recorded at https://www.youtube.com/watch?v=yS7Jb58hcsc), Paul Samuelson, Robert Solow, Paul Krugman, Joseph Stiglitz [186], William Vickrey, and Michael Hudson [108]. Variants of land value taxation inspired by George are in place around the world and there are hundreds of studies of the approach. Marx, however, saw the single tax platform as a step away from socialist progress.

[24] The Progressive Era (1896–1917) was a period of widespread social activism and political reform across the United States focused on the problems caused by rapid industrialization, urbanization, immigration, and political corruption; and by the enormous concentration of industrial ownership in monopolies.

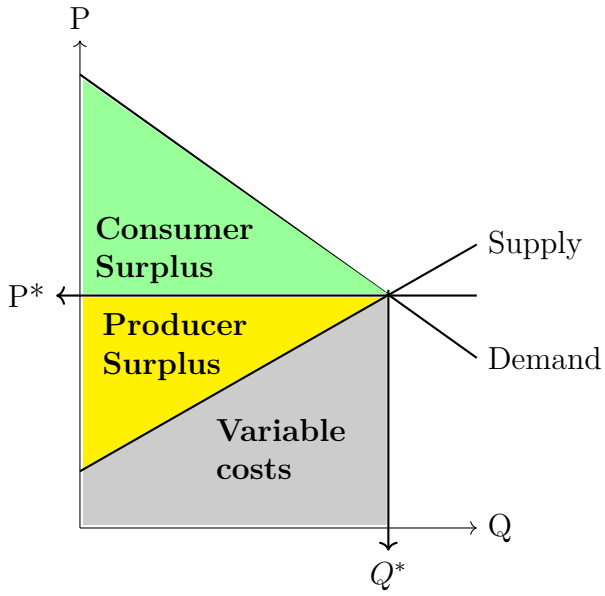


Figure 3.2: The modern concept of producer surplus is graphically and logically equivalent to Ricardian rent.

3.4 Rent in modern economic theory

Neoclassical economics has not abandoned rent theory. It has simply moved it to the side to focus on other topics which marginalist techniques explain more satisfactorily. Despite this, the classical concept of rent is embedded in a great deal of standard analysis.

The most obvious place that rent persists in modern microeconomic theory is in the concepts of 'consumer surplus' and 'producer surplus' Both of these concepts are illustrated in Figure 3.2. They are both variants of rent and are essential in demonstrating the efficiency of markets and the social losses due to monopoly, monopsony, regulation, and taxes. Consumer surplus is the sum of rents that accrue to the class of consumers (buyers). Producer surplus corresponds precisely to land rent. It is an inframarginal quantity, that accrues to the class of landowners. It arises because consumers have differing capacities to produce utility with the good, just as landowners have lands with different abilities to produce agricultural output.[25]

[25]See the similarity between the producer surplus, as illustrated in Figure 3.2 and in Figure 3.1, as illustrated rent in the story of the carter.

Other significant examples of rent in modern microeconomic theory include:

1. The high salaries of sports stars are explained as rents on their scarce talents.
2. The "First Fundamental Theorem of Welfare Economics," proven independently by Kenneth Arrow [16] and Gerald Debreu [55] in 1951, is possibly the most significant theorem in the social sciences. It demonstrates that perfectly competitive markets would maximize producer and consumer surplus, quantities that are variants of rents.
3. The theory of rent-seeking became the subject of durable interest among economists and political scientists after the publication of two influential papers on the topic by Gordon Tullock in 1967 [194], and Anne Krueger [119] in 1974. Rent-seeking occurs when an someone seeks to increase their own wealth without creating any benefits or wealth to the society. Financialization, as we use the term, is a variety of rent-seeking.
4. In resource economics economic rent, defined as "a money payment made for a factor of production that is over and above the minimum payment to keep it in its present use," is a central analytical device [91].

As we will discuss in detail in Chapter 4, the classical concept of rent is also at the heart of modern urban theory, although that work does not bring forward the distributional aspects of the classical analysis. The bid-rent curve, the value of the bid, or what people will pay to live near the center, became a dominant device in urban theory with William Alonso's 1961 thesis [9] and the work that followed.

3.5 Summary

In this chapter, we have examined the historical development of rent theory and its role in distribution theories as the necessary background for our development of a modern theory of urban rent. We explained how the concept of economic rent arose in an agricultural economy, and who gets the rents in that type of economy. We then gave an account of how rent theory and the classical distribution theory were pushed into the background as neoclassical theorists analyzed the industrial market economy that emerged after the Industrial Revolution using the modern theory of production.

We have also sketched the two great theories of distribution in economics. The first is based on the classical concept of rent as explained by David Ricardo [165], in which owners

of land can extract a value beyond what they contribute based on their ownership of a scarce resource. The second is the marginalist approach, developed by John Bates Clark and others, in which workers and other factors in competitive markets receive the marginal value-product of their contribution to production. The two theories coexist and even mingle in modern economics, but it is the marginalist approach that dominates economic teaching.

Both theories developed in response to the social and economic conditions of the periods in which they emerged. Both attempt to explain where the output of society ends up within society. They are, at their heart, stories of who claims what share of production. The classical theory of rent linked a spatially distributed economy, agriculture, with the class structure of the society of the time. The neoclassical approach does not contradict the classical view of rents, it simply displaces the analysis to the point where a competitive equilibrium prevails, and shifts attention away from the distribution of land rents.[26]

Following the eras of agricultural and then industrial dominance, we are now arguably in an era dominated by a third mode of production centered on human capital and urban production. This new mode of production does not yet have a corresponding theory of distribution. This thesis works to fill that gap by re-introducing rent in the classical sense within an urban model which distributes wages and profits as prescribed by the neoclassical model. In the next chapter we introduce a 20^{th} century urban model that is essentially an application of classical rent theory.

[26]Carey and Lachim [36] observe, however, that, "[t]he persistent and growing profit share across a range of advanced economies and within industries fundamentally challenges the assumption of perfect competition and suggests that growing market power is at the heart of many of the economic challenges in America today."

Chapter 4

Urban Land and Land Rent

> Overall, several decades after its creation, the standard urban model seems to still capture surprisingly well the inner structure of many cities across the world, both in developed and in developing countries.
>
> Liotta et al. [127]

The discussion of rent in the previous chapter provides the necessary economic logic underlying the analysis in this thesis, but we need to explain the application of rent theory to the modern urban economy. Classical Ricardian Rent theory does not speak to the importance of land rent in the spatial organization of cities and does not explicitly account for specific features of urban environments. In the automobile-centric modern city, transportation costs become central in determining land values, and largely determine city form. Research in the 1960s gave rise to a model of city form built on the relationship between three variables: location, transportation cost, and land value. We incorporate this model from urban economics and urban geography.

Economic geography in general is the use of the tools of economics to analyze locational decisions. Applied to urban areas, it takes up urban issues such as crime, education, public transit, housing, land use restrictions, local labor markets, agglomeration economies, trade, transportation infrastructure, and local government finance. The early 1960s marked a watershed for the field. Alonso [8, 9], Mills [141] and Muth [148] introduced a theory of the internal structure of a city that rapidly became the workhorse for theorists and empirical researchers.

The new model took the classical concept of land rent from agricultural economics to the centre of modern urban analysis. It helped explain land prices, the built form of the city, and where people live relative to where they work using a logic analogous to Ricardo's theory of rent. Where Ricardo explained land rent partially in terms of the cost of transportation to market, which we illustrated with the story of the carter carrying farm products to market in Section 3.1.2. This new model applied a similar logic to explain the location value of homes in terms of how much commuters will pay to be close the jobs at the city centres.[1]

In this chapter, we will review the development of the core urban model and discuss how it uses urban land rent to explain urban size and structure.

4.1 The basic model

The model that allows us to link rent theory and financialization is often called the 'Alonso model', although it was developed by several scholars working in parallel in roughly the same period. William Alonso published *Location and Land Use* in 1964 [10] based on his 1960 PhD thesis [8], giving him a slender priority in the literature. Richard Muth's [147] and [146] were written roughly simultaneously with and independently of Alonso's thesis, and culminated in Muth's classic book, *Cities and Housing* [148].[2] The model was developed further by Muth [148] and Mills [141], and later formalized by Wheaton [205].[3] Mills' *Urban Economics* [142] followed soon after.

Bruckner [31] describes the resulting model as "a simple yet powerful model of urban spatial structure that successfully explains the principal regularities observed in the urban landscape," and goes on to say "the good predictive performance of the model suggests that its simplifications are artfully chosen, capturing the essential features of real-world cities." It remains the central model in modern urban economics.

[1] The model was quickly recognized as a conceptual twin of August von Thünern's 1826 agricultural planning model [199]. Von Thünern actually wrote down a version of the bid-rent equation 4.1.

[2] See "William Alonso, Richard Muth, 'Resources for the Future,' and the Founding of Urban Economics" [140] for a more detailed discussion of the development of the model.

[3] It is also called the Alonso model, the Alonso-Muth model, the Alonso-Muth-Mills model, the circular city model, and the monocentric city model. It is worth noting that Lowdon Wingo also had what appears to be a working paper, *Transportation and Urban Land* [208], for the organization Resources for the Future that presented core ideas and significantly influenced Muth [140].

4.2 From Ricardo's rent to Alonso's urban model

Alonso's model re-presents Ricardo's conception of rent mathematically for a different class structure and a different production technology. Ricardo had described a model with a central market for an agricultural product like potatoes. Producing potatoes took land, and transporting potatoes to market was costly. Because there is one market price for potatoes, land with low transportation costs near the central market earns a rent. More distant land has a lower value for farmers. In Alonso's model there is a central market and a single price for labour, producing labour takes land, and transporting labour to the market is costly. Rent emerges from the scarcity of space close to the labour market at the city core, just as in Ricardo it emerges from the scarcity of land near the market for potatoes and grains. The bid-rent curve is a simple formula for calculating how much extra people will pay or "bid" or pay to live at a particular location closer to employment.[4]

In the simplest version of the model:

1. (a) Workers are more productive in the city than in the rural economy.
   (b) Urban workers receive a wage premium related to their extra productivity.
2. (a) All urban workers must travel to the centre of the city to earn an income.
   (b) The city is located on a uniform plain.
   (c) The employment district takes no space.
   (d) Transportation, recreation and amenities take no space.
   (e) All workers face the same distance-based transportation cost.
   (f) All workers earn the same wage.
   (g) All workers require one unit of residential land.
   (h) Excluding differences in land prices, housing and living costs are the same for urban workers and for rural workers.
3. (a) Workers will only move to the city if the urban wage premium minus rent-plus-transport-cost leaves them at least as well off living in the city as in the country.
   (b) If the rent-plus-transport-cost is lower in any part of the city, more workers will move there, equalizing the rent-plus-transport-cost.

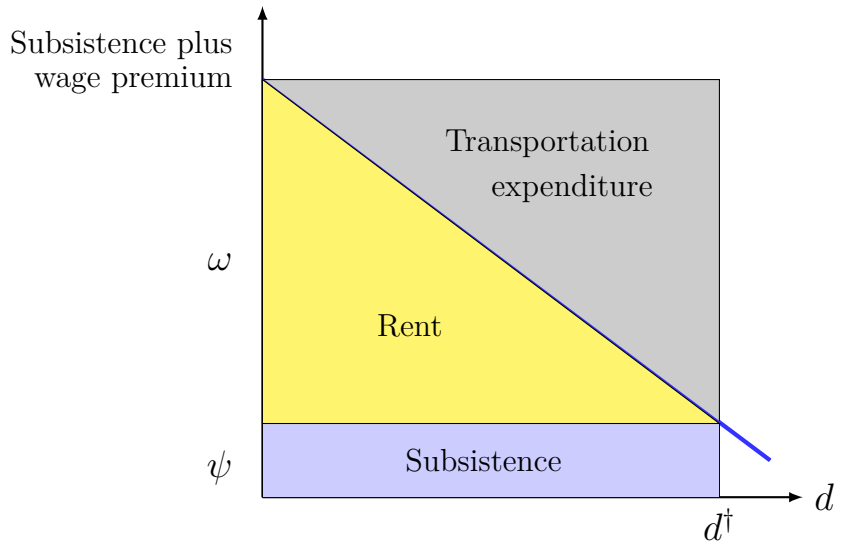


Figure 4.1: The allocation of worker income by distance from the centre of the city, where ψ represents the subsistence wage, which is the same as the rural income, and ω represents the urban wage premium, which is paid out of the increased urban productivity resulting from agglomeration, and $d^\dagger$ is the distance to the edge of the city, where rent per unit of land falls to zero.

Assumptions 1a and 1b are the economic basis of the city. Assumptions 2a to 2h are all convenient simplifications. None of these simplifying assumptions are essential and the model can easily be generalized. Assumptions 3a and 3b are behavioural assumptions that produce the characteristic population equilibrium of the model. There is a substantial body of work extending and varying each of the simplifications in the model as well as substantial work grounding and testing the model empirically.

Assumptions 2a to 2h allow us to construct a bid-rent curve that offers a way to calculate how much landlords can charge at a distance d from the centre of the city *given the wage premium and the transportation costs*.[5] This value, $\mathcal{R}$, is called the bid-rent because it is

[4]It is important to emphasize that the bid-rent curve describes locational value, not the cost of growing potatoes or building housing at any location.

[5]We are describing the simplest possible version of the model. Many excellent versions incorporate more complex spatial geography, multiple spillover effects, and other features—see for example [6] for an example and extensive references, but our focus is on the effects of financialization, so we use the minimal model to bring out effects that would be more difficult to disentangle in a more complex model. Qualitative results should be unaffected by this simplification.

the maximum mobile tenants would pay (bid) for the use of the property.

$$\mathcal{R} = \omega - dc, \tag{4.1}$$

where ω is the urban wage premium, d is the distance from work, and c is the transportation costs.[6] Equation 4.1 describes the downward-sloping line in Figure 4.1 that is known as the bid-rent curve. The figure shows bid-rent declining with distance from the centre and transportation expenditure (the area above the curve) rising.[7] The edge of the city is at $d^{\dagger} = \frac{\omega}{c}$ where $\mathcal{R}$ in Equation 4.1 falls to zero. Beyond $d^{\dagger}$ it costs a worker more to travel to work than the wage premium he or she would get. There is no urban locational surplus that could landlord could extract.[8]

The bid-rent curve[9] is the key to the Alonso model. It represents a special kind of economic equilibrium: a locational equilibrium among mobile households. Since individuals would simply move to any location that offered a higher utility, in an equilibrium all the otherwise identical workers must receive the same utility. This has to be the case even though those farther from the center must pay more for transportation to and from home. The variable that adjusts to maintain equal utility with rising transportation spending is the cost of land. This conception of a locational equilibrium is what underlies the bid-rent curve and all its extensions.[10]

The Alonzo model and all its descendants exploit the relationship between rent and location described in Equation 4.1 to explore the spatial structure of the city. Figure 4.1 illustrates the simplest case. We are looking at a thin slice of the city from the centre to its edge at $d^{\dagger}$. The vertical dimension is dollars of rent or transportation cost. Notice that rent and transportation cost at and distance sum to ω.

In Figure 4.1, the height of the yellow triangle (ω) is the wage premium for urban labour, and also the amount of land rent that can be charged for a property at the centre where transportation costs are zero. The entire yellow triangle is aggregate land rent generated

[6] Fuel, capital, and time costs are all included in the transportation costs, c. If the wage is paid monthly or annually, then c has to be the monthly or annual transportation cost.

[7] Property values at any point are the capitalized (present discounted) value of the stream of rent. Amenities, taxes and building values all modify the value calculation in more realistic cases.

[8] In many discussions of the model it is assumed that beyond $d^{\dagger}$ the best use of the land is for agriculture since it cannot earn an urban rent premium.

[9] The core concept behind the bid-rent curve was presented as early as 1885 by German engineer-economist Wilhelm Launhardt [28, 122]. A bid-rent function was first applied explicitly to the equilibrium of land use patterns in agricultural production by August Losch [130] in Germany and later by Edgar S. Dunn [64] in America.

[10] For economists it is also described as a Nash spatial equilibrium.

by the city along a section from the centre to the edge. The grey triangle represents the aggregate transportation expenditure by residents along a section from the centre to the edge. The entire rectangle, $\omega \times d^{\dagger}$, is the wage bill generated by urban agglomeration for the workers on the strip of land illustrated. Urban land rent is the residual when transport costs at d are deducted from the wage premium.

At the bottom of the figure, we add a 'subsistence wage' earned by a worker whether in the city or outside of the city. In most analyses of urban spaces, this living wage is simply ignored, since it is the wage premium that generates rents. The relative size is unimportant because it is the same for urban and non-urban workers. If urban consumption is higher than non-urban consumption it must come out of the land rent.

4.2.1 The magnitude of rents and transportation costs

From ω, c and population density we can derive population, wage bill, total rent, and transportation costs. The figure above suggests that half of the urban surplus is spent on transportation, but that is because the figure makes it appear that the city is stretched out in one dimension. If the city is circular, the total value of rents can be represented as a cone with radius $d^{\dagger}$, height ω and volume

$$V = \frac{1}{3}\pi d^{\dagger 2}\omega,$$

illustrated in Figure 4.2[11]. Since $d^{\dagger} = \omega/c$ we can substitute out either ω or $d^{\dagger}$ to show that total rent is proportional to the cube of either $d^{\dagger}$ or ω.[12]

The total value of wage payments appears as the volume of the cylinder enclosing the cone, $V = \pi d^{\dagger} 2\omega$, since the wage is the same for each unit of labour no matter where it resides. This is generally a fraction of the value of the city's agglomeration economies. Total transport costs are $\frac{2}{3}\pi d^{\dagger 2}\omega$. With uniform density, the population is proportional to the square of ω while rents and transportation costs are proportional to the cube.

4.2.2 Limitations of the basic model

The simple graphical model we consider above is revealing, but it leaves out many important features of the urban system. For one thing, the only costs included are the

[11] In our computational model the city is laid out on a grid. The volume representing total locational rent is then $V = \frac{2}{3}d^{\dagger 2}\omega$.

[12] Note that if the population density varies across the city the formula will involved integration and an function relating rent to density.

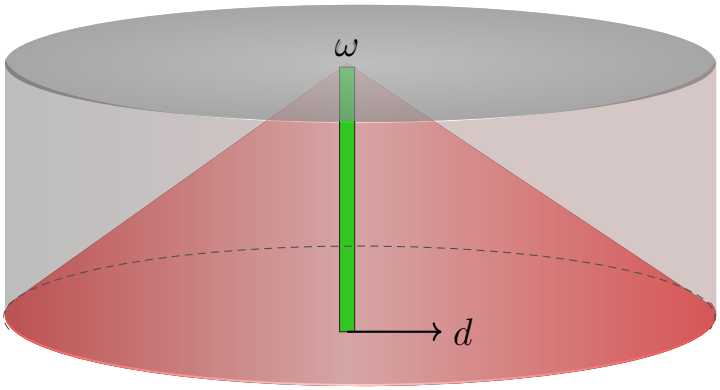


Figure 4.2: A three-dimensional version of the Alonso rent from Figure 4.1, representing the rents and transportation costs in the Alonso model of a circular city. The height is the wage premium ω and the radius, or distance, is $d = \omega/c$. The entire volume of the cylinder is the surplus income generated by agglomeration effects. The darker red cone is the amount that can be captured as locational rents.

transportation costs for the individual. Since urban services and a substantial fraction of urban amenities are financed through the public sector a more complete model must include both servicing costs and property taxation. The relevant rent profile from an economic point of view is net of all service costs. From a financial point of view, it is net of tax liabilities.

Its also worth noting that, since the Alonso model is a model of competitive real estate markets, its utility might vary substantially depending on the competitiveness of the market. In less-than-competitive markets, other factors may affect bid-rents significantly. Gao et al. [85], for example, found that for China, "other exogenous factors—including the distinct land system and centralized political institutions—also matter a great deal." In general, however, research has largely supported the bid-rent model [149, 206]. Muto [149], for example, concluded that, "land usage on average follows the rule that is consistent with the bid-rent function model: whichever usage outbids the others occupies the land." Borba and Dentinho concluded that "The method has proved its usefulness and effectiveness for predicting the impacts of exogenous shocks in complex urban systems." [30].

In a test for the city of Bogota, Gross [94] found that "the bid-rent model works reasonably well in its predictions and in its estimates of the demand for attributes and, in some ways, it may perform better than a hedonic-type model in forecasting the demand for housing attributes."

Clay and Valdez incorporate a bid-rent model into an integrated agent-based model (ABM) transportation-land use model that achieves levels of accuracy similar to the best models currently available. These are the microsimulation of UrbanSim;[13] and the bid-rent sub-module of the PECAS model[14] developed by Abraham and Hunt (2005), the best models currently available. They emphasise that the advantage of agent based models is allowing for agents to differ in composition and in preferences making them unique bidders. An earlier analysis by Curran and Carlson [52], among others, extended the bid-rent model to include two-worker households and a secondary employment location. They showed that households would be expected to segregate spatially, but the pattern will depend on the specific combination of wages, transport costs and the mix of household types in the populations.

The model as described above also says nothing about who gets the rent in the urban economy. Applications of the Alonzo model have typically not considered ownership and the distribution of rent. For classical economists, it was obvious that the agricultural rents went to the class of land-owners, as discussed in Chapter 3. For us it is a question to examine, since it depends on who owns the land, and land ownership in Canada is now widely held and available even to members of Ricardo's labouring classes.

Briefly, if workers own their homes, they are the landlords, and they capture the rents. If the home is mortgaged, the mortgage holder will be capturing a share of the locational rents. If on the other hand, urban workers are renting their homes, landlords will charge a premium for being closer to the center of the city where transportation costs are lower. To capture the phenomena then, an analysis of how the locational rent generated by urban agglomeration effects is distributed must consider at least tenants, owner-occupiers, owners of rental properties, and mortgage holders.

4.3 Summary

In this chapter, we have described a very stylized model to establish how the urban system generates rents. So far, however, applications of the bid rent model have not brought forward the distributional and class features derived by classical economists. To do that, we need three things: rent, space, and growth. We now have we have the rent and the

[13] UrbanSim is a micrcosimulation land use model, designed to support the need of Metropolitan Planning Organizations (MPOs), cities and other organizations in analyzing the potential effects of land use policies and infrastructure investments on the development and character of cities and regions [201].

[14] PECAS is HBA Specto Incorporated's commercial modeling system for simulating spatial economic systems.

urban spatial mechanism in place. We next have to add the growth mechanism that drives it. That is what the next chapter will develop.

Chapter 5

Theories of Growth and Urban Scaling

> Cities are the engines of economic growth (Jacobs, 1969; Bairoch, 1988). It is in cities that a large share of the innovations and entrepreneurship takes place that fosters economic growth in the long run.
>
> Johanna Palberg [154]

> If we postulate only the usual list of economic forces, cities should fly apart. The theory of production contains nothing to hold a city together.
>
> Robert E. Lucas Jr. [131]

In Chapter 4 we described a very stylized, very standard model of the urban system to show how cities generate locational rents. The model as it stands represents a static city, however, and a fundamental feature of cities is that they grow and when they grow they produce a growing stream of value that is available for capture. This growing stream of value is what is referred to in economics as growth. If financialization is the process of capturing a stream of value for financial actors, growth is the value available for capture in cities. To understand what's at stake in cities, we therefore have to incorporate growth

into our model. We're modelling how financialization captures the value created in cities. To show how it does this, we need a model of growth that can show how value is created and concentrated in cities.

In this chapter we introduce two approaches to understanding the mechanism of growth. These two theories come from very distinct literatures: one from neoclassical growth theory and the other from the newer research on scaling laws. Both are supported by substantial bodies of empirical research and they both rely on an overlapping set of ideas to explain their results, including notions of knowledge spillovers, network effects, and variants of specialization and human capital.

As it turns out, they lead to a common formulation that we will incorporate into the Alonzo model described in Chapter 4. Incorporating growth will complete the urban economy model we use to test our central hypotheses about the impact of financialization in the housing market.

Although they lead to essentially the same formal model at the level of generality we require for our model, the emphases and causal logics differ. One emphasizes processes in the industrial sector as drivers of growth, the other, associated with Jane Jacobs, emphasises mechanisms happening in cities as part of the urban system. Both arrive at an exponential model of growth, but the first comes to this through a focus on industrial and economic activity, while the second looks more at the ways cities serve to concentrate economic activity and social connections. The latter is the explanation most relevant to our work.

In *The Economy of Cities*, Jacobs [111] argued that cities are the primary drivers of economic development, and the mechanism that explains growth is the expansion of opportunities for sharing and creating ideas as population and population density increase. Jacob's argument is essentially that the density of cities produces an agglomeration effect that drives economic growth.[1] Robert E. Lucas, one of the leading pioneers of the neoclassical growth theory, argues that the Jacobs approach explains something essential about how cities create value that is not captured in accounts that don't centre the specific advantage of urban density:

> Her emphasis on the role of cities in economic growth stems from the observation that a city, economically, is like the nucleus of an atom: If we postulate only the usual list of economic forces, cities should fly apart. **The theory of production contains nothing to hold a city together (emphasis ours)**. A

[1] Glaeser et al. [88] refer to the Jacobs model as the Jacobs-Rosenberg-Bairoch [20, 170] model.

> city is simply a collection of factors of production—capital, people, and land—and land is always far cheaper outside cities than inside. Why don't capital and people move outside, combining themselves with cheaper land and thereby increasing profits? Of course, people like to live near shopping, and shops need to be located near their customers, but circular considerations of this kind explain only shopping centers, not cities. Cities are centered on wholesale trade and primary producers, and a theory that accounts for their existence has to explain why these producers are apparently choosing high rather than low-cost modes of operation. [131]

Lucas goes on to suggest that:

> "[t]he 'force' we need to postulate to account for the central role of cities in economic life is of exactly the same character as the 'external human capital' I have postulated as a force to account for certain features of aggregative development."

He concludes that if this is so "**. . . land rents should provide an indirect measure of this force (emphasis ours)**" [131].

Lucas' observation is important for our work because it implies that there should be a link between the Jacobs urban mode, which is based on urban agglomeration, the results of the neoclassical growth model operating at the level of nations, the scaling literature on cities and rent theory. We believe that the urban rent profile provides that link.

5.1 Cities and the scaling literature

There is another whole literature that has come to approximately the same conclusion as Jacobs and Lucas, uncovering a mass of empirical evidence that wealth scales with density and that the relationship is a power-law distribution with a remarkably consistent scaling factor.

Scaling analysis is a tool developed originally in complex systems science to investigate how extensive properties of the system vary with a system's size, or 'scale.' Our particular interest is in studies linking city population and economic output, but in urban science, it has been used in many studies of the relationships between urban population size and features like urban economic output, area, growth, traffic congestion costs, and even social

indicators like crime and homicide rates. These studies provide insight into how these processes are affected by the size of a city.

The scaling literature has developed the basic result of the form:

$$Y = AN^{\beta}. \tag{5.1}$$

In this example, Y is total value produced in a city and N is city population,[2] A is a baseline value and β relates the 'extensive property' N to the measure Y. Exponential relationships between input and output are so common across datasets that they've become known as scaling laws [204, 27, 25, 143, 89, 114, 129, 164].

Three general observations about urban scaling appear to be widely accepted:

1. Socioeconomic outputs like wealth, innovation, congestion, and number of homicides per year all scale superlinearly with the size of cities ($\beta > 1$) [89].
2. The relationship appears to have applied well back into pre-history [204], from the smallest human communities to modern megacities.
3. Scale effects derive from the capacity of people to interact, as Jacobs suggested [102].

These scale effects are the same as the agglomeration effects long discussed in the economics literature.

5.2 Agglomeration effects

The history of economic thinking about agglomeration effects goes back a long way, at least to Alfred Marshall in 1890 [136]. More recently, a large body of literature has demonstrated the existence of agglomeration economies in developed economies (see Rosenthal and Strange [171] for a review). Empirical support for the framework includes [182, 65, 66].

Our treatment of the urban surplus, which is central to this thesis, is illustrated in Figure 5.1. which illustrates how agglomerations might affect returns to scale in the aggregate. In the lower left, we illustrate a single firm with decreasing returns (DRS) to scale

[2] We follow the common convention in the scaling literature in using N for the population of the city. In the neoclassical growth literature we discuss below, L stands for the working population of a nation and, often a firm.

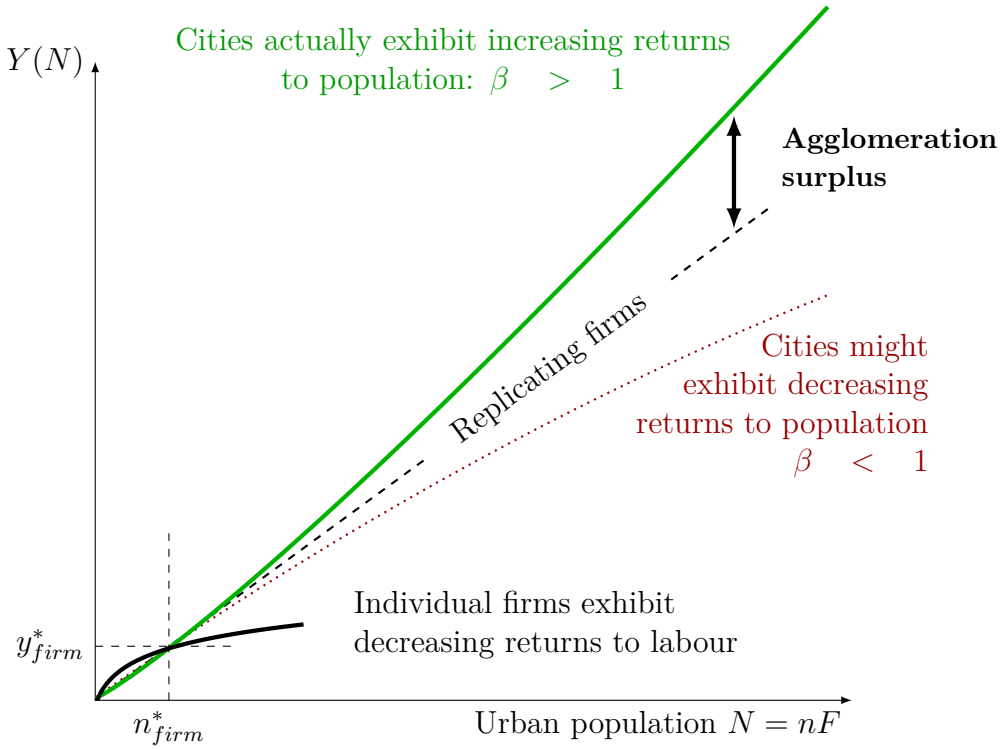


Figure 5.1: City output is Y and firm output is y. Both are specified on number of workers N and n respectively. Each individual firm exhibits decreasing returns to scale, with optimal labour force n^*_{firm} and output y^*_{firm}. Replicating optimal firms yields the dotted diagonal line showing constant returns to scale for the city. The city population as a whole exhibits increasing returns, however, as illustrated by the green line AN^β with exponent $\beta > 1$. Increasing returns produces an agglomeration surplus, $AN^\beta - Fy^*_{firm}$, where $F = \frac{N}{n^*_{firm}}$ is the number of optimal firms at N.

operating at its optimal scale, n. The thick diagonal line represents the effect of increasing the number of firms operating at the optimal scale. It is the constant returns (CRS) line. If congestion effects from bringing a large number of firms together were dominant, a city would exhibit decreasing returns to scale, N, and agglomeration would not occur. Research indicates that cities exhibit increasing returns to scale (IRS), illustrated by the upper line, which shows the city generating an increasing surplus as it grows. Even though there are other effects/phenomena, such as congestion as density increases that could theoretically result in cities exhibiting diminishing returns to scale, the evidence suggests that agglomeration effects dominate. The curvature of the line in Figure 5.1 is determined by

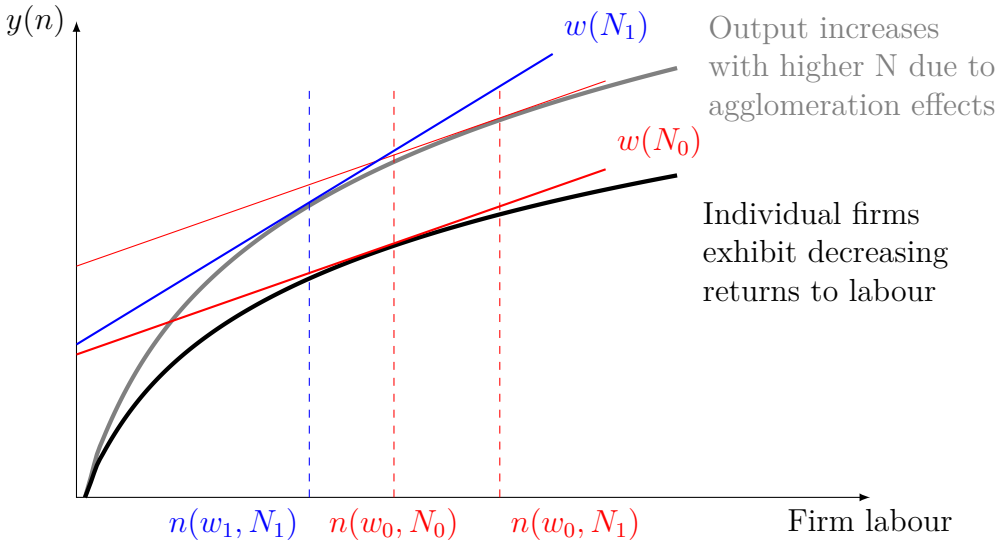


Figure 5.2: Increasing population from N_0 to N_1 raises the productivity of workers, shown as an upward shift of the original black production curve to the higher grey curve. The slope of the two red lines represents the initial wage. The firm selects a labour force at $n(w_0, N_0)$ where the marginal product of labour, the slope of the production curve, is equal to the slope of the red line. If the wage remained the same, firm labour demand would rise to $n(w_0, N_1)$, but the higher population requires a higher wage. If the wage rose to that shown by the blue line, firm employment would fall rather than rising as a result of higher labour productivity.

an overall function of the form N^γ, which we will introduce into the production function for urban firms.[3]

The empirical scaling laws is a feature of urban systems on average across many different contexts. Empirical work has found scale economies in the range of 3–8 percent (a 10 percent increase in the size of an activity in a city raises productivity in this activity by 0.3–0.8 percent). These agglomeration effects take place both within sectors (localization economies) and between sectors (urbanization economies), in developed and developing countries, a throughout different historical periods [26].

The effect of rising agglomeration effects for the firm in our model is ambiguous. Workers are more productive, leading firms to increase employment, but increasing the popula-

[3]The way N enters the firm production function appears to be different from the way it enters the scaling law. We explore the underlying identity below.

tion requires a higher wage, which negatively affects employment. The result depends quite sensitively on the specific parameterization. We illustrate the two effects in Figure 5.2. Fortunately, for our analysis we do not need to know how much population growth goes to existing firms and how much goes to an increase in the number of firms.

5.3 Neoclassical growth theories

Growth theory offers one of the most influential efforts to understand the wealth agglomeration effects established in the scaling and agglomeration literatures. Growth theory originally focused on identifying the dynamics of macroeconomic systems, and in particular with the implications for the growth of national income.[4] Early models [115, 99, 60] employ a macroeconomic savings function which usually has a fixed savings rate, with savings being reinvested in productive capital. Later models endogenize the savings-investment process.

The growth models, however, were not spatial models and necessarily abstracted from land rents and distribution. They have nothing to say about the distribution of city products and the effect that distribution might have on growth. When we focus on cities, however, it will become necessary to develop an analysis of city-level saving and investment. To do this we begin it the early Solow-Swan growth model, show how it develops into endogenous growth theory, and finally link the formulations of endogenous growth theory to the scale literature and Jacobs-style agglomeration effects.

5.3.1 The Solow-Swan growth model

In addition to not being a spatial model, urban growth theory had an important flaw. It did not completely explain the data. The approach taken to address that challenge offers parallels to how we can model urban agglomeration mechanisms. Existing models of production had described national output as a function of two factors, the national capital and labour stocks. Output should therefore have been completely determined by the growth of those stocks and nothing else. Productivity actually grew more over time

[4] A model of a national economy that uses the number of urban dwellers would probably track output just as well as one using the number employed as the mainline growth models do. As countries develop, cities account for an ever-increasing share of national populations and an ever-increasing share of national income. This is even more likely when we recall that the principle insights coming out of neoclassical growth theory point to human capital and education as the mystery factor in growth and cities are where the most skilled workers concentrate and where the strongest educational institutions tend to be.

than the increases in labour and capital stocks could explain if the production function was correct.

In 1956 Robert Solow [180] and Trevor Swan [188] addressed this gap in neoclassical production theory. Solow's paper in particular stimulated a whole literature in the 1960s and launched an entire subfield known as neoclassical growth theory.[5]

The Cobb-Douglas production function that is still widely used in neoclassical production theory had been estimated by Cobb and Douglas [48] as early as 1928. It had the form

$$Y = AK^{\alpha}L^{\beta},$$

where L represented the national labour stock, K the national capital stock and A a convenient scale factor. This Cobb-Douglas form captured important regularities in the cross-sectional national data.[6]

By the early 1950s, it was clear that estimated model parameters were underpredicting output when current levels of national capital and labour stocks were used. Something that was not captured in the initial model was changing over time. The obvious conclusion was that value of the the scale constant A was not constant, it was time-dependent

$$Y = A(t)K^{\alpha}L^{\beta}.$$

Solow and Swan proposed a way to extend the standard Cobb-Douglas production to explain rising productivity over time. Solow argued that "As a result of exogenous population growth the labour force increases at a constant relative rate" that we will represent by g:

$$L(t) = L_0 e^{gt}.$$

If we insert this term into the production function we get a scale term that depends on the changing population

$$\begin{aligned} Y &= AK^{\alpha}(L_0 e^{gt})^{\beta} \\ &= A(e^{gt})^{\beta}K^{\alpha}L^{\beta}, \end{aligned} \tag{5.2}$$

[5]Solow and his contemporaries, including Edward F. Denison [56], were attempting to account for the trajectory of U.S. GDP growth, not to provide a theory of economic development as later theorists were. The distinction, although it does not seem to be commonly drawn, is between quantitative change in the level of GDP and qualitative change resulting from innovation and structural transformations.

[6]The function remains the workhorse of growth theory, although later work has found models that perform better empirically. A 2021 meta-analysis of 3186 estimates concluded that "the weight of evidence accumulated in the empirical literature emphatically rejects the Cobb-Douglas specification" [86]. More sophisticated models such as the constant elasticity substitution (CES) and translog functions are now preferred for estimating production functions [116].

we see that $A(t)$ can be written

$$A(t) = Ce^{gt\beta}.$$

transformation provided the time-dependent term needed to allow the model to track the data better. The model is now known as the Solow-Swan model.

The Solow-Swan model correctly predicts the directions of savings and population growth, but not the magnitudes [134]. It successfully explained a good deal of the until-then-unexplained variation over time and between nations. More than half of the cross-country variation in income, for example, can be explained by differences in per capita saving (capital) and population growth alone. The estimated influences of saving and population growth with the Solow model appear too large, however. To understand the relationship between saving, population growth, and income, it was necessary to go beyond the Solow-Swan model.

In the Solow-Swan model growth in productivity is exogenous. By treating economic expansion as exogenously driven, neoclassical growth theory did not explain the underlying forces which determine the long-run development of nations. Robert E. Lucas [131] would observe that

> "[i]t seems to be universally agreed that the model ... is not a theory of economic development. ... while it is not exactly wrong to describe these differences (in GDP growth rates) by an exogenous, exponential term like A(t), neither is it useful to do so. We want a formalism that leads us to think about individual decisions to acquire knowledge and about the consequences of these decisions for productivity."

The models that followed Solow-Swan, starting with Arrow's 1962 model of 'learning by doing' [17], introduced human capital and learning in a variety of ways, thus 'endogenizing' the growth process. Arrow's dynamic interpretation of increasing returns was perhaps the first to render technological progress endogenous in a growth model.[7] Arrow used aggregate prior capital investment, K as a proxy for knowledge. The scale term A then becomes $A(K)$. Other proxies for learning were considered by various authors. [125, 177], including the amount of innovation by other firms and sectors [117]. Sheshinski and Levhari showed

[7] The version of how the field has developed that we present leaves out many who were engaged in and contributing to the evolution of growth theory. The introduction to Arrow's paper cites several. Spear and Young [181] provide a more inclusive overview. It seems clear that neoclassical growth theory was the result of a general ferment in the economic profession, not simply the product of a few pioneering individuals.

that Arrow's formulation was quite general and could incorporate a range of effects as well as different forms for the production function.

To understand growth theories based on human capital, sometimes called 'effective labour,' it is helpful to notice that Solow's formulation is unchanged if we substitute 'labour $\times$ skill' for L in his model. Both components of 'labour $\times$ skill,' or effective labour grow over time. Output then grows at the same rate as the effective labour supply. Mankiw, Romer and Weil [134] showed that Solow's model augmented by including human capital H fit the data better than the unamended Solow-Swan model. Their equation was, in our notation,

$$Y = A(t)K^{\alpha}H^{\gamma}L^{\beta},$$

where H^{γ} stand for human capital or skill. Notice that the term H^{γ} could be combined with L to give us effective labour, or incorporated into $A(t)$ as Arrow suggested. Mankiw, Romer and Weil assumed the exponents $\alpha+\gamma$ on the two forms of capital sum to less than one, which implies decreasing returns to all forms of capital taken together, but allowed $\alpha+\gamma+\beta > 1$ which implies increasing returns to scale when all factors are considered. The apparent effect of increasing labour supply and technological change could be, therefore, the combined effect of rising labour supply, technological change, and increasing labour skill and even agglomeration. Later studies would attempt to disentangle the four components.

Identifying plausible ways that human capital might affect development was relatively easy. However, the measurement of human capital presents great practical difficulties. To extract the implications of a particular path, it was also necessary to construct a tractable model, analyze its dynamic properties, and find proxy data to test the initial hypothesis. A series of papers did exactly that. It is important to note that these models all open the possibility that governments can promote growth through investment in education, research, technology transfer, and incentives for firms.

5.3.2 Endogenous (neoclassical) growth models

A new wave of research on economic growth was stimulated by Romer [169] and Lucas [131]. In their models, returns to scale are external to single economic agents and internal to a sector or larger parts of the economy. In other words, private decisions by firms or individuals may enhance the productivity of other firms or individuals. This insight is built into our urban models as a growth-enhancing effect of agglomeration.

Paul Romer's 1986 model, based on his 1983 thesis [169], describes 'learning by investment.' In this model, the increase in total factor productivity depends on firms' learning, or

investment specifically in knowledge accumulation through research, rather than output. He goes on to explicitly model the decision to invest in the production of knowledge. The production function for the firm can be written:

$$y = A(R_{total})R^{\gamma}K^{\alpha}L^{\beta},$$

where R is the research effort of the specific firm, and $R_{total} = \sum_i R_i$ is the total research in the industry. R is a choice variable for the firm, which is to say it decides how much to invest in research. The distinctive feature of this model is the spillover effect on all other firms of the firm's R&D investment. Economy-wide or total factor productivity is enhanced by individual firms investing in their own productivity. $A(R^T)$.

In 1988 Lucas also argued that technical progress is endogenous. He proposed a model that is close technically to the models of Arrow [17], Uzawa [197], and Romer [169]. Following our notation,

$$Y = A(H^e)K^{\alpha}(HeL)^{\beta}$$

where H^e is the economy's average level of skill (human capital). Improvements in skill in any firm will increase overall productivity. The compound term, HeL, can be understood as the 'effective' labour force of the firm, where L is the size of the workforce, H is the skill level of the workers that the firm hires, $1 - e$ is the fraction of worker time spent in training, and e, is the fraction of work time spent working.[8] More time training increase H but reduces e, so the firm faces a tradeoff between investing time in training and working in firms.

The difference between Romer-style and Lucas-style theories is that endogenous growth in the theory of Romer is caused by accumulating technology (or knowledge), which can be called social capital, while in Lucas it is through training, which increases human capital. Although Romer emphasizes the decisions made by firms and Lucas bases his theory mainly on decisions by households, both rely on the effects of human capital. In one case the 'spillover' that increases the productivity of all firms arises from firm investments, in the other it is the individual worker undergoing training to become more productive.

Thompson [190] summarizes the evidence supporting the existence of significant external learning spillovers in a variety of industries. From his survey we would call attention to studies spanning 20 years. Mansfield [135] found using survey data that information about new processes and products in ten industries surveyed had widely diffused within a year. Econometric studies also find significant spillovers: Irwin and Klenow [109] find them in

[8] A feature of this formulation is that e is a choice variable for the firm. It could as easily be a choice variable for workers in the aggregate model.

semiconductors; Thornton and Thompson [163] in wartime shipbuilding; Lieberman [137] in chemicals; Foster and Rosenzweig [79] in the adoption of high-yielding seed varieties; and Conley and Udry [192] in the adoption of best practices by Ghanaian pineapple farmers.

5.4 Jacobs-style agglomeration effects and the scaling law

Jane Jacobs' work, mentioned above, formulates an alternative but compatible explanation for the increasing productivity that growth theorists tried to explain. She argued that when people come together in cities they make each other more productive [111]. In her view the increase in productivity is a result of increasing communication and other network effects between people. If we take the relationship implicit in her work, and write it in the language of modern growth theory, we get:

$$y(t) = A_f(L_{total}, t)K^{\alpha}L^{\beta} \tag{5.3}$$

where the lowercase y indicates that Equation 5.3 is a **firm-level**, or micro-economic, formulation. The L_{total} in the function A_f gives the size of the total urban labour force or urban population.

We impose the standard neoclassical diminishing returns to scale[9] assumption on the Cobb-Douglas production function, i.e. that $\alpha + \beta < 1$. If we then sum across all F firms and assume that all firms are identical we get the **aggregate** urban production function:

$$Y(t) = A(L_{total}, t)\ F\ K^{\alpha}L^{\beta}. \tag{5.4}$$

If we use consider a fixed capital-labour ratio d as Arrow does, capital used by the firm is $K = d * L$ and Equation 5.4 becomes:

$$\begin{aligned} Y &= A(L_{total}, t)Fd^{\alpha}L^{\alpha}L^{\beta}) \\ &= A(L_{total}, t)Fd^{\alpha}L^{\alpha+\beta} \\ &= A(L_{total}, t)F^{1-\alpha-\beta}d^{\alpha}\ (FL)^{\alpha+\beta} \\ &= \bar{A}(L_{total}, t)(L_{total})^{\alpha+\beta}, \end{aligned} \tag{5.5}$$

where the multiplicative constants, $F^{1-\alpha-\beta}d^{\alpha}$, are incorporated into the scale factor $\bar{A}$.

If we now specify $\bar{A}$ in Equation 5.5 by

[9] $Y(\delta K, \delta L) < \delta Y(K, L)$.

1. assuming that the term L_{total} enters $\bar{A}(L_{total}, t)$ exponentially as in the scaling literature, say as L_{total}^{γ},
2. defining $Y_0 = FK(0)^{\alpha} L(0)^{\beta}$, and
3. allowing for additional time-dependent growth, e^{g*t},

we can write Equation 5.5 as:

$$Y_c = Y_0 e^{g*t} (L^T)^{\alpha+\beta+\gamma}. \tag{5.6}$$

This is the model commonly used in the scaling literature. We use it as the base for our market model.

Social Rates	**Exponent**	**Error**	**Nation**	**Observations**	**Data Year**	**Admin Unit**	**Reference**
GDP	1.13	[1.11, 1.15]	US	363	2006	MSA	Bettencourt (2013)
GDP	1.17	[1.11, 1.22]	EU	102		MA	Bettencourt & Lobo (2016)
GDP	1.22	[1.17, 1.27]	China	293	1996-2014	prefectural	Zund & Bettencourt (2019)
GDP	1.14	[0.98, 1.30]	India	22	2011	UAs	Sahasranaman & Bettencourt (2019)
Personal income	1.1	[1.03, 1.20]	Brazil	39	2010	MAs	Breisford et al. (2017)
Personal income	1.35	[1.19, 1.53]	South Africa	8	2001	MMs	Breisford et al. (2017)

Table 5.1: Observed scaling exponents for urban systems around the world. The exponent column is $\alpha + \beta + \gamma$ from Equation 5.6

(source: Bettencourt [26] table 3.1)

To achieve increasing returns at the urban level, it is necessary that the exponents not exceed one, $\gamma = \alpha + \beta + \delta > 1$. Empirical estimates summarized in Table 5.1 show that this condition is satisfied. These estimates provide a plausible parameter range for modelling.

5.4.1 Dynamics of the Alonzo model with Jacobs agglomeration

The increase in productivity at the firm level due to agglomeration is the force that drives the formation and growth of cities. In our model, the agglomeration-driven increases in productivity result in an urban wage premium. The urban wage premium attracts workers to the city and pays their transportation costs. The size of the wage premium determines the size of the city.

The urban economy modeled this way provides the foundation for our analysis of the urban housing market. We are not attempting to explain the specific process that gives rise to the wage premium: there is strong empirical evidence that it exists, and it is theoretically consistent with the explanations of the growth theories described above. We do need to point to how these agglomeration effects feed into the dynamics of the housing market.

Conventional microeconomic theory provides us with a rough sketch of the complex process that must occur as agglomeration effects grow. The process will generally be slow, variable, and may involve multiple unsynchronized lags. The basic process, however, is that a firm, discovering its workers are more productive than expected, enjoys unexpected output and profits. Unexpected profits in existing firms, due to agglomeration effects, will lead to new firms entering the industry. Since the marginal product of each worker is higher than expected, existing firms will want to hire more workers. To do so in a city with full employment, they must raise their wage offers. The increased wage attracts workers from other firms, putting pressure on them to also increase their wage, so wages rise across the city. The general increase in the wage attracts more workers to the city.

The increase in population will eventually generate additional agglomeration benefits, further increasing wages. At the aggregate level, this positive feedback appears to be solidly supported, but locally, within firms and between firms there will be long and variable lags. Analytical equilibrium models seek to bypass these messy processes, while agent-based models attempt to incorporate them.

Assuming that marginal land use per new resident is constant, the city diameter will eventually expand in proportion to the increase in the wage. Population increases in proportion to the square of the increase in diameter.

In our model, we connect this agglomeration with financialization through the housing market. The mechanism is that increased wage is translated, with further lags, into rising home prices across the city and rising rental prices for tenants. This means that landowners capture some of the gains due to agglomeration. Owner-occupiers retain the gain and eventually realize it as increased property values. Financialized owners claim it as rents, and can charge higher rental rates when there is more value to living in the city because of

agglomeration effects. This flow takes the value created in cities through any mechanism of agglomeration, and captures the flow for finance.

5.5 Summary

Growth theory, the agglomeration effects identified in Jane Jacob's work, and urban science's empirical work on scaling all produce the same equation. They come from different traditions, draw on different datasets and use different methodologies, but they get to the same place. In all cases, the reason super-linear scaling of productivity in cities is that the conditions in cities make people more productive. Cities bring people together where they can specialize, get more education, and learn from another. These are all essentially agglomeration effects.

Agglomeration effects are the third piece needed to build a model relating urban productivity and the financialization of the urban housing market. We build our model of the housing market on top of a model of the urban system that exhibits positive agglomeration effects. We model the agglomeration effects by embedding an urban scaling law to model how value is created in cities. The value created by the agglomeration effects are the value that financial actors can capture through the financialization of the housing market.

Chapter 6

Linking Financialization and Urban Productivity

> Alternative micro-foundations cannot be regarded as interchangeable contents for the black box . . . different micro-foundations have different welfare and policy implications.
>
> Duranton and Puga [67]

> A large body of literature documents the existence of agglomeration economies in developed economies ... The main conclusion of this literature is the finding of scale economies of 3–8 percent (that is, a 10 percent increase in the size of an activity in a city raises productivity in this activity by 0.3–0.8 percent).
>
> Gilles Duranton [65]

So far, we have introduced the concepts needed to model how productivity creates value that is captured by financialization. This chapter explores the possibility that there is a link going the other way, from financialization to productivity.

As established in Chapter 5, productivity scales superlinearly with population. However, there is substantial variation in productivity among regions. This makes it clear that

other factors influence the scaling effect. In this chapter, we explore the possibility that the capture of surplus value through financialization is one of the factors that can affect productivity. We first establish the empirical differences between regions, and then sketch possible channels through which financialization might drive a change in productivity.

6.1 Background

In general, the relationship between population and output at the urban level follows [129]:[1]

$$Y = AN^{\beta}, \qquad \beta > 1. \tag{6.1}$$

The equation expresses one of the most robust "stylized facts" in economics: output Y scales superlinearly with population N. We drew on neoclassical growth theory, in Chapter 5 on growth, to show that a version of this relationship can be derived from a standard neoclassical firm production function of the form, where y is firm output, k is firm capital, and n is the size of the firm workforce:

$$y = AN^{\gamma}k^{\alpha}n^{\beta}, \qquad \alpha + \beta < 1. \tag{6.2}$$

We use Equation 6.2 to model the production sector in our model. The model incorporates an agglomeration effect through both the prefactor A and the scaling exponent γ. We will use the model to explore how financialization enables capital to capture the surplus value produced in cities by agglomeration effects. This capture affects wealth distribution by shifting surplus value generated by the urban system from residents to owners of capital. This raises the question of whether this shift in resource flows may be driving some of the differences in the scaling of productivity between regions.

Substantial empirical research has revealed considerable variation in estimates of γ and A between regions. [139, 102, 160, 129] The World Bank (2016), for example, reported that every 1% growth in urban population correlates with an increase in GDP per capita by 13%, 10%, and 7% in India, China, and Thailand, respectively. Indonesia realizes only 4% GDP growth for every 1% increase [102]. McCoskey and Kao [139] also show that the impact of urbanization on growth varies greatly among countries. Interestingly the residuals or unexplained components for smaller cities are much larger than they are for

[1] We use β here because it is the most common form in the literature on urban agglomeration, although when we discuss firm production functions we use α and β for the coefficients on capital and labour as is most common in the economics literature. γ is an arbitrary choice for the exponent on aggregate labour in the firm's production function.

large cities, as Figure 6.1 from Lobo et all [129] illustrates. The literature [129, 160] has not yet settled on an explanation of the variation.[2] These considerations lead us to consider

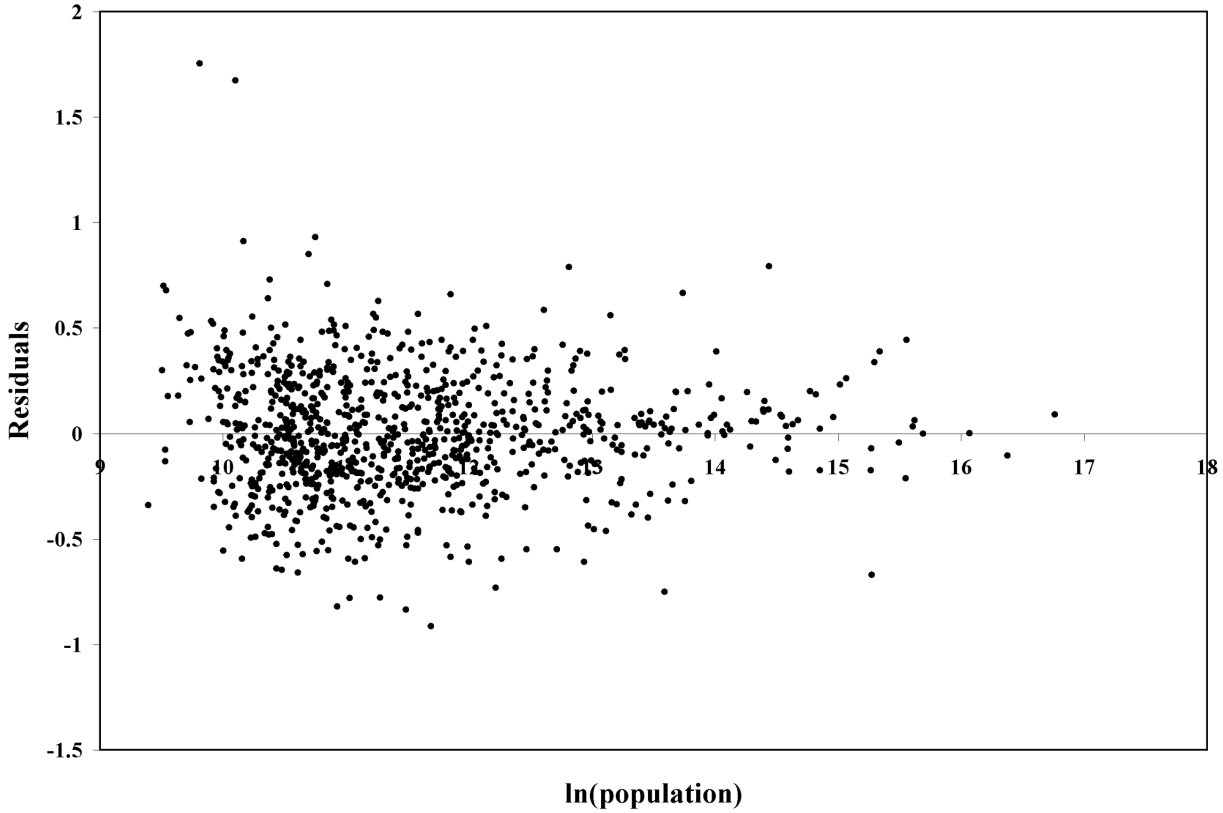


Figure 6.1: Residuals from regressing ln(total wages) on ln(population) using data for all 943 urban areas of the United States showing larger unexplained components for smaller cities [129].

the question: if financialization is redistributing the surplus generated by the growth of the urban system, could it also affect productivity of the city itself, explaining a portion of the variation identified in the scaling literature?

[2]The observation suggests that clues about the mechanisms may be found by examining smaller and mid-sized cities and that potential policy impacts may be greater for these cities.

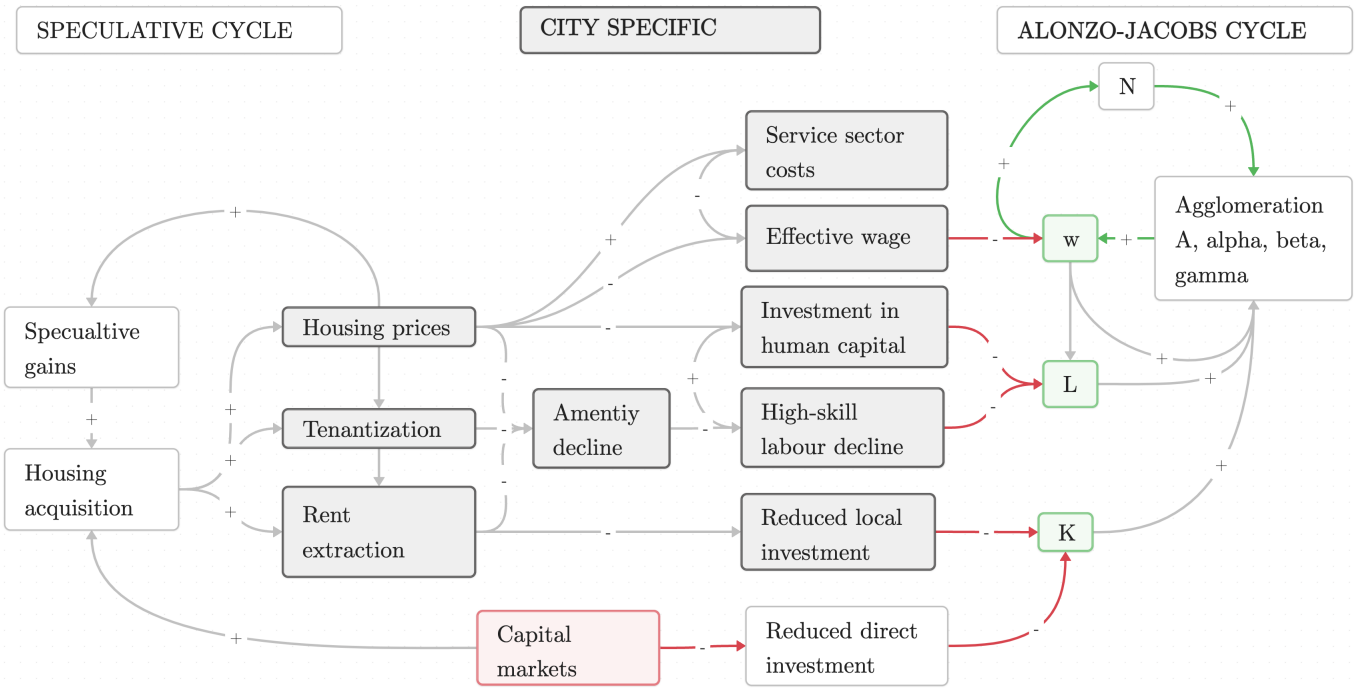


Figure 6.2: Impact channels relating financialization and urban productivity. The named processes on the left can only affect urban output through their direct or indirect effect on the variables of the Alonzo-Jacobs cycle on the right. These are the factors of production, labour L and capital K; the wage, w; and the agglomeration population, N. A, α, β, and γ are constants in the production function.

6.2 Channels through which financialization may affect productivity

There are multiple and variable channels that might link financialization to the magnitude of agglomeration effects in different regions. Figure 6.2 illustrates potential channels. In the figure, the production sector is on the right, the processes occurring within the city are central, and the speculative intervention in the housing market is to the left. In the upper right, we show the Alonzo-Jacobs cycle, described in Chapter 8. In the Alonzo-

Jacobs cycle, the strength of the agglomeration effect determines productivity, which in turn drives wages, which determines population which feeds back to agglomeration. In our model, anything that affects productivity must work through the parameters A, α, β, or γ or through factor supply. If any of the channels we describe below are significantly affected by financialization, governments may be able to increase social wealth and well-being through policy instruments at affect the level or impact of financialization.

The fairly preliminary typology we present below, is intended to establish that links between financialization and productivity should be explored. We believe that the arguments in this section do establish the plausibility of linkages, but have found relatively little research on how financialization might affect productivity, so there is little explicit empirical work on the linkages to draw on. If there is any effect at all, however, it would be significant since any negative effect on urban productivity can have significant consequences at the national level. Over 80% of Canadians live in urban centres. Two-thirds of the economic growth in Canada was generated in its six biggest metropolitan areas and about 80% of the growth comes from the urban areas in total [200]. Simply calculating values, a reduction of 1.5% in the productivity growth of these six large metropolitan areas alone would reduce the national growth rate by 1%. Over 40 years the loss would be equivalent to 33% of current GDP.

In this Chapter, we will describe the potential linkages between productivity and financialization and describe potential implementations for each linkage. In Chapter 10 on results, we implement a single aggregate linkage and show evidence from the model that the impact of these linkages would be substantial, suggesting that further research would be valuable.

6.2.1 Reduced capital stock

Theorists have argued that financialization diverts capital investment from productive investment to financial enterprises [123, 100, 101, 43]. If more capital is diverted, it does not go into investments that increase the productivity of firms over time like equipment, facilities, etc. This direct reduction in capital stocks is illustrated at the bottom of Figure 6.2, where capital markets can divert capital from the productive activities on the right to speculative activities on the left. Switching happens in response to the relative rates of return on the two sides. We have assumed a perfectly elastic supply of capital to firms and speculators. Extensions could model the effects of more complex and possibly more realistic capital markets. We allow the rate of return on housing investment to rise in response to city growth in the model, however, attracting speculative investment. We

could also simulate a falling rate of return on non-housing investment by reducing the cost of capital to investors or by inhibiting the rate of growth of capital on the production side in response to rising investment in housing purchases.

6.2.2 Local investment

Financialization may reduce the amount of local capital available, reducing investment in local activity. There are at least two mechanisms by which local investment capital may be affected. First, if increased tenantization and rent extraction reduce household wealth, we would expect household investment to decline. Second, this decline might be correlated with a decline in direct outside investment: when there is less money in a local economy, outside investors are less likely to see that economy as being as worthwhile an investment. This channel would act slowly and persist after an initial round of speculative activity as local housing is bought, and the money circulates in the economy.

The second mechanism arises because taxing residents funds public infrastructure and services that are inputs to private production. Public inputs are usually ignored in the theory of the firm, but should not be ignored in the theory of the city. The transportation network, for example, can usually be treated as an environmental constant, but transportation is a large sector and transportation costs may be a substantial share of firm costs. It is possible that with tenantization the city might face challenges in raising the tax revenue for spending on infrastructure, leading to a decline in overall productivity. The opposite might occur as well. Municipalities generally spend less on areas with tenants[3] and collect more tax revenue per capita from rental housing [24], so tenantization might lead to more money available for infrastructure expenditures.

We could capture these effects by linking the owner-occupier ratio to the capital stock. We might also introduce a political market in which tenants and owners vote according to their own interests. Owners gain from property value increases, while tenants do not, giving them different incentives for voting at the municipal level. A more detailed approach might make the share of municipal taxes allocated to increasing agglomeration effects depend on a voting rule.

[3]Municipality budgets consist largely of linear services and infrastructure. These are cheaper to provide in high density areas, which tend to be tenant areas and poorer areas of a municipality. As a result, these area tend to subsidize areas that are primarily owner-occupied.

6.2.3 High-skill labour decline

Rising housing prices and a market dominated by rentals may make a city less attractive to highly skilled labour, making it more difficult to attract people with the specific adaptive skills needed for productive activities. Slowing in-migration or increasing out-migration of the more skilled members of the labour force will *ceteris paribus* reduce the effective supply of labour. For example, Liu et al. [128] found for China that an increase in urban housing prices has a crowding-out effect on labour mobility. Duffy et al. [62] found that, for Ireland, rising house prices, by discouraging potential migrants, could significantly reduce the growth potential of the economy, shifting the balance of labour market growth from employment to wages, with a consequent deterioration in competitiveness.

The reduction in highly skilled labour might be offset by importing human capital though immigration or raising wages for talent in the city. Florida [74, 75] has suggested that urban growth is strongly linked to the ability to attract talent. There is also a possible counter effect as some of the investment in financialized buy up of land may go towards improving neighbourhoods to attract higher rents. While tenantization pushes skilled labour out of neighbourhoods, gentrification can pull it in. Gentrification can be seen as trend opposing tenantization. Cornelissen and Jang-Trettien [50] point out that tenantization, neighborhood decline, and disinvestment are more common than gentrification in low-income neighborhoods and are likely to produce the opposite of the effects of gentrification. Althobaiti et al. [11] show that with gentrification, high-skill workers move closer to the city center in response to the increase of median housing prices while low-skill physical skills moved further from the center.

In the model, we could introduce this channel by making the labour elasticity of output in the Cobb-Douglas function, β, depend on the home-ownership ratio. High home ownership correlates with high income and high education, two factors that influence individual productivity. Individual productivity is represented by β.

6.2.4 The effective wage

Lobo et al. [129] find the effective wage is one of the determinants of growth. The effective wage, also called the real wage is the wage corrected for changes in prices. If people have to pay more to live in the city at a given money wage as they do when rents rise, the effective wage has fallen. With a single sector as in our model, the level of wages and the level of rents are tightly linked. But what if some of the city population is producing services for the local population? That sector is unlikely to enjoy these same positive agglomeration

effects as the export sector does when the population grows. Rising rents would lower the effective wage for workers in that sector. The cost of living rises for everyone but wages fall behind for service workers.

In Figure 6.2 we can see that inflation, coming from the right side of the diagram may reduce the effective urban wage, although we do not show sectoral effects. General financialization may also reduce the bargaining power of labor, as Tomaskovic-Devey and Lin argue [193], reducing wages.[4]

6.2.5 The amenity channel

Urban amenities are part of the incentive for choosing city life, and a decline in amenity will have a similar qualitative effect on productivity as a decrease in the wage. If the effective wage of baristas declines, for instance, the supply of labour to coffee shops should decline. To compensate, the wages of baristas would have to rise. Some cafés could close and others raise prices to cover the higher cost of labour. Closing businesses directly reduces, but both closures and higher prices affects the amenity of other residents. Reduced amenity might then reduce the concentration of educated personnel by making urban living less attractive, reducing labour supply, or raising its cost. On the other hand, if developers compete for a limited number of higher income residents, they may compete to raise amenity along with costs in some neighbourhoods. If there are higher rents, or a larger share of taxes from increased tenantization, public investment in amenity could go up at least in the short term.

To explore the questions that arise with the introduction of amenity, we might introduce agents with different preferences and perhaps different skills. We might also explore the ways that amenity is produced—for instance though arts and entertainment, or the provision of things like parks and street maintenance by the city.

6.2.6 Impact on the service sector

Financialization may also have effects on the service sector that could feed back to affect productivity. The service sector is large. It makes up about two thirds to three quarters of

[4]Tomaskovic-Devey and Lin point to a shift in behaviour of non-finance firms away from production and non-financial services and toward financial investments and services. This shift, they argue, has led to lower employment, income transfers to executives and capital owners, and increased inequality among workers [193]

the Canadian economy and includes transportation, education, healthcare, construction, banking, communications, retail services, tourism, other government services, and 'non-material' activities or 'intangible goods.' The service sector includes everyone from the baristas mentioned above to real estate agents and university professors.

Financialization might have a number of potential impacts on productivity via the service sector. To consider one example, rising housing costs at the centre of a city may push low-wage service workers to the edges, producing a spatial sort by income. We'd expect to see particular impact on the personal service sector. Pushing service workers to the edge of the city might also increase their transportation costs, putting further downward pressure on their effective wages while increasing the costs of those amenity services that rely on lower-cost workers, and thus reducing the amenity and effective wage for other workers in the city.

We restrict our model to a single export industry in the base model. To explore the effect of financialization on the service sector, we would need to model specific subsectors. Because there are ages and income differences across the sectors we would also need to enrich our list of agent attributes.

6.2.7 Reduced investment in human capital

Finally, there may be impacts on productivity through the reduction of human capital. It is possible to grow a city's human capital by increasing how many workers there are, i.e. increase the labour supply, or by increasing their effectiveness by making workers more productive through training, education, etc. This means investment in human capital can grow the effective labour supply even without growing the total population.

Growth theory, discussed in Chapter 5, suggests that the growth of human capital is a major driver of productivity. Increasingly effective human capital increases returns to scale in the industrial sector and at the national level. Solaki [179] demonstrates a causal relationship between education and growth at the national level. Empirical results for Bangladesh [110] show evidence of bidirectional causality between education and growth, which means that means if there is lower education, there is lower growth. Among others, Büchler et al. [32] have recently confirmed the important of human capital growth for urban growth. Rising productivity due to increasing human capital would raise wages.

There are at least two mechanisms by which investment in human capital may be affected by financialization. The most direct is by reducing household incomes. Increasing housing prices increases the wealth of owner-occupiers which may result in, for instance,

increased spending on education for offspring.[5] Less directly, we suspect financialization will increase the cost of living through, for example, increasing labour costs in the service sector since it raises the cost of living and thus the wages people need to live in the city and work. Higher cost of living that may result in a reduction of the effective wage might also reduce income available for human capital investments.

We can simulate some human capital effects by making a link from the home-ownership ratio to the productivity parameters β and A. A more nuanced approach would be to introduce a training industry.

6.3 Summary

In this chapter, we have described a number of channels through financialization is likely to affect productivity. Our list is not complete but it provides theoretical grounds for testing the model's sensitivity to a range of policy interventions and lays the foundation for empirical work.

The dominant effect of financialization is to shift ownership of housing from occupiers to those who own financial capital. Understanding the mechanisms by which that might affect productivity has considerable policy importance because it raises the possibility that there are channels for public policy to enhance the positive effects of agglomeration.

In Chapter 8 we present a model in which we can systematically test the model's sensitivity to a range of policy interventions under the assumption that a link does exist. In the results section we will further explore, based on our analysis and simulations, how the impacts of financialization of the urban housing market may also have impact the economy as a whole. Although determining the relative importance impact channels is an empirical problem outside scope of this work, the model can suggest directions for future work.

[5] On the other hand, increased housing costs for tenants may result in reduced human capital investment. Glaeser and Saiz found evidence for skill upgrading in declining cities, which suggested to them efficient investment in less skilled workers is a key adaptive/growth mechanism. If powerful enough, this effect might offset some of the negative impacts of financialization we have suggested.

Part II

Model and Results

Chapter 7

Methodology

> The choice, then, is not whether to build models; it's whether to build explicit ones.
>
> Joshua M. Epstein [69]

So far, we have introduced the theoretical frameworks for understanding locational value, the structure of the city and how productivity scales with wealth. In the following chapters, we introduce a model that brings these together to explore the effects of financialization on the urban system. In this chapter, we consider some of the broader methodological issues involved. Section 7.1 considers the general purpose and strategy of modelling. Section 7.2 explains what type of model we use and why, describing how we integrate agent-based modelling and equilibrium approaches in the model.

7.1 Purpose and strategy

The purpose of the model is its goal, and the strategy is the means by which it seeks to achieve its goal. To define our purpose and strategy, we are guided by the guidelines laid out by Mader et al. for the properties of a good model [132]. They argue that a model should be:

1. Truthful. The model has to represent the relevant behaviour of the system.
2. Complete. It must include necessary features of the system.

3. Simple. It must be possible to verify and debug the model.
4. Understandable. Elements should be clearly described or derived and documented.
5. Traceable. It should be obvious what elements of the artifact went into which design decision and are reflected at which point in the model.
6. And finally, efficiently constructable and maintainable.

Frits Vaandrager augments their list to produce the following.[1] A good model:

1. has a clearly specified object of modelling;
2. has a clearly specified purpose;
3. is traceable: each structural element of a model either (1) corresponds to an aspect of the object of modelling, or (2) encodes some implicit domain knowledge, or (3) encodes some additional assumption;
4. is truthful: relevant properties of the model should also hold for the object of modelling;
5. is simple (but not too simple);
6. is extensible and reusable;
7. has been designed and encoded for interoperability and sharing of semantics.

These principles inform the purpose and strategy of our model.

7.1.1 Model purpose

Edmonds et al. lay out seven purposes of modelling [68]. These range from prediction of new data and explanation of patterns in the world, to analogy that merely illustrates some phenomena informally. One of the purposes they identify is theoretical exposition, which means the purpose is to explore the relationships between variables in the model. This is the purpose of our model. While it would require further empirical work to make specific claims about the outside world, the model can illustrate relationships and give insight into the implications of theory.

[1] Vaandrager's useful list appears on his faculty webpage at the Institute for Computing and Information Sciences, Raboud University http://www.cs.ru.nl/~fvaan/PV/what_is_a_good_model.html.

7.1.2 Model strategy

A common approach to strategy is to follow principles or rules of thumb suited to the purpose of the model. A model designed for theoretical exposition is built to illustrate the implications of theory, not to establish that theory applies in any given situation beyond the model. Our strategy thus has two aspects. Firstly, to understand the implications of theory, we remove elements that are not central to understanding the central theoretical questions. Secondly, since we are not attempting to make predictions, we focus on patterns and qualitative relationships rather than quantitative values. Our strategy is thus to keep the model simple and descriptive. Edmonds et al. use the acronyms KISS, 'keep it simple stupid,' and KIDS, 'keep it descriptive stupid' [68].

We intentionally leave features out of our model to focus attention on the features that matter most to understanding how financialization captures the value produced in cities. We have two basic propositions:

1. Financialization of the urban housing stock extracts wealth produced by urban agglomeration effects.
2. Financialization of the urban housing stock can limit urban productivity growth.

In considering whether to add a feature to the model, we ask:

1. Is it necessary to demonstrate the principle?
2. Would incorporating it result in falsifying our result?
3. Would incorporating it result in a qualitative difference in our result?
4. Would incorporating it result in clarifying our result?

For example, we need to model how firms set the urban wage and how land markets distribute surplus value to understand the relationship between financialization and the housing market. However, while varying housing density across our model urban system is technically straightforward, it is not necessary to explore or demonstrate any of our two propositions. Including density variation would not undermine our results nor clarify them. We can say the same about other extensions discussed in Chapter 11 on future work. Those extensions are interesting and would add fine-grained detail to our understanding of how the effects of the financialization of the housing market are distributed, but none of them are essential to exploring the basic relationship.

7.2 Types of models

We combine two distinct approaches to modelling social systems: agent-based techniques and equilibrium reasoning. Where agent-based models describe behaviours and observe the outcome of the behaviours computationally, most economic modelling is built around equilibrium conditions that are identified *a priori*. Agent-based modelling and equilibrium analysis are complementary, however, and we employ both. We combine a spatially explicit agent-based land market model with equilibrium assumptions about rent levels and an equation-based model of urban production. We employ equilibrium arguments to get clear inputs for the ABM from the peripheral models, where there is a great deal of existing theory about how that part of the system should behave.[2]

7.2.1 Agent-based modelling

Agent-based models employ populations of simple submodels (automata, or agents) [176]. They are part of a wide class of models that incorporate the behaviour of distinct entities and explore the interactions among them. The approach was developed in the 1940's when von Neumann and Ulam introduced cellular automata, a simple form of agent model where agents are typically squares on a grid following rules based only on the state of their neighbours [21].

ABMs have proven effective across a range of domains. Examples of ABMs range from models of Bali's traditional economic and social structure, delays in traffic flow, economic bubbles, traditional foraging patterns, social segregation, and ecological succession networks, to patterns of poverty and crime [152]. Recent results from disciplines including physics, biology, anthropology, and economics have built a record of useful empirical results [155, 156, 104]. These have shown ABMs reliably produce phenomena through simulation that were difficult if not impossible to derive from simpler analytical/closed-form expressions.

In an ABM, agents are defined as having adjustment rules or behaviours that respond to environmental variables.[3] Unlike equilibrium approaches common in economic analysis,

[2]Combining agent-based models with components represented as systems of equations is an established approach to modelling:"...in an agent model, physical subsystems can be represented naturally using systems of differential equations (e.g. climate, energy, etc.) (Chappin, Dijkema and Vries, 2010; Chappin and Dijkema, 2009; Davis et al., 2009; Nikolic, 2009)" ([41] p 61).

[3]Modelling agents with agents are defined as having adjustment rules and behaviours has a long history in economic, going back to the 1838 Cournot duopoly model [51], for example, which is analyzed using

agent-based modelling commits to using computational methods to mimic the distributed decision-making of complex systems like cities. A program is written that considers each agent sequentially and updates agent and system states as it goes. The program is allowed to iterate, and the values of any state variables of interest are recorded at each step. The model may or may not settle into a steady state. As with other modelling approaches, ABMs can be used explore the behaviour of the system by varying individual parameters, and to explore the parameter space using Monte Carlo methods.

One advantage of beginning with an agent-based model is that we are not imposing linearity, or *a-priori* distributions on the behaviour of agents. In an ABM, agents do not make exactly the same decision at exactly the same time. Decisions and timing depend on the speed of information flows, proximities, and other factors. As a result, suites of agents behave differently than the "representative agents" typical in economic models [54, 189]. By including individuals explicitly, agent-based models offer nuance in exploring the effects of individuals on a system, and the make it possible to study distributional effects, space, and individual differences in a much richer way. The structures that emerge result from assumptions about the decisions of those in the system rather than from assumptions about the behaviour of the system. Agent-based models thus may reveal non-obvious implications of structural changes in particular locations, for particular individuals [54, 97].

A challenge with ABMs is that they can be hard to extract meaningful information from. ABMs can be computationally intensive, raising significant problems for analysis since there is so much happening in them. This can make them difficult to use in a practical context [21]. Their complexity is also their strength, however. An advantage is that agent-based models represent the structure of individuals interacting in social systems. They thus make it possible to look at the structural impact of interventions on particular individuals and in particular contexts. This makes agent-based modelling particularly relevant for policymakers because the can provide a more accurate picture of the whole systems policymakers would be working in.

7.2.2 Equilibrium reasoning

Economists rely heavily on equilibrium analysis in their study of systems. Under the equilibrium approach, a set of necessary conditions describing the steady state of interest are imposed. This approach produces tractable models that can often be solved explicitly. It bypasses the often intractable and complex process of adjustment, focusing on the

'reaction functions' which simply describe a firm's optimal response to a second firm's output choice. In Cournot's simple case an equilibrium can be directly computed.

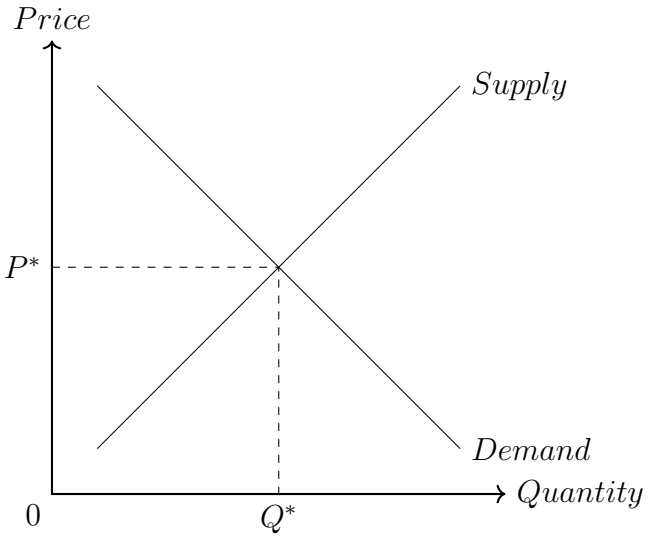


Figure 7.1: Supply and demand.

conditions that must be true if a particular situation is to persist. This tractability was particularly important before computers became widespread.

The most familiar example of an equilibrium model is the ubiquitous supply and demand model. A supply and demand model consists of two curves, each describing a functional relationship between two variables, price and quantity. Each curve represents the preferences of a class of agents, and the model explores the combinations that satisfy the behavioural intentions of both classes i.e. are on both curves. The demand curve, illustrated in Figure 7.1 visually represents the quantity of a product demanded by potential buyers at each price. The supply curve is the quantity that suppliers would be willing to sell at each price. Equilibrium, in this example at the combination (Q^*, P^*), refers to a state in which the preferences of both agent classes are satisfied. A situation is unlikely to persist if either class of agents is unsatisfied with the combination of price and quantity. The question at the heart of the equilibrium approach is, "What conditions are necessary if the situation is to be stable?" In the case of supply and demand, The quantity supplied must equal the quantity demanded, and the price must be the same for both classes.[4] If the two curves can be described mathematically, equilibrium prices and quantities can be derived by solving the two-equation system.

[4]Taxes introduce an additional condition that results in different prices for the two sides.

7.2.3 Where we use agent-based models and equilibrium reasoning

We use an agent-based model for the core model of the process of financialization, where we need to understand individual behaviour and distributional effects. The agent-based model allows us to explore how patterns of distribution emerge within a spatial system with many agents.

We use equilibrium approaches to model urban production. There are two reasons for this choice. First, firms can generally adjust much more quickly than the housing market, so it is reasonable to assume that the quickly adjusting variables like price and employment are close to equilibrium values. Second, we want to drive the central process with a sub-model that is well understood to ensure that results can be explained easily. Nothing prevents us from replacing the sub-model with one with long lags or a different theory of firm behaviour.

Our model of firm behaviour uses a single representative firm to determine the wage. This approach does not explicitly model multiple interacting firms but using equilibrium reasoning here has the advantage of simplicity and being among the most common approaches to modelling production. We sacrifice some complexity in this part but the model of production is less central to our model and we get the advantage of connecting the work with standard work on theory of the firm using simple, well-understood models. Using a representative firm allows us to focus on the relationship between the scaling of urban productivity and the financialized ownership that can extract that value, which is the core conceptual contribution of this work.

There is no loss of generality in using a single firm: we are not interested in the structure of the production sector. Because our focus is financialization in the land market, we only require that wages and employment behave as economic theory tells us they should. Our representative firm is a neoclassical profit-maximizer, adjusting employment and capital stock in every period toward the optimal quantities according to the marginalist rules for maximizing profit. The model is fully extensible and future implementations could replace the equilibrium model of representative firms with a larger agent-based model of interacting firms. Our overall model is sufficiently modular to plug in a different production sector, perhaps to introduce agents or to link to a model developed elsewhere.

By integrating the agent-based land market model, the equilibrium assumption about rent and the equation-based model of urban production, three pieces which are traditionally studied separately, this work combines elements of classical rent theory and neoclassical distribution theory with agent-based modelling.

7.3 Summary

In this chapter, we have made our solutions to certain high-level modelling questions explicit. We have explained our purpose and strategy in building the model. We then described the type of modelling used for each piece, the use of agents and the role of equilibrium analysis. In our case, the purpose of the model is theoretical exposition and we describe our strategy as an attempt to make a model that is simple, extensible, and reusable, while meeting rigorous criteria for good modelling practice.

The model type is a blend of agent-based and equilibrium modelling. In integrating models of the firm, the urban spatial system, the housing market and the financial system, this work combines elements of classical rent theory and neoclassical distribution theory with agent-based modelling. We have a spatially explicit agent-based land market model, an equilibrium urban rent model, a neoclassical equation-based model of urban production, and a rule-based mortgage provision system.

The work thus draws on a variety of methodologies. We have at each point grounded modelling decisions in established theory and eliminated elements that would add unnecessary complexity, while focusing on building an extensible model that illustrates the relationship between urban production and the capture of rent through land markets.

Chapter 8

Model

> One of the very important components in the urban and agricultural land use model is the so-called bid-rent curve. Regional and urban economists, city planners, and economic geographers have used this curve extensively as an analytical device.
>
> Yeung-Nan Shieh [178]

In this thesis we describe an agent-based spatial model of an urban housing market that includes a production function modelling how urban regions generate wealth and an explicitly financialized housing market. Where previous chapters discussed the general principles that underlie our theoretical model, this chapter presents details about the how the variables in the computational model are defined. The next chapter, Chapter 9 introduces the details of the agent based model.

Our goal has been to make an accessible model that can provide insights about the impact of the financialization of the housing market on urban productivity and wealth distribution. The model has three major blocks:

1. We incorporate the spatial structure of the city and its transportation system using a version of the bid-rent function that drives all Alonso-style models. This equation is embedded in the decision of every agent because it determines the economic rent for each piece of property.

2. We incorporate the fundamental wealth production process of the city using an urban scaling law that captures Jacobs-style agglomeration effects. This allows us to bypass

the complexities of labour and goods market adjustments and instead to deal with the underlying long-term relationship between city population and production. We call the combination of this Jacob agglomeration effect with the Alonso model an Alonso-Jacobs model. Our agent-based model, in effect, mimics two difference equations, operating on two aggregate variables, and incorporating the major insight of a half-century of neoclassical growth theory.

3. To link the Alonso-Jacobs model to the financial system, we develop an overlapping generations model of the housing market with borrowers and lenders that tracks ownership and wealth. This turns out to be the most detailed and computationally intensive part of the model. To model the effects financializing housing in our agent-based model we are forced to carefully specify the microeconomics of individual decisions. We therefore describe the microeconomic objective function that individuals and our bank agent employ in deciding to purchase a property.

In addition to the main blocks, to explore the potential effect of financialization on urban productivity

> We introduce an investment link from housing ownership to the urban production firm's production function.

The figure above shows the model logic. The following three sections will discuss each of the three primary components, the spatial structure, the productivity mechanism, and the housing market in order. To focus the model on the core questions of the relationship between urban productivity and rent, we keep the first two components, the spatial structure and the growth mechanism, as simple as possible, modelling the market for housing in more detail.

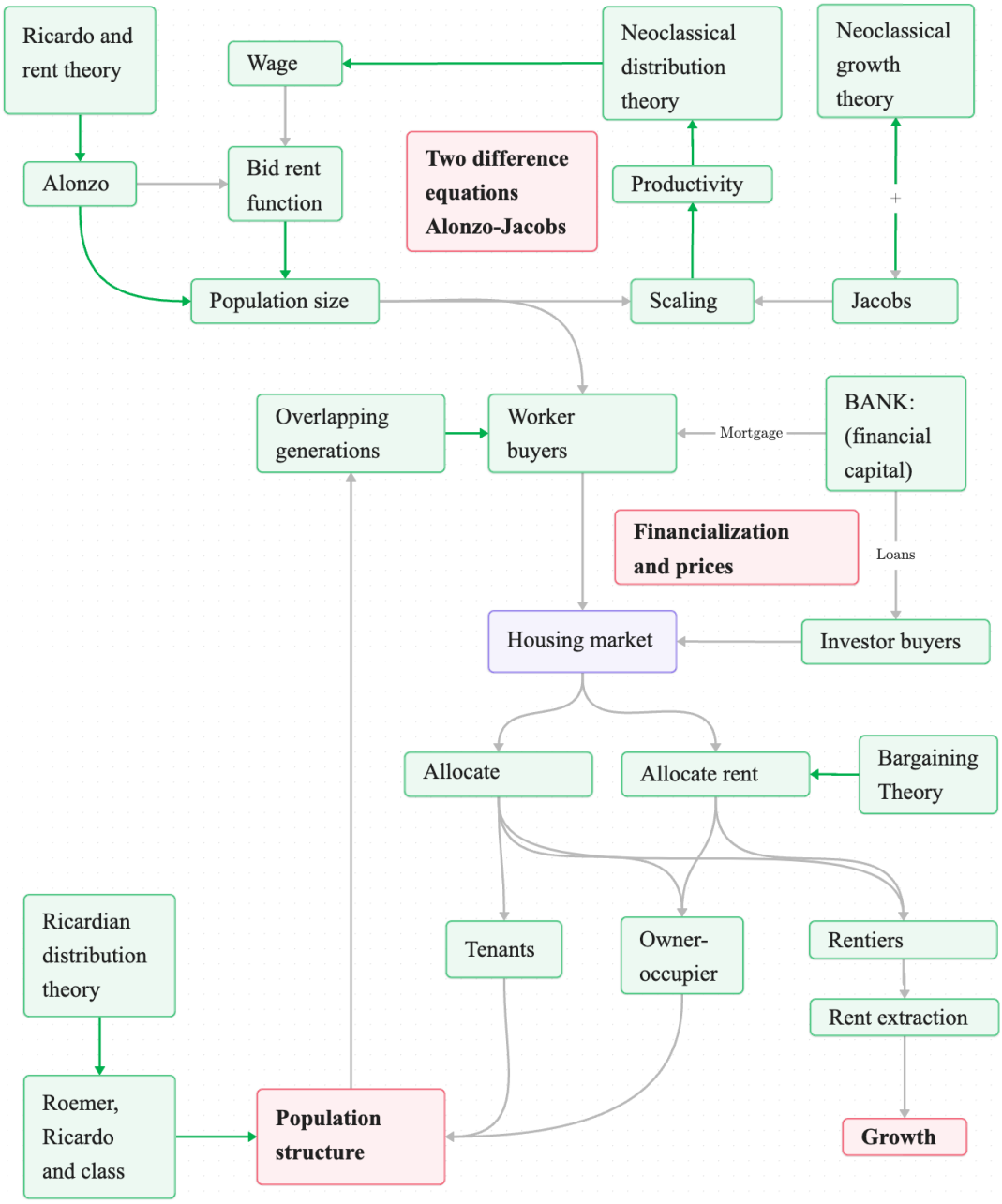


Figure 8.1: Model logic.

8.1 Spatial structure

We begin with a model of a circular city.[1] In the Alonso model [9, 10], firms are located at the centre of a circular city, the central business district. Residents live distributed across space, can take jobs, and commute to work at the urban center.

Firms produce perfectly substitutable goods that they sell into a commodity market. Demand for the product is perfectly elastic, so the price remains constant. Firms purchase the time of workers. With the neoclassical model of distribution,[2] workers receive the value of their marginal product. Because of agglomeration effects, workers in the city are more productive than workers in the countryside. They therefore receive an urban wage premium.

As in the Alonso model, described in Chapter 4. The urban wage premium and transportation costs together determine both the radius of the circular city and the size of the labour force, since agents work if the wage premium is greater than the cost of travel. The higher the wage, the farther workers will commute. The farthest that workers will travel is $\frac{w}{c}$, where c is the cost of transportation per unit distance. This defines the radius of the city and the commuter shed.

The urban labour supply is an aggregate measure that emerges from individual agents' choice to commute. Considering a standard, Alonzo-style circular city with a uniform lot size, s, and one worker per unit land. For illustrative purposes, the labour available, N, is simply the area of the circle divided by the lot size

$$N = \frac{\pi}{s}\left(\frac{w}{c}\right)^2, \tag{8.1}$$

where ω is the wage premium, c is the cost of transportation, and s is lot size (land per person).[3] This is the equilibrium urban labour supply function for the circular city. For a city with an idealized rectangular grid of streets, the city shape is rectangular rather than circular and the labour supply function is

$$N = \frac{2}{s}\left(\frac{w}{c}\right)^2.$$

[1] In our computational model we use a grid structure with a block metric, which is computationally more convenient and provides a slightly more natural representation of the property structure of actual cities.

[2] Clark's neoclassical assumption is that workers receive the value of their marginal product [46].

[3] The formula is for the case with a uniform density of one worker per lot. In the computation model density is a variable.

8.2 Agglomeration and productivity

The agglomeration effect that augments the productivity of workers means firms produce more goods with a given stock of labour if the city is larger and urban workers are more productive. Figure 5.1 in Chapter 5 illustrates the increasing returns to urban size. These increasing returns mean that urban firms can pay a premium that depends on, among other things, the size of the city. Because workers face transportation costs, firms have to pay this premium to attract workers.

To focus the model on urban productivity and the growing urban wage premium, we model workers as receiving a subsistence wage ψ in the countryside.[4] This subsistence wage could come from work in the local community, living off the land, family support, social support, or something else. Urban workers give up the subsistence income and receive the urban wage, $\psi + \omega$, the subsistence wage plus the urban wage premium that firms pay to attract workers.

8.2.1 Wage determination

According to neoclassical distribution theory, the firm maximizes profit by setting the marginal value of the product of each factor of production equal to the unit cost per factor. If we calculate the physical marginal product of labour for the Cobb-Douglas with the Jacobs externality $A(L^T)$ from Equation 5.3, we get

$$\begin{aligned} y =& A(L^T)k^{\alpha}n^{\beta} \\ \frac{\partial y}{\partial L} =& \beta A(L^T)k(t)^{\alpha}n^{\beta-1} \\ =& \frac{\beta A(L^T)k(t)^{\alpha}n^{\beta}}{n} \\ =& \frac{\beta y}{n}. \end{aligned} \tag{8.2}$$

This is clearly positive and increasing in L^T, the aggregate labour force for the city. It follows that population growth increases marginal product in this model.

Since optimizing firms are assumed to adjust their wage offer and hiring to achieve a

[4] Classical economists employed the subsistence wage assumption to simplify their analysis in a similar way.

wage that is equal to the marginal **value** product of labour

$$\omega + \psi = P_y \frac{\beta y}{n}. \tag{8.3}$$

where P_y is the price of output. We assume the price of output is constant and will treat it as \$1 per unit output for the rest of the chapter. As a result, the wage increases, perhaps with a lag, when urban population rises

$$\frac{\partial(\omega + \psi)}{\partial L^T} > 0. \tag{8.4}$$

In our model the subsistence wage ψ is fixed, so the wage premium must rise if the marginal product of labour rises. We have shown that a rising wage premium increases the distance that workers will travel to work, so the city grows and population rises, as the upper loop in Figure 8.1 illustrates.

Equation 8.3 is an equilibrium condition for the firm. Firms, however, are agents setting wages and hiring while labour supply and demand are shifting. We assume that they do know the marginal product of their current workforce and can observe the wage level from period to period. It is reasonable to assume that when their marginal product of labour rises they adjust both their labour demand and their wage offers. The marginal product of labour can be seen as a target wage. Equation 8.3 implies that the firm's target labour demand is

$$n = \frac{\beta y}{\omega + \psi}. \tag{8.5}$$

It is reasonable to assume that the wage premium ω and the size of the firm's workforce n both adjust slowly toward target values in each period.[5] We also allow the number of firms to adjust gradually.[6]

8.3 Housing market

In this section, we describe the housing market sub-model model. We have emphasized that urban properties generate economic surpluses that give rise to land rents. We therefore

[5]The analytic model offers an equilibrium solution with full employment. The assumption of full employment is unrealistic. Workers are laid off, and take time to find new employment. The time people spend moving between jobs causes frictional unemployment which varies with economic conditions. Partial adjustment by agents allows for frictional unemployment in our model, although we do not treat it explicitly.

[6]We have assumed that the firm does not notice that, by hiring, it increases the agglomeration effect for the city. This assumption is convenient as well as plausible since it removes a term, $\frac{F\gamma y}{N} = \frac{\gamma y}{n}$, that is both small and very hard to observe.

explicitly discuss land rents and their relationship to prices. In subsection 8.3.1 we begin by describing the stream of benefits that a property generates, including locational services, housing services and other amenities. We describe the variables involved in calculating the value of a property based on these services. We term this the warranted rent. Then in Subsection 8.3.2 we describe a simple model of the costs of providing housing to get a net value.

Because participation in the housing market depends on financing, in subsection 8.3.3 we look in detail at the on mortgage availability. We distinguish economic benefits arising from the services provided by a property from the financial gains that ownership might provide, so in subsection 8.3.4 we model value from the point view of an investor or non-resident owner and develop what we call a maximum bid price. The subsection 8.3.7 derives specific bid and reservation prices for different agents. Agents' maximum bid prices are used the bargaining model in subsection 8.3.8 to determine the market prices for each property.

The explicit treatment of rents, prices, and productivity premium and use of the subsistence wage as an analytical device make this a 'classical' model despite its reliance on supply and demand to set prices. To develop the analysis, we track the price and rent quantities, outlined in Table 8.1.[7]

	Warranted	Market	Expected	Expected, agent i	Reservation	Asking	Bid	Net
Price	P_{W_j}	P_{M_j}	$P^{\epsilon}_{M_j}$	$P^{\epsilon}_{M_{ij}}$	$P_{R_{ij}}$	P_{Aij}	P_{Bij}	
Rent	$\mathcal{R}_{W_j}$	$\mathcal{R}_{M_j}$	$\mathcal{R}^{\epsilon}_{M_j}$	$\mathcal{R}^{\epsilon}_{M_{ij}}$				$\mathcal{R}_{N_j}$

Table 8.1: Price and rent notation

8.3.1 Warranted rent

Warranted rent is the maximum rent that could be extracted from tenants for the stream of services provided by location and the housing supplied. In this case, the price to rent in the common usage is the same as the economic rent. A higher level of rent extraction would convince tenants they are better off leaving the city.[8]

[7] In the table, we include indices for agent i and property j, for clarity. In the following development we'll only use the subscripts where needed to distinguish between agents and properties.

[8] Abstracting from the adjustment process, the warranted rent can be thought of as a kind of attractor or equilibrium towards which prices evolve. Combining a model of long-run attractor dynamics with

Capozza et al. [35] show that land price has four additive components: the value of agricultural land rent, the cost of conversion, the value of accessibility, and the value of expected future rent increases. We treat the first two as constants. The value of accessibility can be expanded to include amenities. In our base model the value is determined by the urban wage premium, which rests on the productivity of the city firms. Expected future price increases are driven by increases in the value of accessibility, which is to say, the rising productivity of the city. Productivity rises in our model due to pure agglomeration effects. Our concern is with what happens to the city and its people when financial capital captures the growing value generated by the agglomeration process.

Locational (economic) rent

The economic rent is the value of surplus that arises from access to jobs in the centre of the city where agglomeration economies generate a wage premium. These are represented on an annual basis, The locational rent $\mathcal{R}_d$ for a property a given distance, d, from the center is the wage premium ω minus the transportation costs dc, where c is cost per unit distance:

$$\mathcal{R}_d = \omega - dc.$$

Locational amenity

The warranted locational rent includes the economic rent as well as the value of a locational amenity. In addition to a general urban amenity, $\mathbb{A}$, locational amenity may include very local site-specific amenities like access to schools or views, $\mathbb{A}_j$ as well as an element that depends on individual preferences, $\mathbb{A}_{ji}$.[9]

Housing services

Housing services $\mathcal{H}_j$ are tied to a particular property. They include the value of features like a building having a certain number of rooms, particular finishes, or landscaping, extensions

distributed agent interactions, combines the advantages of agent-based modeling and standard classical and neoclassical economic analysis to give insight into the dynamics of financialization. Chapter 7 on methodology discusses the approach.

[9] We will report results only for cases with $\mathbb{A} = 0$.

or upgrades. To maintain our focus on locational rents, we simplify, fixing the value of the stream of housing services to a fraction a of the subsistence wage,

$$\mathcal{H}_j = a\psi.$$

Warranted rent calculated

Combining the three streams, the economically warranted rent, $\mathcal{R}_W$, is then

$$\mathcal{R}_W = \omega - dc + \mathbb{A} + a\psi. \tag{8.6}$$

8.3.2 Market rent

The market rent, $\mathcal{R}_M$, is what tenants actually pay. The market differs from the economically warranted rent as investors make individual decisions about rents, setting rents based on market conditions and their own expectations. If, for example, the price of output for the firm falls, the value of labour for firms also falls and the number of workers will be reduced. The city would shrink and locational rents would fall.

As our simulation proceeds, the market price of land and market rental price generated by the agent-based housing market mechanism might diverge from the economically warranted rents and prices because growth introduces an opportunity for speculation on future values which could offset lower than warranted rents.

Net warranted rent

Owners receive, not the total warranted rent, but the net rent after expenses, including maintenance, taxes, and the cost of financing. The following sections detail the computation of each expense, and their combination into the net rent calculation.

Annual taxation

Owners pay property taxes[10] based on appraised price, P_τ

$$\mathcal{T} = \tau\mathcal{P}_\tau.$$

where τ is the municipal tax rate or mill rate, and the appraised value is based somewhat approximately, and with a lag, on the market price, so $\mathcal{P}_\tau$ is some fraction of $\mathcal{P}_{M,t-n}$.

[10]Property taxation is an entire field in economics, but we simply make provision for later work by including a term for taxes collected. How the taxes are spent will affect amenity and transportation costs.

Annual maintenance

Annual maintenance costs apply to buildings and lands but not to locational value, so it can be modelled as a share, b, of the housing services costs, $a\psi$

$$\mathcal{O} = ab\psi. \tag{8.7}$$

Calculated net rent,

Combining, the net rent $\mathcal{R}_N$ is[11]

$$\mathcal{R}_N = \mathcal{R}_W - \mathcal{O} - \mathcal{T}. \tag{8.8}$$

8.3.3 Mortgage availability

Mortgage lenders often put two limits on the size of the mortgage, one based on assets owned, (a wealth constraint), and one based on income, (a carrying constraint) [1]. We have implemented these constraints by making both mortgage size and the interest rate on borrowing depend on income and wealth. As a result, high-income and wealthy agents can borrow larger amounts, at lower interest rates than the less wealthy.[12]

Wealth-based mortgage maximum

We define household wealth, for the purpose of credit assessment, as

$$W_i = P_i^{expected} - M_i + S_i, \tag{8.9}$$

[11] We are short-cutting the rent price formation process with a long-run equilibrium approximation based on the rents that can be extracted before people leave the city, so the mechanisms that push rent up to that extraction value are abstracted. Net warranted rent, $\mathcal{R}_N$, can diverge from market rent, $\mathcal{R}_M$, particularly in the short run, for many reasons. For instance, agents who have purchased a house may be able to pass a share of financing costs through to tenants as part of the market rent depending on their market power. Some workers may accept lower utilities or may have access to higher wages.

[12] The income constraint is sometimes called a housing expenditure share cap, and may be imposed to stabilize the hosing market. Gong and Leung [90] have investigated the distributional effects of income constraints.

where $P_i^{expected}$ is the expected value of an existing owned home, M_i is the mortgage on the home, and S_i is personal savings, including the net value of assets other than the home. For a newcomer who owns a rural home and owes no mortgage, the value of the rural home is simply the capitalized value of rural housing services

$$P_i^{expected} = \frac{a\psi}{r}. \tag{8.10}$$

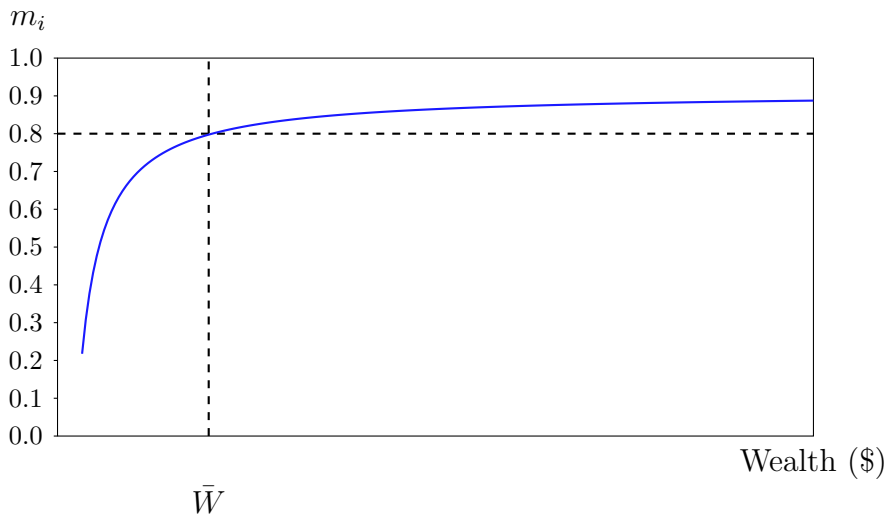


Figure 8.2: m_i is the fraction of the value of a property that the bank will mortgage for individual i. The fraction is higher for wealthier individuals, as Equation 8.11 indicates. The variable $\bar{W}$ is the mean wealth of the population.

The borrowing ratio, m is the fraction of a property's price that can be mortgaged. We assume that the bank uses a function of the form

$$m_i^{max_permitted} = \text{max_mortgage_share} - 0.1 * \left(\frac{\bar{W}}{W_i}\right), \tag{8.11}$$

where $\bar{W}$ is mean wealth and W_i is individual wealth.[13]

[13]To shift the curve so that the curve approaches $m = 0$ when $W = 0$ we add $Z = (1 - m^{max})\bar{W}$ to the numerator and the denominator. The value is calculated by solving Equation 8.11 for $m_i^{max} = 0$.

Income-based mortgage maximum

A common rule is that mortgage payments cannot exceed some fraction of income, $Y_i = \omega + \psi + rS_i$, where S_i is individual savings. If $\mathbb{C}$ a person's carrying capacity, The annual payment that their income allows, the capitalized value gives us an **income-based mortgage maximum** of

$$M_{Y,i}^{max} = \frac{\mathbb{C}(\omega + \psi + rS_{Ni})}{r^{prime}}, \tag{8.12}$$

where r is i's rate of return on $S_{Ni} = (S - M)$, the savings remaining after making the down payment,[14] as the maximum a buyer should pay. In our model the bank uses a rule of this form to decide how much it is willing to lend to.

Combined mortgage maximum permitted by the bank for new buyers and second home buyers

The above two equations specify two constraints on the mortgage. Combining, we get

$$M_i^{max} = min\left\{m_i^{max} * P,\ M_{Y,i}^{max}\right\}. \tag{8.13}$$

The two constraints on mortgage size that the bank imposes are incorporated in the red line in Figure 8.3. The maximum permitted mortgage is thus combined with the savings constraint to determine the maximum price that a potential home buyer can offer. The top dashed diagonal line, in Figure fig:dual-constraint, is the price, P = mortgage + savings. The difference between the two diagonal lines is what the purchaser pays from savings.

Individualized borrowing rates

The cost of capital differs for rich and poor. We tie the individual cost of capital to the lender's target rate r^{target}, and to individual wealth. Figure **??** illustrates the cost of the

[14] If the constraint is binding we can substitute M^{max} for $M$and explicit function to get :

$$\begin{aligned} M^{max} &= 0.28 * (wage + r(S - M^{max}))/r' \\ &= 0.28(wage + r(S))/r' - 0.28rM^{max})/r' \\ M^{max}(1 + \frac{0.28r}{r'} &= 0.28(wage + rS)/r' \\ M^{max} &= \frac{0.28(wage + rS)}{1 + 0.28r} \end{aligned}$$

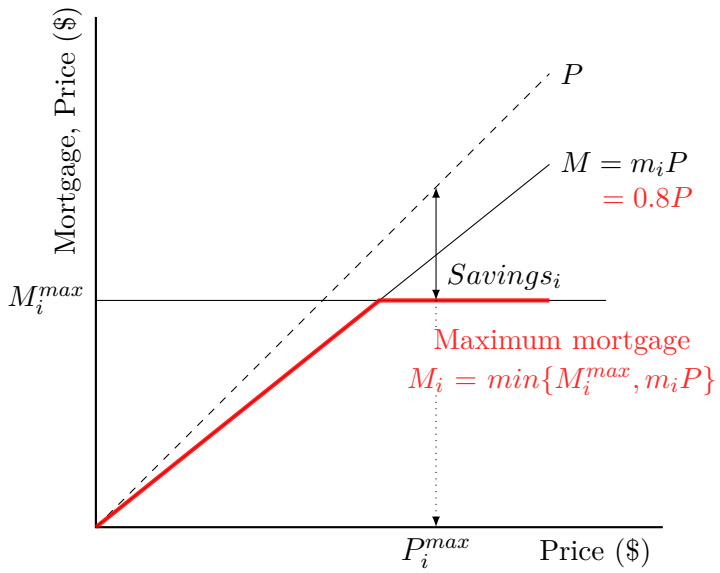


Figure 8.3: The bank's dual mortgage constraint and the savings constraint determine the maximum bid price. The upper, dashed diagonal line is the price P. Below it, the solid diagonal is the maximum fraction the bank will lend as a fraction of the price, determined in Equation 8.11. The horizontal line is the maximum the bank will lend given the potential buyer's income, M_i^{max}. The result is the kinked borrowing constraint, shown in red. The difference between price and maximum lending must be covered by savings.

borrowing model we implement, which is roughly consistent with the stylized facts about lenders.

$$r = r^{target} + K/(W - W_{min}) - K/(\bar{W} - W_{min}) \tag{8.14}$$

for $W > W_{min}$, where r^{target} is the bank's target rate of return, $\bar{W}$ is mean wealth and W_i is individual wealth, W_{min} is the level of wealth the bank requires to lend at all, and K is a parameter for the wealth-sensitivity of lending. The denominator in the last two terms is simply wealth above the lender's minimum. We assume that the wealthy are lower-risk borrowers and are given preference on rates. The final term ensures that the target rate is charged for borrowers with average wealth.

Declining principle

Mortgages are renewed after $\mathbb{T}$ years. During that period some of the principle has been paid off. This is most important when a property is sold. The seller gets $P - M_{i,\mathbb{T}}$, where

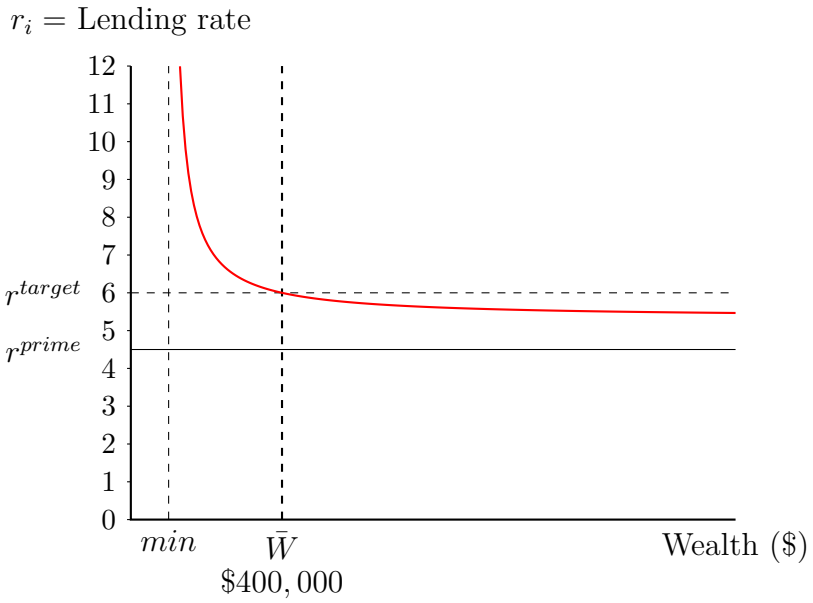


Figure 8.4: Individual borrowing rate r_i is set by the bank. There is a wealth minimum below which lenders will not lend. Above that level of wealth, to the right, the interest rate offered by lenders declines. Borrowers with wealth above $\bar{W}$ receive preferential rates which are above the bank's cost of capital r^{prime} but may be below the bank's target rate r^{target}.

$M_{i,\mathbb{T}}$ is its remaining mortgage.

8.3.4 Bid price

A bidding process determines the realized market price, with bidders taking into account potential capital gains. In this section, we describe the formation of the maximum bid price that we use in the bidding model. The maximum bid price, $P_{B,ij}^{max}$ is the value of a property to the owner or to a potential buyer. It will differ across individuals depending on their cost of capital, discount rates, savings, and access to mortgage funding. The same equation used to calculate the bid price used to compute the reservation price, the minimum price that an owner will sell a property for.

The model distinguishes between two types of buyers, institutional buyers and home-owners buying a home. They use the same investment formula, but may have different values of the parameters determining their bid prices.

We first calculate the net present value of the purchase, then divide by the amount of capital employed, which we assume is simply the size of the down payment made at the beginning of the period. This gives us a rate of return.[15] The rate of return on the investment must exceed some required rate of return. This condition allows us to calculate the maximum bid that will satisfy that criterion. We then solve this for the maximum bid, P_{max}^{bid} that achieves the desired rate of return.

The agent who purchases makes a down payment, D on a house for a price, P_0, and agrees to pay off a mortgage, M with interest at the end of the mortgage period. The purchaser receives the increased price $P_T = (1 + \dot{P})^{\mathbb{T}} P_0 = (1 + \dot{P}_{\mathbb{T}}) P_0$, after a period $\mathbb{T}$, Where $\dot{P}$ is the expected annual rate of price increase and we define $\dot{P}^{\mathbb{T}}$ or $\dot{P}^{\mathbb{T}}$ as the $\mathbb{T}$-period price-growth rate. The agent also receives either the net market rental value of the property throughout the period, $\mathcal{R}_N$, or if the owner is also the resident, the locational rents.

Rent and mortgage costs

Both mortgage payments and net rent revenue can be calculated as sum of regular payments, each of which accumulates interest to the end of the mortgage period. This is called a "uniform series compound amount" [187]. For net rent at the end of the mortgage renewal term we write

$$\mathcal{R}_{N,\mathbb{T}} = \frac{(1+r)^{\mathbb{T}} - 1}{r} \mathcal{R}_N. \tag{8.15}$$

The regular mortgage payment for each period is $rM = rmP_0$.[16] Using the same calculation, the value of the mortgage payments is

$$\mathcal{M}_{\mathbb{T}} = \frac{(1+r)^{\mathbb{T}} - 1}{r} rmP_0. \tag{8.16}$$

Annual payments are rmP_0, where r is the interest rate and m is the fraction of the price which is mortgaged. Both these amounts are discounted by $\delta^{\mathbb{T}} = \frac{1}{(1+r)^{\mathbb{T}}}$ to the present.

[15] An alternative approach would be to calculate an internal rate of return (IRR), but the IRR is in general the solution to a polynomial and does not guarantee a single-valued result [167]. Multiple real-valued IRRs may arise; complex-valued IRRs may arise; the IRR is, in general, incompatible with the net present value (NPV) in accept/reject decisions; the IRR ranking is, in general, different from the NPV ranking; the IRR criterion is not applicable with variable costs of capital. Ways to salvage the IRR as a usable criterion have been proposed that are consistent with our approach [133].

[16] We assume that the regular payment covers only the interest and that the full mortgage is due at the end of the period.

8.3.5 The value of an investment with price growth or interest

The model in this section is central to our agents' housing purchase decisions. It incorporates individual access to capital and capital costs, expected capital gains and property revenues. For an agent, the present value V of a property investment over $\mathbb{T}$ years is the sum of capital gain plus accumulated net rent $R_{N,\mathbb{T}}$ from Equation minus the mortgage, which must be paid back with any financing costs $\mathcal{M}_{\mathbb{T}}$ from Equation 8.16, all discounted to the present.

The capital gain is $P_{\mathbb{T}} - P_0$, where P_0 is the purchase price and P_T is sale price the at the end of T years. We can therefore write V

$$\begin{aligned} V &= \delta^{\mathbb{T}} \left(P_{\mathbb{T}} - P_0 - \mathcal{M}_{\mathbb{T}} - M + \mathcal{R}_{N,\mathbb{T}} \right) \\ &= \delta^{\mathbb{T}} \left(P_{\mathbb{T}} - P_0 - \left(\frac{(1+r)^{\mathbb{T}} - 1}{r} rmP_0 \right) - M + \mathcal{R}_{N,\mathbb{T}} \right) \\ &= \delta^{\mathbb{T}} \left(\dot{P}_{\mathbb{T}} P_0 - \left((1+r)^{\mathbb{T}} - 1 \right) mP_0 - mP_0 + \mathcal{R}_{N,\mathbb{T}} \right) \qquad (8.17) \\ &= \delta^{\mathbb{T}} \left((\dot{P}_{\mathbb{T}} - (1+r)^{\mathbb{T}} m) P_0 + \mathcal{R}_{N,\mathbb{T}} \right), \qquad (8.18) \end{aligned}$$

where $\dot{P}_{\mathbb{T}} = \frac{P_{\mathbb{T}} - P_0}{P_0}$ is the expected change in the market price over the term of the mortgage as a fraction of the original price. V is the net present value of buying and selling after one mortgage renewal period of $\mathbb{T}$ years.

Rate of return on investment

We divide V by the size of the down payment, $D = P_0 - mP0$, to get the rate of return

$$\begin{aligned} r^{return} = &= \frac{V}{D} \\ &= \delta^{\mathbb{T}} \left((\dot{P}_{\mathbb{T}} - (1+r)^{\mathbb{T}}) m \frac{P_0}{D} + \frac{\mathcal{R}_{N,\mathbb{T}}}{D} \right) \\ &= \delta^{\mathbb{T}} \left((\dot{P}_{\mathbb{T}} - (1+r)^{\mathbb{T}}) m \frac{P_0}{P_0 - mP_0} + \frac{\mathcal{R}_{N,\mathbb{T}}}{P_0 - mP_0} \right) \\ &= \frac{\delta^{\mathbb{T}}}{1-m} \left((\dot{P}_{\mathbb{T}} - (1+r)^{\mathbb{T}}) m + \frac{\mathcal{R}_{N,\mathbb{T}}}{P_0} \right). \qquad (8.19) \end{aligned}$$

Notice that the return depends on the price paid, P_0, which is determined in the market though competitive bidding.

Capital gains tax

The capital gains tax is a tax on the increase in value of a property that results form an increase in the price. The capital gains tax is a tax on speculative return on housing as an investment. In our model captures some or all of the expected gain from rising locational rents. We can introduce it in Equation 8.19 by multiplying $\dot{P}_{\mathbb{T}}$ by 1 minus the capital gains tax rate, representing the share of the capital gains that a buyer is permitted to keep. We allow the rate for occupant owners to differ from the rate for non-occupant owners.

8.3.6 Criterion for investment

Equation 8.19 provides a criterion for investors. Agents invest if their expected return is greater than the target return they are seeking:

$$r^{target} \leq r^{return} \tag{8.20}$$

For the bank R target is the prime rate plus a margin. For individuals it woulds be the the best alternative investment they have. It can be argued that r_i^{target} should be the long-term bond rate. We provisionally set $r_i^{target} = r^{prime}$.

Maximum bid for investors

Equation 8.20 combined with the rate of return calculation in Equation 8.19 are used to calculate a maximum bid price for investors for use in the bargaining model. Buyers and sellers calculate the maximum amount they are willing to pay for a property. Investors are not concerned with amenities, while residents are. Amenities enter through the net rent term for investors, to the extent that residents are willing to pay for amenity. Buyers differ in having individualized values for r, δ, m, and M.[17]

[17]Transaction costs on the sale are omitted. They are actually large. We can easily add a term to Equation 8.21 to examine the effect of transaction costs.

$$
\begin{aligned}
r^{target} &\leq \frac{\delta^{\mathbb{T}}}{1-m}\left((\dot{P}_{\mathbb{T}} - (1+r)^{\mathbb{T}})m + \frac{\mathcal{R}_{N,\mathbb{T}}}{P_B^{max}}\right) \\
\frac{(1-m)}{\delta^{\mathbb{T}}} r^{target} &\leq \dot{P}_{\mathbb{T}} - (1+r)^{\mathbb{T}}m + \frac{\mathcal{R}_{N,\mathbb{T}}}{P_B^{max}} \\
\frac{(1-m)r^{target}}{\delta^{\mathbb{T}}} - \dot{P}_{\mathbb{T}} + (1+r)^{\mathbb{T}}m &\leq \frac{\mathcal{R}_{N,\mathbb{T}}}{P_B^{max}} \\
P_B^{max} &\leq \frac{\mathcal{R}_{N,\mathbb{T}}}{(1-m)r^{target}/\delta^{\mathbb{T}} - \dot{P}_{\mathbb{T}} + (1+r)^{\mathbb{T}}m}. \qquad (8.21)
\end{aligned}
$$

We call this $i's$ maximum bid.[18] It represents the maximum a buyer is willing to pay, the value of the stream of rent plus any capital gains.[19] If the buyer intends to become a resident, the net rent term Equation 8.21 is replaced by a housing-services-and-amenity term, which represents non-monetary income.

A simple proxy for $\dot{P}_{\mathbb{T}}$

The market price or the price at which a property is exchanged on the market, P_M will not be known in advance, nor will the future sale price. To make decisions, agent i must form an expectations or prediction $P^{\epsilon}_{M_i}$ of the as yet unrealized future market price. Case and Shiller observe that "People seem to form their expectations from past price movements rather than having any knowledge of fundamentals. [38]. They further argue that the 1-year expectations are fairly well described as attenuated versions of lagged actual 1-year price changes. Our $\dot{P}_{\mathbb{T}}$ is a forecast or expectation by agents in the model of the change in price over a period $\mathbb{T}$.

Since our version of the Alonzo model implies that house prices will rise by the capitalized value of an increase in the wage premium, a rational investor might use a forecast of the wage premium to develop a long-term forecast of house prices, and from that of $\dot{P}_{\mathbb{T}}$. We will assume that agents simply observe the most recent change in ω correctly and expect it to persist.[20]

[18] The denominator in Equation 8.21 can be seen as an adjusted rate of return for capitalizing net rents, analogous to the value of r in the standard capitalization formula.

[19] If there is a capital gains tax t^{cg} , $\dot{P}_{\mathbb{T}}$ in Equation 8.21 is multiplied by $1 - t^{cg}$.

[20] In principle, agents might form an expectation by observing past prices for each class of home. To mimic this process we could compute average price changes per period at each distance from the centre and use them to form a forecast for the mortgage period $\mathbb{T}$.

In Equation 8.18 we defined $\dot{P}$ as $\frac{P_{\mathbb{T}}-P_0}{P_0}$, where $\mathbb{T}$ indicates the end of the mortgage period. P_0 is the warranted price,

$$P_W = \frac{1}{r}\left[\omega - dc + \mathbb{A} + a\psi + a * b * \psi\right]$$

Only the wage premium changes in this analysis. A change in the wage premium that is expected to be permanent results in a change in the warranted price:

$$\frac{\partial P_W}{\partial t} = \frac{1}{r}\frac{\partial \omega_t}{\partial t}.$$

If we assume that the price will continue to change at the same rate over the mortgage term, the change is compounded, and we write

$$\begin{aligned}\dot{P} &= \frac{1}{r}\left[\left(\frac{\omega_t - \omega_0}{\omega_0} + 1\right)^{\mathbb{T}} - 1\right], \\ &= \frac{1}{r}\left[\left(\frac{\omega_t}{\omega_0}\right)^{\mathbb{T}} - 1\right].\end{aligned}$$

8.3.7 Illustrating constraints on the bid price

Buyers calculate their maximum bid based on value, but actual bids are constrained by the mortgage limits imposed by the bank illustrated in Figure 8.3 and the buyer's savings. The mortgage constraint may or may not bind, depending on the price of the final price. Figure 8.5 illustrates how these considerations affect the actual bid.

We choose a price on the horizontal axis and project it up to the black dashed diagonal. Three lines show the levels of the constraints at that price.

1. The horizontal dashed line P_B^{max} represents **the maximum the buyer is willing to pay**, as calculated in Equation 8.21, if the mortgage funding were available. No bid will be above this line.

2. The kinked thick red line combines the three conditions on the size of the mortgage imposed by the bank based on wealth and income and on the bank's equity requirement.

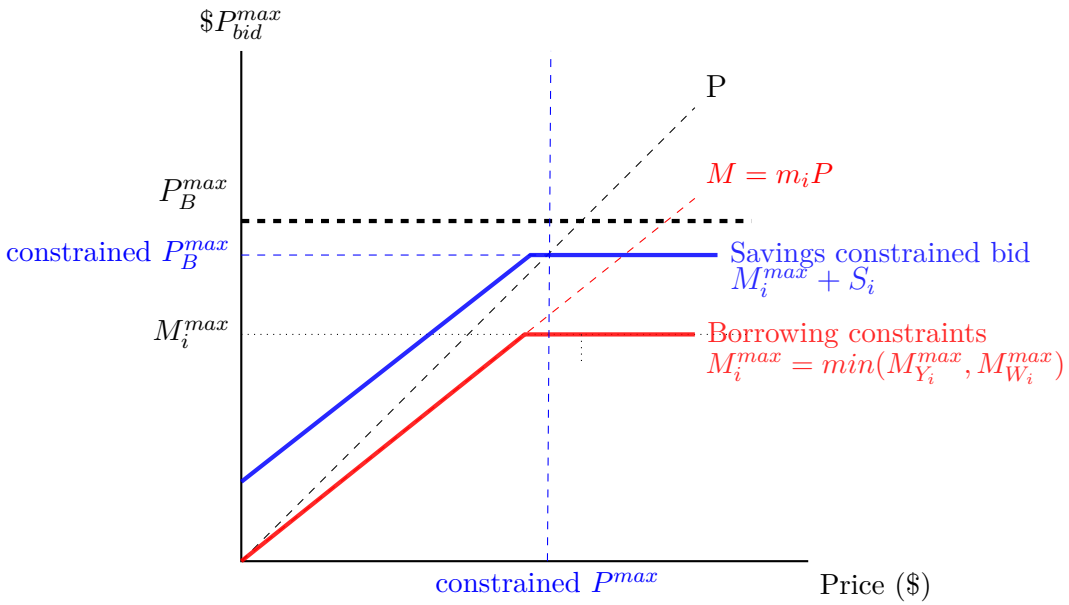


Figure 8.5: Extending Figure 8.3 to include a savings constraint. The red solid line shows the maximum amount the bank will lend as described in Figure 8.3. The borrower adds his or her available savings to the available mortgage to reach the blue solid line. The maximum price the borrower can bid is given by the intersection of the blue line with the diagonal dashed line representing prices.

3. The thick blue line, $min\{m_i P,\ M_i^{max}\} + S$, represents the purchaser's combined financial constraints, determined by mortgage availability and savings. It is **the maximum the buyer is able to pay**. No bid will be above this line either.

As a result the combined curve will be the constraint for buyers, and the requirement that the bid be below both the blue and black lines can be written

$$Constrained\ P_B \leq min\{P_B^{max}, min\{m_i P,\ M_i^{max}\} + S\}. \tag{8.22}$$

8.3.8 The bargaining model

Buyers place bids and a sale occurs if there is a surplus created by the transaction, that is if the the buyer's maximum bid exceeds owner's reservation price, the maximum the owner

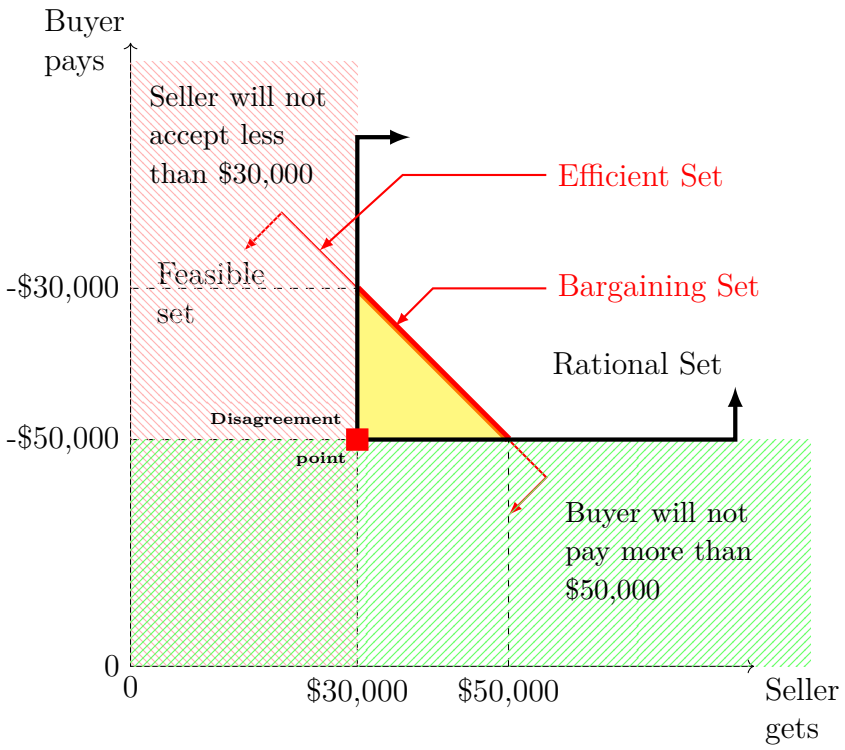


Figure 8.6: The Nash bargaining game. The seller has a reservation price of $30,000 and the Buyer values the property at $50,000. There is a potential gain from trade of $20,000 to be divided. The thick red line, known as the bargaining set, represents all the efficient divisions of the gain. Theory predicts that bargaining will lead to a point on the bargaining set.

would pay to retain their own property. Bargaining models attempt to identify the way the surplus available from a transaction is divided between the parties involved. Possible divisions are described by the red line in Figure 8.6.[21]

In Figure 8.6 we imagine the seller values the property at $30,000 (the reservation price) and the buyer values it at $50,000 (the maximum bid price). At any price above $30,000 the seller is better off. At any price below $50,000 (above -$50,000 on the vertical axis)

[21]The classic formulation by John Nash identifies 'disagreement point,' which which is the lowest value each player will accept. The combination of reservation price and maximum bid together are the disagreement point for a two-person price bargaining game. Since paying for the house is a negative for the buyer, the scale on the vertical axis in Figure 8.6 is reversed to generate a version of the most common Nash bargaining figure.

the buyer is better off. The set of acceptable bargains acceptable to both is above and to the right of the point labeled 'disagreement point.'

In principle the buyer could pay more than $50,000 or the seller could accept a price below $30,000, but neither would do so if they are rational. The thick red line segment, called the bargaining set, represents all the outcomes that are

1. efficient, because the entire $20,000 surplus is allocated to the players.
2. feasible, because the players involved gain no more in total than the potential increase in value generated by the transaction.
3. rational because neither player has to accept an outcome that makes them worse off.

The bargaining processes will ideally lead to a point on that thick red line segment. In practice, some of the surplus is dissipated in the sale process, and some is absorbed by intermediaries. We ignore this refinement for the current version of the model. Differences in relative power will tip the outcome in favour of the stronger player. Players who can afford to wait will get a larger share of the gain. Excess demand favours sellers. Low vacancy rates favour owners over tenants. If there is a deal, it will still be at a price between the maximum bid and the reservation price, and in most cases probably somewhere near the midpoint. Sellers might reduce the asking price if the home fails to sell in the first period it is on the market.[22] [23]

The many-to-one matching problem

The housing market is usually a many-to-many matching problem: which property goes to which buyer? For each property that comes on the market, there will be a set of potential buyers with differing maximum bids. Some simplifications are available. In each sale, the bidder with the highest bid price among those currently bidding on that property will make the purchase.[24] Since the highest bidder is competing with the second-highest bidder, we

[22] Uncertainty adds further complications. Parties may not know each other's disagreement point. PartieS post asking prices greater than their reservation price or initial offers much lower than their true valuation. Negotiations often proceed through a series of offers and counteroffers.

[23] In an overheated housing market bid prices might exceed asking prices, but the price won't exceed the maximum expected profitable bid price, P_B^{max*}. We could elaborate the model by defining a measure of sellers' bargaining power based on vacancies and expected prices.

[24] For many reasons the process is likely to exhibit a good deal of randomness and inefficiency. For our purpose, the general messiness of the market is unlikely to do more than slow and blur results somewhat.

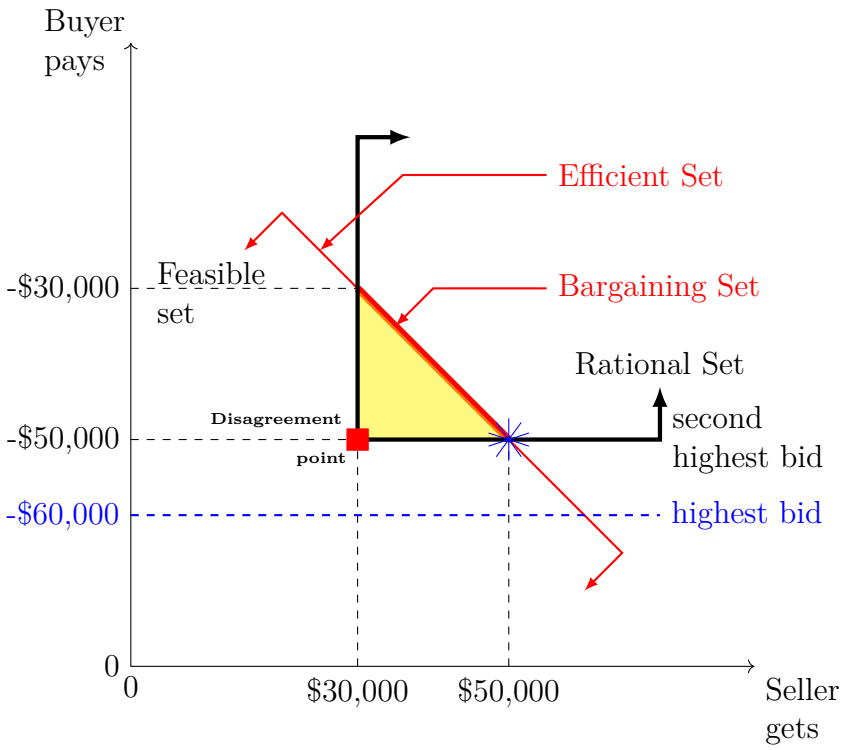


Figure 8.7: Auction with a second, higher bid. The bidder who values the property most (blue) only has to pay a small amount more than the second-highest bidder to win.

expect the final price to be equal to the second-highest maximum bid, shown as the star in figure 8.7.

When there is one bidder, we will employ a simple rule for splitting the gain from trade. Both simplifications are grounded in standard bargaining theory.

The bargaining process

We have now identified a set of bids and a reservation price for each property on the market that must be converted to a price for that property using the bargaining rule. The bargaining mechanism then simply has to compare the maximum bid price P_B with the seller's reservation price. If the $P_B^{max} > P_R$, a deal that is between the two values is possible. Otherwise, the transaction does not proceed. If a bargain is possible, the rule is simple:

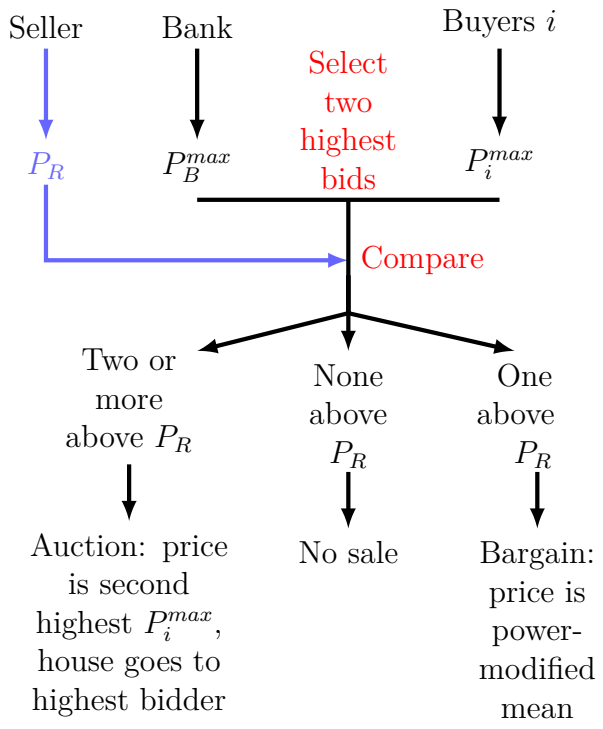


Figure 8.8: The bargaining model and price determination mechanism. Sellers set a reservation price P_R. Sellers determine their maximum valuation P_i^{max} and a maximum bid P_B^{max}, given borrowing constraints set by the bank. The realtor identifies the highest bids and determines the outcome.

1. If there is only one maximum bid above the reservation price, split the difference between the bid and the reservation price evenly.[25] If $P_B^{max} > P_R$, the bargaining rule selects a value

$$P = xP_B^{max} + (1-x)P_R, \quad x \in [0 \ldots 1]$$

where x is typically 0.5.

2. If there are two or more maximum bids above the reservation price, the property goes to the highest and since the bids are the maximum the buyers would pay under any circumstances, the price is set to the second highest bid to reflect the tightness of the market.[26]

[25] It is fairly simple if perhaps not very revealing to incorporate relative power.
[26] This is an application of Vickrey second-price auction theory[126].

8.4 Linking financialization and urban productivity

As we point out in Chapter 6 there are numerous channels through which financialization might affect the productivity of the city. The available literature does not tell us which channels are active, and which, if any, have a significant effect. Our goal in modelling is to establish whether or not linkages are likely to have significant effects on the economy. If our model establishes that the effects are potentially significant, it might encourage researchers to explore this neglected area in urban economics.

To introduce the potential effect of financialization and ownership as simply as possible, we rewrite A from the basic model as:

$$A = A_0 + \text{effectiveness} * \text{share} * \text{rent}$$

where A_0 represents outside or general factors contributing to productivity, $0 <$ effectiveness $<$ 1 is how much the local share of rents matters, and share $*$ rent stands for the share of the urban locational rents captured by residents and contributing to local productivity. That there are local factors is indicated by the variability of estimates of A in empirical studies.[27] The share term is itself a composite of the actual land-ownership share of residents determined by the housing market and the propensity to invest locally.

In the class of models we draw on, the scale parameter A controls the overall productivity. It might capture a range of productivity-enhancing effects: the contribution of urban infrastructure (including transportation infrastructure), technology, ownership ratios, participation by residents, local investment in productive capital, regulatory structure, the presence of local universities, the skill level of the supporting workforce, the complexity of supply chains, or other factors. None of these are explicit inputs in our model in the way technology is in some of the growth literature described in Chapter 5.[28] Missing explanatory variables are likely to inflate the residuals in estimates of A. It is likely to be difficult to disentangle influences on the parameters empirically, this simple model makes it possible to study the effect of a range of linkages.

8.5 Summary

In this chapter, we developed the rules that agents in our agent-based model follow. In doing this we have defined variables and institutional features and developed a description

[27] See Chapter 6 Subsection 6.1 for references and an illustration.

[28] Public inputs like the transportation system do not appear directly in any of the models.

of the bargaining process behind all of the adjustments. The formulae developed here are implemented in the Python simulation model. Appendix B contains the parameter values used for the model.

We use equilibrium conditions for competitive labour markets to bypass the complex and partially understood wage-setting process. We apply a standard theoretical result from the theory of the firm, that workers are paid their marginal value-product. We ground our approach in recent research that has derived and estimated an aggregate urban production function consistent with modern neoclassical growth theory.[29] Our augmented representative firm determines the urban wage premium that drives city growth. We assume that, since housing and labour markets can adjust more quickly than urban productivity, the production sector responds continuously to the slower movement of population and productivity. We also assume investors behave rationally in that they estimate the potential returns on their investments and seek the highest returns they can get. They calculate an offer price in each transaction based on several factors: land rents, expected price changes, their price of capital and discounting rate, and other information available to them. We do not, however, impose an equilibrium on the housing market.

The relationships set out in this chapter are theoretically grounded and realistic. They allow us to implement the three sub-models described in the introduction to this thesis in code. The resulting simulation model lets us demonstrate some implications of standard urban economic theory that were plausible *a priori*, but that have not been formally demonstrated before.

[29] We are not aware of other research that has taken this step yet.

Chapter 9

Implementation as an Agent-Based Model

In this chapter we document the implementation of the core agent-based model using the 'Overview, Design concepts, and Details' (ODD) standard [92]. The objective of the standard is to assist researchers in making model descriptions sufficiently complete and explicit that the model can be reproduced. The standard was originally envisioned as a protocol for describing ABMs in ecology, but it has been widely used in other fields.

Although we have explained a great deal of the theory behind the model and even specific modelling decisions in the previous eight chapters, applying the ODD protocol allows us to make explicit the computational structure of our model and the way the agents are implemented. Following Grimm et al. [93] this ODD consists of seven elements:[1]

1. purpose
2. state variables and scales
3. process overview and scheduling
4. design concepts
5. initialization
6. input

[1] Appendix B details the model parameters, and Appendix D gives the pseudo code for the agent based model.

7. submodels

9.1 Purpose

The purpose of this ABM is to provide a representation of city development subject to financialization, where financialization refers to the purchase of land and housing by owners of capital. More specifically, we seek to understand the links between financialization and the distribution of housing ownership, the capture of rents, and urban productivity.

The model is intended to combine a theoretically correct simulation of the spatial and temporal growth of a city with a new model of a housing market in which individual agents buy and sell property, live, work, and retire subject to a realistic financial system.

9.2 State variables and scales

9.2.1 State variables

State variables refer to the attributes of each kind of entity that vary over time. The entities in our model are the six agents types illustrated in Figure 9.1:

1. persons, residents who are either owners or tenants on properties,
2. an investor who purchases housing for profit,
3. a bank that provides financing for property buyers,
4. a realtor that manages property sales and finds tenants,
5. an urban firm that provides employment and wages, and
6. land units (properties or lots), which are locations to which persons are attached.

In Figure 9.1, agents are identified by black boxes around the agent type. Persons are classified by location, (as urban workers or rural workers), by ownership status (as owner-occupiers or tenants), or as in-migrants who may bid on properties that come up for sale. Persons are always associated with specific units of land. Each cell in the figure's grid is a

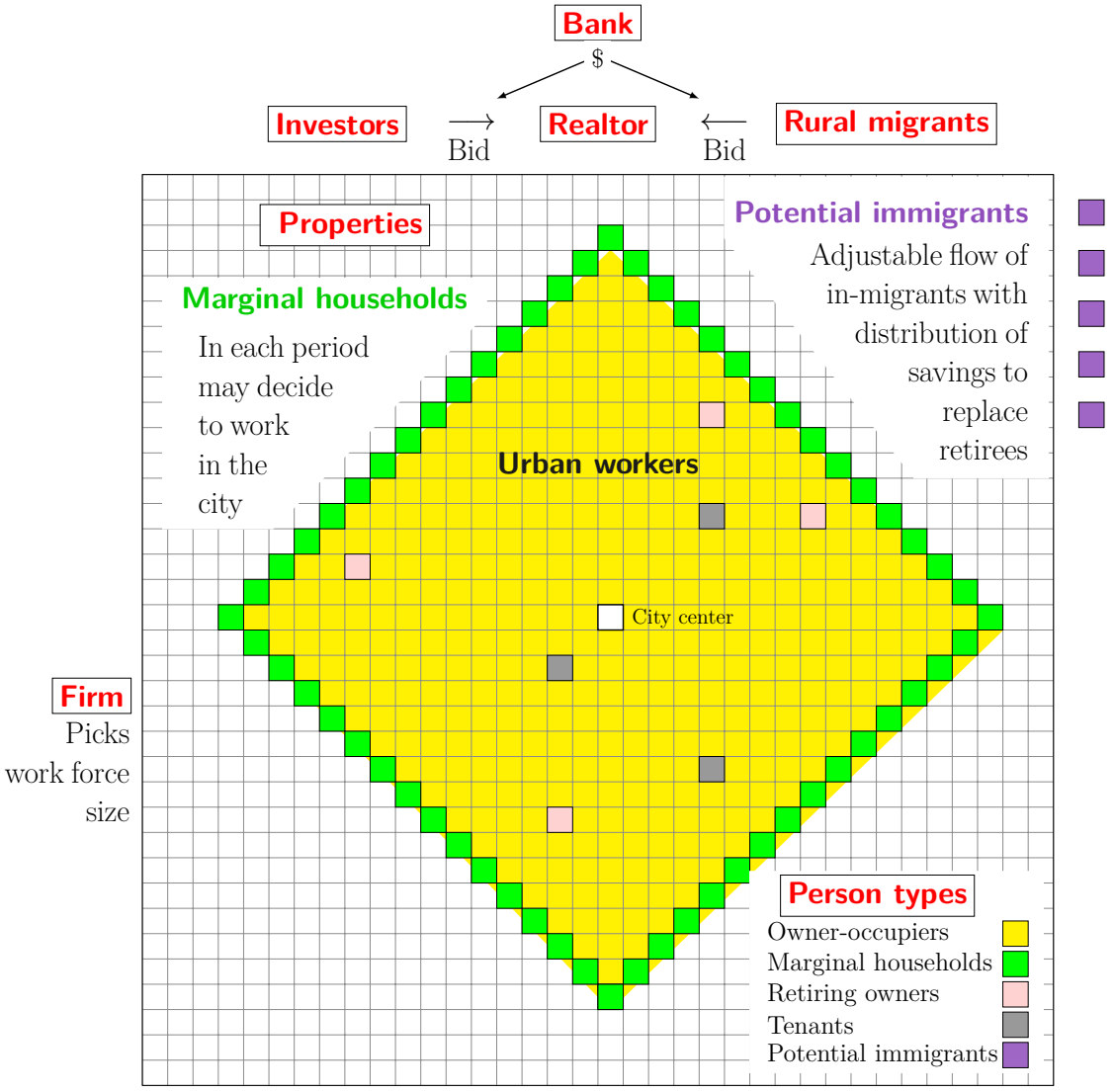


Figure 9.1: Relationships among the agents in the model. The model operates on a grid of properties. Coloured squares make up the urban region. Owner-occupiers are yellow, tenants grey, and properties which are available for purchase because owners have retired are pink. Agents at the edge in green decide in each period whether to participate in the urban labour market. In each period a pool of potential in-migrants may bid on available. The firm, realtor, bank, and investor do not have a grid location and are shown outside of the grid.

land agent. The number of person agents is equal to the number of land units plus a small pool of in-migrants temporarily located in the center of the city.

The investor, bank, realtor and firm are are representative agents. The are assumed to represent the actions of the entire class of agents of their type.

Combined with rules for every agent these elements provide a simulation of an evolving city in a rural region.

Parcels of land are individual agents

Because we have a spatial model, it is convenient to begin by describing the grid of properties representing a central city and a surrounding rural region. Each cell is a computational agent in the class of Land agents. Each cell has an address in a Cartesian space. Each has a set of attributes. Attributes that are adjusted as the model evolves are the state variables in the terminology of the documentation format we are using. Each cell is associated with one resident person-agent.

The city is the subset of cells or the region over which workers choose to work at the urban center. The urban center is located in cell (0, 0). Properties are in the city, if the resident chooses to commute to work at the center of the city. The city as a whole is not an agent.

Each unit of land has an owner, either resident or non-resident, and a resident worker who may be an owner or a tenant. For simplicity, rural residents are always owners.

When owner-occupiers retire or when investors choose to sell a property, it is listed for sale. The potential buyers are the investor and a selection of rural migrants with savings drawn from a distribution. Low savings may limit the bid that the new resident can make.

If no newcomer or investor purchases a listed property, the property remains on the market and a tenant is found.

Attributes associated with each location are:

1. location
2. ownership type
3. owner, with age and savings
4. mortgage
5. warranted price

6. warranted rent
7. appraised price
8. realized price
9. price change
10. transport cost
11. maintenance costs
12. tax rate
13. density.

The last three, maintenance costs, tax rate and density are the same for all properties in the current implementation. Transport cost combines location with a uniform cost per unit of distance. The price variables are re-computed for properties when they are on the market when an owner retires or an investor decides to sell. Price change is used in expectation formation.

Persons

Rural and urban owner-occupiers and urban tenants belong to the agent class Person. Urban owner-occupiers have a 40-period working life, after which they retire and list their home for sale. In the current implementation, they are removed from the model. Perhaps they retire to the countryside. They could be allowed to age in place, but without relevant amenities there is a financial motive for moving out.

Marginal households are persons with properties at the edge of the city. If the wage justifies travel to the city center, rural owner-occupiers may join the urban workforce as owner-occupiers. The geometry suggests there will be a discrete jump in population each time the wage passes a threshold, but the firms, target population is only allowed to adjust partially, which smooths population growth.

Newcomers are persons seeking to purchase or rent land and to join the urban workforce in each period. In the current implementation there are always enough newcomers to replace retirees. Each has savings, with the amount drawn from a distribution that allows at least some of them to bid on properties. If newcomers make a successful bid they become owner-occupiers. If they cannot purchase they are removed from the model. A new pool of newcomers is drawn in each period. Because computations are ordered by location, newcomers are arbitrarily associated with the center of the city at cell (0, 0).

If an investor purchases a property, the rent it to a newcomer who then pays rent. If renters retire, they are replaced with new renters. If the investor chooses to sell, and an owner-occupier purchases the property, they displace the renter and move in.

For simplicity, individuals have the same preferences, employment opportunities and transportation costs. Each person occupies one property.

The state variable of persons are location, ownership status, working period, and savings. Other attributes include capital gains tax rate and borrowing rates.

Bank

The bank is the sole member of the class of Bank agents. It sets maximum mortgage share and credit-worthiness using person attributes and bank parameters. It sets lending rates for persons and investors based on the prime rate. Mortgages payments are calculated for a 5-period term. The bank has no state variables.

Investors

There is one member of the class of Investor agents. The investor bids on all properties for which the calculated rate of return at least matches alternative investments. The investor draws on the global pool of capital. If the investor outbids tenants and newcomers, the property purchased is then owned by non-resident capital.

The investor's decision-making is treated in detail in Chapter 8. Variables for the investor are the borrowing interest rate, properties owned, a capital gains tax rate, expectations about the rate of price change, and the maximum fraction of owned properties that may be listed for sale in each period. A fraction of investor-owned properties are listed for sale in each period. There are no state variables, but the list of properties owned evolves. Investor wealth, the wealth of the class of investors, is calculated using the attributes of the properties, including price information.

Realtor

There is one member of the class of Realtor agents. The realtor keeps lists of properties for sale and for rent in each period, conducts bidding, and allocates properties to the winning bidder. The realtor interacts in each period with listed properties and all bidders. It's state variable is the data structure with the details of the property listings for properties currently for sale.

Firm

A representative firm is the sole member of the class Firm. The state variables for the firm are capital stock and workforce. At any price, wage, and cost of capital; the firm identifies target employment and capital stock. The targets are calculated using the rules derived from standard neoclassical firm theory. The firm then adjusts its current workforce and capital stock toward the target.

The firm is a price-taker: it does not set wages or output prices. Although the model employs a single representative firm to determine labour demand, we imagine that the wage adjustment process occurs in a decentralized and competitive market with many firms, each forced to adjust their own wage offer given excess demand or supply. This uncoordinated market response is captured in our model by a partial adjustment mechanism.

The target employment for the firm, multiplied by the number of firms gives the aggregate target labour. We term this value labour demand. Demand is therefore planned employment rather than actual employment. It is the number of posted job openings rather than the number of hires that firm actually achieve. Similarly, labour supply is the number of person agents who decide to work. The number changes as agents near the edge of the city (marginal agents) decide to begin or stop work in the city or based on the previous period's wage. If labour demand exceeds the current population the wage is adjusted upward. Firms adjust to the revised wage in the following period.

The aggregation population N used in the firm's production function differs from the aggregate firm workforce. In the current implementation, we compute the workforce as the number of cells that are urban, multiplied by the density. To account for the fact that not everyone who contributes to the agglomeration effect may work for firms, we add a seed population and scale the combination by a factor greater than one. The adjustment factors provide flexibility for later versions of the model.

9.2.2 Scales

This section describes the temporal and spatial resolution and extent of the model. We typically examine results for 100 cycles. Cycles are intended to roughly represent 100 chronological years of city. Over that period our model city grows to approximately 2.5 million. The city does have an asymptotic limit, but since we are interested in financialization during periods of growth, parameters that control the scale have been chosen to let us examine the growth of a mid-sized city.

The computational field is a grid of properties. To limit computational time, population is modelled coarsely and the size of the grid is restricted. Grid size is typically a square 100-200 properties which, which is sufficient to contain the city while still leaving properties in the 'rural' state in every direction after a typical 100 period run.

Each cell has a single owner but represents a specific number of individuals for the population count and for the labour market. A density parameter is set at 100 so that the limited number of cells in the city provides a plausible urban population.[2]

The population determines the magnitude of the agglomeration effect that enters the firm's production function. Population is a function of density, the cost of transportation and the wage premium, which is determined by firm productivity. Transportation cost is the grid distance from the center. The distance is the sum of the absolute values of the x and y displacements from (0, 0), multiplied by the annual transport cost, which is set at 500 per cell-length. The transport cost per unit distance must be high enough to ensure that the city that emerges will remain within the boundaries of the grid in the course of a simulation run.

The firm's production function is subject to two conditions. First, the parameters α and β must sum to less than one. Second, $\alpha + \beta + \gamma$ must be slightly larger than one. The β exponent is the labour-force-share of firm revenue cost when we use a Cobb-Douglas production function. It is a scale factor in the or the wage and therefore controls the wage premium. We use a value in the range 0.7-0.8 that is consistent with typical values for developed countries. Different values do not change our qualitative results, however.

The representative firm is quite small, rising to about 60 workers. The number of firms is correspondingly large. Person agents have a working life of 40 cycles (years). Mortgage contracts are for five years and are renewable.

The effect of modifying parameters of the financial system are discussed at length in Chapter 10. The parameter space is large and the parameters interact to determine model variable such as population. We report variation around a single point in the parameter space to have easily compared results, however the results are consistent across a substantial region of the parameter space.

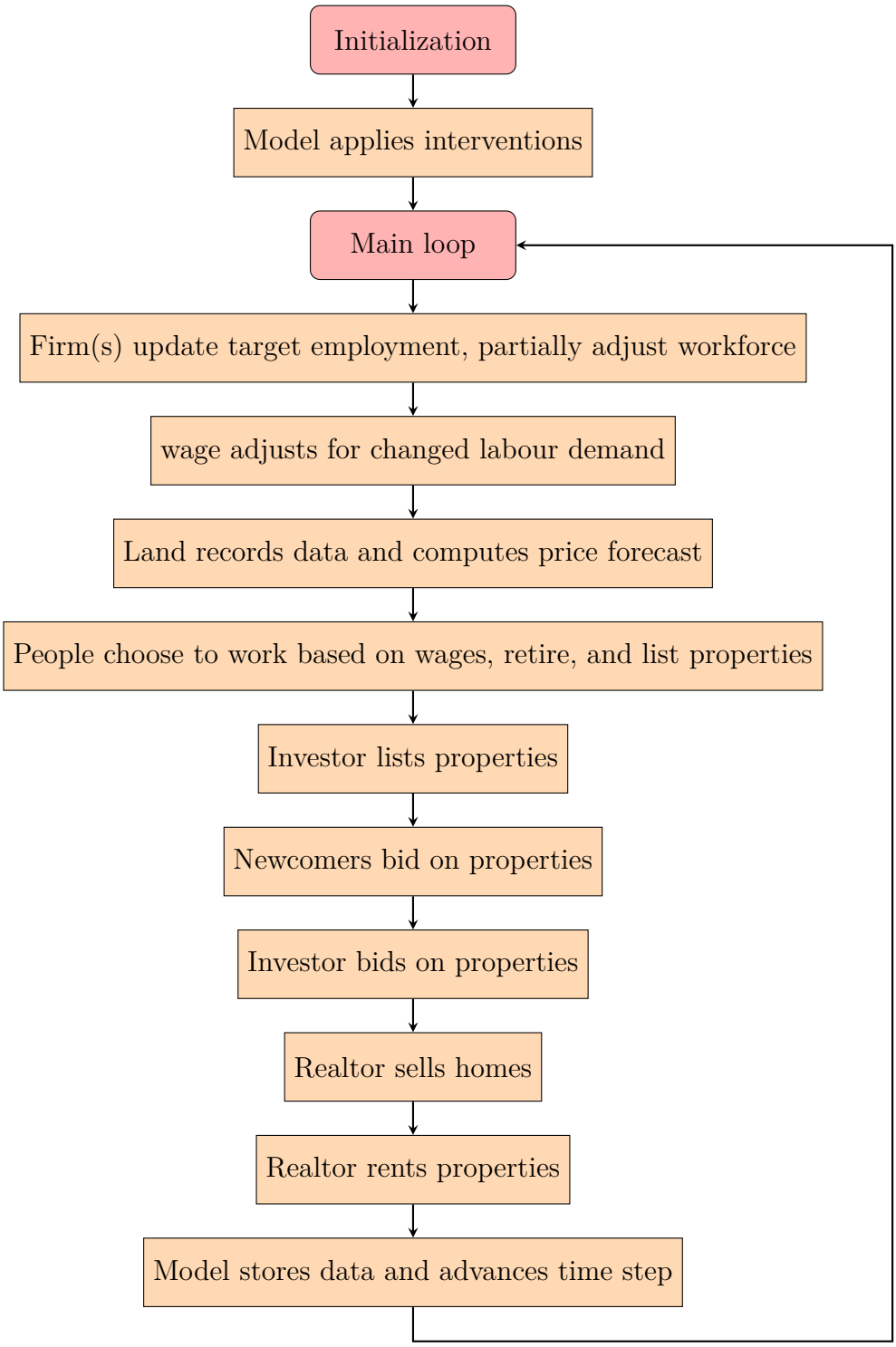


Figure 9.2: Flow diagram for the agent based model.

9.3 Process overview and scheduling

The model proceeds in discrete steps. Each time step represents one year. Agents of a particular kind execute their step function in randomized order and use state variables from the prior time step. Figure 9.2 illustrates the sequence. Figure 9.3 illustrates the major information flows between agents and functions.

In each time step:

1. The representative firm computes the value of the marginal worker's value product at current prices, chooses a new target workforce. It follows a partial adjustment rule in choosing current, labour force, capital stock for the following period. Firm size is constrained by diminishing returns to scale. New firms enter when population grow beyond what existing firms target.
2. Aggregate current labour demand is computed, compared to existing supply, and a new wage is selected.
3. The wage premium is calculated from the wage and used by agents to decide whether to work in the city.
4. Each lot, or unit of land, is an agent. Each uses the wage premium and its own location to compute its locational value, or warranted price, and potential rental earnings.
5. The bank determines mortgage availability for newcomers and tenants.
6. Newcomers and investors bid on properties listed for the period. They use an expected price that includes information about how the market has behaved, so it is possible for price bubbles and expectations to feed back into the dynamics.
7. The realtor takes the list of bids and coordinates a bargaining process to reach a final price, if possible.
8. If the new property owners do not choose to occupy their own houses, they rent the properties to newcomers as tenants.

Figure 9.2 illustrates the computational sequence. Figure 9.3 traces the economic relations among agents in the flow diagram.

[2]The density parameter is the simplest possible version of a density function, which is itself a simplification of a mixed population. At the cost of additional computation, properties can have individualized densities or can be subdivided to allow for more complex populations.

9.4 Design concepts

The model is intended to combine a theoretically grounded simulation of the spatial and temporal growth of a city with a new model of a housing market in which individual agents buy and sell property, live, work, and retire subject to a realistic financial system. To achieve this, not all the parts are modelled at the same level of resolution. We combine coarse generalizations about long-term agglomeration effects with fine-grained housing and financial market processes.

The principles explored include the relationship between urban agglomeration effects and the financialization of the urban housing market. To explore these principles, we combine two distinct approaches to modelling social systems: agent-based and equilibrium-oriented economic modelling.

9.4.1 Convergence to equilibrium

To bypass the complex and partially understood wage-setting process we convergence to equilibrium conditions for the firm internally and for labour markets. In this approach, we do not assume that the agents are constantly achieving equilibrium or even that decisions are correct, only that they represent adjustments in the correct direction. We assume that the firm is setting targets for its workforce and capital stock intended to achieve maximum profit, then adjusting partway toward those targets. Similarly, while demand for labour is determined by the collection of firms, supply is determined by the response of potential workers to the level of the wage. We allow the wage to move upward if there is excess demand or downward if there is excess supply.

This partial adjustment process evades the common criticism of equilibrium modelling that it requires perfect information and perfect rationality.

In the housing market, investors also seek to maximize their profits. They calculate the return on their investments accurately (up to the limits of their knowledge) over a 5-year mortgage period. Our treatment of how they form expectations about the potential capital gains is frankly simplistic. We assume that the expected price change over a 5-year mortgage period is just a linear projection of the rate of change in the previous period.

We also use equilibrium arguments to compute land rents from the transportation cost and urban wage premium that drive urban locational decisions. Realistically, like capital gains, the rents that can be extracted are a slow-moving target that is difficult to forecast. We essentially assume that marginal agents and potential buyers accurately estimate their annual travel costs and local rents, and do not face fixed costs of change.

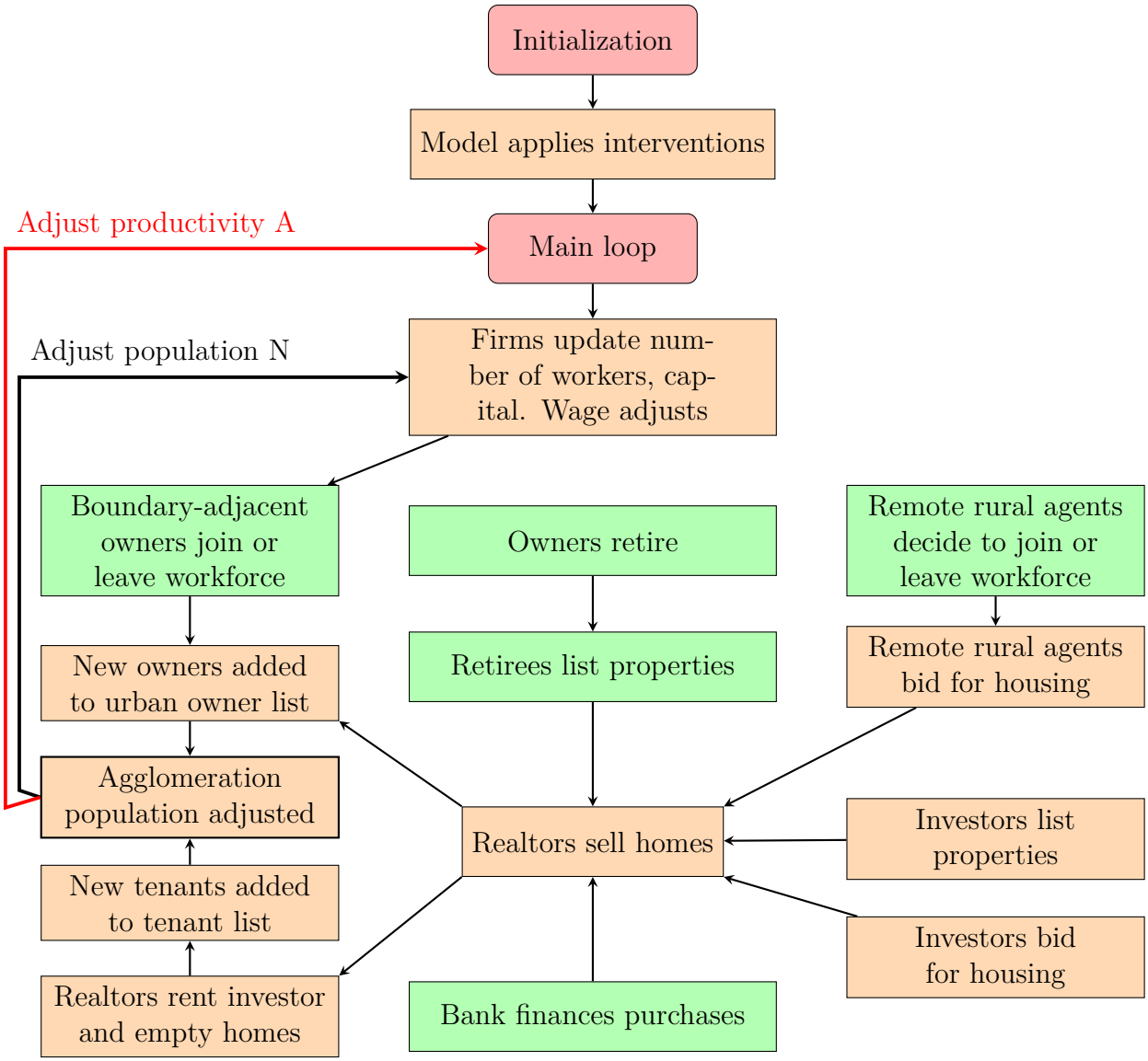


Figure 9.3: Agent decisions and information flows. Two feedback loops are emphasized. Firm decisions lead to adjustment of population N, which influences the agglomeration effects on firm productivity, and ownership changes affect the productivity prefactor A.

Chapter 7, on methodology, provides more detail about the methodological decisions that inform the modelling decisions.

9.4.2 Emergence

The city is an emergent entity that arises out of the rural economy as a result of agglomeration economies. The social structure is also emergent. We begin our exploration after the city and a two-class structure has emerged. We then examine how their class structure evolves. The classes are:

1. rural owner-occupiers
2. urban owner-occupiers.

Members of both classes own the land they live on. Urban owners differ in that they have access to an urban labour market. We do not specify whether rural owners gain an income as producers for example, as peasant owners, or as labourers. The logic of the migration equilibrium requires all agents be equally well off. The urban owners are a mixed class in the sense that they sell their labour like classic proletarians but also own a valuable capital asset, which is their land. Introducing additional differences among agents would open the possibility the endogenous emergence of further class distinctions based on access to various forms of capital, a process explored by John Roemer in his General Theory of Exploitation and Class [168].

Two more classes emerge in our simulations:

3. urban tenants
4. investors.

There are now two possible pure urban regimes, an owner-occupier regime and a tenant regime, in which investors own all properties. We start our experiments with a pure owner-occupier regime in which those who own houses and work can build equity. The city may then transition toward the investor-owned regime as investor-agents purchase properties based on local expected financial return calculations. Our experiments explore some policy interventions that could affect the transition.

9.4.3 Sensing

All agents have lagged information about the wage. They observe job postings by firms. They know their own savings and borrowing costs. They can calculate warranted price and expected price growth.

9.4.4 Adaptation, learning and prediction

There is no learning in the sense that agents do not change their traits based on experience. Agents do, however, make predictions, anticipating prices based on the rate at which those prices have increased in the past, with the prediction variable $\dot{P}$.

9.4.5 Interaction

Agents make decisions to work, retire, purchase, or invest independently but because of agglomeration effects, their decision to work and its effect on the size of the labour market feed back to affect wages and the decisions of others in the next step.

The central interaction is in the housing market through the competitive bidding process that allocates properties and rents. A secondary, parametric interaction occurs if the allocation of housing or rents influences the production function as described in chapter 6.

9.4.6 Stochasticity

Agents do not face uncertainty. Stochasticity comes into the main model two ways: through the distribution of agents' initial savings, and through randomizing the order in which agents act.

9.4.7 Feedback loops

Feedback loops are not part of the ODD standard, but are an important concept in this work.[3] There are three feedback loops in the model:

1. the productivity-wage, population-productivity loop that we call the Alonso-Jacobs cycle;

[3]Feedback loops are a fundamental feature of almost all systems. They have probably been recognized by theorists for centuries. Marx, to take one relatively modern example, identified the growth dynamic of the capitalist system as a feedback loop, with capital investments producing a surplus that was fed back into investment, growing the stock of capital. Marx claimed that this loop produced dynamic instability and a great deal of subsequent work has supported his insight [63] [174]. More recently, the Keynesian multiplier is a result of feedback in macro models between expenditure and jobs. That loop produces a stable equilibrium. Neoclassical growth theory built on that mechanism to explore the determinants of economic growth using differential and difference equations. [161]

2. a speculative price-expectations cycle that may produce price bubbles; and
3. the hypothesized feedback from financialized ownership to the production function, which depresses wages, reduces growth and therfore inhibits financialization.

The loops are linked. Rising productivity raises wages, which then works through two paths. It can raise rents, effectively transferring productivity gains to landowners, and it can draw more workers into the city workforce, enhancing the Alonzo-Jacobs cycle. Much depends on the speed of response of the city population and the rate of transmission of agglomeration effects to wages through the firm. Our base model allows the boundary to respond to increments in the wage with a small lag. In the base model, financial flows are unrestricted but the rate of financialization is limited by the rate of turnover of ownership. We parameterize the rate of adjustment for each of the stocks in a simple way to facilitate sensitivity analysis.

9.4.8 Observation

The output variables we report are the urban wage, land prices, city size, owner-occupier population, tenant population, total urban population, who owns which property, previous prices, firm capital stock, firm workforce size, and number of firms.

9.5 Initialization

Initial values for the model are detailed in Appendix B on initial values.

9.6 Input

Parameters have been chosen to be in ranges consistent with theory and, where possible, empirical work. The combination of parameter values for the production model was chosen to produce a plausible growth trajectory for a city that grows from small to large over a reasonable time period. To model interventions, we change key parameters mid-run to represent shocks to the system, such as labour market shocks, price shocks, and cyclical patterns. The model does not draw on outside digital datasets.

9.7 Submodels

We have described our model in terms of a few major components: the Alonzo-Jacobs model, the financial sector, and the housing market. The large components themselves each rests on a large number of modelling decisions that we have discussed in Chapters 1 through 8. We prefer to think of these as sub-models rather coding decisions because each is derived from theoretical or empirical considerations based on our readings of the literature (which is often extensive, varied, and inconclusive). They are also influenced by pragmatic decisions about how to keep the overall model simple and model. Individual submodels can be modified or replaced to reflect different assumptions or conditions.

1. the spatial structure of the model, with each land unit having a transportation cost based on linear distance from the urban center;
2. the population model, with a uniform density of owners or tenants located spatially;
3. the overlapping generations lifecycle model with retirement after 40 years;
4. the population replacement model;
5. the population determination model driven by decentralized agent decisions;
6. the representative firm model that generates the labour demand. This includes a specific production function and a model of how a profit-maximizing firm hires inputs and how rapidly it adjusts;
7. the firm entry model that adjusts the number of firms toward the number of optimally sized firms the populations will support;
8. the aggregate firm sector model that determines labour demand for the entire city as the representative firm demand times the varying number of firms;
9. the perfectly elastic export demand for output model;
10. a household decision-making model that determines whether individuals work in the city based only on the wage and transportation cost for each property;
11. the agglomeration model that augments firm productivity based on a function of the number employed;
12. the land valuation models used by agents;

13. the price expectations model;

14. the land market model in which homeowners and financialized investors bid on properties for housing or to capture the rising rents due to agglomeration;

15. the auction model that allocates properties and generates property prices for each period.

9.8 Expectations

Expectations introduce a mental model of the future state of agents into current decisions. We employ a simple backwards-looking expectation formation anchored to current rental returns.[4]

[4]Forecasts based on recent price movements can give rise to price bubbles through either speculative or precautionary motives. Expectations anchored in perfect foresight have different dynamics since agents correctly forecast the path of prices [146]. We describe an investment rule of this sort in Chapter 2 on financialization.

Chapter 10

Results

The two main propositions of this thesis are, first, that financialization affects the ownership of housing and therefore the class structure of society, and, second, that this may have implications for urban productivity. In this chapter, we present model results relevant to these propositions:

1. We describe the results from the model with no policy interventions.
2. We explore the effects of seven policy interventions in the model, showing the effect of varying the parameters and discussing the effect of changes.
3. We then repeat the seven policy interventions, introducing a link from housing ownership to productivity, and comparing the revised model with the base case to explore how the productivity linkage affects the effectiveness of policy interventions.
4. Finally, we explore the effects of a shock and demonstrate that the model exhibits hysteresis or non-reversibility.

10.1 Seven policy interventions

The policy variables we consider are:

1. Capital gains taxes, which capture part or all of the speculative gains on property ownership. A capital gains tax is a tax on the property price at the point of sale on

the gains or profit accrued since the property was acquired. It captures the increase in the price of an asset due to changes in the market rather than any increase in value contributed by the owner. The Canadian capital gains tax rate is lower than the tax on interest or dividend income so capital gains are currently an especially attractive form of income for investors.

2. The cost of capital, or the rate at which investors can borrow, which affects the net return on property speculation.

3. Transportation costs, which are affected by public infrastructure investment, and reduce the amount of locational value that is spent on transportation, increasing the wealth of the community.

4. Urban density, which is controlled by zoning regulation, and which multiplies locational rents.

5. The sensitivity of the cost of borrowing to borrower wealth, which affects whether low-asset households can purchase housing and the likelihood they will service mortgages.

6. The property tax rate, which is a cost of living in the city. The tax is deducted from locational rents for individuals or speculators.

Because there are multiple effects of each intervention, we use separate figures to represent the impact of each policy intervention on the trajectory of each of the seven indicator variables over time.

10.2 Seven output variables

The economic output variables we consider are wage, capital stock, firm workforce, total employment, city extent, number of firms and the share of properties owned by their occupants. Figure 10.1 shows the trajectory of each variable in the base model with no interventions. It is useful to describe the trajectory for each variable for the baseline case before we introduce the policy experiments.

1. In the upper left is the equilibrium wage path. Firms set a wage target based on the value of the marginal product of labour, which rises at a decreasing rate as the population rises due to the agglomeration effect on firm productivity.

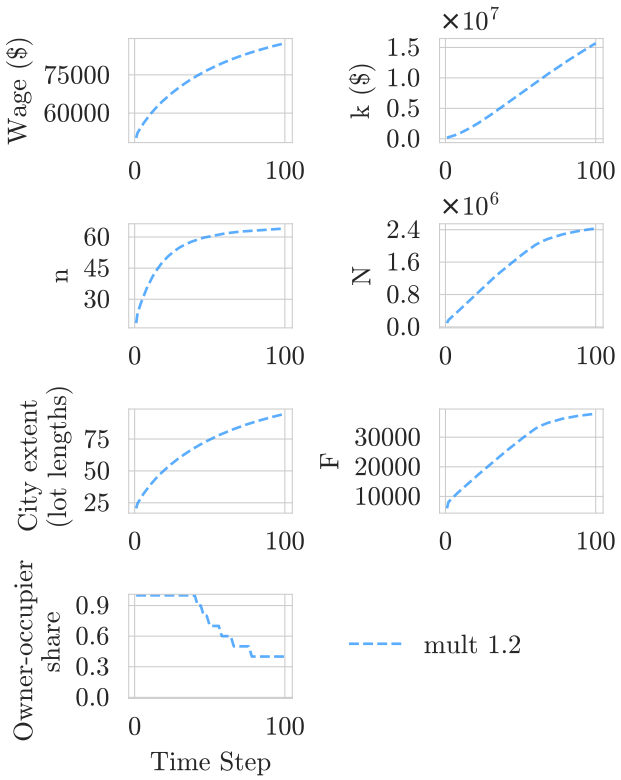


Figure 10.1: Graphic presentation of seven output variables with baseline parameter settings. In the lower right the active parameter variations are indicated. In this case one parameter, 'mult', is listed with its base value and with no variation. 'mult' stands for the 'ratio of population affecting agglomeration,' indicating that the number of worker-residents is scaled up by 20% to compose the population value.

2. The upper right shows the individual firm's capital stock k, which adjusts more slowly but rises as productivity and firm employment rise.

3. Second from the top on the left, below the wage figure, is the number of workers in each firm, n. Firms set an employment target based on the value of the marginal product of labour, which rises due to the agglomeration effect.

4. On the right, below the capital plot, is the urban population N, which rises as the wage rises. There is circular causation between wage and population. Population increases feed back to increase the wage, a rising wage in turn drives population growth and population growth feeds back to productivity, increasing the wage. Rising

transportation costs gradually slow growth.

5. In the third row, below the wage figure, is the city extent, which grows as the wage rises and homes are added to the periphery.

6. To the right of the city extent is the number of firms F, which grows slightly slower than the population because firms increase their workforce size as productivity rises.

7. The final figure shows the share of properties owned by their occupants. The rest are owned as investment properties by speculators. This figure shows the effect of financialization when there is no feedback to productivity.

In total, there are forty-two plots in the first section, some showing a null effect. There are an additional forty-two plots in the second section. We discuss each experiment, point out the most significant effects, and provide some explanation of results that may seem surprising.

10.3 A note on how to interpret results

Without strong empirical support for parameter values, we can say little about the magnitudes of any effects, although we can have some confidence in the directions and relative sizes. The results we present are conditioned on the selection of the parameters of the firm and migration models that form the environment for the housing market-financialization model. We have chosen parameter values to roughly approximate those for a mid-sized North American city so that the results may be more easily interpreted. The size of the effect we report would vary if different parameters had been chosen. For the experiments, we test relatively large perturbations of the parameters to make the effects of interventions clear. Appendix B documents the baseline parameter values.

It is encouraging to note, given these constraints, that the results the model produces are consistent with theory, the stylized facts of urban development, and recent changes we are observing in cities. This suggests that the results may indeed provide insight into the effectiveness of the policy interventions we consider, and thus that these results might reasonably be used to suggest useful questions, hypotheses or topics for future work.

10.4 The basic ownership result

The first question is whether the model produces the pattern where investors own an increasing share of urban housing and home ownership is declining.

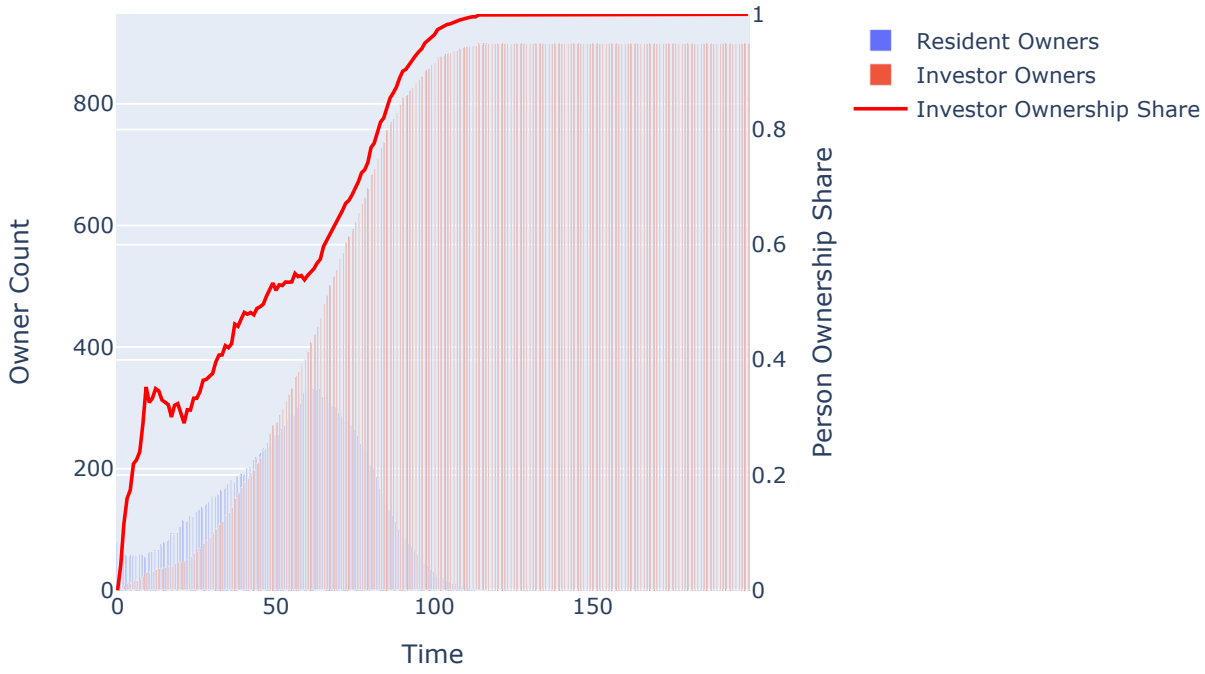


Figure 10.2: The transformation from a city of homeowners to a city of tenants in the baseline model.

Figure 10.2 illustrates the evolution of home ownership using a version of the model that grows over 200 years from 50 homeowners to a population of 1,000. The number of homeowners is shown by vertical blue bars. Red bars show counts of investor-owners and the solid red line shows the share. This plot shows ownership numbers, while in the rest of this chapter, we report only shares. The red line, with its scale on the right of the figure, shows the share of the housing stock owned by investors.

At first, there are no investor-owned homes. The number of owner-occupiers initially rises faster than the number of investors, but after one hundred periods it falls to zero. By the time the city reaches its maximum size, the city has transformed from a city of homeowners to a city of tenants. The unevenness in the rise of the red line signals a

transitional range in which investors and would-be owner-occupiers are similar in number and competitive in strength. In that range, randomness in the savings of new entrants affects the number of units going to each type of buyer.

Investors eventually own all of the housing in this example. With plausible parameter settings, our model consistently produces trajectories similar to this example. This result supports the hypothesis that without countervailing forces, financial actors will take an increasing share of ownership in the housing market. The tendency for investors to own an increasing share of the housing stock is robust across experiments in the model.

The distribution of ownership determines the distribution of the locational land rents, which are the product of agglomeration effects, so this example sees owners of capital capturing an increasing share of the surplus value generated by urban agglomeration. As the city grows, rents increase. Total annual locational rents a hundred steps in, at the end of the run, are approximately twenty times their initial size. At that point, 100% of the surplus accrues to the owners of financial capital.

10.5 Policy interventions without the productivity link

This section examines the seven potential policy interventions, introduced above, and their effects over 100 periods on city size, wage level, and home ownership. In each case, we vary one parameter to simulate a policy intervention, and examine the effect on the city's evolution.

10.5.1 Capital gains tax on investors

A capital gains tax is a tax on profit from the sale of property or an investment. It captures the increase in the price of an asset due to changes in the market rather than any increase in value contributed by the owner.[1] We define any homeowner who does not occupy the housing unit they own as an investor.

The baseline value for the capital gains tax is 15% for investors and 1% for owner-occupiers, who are exempt from capital gains tax on their first residence, but have some costs to realize their capital gains. In this experiment, we explore the effect of substantial

[1]The Canadian capital gains tax rate is lower than the tax on interest or dividend income so capital gains are an especially attractive form of income for investors. In Canada, homeowners currently do not pay capital gains taxes on their primary residence.

changes to the capital gains tax rate for investors. We substitute three levels of capital gains tax for investors (0%, 50%, and 100%), keeping the tax level constant at 1% for homeowners.

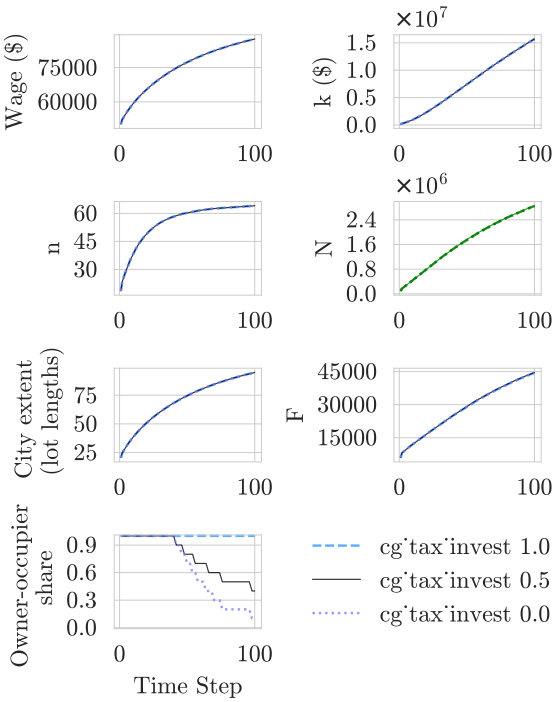


Figure 10.3: The effect of changing the capital gains tax for investors. This figure illustrates the effect on seven policy variables over time, with a capital gains tax rate of 0%, 50%, and 100% for investors, the default 1% rate for homeowners, and no productivity linkage.

In general, since capital gains are part of the objective of investors, a capital gains tax should, in theory, reduce investor participation. Figure 10.3 shows that if 100% of gains are taxed away, investors do not enter the market. A capital gains tax on housing investment will have a powerful effect on the ownership ratio. It does not, however, affect the other economic variables.

10.5.2 Capital gains tax on owner-occupiers

We can also change the capital gains tax for homeowners. Figure 10.4 shows of the effect of four different capital gains tax rates, 0%, 10%, 20% and 30% on owner-occupiers. The capital gains tax rate for investors in this set of experiments is 15%. Increasing the capital gains for owners makes purchasing a home less attractive as an investment for owner-occupiers but not for non-resident owners.

There's a bifurcation in the ownership results depending on whether the rate is above or below the investor's tax rate. If the owner-occupiers' tax rate is higher than the rate for investors, shown by the solid and the dashed lines, the homeownership rate is 30% lower at 100 time steps.

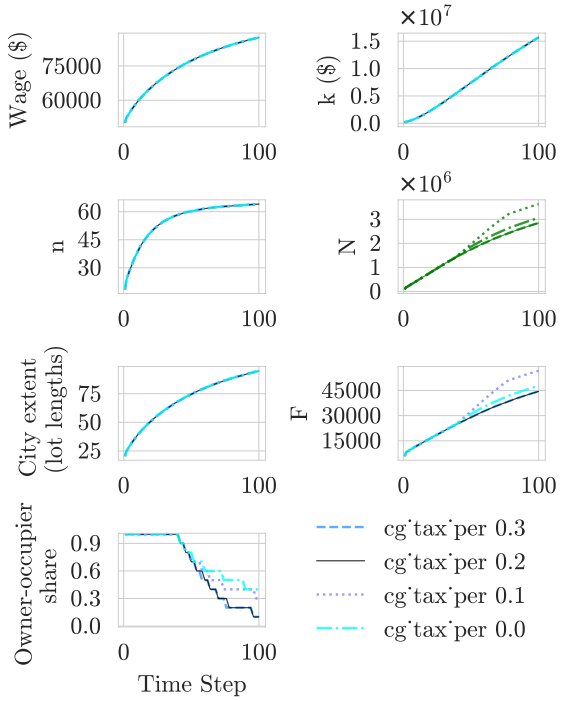


Figure 10.4: The effect of introducing a capital gains tax for owner-occupiers. This figure illustrates the effect on seven policy variables over time, with a capital gains tax rate of 0%, 10%, 20% and 30% for owner-occupiers, the default 15% rate for investors, and no productivity linkage.

10.5.3 The cost of capital for investors

The cost of capital is the interest rate on borrowed money. Higher capital costs for investors might be expected to slow the rate of housing acquisition because it makes acquiring housing more expensive for investors. Figure 10.5 shows that increasing capital costs for investors does not affect the final level of investor ownership. It does, however, decrease the wage slightly and, therefore, decrease the population. This suggests that the model appears to be less sensitive to the cost of money, than to other interventions.

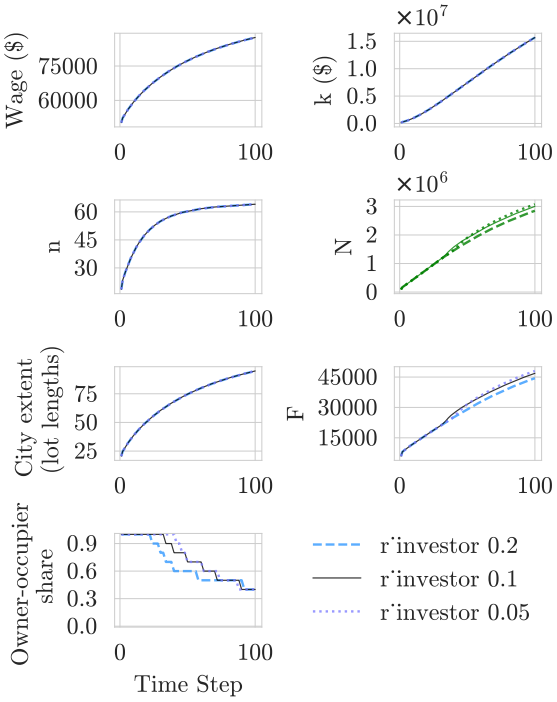


Figure 10.5: The effect of raising capital costs for investors. This figure illustrates the effect on seven policy variables over time, with an investor rate of 5%, 10% and 20%, a rate for owner-occupiers near 5.1%, just above the bank's prime rate, adjusted based on individual assets and income, and no productivity linkage.

10.5.4 Transportation costs

Transportation costs are the costs of getting from a residence to work. Policy can shape transportation costs through, for instance, improving roads, managing road congestion, or supplying public transit. Figure 10.6, shows the results of reducing transportation costs for all residents by 40%. The city grows faster and gets larger with lower transportation costs.

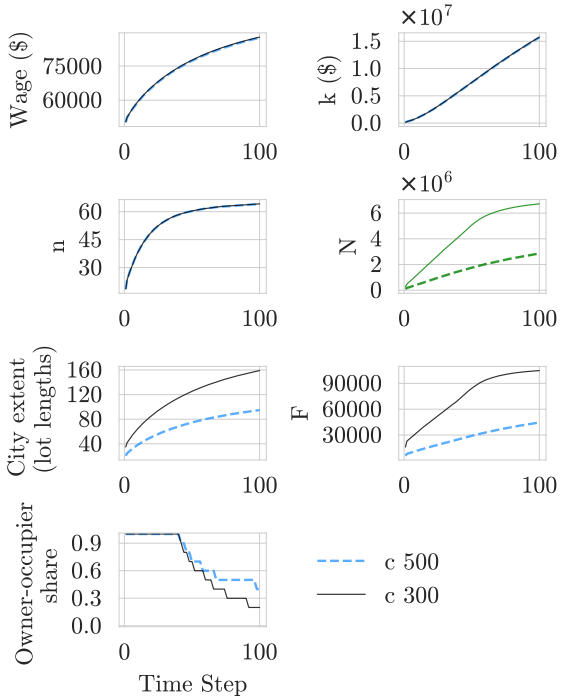


Figure 10.6: The effect of decreasing transportation costs. Illustrates the effect on seven policy variables over time, with a cost of $300 and $500 per unit distance per year, and no productivity linkage.

Surprisingly, lower transportation costs also served to decrease the home-ownership ratio. This is likely because the reduction in transportation costs leads to an increase in willingness to pay land rents. The resulting increase in land rents allows prices to rise, leading to higher expected capital gains. Investing in housing is then more attractive for speculators and increased participation by speculators leads to less ownership by residents.

10.5.5 Density

Density is the number of residents per grid space. Increasing density is proposed as a way to increase the availability of housing and the ability of people to buy homes. Figure 10.7 shows that the effect of density on city population is significant. It has no effect, however, on the city's extent, and no effect on the ownership ratio.

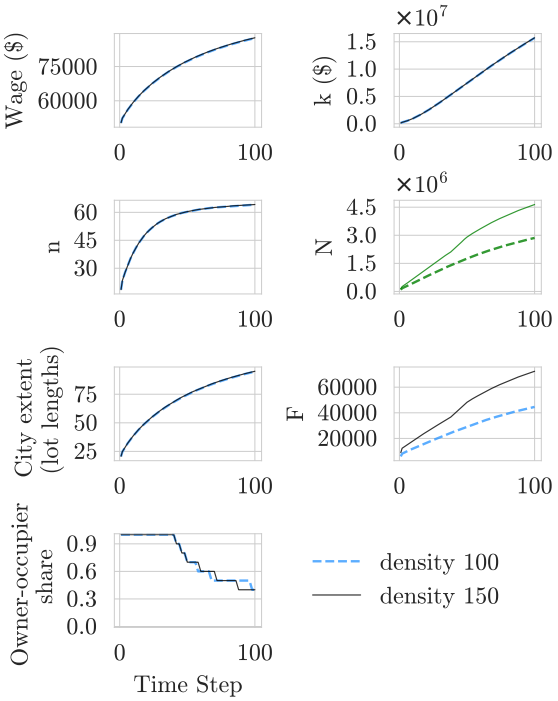


Figure 10.7: The effect of increasing density. This figure illustrates the effect on seven policy variables over time, with a population density of 100 and 150 per grid space, and no productivity linkage.

Increasing density does not affect long-term ownership ratios because rent per unit is unchanged, so density alone does not affect the relative advantage of new home buyers. There are more homes, however, and since the ratios are consistent, there are more homeowners overall.

10.5.6 Cost of financing's dependence on borrower's wealth

Wealth sensitivity determines the assets required for people to secure a mortgage. A higher parameter value is more restrictive. Figure 8.4 in Chapter 8 on the model illustrates the effect of the parameter on the maximum mortgage available to borrowers with different asset levels.

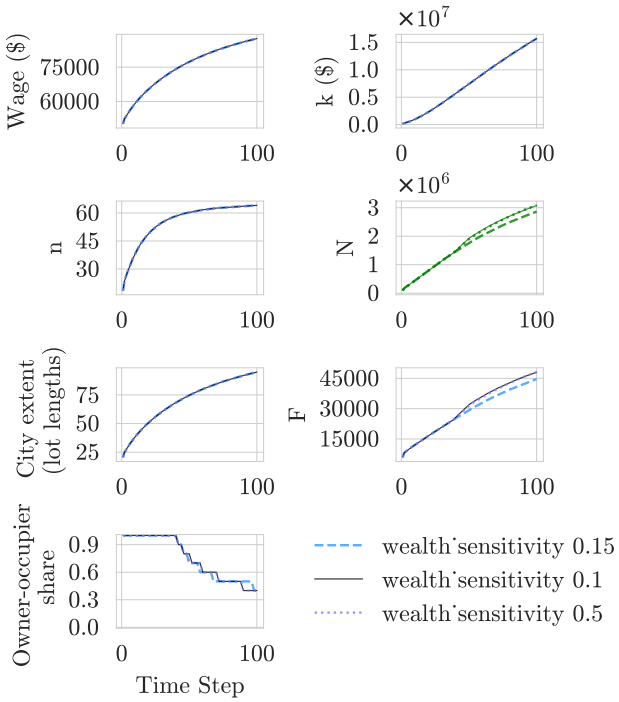


Figure 10.8: The effect of the wealth sensitivity parameter. This figure illustrates the effect of the parameter on seven policy variables over time, with parameter values of 0.15, 0.1, and 0.5, and no productivity linkage. The wealth sensitivity parameter controls the wealth required for accessing a mortgage and its effect is illustrated in Figure 8.4 in the model chapter.

Figure 10.8 illustrates that a restrictive mortgage regime slightly reduces the labour supply and city population. It has no noticeable effect on the ownership ratio.

10.5.7 The property tax rate

The property tax rate is the annual tax paid, as a share of the property's total value. We consider a property tax rate between 1% and 10%. Figure 10.9 shows that the effect of

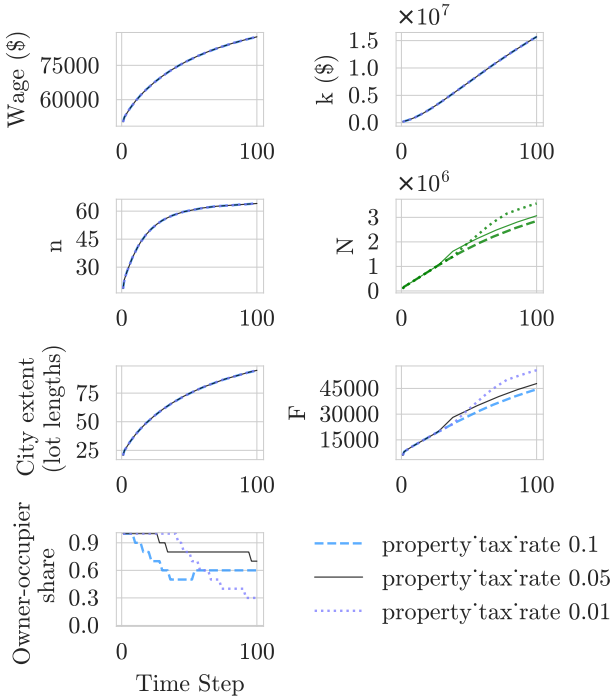


Figure 10.9: The effect of varying the property tax rate. Illustrates the effect on seven policy variables over time, with rates between 1% and 10%, and no productivity linkage.

the property tax varies with the size of the tax. The highest rate we consider decreases city size as shown by the dashed blue line. A higher property tax rate reduces the share of the locational rent captured by investors. It does seem to affect the ownership ratio. The results suggest that departure from the current level in either direction might lead to a greater decline in the fraction of owner-occupiers. Further analysis would be required to more fully characterize this result.

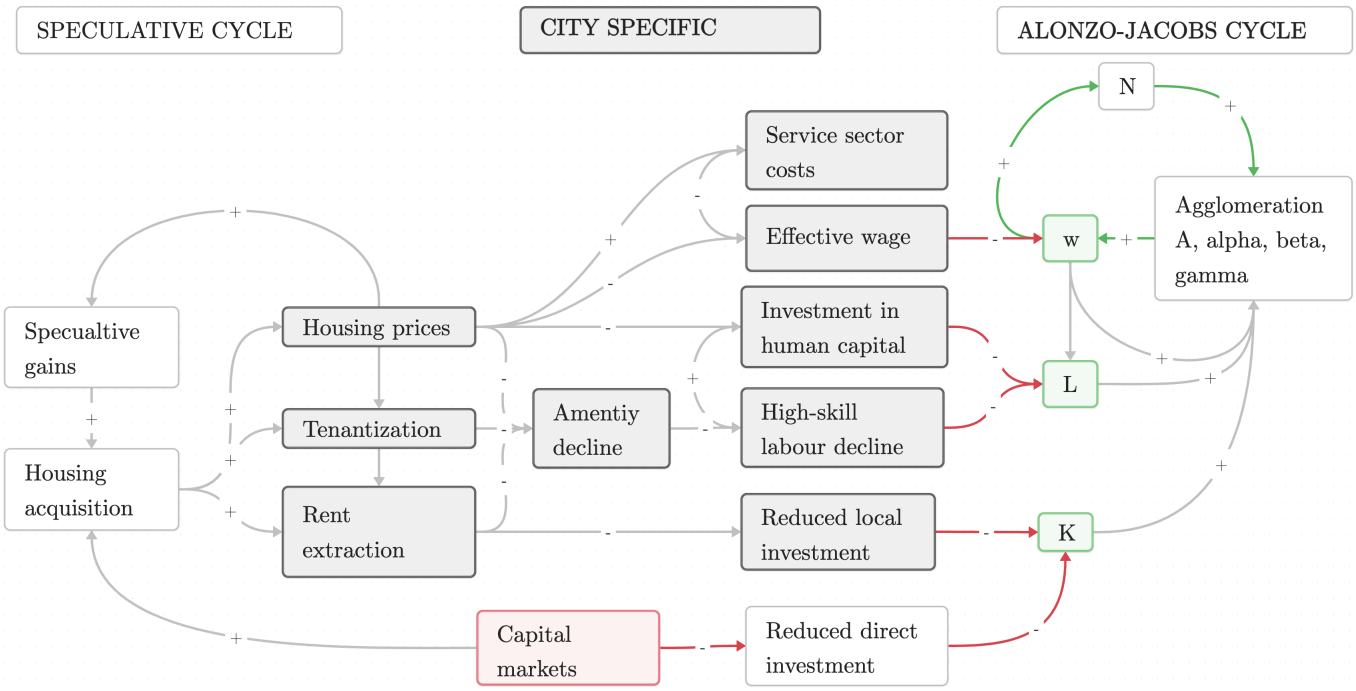


Figure 10.10: Impact channels relating financialization and urban productivity. Urban production works through the Alonso-Jacobs cycle on the right. For any change in the system to affect output it must at leat one of the variables that regulate the cycle - the capital stock, K, effective supply L, workers net wage w or the population N providing agglomeration effects.

10.6 Policy interventions with a productivity link

We have suggested that the financialization of the urban housing market may affect urban productivity, laying out plausible links in Chapter 6. By adding this link to our model, we can explore how it would affect the results of policy interventions. If the model shows that a linkage would have a significant effect on the effectiveness of policy tools, determining whether a link exists, how strong it is, and which channels it operates through become promising targets for urban policy research. The new component in this experiment is the

formal linkage of the financialized housing market to urban productivity.

To capture the effect of the hypothesized link, we make a rising investor share of the housing stock reduce the scale term A in the production function. A is the multiplicative constant term in the Cobb-Douglas production function In the following section, we replace A with:

$$A^* = (1 - 0.33s)A,$$

where s is the investor share. $A^* = A$ if the investor share is zero and is reduced by 33% if the investor share goes to 100%. A^* thus becomes a dynamic parameter that changes as the model develops.[2]

A simulation of this linkage is illustrated in Figure 10.11. The solid black line represents the base case with none of the policy interventions. The dashed blue line shows the effect of introducing the linkage described above. The linkage has, as we hypothesized, substantial economic implications. The linkage reduces wages, city size and population. Declining productivity is the primary channel for this change, which pulls down the wage and the other population variables. The change is amplified by the resulting reduction in aggregation effects.

There is also a change in ownership share shown in the lower panel of Figure 10.11, where the effect of the linkage reduces the degree of investor ownership. With declining growth, housing investment is less attractive. The model suggests that the linkage is harmful to the economy but the effect on the ownership share is somewhat self-limiting. If the linkages we have hypothesized exist, the result of financialization would be that we end up with smaller cities with a higher share of owner-occupiers than we would see without the linkage.

In the sections below, we analyze the effect of the productivity linkage on the function of policy interventions, by repeating the experiments above with the linkage in place. We examine the effect of each policy on the trajectory of each of the seven economic variables over time. The results indicate that the effect of public sector policies may differ in the presence of a productivity link, and that further investigation should be on the agenda of researchers.

[2]The magnitude of the relationship is somewhat arbitrary. We choose 33% because it gives values within the range of values for A empirically estimated for cities and large enough to make qualitative impacts easy to see.

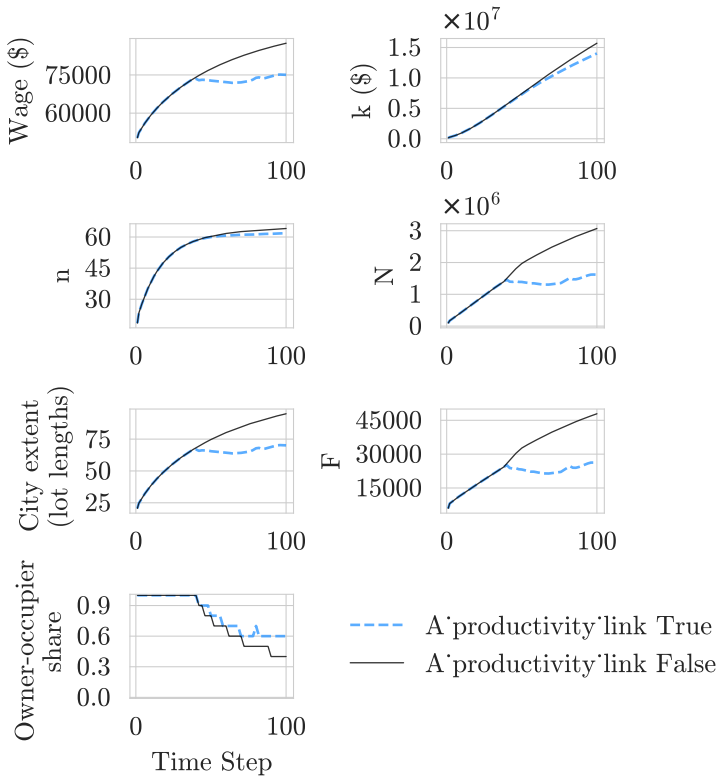


Figure 10.11: The effect of introducing a productivity linkage in the base model. The solid black line shows the case with no linkage, and the dashed blue line shows the case with the productivity linkage. With this linkage, the prefactor value A in the scaling equation is a third, roughly 33%, lower with 100% financialized ownership than when property is 100% owner-occupied.

10.6.1 Capital gains tax on investors with linkage

Figure 10.12 shows that, with or without the productivity link, a capital gains tax on housing speculation will have a powerful effect on the distribution of ownership. While it has little effect on other variables without the linkage, when we introduce a capital gains tax on investors in the presence of the productivity linkage we see more significant effects on other variables.

With the productivity linkage, when the ownership ratio drops dramatically, the falling owner-occupier rate reduces productivity to a level where increasing returns to the population are offset by decreasing productivity, effectively crashing the local economy. On the

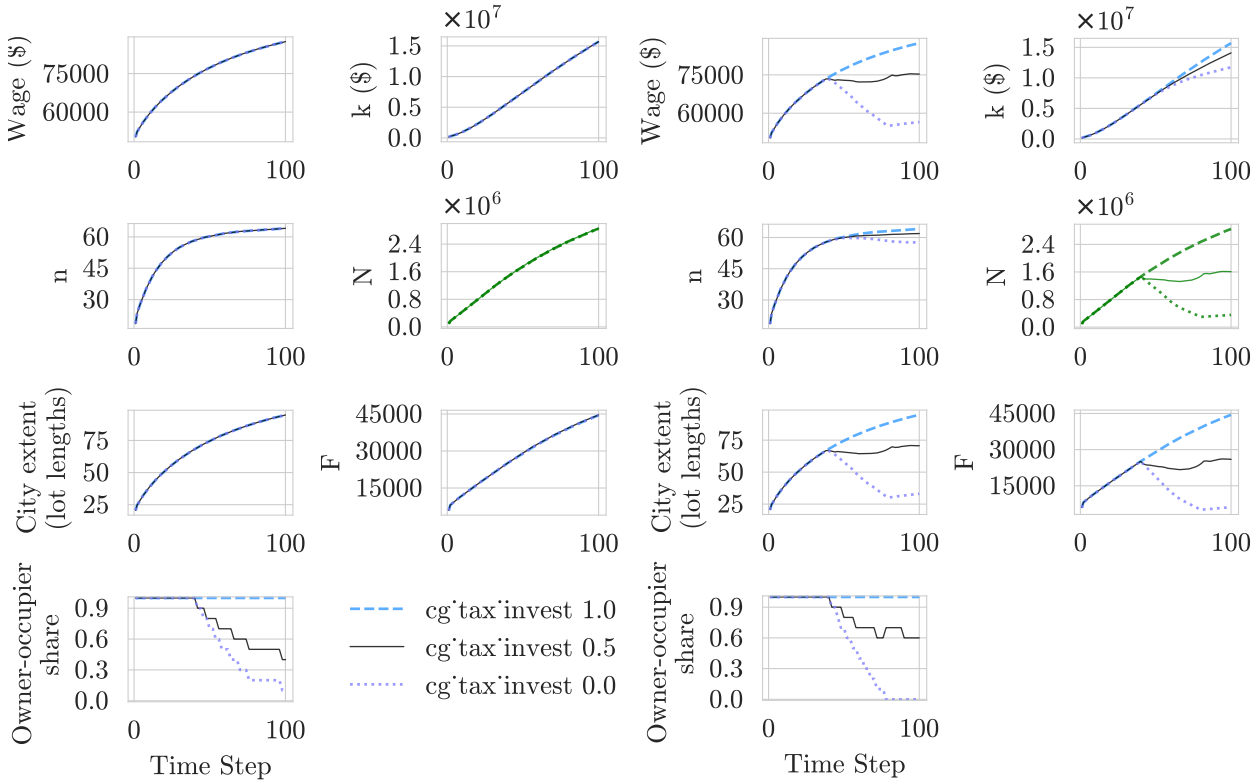


Figure 10.12: Comparing the effect of changing the capital gains tax for investors with (left two columns) and without (right two columns) the productivity linkage. This figure illustrates the effect on seven policy variables over time, with a capital gains tax rate for investors of 0%, 50%, and 100%, and the default 1% rate for homeowners.

other hand, a 100% capital gains tax on land speculation is one of the few interventions that can entirely eliminate investor participation in the housing market, and thus leave 100% owner-occupancy, the dashed line in the lower left of the same figure. With a 100% capital gains tax on speculation, wages are higher, the city is larger, and there are more firms. This experiment demonstrates that policy parameters are likely to have different effects when there is a link between financialization and urban productivity and when there is no link.

10.6.2 Capital gains tax on owner-occupiers with linkage

In this subsection, we explore the effect of a capital gains tax for owner-occupiers in the presence of linkages. In Figure 10.13, the dotted line represents the case with no capital gains tax for homeowners, the solid line represents a 50% tax, and the dashed line represents a 100% tax. Taxing capital gains tax for owner-occupiers advantages investors.

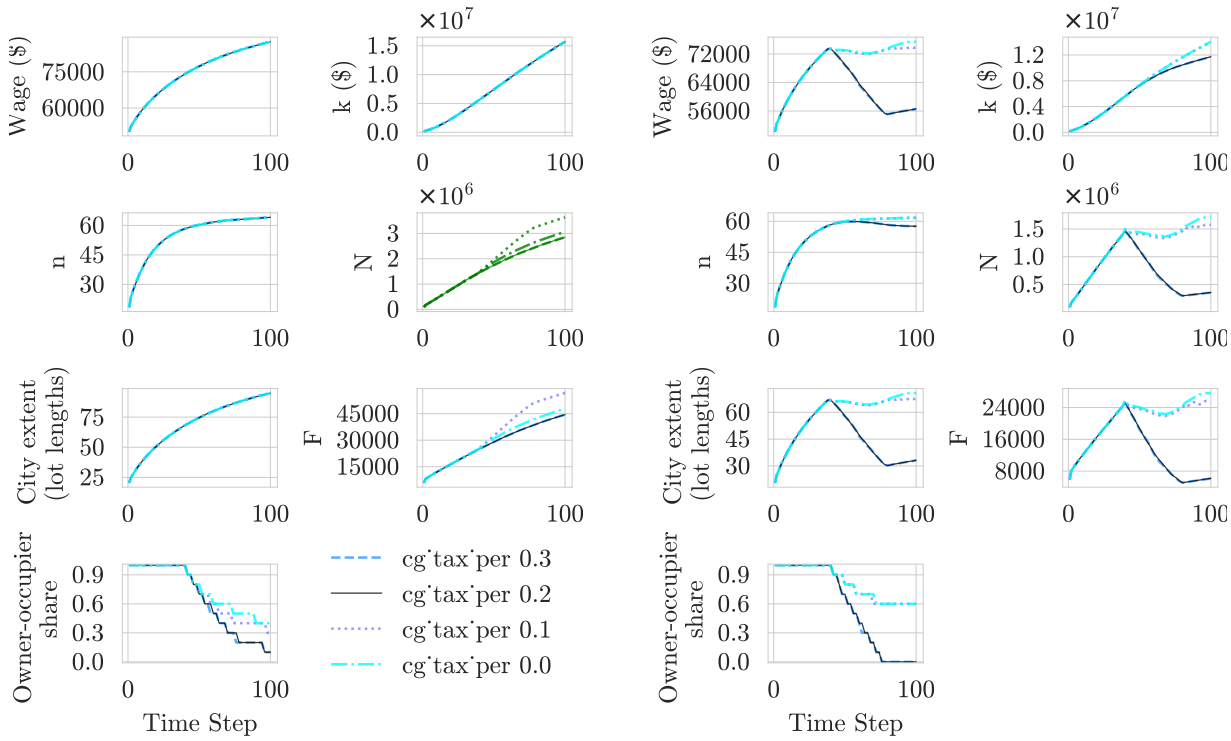


Figure 10.13: Comparing the effect of introducing a capital gains tax for owner-occupiers with (left two columns) and without (right two columns) a productivity linkage. this figure illustrates the effect on seven policy variables over time, with a capital gains tax rate of 0%, 10%, 20% and 30% for owner-occupiers, and the default 15% rate for investors.

A higher capital gains tax on homeowners than investors results in home ownership falling substantially more than when it is lower. It also results in a much lower population and city size, which leads to lower rents for tenants because locational rents are lower. The sensitivity of the model economy to capital gains taxes on owners suggests a need for further research.

There is some rebound from the lowest level. With a productivity link, a high relative tax rate produces a city that rises rapidly and then declines. Slow growth begins after the decline. The economic variables decline rapidly, then city extent, wage and firm count all recover slightly from their initial decline. Regardless of the presence or absence of a productivity link, when the capital gains tax on homeowners is above the rate of investors, home ownership falls farther and faster than when it is lower than the investor rate. It drops a bit as a result of the increase in investor-owned population. There is a bit of a wobble after that, and that's because the population grows a little bit after that. The rebound occurs because financialization actually appears to suppress growth for a period, and then growth starts to come back over time.

10.6.3 The cost of capital for investors with linkage

Figure 10.14 shows the effect of increasing capital costs for investors. Even in the presence of strong productivity spillovers, it has little effect in this experiment which suggests that the cost of capital for investors is dominated by other factors in this model. The low effect on ownership means even with the linkage in place, it has less effect on other economic variables. Higher capital costs for investors appear to increase the speed at which the effects

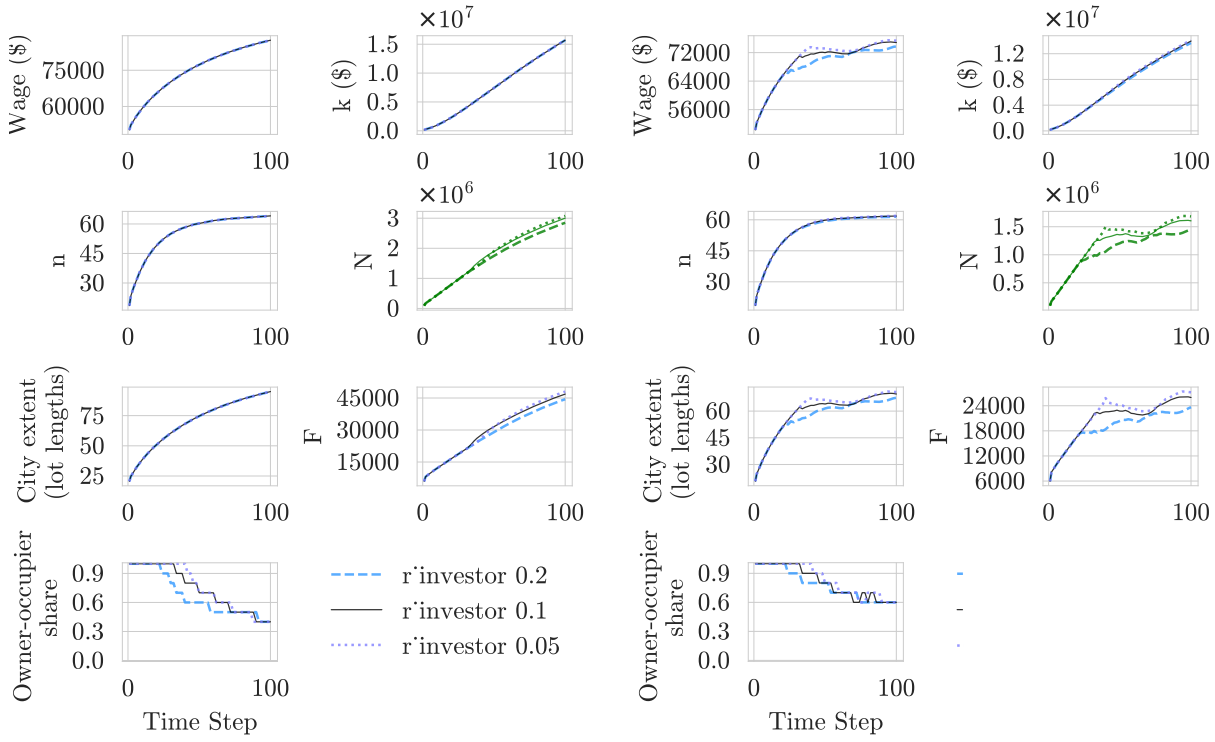


Figure 10.14: Comparing the effect of raising capital costs for investors with (left two columns) and without (right two columns) a productivity linkage. Illustrates the effect on seven policy variables over time, with an investor rate of 5%, 10% and 20%, and a rate for owner-occupiers near 5.1%, just above the bank's prime rate, adjusted based on individual assets and income.

take place but do not affect the final level of investor ownership. Productivity spillovers cut population and wages, keep the owner-occupier share just 20% higher, and introduce what may be a weak speculative cycle.

10.6.4 Transportation costs with linkage

In Figure 10.15, we reduce transportation costs for everyone by 40%, this time in the presence of productivity impact. The linkage reduces wages and city size to the base case without the linkage, but city size and population increase with lower transportation costs as expected. The linkage also introduces large oscillations in population and city size.

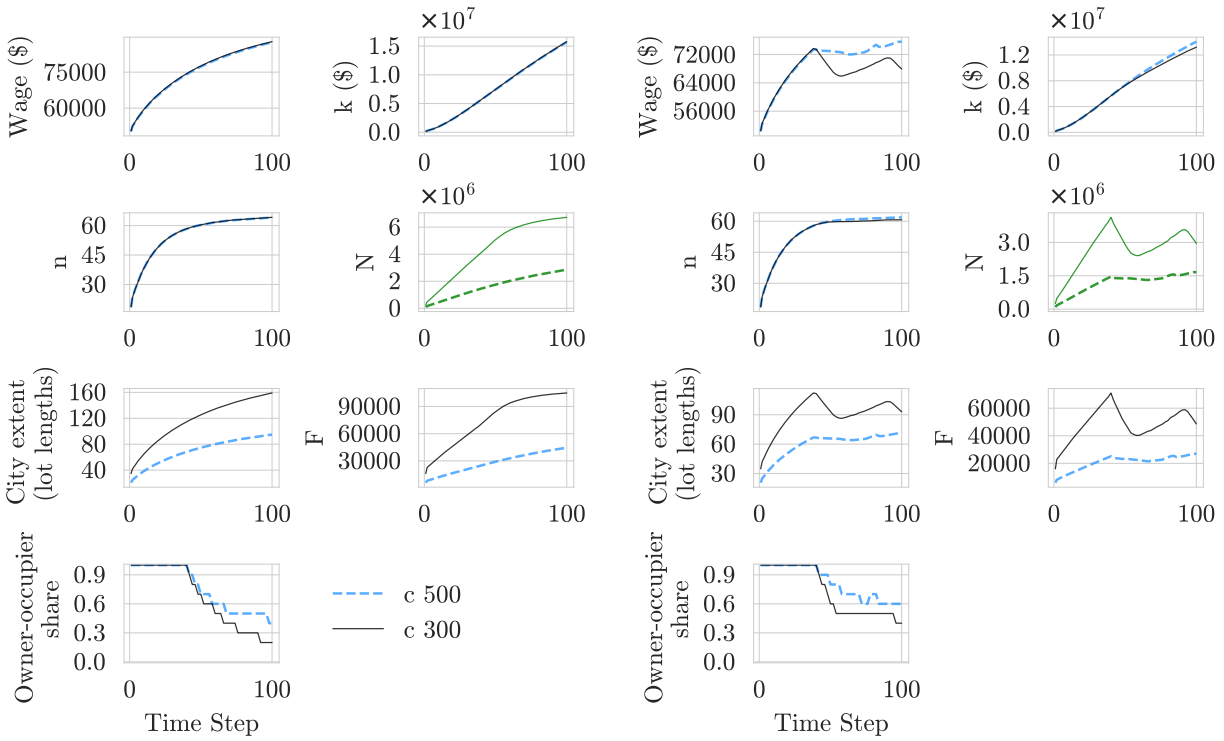


Figure 10.15: Comparing the effect of decreasing transportation costs with (left two columns) and without (right two columns) a productivity linkage. This figure illustrates the effect on seven policy variables over time, under circumstances where transportation costs $300 and $500 per unit distance per year.

With or without productivity links, lower transportation costs decrease the home-ownership ratio. Lower transportation costs lead to higher land rents, which increases property prices and capital gains, which makes investment more appealing to speculators and ultimately leads to a smaller fraction of owner-occupiers.

A decline in the wage also appears to accompany reduced transport costs. This may

be understood by noticing that lower transport costs reduce the wage needed to attract workers to the city, so the size of the city is larger at any given wage level.

A productivity link reduces wage and population growth in all transportation cost experiments, but Figure 10.15 shows that low transportation costs with a link may produce especially large speculative cycles. If we look more carefully at the patterns, it appears that the trajectories initially follow those without linkage and then diverge when the ownership ratio drops. A period with stable ownership results in another period of growth, which attracts another round of speculation that further reduces productivity and wages. Smaller irregularities in other experiments are probably due to the same effect.

10.6.5 Density with linkage

Relaxing restrictions on density should, in theory, affect the ability of people to buy homes. Our results indicate that the effect of increasing density is significant but has no effect on city extent and no effect on the ownership ratio. The share of homeowners is not affected, since rent per unit is unchanged at any distance, density alone does not affect the relative advantage of new home buyers and investors, leaving the ratio constant. With productivity links, wages are depressed, and population is lower and appears to cycle.

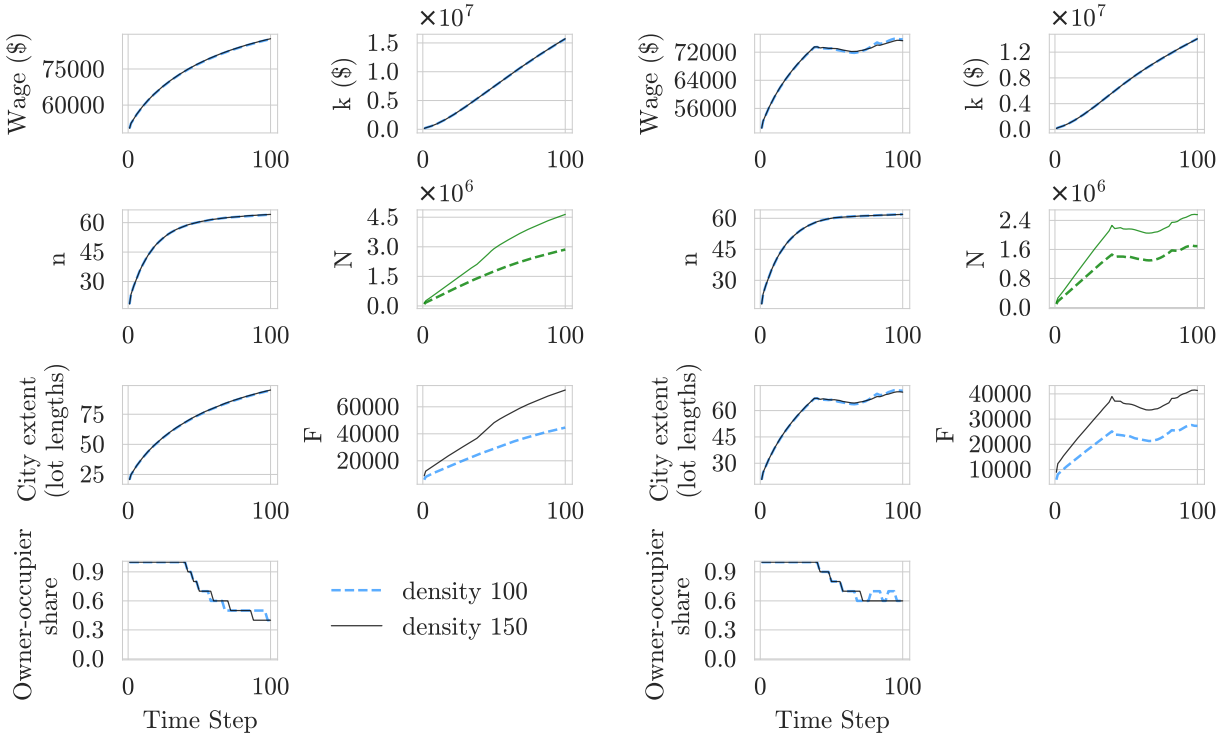


Figure 10.16: Comparing the effect of increasing density with (left two columns) and without (right two columns) a productivity linkage. Illustrates the effect on seven policy variables over time, with a population density of 100 and 150 per grid space.

10.6.6 Cost of financing's dependence on borrower's wealth with linkage

In Figure 10.17 we vary the wealth sensitivity in the presence of a productivity linkage. The higher value is more restrictive, lowering the threshold so more assets are required to secure a mortgage. The intervention has no substantial effect on the ownership ratio. With or

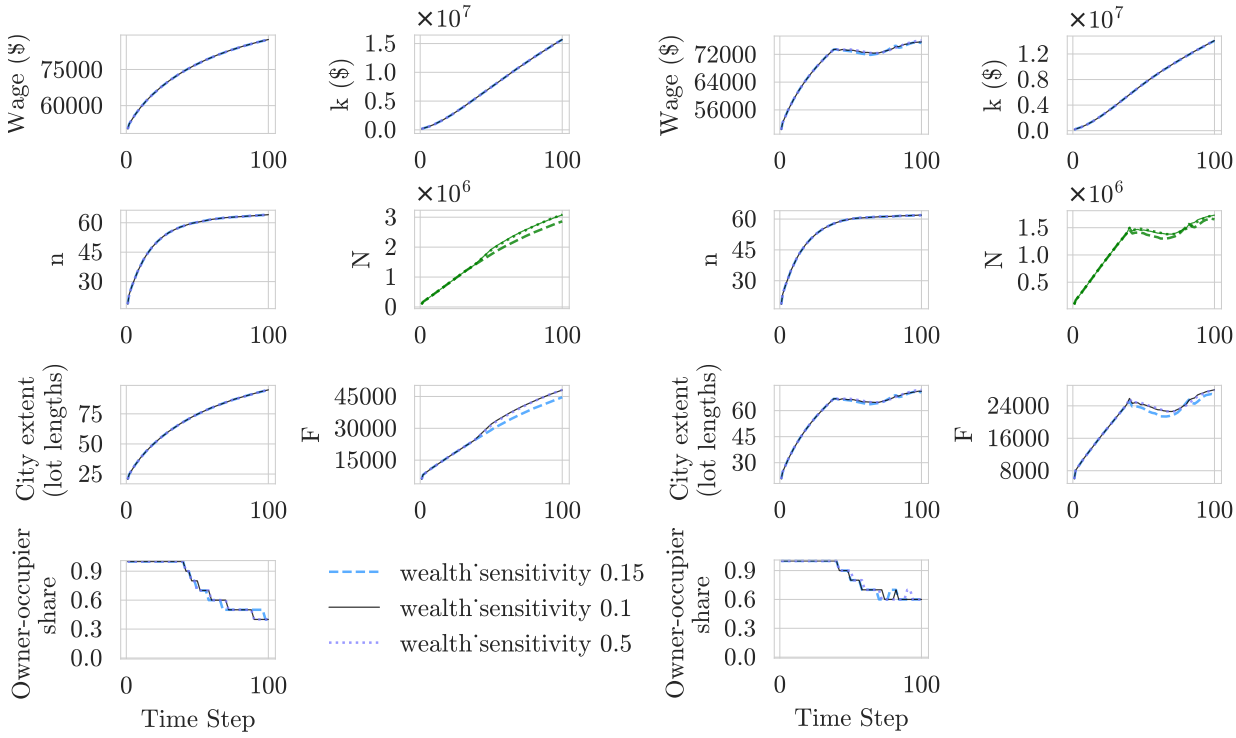


Figure 10.17: Comparing the effect of the wealth sensitivity parameter with (left two columns) and without (right two columns) a productivity linkage, with wealth sensitivity parameter values of 0.1, 0.15, and 0.5. The wealth sensitivity parameter controls the wealth required for accessing a mortgage, and its effect is illustrated in Figure 8.4 in the model chapter.

without productivity links, a restrictive mortgage regime slightly reduces the labour supply and city population. It has no noticeable effect on the ownership ratio. In the presence of a productivity linkage, the population is more variable and lower. Wages are lower, consistent with lower rents in a smaller city. With low growth, property speculation is not

profitable and investors do not enter the market. The ownership ratio is, therefore, higher not because there are more owners, but because there are fewer investment properties.

10.6.7 The property tax rate with linkage

A high annual tax rate on properties Both high and very low property tax rates appear to decrease the ownership ratio and reduce the wage and city size. With a productivity

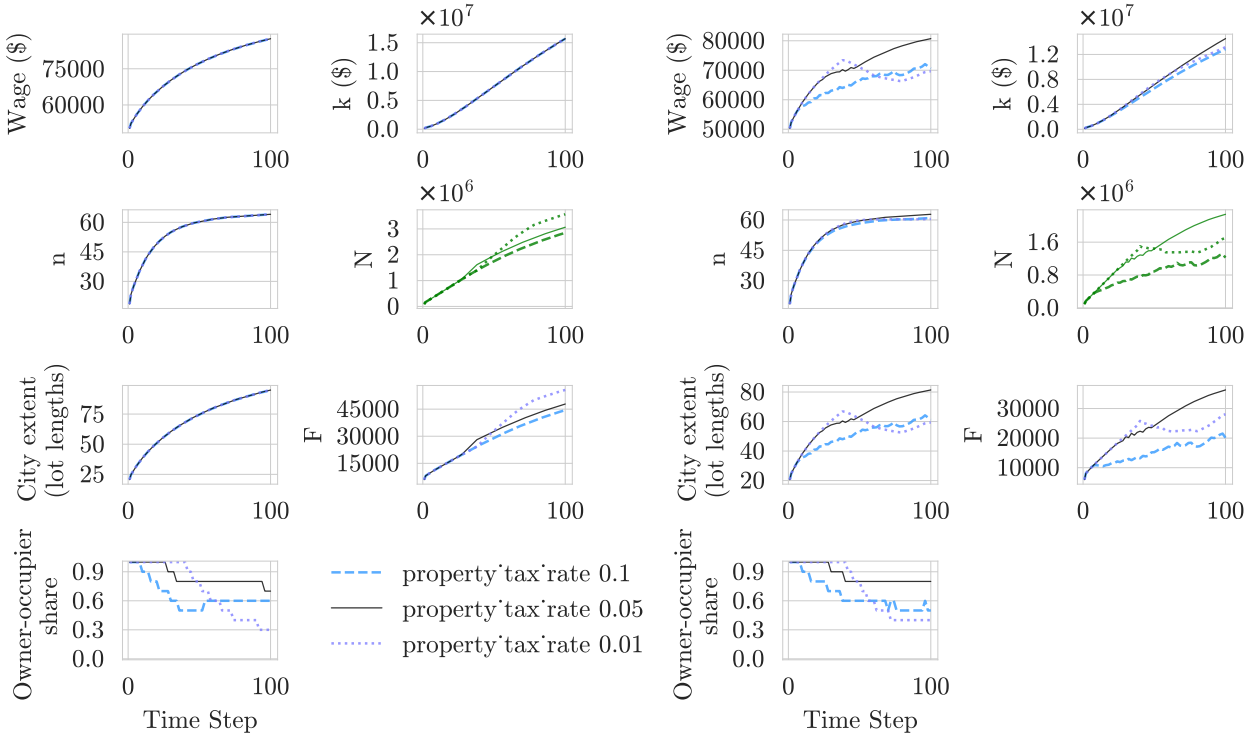


Figure 10.18: Comparing the effect of varying the property tax rate with (left two columns) and without (right two columns) a productivity linkage. Illustrates the effect on seven policy variables over time, with rates between 1% and 17%.

link, differences in the property tax rate have a much more dramatic effect on wages and urban size. The variable effect is clear from the spread of the lines on the right panel of Figure 10.18.

10.7 Transitory policy shocks

This section explores the effect of a change in policy using our model and illustrates that policy shocks appear to drive cyclic behaviour with the linkage.

10.7.1 A temporary surge of speculation

After 50 years of growth with a capital gains tax on investors of 100%, we reduce the capital gains to zero for 25 years, then return the tax level to 100%, with the productivity linkage. The blue dashed line shows the case with the capital gains tax held at 100%. There is no property speculation because no capital gains are available to investors. The solid black

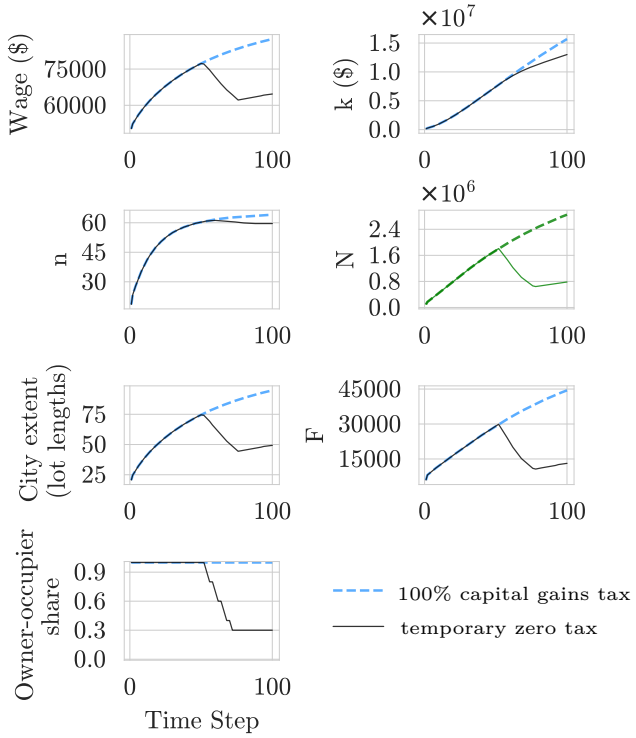


Figure 10.19: The effect of temporarily reducing the capital gains tax for investors from 100% to zero for 25 years, with the productivity linkage. The black line shows the case with the policy shock. The blue dashed line shows the reference case in which the original 100% capital gains tax is maintained.

line shows that, following the drop in the investor capital gains tax, the owner-occupier share of housing falls to 30%, meaning 70% of the city housing stock is financialized. With the intervention, there is also a steady decline in wages, some reduction in firm size and capital stock, a two-thirds reduction in population and number of firms, and a one-third reduction in city diameter, over the 25 periods. At the end of that period, the city has declined to a level approximately where it was at approximately thirty-years periods before the policy change.

10.7.2 Variant with 300-year time horizon, different initial level of the capital gains tax

To explore a slightly more realistic situation, we consider an initial capital gains tax on investors of 15%, rather than 100%. After 50 years of growth with a 15% rate we reduce the capital gains for investors to zero for 25 years as we did in the previous example. After 50 years we return the tax level to 100% to remove the effect of any further speculative investment. In this case, the dashed blue line represents the path of the economy with a

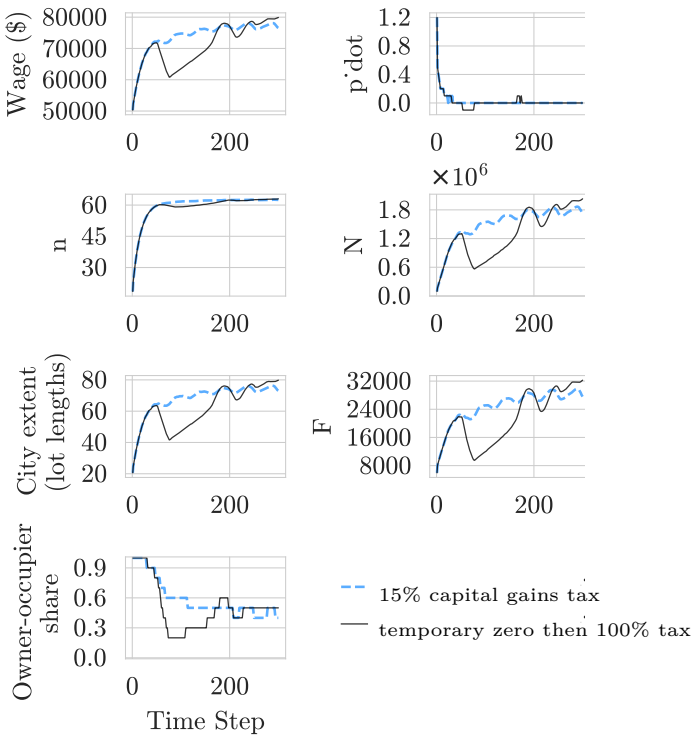


Figure 10.20: The effect of temporarily reducing the capital gains tax for investors from 100% to zero for 25 years, with the productivity linkage. The black line shows the case with the policy shock. The blue dashed line shows the reference case in which the original 15% capital gains tax is maintained.

15% capital gains tax following the drop in the investor capital gains tax. With a sustained capital gains tax on speculation of only 15%, the city is smaller and investors own more of the housing. About half of the housing stock is captured by the financial sector. Growth

is slower growth than in the case that began with 100% capital gains tax. The solid black line in Figure 10.20 shows the effect of dropping the tax to zero for 50 years then raising it to 100%. Again, the trajectory displays a sharp drop and a slow return.

10.8 Summary

We set out to explore the two propositions:

1. Financialization of the housing market will result in the tenantization of the urban middle class as financial capital acquires more of the housing stock.

2. Financialization of the housing market could result in reduced growth of urban productivity as the flow of rents is diverted from real investment to the financial sector.

In this chapter, we have thus explored two things. First, what policy interventions might affect the basic financialization ownership result, reducing or increasing the rate at which financialized actors take over the urban housing market and their penetration of the market? Second, what would the effect be if there were a feedback linkage between financialization and productivity?

We presented 84 outputs from experiments about policy actions in our model, examining the effect of seven policy interventions on seven economic variables. Forty-two of the outputs explore the effects without a linkage between financialization and productivity, and forty-two explore the effect with the linkage added. We did not demonstrate that the link exists, although we laid out seven channels through which a linkage might act in Chapter 6, and the discussion in that chapter strongly suggessts that there may be such a linkage. The results in this chapter suggest that the linkage, if it exists, would have a powerful impact on the city, and thus that further research on the linkages between productivity and financialization could play a powerful role in improving our understanding of the way the urban economy is evolving.

More generally, several observations may be drawn from our results.

1. In the absence of linkages between the housing market and the production sector, of the policy tools we consider, only density and transportation have a substantial effect on ownership or the other economic variables.

2. In the presence of linkages, policy tools have much more dramatic effects. The presence of linkages seems to make the city vulnerable, not just to static effects, but to cycles of speculation that could induce boom-bust cycles.

3. A capital gains tax on speculative investment in housing has a powerful and positive effect on economic variables, both with and without a productivity linkage. Without the linkage, a higher tax on investors increases owner-occupancy. With a productivity linkage, there are also effects on economic markers, as reducing the capital gains tax reduces the size of the city and wages.

4. Increasing the capital gains tax on owner-occupiers above the level of the capital gains tax on investors has a powerful negative effect on population and wages.

5. The cost of capital has surprisingly little effect on any variables in either case.

6. Transportation cost has a strong effect on city growth rate and size, as expected. It also decreases the home-ownership ratio, likely because of the attractiveness of a more rapidly growing city to investors. Warranting further investigation is that low transportation costs with financial system spillovers appear to induce something like cyclical behaviour.

7. Increasing density increases the population but does not affect wages, city extent, or ownership ratios, as expected.

8. A more restrictive mortgage market does not affect the production sector, city size or ownership ratios with or without the linkage.

9. Increasing property taxes has a mixed effect on the number of owner-occupiers and city size when there is no linkage to financialization, but depresses wages, population and city size when there is a linkage.

While these results do not allow us to make claims about the world outside the model, they do provide indications of areas that would be useful to explore further.

Part III

Conclusions and Future Work

Chapter 11

Future Work

> [W]e have adhered to the late Thomas Schelling's dictum that a model is finished not when nothing else can be added, but rather when nothing else can be taken away.
>
> Rob Axtell [19]

Our goal in this thesis has been to make a simple model that illustrates essential principles. We have sharply restricted our model in order to focus on one process of significance: financialization and its effects. However, with simple extensions, the model is capable of generating testable empirical hypotheses on a series of policy issues.

In this model, we have three distinct elements:

1. A model of how cities produce value,
2. A model of the spatial distribution of that value through rents and
3. A model of the institutional mechanisms by which some agents capture the rents through property markets.

Each component is extensible, and the model is modular enough that any given segment may be removed and replaced with another, perhaps more detailed, implementation of the sector. In the following sections, we describe possible extensions to each of the three components. Many of the extensions are illustrated in red in Figure 11.1. Figure 11.1 is based on Figure 8.1 of Chapter 8 which illustrates the main logic of our simulation model.

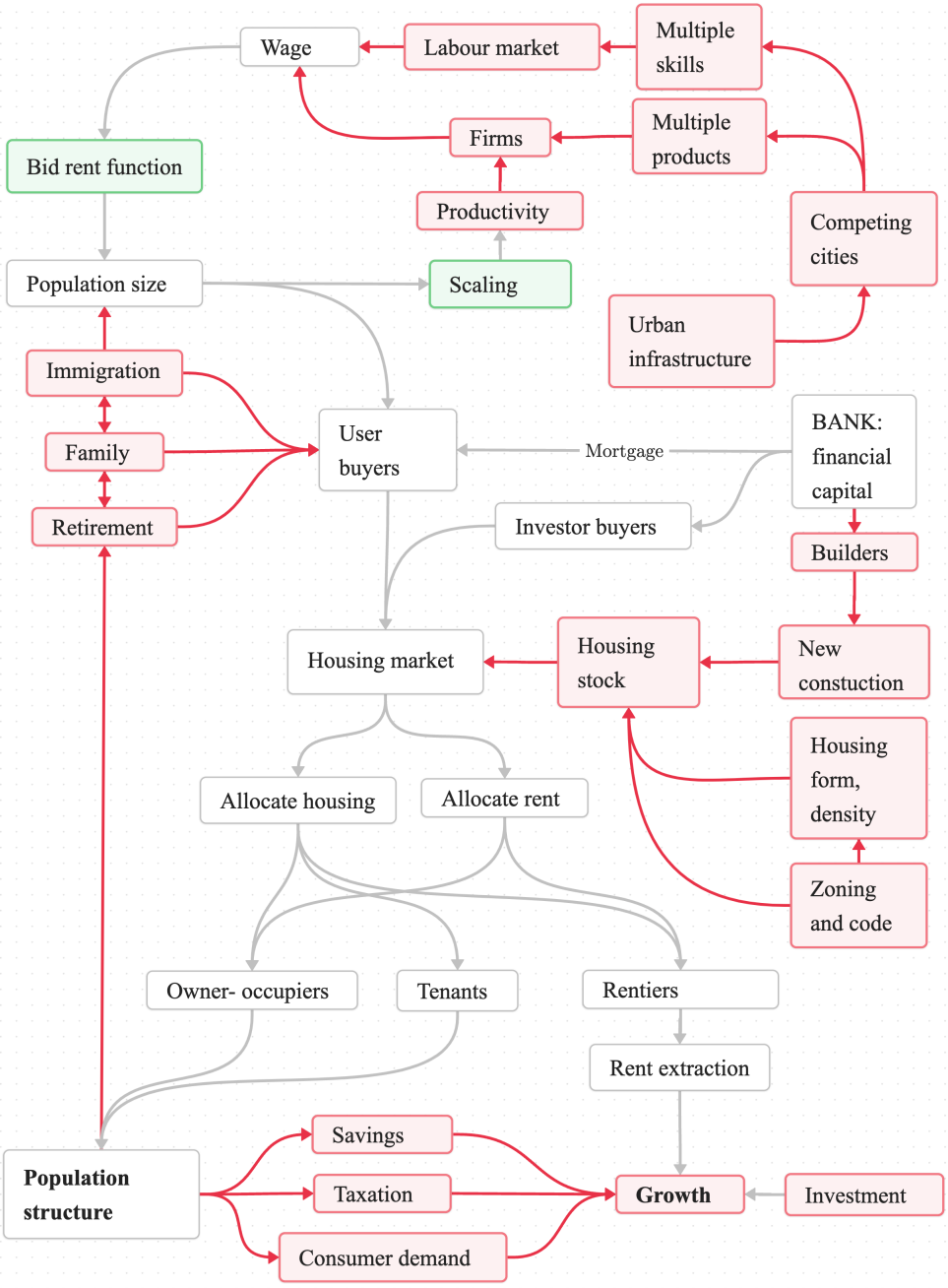


Figure 11.1: Model extensions.

11.1 Extensions to model of housing market

The base housing market model may be extended to introduce the study of production, varied density, amenity and locational preference, transportation costs, regulations, zoning, and the relationship of each city with the larger work and other cities. Each extension raises interesting questions related to the core issues of financialization.

11.1.1 Housing production and density

Financialization interacts with the production of housing because land acquisition and construction require financing and prospects for sales depend on the housing market which is affected by financialization.

Introducing a housing production sector requires adding a dynamic housing stock, either directly in the equations or explicitly by modelling the actions of agents acquiring and developing land. An explicit agent model would describe the classes of agents involved in housing production such as land assemblers, construction companies, developers. Financing developments involves financial institutions and financial instruments. Decisions are made on the basis of relatively long term forecasts and the housing production system is likely to exhibit strong lags with the potential to produce cyclic behaviour.

Cities also contain a rich variety of housing forms and neighbourhoods and the varied populations that occupy them. Separable from production, it is possible to introduce variation of housing form and density.

11.1.2 Amenity and locational preferences

In our base model, an urban wage premium is the only labour attractor. Effectively, we have set the level of amenities to zero in order to focus on the productivity effects. In reality, buying a home is always the purchase of a bundle of characteristics such as location, building space, yard, local density and local amenities. Stegman found that "a large majority of families who have recently moved to the suburbs are more concerned with neighborhood quality than with accessibility to other parts of the metropolitan region." Importantly, "There is evidence that the amenities offered by a city enhance its growth" [47, 70] and that amenity effects themselves scale superlinearly [118]. Appendix C discusses amenities in more detail.

Introducing differences in amenity involves adding attributes and preferences to agents about they prefer their housing to be close to. One version would be to include distance to the edge of the city as an amenity in resident's utility function. Another would be to locate amenities within the city. These would lead to higher prices near amenities. A third variant would be to have earning depend on location. If there were several locations a polycentric city would emerge. Locational preferences may result in segregation by neighbourhood depending on preferences.

11.1.3 Transportation costs

Another spatial feature that could be explicitly modeled is the transportation cost. Transportation costs to the urban center determine land values. Varied transportation costs based on location and mode of transportation will result in segregation by neighbourhood depending on income and transportation costs.

The theory implies that transportation improvements that reduce the cost of travelling to work should affect rents, but there may be spillover effects or leakage into wages at the centre. The degree of spillover will likely be sensitive to the relative elasticities of demand and supply for labour, land, consumption, and local densities. These leakages may reduce the amount of the social gain captured as land rent.

11.1.4 Regulation and zoning

Economic dictates and building codes and master plans regulate which land is developed at what density and when. In future work, we could model the effects of rules. For example, we could explore the effects of a hard zoning boundary and the effects of relaxing it. We could also explore the effect of speeding the rate of conversions from one size home to another, or of locating high density pocket on a transportation route. By adding rules like these, many significant urban policy questions could be examined with a limited amount of additional programming.

11.1.5 Systems of cities

Modern cities are not lonely and autarkic beasts wandering their own exclusive territory. Each city is one in a global system of cities that compete with and complement each other. There are important questions to explore when the city is one city among others, but,

as DiBartholemeo and Turnbull [57] point out,"[t]he empirical literature examining the determinants of city size almost exclusively uses the closed city version of the Mills–Muth model,"[1] However, flows of information, capital and even labour between cities are substantial and matter in the long run. With free movement, policies in one city will affect outcomes in other cities. Henderson [106], Abdel-Rahman [5], Fujita [81], Fujita, Krugman, and Venables [82], and Fujita and Thiess [83] among others provide approaches for expanding the model in this direction.

At the cost of additional computational complexity, the simple circular city can be extended to to produce other forms, including polycentric cities and hierarchies of cities. Embedding the city in a system of cities makes it possible to explore questions such as:

1. How does the city connect with the larger system of cities and does a dominant city emerge?
2. To what extent will we see specialization?
3. When are systems of cities stable?

To explore these and other questions we would simply clone the model and connect the clones with population flows that respond to local variables.

11.2 Extensions to model of firms

We have built a simple firm model in which firms hire workers and produce value. Developing a richer firm sector would allow us to have variable wages endogenously, as well as local goods production and even a variety of exports.

11.2.1 Making labour market and firm behaviour explicit

There are two directions to go in order to make firm behaviour explicit. First, we could model individual firms as agents. Second, we could add detail to the equilibrium-based model we have in our model.

In the first case, we could explicitly model labour markets and competing firms as firms. In a good example of this approach, Axtell explicitly models all firms in the US market

[1] Our model is intermediate in the sense that it allows for labour flows between city and countrysides, but not between cities.

interacting according to simple rules [19]. Such a model could get very large, but it would allow much more nuance in understanding firm behaviour.

In the second case, we could add additional detail as an extension of the equilibrium approach implemented in our model. For instance, we could model sectors or labour markets with multiple firms. This would require introducing ancillary assumptions and selecting among alternative models of agglomeration.

11.2.2 The consumer city

Our model has assumed there is production only for a perfectly elastic export demand, but in the real world, much of the demand for what is produced in the city is local consumer demand. For example, manufacturing, which tends to meet non-local demand, typically provides less than a quarter of employment and exports from a city are generally on a similar scale. We might therefore consider firms producing different products, some for export and some for the local market, and hiring multiple types of labour. We can then imagine a city that has differentiated agglomeration effects, for instance by profession. This kind of model could allow individual wages to be linked to sectoral agglomeration effects of other workers.

A minimal extension would be to introduce a second sector representing local consumption demand. To do this, a share of locally generated income would support production for the city's population. The labour force would be split between the two sectors. A more complex treatment could introduce a range of service, entertainment and retail producers. This might be done with monopolistically competitive firms as in Dixit and Stiglitz [59]. These extensions are unlikely to affect the allocation of housing.

Productivity and wages might differ across sectors. Introducing different wages would be a major step toward generating a realistically diverse city. In our model, wages would equalize unless low-wage workers are willing to live in the city at different wages. Simply adding more firms or labour types will not give us multiple wages and will not allow us to explore sorting by income. That suggests that we would have to introduce different housing costs, different household structures, different transportation costs and/or a secondary benefit for some workers. Extensions such as these would be expected to have effects on housing markets.

Both agent-based and equilibrium models of explicit firm behaviour would make it possible to explore the effects of different skills, and wages. An agent model could allow much more nuanced exploration of adjacent properties, including questions about amenity, sectors, and individual behaviour.

11.3 Extensions to model of the institutional, legal, and financial mechanisms distributing the urban surplus

The forecast rents and thus bids agents are willing to pay for property embed a minimal model of the contract and legal structure for the distribution of surplus value produced in the city. This is a minimal model of the institutional arrangement linking production and rents via the land market. While minimal, this linkage is among the most precisely specified components of our model, and extensions to the model open up a number of interesting questions.

11.3.1 Urban savings

Conventional growth models specify a savings/investment mechanism at the national level. To our knowledge, this has not been done for the city level. We require savings at two levels. First, since we want to incorporate households, home ownership, and a relationship to the financial sector through mortgages, we specify a savings rate out of the spending we have isolated in the 'subsistence wage' This means that both urban and rural workers accumulate savings, that savings are age-dependent, making the size of mortgage available also age dependent. Homeowners in addition have equity in their homes. A second level of saving is the investment in capital out of the city surplus.

11.3.2 Making public infrastructure investment explicit

We incorporated a property tax in the investment model but did not explicitly model how the revenue was spent. Public and private investment in human capital is largely urban as well, but as with infrastructure, investment and response take effect over time periods much longer than our model is concerned with. Private sector innovation in technology, marketing, or products draws on local saving less but still significantly on local savings. We have little in the way of theory or empirical research on this channel. Lags between investment and any rise in the urban wage premium are almost certainly long and variable.

One target is public investment in transportation infrastructure. We have discussed how falling transportation costs increase surplus generation. We can make transport cost depend on investments out of the property tax. Investments like this are made slowly and adjust and take effect over time periods that are very long compared to the variables our

model has been concerned with. We can introduce deterioration and set the property tax sufficient to maintain the stock of infrastructure, or we can allow debt. There may be many other channels through which surplus flows into productive investment in the urban context.

The scaling literature also provides relationships between density, population and infrastructure cost that we can explore as well. In the scaling literature, these relationships are increasingly theorized in terms of network effects, which is consistent with the Jacobs analysis and the more recent neoclassical growth modeling.

11.3.3 Domestic investment

It is known that local ownership is associated with local investment. We have dealt with this by linking local capital ownership with the scale factor, with local capital ownership proxied by homeowner equity as a share of the local housing stock.

11.3.4 Distribution of rents

Rents go to landowners, with a share taken for maintenance and taxes. Rents may also be taxed, could be shared between multiple owners, etc. In principle the gains from urban productivity and amenity can be allocated as social wealth through shared ownership, as is often done on a small scale with cooperatives and land trusts, distributed to all citizens through something like a social wealth fund, or captured in taxes or fees as Henry George suggested.

11.3.5 Investment fund modelling

Agents may fund their retirement from savings, as well as returns on their home if they have one to sell. Savings may be invested in a pension fund, or in local property, depending on expected risks and returns. In the real world, financial institution manages most pensions, investing in the market or in property. This institutional structure might be handled by implementing a savings account for each agent. We could also consider a case where outside money can come under institutional management, not just local retirement savings. A parameter would control the inflow of additional money beyond local investment in the pension fund.

11.3.6 Transaction costs

Transaction costs on the sale of property are omitted. They are actually large. We can easily add a term to Equation 8.21 to examine the effect of transaction costs on the distribution of wealth.

11.3.7 Risk, speculation, and business cycles

There are many areas to explore in terms of the dynamics of the model. Risk plays a role in property markets. For example in Canada, backing mortgages is the largest fiscal investment at the national level [150]. It is also possible to model the effect of speculative over-investment as expectations rise and fall, and the effects of business cycles as forcing of price and other parameters with external input to examine the effects.

11.3.8 Taxes and productivity

This is a major issue with considerable development in the economics literature. Property taxes reduce the net locational value that flows to an individual owner but provides services and wages that make the city attractive. Localized tax advantages can move a share of financialized investment into private consolidation of land, including the structure of taxes for investment properties, institutional investors, individuals, etc.

Just as financialization may extract resources that would otherwise be invested in increasing human capital, consumption or productivity, reducing productivity. Taxes could either be extracted or reinvested. There is some evidence taxes can increase productivity through infrastructure, education, public spaces, recruiting employers, and direct investment, etc. Re-distributive programs are expected to have direct distributional effects. These could be explored through additional linkages in the model.

11.3.9 Financialization as system change

Financialization expands investor ownership but does not expand the housing stock, as Figure 11.2 illustrates. It is not inherently a productive process, but it is a transformational process. Our model shows that financial institutions and the wealthy are likely to own increasing shares of the housing stock.

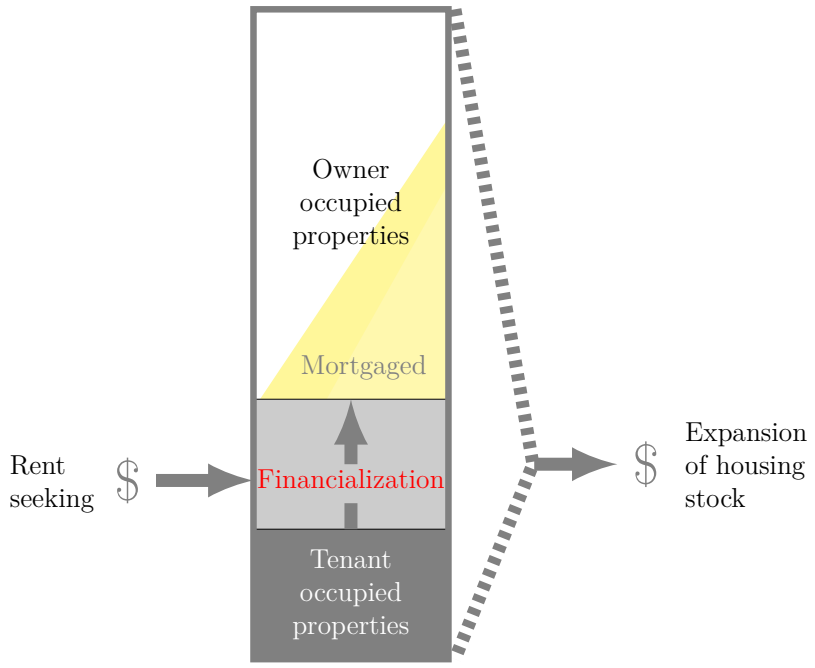


Figure 11.2: Financialization expands investor ownership but does not expand the housing stock. The white area represents the part of the housing stock that is owner-occupied and not currently mortgaged, yellow privately owned homes that are partially mortgaged, dark grey the portion already owned by investors, and light grey the part of the housing stock undergoing financialization. Financialization is orthogonal to housing creation.

The conclusion drawn from both theory and our simulation is consistent with what has already happened in the Canadian Housing market. Recent data from Statistics Canada [76] suggests people who own more than one property in Ontario make up more than 25% of buyers in the province. Just under one in five properties overall was used as an investment. In Ontario 41.9% of condominium apartments are investment properties [33].

The immediate social implications are fairly obvious. As Statistics Canada points out, these trends might limit the number of properties available to buyers who intend to use it as a primary place of residence [76]. Statistics Canada reports that latest census release, two-thirds of Canadians owned a home in 2021, down from a peak of 69 per cent a decade earlier. The decline is was higher for younger members of the population.

When the homeownership rate goes down, the rental rate goes up. The 2021 Canadian Housing Survey reported that the number of renter households increased at over twice the

pace of owner households, pushing down the homeownership rate in Canada. If the trends continue, Urban Canada will gradually change from a society dominated by homeowners to a predominantly tenant society. Since wealthier buyers are advantaged in the market, the younger and poorer parts of the community will be increasingly excluded from ownership. Financialization will increase income and asset inequality in cities.

Combined with rising housing prices the effect will be to squeeze lower-wage households closer to what we have termed to subsistence level and make it harder for low-wage workers to live in the city. The city requires low-wage workers for many of the services, so labour shortages are a possibility. Labour shortages will squeeze some activities out of the city and are likely to reduce productivity. Labour shortages may push up wages, but in rental markets, landlords can capture much of any increase in wages.

The incentive structure in our model was derived purely from the point of view of an individual investor. Examination shows that investment incentives favour the wealthy and institutional buyers, but that does not necessarily imply that the process of financialization will drive social transformations. Modelling allows us to ask which parameters are most influential. A question that is especially important is whether the process of financialization and tenentization our micro model suggests is reversible.

11.4 Summary

The simplifications in the model we have built allow us to focus on the general, and neglected, distributional features of this class of models. In this chapter, we've sketched several promising directions to extend the model, dividing extensions by the three main elements of the model: the model of the city and it's land market, the model of firms and production, and the model of the institutional and legal structures by which some agents may claim a share of the value created in the city.[2] Introducing many of these changes, such multiple wages, amenity, and differing densities are relatively simple. The resulting sorting by wealth, income and preference, is of considerable interest for social policy. The extensions will allow us to test whether financialization affects the sort and whether public policies can have positive effects. It's likely none of them would change our qualitative results greatly, however each would deepen our understanding of mechanisms and of the detailed impacts.

[2]The extensions detailed here also combine. Models are by nature combinatoric: every added element involves making a choice among alternative assumptions and implementations. Each extension is potentially as complex as the core model, and each introduces additional assumptions. A model incorporating n binary choices is one of an implicit family of 2^n alternative models.

Chapter 12

Conclusion

We set out to determine whether financialization is likely to shift the ownership of property in cities away from residents, affect the distribution of resources and change the ability of cities to grow, thrive, and produce wealth. We have produced a theoretical simulation that suggests that financialization of the housing market may indeed have worrying implications for the success of cities and the nature of our social fabric.

Financialization expands financial ownership and tenancy, while reducing the share of owner-occupied housing. Its goal is the capture of spatial rents, which is fundamentally nonproductive rent-seeking, meaning that it does not contribute to the production sector or to the wealth of city residents. It could, if it follows the pattern in the model, progress to the point where owner-occupiers are entirely squeezed out of the city. Currently home ownership in Canada exceeds 60%, but that number is falling. If it continues to fall, the resulting tenantization would radically change Canadian social structure and have a profound negative impact on the distribution of wealth. Our analysis raises the question of whether Canadian cities, given the current housing crisis and the progression of financialization, can continue to attract people and accumulate wealth for residents and industries.

We also explore the possibility that financialization of the housing market may spill over to urban productivity, reducing urban growth and the urban wage. This is a worrying prospect, given the continued urbanization of the Canadian population and the widespread concern about falling Canadian productivity. We have identified a number of potential channels for such spillover and suggest that identifying which, if any, are active should be high on the national research agenda.

The purpose of our model is theoretical exposition. It tells us about the relationship between variables in the model. It makes no claims about the world outside the model,

however it can suggest questions or directions for empirical work. With simple extensions and calibration the model is capable of generating testable empirical hypotheses on furthur policy issues.

Contributions from this work, include that the model:

1. incorporates classical rent theory into an agent-based urban model;
2. allows the creation and distribution of rents to influence urban growth;
3. incorporates current research on urban scaling into an explicitly spatial framework;
4. integrates an urban agent-based model with neoclassical growth theory;
5. integrates financial capital into a standard spatial model;
6. integrates financial capital into an overlapping generations population model of the urban system;
7. uses an agent-based model to examine how financial markets impact an urban land market; and
8. can be easily extended to explore a range of issues and used to evaluate policy options.

To summarize, we have built a simulation model linking theories across economics, finance, and urban theory that allowed us to contribute to the understanding of how financialization interacts with housing allocations and productivity. The model is extensible and has been designed to support trans-disciplinary collaborative research in an understudied but important policy area. It is also suitable for use as a teaching tool. The simulation code is structured to make experiments easy and fast. We hope to develop an interface that will make experimentation even easier.

We have also provided a careful exposition of the theoretical work from several fields and periods that form the basis of our modelling. Our synthesis is new, and we hope, illuminating for others working on urban economics and housing policy.

As financial actors buy up more of the property near cities, it can affect both the distribution of wealth and the capacity of cities to build human capital and create value.

References

[1] Canada's Housing Supply Shortages: Estimating What Is Needed to Solve Canada's Housing Affordability Crisis by 2030. Technical report, CMHC, June 2022.

[2] Manuel B. Aalbers. The Potential for Financialization. *Dialogues in Human Geography*, 5(2):214–219, 2015.

[3] Manuel B. Aalbers. The Variegated Financialization of Housing. *International Journal of Urban and Regional Research*, 41(4):542–554, 2017.

[4] Manuel B Aalbers. A Conversation About Land Rent, Financialisation and Housing. *Urban Studies*, 55(8):1821–1835, 2018.

[5] Hesham M. Abdel-Rahman. Agglomeration Economies, Types, and Sizes of Cities. *Journal of Urban Economics*, 27(1):25–45, 1990.

[6] Gabriel M. Ahlfeldt, Stephen J. Redding, Daniel M. Sturm, and Nikolaus Wolf. The Economics of Density: Evidence From the Berlin Wall. *Econometrica*, 83(6):2127–2189, 2015.

[7] David Albouy. What Are Cities Worth? Land Rents, Local Productivity, and the Total Value of Amenities. *The Review of Economics and Statistics*, 98(3):477–487, 2016.

[8] William Alonso. *A Model of the Urban Land Market: Locations and Densities of Dwellings and Businesses*. PhD thesis, University Of Pennsylvania, Philadelphia, 1960.

[9] William Alonso. A Theory of the Urban Land Market. *Papers in Regional Science*, 6(1):149–157, 1960.

[10] William Alonso. *Location and Land Use: Toward a General Theory of Land Rent*. Harvard University Press, Cambridge, MA, 1964.

[11] Shahad Althobaiti, Saud Alghumayjan, Morgan R. Frank, Esteban Moro, Ahmad Alabdulkareem, and Alex Pentland. Housing Prices and the Skills Composition of Neighborhoods. *Frontiers in Big Data*, 4:652153–652153, 2021.

[12] Alex Anas, Richard Arnott, and Kenneth A. Small. Urban Spatial Structure. *Journal of Economic Literature*, 36(3):1426–1464, 1998.

[13] Dan Andrews and Aida Caldera Sánchez. The Evolution of Homeownership Rates in Selected OECD Countries: Demographic and Public Policy Influences. *OECD Journal: Economic Studies*, 2011(1):207–243, 2011.

[14] Patricia Annez and Robert Buckley. Urbanization and Growth: Setting the Context. In Michael Spence, Patricia Clarke Annez, and Robert M. Buckley, editors, *Urbanization and Growth*. World Bank, Washington, DC, 2009.

[15] Richard Arnott and Joseph E. Stiglitz. Aggregate Land Rents, Expenditure on Public Goods, and Optimal City Size. *Quarterly Journal of Economics*, 93(4), 1979.

[16] Kenneth J. Arrow. An Extension of the Basic Theorems of Classical Welfare Economics. In N. J. Neyman, editor, *Proceedings of the Second Berkeley Symposium on Mathematical Statistics and Probability*, volume 2, pages 507–532. University of California Press, Berkeley, 1951.

[17] Kenneth J. Arrow. The Economic Implications of Learning by Doing. *The Review of Economic Studies*, 29(3):155–173, 1962.

[18] Martine August and Alan Walks. Gentrification, Suburban Decline, and the Financialization of Multi-Family Rental Housing: The Case of Toronto. *Geoforum*, 89:124–136, 2018.

[19] Robert L Axtell and Omar A. Guerrero. *Dynamics of Firms: Data, Theories, and Models*. Forthcoming edition, 2024.

[20] Paul Bairoch. *Cities and Economic Development: From the Dawn of History to the Present*. University of Chicago Press, Chicago, 1988.

[21] David L. Banks and Mevin B. Hooten. Statistical Challenges in Agent-Based Modeling. *The American Statistician*, 75(3):235–242, 2021.

[22] Rosemary Bat, Eileen A. Appelbaum, and Tamar Katz. The Role of Public REITs in Financialization and Industry Restructuring. Working Paper 189, Institute for New Economic Thinking, July 2022.

[23] Desmond Beckstead, W. Mark Brown, and Guy Gellatly. Cities and Growth: The Left Brain of North American Cities: Scientists and Engineers and Urban Growth. Research Paper 017, Statistics Canada, 2008.

[24] Christopheer Berry. Reassessing the Property Tax. March 2021.

[25] Luís M. A. Bettencourt. The Origins of Scaling in Cities. *Science*, 340(6139):1438–1441, 2013.

[26] Luís M. A. Bettencourt. *Introduction to Urban Science: Evidence and Theory of Cities as Complex Systems*. The MIT Press, Cambridge, MA, 2021.

[27] Luís M. A. Bettencourt, José Lobo, Dirk Helbing, Christian Kühnert, and Geoffrey B. West. Growth, Innovation, Scaling, and the Pace of Life in Cities. *Proceedings of the National Academy of Sciences of the United States of America*, 104(17):7301–7306, 2007.

[28] Mark Blaug. *Economic Theory in Retrospect*. Cambridge University Press, New York, 4th edition, 1985.

[29] Ralph L. Block. *Investing in REITs Real Estate Investment Trusts*. Bloomberg ; 141. Bloomberg Press, an imprint of Wiley, Hoboken, N.J, 4th ed. edition, 2012.

[30] João O. Borba and Tomaz Ponce Dentinho. Evaluation of Urban Scenarios Using Bid-Rents of Spatial Interaction Models as Hedonic Price Estimators: An Application to the Terceira Island, Azores. *The Annals of Regional Science*, 56(3):671–685, 2016.

[31] Jan K. Brueckner. The Structure of Urban Equilibria: A Unified Treatment of the Muth-Mills Model. In *Handbook of Regional and Urban Economics*, volume 2, pages 821–845. Elsevier, Amsterdam, 1987.

[32] Simon C Büchler, Dongxiao Niu, Anne K Thompson, and Siqi Zheng. The Impact of Human Capital and Housing Supply on Urban Growth. *Urban Studies*, 61(2):214–230, 2024.

[33] Statistics Canada. To Buy or to Rent: The Housing Market Continues to Be Reshaped by Several Factors as Canadians Search for an Affordable Place to Call Home. Report, September 2022.

[34] Edwin Cannan. Early History of the Term Capital. *The Quarterly Journal of Economics*, 35(3):469–481, 1921.

[35] Dennis R. Capozza and Robert W. Helsley. The Fundamentals of Land Prices and Urban Growth. *Journal of Urban Economics*, 26(3):295–306, 1989.

[36] Lachlan Carey and Amn Nasir. Something for Nothing? How Growing Rent-seeking is at the Heart of America's Economic Troubles. *Journal of Public and International Affairs*, 2019.

[37] Gerald A. Carlino. Agglomeration Economies: A Survey of the Literature. In *Economies of Scale in Manufacturing Location: Theory and Measure*, Studies in Applied Regional Science, pages 6–29. Springer, Boston, MA, 1978.

[38] Karl Case and Robert Shiller. Is There A Bubble in the Housing Market? *Brookings Papers on Economic Activity*, 68(2):299–362, February 2003.

[39] K. C. Chan, Patric H. Hendershott, and Anthony B. (Anthony Bown) Sanders. Risk and Return on Real Estate: Evidence from Equity REITs. Report 3311, National Bureau of Economic Research, Cambridge, MA, 1990.

[40] T. C. Chang, H.H. Lean, and W.K. Wong. Do REITs Outperform Stocks and Fixed-Income Assets? New Evidence from Mean-Variance and Stochastic Dominance Approaches. *Journal of Risk and Financial Management*, 1:1–40, 2008.

[41] Émile Jean Louis Chappin. *Simulating Energy Transitions*. PhD thesis, Technische Universiteit Delft, Delft, 2011.

[42] Albert Chevan. The Growth of Home Ownership: 1940-1980. *Demography*, 26(2):249–266, 1989.

[43] Brett Christophers. Revisiting the Urbanization of Capital. *Annals of the Association of American Geographers*, 101(6):1347–1364, 2011.

[44] Brett Christophers. Class, Assets and Work in Rentier Capitalism. *Historical Materialism*, 29(2):3–28, 2021.

[45] John B. Clark. Distribution as Determined by a Law of Rent. *The Quarterly Journal of Economics*, 5(3):289–318, 1891.

[46] John B. Clark. *The Distribution of Wealth: A Theory of Wages, Interest and Profits*. Macmillan, London, 1899.

[47] Terry Nichols Clark, Richard Lloyd, Kenneth K. Wong, and Pushpam Jain. Amenities Drive Urban Growth. *Journal of Urban Affairs*, 24(5):493–515, 2002.

[48] Charles W. Cobb and Paul H. Douglas. A Theory of Production. *The American Economic Review*, 18(1):139–165, 1928.

[49] David Colander. The Death of Neoclassical Economics. *Journal of the History of Economic Thought*, 22(2):127–143, 2000.

[50] Sharon Cornelissen and Christine Jang-Trettien. Housing in the Context of Neighborhood Decline. In *The Sociology of Housing: How Homes Shape Our Social Lives*. University of Chicago Press, Chicago, 2023.

[51] Antoine Augustin Cournot. *Recherches Sur Les Principes Mathématiques de La Théorie Des Richesses*. Hachette, Paris, 1838.

[52] Christopher Curran, Leonard A. Carlson, and David A. Ford. A Theory of Residential Location Decisions of Two-Worker Households. *Journal of Urban Economics*, 12(1):102–114, 1982.

[53] Alberto Dalmazzo and Guido de Blasio. Amenities and Skill-Biased Agglomeration Effects: Some Results on Italian Cities. *Papers in Regional Science*, 90(3):503–527, 2011.

[54] Vince Darley. *Towards a Theory of Autonomous, Optimising Agents*. PhD thesis, Harvard, Cambridge, MA, 1999.

[55] Gerard Debreu. The Coefficient of Resource Utilization. 1951.

[56] Edward F. (Edward Fulton) Denison. The Sources of Economic Growth in the United States and the Alternatives Before Us. Supplementary Paper 013, Committee for Economic Development, New York, 1962.

[57] Jeffrey A. DiBartolomeo and Geoffrey K. Turnbull. Closed vs. Open City Models: A New Empirical Approach to an Old Question. *Papers in Regional Science*, 102(5):1031–1059, 2023.

[58] Robert W. Dimand and Barbara J. Spencer. Trevor Swan and the Neoclassical Growth Model. *History of Political Economy*, 41(Suppl_1):107–126, 2009.

[59] Avinash K. Dixit and Joseph E. Stiglitz. Monopolistic Competition and Optimum Product Diversity. *The American Economic Review*, 67(3):297–308, 1977.

[60] Evsey D. Domar. Capital Expansion, Rate of Growth, and Employment. *Econometrica*, 14(2):137–147, 1946.

[61] Lei Dong, Zhou Huang, Jiang Zhang, and Yu Liu. Understanding the Mesoscopic Scaling Patterns Within Cities. *Scientific Reports*, 10(1):21201, 2020.

[62] David Duffy, John Fitzgerald, Ide Kearney, and John Gerald. Rising House Prices in an Open Labour Market. *The Economic and Social Review*, 36(2):251–272, 2005.

[63] G. Duménil and D. Lévy. Stability and Instability in a Dynamic Model of Capitalist Production (abridged version). In Willi Semmler, editor, *Competition, Instability, and Nonlinear Cycles*, pages 132–169. Springer, Berlin, 1986.

[64] Edgar S. Dunn. The Equilibrium of Land-Use Patterns in Agriculture. *Southern Economic Journal*, 21(2):173–187, 1954.

[65] Gilles Duranton. Are Cities Engines of Growth and Prosperity for Developing Countries? In Michael Spence, Patricia Clarke Annez, and Robert M. Buckley, editors, *Urbanization and Growth*, pages 67–113. World Bank, Washington, DC, 2009.

[66] Gilles Duranton, Richard J. Arnott, and Daniel P. McMillen. Human Capital Externalities in Cities: Identification and Policy Issues. In *A Companion to Urban Economics*. Blackwell Publishing, Oxford, 2006.

[67] Gilles Duranton and Diego Puga. Micro-Foundations of Urban Agglomeration Economies. In J. Vernon Henderson and Jacques-François Thisse, editors, *Handbook of Regional and Urban Economics*, volume 4 of *Cities and Geography*, pages 2063–2117. Elsevier, January 2004.

[68] Bruce Edmonds, Volker Grimm, Ruth Meyer, Cristina Montañola, Paul Ormerod, Hilton Root, and Flaminio Squazzoni. Different Modelling Purposes. *Journal of Artificial Societies and Social Simulation*, 22(3):1–30, 2019.

[69] Joshua M. Epstein. Why Model? *Journal of Artificial Societies and Social Simulation*, 11(412):1–5, 2008.

[70] Oliver Falck, Michael Fritsch, and Stephan Heblich. The phantom of the opera: Cultural amenities, human capital, and regional economic growth. *European Association of Labour Economists, 3rd World Conference EALE/SOLE, London UK, 17-19 June2010*, 18(6):755–766, December 2011.

[71] Leilani Farha. Report on the financialization of housing and the right to adequate housing. Report A/HRC/34/51, OHCHR, January 2017.

[72] Frank Flatters, Vernon Henderson, and Peter Mieszkowski. Public Goods, Efficiency, and Regional Fiscal Equalization. *Journal of Public Economics*, 3(2):99–112, 1974.

[73] Richard Florida. The Economic Geography of Talent. *Annals of the Association of American Geographers*, 92(4):743–755, 2002.

[74] Richard Florida. *Competing in the Age of Talent*. Routledge, London, 2005.

[75] Richard Florida. The Creative Class and Economic Development. *Economic Development Quarterly*, 28(3):196–205, 2014.

[76] Joanie Fontaine and Joshua Gordon. Residential Real Estate Investors and Investment Properties in 2020. Report 46280001, Statistics Canada, February 2023.

[77] Jay W. Forrester. *Industrial Dynamics*. MIT Press, Cambridge, MA, 1961.

[78] Jay W. Forrester. *Urban Dynamics*. MIT Press, Cambridge, MA, 1969.

[79] Andrew D Foster and Mark R Rosenzweig. Learning by Doing and Learning from Others: Human Capital and Technical Change in Agriculture. *Journal of Political Economy*, 103(6):1176–1209, 1995.

[80] Milton Friedman. An Interview with. *Human events (Washington)*, 38(46):14, 1978.

[81] Masahisa Fujita. A Monopolistic Competition Model of Spatial Agglomeration: Differentiated Product Approach. *Regional Science and Urban Economics*, 18(1):87–124, 1988.

[82] Masahisa Fujita, Paul R. Krugman, and Anthony Venables. *The Spatial Economy: Cities, Regions, and International Trade*. MIT Press, Cambridge, MA, 1999.

[83] Masahisa Fujita and Jacques-François Thisse. Economics of Agglomeration. *Journal of the Japanese and International Economies*, 10(4):339–378, 1996.

[84] Davide Furceri and Prakash Loungani. Capital Account Liberalization and Inequality. *IMF*, November 2015.

[85] Jinlong Gao, Zhixuan Wu, Jianglong Chen, and Wen Chen. Beyond the Bid-Rent: Two Tales of Land Use Transition in Contemporary China. *Growth and Change*, 51(3):1336–1356, 2020.

[86] Sebastian Gechert, Tomas Havranek, Zuzana Irsova, and Dominika Kolcunova. Measuring Capital-Labor Substitution: The Importance of Method Choices and Publication Bias. *Review of Economic Dynamics*, 2021.

[87] Henry George. *Progress and Poverty: An Inquiry into the Cause of Industrial Depressions and of Increase of Want with Increase of Wealth.* AMS Press, New York, 1973.

[88] Edward L Glaeser, Hedi D Kallal, Jose A Scheinkman, and Andrei Shleifer. Growth in Cities. *National Bureau of Economic Research Working Paper Series*, No. 3787, 1991.

[89] Andres Gomez-Lievano, HyeJin Youn, and Luís M. A. Bettencourt. The Statistics of Urban Scaling and Their Connection to Zipf's Law. *PLOS ONE*, 7(7):e40393, 2012.

[90] Yifan Gong and Charles Ka Yui Leung. Does Space Matter? The Case of the Housing Expenditure Cap. *Regional Science and Urban Economics*, 104(103974), 2024.

[91] Lewis Cecil Gray. Rent Under the Assumption of Exhaustibility. *Quarterly Journal of Economics*, 28:466–489, 1914.

[92] Volker Grimm, Uta Berger, Donald L. DeAngelis, J. Gary Polhill, Jarl Giske, and Steven F. Railsback. The ODD Protocol: A Review and First Update. *Ecological Modelling*, 221(23):2760–2768, November 2010.

[93] Volker Grimm, Steven F. Railsback, Christian E. Vincenot, Uta Berger, Cara Gallagher, Donald L. DeAngelis, Bruce Edmonds, Jiaqi Ge, Jarl Giske, Jürgen Groeneveld, Alice S.A. Johnston, Alexander Milles, Jacob Nabe-Nielsen, J. Gareth Polhill, Viktoriia Radchuk, Marie-Sophie Rohwäder, Richard A. Stillman, Jan C. Thiele, and Daniel Ayllón. The ODD Protocol for Describing Agent-Based and Other Simulation Models: A Second Update to Improve Clarity, Replication, and Structural Realism. *Journal of Artificial Societies and Social Simulation*, 23(2):7, 2020.

[94] David J. Gross. Estimating Willingness to Pay for Housing Characteristics: An Application of the Ellickson Bid-Rent Model. *Journal of Urban Economics*, 24(1):95–112, 1988.

[95] A Haila. The Theory of Land Rent at the Crossroads. *Environment and Planning D: Society and Space*, 8(3):275–296, 1990.

[96] Per H. Hansen. From Finance Capitalism to Financialization: A Cultural and Narrative Perspective on 150 Years of Financial History. *Enterprise and Society*, 15(4):605–642, 2014.

[97] Kathrin Happe, Alfons Balmann, and Konrad Kellermann. The Agricultural Policy Simulator (AgriPoliS): An Agent-Based Model to Study Structural Change in Agriculture (Version 1.0). IAMO Discussion Paper 71, Leibniz Institute of Agricultural Development in Central and Eastern Europe (IAMO), 2004.

[98] Richard Harris. The Growth of Home Ownership in Toronto, 1899-1913. Technical report, Centre for Urban and Community Studies, University of Toronto, 1977.

[99] R. F. Harrod. An Essay in Dynamic Theory. *The Economic Journal*, 49(193):14–33, 1939.

[100] David Harvey. Class-Monopoly Rent, Finance Capital, and the Urban Revolution. *Regional Studies*, 8(3-4):239–255, 1974.

[101] David Harvey. The Urban Process Under Capitalism: A Framework for Analysis. *International Journal of Urban and Regional Research*, 2(1-3):101–131, 1978.

[102] Tri Haryanto, Angga Erlando, and Yoga Utomo. The Relationship Between Urbanization, Education, and GDP Per Capita in Indonesia. *The Journal of Asian Finance, Economics and Business*, 8(5):561–572, 2021.

[103] Colin Hay. Common Trajectories, Variable Paces, Divergent Outcomes? Models of European Capitalism Under Conditions of Complex Economic Interdependence. *Review of International Political Economy*, 11(2):231–262, 2004.

[104] Dirk Helbing and Stefano Balietti. From Social Simulation to Integrative System Design. *The European Physical Journal Special Topics*, 195(1):69—100, 2011.

[105] Helleiner and Gerald (Gerry). 20. Political Economy and Economics at the University of Toronto. In *20. Political Economy and Economics at the University of Toronto*, pages 265–282. University of Toronto Press, January 2018.

[106] J.V. Henderson. The Sizes and Types of Cities. Queen's Economics Department Working Paper 75, Queen's University, Department of Economics, Kingston ON, 1972.

[107] Christopher E. Herbert, D. McCue, and Rocio Sanchez-Moyano. Is Homeownership Still an Effective Means of Building Wealth for Low-income and Minority Households? (Was it Ever?). In *Homeownership Built to Last: Lessons from the Housing Crisis on Sustaining Homeownership for Low-Income and Minority Families*, Boston, 2013.

[108] Michael Hudson, George James Miller, and Kris. Feder. *A Philosophy for a Fair Society*. Georgist Paradigm Series. Shepheard-Walwyn, London, 1994.

[109] Douglas A Irwin and Peter J Klenow. Learning-by-Doing Spillovers in the Semiconductor Industry. *Journal of Political Economy*, 102(6):1200–1227, 1994.

[110] Tariq Saiful Islam, Md Abdul Wadud, and Qamarullah Bin Tariq Islam. Relationship Between Education and GDP Growth: A Multivariate Causality Analysis for Bangladesh. *Economics Bulletin*, 3(35):1–7, 2007.

[111] Jane Jacobs. *The Economy of Cities*. Random House, New York, 1969.

[112] Johannes Jager. Urban Land Rent Theory: A Regulationist Perspective. *International Journal of Urban and Regional Research*, 27(2):233–249, 2003.

[113] Alvin Saunders Johnson. Rent in Modern Economic Theory: An Essay in Distribution. *Publications of the American Economic Association*, 3(4):1–129, 1902.

[114] Talia Kaufmann, Laura Radaelli, Luís M. A. Bettencourt, and Erez Shmueli. Scaling of Urban Amenities: Generative Statistics and Implications for Urban Planning. *EPJ Data Science*, 11(1):50, 2022.

[115] J. M. Keynes. The General Theory of Employment. *The Quarterly Journal of Economics*, 51(2):209–223, February 1937.

[116] H. Youn Kim. The Translog Production Function and Variable Returns to Scale. *The Review of Economics and Statistics*, 74(3):546–552, 1992.

[117] Mervyn King and Mark Robson. Endogenous Growth and the Role of History. 1989.

[118] George P. Kraemer. Cultural Sustainability of US Cities: The Scaling of Non-Profit Arts Footprint with Population. *Sustainability*, 14(7), 2022.

[119] Anne O. Krueger. The Political Economy of the Rent-Seeking Society. *The American Economic Review*, 64(3):291–303, 1974.

[120] Conway L. Lackman. The Classical Base of Modern Rent Theory. *The American Journal of Economics and Sociology*, 35(3):287–300, 1976.

[121] William Larson and Anthony Yezer. The Energy Implications of City Size and Density. *Journal of Urban Economics*, 90:35–49, 2015.

[122] Wilhelm Launhardt. *Mathematische Begründung der Volkswirthschaftslehre*. W. Engelmann, 1885.

[123] Henri Lefebvre. *La Révolution Urbaine*. Gallimard, Paris, 1970.

[124] Henri Lefebvre. *The Urban Revolution*. University of Minnesota Press, Minneapolis, 2003.

[125] David Levhari. Extensions of Arrow's "Learning by Doing". *The Review of Economic Studies*, 33(2):117–131, 1966.

[126] Jonathan Levin. Auction Theory. *Manuscript available at www.stanford.edu/jdlevin/Econ*, 20286, 2004.

[127] Charlotte Liotta, Vincent Viguié, and Quentin Lepetit. Testing the Monocentric Standard Urban Model in a Global Sample of Cities. *Regional Science and Urban Economics*, 97:103832, 2022.

[128] Guang Liu, Yunying Huang, and Khaldoon Albitar. The impact of urban housing prices on labour mobility: Evidence from cities in China. *Economic Research-Ekonomska Istraživanja*, 36(2):2106284, December 2023.

[129] José Lobo, Luís M. A. Bettencourt, Deborah Strumsky, and Geoffrey B. West. Urban Scaling and the Production Function for Cities. *PLoS ONE*, 8(3):e58407, 2013.

[130] August Lösch. *The Economics of Location*. Yale University Press, New Haven, 1954.

[131] Robert E. Lucas. On the Mechanics of Economic Development. *Journal of Monetary Economics*, 22(1):3–42, 1988.

[132] Angelika Mader, Hanno Wupper, and Mieke Boon. The construction of verification models for embedded systems. *International Journal of Web Information Systems - IJWIS*, January 2007.

[133] Carlo Alberto Magni. Average Internal Rate of Return and Investment Decisions: A New Perspective. *The Engineering Economist*, 55(2):150–180, May 2010.

[134] N. Gregory Mankiw, David Romer, and David N. Weil. A Contribution to the Empirics of Economic Growth. *The Quarterly Journal of Economics*, 107(2):407–437, May 1992.

[135] Edwin Mansfield. How Rapidly Does New Industrial Technology Leak Out? *Journal of Industrial Economics*, 34(2):217–223, 1985.

[136] Alfred Marshall. *Principles of Economics*. Macmillan and Co, London, 8 edition, 1890.

[137] Marvin B. Lieberman. The Learning Curve, Technology Barriers to Entry, and Competitive Survival in the Chemical Processing Industries. *Strategic Management Journal*, 10(5):431–447, 1989.

[138] Karl Marx. *Das Kapital, a Critique of Political Economy*. H. Regnery, Chicago, 1959.

[139] Suzanne McCoskey and Chihwa Kao. *A Panel Data Investigation of the Relationship Between Urbanization and Growth*. PhD thesis, University of Munich, Germany, 1999.

[140] John F. McDonald. William Alonso, Richard Muth, Resources for the Future, and the Founding of Urban Economics. *Journal of the History of Economic Thought*, 29(1):67–84, March 2007.

[141] Edwin S. Mills. An Aggregative Model of Resource Allocation in a Metropolitan Area. *The American Economic Review*, 57(2):197–210, 1967.

[142] Edwin S. Mills. *Urban Economics*. Scott, Foresman and Company, Glenview (Illinois):, 1972.

[143] Carlos Molinero and Stefan Thurner. How the geometry of cities determines urban scaling laws. *Journal of The Royal Society Interface*, 18(176):20200705, 2021.

[144] Randall Morck, Andrei Shleifer, Robert W. Vishny, Matthew Shapiro, and James M. Poterba. The Stock Market and Investment: Is the Market a Sideshow? *Brookings Papers on Economic Activity*, 1990(2):157, 1990.

[145] Louis Moreno. The Urban Process Under Financialised Capitalism. *City*, 18(3):244–268, 2014.

[146] John F. Muth. Rational Expectations and the Theory of Price Movements. *Econometrica*, 29(3):315–335, 1961.

[147] Richard F. Muth. The Spatial Structure of the Housing Market. *Papers of the Regional Science Association*, 7(1):207–220, 1961.

[148] Richard F. Muth. *Cities and Housing: The Spatial Pattern of Urban Residential Land Use*. Studies in Business. University of Chicago Press, Chicago, 1969.

[149] Sachio Muto. Estimation of the Bid Rent Function with the Usage Decision Model. *Journal of Urban Economics*, 60(1):33–49, 2006.

[150] Andrea Nemtin, Chris Makris, Claire Buré, Joel Roberts, Maryam Mohiuddin Ahmed, and Stephanie Cheng. Financialization and housing: A social innovation approach to a better housing system. Report, December 2021.

[151] Peter Newman and Jeffrey R. Kenworthy. *Sustainability and Cities: Overcoming Automobile Dependence*. Island Press, Washington, DC, 1999.

[152] Open Agent Based Modeling Consortium. CoMSES.

[153] Thomas Palley. Financialization: What it is and Why it Matters. Report, The Levy Economics Institute, New York, NY, 2007.

[154] Jkohanna Palmberg. Spontaneous Orders and the Emergence of Economically Powerful Cities. Report, Stockholm, 2013.

[155] Dawn C. Parker, Steven M. Manson, Marco A. Janssen, Matthew J. Hoffmann, and Peter Deadman. Multi-Agent Systems for the Simulation of Land-Use and Land-Cover Change: A Review. *Annals of the Association of American Geographers*, 93(2):314–337, 2003.

[156] Dawn C. Parker, Steven M. Manson, Marco A. Janssen, Matthew J. Hoffmann, and Peter Deadman. Multi-Agent Systems for the Simulation of Land-Use and Land-Cover Change: A Review. *Annals of the Association of American Geographers*, 93(2):314–337, 2003.

[157] Jeff Pickel. Investors Own 77 Per Cent of New Condos in Waterloo Region. *CTV News*, February 2023.

[158] Arthur Cecil Pigou. *The Policy of Land Taxation.* Longmans, Green, New York, 1909.

[159] Thomas Piketty and Arthur Goldhammer. *Capital in the Twenty-First Century*. Harvard University Press, 2014.

[160] Diego Puga. The Magnitude and Causes of Agglomeration Economies. *Journal of Regional Science*, 50(1):203–219, 2010.

[161] Michael J. Radzicki. Introduction to Feedback Economics. In *Feedback Economics*.

[162] Jordan Rappaport. Consumption Amenities and City Population Density. *Regional science and urban economics*, 38(6):533–552, 2008.

[163] Rebecca Achee Thornton and Peter Thompson. Learning from Experience and Learning from Others: An Exploration of Learning and Spillovers in Wartime Shipbuilding. *American Economic Review*, 91(5):1350–1368, 2001.

[164] Fabiano L. Ribeiro and Diego Rybski. Mathematical models to explain the origin of urban scaling laws: A synthetic review, November 2021.

[165] David Ricardo. *An Essay on the Influence of a Low Price of Corn on the Profits of Stock*. John Murray, London, 1815.

[166] Jennifer Roback. Wages, Rents, and Amenities: Differences Among Workers and Regions. *Economic Inquiry*, XXVI(1):23–41, 1988.

[167] David Robinson and W. Rupert Cook. Optimal Termination and the IRR Revisited. *The Engineering Economist*, 41(3):271–281, 1996.

[168] John E. Roemer. *A General Theory of Exploitation and Class*. Harvard University Press, Cambridge, MA, 1982.

[169] Paul M. Romer. Increasing Returns and Long-Run Growth. *Journal of Political Economy*, 94(5):1002–1037, 1986.

[170] Nathan Rosenberg. Technological Change in the Machine Tool Industry, 1840-1910. *The Journal of Economic History*, 23(4):414–443, 1963.

[171] Stuart Rosenthal and William Strange. Evidence on the Nature and Sources of Agglomeration Economies. In J. V. Henderson and J. F. Thisse, editors, *Handbook of Regional and Urban Economics*, volume 4, pages 2119–2171. Elsevier, 2004.

[172] Smita Roy. Evolution of the Concept of Capital: A Historical Perspective. *SSRN Electronic Journal*, (14208), March 2009.

[173] Paul Anthony Samuelson. *Foundations of Economic Analysis*. Harvard Economic Studies. Harvard University Press, Cambridge, MA, 1983.

[174] Joseph Schumpeter. The Instability of Capitalism. *The Economic Journal*, 38(151):361–386, 1928.

[175] Mario Seccareccia. Understanding Financialization: History, Theory, and Institutional Analysis. *International Journal of Political Economy*, 42(4):3–4, 2013.

[176] Cosma Rohilla Shalizi. Methods and Techniques of Complex Systems Science: An Overview. In Thomas S. Deisboeck and J. Yasha Kresh, editors, *Complex Systems Science in Biomedicine*, Topics in Biomedical Engineering International Book Series, pages 33–114. Springer, New York, NY, 2006.

[177] Eytan Sheshinski. Optimal Accumulation with Learning by Doing. In *Essays on the Theory of Optimal Economic Growth*. MIT Press, Cambridge, MA, 1967.

[178] Yeung-Nan Shieh. Wilhelm Launhardt and Bid-Rent Curves: A Note. *Journal of the History of Economic Thought*, 26(4):537–542, 2004.

[179] Melina Solaki. Relationship Between Education and GDP Growth: A Bi-variate Causality Analysis for Greece. *International Journal of Economic Practices and Theories*, 3(2):133–139, 2013.

[180] Robert M. Solow. A Contribution to the Theory of Economic Growth. *The Quarterly Journal of Economics*, 70(1):65–94, 1956.

[181] Stephen E. Spear and Warren Young. Macroeconomic Dynamics Survey: Endogenous Growth Theory and Models: The 'First Wave,' 1952–1973. *Macroeconomic Dynamics*, 22(6):1695–1720, 2018.

[182] Michael Spence, Patricia Clarke Annez, and Robert M. Buckley, editors. *Urbanization and Growth*. The World Bank, Washington, DC, 2009.

[183] Ben Sprung-Keyser, Nathaniel Hendren, and Sonya Porter. *The Radius of Economic Opportunity: Evidence from Migration and Local Labor Markets*. Working Paper.

[184] Guy Standing. *The Corruption of Capitalism: Why Rentiers Thrive and Work Does Not Pay*. Biteback Publishing, London, 2017.

[185] Michael A. Stegman. Accessibility models and residential location. *Journal of the American Institute of Planners*, 35(1):22–29, January 1969.

[186] Joseph E. Stiglitz. The Theory of Local Public Goods. In Martin S. Feldstein and Robert P. Inman, editors, *The Economics of Public Services: Proceedings of a Conference Held by the International Economic Association at Turin, Italy*, pages 274–333. Palgrave Macmillan UK, London, 1977.

[187] William G. Sullivan, Elin M. Wicks, and James T. Luxhoj. *Engineering Economy*. Prentice Hall, Upper Saddle River, NJ, 12th ed. edition, 2003.

[188] Trevor W. Swan. Economic Growth and Capital Accumulation. *Economic Record*, 32(2):334–320, 1956.

[189] Leigh Tesfatsion. Agent-Based Computational Economics: Growing Economies from the Bottom Up. *Artificial Life*, 8(1):55–82, 2002.

[190] Peter Thompson. Learning by Doing. In Bronwyn H. Hall and Nathan Rosenberg, editors, *Handbook of the Economics of Innovation*, volume 1 of *Handbook of The Economics of Innovation, Vol. 1*, pages 429–476. North-Holland, January 2010.

[191] Frances Thomson and Sahil Dutta. *Financialisation: A Primer*. Transnational Institute, Amsterdam, 2018.

[192] Timothy G. Conley and Christopher R. Udry. Learning About a New Technology: Pineapple in Ghana. *Proceedings*, 2005.

[193] Donald Tomaskovic-Devey and Ken-Hou Lin. Financialization: Causes, Inequality Consequences, and Policy Implications. *NC Banking Institute*, 18:167–194, 2013.

[194] Gordon Tullock. The Welfare Costs of Tariffs, Monopolies, and Theft. *Economic Inquiry*, 5:224–232, 1967.

[195] Edward L Ullman. Amenities as a Factor in Regional Growth. *Geographical Review*, 1:119, 1954.

[196] Urbanation. National Rent Report. Technical report, Canada, Canada, 2024.

[197] Hirofumi Uzawa. Optimum Technical Change in An Aggregative Model of Economic Growth. *International Economic Review*, 6(1):18–31, 1965.

[198] John Von Neumann, 1903 and Oskar Morgenstern. *Theory of Games and Economic Behavior*. Princeton University Press, Princeton, 3rd edition, 1967.

[199] Johann Heinrich von Thünen. *Der Isolirte Staat in Beziehung Auf Landwirtschaft Und Nationalökonomie*. Wirtschaft & Finan, Hamberg, 1826.

[200] W. Fan, S. Kongnetiman, and P. Walters. Importance of Cities: With Emphasis on Canadian Urban Areas. Report, Calgary, 2010.

[201] Paul Waddell. UrbanSim: Modeling Urban Development for Land Use, Transportation, and Environmental Planning. *Journal of the American Planning Association*, 68(3):297–314, 2002.

[202] Susan M. Walcott. Comments on Edward Ullman's "Amenities as a Factor in Regional Growth". *Geographical Review*, 100(3):301–303, 2010.

[203] Guolin Wang. Analyze the Impact of REITs on the Irish Real Estate Market:. In *International Conference on Economic Management and Cultural Industry*, Guangzhou, China, 2021.

[204] Geoffrey West. *Scale: The Universal Laws of Growth, Innovation, Sustainability, and the Pace of Life in Organisms, Cities, Economies, and Companies*. Penguin Press, New York, 2017.

[205] William C. Wheaton. A Comparative Static Analysis of Urban Spatial Structure. *Journal of Economic Theory*, 9(2):223–237, 1974.

[206] William C. Wheaton. A Bid Rent Approach to Housing Demand. *Journal of Urban Economics*, 4(2):200–217, April 1977.

[207] G Wijburg, Manuel B. Aalbers, and S Heeg. The Financialisation of Rental Housing 2.0: Releasing Housing into the Privatised Mainstream of Capital Accumulation. *Antipode*, 50(4):1098–1119, 2018.

[208] Lowden Wingo. *Transportation and Urban Land*. Resources for the Future, Washington, DC, 1961.

APPENDICES

Appendix A

Notation

Table A.1: Firm productivity

$Y = AN^{\gamma}k^{\alpha}n^{\beta}$	a Cobb-Douglas Production function
k	firm Capital
n	Firm workforce
F	Number of firms
N	Population, inclusive
A	The multiplicative constant term in the Cobb-Douglas and scaling functions
$\mathbb{A}$	Amenity
α	Elasticity of output with respect to firm capital
β	Elasticity of output with respect to firm labour
γ	Elasticity of agglomeration with respect to population
n	Number of workers at a firm

Table A.2: Labour market

ψ	Rural subsistence wage
ω	Urban wage premium
w	urban wage
c	Transportation cost per unit distance
d	Distance from city centre
$d^* = w/c$	City extent

Table A.3: Housing market

P_W	Warranted price for a property
P_B	Bid price
P_A	Asking price
P_M	Realized market price
P_M^e	Expected market price
$\dot{P}$	Rate of price growth
$\dot{P}_{\mathbb{T}}$	Rate of price growth over some period $\mathbb{T}$
$\mathcal{R}$	Rent
$\mathcal{R}_N$	Net rent
R_N^w	Warranted rent
ρ	Rent ratio
ϕ	Rent share
$\mathcal{O}$	Operational costs
$\mathcal{T} = \tau P_W$	Taxes
τ	Property tax share of property value
r	Interest rate
δ	Individual's subjective discount factor
t	Time
W	Wealth
m	Mortgage share
M	Mortgage
S	Savings
$\mathbb{T}$	Mortgage term
a	Share of subsistence wage used for land and building
b	Maintenance share of share of subsistence wage

Table A.4: Rent

$\omega - dc$	Warranted (economic) rent
$\mathcal{R} = \omega - dc$	Equilibrium rent payment of tenant
PDV	Present discounted value (PDV)
$\mathcal{R}^{\mathbb{T}}$	PDV of rent collected over period $\mathbb{T}$
$\mathcal{R}_N^{\mathbb{T}} = (1 - \kappa - \sigma)\mathcal{R}^T$	PDV of net rent collected over period $\mathbb{T}$

Table A.5: Bidding

$\mathcal{R}_N$	Net rent
r^{prime}	Prime interest rate
r^{target}	Investor or banks target interest rate, $\bar{r} + margin$
r_i	Agent i's personal borrowing rate
$r_i^{\mathbb{T}}$	Agent i interest rate compounded over a period $\mathbb{T}$
r_i^{disc}	Agent i's subjective discount rate (which may equal r_i)
r_δ	Discount rate
$\delta_i^{\mathbb{T}}$	Discount factor for agent i over period $\mathbb{T}$
m^W	Wealth-based share of home price a worker can mortgage
m^ω	Income-based share of home price a worker can mortgage
$m_i = min(m_i^W, m_i^\omega)$	Mortgage, the share of home price worker i can mortgage

Note: Agent counts and indices are subscripts. Values related to time are superscripts. Time as a continuous variable is small case, e.g. t. Time as a period is capitalized, for instance the period $\mathbb{T}$ of some number of years. In general values are capitals, rates are small letters.

Appendix B

Initial values

These are the values passed to the program on initialization. Some are initial values for endogenous variables, for instance '`init_F`,' '`init_n`,' and '`init_k`;' some, like "output for a typical rural firm," are intermediate variables used in further calculations; and some are parameters. While parameters typically remain constant through the run, experiments can perturb them. For instance, introducing a forcing function driving the '`price_of_output`' is a natural way to model the effect of business cycles on firm production.

```
# LABOUR MARKET AND FIRM PARAMETERS
'subsistence_wage': 40000.,     # psi, wage for rural worker
'seed_population':     400,     # Initial population at the urban center
'c':                  500.0,    # Transportation costs
'price_of_output':      10,     # Price, received by firms per unit of output
                                # Eqn is A_base + (1-share) * A_slope,
                                # where "share" is share of rents capture by investors
'A_base': 1200,                 # Fixed component of A, the scale parameter
'A_slope': 600,                 # Part of A from local investment
'density': 100,                 # Number of workers per unit land
'alpha':  0.18,                 # Cobb-Douglas exponent for firm capital
'beta':   0.75,                 # Cobb-Douglas exponent for firm labour
'gamma': 0.003,                 # exponent for agglomeration effect of
                                # Adjusted city population N
'overhead': .5,                 # Extra cost associated with an additional employee
'mult':    1.2,                 # Ratio of population affecting agglomeration
                                # to total number of workers
```

```
# SPEED OF ADJUSTMENT PARAMETERS
‘adjN’: 0.015,                  # Adjustment speed, firm
‘adjk’: 0.010,                  # Adjustment speed, firm capital
‘adjn’: 0.075,                  # Adjustment speed, firm workforce
‘adjF’:   0.3,                  # Adjustment speed, number of firms
‘adjw’: 0.002,                  # Adjustment speed, wage paid by firm
‘adjs’:   0.2,                  # Adjustment speed, aggregate worker supply
‘adjd’:   0.2,                  # Adjustment speed, aggregate worker demand
‘adjp’:   0.2,                  # Adjustment speed, aggregate agglom_pop population

# HOUSING AND MORTGAGE MARKET PARAMETERS
‘r_prime’:    0.05,            # Bank rate, basic interest rate
‘r_margin’:   0.01,            # Additional return bank requires to lend
‘r_investor’: 0.05,            # Next best alternative return for investor
‘ability_to_carry_mortgage’: 0.28, # Share of total income that may be spent on mortgage
‘wealth_sensitivity’: 0.1,     # Degree of mortgage tightness for low wealth
‘mortgage_period’:    5.0,     # T, in years
‘working_periods’:     40,     # Years in workforce before retirement
‘savings_rate’:       0.3,     # Share of income that homeowners save
‘discount_rate’:     0.07,     # Rate at which homeowners discount future income
‘housing_services_share’: 0.3, # a, fraction of rural subsistence spent on housing
‘maintenance_share’:  0.2,     # b, annual fraction of building cost spent on  maintenance
‘property_tax_rate’: 0.04,     # tau, annual rate, was c
‘max_mortgage_share’: 0.9,     # m, share of property price eligible for mortgage
‘cg_tax_per’:        0.01,     # Capital gains  tax rate for owner-occupiers  (0-1)
‘cg_tax_invest’:     0.15,     # Capital gains  tax rate for investors  (0-1)
‘investor_turnover’: 0.05,     # Fraction of investor land holdings put
                               # up for sale each period
‘investor_expectations’: 1.,   # Optimism of investor’s estimate of capital gains
```

Appendix C

Amenity

The agent-based model presented in this thesis extends fairly naturally to model a variety of non-monetary locational attributes and a range of preferences for people living there. People choose to live in cities, not only because of higher wages, but for a range of priced and un-priced location-specific attributes referred to as locational amenities. We sketch, in this appendix, several ways in which amenities can be incorporated into our model and indicate some of the questions that incorporating amenities would make it possible to explore.

Housing choice, in reality, is always the purchase of a bundle of characteristics such as location, building space, yard space, local density and local amenities. Stegman [185] found that "a large majority of families who have recently moved to the suburbs are more concerned with neighborhood quality than with accessibility to other parts of the metropolitan region." and "There is evidence that the amenities offered by a city enhance its growth" [47, 70]. Kaufmann et al. [114] argue that amenities are central for generating and supporting economic agglomeration effects, attracting investment to "developing neighborhoods, promoting economic growth, supporting innovation clusters and facilitating businesses linkages."

The amenity value offered by a city can be seen as a form of non-market, non-monetary income [114]. In many cases, it can be treated as an addition to monetary income. Greater consumption amenities in a city will make workers willing to accept lower wages or higher rents. For firms, lower wages mean lower costs. Thus, higher amenity levels may lead to lower money wages as workers trade amenity for money income. With lower wages, more workers can be hired leading to higher output and a larger population [160]. When positive urban amenities prevail, rents and housing prices will be higher in larger cities, but wages

may be unaffected [166, 53]. This greatly simplifies incorporating amenity value into the model.

C.1 Adding amenities to the existing model

To introduce amenities we can simply add a vector of amenity values $\mathcal{A}_j$ to the list of attributes of each unit j of land.[1] The vector can depend on location, allowing for 'better' and 'worse' neighbourhoods. Household i can have a function $\mathcal{A}_i(\mathcal{A}_j)$ that adds an amenity income to wage income. $\mathcal{A}_i$ would depend on household attributes: a family with children might value a neighbourhood with a school or a park more highly.

C.1.1 A simple example

Consider, for example, a single amenity that depends on distance, d from the centre and urban population N. We can define a function for the amenity premium:

$$\mathcal{A}(d|N), \qquad \text{where} \qquad \frac{\partial \mathcal{A}}{\partial N} > 0 \quad \text{and} \quad \frac{\partial \mathcal{A}}{\partial d} < 0.$$

We can now write the household's net wage plus locational amenity at d:

$$\psi + \omega - cd + \mathcal{A}(d|N), \tag{C.1}$$

where $\psi + \omega$ is the urban wage, cd is transportation cost from the centre to d.[2] Since the rural wage is ψ, the advantage of living in the city may is simply $\omega - cd + \mathcal{A}(d|N)$.

This model can produce variations on the standard result in the Alonso model. Figure C.1 illustrates a linear amenity function, $\mathcal{A}(d|N) = a - b * d$. It shows how a particular amenity function might affect the rent profile, and hence city size, and it allows simple experiments with the effect of increasing population on city size, wages and rents.

In the figure, amenity falls below zero in the outer regions of the city and thus the geographical size of the city would be smaller, incorporating amenity. With a linear transportation function,[3] this happens if $\frac{a}{b} < \frac{w}{t}$. A smaller city would have a secondary effect

[1] An elaborated implementation of amenity might include transportation costs to adjacent desired amenities, and amenities that themselves scale superlinearly with population.

[2] Income can be treated as an indirect utility function, a function that depends on income and prices rather than goods and services. Income does not generate utility, but it can generate utility indirectly' by enabling people to purchase goods and services.

[3] Note Anas et al. [12] show that a linear transportation cost will not hold if congestion declines with d.

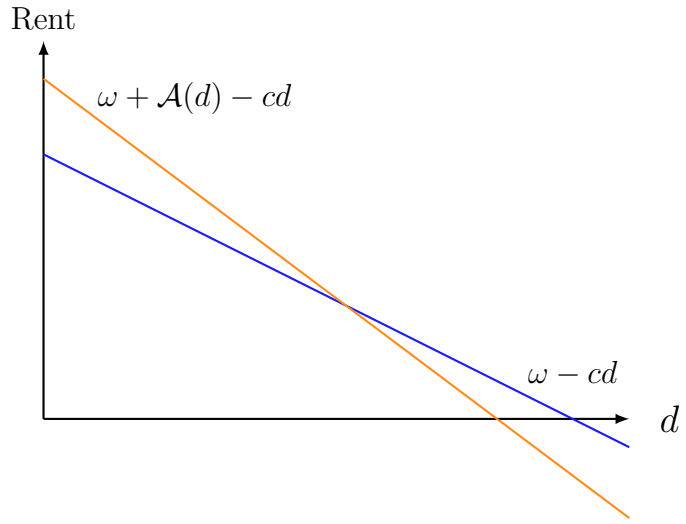


Figure C.1: Rent profile with amenities.

on wages, since with fewer workers' marginal productivity would be higher and therefore wages would rise. This would partially offset the initial decline in population.

There would also be a band of land around the city with negative amenity for commuters.[4] A perhaps more likely case is that $A(d) > 0$ when $w - T(d)$ falls to zero. In this case, there is a band of residents around the city, outside of the population commuting to work. They do not travel to work, do not collect a wage, but still enjoy the amenity of being close to a city. This might be a population of retired persons enjoying occasional visits and healthcare facilities.

C.1.2 Neighbourhood amenity

In Figure C.1 the source of the amenity is at the centre of the city. We can easily imagine an amenity profile that is high for some neigbourhoods and lower for others, as in In Figure C.2. The jagged area below the orange line is rent accruing to landowners. The variable rent comes not from a desire to be close to the source of the wage income but from household demand for local amenity. Financialization might or might not affect neighbourhood amenity. If it does it might have its effect by changing the ownership mix.

[4]The very simple graphical result rests on several assumptions—no other housing expense, housing all the same size, wages all equal, preferences identical, transportation costs.



Figure C.2: Rent profile with neighbourhood amenities.

C.2 Other amenity effects

For some households, the amenity of an area may depend on the density of the city or of certain types in a neighbourhood. There are also agglomeration effects in consumption goods. Larger consumer markets support more variety in goods and services. This variety allows a greater range of preferences to be satisfied. A larger city may have more production sectors and a larger array of consumer services, increasing the value received from a given income. These closely related but different effects can be modelled by introducing the amenity terms in various ways

An amenity-induced rise in housing prices may absorb what would otherwise be consumption expenditure on other goods. Residents might accept smaller housing units for access to urban amenities.[5] In any case, there will be distributional effects as amenities play a larger role in urban agglomeration. Property owners will capture increased land rents. If amenities are funded out of taxes, the burden falls on all residents, since property taxes are roughly related to housing consumption, but the land rents are captured by institutional owners as well as owner-occupiers and not by tenants.

[5]Some costs may fall with agglomeration. There is evidence of a strong negative correlation between the total energy consumption of a city and its overall urban density [151]. Larson et al. [121] show that per-capita energy use is relatively invariant to city size when growth is driven by wages but falls modestly with growth induced by rising amenity.

C.3 Public provision of amenities

Previous sections suggest amenities may work as a wage subsidy, potentially increasing output. Since employers will not pay for urban amenities, some amenities may be financed publicly. It is common to introduce the cost of generating amenities as a tax on residents. Since public amenities may be public goods in the economic sense, the municipal government may be able to achieve significant wage economies with a small public expenditure.

A simple way to incorporate publicly provided amenities to make an amenity function that is proportional to a fraction of public revenue, which is a fraction τ of the land value, in the case in which municipalities depend on property taxes. Assuming a uniform property tax rate, total property tax revenue in a circular city is approximately $\tau(\phi + 2/3\omega)\pi\frac{\omega}{c}^2$. We can therefore include in the buyer's maximum bid function a fraction of this value. Property investors would not include this amenity component, but it would affect their decisions because amenity raises their net rent. Even though amenity raises property values, it does not raise tax revenue unless the population rises immediately, because the property tax rate is adjusted to balance the budget.

C.4 An amenity sector

Producing amenities takes resources. Some fraction of the workforce must be engaged in producing the amenity services. A simple approach to incorporating this into a model would be to assume that the base employment that we consider demands a layer of amenities that represent the additional fraction of the population needed to provide the amenities—say 10%

A perhaps more interesting approach might be introduce a separate production function and workforce. In the resulting two sector model agents would choose a sector to work in. Additional equilibrium conditions would link wages levels in the two sectors. This extension would be similar to the extension needed to introduce a housing production sector.

C.5 Research on amenities

Most of the literature on amenities deals with livability and the benefits for the individual. There is a strand in the literature, however, that links amenities to growth. In 1954, for example, Edward Ullman [195] published "Amenities as a Factor in Regional Growth," an

article that came to be seen in the geographical literature over the following 50 years as prescient [202] for introducing the notion that amenities could be an important mobility magnet.

Many have since extended this approach. Richard Florida examined the notion that urban growth depended on attracting the creative class and that in turn rested in part on the amenities a city offered [75, 73, 74]. In a 2008 Statistics Canada study, 'Cities and Growth: The Left Brain of North American Cities,' Beckstead et al. found substantial differences in average growth for cities with higher cultural employment and urban amenities. Clark et al. [47] argue that much of Chicago's recent growth to 2003 should be attributed to reforms instituted by Mayor Richard M. Daley explicitly linked to amenities and quality of life issues, including parks and schools. On the other hand, Abouy [7] finds that wage and housing cost differences across metropolitan areas are accounted for more by productivity than quality-of-life differences.

Beckstead et al. [23] identify amenities with the unexplained variation in median urban house price after controlling for median household income.[6] Rappaport [162] presents empirical evidence that amenities do support high-density levels and that amenities cause approximately one-fifth of the cross-sectional variation in metro population density.

At the same time, there are economies of scale in the production of at least some amenities. Kraemer [118] found amenity effects scale superlinearly. Though Kaufmann et al. [114] show that for approximately 74% of amenity types, they cannot reject linear scaling, four percent clearly exhibit super-linear scaling. They list takeaway restaurants and travel agents in this range. Sub-linear scaling is associated with libraries, universities, and movie theatres. Since larger cities can support larger and more varied amenities, the effect of amenities on property values might therefore be larger in larger cities. We have no strong prior about how in amenity sector would be affected by financialization of housing. An effect might work through changing ownership.

C.6 Summary

Amenity is an important feature of the urban system. We have shown in this appendix that our model can easily be extended to incorporate a variety of amenity effects. Although it is unlikely to have more than a second-order effect for our main thesis about financialization,

[6]The basic premise would be that after conditioning on household income, variation in home prices across cities would be a function of the relative attractiveness of these places. The residuals yield a continuous ranking of cities based on the estimated variation in urban amenities.

including amenities makes it possible to explore a wide range of questions about cities and neighbourhoods and the way cities serve different sub-populations.

Appendix D

Pseudo Code

```
Class City:

    Method __init__(parameters):
        # Initialize model parameters
        Set self.params to default_parameters merged with parameters

        # Initialize interventions if interventions_on is True and interventions is non-empty
        If ‘interventions’ in self.params and self.params.get(‘interventions_on’, False):
            Set interventions to self.params[‘interventions’]
            If interventions is empty:
                Set interventions to None
        Else:
            Set interventions to None

        # Add a bank, firm, investor, and realtor
        Initialize Bank(unique_id, self, center)
        Initialize Firm(unique_id, self, center, various parameters...)
        Initialize Investor(unique_id, self, center, various parameters...)
        Initialize Realtor(unique_id, self, center)

        # Add land and people to each cell
        For each cell in grid.coord_iter():
            Set pos to (cell[1][0], cell[1][1])
            Initialize Land(unique_id, self, pos, self.params[‘property_tax_rate’])
            If self.params[‘random_init_age’]:
                Set init_working_period to random integer between 0 and self.params[‘working_periods’] - 1
            Else:
                Set init_working_period to 0
            Set savings to init_working_period * savings_per_step
            Initialize Person(unique_id, self, pos, init_working_period, savings, capital_gains_tax, land)

        # Set up data collection
        Call self.setup_mesa_data_collection()

    Method step():
        # Apply interventions for this time step
        If interventions:
            Call self.apply_interventions to apply interventions for this time step

        # Firms update wages based on worker supply
        Set firm.worker_supply to firm.get_worker_supply()
        Set firm.agglom_pop to firm.get_agglomeration_population(firm.worker_supply)
        Call firm.step() for each Firm agent

        # Land records locational rents and calculates price forecast
        Call land.step() for each Land agent

        # People work, retire, and list properties to sell
        Call person.step() for each Person agent
```

```
        # Investors list properties to sell
        Call investor.list_properties() for Investor agent

        # Add newcomers to replace retiring urban owners
        For each retiring urban owner:
            Initialize newcomer Person()
            Call person.bid_on_properties()

        # Investors bid on properties
        Call investor.bid_on_properties() for Investor agent

        # Realtors sell homes
        Call realtor.sell_homes() for Realtor agent

        # Realtors rent properties
        Call realtor.rent_homes() for Realtor agent

        # Advance model time
        Call schedule.step_time()

        # Record step data
        Call self.record_step_data()

    Method run_model():
        For t in range(num_steps):
            Call self.step()
        Call self.record_run_data_to_file()

    Method apply_interventions(current_time_step):
        For each intervention_name and intervention_details in self.interventions:
            If current_time_step equals intervention_details['time']:

                # Split the attribute path into components
                Split intervention_details['var'] by '.' and store in attr_components
                Set target_obj to self

                For each attr_name in attr_components:
                    Set target_obj to the attribute of target_obj named attr_name

                Set the value of the final attribute using setattr(target_obj, attr_components[-1], intervention_details['val'])
```

D.1 Agent Pseudo Code

```
Class Land:

    # Properties
    Property market_rent:
        Return self.warranted_rent

    Property net_rent:
        Return self.warranted_rent - self.maintenance - self.property_tax

    Property appraised_price:
        Return self.warranted_price

    Property property_tax:
        Return self.property_tax_rate * self.appraised_price

    # Initialization method
    Method __init__(unique_id, model, pos, property_tax_rate=0., resident=None, owner=None):
        Initialize instance variables with provided parameters

    # Step method
    Method step():
        Set self.warranted_rent to result of self.get_warranted_rent()
        Set self.warranted_price to result of self.get_warranted_price()

        If self.model.firm.wage_premium is greater than self.transport_cost:
```

```
            Set self.p_dot to self.model.firm.p_dot
        Else:
            Set self.p_dot to None

    # Method to calculate distance from center
    Method calculate_distance_from_center(method='euclidean'):
        If method is 'euclidean':
            Return Euclidean distance between self.pos and self.model.center
        Else if method is 'cityblock':
            Return Cityblock distance between self.pos and self.model.center
        Else:
            Raise ValueError for invalid distance calculation method

    # Method to calculate transport cost
    Method calculate_transport_cost(dist=None):
        If dist is None:
            Set dist to self.distance_from_center
        Set cost to dist * self.model.transport_cost_per_dist
        Return cost

    # Method to change owner of the land
    Method change_owner(new_owner, old_owner):
        Set self.owner to new_owner
        Remove self from old_owner's properties_owned list
        Add self to new_owner's properties_owned list

    # Method to get maintenance cost
    Method get_maintenance():
        Return self.model.housing_services_share * self.model.maintenance_share * self.model.firm.subsistence_wage

    # Method to get warranted rent
    Method get_warranted_rent():
        Set wage_premium to self.model.firm.wage_premium
        Set subsistence_wage to self.model.firm.subsistence_wage
        Set a to self.model.housing_services_share
        Set warranted_rent to wage_premium - self.transport_cost + a * subsistence_wage
        Return max(warranted_rent, 0)

    # Method to get warranted price
    Method get_warranted_price():
        Return self.warranted_rent / self.model.r_prime

    # Method to check if owners match
    Method check_owners_match():
        For each owned_property in self.owner.properties_owned:
            If self.unique_id equals owned_property.unique_id:
                Return True
        Return False

Class Person:

    # Properties
    Property borrowing_rate:
        Return self.model.r_target + self.individual_wealth_adjustment

    Property individual_wealth_adjustment:
        Set K to self.model.wealth_sensitivity
        Set W to self.get_wealth()
        Set W_min to 10000
        Set W_avg to self.model.bank.get_average_wealth()
        Return K / (W - W_min) - K / (W_avg - W_min)

    # Initialization method
    Method __init__(unique_id, model, pos, init_working_period=0, savings=0., debt=0., capital_gains_tax=None, residence_owned=None):
        Initialize instance variables with provided parameters

    # Step method
    Method step():
        Increment self.count by 1
        Increment self.working_period by 1
        Set premium to self.model.firm.wage_premium

        # Urban agents past the working age retire
        If premium > self.residence.transport_cost:
            If self.working_period >= self.model.working_periods:
                If self.residence in self.properties_owned:
                    Set reservation_price to result of self.model.bank.get_reservation_price with relevant parameters
```

```
                Call self.model.realtor.list_property_for_sale with self, self.residence, and reservation_price
                Log debug message for person retiring

        If self.working_period > self.model.working_periods:
            If self.residence in self.properties_owned:
                Call self.model.workforce.remove with self and self.model.workforce.workers
                Log warning for urban homeowner still in model
            Else:
                Reset self.working_period to 1
                Reset self.savings to 0

    Else:
        Call self.model.workforce.remove with self and self.model.workforce.workers
        If self.working_period > self.model.working_periods:
            Reset self.working_period to 1
            Reset self.savings to 0

    Increment self.savings by self.model.savings_per_step

    If self.residence:
        If isinstance(self.residence.owner, Person):
            If self.residence.owner.purchased_property:
                Set self.residence.ownership_type to 1
            Else:
                Set self.residence.ownership_type to 0
            If premium > self.residence.transport_cost:
                Increment self.model.urban_resident_owners_count by 1
        Else if isinstance(self.residence.owner, Investor):
            Set self.residence.ownership_type to 2
            If premium > self.residence.transport_cost:
                Increment self.model.urban_investor_owners_count by 1
        Else:
            Set self.residence.ownership_type to 3
            If premium > self.residence.transport_cost:
                Increment self.model.urban_other_owners_count by 1

# Method to work if worthwhile to work
Method work_if_worthwhile_to_work():
    Set premium to self.model.firm.wage_premium
    If premium > self.residence.transport_cost:
        Call self.model.workforce.add with self and self.model.workforce.workers
    Else:
        Call self.model.workforce.remove with self and self.model.workforce.workers

# Method to bid on properties
Method bid_on_properties():
    Set max_mortgage_share to self.model.max_mortgage_share
    Set max_mortgage to self.get_max_mortgage()

    For each listing in self.model.realtor.bids:
        Set net_rent to listing.sale_property.net_rent
        Set p_dot to listing.sale_property.p_dot
        Set transport_cost to listing.sale_property.transport_cost
        Set P_bid and bid_type to result of self.get_max_bid with relevant parameters
        Call self.model.realtor.add_bid with self, listing, P_bid, and bid_type

# Method to get max mortgage
Method get_max_mortgage(savings=None):
    Set S to savings if provided, else self.savings
    Set r to self.borrowing_rate
    Set r_prime to self.model.r_prime
    Set r_target to self.model.r_target
    Set wage to self.model.firm.wage

    Set M to 0.28 * (wage + r * S) / r_prime
    Return M

# Method to get max bid
Method get_max_bid(m, M, R_N, p_dot, transport_cost, savings=None):
    Set S to savings if provided, else self.savings
    Set r to self.borrowing_rate
    Set r_prime to self.model.r_prime
    Set r_target to self.model.r_target
    Set wage to self.model.firm.wage

    Set value_bid to result of self.model.bank.get_max_desired_bid with relevant parameters
    Set equity_bid to S / (1 - m)
```

```
        Set income_bid to 0.28 * (wage + r * S) / (1 + 0.28 * r) * m

        Set P_bid to value_bid
        If equity_bid <= P_bid:
            Set bid_type to 'value_limited'
            Set P_bid to value_bid

        If income_bid <= P_bid:
            Set bid_type to 'equity_limited'
            Set P_bid to income_bid
        Else:
            Set bid_type to 'value_limited'

        Return P_bid and bid_type

    # Method to get wealth
    Method get_wealth():
        Return self.savings

    # Method to remove person
    Method remove():
        Increment self.model.removed_agents by 1
        Call self.model.workforce.remove_from_all with self
        Call self.model.schedule.remove with self
        Call self.model.grid.remove_agent with self


Class Firm:

    Method __init__(unique_id, model, pos, subsistence_wage, init_wage_premium_ratio,
                    alpha, beta, gamma, price_of_output, r_prime, seed_population, density,
                    overhead, mult, adjN, adjk, adjn, adjF, adjw, adjs, adjd, adjp, dist,
                    init_F, init_k, init_n, A_productivity_link, A_base, A_slope):
        Initialize instance variables with provided parameters, such that:
            y = 100000
            Y = 0
            F = init_F
            k = init_k
            n = init_n
            F_target = init_F
            n_target = init_n
            wage_premium = init_wage_premium_ratio * subsistence_wage
            old_wage_premium = 8000
            wage = (1 + init_wage_premium_ratio) * subsistence_wage
            wage_target = wage
            MPL = 7200
            worker_demand = F * n
            worker_supply = F * n
            agglom_pop = F * n
            p_dot = 0
            N = F * n
            A = A_base + A_slope

    Method step():
        If A_productivity_link is False
            Set investor_ownership_impact_share to 0
        Else
            Set investor_ownership_impact_share to model's investor_ownership_share

        Update A based on A_base, A_slope, and investor_ownership_impact_share
        Log current step information

        Store initial values for calculations:
            y = A * agglom_pop^gamma * k^alpha * n^beta
            MPL = beta + y / n
            N_target = N

        Update N using adjN and N_target
        Store old values of n and wage
        Calculate overhead ratio as 1 + overhead
        Calculate VMPL as price_of_output * MPL
        Calculate revenue as price_of_output * y
        Calculate cost as r * k + wage * n
        Calculate profit as revenue - cost
        Calculate profit_ratio as revenue / cost
        Update old_wage_premium with current wage_premium
```

```
        Set k_target using price_of_output, alpha, y, and r
        Set n_target based on beta, A, agglom_pop, and k
        Calculate worker_demand as n_target * F

        Update F based on worker_supply and n
        Set wage_target as VMPL / overhead ratio
        Update wage based on adjw and wage_target

        Increment state variables towards targets:
            Update n using adjn and n_target
            Update k using adjk and k_target
            Update wage using adjw and wage_target

        Update wage_premium as wage - subsistence_wage
        Calculate p_dot using get_p_dot

    Method get_worker_supply(city_extent = None):
        If city_extent is provided
            Calculate agent_count using block metric radius of the city
            Calculate worker_supply as density * agent_count + seed_population
        Else
            Get agent_count from model's workforce
            If the city is centered
                Calculate worker_supply as density * agent_count + seed_population
            Else
                Calculate worker_supply as 4 * density * agent_count + seed_population

        If worker_supply is 0
            Set worker_supply to 1

        Return worker_supply

    Method get_agglomeration_population(worker_supply):
        Return mult * worker_supply

    Method get_p_dot():
        Try to calculate p_dot as ((wage_premium / old_wage_premium)^mortgage_period - 1) / r
        If ZeroDivisionError occurs
            Log error with time_step and unique_id
            Set p_dot to None
        If any other exception occurs
            Log the error
            Set p_dot to None
        Return p_dot


Class Bank:

    Method __init__(unique_id, model, pos):
        Initialize instance variables with provided parameters

    Method get_reservation_price(R_N, r, r_target, m, p_dot, capital_gains_tax, transport_cost, expectations):
        Call get_max_desired_bid with the same parameters and return the result

    Method get_max_desired_bid(R_N, r, r_target, m, p_dot, capital_gains_tax, transport_cost, expectations):
        Set T to model's mortgage_period
        Set delta to model's delta

        If all parameters are not None
            Calculate R_NT using the formula (((1 + r)^T - 1) / r) * R_N
            Return the reservation price using the revised formula
        Else
            Log error with details of the parameters
            Return 0

    Method get_average_wealth():
        Calculate rural_home_value using get_rural_home_value
        Calculate avg_locational_value based on wage_premium and r_prime
        If the city is not centered
            Divide avg_locational_value by 4
        Return sum of rural_home_value and avg_locational_value

    Method get_rural_home_value():
        Set a to model's housing_services_share
        Set subsistence_wage to firm's subsistence_wage
        Set r to model's r_prime
        Return value of a * subsistence_wage / r
```

```
Class Investor:

    Method __init__(unique_id, model, pos, r_investor, capital_gains_tax, investor_expectations, investor_turnover, properties_owned):
        Initialize instance variables with provided parameters

    Method list_properties():
        Get number of properties owned
        For each property in properties_owned
            If a random chance based on investor_turnover
                Calculate reservation_price using bank's get_reservation_price with property details
                List property for sale using realtor's list_property_for_sale

    Method bid_on_properties():
        Set m to model's max_mortgage_share
        For each listing in realtor's bids
            Get property details from listing
            Call get_max_bid with the property details
            Log the bid details
            If P_bid is greater than 0
                Add bid using realtor's add_bid
            Else
                Log that the investor doesn't bid

    Method get_max_bid(m, R_N, p_dot, transport_cost):
        Set r to borrowing_rate
        Set r_target to model's r_target
        Calculate P_bid using bank's get_max_desired_bid with property details
        Set bid_type to 'investor'
        Log the bid details
        Return P_bid and bid_type

Class Realtor:
    Method __init__(unique_id, model, pos):
        Initialize instance variables with provided parameters

    Method step():
        pass

    Method list_property_for_sale(seller, sale_property, reservation_price):
        Create a Listing object
        Initialize bids for the listing

    Method add_bid(bidder, listing, price, bid_type):
        Create a Bid object
        Append the bid to the bids list for the listing

    Method sell_homes():
        Initialize allocations list
        Log number of listed properties
        For each listing and its bids in self.bids:
            Initialize final_price to None
            Get reservation_price from listing
            If there are bids:
                Sort bids by price in descending order
                Get highest_bid, highest_bid_price, second_highest_bid_price
                If seller is not highest_bidder:
                    Apply negotiation rules (if any)
                    Set final_price based on highest_bid_price or other rules
                    If final_price:
                        Create Allocation object
                        Append allocation to allocations list
                        If buyer is Person:
                            Remove buyer's other bids
                    Else:
                        If seller is Person:
                            Add property to rental_listings
                            Track property with retired_agents
                            Remove seller from model
                        If seller is Investor:
                            representative investor keeps property
        Complete transactions with allocations
        Clear bids
        Return allocations

    Method complete_transactions(allocations):
        For each allocation in allocations:
```

```
        Log transaction details
        Record property sale data
        If buyer is Investor:
            Handle investor purchase
        If buyer is Person:
            Handle person purchase
        Handle seller departure

Method handle_investor_purchase(allocation):
    Change property owner
    Set property resident to None
    Set buyer residence to None
    Add property to rental_listings

Method handle_person_purchase(allocation):
    Change property owner
    Set property resident to buyer
    Move buyer to property position
    Set buyer purchased_property to True
    If wage_premium > transport_cost:
        Add buyer to workforce

Method handle_seller_departure(allocation):
    If seller is Person:
        If seller is in retiring_urban_owner:
            Remove seller

Method rent_homes():
    Log number of properties to rent
    For each rental in rental_listings:
        Create renter
        Set property resident to renter
        Set renter residence to property
        Remove renter from newcomers list
        Log renter details
        renter.work_if_worthwhile_to_work()
    Clear rental_listings
```

Glossary

agent-based See agent-based model. 8, 172

agent-based model Agent-based models are computer simulations. They are often stochastic models, used to study the interactions between people, institutions and things, across places and time. The approach is to model from the 'bottom up,' modeling individual agents and exploring the the effect of interactions, including macro level effects, and the effects on larger systems. Agents are essentially sub-programs that respond to other agents and the environment in certain ways. Agent-based models allow for the exploration of complex systems that display non-independence of individuals, heterogeneity, distributions, and feedback loops. 9, 86, 172, 211

agglomeration A collection of similar items in one location. A city is an agglomeration of people, firms, and other entities. Agglomerations may have properties that individuals do not have, giving rise to agglomeration effects or agglomeration economies, for instance in economics. 6, 9, 211, 212, 216

agglomeration economies Economic advantages resulting from agglomeration effects. 211

agglomeration effect The result of agglomeration. In economics, agglomeration effects refer to the external economies associated with size and concentration. The benefits of size and concentration vary for different cross-sections of the urban population. Three such groupings of benefits may be identified as: 1. consumer agglomeration economies; 2. business agglomeration economies; and 3. social agglomeration economies [37]. In general, the effects of increasing the number of firms or workers in one place include larger, deeper, more specialized labour pool, which enables workers to better match their skills to the needs of firms or creates knowledge spillovers in which firms and workers learn from each other. 211, 225, 229

aggregate A total or derived variable, formed by the combination of many separate data points. 88

Alonso model The model credited to William Alonso, also called the Alonso-Muth model. It is discussed in Chapter 4, and a full development of the theory is presented in Alonso's doctoral dissertation [9]. 88, 212, 213

Alonso-Jacobs model A model combining the Alonso model of the urban land use [8] with the agglomeration theory of Jane Jacobs [111] which explains the productivity of cities. 86

Alonzo model An circular city model developed in the 1960s in which transportation costs combine with residential mobility to determine land rents, and hence urban land use. 46, 49, 102, 212

Alonzo-Jacobs cycle a feedback loop between an Alonzo model determining land rents Jacobs-style agglomeration model determining productivity and population. 69, 125

amenity a desirable or useful feature or facility of a building or place. 162, 196

amenity premium The amount of extra income it would take to make the household as well with out the amenity as they would be with it. Economists call this an "equivalent variation". 197

appraised value an evaluation of a property's value at a given point in time. The evaluation is typically performed by a professional appraiser during the mortgage origination process. 93

attractor In dynamical system theory as described by difference or differential equations, an attractor is a point or orbit inside a region of the phase space. The phase space is a representation of all possible states of the system each corresponding to a unique point in the phase space. If there is an attractor in the region, if the system starts at any point in the region, it will eventually evolve to the attractor. Types of attractors include point attractors, limit cycle attractors, torus attractors, and strange attractors 91

bid price The price that an agent offers to pay to purchase a property. Agents bid during the transaction process. 98

bid-rent curve The height of a graph showing distance from employment horizontally and the amount that residents will pay to rent land at that distance. Also called the rent profile, and the bid-rent function, it is the rent premium for a particular distance from the urban center, and is at the heart of the Alonso model. More generally, with varying agents and property attributes, the bid-rent curve can be seen a set of functions of location, each of which generates a bid price for one category of agent, representing what that agent is willing to pay for that property at that distance from a set of desired amenities and opportunities. 40, 44–46, 85, 213, 226

bid-rent function See bid-rent curve. 46, 85, 213, 226

capital gains 133

capital gains tax a tax on the increase in the financial value of a property that results from an increase in the price. The capital gains tax is a tax on speculative return on housing as an investment. In our model, it captures some or all of the expected gain from rising locational rents, which represents a real increase in value that was not produced by the owner of the property. 101, 128

capital market institutions (sometimes places) through which people who control funds transfer the right to use the funds to those who bid to use them in exchange for promises to pay in the future. Capital markets bring lenders and borrowers together in trade. Capital Markets establish prices (interest rates) for borrowing. Rates vary over time and for different customers. 70

capital stock A term used differently by economists and people in finance. In economics, the term capital stock generally refers to capital goods, real capital, or capital assets. In finance, it generally means the amount of lendable wealth a person or institution controls. for a company the term usually refers to the value of the common and preferred shares in the company. We use the term in the economics sense to refer to the capital goods and other assets used by a firm in production. 70

circular city In urban theory, an idealized city form predicted by models with uniform travel costs. It is the urban form that emerges in the basic Alonso model. 88

class In our usage, which is consistent with classical economics, class is based on the types and amounts of productive capital the individual owns. This is a functional definition distinct from socioeconomic status. Our treatment, of the evolution of class structure with financialization, draws on [168] work on class and exploitation. We allow people

in different functional classes to own financial capital, producing intermediate classes like those appearing in Roemer's work. 123, 214, 216, 225

classical with reference to economic theory see classical economics. 91, 92, 214

classical economic theory See classical economics. 214

classical economics Also called classical political economy. A school of thought in political economy that flourished, primarily in Britain, in the late 18th and early-to-mid 19th century. It was part of the intellectual development of Western liberal democracies in the 18th and 19th centuries and was brought into the mainstream by Scottish economist Adam Smith. Its main thinkers include Adam Smith, Jean-Baptiste Say, David Ricardo, Thomas Robert Malthus, and John Stuart Mill. The term classical was coined by Karl Marx as a description of David Ricardo's formal economics [49]. After 1850, key features of the classical approach were carried forward by Marx, and his followers, and by Henry George. Classical economics provided the foundation for the development of neoclassical economics. See also classical. Classical economic theory explains the cost-of-production, pricing, and the consumption of goods and services as a consequence of ownership of the factors of production. 7, 23, 214, 216, 222

classical rent theory A theory developed in classical economic theory, explaining how land generated surplus value for its owner, and how that surplus explained the wealth and income of the land-owning class. David Ricardo produced the classic description in 1815 based on extensive work by others in the preceding century. The key notion in his analysis is the 'marginal' unit of land. It is just barely worth putting this land into production because it just barely produces enough to justify the cost of production and transportation. More productive land or better-located land produces a surplus that the landowner collects in the form of land rent collected from tenant farmers. No tenant would pay to cultivate that unit of land. The theory employed the basic logic of later the later 'marginalist' school of economic analysis. See also class and rent. 8, 26, 172, 225

Cobb-Douglas A specific production function, commonly used for illustration or estimation in economics. Essentially a form of the geometric mean. 58, 62

complex system a system that exhibits complex behaviour arising from the interplay between multiplicative causation and positive and negative feedbacks. A signature of such systems is that small causes do not always produce small effects. This feature is often called "non-linearity." Nonlinear systems can undergo sudden flips between

stable states or equilibria. A second signature is the "emergence" of structured macroscopic patterns that are not inherent in the microscopic components of the system. (paraphrase of the description by the Waterloo Institute for Complexity and Innovation. 53, 211

consumer surplus At the individual level, consumer surplus is the net benefit from the purchase of any commodity, i.e. it is the total benefit to the person minus the cost paid. At the level of a market, consumer surplus is the sum of the individual consumer surpluses. In supply and demand diagrams it is shown as a triangle above the price line and below the demand curve. See also producer surplus. 39

demand function An equation describing how much a potential buyer or group of buyers will purchase at any given price. A demand function can express price as a function of quantity or quantity as a function of price. In either case it will typically include other variables that are said to 'shift' demand. 221

differential rent Additional payment for the use of a parcel of land based on some advantage that is not shared with all other parcels, such as location or fertility. 220, 226

digitization The process of converting stored information to digital form, or the process of replacing human mental and physical actions with digital processing and digitally mediated actions. 15

disagreement point In a bargaining game the disagreement point is a pair of values that present the lowest value each player will accept. Neither player will accept an outcome that gives them less than their disagreement value. We usually assume that they have an alternative activity or purchase available that is as attractive as their disagreement value for the bargain under consideration. 105

discount factor The present value of one dollar received at a particular point in the future, given the date of receipt and the discount rate. It is the factor by which a benefit at a particular point in the future is multiplied to convert it to a present value. It is smaller when the wait for the future benefit is longer. The most commonly used discount function is the exponential discount function, although that function fails to match several empirical regularities. 192, 215, 223

discount rate A rate used in estimating the current value of future returns. Discount rates vary across time and individuals. It is used in calculating the discount factor for any given future period. 215

distribution The way some amount such as total output, income, wealth or assets are distributed among individuals, classes, factors of production, etc.. The term may refer to a theoretical approach or to an empirical distribution of any of these. Theories of distribution are systematic attempts to account for the sharing of the national income. Distributions across classes is known as a functional distribution distribution and corresponds to the the approach of the classical economics. Neoclassical economics examined distribution through the payment to factors of their marginal value-product. 40

dynamical system A system that changes over time. Typically refers to a system, described by a set of equations, at least one of which is time-dependent. 212

dynastic model A multi-agent model consists of a countable number of dynastic families each of which solves a multi-generation or infinite horizon problem. Generations within a family typically overlap. 223

economic rent Any payment to the owner of a factor of production in excess of the cost needed to bring that factor into production. In classical economics, economic rent is any payment or benefit received for non-produced inputs such as location and through creating official privilege over natural opportunities. See rent. 26, 27, 40, 92, 217

effective labour nominal labour augmented by human capital. One skilled worker might be as productive as two unskilled workers. In that case, the skilled worker would be represented as two units of effective labour in the production function. Similarly, when we introduce agglomeration economies, labour effectiveness depends on the size of the enterprise or community. 60, 216

effective labour supply the quantity of effective labour available in an economy. 74

effective wage The effective wage, also called the real wage is the wage corrected for changes in prices. Firms set a wage, but changing prices for workers may change the effective wage. 72

elasticity The ratio of the percentage change in a quantity to the percentage change in another quantity. The price elasticity of demand, for example, is the percentage change in the quantity demanded that accompanies a one-percent change in price. It is a local property of a demand curve and is typically a negative number, such as -0.3 or -1.5, since demand typically slopes downward. See perfectly elastic. 72, 224

emergent A system property that is not inherent in any of the individual parts of the system. 15

equilibrium In economics and other sciences, an equilibrium is a situation in which forces such as supply and demand are balanced, and in the absence of external influences the equilibrium value of a variable will not change. In economics an equilibrium is often understood as a situation in which no agent has an incentive to change behaviour given what others are doing. Such a situation is called a Nash Equilibrium or a Cournot-Nash equilibrium. 45, 91

expectation Predictions of future events or values, formed by agents for use in decision-making. Agents may form their expectations by looking backward at data on previous values, or by projecting forward using a mental model of how the system works. If agents are fully informed about the state of the system and how it works, their expectations are essentially the same as the predictions of the relevant economic theory and they are termed 'rational expectations' [146]. In probability theory, the expected value of a variable is the mean of its true distribution (the rational expectation), which is usually estimated using the observed realizations (a backward-looking estimate). 102, 127

extensive margin A term from Ricardian rent theory that refers to either land at the greatest distance from the market, or land that has the minimum fertility to justify bringing it into commercial production. A feature of land at the margin is that it generates no economic rent. 29–31, 219–221

extensive property In classical physics, an extensive property is a physical quantity whose value is proportional to the size of the system it describes. In more recent times, in statistical mechanics, or urban studies, for example, the expression "extensive property" has been extended from the "scale-invariant" case in which doubling quantity A exactly doubles property B (doubling the length doubles the volume) to allow for scaling laws of the form $B = c * A^{\beta}$. These scaling laws still deal with extensive properties, but the classical usage is seen to be a special case: $B = c * A^{1}$. 53, 54, 226

factor of production (such as labour, land, financial capital, and human capital) 89, 216, 222, 225

feedback A term originating in cybernetics and systems theory referring to a signal from a part of the system that is changed to the part of the system that is causing the change. See feedback loop. 211

feedback loop Where an output from a system is an input to a future cycle. Feedback loops may damp or reinforce change. 124, 217

financial capital Lendable purchasing power. Owners of financial capital provide their liquidity to borrowers in exchange for a future return. Interest rates are the prices charged for the use of financial capital. It is generally based on, and secured by, ownership of tradable assets. Anything can be a form of financial capital as long as it has a monetary value and can be used in the pursuit of future revenue. Marx distinguished financial capital, then called circulating capital or money capital, from fixed or real capital. 10, 172

financial instrument A monetary contract which confers a right or claim against some counterparty. It may involve a payment (for instance checks, bearer instruments), equity ownership or dividends (such as stocks), debt (such as deposit accounts, bonds, or loans), currency (such as foreign exchange), or derivatives (such as futures, forwards, options, and swaps). There are many types of financial instruments. 16, 218

financialization Financialization is process of creating and using financial instruments to facilitate exchange of real or financial assets. The process may permit real goods, services, and risks to be more easily exchanged, providing access to unrealized economic value. Something is financialized when a financial instrument representing it is created. The home mortgage market was financialized when financial institutions developed markets that let investors buy and sell mortgages between themselves. These secondary transactions gave investors ownership of the stream of income established by the mortgage contract. The transaction did not affect the mortgage conditions or the home: they simply added a new product for investors to speculate on. 13

gentrification changing a neighbourhood occupied by the poor into , typically displacing current inhabitants in the process. 72

ground rents all economic value accruing to owners of land, regardless of whether payments are explicitly made or the rents are imputed. 38

Henry George Theorem A proof by Arnott and Stiglitz [15] of the proposition that if economic activity is efficiently organized over a "large" space, aggregate land rents equal the aggregate losses from the decreasing returns to scale activities. In other words, consistent with the assertions of Henry George, under certain circumstances the single tax would finance all the infrastructure costs of a city. 38

human capital refers to the economic value of a worker's experience and skills. Human capital includes assets like education, training, intelligence, skills, health, and other things employers value such as loyalty and punctuality. It is a produced but intangible asset embodied in workers that affects firm productivity but can't be listed on a company's balance sheet. It is however a measurable asset of communities and even nations. 59, 60, 74, 216

hysteresis An event in the economy that persists even after the factors that led to that event have been removed or otherwise run their course. 128

imperfect competition A market in which any of the conditions required for perfect competition are not met. 222

inframarginal Coming before the margin is reached. For example, if the wage is x, all workers willing to work for less than x are inframarginal. They are selling their time for more that it is worth to them. They come out ahead on the bargain. Workers who will work for x but not a penny less are marginal. Similarly, with land, the most remote or the least productive land in use is 'marginal' while inframarginal land is more productive and generates a surplus. 30, 39, 221

input In production theory, an input is any good or service used to produce another another good or service. For example, labour is a necessary input for producing food. 222, 224

intensive margin Distinguished from the extensive margin, which is a locational concept. Intensive refers to enhancing the productivity of the land by adding labour, fertilizers or other inputs, i.e. by intensifying cultivation efforts. The intensive margin refers to the maximum intensity of additional factors of production that makes sense economically. 30, 221

internal rate of return or IIR. The solution to the polynomial produced by setting the net present value equal to zero. In capital budgeting, it is often seen as the relevant measure of the rate of return on a project. It does not guarantee a single-valued result [167]. Multiple real-valued IRRs may arise; complex-valued IRRs may arise; the IRR is, in general, incompatible with the net present value (NPV) in accept/reject decisions; the IRR ranking is, in general, different from the NPV ranking; the IRR criterion is not applicable with variable costs of capital. Ways to salvage the IRR as a usable criterion have been proposed that are consistent with our approach [133], and are worth exploring.' 99, 223

joint-stock company A joint-stock company is a business owned by its investors, with each investor owning a share of the company based on the amount that they've invested. It is a predecessor to the modern-day corporation and other types of registered companies. A joint-stock company is an artificial person; it has legal existence separate from persons composing it. It can sue and can be sued in its own name. The shareholders are usually not liable for any of the company debts that extend beyond the company's ability to pay up to the amount of them. 16

land market The entire complex of institutions, agents, and rules involved in transferring ownership of land. A land market exists wherever it is possible to exchange rights in land for agreed amounts of money or services rendered. 10, 172

land rent Ricardo payment for the natural productivity of the land or for proximity to markets (locational advantages) See locational rent, differential rent. 27, 28, 220

linear services and infrastructure Linear infrastructure refers to projects that extend over a significant distance in a linear fashion. This category includes roads, railways, pipelines, power lines, and canals. Linear services include maintenance and distribution and collection services such as water distribution, wastewater and garbage collection, bus services, and power distribution. Linear services are generally provided using linear infrastructure. The cost of linear services and infrastructure is closely related to length and may not be tied to number of users. 71

locational equilibrium A situation in which no resident will make herself better off by moving to another location. A Nash equilibrium with housing efficiently allocated given market prices. See migration equilibrium. 46

locational rent A form of differential rent. Income or payment to a landowner for the advantage provided by the location of the property. Locational value is largely created by access to people, not by landowners, hence any payment for locational advantages is a rent. See rent or land rent. 3, 213, 220, 227

margin edge or boundary. In economics, the term has an expanded metaphorically supported technical usage. Ricardo referred to the extensive margin as the geographical limit of production and emphasized that that limit was the limit of profitable cultivation. It was where a sensible person would stop expanding the area of cultivation for economic reasons. Later economists extended the notion to the stopping point for all kinds of decisions. Using calculus they identified the conditions under which producing more would add more cost than the additional sales added in revenue.

Margin appeared as a metaphor in the adjective marginal and in compound terms like marginal product, where it refers to the effect of a small change on some variable such as a small increase in output from a small increase fertilizer or labour employed. Focus on such quantities is the main feature of the marginalist approach. 30

marginal relating to or situated at the edge or margin of something. In the marginalist approach to economics, it refers to technique of focusing on the cost or benefit of the next unit or individual. See extensive margin, intensive margin, marginal product, marginal value-product, inframarginal. 221, 223

marginal product the amount that the last unit of any factor adds to output while holding all other factors constant. See marginal product of labour (MPL). 34, 36, 221, 222

marginal product of labour (MPL) the amount that the last worker adds to output without changing the quantities of other inputs used. The firm's demand function for labour in a competitive market is identically the marginal product of labour function, represented as a downward sloping curve due to the diminishing marginal productivity of labour. See marginal. 221

marginal value-product Also known as the marginal revenue product. The marginal revenue created due to an addition of one unit of productive resource, such as one more worker. Calculated by multiplying the marginal physical product by the price, or the marginal revenue in the case of a non-competitive market. 41, 110, 216, 221

marginalism see marginalist 34, 35

marginalist A style of economic analysis that emphasizes marginal values as opposed to total values or average values. The significance of the distinction lies in the fact maximizing a function like the profit function or utility gives rise to expression in terms of marginal quantities like marginal cost, marginal revenue, and marginal utility. It is then possible to say a person wishing to maximize their profit or utility should want to satisfy the derived conditions on marginal values (prescription). Another step allows economists to assume that those conditions are likely to be satisfied (description). The style of argument generally relies on the use of calculus. The systematic shift to marginalist analysis is seen as the dividing line between classical and modern economics. 31, 35, 36, 221

market a means by which the exchange of goods and services takes place as a result of buyers and sellers being in contact with one another, either directly or through mediating agents or institutions. 222

market price The price that emerges in a market as a result of the interaction of buyers and sellers. It may vary as the mixture of buyers and sellers changes or as their information changes. 93, 102

market rent The amount a landlord charges a tenant for the use of a property in a competitive market. 93

migration equilibrium The theoretical situation in which no resident can make themselves better off by moving to another location. It is a logical consequence of utility maximization and free mobility that results in a Pareto optimal allocation of housing. Technically it is a Nash equilibrium, While extremely useful in analysing urban systems, the concept does not closely describe real cities. 220

mill rate The municipal tax rate: the amount per $1,000 of the assessed value of a property which will be due as property tax. 93

monopoly Market power means you can price above marginal costs. Need free entry to get rid of it—it doesn't drive out profit—profits can be sustained over longer. Monopolist can charge a higher price but pays a competitive price for all inputs including labour. If a firm also had a monopoly on offering jobs, they could drive down wages. 39

monopsony A market with one buyer who therefore has some power to determine the purchase price by varying the quantity purchased. An example of imperfect competition. 39

neoclassical refers to a period in economic theorizing beginning about 1870 that overlaps with but largely follows classical economics. The neoclassical reuslts remain central to economic theory even today although interests have expanded far beyond the core neoclassical disccoveries. The term neoclassical was coined by Thorstein Veblen (1900) The term neoclassical was initially coined by Thorstein Veblen (1900) as a negative description of Alfred Marshall's economics [49]. See classical economics, neoclassical economics. 92

neoclassical distribution theory A theory that states that in perfect competition the owner of every unit of every factor of production will be paid precisely the value of the marginal product of that factor for each unit they contribute to production. 89

neoclassical economics An approach to the study of the economy and economic behaviour that attempts to explain the production, pricing, and the consumption of

goods and services through supply and demand, and to explain agent behaviour using a theory of rational agents who satisfy marginal efficiency conditions. It integrates, within a mathematical framework, the cost-of-production theory from classical economics with a consumer demand theory based on utility maximization. 214, 222

neoclassical growth theory An economic theory that outlines how a steady economic growth rate results from a combination of three driving forces—labour, capital, and technology. Robert Solow and Trevor Swan developed and introduced the model of long-run economic growth in 1956. It is the foundation of most empirical and theorical attempts to explain macroeconomic growth. 86, 110

net present value or NPV The net value in present dollars of a stream of future benefits and costs. It is represented by $\sum_{t=0}^{t=\infty} \delta)_t R_t$ where R_t represents positive or negative revenues at time t and δ_t is a discount factor for period t. NPV is perhaps the most common tool for evaluating projects in capital budgeting. Unlike the internal rate of return (IRR), it is consistent and unique. 99, 219

net rent Or net market rent. The warranted rent minus taxes and maintenance costs. 93, 94

output In production theory, an output anything produced. 216, 224

overlapping generations In an overlapping generations (OLG), model individuals live a finite length of time, long enough to overlap with at least one period of another agent's life. The OLG model is the natural framework for the study of life-cycle behavior (investment in human capital, work and saving for retirement). An overlapping generations mode is not the same as a dynastic model in which multiple generations are linked by family ties. 10, 86, 172

perfect competition An imaginary but analytically useful ideal market condition with the following characteristics: 1. Large numbers of buyers and sellers in each market so that no individual buyer or seller can affect the price. 2. Free entry and exit of firms in the market. 3. Firms in each market sell a homogeneous product. 4. Buyers and sellers possess complete knowledge of the market. 5. No price controls.
Economists often compare the markets they study to the‘ idealized, perfectly competitive market structure. 219

perfect foresight The correct prediction of future events. If agents have all relevant information and a correct model to use for prediction. When there is uncertainty it

is not possible to have perfect foresight. In solving a complex intertemporal model, economists may assume agents have perfect foresight. This is called the rational expectations approach. 127

perfectly elastic Producing more won't affect the product's price. The term describes a horizontal supply or demand curve. See elasticity. 88, 216

political economy Political economy is a branch of social science that studies the relationship between government and the economy. As a discipline, it dates back the 16^{th} but is usually associated with the political economists of the mid-18^{th} and early 19^{th} century like Adam Smith who began to explore the economic implications of free markets and industrialization. Departments of political economy persisted well into the mid 20^{th} C before splitting into separate departments of economics politics [105]. 27, 214

premium The difference between the base price and the price paid in a particular market or buy a particular buyer. In our model is is the difference between the wage of rural workers and the wage of urban workers required to induce workers to live in the city and incur commuting costs. See urban wage,urban wage premium, rent premium. 91

price bubble The sustained rise in the price of an asset above its 'normal' market value caused by agents (mainly speculators) forecasting further price increases base on previous increases, rather than on estimates on intrinsic value. Price bubbles are sustained by expectations of future increases in the price of an asset. They may end sharply, or crash, when expectations shift. 127

producer surplus For a producer selling a product, it is the revenue from sales minus the total variable cost. Profit is producer surplus minus fixed costs. Producer Surplus is a technical term in supply and demand analysis of markets referring to the area under the price line and above the marginal cost curve. 30, 39, 215

product A product is anything produced. It is an output of a production process. Rather than specific products, the city in our model produces an aggregate output, which is not a variable in our analysis. Instead of producing explicit list of discrete products, output is defined by an implicit production function relating labour as an input to aggregate productivity and thus to wages. 88

production function A representation of the technology of production, often a functional relationship between the inputs that enable production and the quantity of output. 35, 216

produit net Profit from a sale after having deducted the costs and charges related to the manufacture and marketing of a product. 29

public good A good, like a view, which is not used up when it is 'consumed' by an individual, and can therefore be consumed again. The definition generally includes that it is not feasible to prevent others from enjoying it, which means that the private sector would have difficulty charging for the public good, and therefore not supply it. 200

quasi-rent A term coined by economist Alfred Marshall for any return to capital in excess of the cost of capital. It is a rent, in Marshall's view because, like land rent it is unearned and based on the ownership of a scarce productive asset. It is 'quasi', or apparent rather than real, because industrial machinery is reproducible and the quasi-rent will be competed away if there are no barriers to entry. Unlike land, productive capital is only scarce until more is produced. 34

REIT Real Estate Investment Trust. A REIT is a financial instrument that makes it possible for individual investors to earn dividends from real estate investments without having to buy, manage, or finance properties themselves. Structured as a company that owns and sometimes operates income-producing real estate or related assets. 21

rent The economic surplus generated in production as a result of differences in the quality of some factor of production. Often described as the difference between the opportunity cost of a factor of production and the income it earns. In this thesis we focus on rents generated by agglomeration effects. According to classical rent theory, rent is the price paid for the use of land. More generally it is the surplus generated by any natural resource, up to and including the athletic talents of basketball stars [120]. Land, talent, and mineral resources are seen as 'the free gift of nature,' forms of capital which the owners do not create but do appropriate. Like the productivity of agricultural land in classical theory, urban agglomeration effects produce land rents that are not created but are appropriated by the landowners. See class. 6, 26, 29, 30, 39, 214, 216, 220

rent premium or warranted economic rent is the excess rent that might be charge for the use of urban land relative the non-urban land. In our model the rent premium for an urban property is equal to the urban wage premium minus the transportation costs. 213, 224

rent profile see bid-rent function or bid-rent curve 213

rent share The fraction of locational rents accruing to owner-occupiers. 192

rent-seeking An economic concept that refers to the activity, seeking to gain wealth without contributing to productivity. Gordon Tullock, who introduced the term, identified it as a form of theft[194]. Rent-seeking activities have negative effects on the rest of society. They result in reduced economic efficiency through misallocation of resources, reduced wealth creation, lost government revenue, heightened income inequality. 22, 40, 171, 226

rentier A person living on income from property or investments rather than from current income. The term is from the French *rentier*, "holder of rental properties or investments that pay income," from *rente* 'profit, income.' 13

representative agent A single agent in a model used to represent an entire class. A single consumer might be used to represent all consumer, or a single firm to represent all firms. The technique is easily justified if all agents of the type are identical or if their collective behaviour can be treated as if it were the result of decisions by a single agent. 114

reproducible capital any tangible asset that can be duplicated (reproduced), such as a building or machinery. 31

reservation price Seller's minimum price of to accept a bid. If no offer is at least as large as the reservation price, the seller is effectively the buyer. It is lowest price that a prospective seller will accept, and is computed as seller's maximum bid price, which incorporates the net rent achievable. 98, 104

Ricardian rent theory The version of classical rent theory propounded by David Ricardo in his essay on the corn laws and generally seen as the canonical version of land rent theory. 8

scaling law Scaling laws are the mathematical expressions of the extensive properties of a system. The laws are of the form $B = c * A^{\beta}$, tying the size of B tightly to the size of A but allowing them to grow at different rates. 54, 56, 65, 217

scarcity rent In contrast to locational rents, which depend on location and are a form of differential rent. A scarcity rent is the price for the use of land when its demand exceeds supply. If all units of land are homogeneous and The concept also applies to exhaustible resources. 23

second-price auction A type of sealed-bid auction. Bidders submit written bids without knowing the bid of the other people in the auction. The highest bidder wins but the price paid is the second-highest bid. 108

sellers' bargaining power A measure of the degree to which bargaining over price favours the seller. Sellers have an advantage when prices are expected to rise, a common expectation when prices have been rising. 106

single tax a tax on land and resources that Henry George and his followers suggest is capable of replacing all other taxes since, if properly implemented, it would capture all resource rents. 38, 218

Solow-Swan model a model of macro-economy developed and analysed by Robert Solow and Trevor Swan independently to explain long-run economic growth [58]. It attempts to explain growth in terms of the growth of three contributing factors, capital, labor (population), and productivity. The productivity term is usually referred to as total factor productivity, (TFP) 59

spatial rent See locational rent 3, 6

subsistence wage In most urban models the subsistence wage is treated as base cost that is the opportunity cost of agricultural land. We have extended the technique to include the opportunity cost of urban labour. It is one of the simplifications which makes our model tractable and focuses it on the question of rents and the specifically urban productivity premium. In our model, the subsistence wage is a wage available inside and outside the urban area, which covers the cost of buildings, food, core living costs, and a base cost of land. 45, 89, 91, 228

substitutable One good may be substituted for another without loss of benefit. Two brands of motor oil are good substitutes for each other. Oranges are somewhat substitutable for apples, but not for screwdrivers. 88

surplus Any amount or production or value in excess of what is needed to pay for all the required inputs. Surplus appears in economic accounts as profit or rent. 26, 28, 29, 219

surplus value This term is most often associated with Marxist analysis, where it refers to the value produced by the labor of workers over and above the wages they are paid. In a capitalist enterprise, it appears as profit or profit before capital costs. In a more general sense, all economic activity produces some surplus value or it would not be worth undertaking. 28

tenantization The process of changing a population of homeowners into a population of tenants. 72, 73

the second circuit of capital Marxists usually focus on the first circuit of capital, in which money is used to buy productive capital and labour services and the product is then sold for more money. Marxist urban theorists recognized a second capitalist circuit in which money (financial capital) is used to buy control of commodities like housing rather than production equipment. The commodities are then resold or rented at a profit, completing the cycle of capital. It is argued that capitalism is increasingly reliant on this second, non-productive cycle for growth. 33

theoretical exposition the presentation or explanation of a theory or idea, preferably clearly and logically. 78, 84, 171

total factor productivity total-factor productivity (TFP), also called multi-factor productivity, is usually measured as the ratio of aggregate output to aggregate inputs. It is a scale factor used to explain why the same combination of inputs produces different quantities of output at different places or times. It appears the factor A discussed in Chapter 5 and in cities is influenced by the size of the population. 61, 227

urban labour supply in our model this is simply the urban population, but more generally it is all those in the general population willing to work at the location or occupation. 88

urban scaling Urban scaling laws reliably relate socio-economic, behavioural and physical variables to the population size of cities. They allow for approaches to city planning and for an understanding of urban resilience and economics. . 9, 85, 172

urban wage The urban wage is the urban wage premium plus the subsistence wage. 89, 224, 228

urban wage premium The wage premium is the premium above the subsistence wage payed by employers to attract workers. An urban wage premium appears when workers in larger cities earn higher average wages than workers in smaller cities. In both the U.S. and Sweden a wage premium has been shown to follow a power-law relationship that scales superlinearly with city size. In other words, workers in larger cities not only earn higher average wages, they do so systematically as a power law function of the size of the city. Bettencourt [26], has demonstrated theoretically that

a wage premium should manifest as a power law function and predicted the value of its exponent. 44–46, 64, 88, 89, 224, 228

warranted economic rent The locational value of an urban property. A surplus generated by agglomeration effects, equal to the urban (wage premium) minus transportation costs, $\omega - cd$). This is the the amount that an equilibrium market rent for a property would be expected to exceed the market rent for a similar non-urban property. 225, 229

warranted rent $\mathcal{R}_N$, at an urban location d units from the centre, is the the value of the flow of services provided by the property, including the locational value, or warranted economic rent. It is level of land rent that would be expected in equilibrium based on location and transportation costs. (It may not be the rent actually charged to a tenant. The warranted rent is used as an initial value for the market rent when running the model. 91, 93, 223

wealth In our model, wealth is the set of valuable economic resources owned, by an individual or organization as measured in either real goods or money value, that the bank considers in lending decisions. We model only housing and aggregate financial wealth (savings), but more generally, wealth includes stocks of human capital, equities, land, and other more subtle assets. 216