Essays on Housing and Agglomeration

by

Michael B. Suher

B.A., Duke University; Durham, NC, 2005
M.A., Brown University; Providence, RI, 2009

A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the Department of Economics at Brown University

PROVIDENCE, RHODE ISLAND

May 2014
This dissertation by Michael B. Suher is accepted in its present form by the Department of Economics as satisfying the dissertation requirement for the degree of Doctor of Philosophy.

Date _______________ ____________________________________

Nathaniel Baum-Snow, Advisor

Recommended to the Graduate Council

Date _______________ ____________________________________

J. Vernon Henderson, Reader

Date _______________ ____________________________________

Gauti B. Eggertsson, Reader

Approved by the Graduate Council

Date _______________ ____________________________________

Peter Weber, Dean of the Graduate School

iii
Vitae

Michael Suher was born April 6th, 1983 in Greensboro, NC. He attended Duke University and received a B.A. in Physics (magna cum laude) in 2005. He then worked at the Federal Reserve Bank of New York until he began his doctoral studies in Economics at Brown University in 2008. During his first three years of study, he was supported by a graduate fellowship from the Department of Homeland Security. He received his M.A. in 2009 and his Ph.D. in 2014.
Acknowledgements

There are many people I wish to thank for leading me into and through graduate school. I am especially indebted to my advisors Nate Baum-Snow and Vernon Henderson. They were always generous with their time and their advice was instrumental to my development as an economist. I learned a great deal from them and they will be the standard I will strive for in any future teaching. I additionally benefitted from Gauti Eggertsson’s willingness to provide a different perspective on my research. I am also grateful for the dedication of Angelica Vargas who helped with administrative difficulties and endless queries.

The Department of Homeland Security provided generous support in my first three years of graduate school. Further, they afforded me the opportunity to spend a summer at the CREATE research center at the University of Southern California. There, Adam Rose was a mentor and thoughtfully included me in the publication process early in my graduate career.

As an assistant economist at the Federal Reserve Bank of New York, Hamid Mehran and George Zanjani challenged me with interesting projects. During graduate school, the Federal Reserve Bank of Boston hosted me as a visiting graduate student and offered access to helpful real estate data.

As an undergraduate at Duke, Ed Tower originally sparked my interest in pursuing economics. Charlie Becker introduced me to the field of urban economics.
and encouraged me to pursue graduate studies. Robert Brown provided me early exposure to academic research.

My father, Thomas Suher, kept me motivated and was always interested to hear about my experiences and latest breakthroughs. My wife, Beth, was a constant support throughout this process even though it often meant living in different cities from one another. Graduate school was made much more enjoyable by time spent with and advice from friends in the program, particularly Paul Christian, Nick Coleman, Adam Storeygard and Zhi Wang. Finally, I dedicate this dissertation to my mother, Dana Suher, who instilled me with confidence and whose pride in my academic accomplishments drove me to succeed.
The housing bust that began in the U.S. in 2007 lead to a drastic increase in foreclosures, the failure of many financial institutions, and was arguably the cause of the prolonged period of economic distress known as the Great Recession. Understanding the inflation of the housing bubble is therefore an important task for economists who would like to know how to identify such dangerous situations in the future as well as forestall them. While the housing boom coincided with substantial changes in mortgage finance, it is frequently presumed that swings in optimistic beliefs regarding house price appreciation helped trigger and drive the boom period and precipitate and prolong the bust in housing. Since beliefs are not directly observable, such speculation has been largely theoretical. This dissertation seeks to close that gap by developing and testing a novel means of inferring expectations regarding the housing market.

In chapter 1, a new measure of local house price expectations is proposed. The measure is inferred from household tenure choice decisions: whether to owner occupy or rent a home. This decision is in part a financial one, based on the comparison of the annual cost of the two tenure modes. In turn, the annual cost of owner occupying is in part dependent on anticipated capital gains on housing, which reduce the cost of owning and make it more attractive. The crux of the approach is in recognizing that the other inputs in this financial comparison besides expected price appreciation, such as the current house price and rent levels, and prevailing mortgage interest rates, are observed. This means that variation in the quantity of owner occupancy demanded, essentially different prevailing homeownership rates, that cannot be explained by these observable factors, can be attributed to differences in expected price appreciation, both across areas and over time. Specifically, residual differences in the
propensity for ownership by similar household types living in different cities, after accounting for the observed portion of the relative cost of owning versus renting, are reconciled by differing beliefs regarding house price appreciation in each area, subject to some assumptions regarding the stability of unobserved tastes for ownership unrelated to these financial considerations. Further, the coefficients from the estimated tenure choice model that captures these residuals map directly into an expectations measure in terms of an annual appreciation rate. Thus in contrast to alternative approaches to measuring beliefs in housing, this measure has a natural economically meaningful cardinal scale rather than just an ordinal ranking of the optimism of beliefs.

Expected price appreciation is a crucial input for most models describing house price determination. Because of this, researchers have tried various means of handling this key unobservable. While surveys of people’s beliefs might seem the best route, these have rarely been conducted, and typically only at the national level. In addition, economists, at least traditionally, have cast surveys of beliefs as unreliable since respondents have nothing riding on their answers and so may not think very carefully about their beliefs. Because tenure choice decisions are major financial considerations for households, this criticism is met by the approach proposed here. The more common means of handling expectations is to estimate an econometric forecast. This involves assuming in advance what factors are used by households in forming their forecasts as well as requiring that households possess perfect foresight. It also leaves little room for the forward looking behavior attributed to rational agents and makes it difficult to pick up turning points in people’s expectations. The tenure choice based measure developed in chapter 1 improves on this approach by being completely flexible. It makes no assumptions about what information households draw on in making their forecasts, or whether they are forward or backward looking.
It also does not impose a perfect foresight assumption. Therefore, in addition to being a more defensible measure of expectations on the merits, the nature of the forecast forming process and reasonableness of perfect foresight assumptions can be directly tested using the measure.

Employing this approach, I find direct evidence of shifts in expectations during the housing boom and bust. I cannot reject a perfect foresight model for expectations held in the year 2000, suggesting that households on average anticipated appreciation over the next two to three years. However expectations from 2006 onwards do not perfectly forecast future appreciation, and show little indication of an anticipation of the housing bust. The magnitude of the estimated implied expectations has reasonable concurrence with survey evidence at the national level. Evidence is also provided that the process governing household forecasts of future price appreciation changes over time. Metropolitan area level expectations are found to be related to fundamental demand drivers like local income and population growth, though the sign of the relationship is not consistent over time. Expectations are also associated with direct measures of housing supply elasticity and an indirect measure based on land use regulation. This relationship weakens during the peak years of the boom, and reverses in the bust years suggesting supply constrained areas were more prone to overshooting. The common practice of assuming long lags of historical local price appreciation are the current expectation is found to be reasonable for typical years, but fails during periods with more volatile prices. There is also some evidence that expectations are adaptive in that they may be influenced by more recent house price behavior.

In chapter 2, the question of the extent to which expected price appreciation is impounded into current house prices is addressed. Conventional cost of capital models typically predict a one to one capitalization of expected capital gain rates into
the housing rent to price ratio. I perform such estimates using the new expectations measure developed in chapter 1 and find a capitalization coefficient between 0.1 and 0.2. These estimates likely suffer from attenuation bias due to measurement error as the expectations measure is frequently computed off of small samples of households. Further reverse causation is a possibility, where high house prices lead to more optimistic expectations, either directly, or indirectly through a loosening of credit driven by a collateral channel. To address these issues, I exploit a quasi-experiment on house price expectations created by the Massachusetts Comprehensive Permit Law.

The law was passed in 1969 to provide more affordable housing in a state characterized by substantial use of exclusionary zoning. It was widely labeled the Anti-Snob Zoning Law as it allowed developers of affordable housing to circumvent local town zoning boards if the town had too little subsidized housing. The impact of the law was significantly enhanced after a 1999 court decision made many more developments eligible. Following this intensification of the policy, housing supply elasticity was substantially increased in towns subject to the law relative to towns that were exempt. This meant that in towns subject to the law, a given increase in future demand would be met with more units being constructed rather than with price increases. It follows that if households are forward looking, exposure to this policy should depress expectations for house price appreciation in an area.

I demonstrate that the measure of expectations I developed in chapter 1 does respond as predicted to this expectations altering policy. Further, I show that housing markets which were initially more inelastic have their expectations dampened the most as theory predicts. Using the extent of exposure to this policy as an instrument for the house price appreciation expectations measure, I estimate the causal relationship between expectations and house prices. I cannot reject that expectations are
capitalized at a one to one rate into rent to price ratios.

In chapter 3, I exploit the significant changes to the urban landscape wrought by a commercial real estate boom, largely coincident with the housing boom, to address a central question in urban economics: How tightly must firms cluster to receive the benefits of agglomeration? The productivity benefits that redound to firms from locating in larger cities has been well documented. The geographic scope and mechanism’s underlying these agglomeration benefits, while given much theoretical attention, have received little empirical study. I make use of zip code level data on firm location in conjunction with a source of plausibly exogenous variation in the within city location of firms to address these questions. I focus on firms in the office sectors, largely service oriented industries like information, finance, and professional services. I confirm the existence of wage premiums related to the metropolitan area footprint of an industry. I then jointly estimate the impact on wages of both the scale of an industry in a city’s dense central business district (CBD) and its metropolitan wide footprint.

To generate variation in CBD scale, conditional on metropolitan scale, I make use of a boom in the construction of new office space which was largely national in nature and driven by a reduction in financing costs from a growing demand for commercial mortgage backed securities. This national construction shock interacted with local differences in relative supply elasticity between each city’s CBD and suburbs, partially dictating whether new office stock was delivered downtown or in sparser office parks in the urban periphery. I proxy for these differences using measures of the geographic landscape throughout the metropolitan area and land assembly difficulties in the CBD. The magnitude of productivity differences driven by variation in the within city density of economic activity are estimated using both wage and output data. Results demonstrate that proximity of firms in the central business district,
rather than the overall presence of a sector in the broader metropolitan area, drive estimated agglomeration effects. These findings point to the relative importance of knowledge spillovers as the source of external scale economies in these office based industries.
Contents

Vitae iv
Acknowledgments v
Preface vii

1 Inferring expectations from homeownership decisions: House price forecasts during a boom and bust 1
1.1 Introduction 2
1.2 Background 4
1.3 Model 9
  1.3.1 Landlords 10
  1.3.2 Households 14
1.4 Empirical Strategy 16
1.5 Data 22
1.6 Results 25
  1.6.1 Estimates of implied house price expectations 25
  1.6.2 Capitalization of expectations into house prices 28
  1.6.3 Forecast performance 30
  1.6.4 Determinants of house price expectations 32
  1.6.5 Comparison to survey evidence 35
  1.6.6 Robustness 37
1.7 Conclusion 40
1.8 Tables and Figures 41

2 House prices and expected capital gains: Evidence from the Massachusetts Anti-Snob Zoning Law 58
2.1 Introduction 59
2.2 Background 61
2.3 Theoretical framework 62
2.4 Empirical Analysis 64
2.4.1 Data ................................................................. 66
2.4.2 Results ........................................................... 67
2.5 Conclusion ......................................................... 71
2.6 Tables and Figures ................................................. 71

3 Proximity and productivity: Localization economies in the office sectors 79
3.1 Introduction ....................................................... 80
3.2 Estimating agglomeration economies ............................ 82
3.3 Data ............................................................... 88
3.4 Expansion in the office market and first stage results .......... 90
  3.4.1 The commercial construction boom .................. 90
  3.4.2 Instruments ............................................. 95
  3.4.3 First stage results .................................... 98
3.5 Results .......................................................... 99
3.6 Robustness ...................................................... 101
3.7 Conclusion ...................................................... 105
3.8 Tables and Figures ............................................. 106

A Derivation of multi-period tenure choice decision 118

B Data appendix 123
  B.1 Office market data ........................................ 124
    B.1.1 Office submarket definitions .................... 124
    B.1.2 TWR Submarkets and ZIP codes ............. 125
    B.1.3 TWR markets and metropolitan areas .......... 125
  B.2 Metropolitan areas and ZIP codes ...................... 125
  B.3 Census ZIP Business Patterns ......................... 126
  B.4 BEA metropolitan area GDP data .................... 127
# List of Tables

1.1 Summary statistics .................................................. 42  
1.2 Tenure choice regressions ......................................... 43  
1.3 Summary of implied house price appreciation expectations . 44  
1.4 Capitalization of expectations into house prices ............. 45  
1.5 Perfect foresight regressions ...................................... 46  
1.6 Income and population growth .................................... 47  
1.7 Supply elasticity .................................................... 48  
1.8 Historical price appreciation ..................................... 49  
1.9 Recent price appreciation ......................................... 49  

2.1 Summary statistics .................................................. 75  
2.2 National estimates ................................................ 75  
2.3 First stage ............................................................ 76  
2.4 Massachusetts estimates ......................................... 77  
2.5 Role of initial supply elasticity .................................. 78  

3.1 Office sector statistics ............................................. 114  
3.2 First stage ............................................................ 115  
3.3 Summary statistics ................................................ 115  
3.4 Metro level estimates .............................................. 116  
3.5 Joint CBD and Metro level estimates ......................... 116  
3.6 Output estimates .................................................. 116  
3.7 Suburban submarket growth ..................................... 117
# List of Figures

1.1 Distribution of estimated house price trend breaks .......................... 50
1.2 Timing of mortgage market changes Price break years: 1999, 2002, and 2005 .................................................. 51
1.3 Income growth staggered by price break year .................................. 52
1.4 Future house price appreciation National distribution .......................... 53
1.5 Comparison to rent to price ratio implied expectations ...................... 54
1.6 Comparison to survey expectations: National level ............................... 55
1.7 Comparison to survey expectations: Individual cities .......................... 56
1.8 Robustness to sample income cutoffs ............................................... 57

2.1 Residential construction relative to policy threshold ............................ 72
2.2 Impact of change in supply elasticity .............................................. 73
2.3 Reduced form evidence: Policy impact on house prices ....................... 74

3.1 Office stock and completions ...................................................... 107
3.2 Commercial mortgage backed security issuance .................................. 108
3.3 Office completions - CBD vs. Suburbs .......................................... 109
3.4 Office stock by class and location ................................................ 110
3.5 Changing intra-MSA office space allocation ..................................... 111
3.6 Downtown rent premium .................................................................. 112
3.7 Office vacancy history .................................................................... 113
Chapter One

Inferring expectations from homeownership decisions: House price forecasts during a boom and bust
1.1 Introduction

A conventional narrative of the recent U.S. housing boom and bust posits changing credit market conditions as the precipitating factor. While the period from 1996 to 2006 was marked by an expansion of subprime mortgage lending and an increase in loan-to-value ratios, the observed pattern of house price cycles is difficult to fully reconcile with a narrative based solely on changing credit market conditions. Most notably is the significant variation in the timing of house price cycles across cities and even within neighborhoods in the same city. This is hard to square with the common belief that changing credit conditions are a national phenomenon. A competing hypothesis points to increased optimism about future rates of house price appreciation during the boom period by prospective home buyers. Such shifts in beliefs could boost local housing demand, driving up price appreciation rates and leading lenders to ease credit access in anticipation of capital gains. Additionally, optimistic expectations of continued future price appreciation could cause markets to overshoot fundamentally justified levels.

A central impediment to testing hypotheses surrounding home buyer beliefs is a lack of measurement of expectations of future housing capital gains. Previous attempts have relied either on survey evidence on expectations, which were limited in scope, or on inferring expectations from historical price series, which require strong assumptions about the expectation forming process. I propose a new approach for measuring these expectations using observed tenure choice: the decision of a household to rent or owner occupy their dwelling. Controlling for observable factors impacting the cost of owning relative to renting, residual differences in homeownership rates among migrants are evidence of shifts in expected house price appreciation. Application of a model of the household tenure choice decision then allows this vari-
ation in the propensity for homeownership to be mapped into a measure of the expectation. The technique improves on conventional methods for inferring expectations by not imposing a perfect foresight assumption and allowing the nature of the expectation forming process to change over time.

By computing household specific tax benefits to owner occupying due to the deductibility of mortgage interest and property tax payments, variation in each family’s after tax price of housing can be used to identify the home ownership demand curve. Under assumptions about the stability of tastes for ownership and homogeneity of expectations within a given area, the timing and magnitude of changes in expected housing capital gains rates can be estimated. The analysis combines Census and American Community Survey (ACS) microdata to produce this expectations measure over time at the level of the metropolitan area or division. This provides much greater geographic detail than is captured by existing surveys of consumer sentiment surrounding housing.

Employing this approach, I find direct evidence of shifts in expectations during the housing boom and bust. I also exploit the cross-sectional variation in the expectations measure to investigate how household forecasts of future house price appreciation are formed. Expectations are found to vary significantly across areas and over time within areas, particularly during the peak boom and bust years from 2005 onwards. Expectations are capitalized into current housing prices though at a lower rate than theory predicts.

I cannot reject a perfect foresight model for expectations held in the year 2000, suggesting that households on average anticipated appreciation over the next two to three years. However expectations from 2006 onwards do not perfectly forecast future appreciation, and show little indication of an anticipation of the housing bust. The
magnitude of the estimated implied expectations has reasonable concurrence with survey evidence at the national level.

Evidence is also provided that the process governing household forecasts of future price appreciation changes over time. Metropolitan area level expectations are found to be related to fundamental demand drivers like local income and population growth, though the sign of the relationship is not consistent over time. Expectations are also associated with direct measures of housing supply elasticity and an indirect measure based on land use regulation. This relationship weakens during the peak years of the boom, and reverses in the bust years suggesting supply constrained areas were more prone to overshooting. The common practice of assuming long lags of historical local price appreciation are the current expectation is found to be reasonable for typical years, but fails during periods with more volatile prices. There is also some evidence that expectations are adaptive in that they may be influenced by more recent house price behavior.

The paper is organized as follows. Section 2 provides background on research into the causes of the housing boom and house price expectations. Section 3 contains a model of the link between the housing price to rent relationship, tenure choice, and expected future price appreciation. Section 4 presents the empirical strategy and Section 5 describes the data. Section 6 describes the results and Section 7 concludes.

1.2 Background

Research into the causes of the recent U.S. housing boom and bust have largely focused on the role of changes in credit markets, potentially driven or amplified by
bad incentives or government policies. A series of papers, considering both the theory and empirical evidence, have found such a narrative insufficient to fully explain the housing boom and bust.

In general, the magnitude of house price changes observed nationally is larger than can be justified even by the significant movements in the most commonly cited measures of expansion in credit markets: lower interest rates, lower down-payments, and an increase in approval rates (Glaeser, Gottlieb, and Gyourko (2012) and Adelino, Schoar, and Severino (2012)). Empirically, affordable housing goals promulgated through the Community Reinvestment Act and the GSEs were found not to have impacted subprime mortgage originations (Ghent, Hernandez-Murillo, and Owyang (2012)). The hypothesized link between incentives in mortgage securitization and future defaults has also proven fairly weak (Bubb and Kaufman (2009)). Similarly, Cheng, Reina, and Xiong (2013) find that managers in companies involved in securitized finance do not appear to have anticipated problems in the wider housing market, at least as evidenced by their personal home transactions. As a counterpoint, Mian and Sufi (2009) do find a significant link between the presence of potential borrowers with low credit scores and future credit expansion and subsequent mortgage default rates. They cannot rule out a role for expectations though. Further their evidence against expectations driven credit expansion relies on using housing supply elasticity as a proxy for expectations which this paper demonstrates is not always justified.

More broadly, Sinai (2012) emphasizes the local nature of house price cycles, both in magnitude and timing, making any hypotheses based solely on credit markets or other purely national factors fairly untenable. Ferreira and Gyourko (2011) similarly find substantial geographic variation in the start of house price booms. They directly test the plausibility of credit as the instigator of price booms and find that
even assuming variation in changing credit conditions at the local level, house price expansions do not line up temporally with measures of increased credit availability. They do find evidence of income growth as a plausible instigator of local price booms at least for markets whose price jumps occurred in or before 2000.

I replicate Ferreira and Gyourko’s technique with the Census microdata geography used in this paper’s analysis. While I confirm the varied timing of local price breaks, and the lack of synchronization of these price breaks with measures of local credit expansion, I find another issue with income growth as a plausible driver of the start of local price booms. While I confirm Ferreira and Gyourko’s finding that income growth was high in areas whose prices jumped prior to 2001, it was on average just as high in areas whose price breaks did not come until years later. Sinai (2012) notes a similar empirical difficulty motivating recent price cycles with fundamental drivers of housing demand like income or employment growth.

I employ Ferreira and Gyourko’s proposed method for determining the start of a price boom in a given area as a statistical break in the house price appreciation series for that area. The results from that exercise are summarized in figure 1.1, which plots the number of areas with a local price boom beginning in a given year as a share of all areas tracked. I confirm that local house price cycles begin at substantially different times, ranging from 1998 to as late as 2006.\footnote{The house price data series begins in 1997 so it is not possible to identify breaks occurring earlier than 1998.} Next, in figure 1.2, I present evidence representative of the weak temporal link between credit market changes and the start of local price booms. For the sake of exposition I focus on areas whose price booms began in one of three different years: 1999, 2002, or 2005. Patterns are similar for areas with price booms beginning in other years. Panel A tracks average annual house price appreciation separately for areas corresponding to each
of the three price break years, with vertical lines marking those break years. Annual price appreciation rates can be seen shifting from a low regime to a high one for each series at its corresponding break year. This variation in the timing of shifts in price appreciation rates across areas contrasts sharply with changes in the market for mortgage credit portrayed in Panels B and C. Panel B plots the share of mortgages with a loan to value ratio of exactly 80%. This is an indicator that the borrower took out a second lien so that the actual downpayment was less than 20%. Panel C shows the share of borrowers with FICO credit scores below 620. Each of the two credit series is tracked separately for areas whose house price booms began in 1999, 2002, or 2005, respectively. The charts clearly show a substantial rise in the ability to finance a home purchase with a smaller downpayment and the frequency with which less credit worthy borrowers could get mortgages. If credit expansion was the sole driver of the price cycles, one would expect to see temporal variation in each area’s credit series trends aligning with the timing of the start of a local area’s price boom as portrayed in Panel A. Notably, there appears to be no relationship to the timing of local house price cycles, with credit loosening instead looking like a very national phenomenon. This is again consistent with Ferreira and Gyourko’s finding that the timing of local booms does not line up with local expansions in credit.

Another possibility is that variation in a fundamental driver of housing demand like income growth was underpinning local house price cycles. If this were the case, one would expect both that income growth was high in areas experiencing a price boom and low in areas that weren’t. Figure 1.3 shows that while the former criteria was sometimes met, the latter was not. It plots patterns of per capita income growth by the year in which an area’s price boom began. The circles show income growth in the years leading up to a price break. For example, for areas whose price booms began in 1998, average annual income growth from 1991 to 1998 was 5.8%, while
for areas whose price booms began in 2002, average annual income growth for 1998-2002 was 2.3%. So at least for areas whose price booms began in the earlier years of 1998, 1999, and 2000, contemporaneous income growth was substantial. This was not the case for areas whose price booms started in 2001 through 2005. As for the second criteria, the high income growth experienced in early booming areas was not atypical. This is demonstrated by the x marks, which track average income growth for the fixed period 1991 to 1998 separately for areas grouped by the year in which their price booms began. Areas that did not experience price jumps until years later had, on average, similarly high income growth during the 1990s as areas that did begin booming. This implies that local income growth alone is not enough to be instigating the price jumps.

The inability of credit expansion or income growth to fully account for documented empirical trends in recent house price cycles is one motivation for considering the role of expectations. In addition, some recent work points directly to the potential importance of changing house price expectations in housing booms and busts. In a similar spirit to this study, Gabriel and Rosenthal (2011) find evidence in the changes in national homeownership rates of an increase in the desire to invest in housing. Analysis of survey responses on attitudes about housing or expectations for prices have demonstrated significant swings in optimistic beliefs over time (Case, Shiller, and Thompson (2012); Piazzesi and Schneider (2009)). Some proxy sentiment indicators for the housing market have also been developed: Haughwout, Lee, Tracy, and van der Klaauw (2011) document significant shifts in the prevalence with which people own multiple homes during the boom, while Soo (2013) constructs a measure based on the tone of housing news in local newspapers and finds it can forecast future prices better than observed fundamentals.

There are also potentially important interactions between shifts in expectations
and credit markets that may amplify the impact either of these factors has on house prices. For example, optimistic expectations of house price appreciation can themselves drive lenders to expand credit availability and weaken incentives to screen borrowers (Brueckner, Calem, and Nakumura (2012); Foote, Gerardi, and Willen (2012); Cheng, Reina, and Xiong (2013)). Similarly during a price bust, Foote, Gerardi, and Willen (2008) demonstrate how pessimistic expectations will impact strategic default decisions. On the theoretical side, Glaeser, Gyourko, and Saiz (2008) show the potential for the interaction of optimistic expectations with supply conditions in the formation of house price bubbles, while Burnside, Eichenbaum, and Rebelo (2011) demonstrate how contagion of beliefs can generate both booms and busts. The expectations measure developed and analyzed in this paper allows for better testing of these expectation based theories against other alternatives. The next section turns to the theoretical framework that guides the empirical strategy.

1.3 Model

Here I present a model that formalizes a procedure for using the link between tenure choice, expected price appreciation rates, and the housing price-rent relationship to empirically recover those expectations. The first part of the model assumes rents are determined by a spatial arbitrage condition, while competitive landlords determine the local house price as a function of the rent. This part of the model formalizes the link between expected future price appreciation and current housing prices, but it is not the basis for the empirical strategy. It does illuminate an alternative method for inferring expectations from prevailing rent to price ratios which can be contrasted with this paper’s approach.
I then describe the household tenure choice decision that supports the empirical strategy. Both landlords and households employ the user cost approach to evaluate the financial benefit to owning a housing unit. This is a common tool in the housing literature used, for example, by Poterba (1984) to study the impact of inflation on house prices, and more recently, by Himmelberg, Mayer, and Sinai (2005) to evaluate the sustainability of prevailing price to rent ratios.

A housing market in this model is a metropolitan area \( m \). Each metropolitan area has a fixed stock \( H_m \) of identical housing units and a population of households each of whom inhabit one housing unit \( N_m = H_m \). A household can owner occupy a housing unit, or rent it from a landlord.

The rent price for a housing unit in each metro area \( (m) \) is determined by the equilibrium condition that across metro areas, the average income \( \bar{y}_{m,t} \) plus the annual flow value of local amenities \( S_{m,t} \), net of rent \( R_{m,t} \), must be equal:

\[
\bar{y}_{m,t} - R_{m,t} + S_{m,t} = k_t, \quad \forall m \in M
\]  

(1.1)

Here incomes and amenity values are exogenous, while migration across cities is assumed to occur until rent levels have adjusted to equalize utility across areas.

1.3.1 Landlords

The marginal buyer of housing units in each town is a profit maximizing landlord. When a landlord purchases a housing unit, they must secure a mortgage for the purchase price of the unit at an interest rate \( r_t \). After buying the unit the landlord incurs maintenance costs at a rate \( d \) and must make property tax payments to the
town at a rate $h^l_m$. The landlord then collects the town specific rent which is taxed at the landlord’s income tax rate $\tau^l$. The landlord can also claim an excess depreciation tax benefit. At the end of the period they sell the unit and potentially earn a capital gain (or loss).

When deciding whether to invest in a housing unit, landlords form an expectation of the capital gain over the next period. This is embodied in an expected price growth term of $E_t[\tilde{g}_{m,t}]$ per period, so that $E_t[P_{m,t+j}] = (1 + E_t[\tilde{g}_{m,t}])^jP_{m,t}$. The goal of the empirical strategy is to estimate these $E_t[\tilde{g}_{m,t}]$ for each time period and metropolitan area. For notational convenience, the presentation in the rest of the paper will drop the expectation operator letting $g_{m,t} \equiv E_t[\tilde{g}_{m,t}]$.

The landlord expected profits expression from investing in and renting out a housing unit has three terms: 1.) The rental payment net of the landlord’s income tax rate 2.) The mortgage, property tax, and maintenance costs which are proportional to the purchase price and are deductible at the landlord’s income tax rate and 3.) The expected capital gain which is taxed at the landlord’s capital gains tax rate.

\[ \pi^l_{m,t} = (1 - \tau^l)R_{m,t} - P_{m,t}[(1 - \tau^l)(r_t + h^l_m + d)] + (1 - \tau^c)(P_{m,t+1} - P_{m,t}) \quad (1.2) \]

The assumption of free entry and exit of landlords from the rental market each period entails that housing prices will adjust until expected profits are driven to zero:

\[ \pi^l_{m,t} = (1 - \tau^l)R_{m,t} - P_{m,t}[(1 - \tau^l)(r_t + h^l_m + d)] - (1 - \tau^c)g_{m,t} = 0 \quad (1.3) \]

where the expected price appreciation rate $g_{m,t}$ has been substituted in.

Solving this zero profit condition yields the standard relationship between housing
unit prices and rents: \(^2\)

\[
\frac{R_{m,t}}{P_{m,t}} = r_t + h^l_m + d - \left(\frac{1 - \tau^e}{1 - \tau^l}\right) g_{m,t}
\]

This model characterizes a housing market in equilibrium. An increase in the expected rate of price appreciation raises housing prices and lowers the rent to price ratio:

\[
\frac{\partial}{\partial g_{m,t}} \left(\frac{R_{m,t}}{P_{m,t}}\right) = -\left(\frac{1 - \tau^e}{1 - \tau^l}\right) \leq -1
\]

The speed at which changes in any of these variables, including expected price appreciation, is capitalized into current prices is not specified here, though some empirical evidence on this will be given in section 6. This model formalizes the relationship between expected future price appreciation and the current rent to price ratio but it is largely heuristic. The empirical strategy will instead employ observed rent and price data and therefore not rely on this specific rent to price equation.

While it is a frequently studied topic, there seems to be little consensus on the

\(^2\)For exposition the derivation in the text excluded the impact of excess depreciation. Rental property is assumed to fully depreciate (like business equipment) over a 27.5 year period. This excess depreciation is deductible at the landlord’s income tax rate like actual maintenance expenses, except that it only applies to the structure, so the effective benefit varies by the structure (vs land) share in the initial property value. This additional tax benefit for the landlord is partially recaptured upon sale of the property at a tax rate of 25%. The rent to price relationship including excess depreciation is:

\[
\frac{R_{m,t}}{P_{m,t}} = r_t + h^l_m + d - \left(\frac{\tau^l - .25}{1 - \tau^l}\right) e_m - \left(\frac{1 - \tau^e}{1 - \tau^l}\right) g_{m,t}
\]

where

\[
e_m = \frac{\text{structure share of } P_{m,t} \text{ in metro } m}{27.5}
\]
correct model with wide variation in assumptions. While this model assumed a fixed stock of housing units, other models assume an infinitely elastic supply which leads to house prices being completely pinned down by construction costs. Narwold and Sonstelie (1994) take this approach which results in rents being a function of constant prices and landlord capital costs. While such a model may be informative for certain areas or for longer run questions, it seems inappropriate for studying a period of significant short run price volatility. There is also a question of which agents set prices or determine rent levels. For example, Poterba (1984) and Glaeser, Gottlieb, and Gyourko (2013) make the own-rent decision of households determinative, with an equilibrium where prices adjust until no one rents. Since the rental market is central to the empirical strategy of this study, the existence of landlords who invest in rental units was assumed. A focus on the owner occupiers is also central to the models of Stein (1995) and Ortolo-Magne and Rady (1999) who predict the impact that relaxing credit constraints through lowered mortgage downpayment requirements will have on prices or homeownership rates. Some authors have also focused specifically on the risk-return relationship for housing. For example, Sinai and Souleles (2005) and Han (2013) model and offer empirical evidence on the potentially counterbalancing roles of asset price risk and the hedging benefits of owned housing. The use of a standard model of the household tenure choice decision is a benefit of this paper’s approach to measuring expectations, relative to inferring them directly from rent to price ratios, as the preceding framework is only one possible model of house price formation. This model though, and specifically equation (1.6), will be directly estimated later in the paper using the tenure choice based measure of expectations. It will also be used with observed rent and price data to produce an alternative measure of expectations which can be compared to the tenure choice based measure. The households described in the next section will respond to the relative rent and price levels in their area, and it is their decisions which drive the
empirical results.

### 1.3.2 Households

Each household must occupy one housing unit but can choose whether to owner occupy or rent the unit. There is costless conversion between rental and owner occupied units so the supply of owner occupied units is perfectly elastic. Households get a fixed benefit $V_h$ from consuming a unit of housing services but have individual preference for owner occupancy. The rent price $p_{r_{m,t}}$ represents the price of consuming a unit of housing services, which is equal for all households in a given area and time. In contrast, each household has its own price for consuming housing services via owner occupation. Like landlords, owner occupiers can also benefit from the deductibility of mortgage interest and property tax payments. With increasing marginal tax rates, the value of this deduction is increasing in household taxable income. The annual cost of owning a unit of housing is given by an area’s own price $p_{o_{m,t}}$ times the individual user cost multiplier $c^i_{m,t}$. The quantity of housing services consumed by household $i$ under renting and owning are given by $q^r_i$ and $q^o_i$, respectively.

A household chooses to owner occupy if its utility from doing so exceeds its utility from renting, and if it is able to secure a mortgage. For household $i$, in metro $m$, at time $t$, the per period utility from renting is: $U(Rent)^i_{m,t} = q^r_i(V_h - \beta_1 p_{r_{m,t}})$. The per period utility from owner occupying is: $U(Own)^i_{m,t} = q^o_i(V_h + \alpha^i_{m,t} - \beta_1 c^i_{m,t} p_{o_{m,t}})$, where $\alpha^i_{m,t}$ reflects individual preference for owner occupancy and is received per unit of housing services consumed.

A household is assumed to move exogenously and then makes its tenure choice. As part of this decision process, a household is assumed to speak with local realtors
and current residents to learn the expectation for future price growth \( g_{m,t} \). The probability that a given household will choose to owner occupy its unit is then the result of an utility comparison:

\[
Pr(Own)_{i,m,t}^i = Pr\{U(Own)_{i,m,t}^i > U(Rent)_{i,m,t}^i\} \ast Pr(Mortgage)_{i,t}^i
\]  

(1.8)

where the probability of securing a mortgage, \( Pr(Mortgage)_{i,t}^i \), is assumed to be independent of the tenure choice utility comparison.

The property tax rate \( h_m \) and depreciation costs at a rate \( d \) are applied to the current period’s house price \( p_{m,t}^o \). Mortgage interest and property tax payments are tax deductible at the household’s tax rate of \( \tau^i \).

The individual house price expression or user cost is:

\[
c_{i,m,t}^i p_{m,t}^o = [(1 - \tau^i)(r_t + h_m) + d - g_{m,t}]p_{m,t}^o
\]

\[
= [\tilde{c}_{i,m,t}^i - g_{m,t}]p_{m,t}^o
\]  

(1.9)

where \( \tilde{c}_{i,m,t}^i = (1 - \tau^i)(r_t + h_m) + d \).\(^3\)

There are three simplifications in this casting of the user cost worth highlighting. First, there is no risk premium included. One justification for this is that it is not clear that the sign of the premium is positive. While owning was traditionally

\(^3\)The relevant subsidy rate \( \tau^i \) will not necessarily be the household’s marginal tax rate. The size of the deduction relative to tax brackets, as well as the fact that as a renter the household will get the standard deduction, will tend to reduce the size of the subsidy below the marginal tax rate. For this reason, in implementation, \( \tau^i \) will be based on the difference in tax bills a household is projected to face as an owner and as a renter:

\[
\tau^i = \frac{taxbillrent^i - taxbillown^i}{(r_t + h_m) \ast P_{m,t}^n}
\]

where \( P_{m,t}^n = q_t^o \ast p_{m,t}^o \) is the total home value.
considered the riskier endeavor due to the volatility of home prices, Sinai and Souleles (2005) argue that owning acts as a hedge against volatile future rents. With more survey data, which measure expectations free from risk considerations, it may be possible to better validate the sign and magnitude of the housing risk premium (Frankel and Froot (1987)). That said though, it is a drawback to this study’s implied expectations approach, relative to the survey approach, particularly if the ownership risk premium varies over time.

A second simplification is the assumption of a maintenance or depreciation term which is a constant proportion of the house value across geographic areas and time. This is required by the lack of a data series capturing any such variation. Finally, this derivation has assumed no capital gains taxation for owner occupiers. Since 1997, housing capital gains are exempt from taxation up to $250,000 for individuals or $500,000 for couples, as long as the unit was owner occupied for two of the past five years. Given these large limits, it seems reasonable to ignore capital gains taxes for the estimations using year 2000 and more recent data. For the estimates using 1990 data, the decision to ignore capital gains taxation is based on the significant ability homeowners had to avoid them. Taxes could be postponed after a sale if the proceeds were used to buy a more expensive house. Further, homeowners could take a one time $125,000 exemption on a sale after age 55 (see Shan (2008)). The next section turns to the empirical strategy.

1.4 Empirical Strategy

Household expectations of future house price appreciation are not directly observable. The goal of this empirical strategy is to infer these expectations in a given area and
time period from relative shifts in the propensity for ownership between households whose observable user cost of owner occupying (excluding capital gains expectations) is similar. An increase in expected capital gains lowers the user cost of owning, increasing the propensity for ownership. By controlling for the observable portion of a household’s user cost, residual differences in homeownership rates relative to similar households in other areas can be attributed to differences in expected capital gains. The estimated user cost model can then be used to translate those differences in homeownership rates into an expectation measure.

As formalized in section 3, an increase in expected future house price appreciation is predicted to be capitalized into higher current house prices. This works opposite to the direct effect of the increased expectation, lowering the propensity for ownership, and potentially rendering the overall homeownership rate unchanged or even lower in the face of an upward shift in expectations. The latter would occur if significantly more households were unable to afford a mortgage downpayment at the elevated house prices. For this reason the analysis focuses on individual tenure choice decisions rather than changes in aggregate homeownership rates.

This technique for inferring expectations from the intersection of owned and rented housing is probably most similar to the approach in Capozza and Seguin (1996) and Glaeser and Gyourko (2007). They extract an implied expectation from an area’s prevailing price to rent ratio. That approach requires assuming that the households on the margin between renting and owning are of sufficient number to set prices which, as the latter authors note, may not be the case. The tenure choice approach in this paper uses differences in the quantity of owner occupancy demanded. By using household level decisions, the sample can be restricted to credit unconstrained households to isolate the impact of capital gains expectations from mortgage availability. Additionally, the study focuses on households who recently moved
to account for the role of inertia in the tenure decision.

Variation in the after-tax price facing households is used to estimate the tenure choice equation. The use of tax price variation is common in the housing literature and has also been employed in studies like Gruber and Poterba (1994) investigating the demand for health insurance. The favorability of owner occupying for a given household is based on a comparison of their specific user cost of owning with the cost of renting a dwelling, as well as on individual preference for ownership. If the individual ownership preference is identically distributed in each area, as house prices vary relative to rent, either over time or across locations, the average propensity for owner occupying of dwellings by individuals with equivalent user cost net of rent is predicted to stay constant.

In the empirical specification laid out below, within each time period, households living in different areas but sharing the same observable user cost of ownership relative to rent are compared. Since all households are assumed to be drawing from the same distribution over taste for ownership, after accounting for differences in access to mortgage credit, if the average propensity for ownership for two observably similar households differs, it can be attributed to differences in expected house price appreciation across those areas.

Previous research employing the user cost approach has frequently cast the tenure choice decision as a one period financial comparison. In particular, households are assumed to only compare current house prices and rents, in conjunction with a one period expected price appreciation rate. In such a setting, there is no issue with matching the horizon of the price appreciation expectation and expected duration in the unit, or whether rents grow in tandem with prices. I follow that approach here assuming households have a one year horizon. This is a significant simplifica-
tion as typical stays are significantly longer. In the American Community Survey data, the fraction of the population who moved in the last year is 12.5%. If this probability of moving was constant during the stay then the expected duration in a unit would be 8 years.\footnote{The share of movers declines from 13.8% in 2005 to 11.5% in 2011, corresponding to expected stays of 7.2 and 8.7 years, respectively} In the appendix I present tenure choice as a multi-period forward looking decision with a fixed probability of moving each year and a constant expectation for house price growth. This multi-period decision reduces to the conventional one period user cost comparison under some additional simplifying assumptions.\footnote{These assumptions are a random moving probability each period, which is the same for owners and renters, and a constant per period expected price appreciation rate that is also the rate of rent growth. Further it requires assuming that the idiosyncratic taste for ownership parameter also grows at the same constant rate as price appreciation in each future period that a household is in the same owned unit.} The share of movers among households in rental units is a substantially higher 31.1% which would correspond to about a 3 year expected stay. Though as Sinai and Souleles (2005) note, households tend to move within the same market or to a closely correlated housing market which lengthens their effective horizon. The demographic controls in the tenure choice specification as well as industry of employment indicators will help account for individual deviation from the average expected length of stay in a unit.

The baseline estimating equation is motivated by the household tenure choice utility comparison in equation (1.8). Substituting in the utility and user cost expressions gives:

$$\frac{Pr(Own)_{m,t}^i}{Pr(Mortgage)_{m,t}^i} = \frac{Pr\{q^o_i(V_h + \alpha^i_{m,t} - \beta^1 c^i_{m,t} p^o_{m,t}) > q^r_i(V_h - \beta^1 p^r_{m,t})\}}{Pr\{q^r_{m,t} > q^o_{m,t}\}}$$

(1.10)

The quantities of housing service consumed under either tenure choice are assumed to be the same: \(q^o_i = q^r_i = q_i\). The household therefore makes it decision...
based on a comparison of the costs per unit of housing services under each tenure mode, net of the individual preference for ownership term:

\[
\frac{Pr(Ow\text{\textsuperscript{n}})_{i,m,t}}{Pr(Mortgage)_{i,t}} = Pr\{\alpha^{i}_{m,t} - \beta_{1}c_{m,t}^{i}p_{m,t}^{o} > -\beta_{1}p_{m,t}^{r}\} \tag{1.11}
\]

The individual preference for owner occupancy is assumed to be a function of observable household characteristics and a purely idiosyncratic term: \(\alpha^{i}_{m,t} = \beta_{2}X_{i}^{t} + \epsilon^{i}_{m,t}\).

\[
\frac{Pr(Ow\text{\textsuperscript{n}})_{i,m,t}}{Pr(Mortgage)_{i,t}} = Pr\{\epsilon^{i} > \beta_{1}(c_{m,t}^{i}p_{m,t}^{o} - p_{m,t}^{r}) - \beta_{1}g_{m,t}p_{m,t}^{o} + \beta_{2}X_{i}^{t}\} \tag{1.12}
\]

Assuming \(\epsilon^{i}_{m,t}\) is uniformly distributed, the parameters \(\beta_{1}\) and \(\beta_{2}\) can be estimated via a linear probability model. In order to have enough households off of which to estimate the price appreciation expectation, I estimate an average expectation denoted \(g_{m,t}\) at the metropolitan area or division level rather than at the smaller Census public use microdata area (PUMA) level. While studying housing markets at the metropolitan area level is common, studies like Ferreira and Gyourko and Guerrieri, Hartley, and Hurst (2013) do find finer geographic variation in housing market cycles which will not be captured here.

For metropolitan area \(m \in \{1, ..., M\}\) and for a given period \(t\)

\[
\frac{1(Ow\text{\textsuperscript{n}})_{m,t}}{Pr(Mortgage)_{i,t}} = \beta_{1}(c_{m,t}^{i}p_{m,t}^{o} - p_{m,t}^{r}) - \beta_{1}g_{m,t}p_{m,t}^{o} + \beta_{2}X_{i}^{t} + \epsilon_{a,t}^{i} \tag{1.13}
\]

Since \(g_{m,t}\) is not directly observed, metropolitan area fixed effects interacted with

\[\text{The idiosyncratic component, } \epsilon^{i}_{m,t}, \text{ could reflect things like pride of ownership and aptitude or inclination for home maintenance.}\]
the metropolitan area house price are included instead. When estimated on households without credit constraints, the $Pr(Mortgage)_i = 1$, so that the specification becomes:

$$1(Own)_{i,m,t} = \beta_1(c_{i,m,t} - p_{m,t}) + \sum_{m=1}^{M} [\delta_{m,t} \times 1(Area)_{i,m,t} \times p_{m,t}^o] + \beta_2 X_{i,t}^i + \epsilon_{m,t}$$

(1.14)

where the fixed effect $1(Area)_{i,m,t} = 1$ if the household lives in metropolitan area $m$ and 0 otherwise. The coefficients on the house price interacted area fixed effects are then a function of the rate of expected future house price appreciation and the coefficient $\beta_1$:

$$g_{m,t} = \frac{\delta_{m,t}}{\beta_1}$$

(1.15)

The estimated model thus provides an economically meaningful scaling to the residual differences in homeownership rates in terms of an expected annual house price appreciation rate. This is notable in that it does not require an assumption of perfect foresight in contrast to alternative proxy indicators of sentiment which require estimation of a forecast model with realized returns on housing to be sensibly mapped to an expectation measure.

The sample is restricted to households who recently moved to limit the role of inertia in a household’s current tenure choice status. Gabriel and Rosenthal (2011) use this approach when decomposing the factors driving changes in homeownership rates. In studying the tenure choice decision, Henderson and Ioannides (1987) also focus on movers in addition to stratifying their sample by credit constrained and
unconstrained households. In this study the sample is restricted to households above the 60th percentile of their metropolitan area’s income distribution who are likely to be unconstrained in their ability to obtain a mortgage. The inclusion of household level demographic covariates and measures of recent employment history will also help control for credit access.

Estimation of the the price coefficient $\beta_1$ is based on variation in the user cost of owning. This variation comes from two sources: the tax subsidy rate, which depends on household income level, income source, exemptions, and the quantity of housing service demanded, and property tax variation within a metropolitan area. Identification of the fixed effect coefficients requires assuming that households do not sort across locations on the basis of ownership preference. If this assumption fails, implied expectations in places with low relative owner cost would be biased upwards and vice versa for places with high relative owner cost. Estimating expectations from only higher income household’s decisions also requires assuming that expectations are similar for lower income households, either for some behavioral reason, or more likely because they may consume different quality houses located in different neighborhoods. Some survey evidence is brought to bear on this question and the robustness of the expectation estimates to varying the sample income cutoff is discussed in the results section below. The next section describes the data used in the empirical analysis.

1.5 Data

The baseline specification (3.1) is estimated using households in the 1990 and 2000 Census and 2005 to 2011 American Community Survey microdata (Census). The
household characteristics and components for computing the relative user cost variable come from the Census, except the mortgage interest rate which is the 30-Year Conventional Mortgage Rate provided by the Board of Governors of the Federal Reserve System. Table 3.1 provides summary statistics of the key variables for the sample. The sample itself is restricted to high income movers: specifically households above the 60th percentile of their metropolitan area’s income distribution who moved in the last two years.

The smallest geographic unit revealed in the data is the Census public use microdata area (PUMA). The areas must have at least 100,000 people. Each state is completely partitioned by PUMAs. While the PUMA is used to characterize the price, rent, and property tax rates households face, the expected house price appreciation estimates are constrained to be the same across the larger metropolitan area or division which typically comprise multiple PUMAs. The larger geography is used so that the expectation estimates are based off a sufficient number of households. The specific metropolitan areas and divisions assembled are based on the geographies for which the FHFA produces annual house price indices. These longer historical series of annual house price appreciation are repeat sales indices of single-family house prices. A few metropolitan areas are tracked as earlier as 1975 with the full sample available by 1995. The choice of geography facilitates the analysis of the relation of expectations to historical local price appreciation. Further, the use of these county based metropolitan areas allows for the comparision of 1990 expectation estimates to later years, as the PUMA definitions are not constant between the Censuses. In total there are 429 areas defined: 383 metropolitan areas or divisions and 46 state non-metropolitan areas.

The tenure choice estimations aim to accurately capture the information guiding the decision facing a household on the margin between owning and renting. Two of
the key variables in that decision are the relevant per unit of housing service own and rent prices that the household faces, $p_{m,t}^o$ and $p_{m,t}^r$. These prices should be for the same quantity and quality of housing service, but the the owned stock may differ significantly in quality from the rental stock. I estimate a hedonic regression which attempts to explain rents from the Census, controlling for the potential inclusion of utility payments, using a set of housing characteristic variables suggested by Albouy (2009) covering single family status, number of rooms and bedrooms, persons per room, and the age of the structure. A similar hedonic regression is run for Census house values. Both the rental and owned unit specifications also include PUMA level fixed effects. The coefficients on these fixed effects is then taken as an area’s per unit of housing service own or rent price. It is possible that even restricting to the PUMA level, owned and rented units are located in different neighborhoods. If, for example, rental units are predominantly in neighborhoods with lower amenities, the housing quantity and quality controls which are observed will not fully equalize owned and rented units, rendering a predicted rent price below the ideal owned unit matched value. This mismeasurement would tend to upwardly bias the expectation estimates.

The household specific tax benefit to owner occupying is computed using the NBER Taxsim calculator (Feenberg and Coutts (1993)). To have comparable house values for owners and renters for computing each household’s owner tax subsidy rate, a projected house price is generated for each household using observed choices of housing quantity and quality interacted with the coefficients from the owned unit hedonic estimation described above. The tax bill for each household is computed twice, once as an owner occupier with a mortgage and paying property taxes on their projected house price and once as a renter. Using the Census data I am able to assign values for 17 of the 21 inputs that the tax calculator accepts. The households
annual owner tax benefit is then taken as the difference between these two tax bills.

The house price appreciation trend breaks summarized in figure 1.1 are estimated using quarterly zip code level house price series from Zillow, aggregated to the PUMA level. The measures of credit access plotted in figure 1.2 are computed from data provided by LPS. LPS contracts with a number of mortgage lenders to get loan level information with the zip code of the borrower so this data is also aggregated to the PUMA level. The income trends in figure 1.3 are computed from IRS statistics of income data which is also aggregated from the zip code to the PUMA level.

The data on housing supply elasticity, unavailable land share, and land use regulatory index values is provided by Saiz (2010). The geographic units used in that data (1999 MSA/NECMA) are matched to the FHFA geography using principal cities. Finally the survey data on house price expectations comes from the University of Michigan Surveys of Consumers for the national level and from Case, Shiller, and Thompson (2012) for four local areas. In the next section I present the results and discuss the validity of some of the assumptions in the empirical strategy.

1.6 Results

1.6.1 Estimates of implied house price expectations

The baseline specification predicts tenure choice as a function of relative owner cost (the annual household specific user cost of housing net of the rent price) and a metropolitan area fixed effect. It also includes household level demographic co-variates previously included in studies of tenure choice (e.g. Narwold and Sonstelie
The sample is restricted to households who moved within the past two years and who are above the 60th percentile of their metropolitan area income distribution. Additional household characteristics regarding employment status and recent work history are included as additional credit access controls as the income cutoff may not fully ensure all sample households are credit unconstrained. Finally, industry of employment indicators of the head of household are included to complement household demographic variables in accounting for variation in expected stays across households. Each year is run separately. The results are presented in Table 1.2.

The coefficient on the relative owner cost term is around -0.05 implying that a $1,000 increase in the user cost of owning against a fixed rental price leads to a 5 percentage point reduction in the probability of a household owning. As expected, the married indicator is a positive predictor of ownership, while age is positive and quadratic. The nonwhite indicator is a negative predictor of ownership as has been seen in previous studies of tenure choice. Income after the predicted owner tax subsidy for each household has a positive coefficient indicating that ownership is also a consumption good. The children indicator is positive or insignificant in most years. As described in section 4, metropolitan area fixed effects interacted with the area house price are included to account for the role of capital gains expectations in the user cost of owning.

The coefficients on the price interacted area fixed effects are collected and scaled by the coefficient on relative owner cost to produce the implied house price appreciation expectations for each area. This produces a panel with future house price expectations for each metropolitan and state non-metropolitan area in each data year. Under the model laid out in section 3, these are one year expectations. As described in the appendix, under certain assumptions, they equivalently represent expectations of constant annual appreciation rates over each subsequent year of un-
A summary of the distribution of these estimated expectations across all metropol-itan and state non-metropolitan areas is provided in panel A of table 1.3 and plotted in figure 1.4 along with actual national annual price appreciation rates for reference. The distribution is weighted by the number of housing units in each area. The solid line in figure 1.4 plots the median expectation. The dashed lines plot the 10th, 25th, 75th, and 90th percentile of the national distribution of expectations for each data year. Relative to the figures in table 1.3, the plotted expectations are adjusted for inflation to provide better comparability between 1990 and later years.\(^7\)

Nationally, during the post-1996 boom period, the sample year with the highest expectations was 2000 at 5.6%. Mean national expectations were at a trough of 1.7% in 2010, two years before the trough in nominal house prices. The high degree of dispersion in price expectations across areas is evident from figure 1.4. The interquartile range also varies over time between 1.7% and 5.6%, becoming widest at the start of the price recovery in 2011. Panel B of table 1.3 summarizes the within area changes between each data year, demonstrating that the direction of the evolution in expectations at the local level is not always consistent with the predominant national trend. The largest mean change in expectations was a decline of 2 percentage points between 2000 and 2005, though the trend in the interim years is not measured. While expectations were fairly stable from 2005 to 2008, between 2008 and 2011, each area’s expectations were changing by about one percentage point a year on average. This alone demonstrates that future house price expectations are not a fixed or even always a slow moving property of a metropolitan area.

\(^7\)The expectations are estimated in nominal terms and so are a combination of a forecast of general price inflation and real house price appreciation. Real appreciation figures are obtained by subtracting off ten year inflation expectations from the Philadelphia Fed’s Livingston Survey from the estimated nominal expectations.
1.6.2 Capitalization of expectations into house prices

While the results above have demonstrated the degree to which future house price expectations shifted during the housing boom and bust, it is natural to try to quantify the extent to which these expectation shifts played a direct role in driving house prices during this period. The model presented in section 3.2 describes the theoretical relationship between an area's prevailing rent to price ratio and expectations of future house price appreciation, as summarized in equation (1.6). According to this model, expectations will be capitalized one for one into lowering the rent to price ratio, after accounting for local income and capital gains tax rates. Alternatively, the model can be directly estimated using the implied expectation measure. The results of this estimation are presented in table 1.4 where a metropolitan area’s rent to price ratio is regressed on the local property tax rate, mortgage rate, and the current expectation for price appreciation. The expectation figures are adjusted as specified in the model with local income and capital gains tax rates, so that the predicted coefficient is -1. Specifically, these are the combined federal and state income and capital gains tax rates for high earners from the NBER TAXSIM model.\(^8\) Columns (1) and (2) perform this regression separately for 1990 and 2000, while also controlling for the area median property tax rate. Because the mortgage rate is national it cannot be included in these cross-sectional regressions. The estimated coefficient is -.44 in 1990 and -.33 in 2000. While this is the right sign, the magnitude is significantly lower than predicted. This may indicate that expectations are not fully capitalized into prices, or do so at a lag, though measurement error in the expectations is also likely attenuating the coefficients. It cannot be rejected that the coefficient on the property tax rate is +1 as predicted. Column (3) presents the results from estimating the model using data for all years, which allows the inclusion of the mortgage rate.

\(^8\)Weighted average tax rates are used for metropolitan areas spanning multiple states.
as well. The coefficient on the expectation term falls to -.08. The coefficient on the mortgage term is +.12, which is the right sign but an order of magnitude smaller than predicted.

The mean of national prices relative to rents peak in 2007 with a rent to price ratio of 4.3%. This is a 0.8 percentage point fall from 2000. During the same period, national mean expectations fall by 2 percentage points. Without expectation measures for the late 1990s, or 2001-2004 period, it is not possible to quantify the potential role of increasing expectations on prices. The erosion of expectations during the bust period was more rapid, declining nationally by 1.9 percentage points from 2007 to 2010. The national metropolitan rent to price ratio rose by 2.3 percentage points over this period. Under full capitalization, with the measured tax rate scaling of about 1.3, the decline in expectations can fully support the fall in prices. Using the estimated capitalization rates suggests that between 7% and 36% of the fall in prices relative to rents can be supported by deteriorating expectations for future house price appreciation.

Equation (1.6) also suggests an alternative means of measuring implied house price appreciation expectations. As suggested in Capozza and Seguin (1996) and Glaeser and Gyourko (2007), application of the efficient markets hypothesis to housing markets says that total returns to housing should be equal across areas. So areas with high rent to price ratios should have lower expected future price appreciation and vice versa. In this spirit, equation (1.6) can be solved for the expectation term \( g \), as a function of observed capital costs and the rent to price ratio. Along with an assumption about the relevant tax rates for the marginal home buyer, this technique will produce an implied measure of expectations analogous to the tenure choice based procedure presented in this paper. Using the tax rates described in the capitalization exercise above, I produce such an implied expectations measure.
The national mean of this rent to price based measure is compared with the national mean of this paper’s tenure choice based expectation measure in figure 1.5. The two measures track each other to some degree with a correlation of 0.89 at the national level, though only 0.29 at the metropolitan area level. The national levels are substantially different in 1990, 2000, and 2006, but the trends are similar during the 2008 to 2010 bust period. Differences between the two measures may reflect the absence of credit access effects in the rent to price model, which are controlled for in the tenure choice procedure. Further, it is possible that the rent to price model reflects landlord/investor price appreciation expectations which may differ from the household expectations measured by the tenure choice procedure.

1.6.3 Forecast performance

If households have perfect foresight, and the implied expectation estimates are accurate measures of true expectations, then the expectations should perfectly forecast realized future house price appreciation. Even if the perfect foresight model fails, one would expect the expectations to have some forecasting power. This is akin to an exercise in the bond pricing literature where future realized interest rate changes at different horizons are regressed on the implied predicted change from earlier observed bond rates. Theory suggests that the yield spread between long and short term bonds provides a forecast of future short-term rates and so under perfect-foresight should have a coefficient of one in the regression (see Fama and Bliss (1987) and Campbell and Shiller (1991)).

Table 1.5 shows the results of such ”perfect foresight” regressions at the metropolitan area level. Realized future house price appreciation rates from the FHFA series are regressed on the implied expectations from earlier years with each coefficient
presented in the table coming from a separate regression. Each coefficient is paired with a standard error and the p-value from a test that the coefficient equals one. The estimated expectations assume a constant future rate of appreciation, so they are the same value no matter the forecast horizon tested. So moving across a row the independent variable, the expectation, is constant, while the dependent variable, the realized appreciation rate is changing. For the year 2000 expectations, the perfect foresight model over a two and three year horizon cannot be rejected, implying that on average across metropolitan areas, households were anticipating future appreciation rates over the short term. The same is true for a one year horizon and 2005 expectations.

All other combinations of horizons and expectation years do reject the perfect foresight model (except a seven year horizon against 2000 expectations, which is likely a fluke considering the failure to predict adjacent horizon lengths). In fact the expectations from 2006-2010 are generally negatively related to actual future appreciation rates. Households have tempered their expectations by 2005, but do not appear to have anticipated the price bust. The expectations estimated off of 1990 data have the right forecast sign but with a coefficient well below one. Given that many markets experienced price busts around 1990, one possibility is that households are better at predicting the boom part of the housing price cycle than they are at predicting the busts. It will be useful to revisit the accuracy of the implied forecasts from the post bust years once realized appreciation for longer horizons are available. The next section turns to investigating what factors are potentially determining people’s house price expectations.
1.6.4 Determinants of house price expectations

Whether people accurately forecast house price changes or not, it is instructive to consider what observable factors are driving the expectations. Natural candidates include fundamental housing demand drivers like income and population growth, housing supply elasticity and historical appreciation rates. As detailed below, all of these factors are sometimes related to current expectations, but in a manner that is clearly not consistent over time.

Two fundamental drivers of demand for housing units, and thus rent and price growth, are growth in local income per capita and population. Past research, like Capozza, Green, and Hendershott (1998), has experimented with assuming expectations are formed through econometric forecasts drawing on recent trends in these fundamentals. In table 1.6, the results from regressing the estimated metropolitan area expectation figures on recent income per capita and population growth are considered. Expectations in 1990 are positively related to recent income growth, but this association is absent in 2000. During the peak boom years of 2005 to 2007 the relationship is actually negative, which parallels the findings of Mian and Sufi (2009) of a negative correlation between mortgage credit expansion and local income growth during most of the peak boom years. Recent population growth is generally not significantly associated with current expectations until the peak bust years. From 2008 to 2011, recent population growth is strongly negatively associated with current expectations, which may reflect the role of over building.

As modeled in Poterba (1984), local housing supply conditions should guide expectations of the extent to which demand shocks will result in price increases or more construction. Saiz (2010) shows that inelastically supplied areas have higher house prices and have historically experienced higher rates of price appreciation. Glaeser,
Gyourko, and Saiz (2008) demonstrate how theoretically, inelastic supply can make places more susceptible to house price bubbles when people have adaptive expectations. Panel A of Table 1.7 shows the results from regressing the implied expectations on metropolitan area estimates of inverse housing supply elasticity produced by Saiz (2010), while Panel B shows the results from regressing the expectation measures on two indicators of supply constraints, the restrictiveness of local land use regulation and the geographic unavailability of developable land.

Expectations in 1990 are significantly and positively related to inverse supply elasticity and the restrictiveness of land use regulation. In terms of magnitude, a one standard deviation increase in inverse supply elasticity (+0.3) was associated with 0.2 percentage point higher expectation in 1990. Similarly, a one standard deviation increase in the regulatory index (+0.8) is associated with around a 0.6 percentage point higher expectation. During 2000, and 2005-2007, current expectations become less clearly associated with supply elasticity. During the bust period from 2008 onwards, expectations are strongly negatively related to inverse supply elasticity, and typically to the alternative measures of the ease of adding new housing as well. This is consistent with the prediction of the model in Glaeser et al. where inelastic areas have larger price bubbles and thus deeper busts.

The other factor most commonly believed to drive expectations is historical price appreciation. In fact, many studies directly assume that experienced lagged price appreciation, typically over a long historical period, is the current expectation (e.g. Sinai and Souleles (2005) and Himmelberg, Mayer, and Sinai (2005)) or that people form econometric forecasts based on lagged price appreciation (e.g. Han (2013)). Table 1.8 considers the relationship between historical price appreciation in an area and the current expectation. Panel A and B consider 10 and 20 year lagged price appreciation, respectively, as the current expectation.
For 1990, it cannot be rejected at the 5% level that the 10 year lag is the current expectation, suggesting that in a typical year the expectation assumption frequently used in the literature is sound. During the peak boom and bust years, from 2000 forward, this assumption seems less tenable. The 10 year lag is rejected in all years until 2011, and the 20 year lag in 6 of 8 years. Another possibility is a form of regressive expectations where households believe there is some long run equilibrium level of price appreciation (see Frankel and Froot (1987)). Panel C considers this with 15-year lagged appreciation up to 1995, prior to the start of the national price boom, compared against the current expectation in all future years. This model is rejected in all years.

Other behavioral models of expectation formation in the housing and finance literature consider adaptive or extrapolative expectations which take on, or are heavily influenced by, rates of price appreciation experienced most recently. For example, Case and Meyer (2009) find that short lags of price appreciation are associated with current housing price to rent ratios even after accounting for longer historical price appreciation trends. I perform a similar exercise in table 1.9 where the metropolitan area expectation measure is regressed on shorter lags of experienced price appreciation, while controlling for longer run historical price appreciation. In 2000, current expectations are more strongly positively correlated with the past five years of price appreciation than the longer term trend. This relationship does not hold from 2005 to 2009 though. The clearest pattern concerns the bust years from 2008 forward, when expectations are consistently positively associated with one year price trends. This implies that households in this volatile period are largely extrapolating the most recent experience of price decline.

In summary, historical price appreciation appears to be a reasonable proxy for current expectations when house prices are less volatile, but fails to characterize
beliefs during more volatile periods. Moreover, there is some evidence consistent with adaptive expectations, where beliefs may at least partially respond to an area's most recent experience of price appreciation. The main conclusion from the evidence on the determinants of people's future home price forecasts is that this process is not stable over time. Household expectation formation appears to draw on a changing information set, or at least weights factors differently, in different years, particularly when prices are more volatile. This means that during such periods, any method of inferring expectations that does not admit such flexibility will tend to perform poorly.

1.6.5 Comparison to survey evidence

An alternative approach to measuring expectations, and one that, like the tenure choice method of this paper, does allow for a time varying expectation forming process, is to conduct a survey directly asking people what they expect to happen in housing markets. This approach was employed during the period under study so it is natural to compare the results of this direct approach with the tenure choice implied expectations generated by my analysis. At the national level, the Michigan Survey of Consumers has long asked survey respondents their views on whether or not it is a good time to buy a house and why. Since 2007 they began directly asking respondents their forecast for prices on houses similar to theirs over the next one and five years. The results of those surveys is compared in figure 1.6 with the national mean of the tenure implied expectations.

The tenure choice estimated expectations are most similar in levels to the five year survey values, which are in turn consistently higher than the one year survey values. The trends between this paper's measure and the five year survey responses are
somewhat consistent with a correlation of 0.76, though there are only five data points on which to compute this. The fact that the tenure choice measure is much closer to the 5 year survey expectations indicates that the estimates are likely measuring household expectations over a longer horizon than just one year. Notably, the one year survey responses turn out to be consistently wrongly optimistic by a fair margin until 2011 when prices stop falling.

House price forecast surveys that consider more localized housing markets are conducted by Case, Shiller, and Thompson (2012). Their research provided early evidence that actual beliefs are both more volatile and usually more optimistic than conventional methods for inferring future house price expectations implied. Annually since 2003, they have asked respondents in four cities for their forecast of house prices over the next year and the next ten years. Figure 1.7 presents the results of these surveys alongside the implied expectations estimated in this study for the same locales. The tenure choice based expectation estimates are most similar in levels and trends to the one year survey responses, with a correlation 0.38 relative to only 0.15 with the ten year responses. The fact that the tenure choice measure is less volatile than the one year survey responses suggests that it is estimating average expectations over a horizon longer than one year. This is consistent with the comparison to the national survey evidence above, where estimated expectations are more closely aligned with forecasts for five years ahead.

One issue in comparability, to the extent there is heterogeneity in beliefs, is that the authors only survey recent homebuyers who may be more optimistic. Interestingly, similarly to the national survey evidence, individual city survey responses consistently show longer run expectations exceeding short run ones, as well as 1 year expectations that are consistently higher than realized appreciation rates during the bust period. Both the city level and national survey evidence show that
people’s house price forecasts are not constant each year in the future, though it is not possible to tell whether or not for all horizons beyond one year, expectations are constant.

While survey evidence provides a useful benchmark for the tenure choice based expectations, there is no guarantee that stated beliefs will match measures inferred from economically consequential observed choices like housing decisions. On the other hand, unlike the tenure choice based expectation measure, the survey measures give forecasts independently from risk considerations. Therefore, local survey evidence on expectations, particularly if expanded to more metropolitan areas, would be a useful complement to this paper’s proposed measure.

1.6.6 Robustness

This study assumes in general that expectations are homogeneous across households within the same metropolitan area or division. Theoretical studies have posited heterogeneous beliefs, and in particular the presence of particularly optimistic individuals as plausibly capable of driving housing boom and bust cycles (e.g. Burnside, Eichenbaum, and Rebelo (2011)). Piazzesi and Schneider (2009) use the Michigan Survey data to investigate this possibility. They do find evidence of heterogeneity of beliefs in that there are clusters of pessimistic and optimistic households whose relative size changes over time. The variation in beliefs can not be explained by household demographics though. Further, it is not clear to what extent these clusters of household types may be geographic, as the survey data has little spatial disaggregation. From a national perspective, my analysis allows for a great deal of geographic heterogeneity in the expectations held by households within the same year.
Manski (2004) recommends using self-reports of expectations to validate assumptions about the expectation forming process when inferring expectations from observed choice data in a revealed preference type analysis like this study. One important assumption made in the estimation of the implied expectations was that high income households have the same expectation as low income households living in the same area. The Michigan Survey responses provide some means of assessing the validity of this assumption as they report forecasts separately by respondent income. For the 5 year forecast, the expectations reported by high income respondents, households in the top quintile of the income distribution, are consistently higher than the aggregate reported expectations, though never by more than 0.6%.

Figure 1.8 provides some evidence from the data on the issues of heterogeneity of expectations and credit access in the sample. The solid line plots the national mean of estimated expectations with the sample of households who are above the 60th percentile of their metropolitan area income distribution. This is the sample used in all the analysis above. Expectation estimates produced using alternative income cutoff criteria are then compared. The cutoffs shown are for the 50th and 70th percentiles of metropolitan income distributions. Similarly to the survey data reported above, there is some evidence of expectations tending to be increasing in household income, though the differences are small. The path of expectations between the baseline 60th percentile cutoff sample and the higher income 70th percentile cutoff sample are consistent though. The substantial drop in measured expectations when lower income households are included in the sample, as with the 50th percentile cutoff is likely attributable to credit constraints. As formalized in equation (1.13), if a household’s probability of securing a mortgage is less than one, this will manifest as a lower implied expectation of price appreciation. This is particularly apparent in 2009 and 2010 when mortgage credit was substantially tightened as portrayed in figure 1.2.
The consistency of the estimates using the 60th and 70th percentile income cutoffs is encouraging that the current sample size is being maximized while still excluding credit constrained households. While it is well documented that the stringency of credit constraints was changing over the course of the boom and bust, the expectation estimates will be unaffected as long as they are computed from households who are credit unconstrained in all periods.

Another assumption underpinning the estimates is that households are moving for exogenous reasons. The restriction of the sample to movers was undertaken to avoid attributing an expectation shift to a household who had not yet updated their previous tenure decision in the face of changes in the fundamentals of their local housing market. In reality, one reason households move is to change their tenure status and this may be induced by changes in the fundamentals characterizing a household’s current housing market. This could result in wider differences in the average characteristics of the various pools of households being compared across metropolitan areas. Even with the inclusion of demographic characteristics of a household, there may be few similar households in markets where fundamentals have been more stable leading comparisons to be largely out of sample. Interstate moves should be more exogenous to the tenure choice decision as they tend to be driven by employment changes. If the sample is further restricted to just these interstate movers, the number of observations in the ACS years from 2005 onwards is too small for meaningful estimates. In 1990 and 2000 expectation estimates can be obtained. In 1990 the national mean is 6.9% and in 2000 it is 5.3%. The corresponding estimates from the sample of all movers were a slightly lower 6.7% in 1990 and slightly higher 5.6% in 2000. This suggests that results for other year would be fairly robust to further restricting the sample to only interstate movers.
1.7 Conclusion

In this paper I proposed a novel approach to estimating future house price expectations using observed tenure choice decisions. This technique complements existing survey approaches by providing a measure of expectations for a full set of metropolitan areas. By using quantities of owner occupancy demanded it relies on household tenure choice decisions which are arguably better understood than are the dynamics of price to rent ratios. It improves on conventional methods for inferring expectations by imposing no structure on the expectation forming process and allowing that process to evolve over time. This allows for testing of both the perfect foresight assumption and the determinants of household forecasts of future price appreciation.

I cannot reject that households in 2000 and 2005 accurately anticipate appreciation over the short term, but fail to anticipate the bust. I find that the common practice of assuming long lags of historical local price appreciation are the current expectation is reasonable for typical years, but fails during periods with more volatile prices. I also find some evidence that expectations are influenced by the most recently experienced house price behavior. Further, expectations are related to fundamental demand drivers and measures of supply elasticity, though estimates show that the nature of household’s forecast forming process is not stable over time. Expectations are found to be capitalized into current house rent to price ratios, though at a rate less than one for one.

Future research can employ this new measure of expectations to better understand housing price to rent dynamics. It can also support ongoing research into potentially important interaction and amplification effects between expectations of future price appreciation and credit supply during housing boom and bust cycles.
1.8 Tables and Figures
Table 1.1: Summary statistics

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Owner occupier</td>
<td>0.57</td>
<td>0.63</td>
<td>0.72</td>
<td>0.71</td>
<td>0.69</td>
<td>0.65</td>
<td>0.60</td>
<td>0.55</td>
<td>0.52</td>
</tr>
<tr>
<td>Income ($000s)</td>
<td>76.5</td>
<td>90.3</td>
<td>87.2</td>
<td>88.4</td>
<td>90.7</td>
<td>90.0</td>
<td>88.4</td>
<td>83.9</td>
<td>83.1</td>
</tr>
<tr>
<td>House value ($000s)</td>
<td>145</td>
<td>143</td>
<td>215</td>
<td>233</td>
<td>225</td>
<td>199</td>
<td>185</td>
<td>182</td>
<td>173</td>
</tr>
<tr>
<td>Annual rent ($000s)</td>
<td>6.4</td>
<td>6.5</td>
<td>7.0</td>
<td>7.0</td>
<td>7.1</td>
<td>7.1</td>
<td>7.4</td>
<td>7.4</td>
<td>7.3</td>
</tr>
<tr>
<td>Rent to price ratio</td>
<td>0.039</td>
<td>0.051</td>
<td>0.045</td>
<td>0.045</td>
<td>0.043</td>
<td>0.058</td>
<td>0.063</td>
<td>0.066</td>
<td>0.067</td>
</tr>
<tr>
<td>Owner tax subsidy rate ($000s)</td>
<td>0.16</td>
<td>0.17</td>
<td>0.15</td>
<td>0.16</td>
<td>0.16</td>
<td>0.15</td>
<td>0.14</td>
<td>0.13</td>
<td>0.12</td>
</tr>
<tr>
<td>Mortgage rate</td>
<td>0.101</td>
<td>0.081</td>
<td>0.059</td>
<td>0.064</td>
<td>0.063</td>
<td>0.060</td>
<td>0.050</td>
<td>0.047</td>
<td>0.045</td>
</tr>
<tr>
<td>Property tax rate</td>
<td>0.010</td>
<td>0.012</td>
<td>0.010</td>
<td>0.010</td>
<td>0.010</td>
<td>0.010</td>
<td>0.010</td>
<td>0.011</td>
<td>0.012</td>
</tr>
<tr>
<td>Relative owner cost excl. capital gains ($000s)</td>
<td>6.08</td>
<td>4.67</td>
<td>4.01</td>
<td>4.48</td>
<td>4.85</td>
<td>2.65</td>
<td>1.69</td>
<td>1.34</td>
<td>1.19</td>
</tr>
<tr>
<td>Married</td>
<td>0.78</td>
<td>0.74</td>
<td>0.73</td>
<td>0.73</td>
<td>0.73</td>
<td>0.72</td>
<td>0.70</td>
<td>0.68</td>
<td>0.67</td>
</tr>
<tr>
<td>Children (1/0)</td>
<td>0.50</td>
<td>0.47</td>
<td>0.45</td>
<td>0.45</td>
<td>0.45</td>
<td>0.45</td>
<td>0.44</td>
<td>0.43</td>
<td>0.43</td>
</tr>
<tr>
<td>Age</td>
<td>38.2</td>
<td>40.4</td>
<td>41.7</td>
<td>41.9</td>
<td>42.0</td>
<td>41.9</td>
<td>41.5</td>
<td>41.4</td>
<td>41.7</td>
</tr>
<tr>
<td>Nonwhite</td>
<td>0.11</td>
<td>0.16</td>
<td>0.16</td>
<td>0.16</td>
<td>0.17</td>
<td>0.16</td>
<td>0.17</td>
<td>0.18</td>
<td>0.18</td>
</tr>
<tr>
<td>Households</td>
<td>249,216</td>
<td>266,831</td>
<td>80,003</td>
<td>76,281</td>
<td>72,065</td>
<td>67,823</td>
<td>64,085</td>
<td>60,620</td>
<td>56,009</td>
</tr>
</tbody>
</table>

Note: The sample is drawn from the Census and American Community Survey public use microdata. It is restricted to households who are above the 60th percentile of their metropolitan area’s income distribution and who moved in the last two years. Figures are means with standard deviations in parentheses. Dollar values are in 1999 dollars.
Table 1.2: Tenure choice regressions

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Relative Owner Cost</td>
<td>-0.074***</td>
<td>-0.065***</td>
<td>-0.059***</td>
<td>-0.046***</td>
<td>-0.053***</td>
<td>-0.050***</td>
<td>-0.035***</td>
<td>-0.044***</td>
<td>-0.040***</td>
</tr>
<tr>
<td>($000s)</td>
<td>(0.0081)</td>
<td>(0.0067)</td>
<td>(0.0077)</td>
<td>(0.011)</td>
<td>(0.0079)</td>
<td>(0.0075)</td>
<td>(0.0058)</td>
<td>(0.0073)</td>
<td>(0.0080)</td>
</tr>
<tr>
<td>Married</td>
<td>0.22***</td>
<td>0.25***</td>
<td>0.21***</td>
<td>0.20***</td>
<td>0.22***</td>
<td>0.20***</td>
<td>0.19***</td>
<td>0.18***</td>
<td>0.18***</td>
</tr>
<tr>
<td></td>
<td>(0.0090)</td>
<td>(0.0088)</td>
<td>(0.0089)</td>
<td>(0.010)</td>
<td>(0.012)</td>
<td>(0.0090)</td>
<td>(0.0095)</td>
<td>(0.010)</td>
<td>(0.0095)</td>
</tr>
<tr>
<td>Children (1/0)</td>
<td>0.025***</td>
<td>0.030***</td>
<td>0.0071</td>
<td>0.00999</td>
<td>0.011</td>
<td>0.013*</td>
<td>-0.0053</td>
<td>-0.034***</td>
<td>-0.0058</td>
</tr>
<tr>
<td></td>
<td>(0.0036)</td>
<td>(0.0029)</td>
<td>(0.0073)</td>
<td>(0.0075)</td>
<td>(0.0075)</td>
<td>(0.0073)</td>
<td>(0.0080)</td>
<td>(0.0077)</td>
<td>(0.0077)</td>
</tr>
<tr>
<td>Age</td>
<td>0.014***</td>
<td>0.016***</td>
<td>0.015***</td>
<td>0.014***</td>
<td>0.013***</td>
<td>0.010***</td>
<td>0.0096***</td>
<td>0.0080***</td>
<td>0.0055***</td>
</tr>
<tr>
<td></td>
<td>(0.00084)</td>
<td>(0.00050)</td>
<td>(0.00083)</td>
<td>(0.00086)</td>
<td>(0.00079)</td>
<td>(0.00077)</td>
<td>(0.00082)</td>
<td>(0.00096)</td>
<td>(0.00093)</td>
</tr>
<tr>
<td>AgeSq</td>
<td>-0.000097***</td>
<td>-0.00011***</td>
<td>-0.00012***</td>
<td>-0.00011***</td>
<td>-0.000097***</td>
<td>-0.000064***</td>
<td>-0.000059***</td>
<td>-0.000050***</td>
<td>-0.000015</td>
</tr>
<tr>
<td></td>
<td>(0.000010)</td>
<td>(6.0e-06)</td>
<td>(0.000010)</td>
<td>(0.000010)</td>
<td>(9.1e-06)</td>
<td>(8.9e-06)</td>
<td>(9.7e-06)</td>
<td>(0.000012)</td>
<td>(0.000011)</td>
</tr>
<tr>
<td>Nonwhite</td>
<td>-0.080***</td>
<td>-0.13***</td>
<td>-0.093***</td>
<td>-0.10***</td>
<td>-0.093***</td>
<td>-0.12***</td>
<td>-0.13***</td>
<td>-0.12***</td>
<td>-0.099***</td>
</tr>
<tr>
<td></td>
<td>(0.011)</td>
<td>(0.0067)</td>
<td>(0.0098)</td>
<td>(0.0093)</td>
<td>(0.011)</td>
<td>(0.0093)</td>
<td>(0.0092)</td>
<td>(0.0095)</td>
<td>(0.011)</td>
</tr>
<tr>
<td>After-tax Income</td>
<td>0.0016***</td>
<td>0.00051***</td>
<td>0.00095***</td>
<td>0.00098***</td>
<td>0.00093***</td>
<td>0.0011***</td>
<td>0.0014***</td>
<td>0.0014***</td>
<td>0.0016***</td>
</tr>
<tr>
<td>($000s)</td>
<td>(0.000073)</td>
<td>(0.000065)</td>
<td>(0.000080)</td>
<td>(0.000083)</td>
<td>(0.000090)</td>
<td>(0.000069)</td>
<td>(0.000094)</td>
<td>(0.000094)</td>
<td>(0.000095)</td>
</tr>
<tr>
<td>Credit Access Controls</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Expected Stay Controls</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Area Fixed Effects</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>X House price</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Observations</td>
<td>249,196</td>
<td>266,829</td>
<td>80,003</td>
<td>76,281</td>
<td>72,065</td>
<td>67,823</td>
<td>64,085</td>
<td>60,620</td>
<td>56,009</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.605</td>
<td>0.674</td>
<td>0.713</td>
<td>0.704</td>
<td>0.690</td>
<td>0.656</td>
<td>0.609</td>
<td>0.574</td>
<td>0.546</td>
</tr>
</tbody>
</table>

Note: Each specification includes a full set of metropolitan and non-metropolitan Area fixed effects interacted with PUMA level median house price. There are 424 areas in 1990 and 429 areas from 2000 onwards. Robust standard errors clustered at the metropolitan area level in parentheses. *** p<0.01, ** p<0.05, * p<0.1.
Table 1.3: Summary of implied house price appreciation expectations

<table>
<thead>
<tr>
<th>Year</th>
<th>Areas</th>
<th>Mean</th>
<th>SD</th>
<th>P10</th>
<th>P25</th>
<th>P50</th>
<th>P75</th>
<th>P90</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>424</td>
<td>0.067</td>
<td>0.017</td>
<td>0.045</td>
<td>0.057</td>
<td>0.068</td>
<td>0.077</td>
<td>0.088</td>
</tr>
<tr>
<td>2000</td>
<td>429</td>
<td>0.056</td>
<td>0.014</td>
<td>0.038</td>
<td>0.046</td>
<td>0.055</td>
<td>0.064</td>
<td>0.075</td>
</tr>
<tr>
<td>2005</td>
<td>429</td>
<td>0.035</td>
<td>0.020</td>
<td>0.012</td>
<td>0.028</td>
<td>0.036</td>
<td>0.047</td>
<td>0.056</td>
</tr>
<tr>
<td>2006</td>
<td>429</td>
<td>0.030</td>
<td>0.027</td>
<td>0.000</td>
<td>0.022</td>
<td>0.031</td>
<td>0.043</td>
<td>0.058</td>
</tr>
<tr>
<td>2007</td>
<td>429</td>
<td>0.036</td>
<td>0.019</td>
<td>0.017</td>
<td>0.027</td>
<td>0.035</td>
<td>0.045</td>
<td>0.056</td>
</tr>
<tr>
<td>2008</td>
<td>429</td>
<td>0.039</td>
<td>0.031</td>
<td>0.007</td>
<td>0.022</td>
<td>0.034</td>
<td>0.052</td>
<td>0.082</td>
</tr>
<tr>
<td>2009</td>
<td>429</td>
<td>0.027</td>
<td>0.048</td>
<td>-0.020</td>
<td>-0.001</td>
<td>0.017</td>
<td>0.048</td>
<td>0.091</td>
</tr>
<tr>
<td>2010</td>
<td>429</td>
<td>0.017</td>
<td>0.043</td>
<td>-0.030</td>
<td>-0.008</td>
<td>0.012</td>
<td>0.036</td>
<td>0.072</td>
</tr>
<tr>
<td>2011</td>
<td>429</td>
<td>0.024</td>
<td>0.054</td>
<td>-0.028</td>
<td>-0.008</td>
<td>0.016</td>
<td>0.047</td>
<td>0.089</td>
</tr>
</tbody>
</table>

Panel B: Changes

<table>
<thead>
<tr>
<th>Year</th>
<th>Areas</th>
<th>Mean</th>
<th>SD</th>
<th>P10</th>
<th>P25</th>
<th>P50</th>
<th>P75</th>
<th>P90</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>423</td>
<td>-0.011</td>
<td>0.014</td>
<td>-0.025</td>
<td>-0.020</td>
<td>-0.012</td>
<td>-0.002</td>
<td>0.004</td>
</tr>
<tr>
<td>2005</td>
<td>429</td>
<td>-0.020</td>
<td>0.018</td>
<td>-0.041</td>
<td>-0.028</td>
<td>-0.018</td>
<td>-0.010</td>
<td>-0.005</td>
</tr>
<tr>
<td>2006</td>
<td>429</td>
<td>-0.005</td>
<td>0.023</td>
<td>-0.024</td>
<td>-0.011</td>
<td>-0.004</td>
<td>0.002</td>
<td>0.016</td>
</tr>
<tr>
<td>2007</td>
<td>429</td>
<td>0.006</td>
<td>0.024</td>
<td>-0.011</td>
<td>-0.003</td>
<td>0.003</td>
<td>0.012</td>
<td>0.030</td>
</tr>
<tr>
<td>2008</td>
<td>429</td>
<td>0.003</td>
<td>0.029</td>
<td>-0.022</td>
<td>-0.011</td>
<td>-0.002</td>
<td>0.013</td>
<td>0.036</td>
</tr>
<tr>
<td>2009</td>
<td>429</td>
<td>-0.012</td>
<td>0.038</td>
<td>-0.046</td>
<td>-0.027</td>
<td>-0.016</td>
<td>-0.002</td>
<td>0.029</td>
</tr>
<tr>
<td>2010</td>
<td>429</td>
<td>-0.009</td>
<td>0.040</td>
<td>-0.047</td>
<td>-0.022</td>
<td>-0.008</td>
<td>0.005</td>
<td>0.024</td>
</tr>
<tr>
<td>2011</td>
<td>429</td>
<td>0.007</td>
<td>0.044</td>
<td>-0.030</td>
<td>-0.008</td>
<td>0.003</td>
<td>0.022</td>
<td>0.053</td>
</tr>
</tbody>
</table>

Note: Each year’s distribution of expectations is across metropolitan areas and is weighted by the number of housing units in each area. In Panel B, the changes in expectations are computed for each metropolitan area between the listed Census/ACS year and the previous Census/ACS year.
<table>
<thead>
<tr>
<th>Dependent variable: Rent to price ratio</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1990</td>
<td>2000</td>
<td>Pooled</td>
</tr>
<tr>
<td>Expected price appreciation</td>
<td>-0.44***</td>
<td>-0.33***</td>
<td>-0.081***</td>
</tr>
<tr>
<td></td>
<td>(0.043)</td>
<td>(0.044)</td>
<td>(0.0068)</td>
</tr>
<tr>
<td>Property tax rate</td>
<td>1.13***</td>
<td>0.86***</td>
<td>1.25***</td>
</tr>
<tr>
<td></td>
<td>(0.15)</td>
<td>(0.18)</td>
<td>(0.073)</td>
</tr>
<tr>
<td>Mortgage interest rate</td>
<td></td>
<td></td>
<td>0.12***</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.026)</td>
</tr>
<tr>
<td>Constant</td>
<td>0.071***</td>
<td>0.074***</td>
<td>0.034***</td>
</tr>
<tr>
<td></td>
<td>(0.0027)</td>
<td>(0.0036)</td>
<td>(0.0020)</td>
</tr>
<tr>
<td>Observations</td>
<td>371</td>
<td>376</td>
<td>3,374</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.402</td>
<td>0.380</td>
<td>0.297</td>
</tr>
</tbody>
</table>

Note: The expected price appreciation variable is adjusted using a metropolitan area’s high earner regular income and capital gains tax rates as specified in equation (1.6) in the text. Robust standard errors in parentheses. Pooled regressions cluster standard errors at the metropolitan area level. *** p<0.01, ** p<0.05, * p<0.1.
Table 1.5: Perfect foresight regressions

<table>
<thead>
<tr>
<th>Forecast year</th>
<th>Future appreciation years</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td></td>
<td>0.41</td>
<td>0.44</td>
<td>0.44</td>
<td>0.45</td>
<td>0.46</td>
<td>0.47</td>
<td>0.46</td>
<td>0.49</td>
<td>0.50</td>
<td>0.52</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.029)</td>
<td>(0.025)</td>
<td>(0.024)</td>
<td>(0.026)</td>
<td>(0.025)</td>
<td>(0.023)</td>
<td>(0.021)</td>
<td>(0.019)</td>
<td>(0.017)</td>
<td>(0.016)</td>
</tr>
<tr>
<td>2000</td>
<td>1.09</td>
<td>0.99</td>
<td>0.96</td>
<td>1.06</td>
<td>1.19</td>
<td>1.17</td>
<td>1.04</td>
<td>0.82</td>
<td>0.64</td>
<td>0.51</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.030)</td>
<td>(0.029)</td>
<td>(0.030)</td>
<td>(0.036)</td>
<td>(0.042)</td>
<td>(0.041)</td>
<td>(0.033)</td>
<td>(0.025)</td>
<td>(0.019)</td>
<td>(0.017)</td>
</tr>
<tr>
<td>2005</td>
<td>1.11</td>
<td>0.63</td>
<td>0.15</td>
<td>-0.10</td>
<td>-0.22</td>
<td>-0.29</td>
<td>-0.26</td>
<td>-0.00</td>
<td>0.66</td>
<td>0.24</td>
<td>0.08</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.082)</td>
<td>(0.051)</td>
<td>(0.045)</td>
<td>(0.045)</td>
<td>(0.041)</td>
<td>(0.039)</td>
<td>(0.034)</td>
<td>-0.00</td>
<td>0.28</td>
<td>0.00</td>
</tr>
<tr>
<td>2006</td>
<td>0.012</td>
<td>-0.28</td>
<td>-0.39</td>
<td>-0.42</td>
<td>-0.42</td>
<td>-0.37</td>
<td>-0.69</td>
<td>-0.08</td>
<td>0.00</td>
<td>0.28</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.063)</td>
<td>(0.053)</td>
<td>(0.052)</td>
<td>(0.048)</td>
<td>(0.046)</td>
<td>(0.039)</td>
<td>(0.034)</td>
<td>-0.00</td>
<td>0.28</td>
<td>0.00</td>
</tr>
<tr>
<td>2007</td>
<td>-0.59</td>
<td>-0.68</td>
<td>-0.67</td>
<td>-0.66</td>
<td>-0.55</td>
<td>-0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.077)</td>
<td>(0.070)</td>
<td>(0.059)</td>
<td>(0.053)</td>
<td>(0.045)</td>
<td>-0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>2008</td>
<td>-0.30</td>
<td>-0.31</td>
<td>-0.31</td>
<td>-0.24</td>
<td>-0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.036)</td>
<td>(0.031)</td>
<td>(0.029)</td>
<td>(0.024)</td>
<td>-0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>2009</td>
<td>-0.12</td>
<td>-0.12</td>
<td>-0.080</td>
<td>-0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.023)</td>
<td>(0.022)</td>
<td>(0.017)</td>
<td>-0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>2010</td>
<td>-0.058</td>
<td>-0.019</td>
<td>-0.019</td>
<td>-0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.030)</td>
<td>(0.021)</td>
<td>-0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>2011</td>
<td>0.021</td>
<td>-0.019</td>
<td>-0.019</td>
<td>-0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.014)</td>
<td>-0.014</td>
<td>-0.014</td>
<td>-0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Note: This table reports the coefficients from a regression of realized appreciation rates on expected rates for each combination of expectation years and possible horizons of future appreciation available in the data. Realized appreciation rates are computed from the FHFA house price index for each metropolitan area or division in the sample. Each coefficient is paired with a robust standard error in parentheses and the p-value from a test that the coefficient equals 1.
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>5-year change in log population</td>
<td>0.0018</td>
<td>-0.029*</td>
<td>-0.030</td>
<td>-0.018</td>
<td>-0.035</td>
<td>-0.14***</td>
<td>-0.27***</td>
<td>-0.15**</td>
<td>-0.36***</td>
<td>-0.095***</td>
</tr>
<tr>
<td>Constant</td>
<td>0.056***</td>
<td>0.057***</td>
<td>0.042***</td>
<td>0.045***</td>
<td>0.047***</td>
<td>0.055***</td>
<td>0.051***</td>
<td>0.028***</td>
<td>0.049***</td>
<td>0.070***</td>
</tr>
</tbody>
</table>

Note: Robust standard errors in parentheses. Pooled regressions include year fixed effects and clustering of standard errors at the metropolitan area level. *** p<0.01, ** p<0.05, * p<0.1.
Table 1.7: Supply elasticity

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Panel A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inverse Supply Elasticity</td>
<td>0.0078***</td>
<td>-0.0018</td>
<td>0.0066</td>
<td>0.0082</td>
<td>0.0018</td>
<td>-0.034***</td>
<td>-0.057***</td>
<td>-0.049***</td>
<td>-0.058***</td>
<td>-0.019***</td>
</tr>
<tr>
<td>(0.0033)</td>
<td>(0.0027)</td>
<td>(0.0042)</td>
<td>(0.0060)</td>
<td>(0.0045)</td>
<td>(0.0067)</td>
<td>(0.010)</td>
<td>(0.0083)</td>
<td>(0.011)</td>
<td>(0.0035)</td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>0.060***</td>
<td>0.057***</td>
<td>0.031***</td>
<td>0.026***</td>
<td>0.035***</td>
<td>0.063***</td>
<td>0.065***</td>
<td>0.049***</td>
<td>0.063***</td>
<td>0.075***</td>
</tr>
<tr>
<td>(0.0025)</td>
<td>(0.0021)</td>
<td>(0.0036)</td>
<td>(0.0051)</td>
<td>(0.0037)</td>
<td>(0.0054)</td>
<td>(0.0084)</td>
<td>(0.0067)</td>
<td>(0.0092)</td>
<td>(0.0025)</td>
<td></td>
</tr>
<tr>
<td>R-squared</td>
<td>0.014</td>
<td>0.001</td>
<td>0.005</td>
<td>0.004</td>
<td>0.000</td>
<td>0.061</td>
<td>0.070</td>
<td>0.075</td>
<td>0.061</td>
<td>0.091</td>
</tr>
<tr>
<td>Panel B</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land Use Regulation Index</td>
<td>0.0041***</td>
<td>0.00069</td>
<td>0.0033</td>
<td>0.0047*</td>
<td>0.0018</td>
<td>-0.0032</td>
<td>-0.013**</td>
<td>-0.0099**</td>
<td>-0.0053</td>
<td>-0.0018</td>
</tr>
<tr>
<td>(0.0016)</td>
<td>(0.0012)</td>
<td>(0.0020)</td>
<td>(0.0026)</td>
<td>(0.0019)</td>
<td>(0.0034)</td>
<td>(0.0052)</td>
<td>(0.0039)</td>
<td>(0.0058)</td>
<td>(0.0019)</td>
<td></td>
</tr>
<tr>
<td>Share Land Unav. for Dev.</td>
<td>0.0092</td>
<td>0.00073</td>
<td>0.0061</td>
<td>0.0048</td>
<td>0.0044</td>
<td>-0.032***</td>
<td>-0.027</td>
<td>-0.031**</td>
<td>-0.048***</td>
<td>-0.012*</td>
</tr>
<tr>
<td>(0.0056)</td>
<td>(0.0044)</td>
<td>(0.0071)</td>
<td>(0.0089)</td>
<td>(0.0070)</td>
<td>(0.011)</td>
<td>(0.017)</td>
<td>(0.013)</td>
<td>(0.018)</td>
<td>(0.0066)</td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>0.063***</td>
<td>0.056***</td>
<td>0.033***</td>
<td>0.029***</td>
<td>0.035***</td>
<td>0.053***</td>
<td>0.041***</td>
<td>0.030***</td>
<td>0.044***</td>
<td>0.068***</td>
</tr>
<tr>
<td>(0.0020)</td>
<td>(0.0017)</td>
<td>(0.0030)</td>
<td>(0.0039)</td>
<td>(0.0029)</td>
<td>(0.0042)</td>
<td>(0.0061)</td>
<td>(0.0052)</td>
<td>(0.0070)</td>
<td>(0.0023)</td>
<td></td>
</tr>
<tr>
<td>R-squared</td>
<td>0.048</td>
<td>0.002</td>
<td>0.015</td>
<td>0.013</td>
<td>0.005</td>
<td>0.037</td>
<td>0.042</td>
<td>0.049</td>
<td>0.030</td>
<td>0.080</td>
</tr>
<tr>
<td>Year FE s</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>Observations</td>
<td>263</td>
<td>263</td>
<td>263</td>
<td>263</td>
<td>263</td>
<td>263</td>
<td>263</td>
<td>263</td>
<td>263</td>
<td>2,367</td>
</tr>
</tbody>
</table>

Note: Robust standard errors in parentheses. Pooled regressions include year fixed effects and clustering of standard errors at the metropolitan area level. *** p<0.01, ** p<0.05, * p<0.1.
Table 1.8: Historical price appreciation

Dependent variable: Expected house price appreciation

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Panel A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lagged 10-year appreciation</td>
<td>1.07 (0.040)</td>
<td>1.29 (0.031)</td>
<td>0.54 (0.021)</td>
<td>0.42 (0.026)</td>
<td>0.53 (0.022)</td>
<td>0.72 (0.042)</td>
<td>0.71 (0.071)</td>
<td>0.53 (0.074)</td>
<td>1.05 (0.14)</td>
<td>0.65 (0.026)</td>
</tr>
<tr>
<td>Observations</td>
<td>163</td>
<td>348</td>
<td>382</td>
<td>382</td>
<td>382</td>
<td>382</td>
<td>383</td>
<td>383</td>
<td>383</td>
<td>3,187</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.795</td>
<td>0.806</td>
<td>0.541</td>
<td>0.285</td>
<td>0.526</td>
<td>0.373</td>
<td>0.170</td>
<td>0.100</td>
<td>0.133</td>
<td>0.297</td>
</tr>
<tr>
<td>Panel B</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lagged 20-year appreciation</td>
<td>1.23 (0.036)</td>
<td>0.67 (0.024)</td>
<td>0.61 (0.032)</td>
<td>0.73 (0.027)</td>
<td>0.92 (0.051)</td>
<td>0.80 (0.082)</td>
<td>0.54 (0.075)</td>
<td>0.93 (0.11)</td>
<td>0.77 (0.032)</td>
<td></td>
</tr>
<tr>
<td>Observations</td>
<td>163</td>
<td>238</td>
<td>294</td>
<td>325</td>
<td>334</td>
<td>343</td>
<td>348</td>
<td>357</td>
<td>2,402</td>
<td></td>
</tr>
<tr>
<td>R-squared</td>
<td>0.883</td>
<td>0.714</td>
<td>0.460</td>
<td>0.656</td>
<td>0.485</td>
<td>0.217</td>
<td>0.121</td>
<td>0.158</td>
<td>0.334</td>
<td></td>
</tr>
<tr>
<td>Panel C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant 15-year appreciation to 1995</td>
<td>1.23 (0.036)</td>
<td>0.83 (0.031)</td>
<td>0.75 (0.032)</td>
<td>0.88 (0.034)</td>
<td>0.79 (0.052)</td>
<td>0.44 (0.059)</td>
<td>0.30 (0.073)</td>
<td>0.42 (0.033)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observations</td>
<td>163</td>
<td>163</td>
<td>163</td>
<td>163</td>
<td>163</td>
<td>163</td>
<td>163</td>
<td>163</td>
<td>1,304</td>
<td></td>
</tr>
<tr>
<td>R-squared</td>
<td>0.866</td>
<td>0.786</td>
<td>0.743</td>
<td>0.774</td>
<td>0.509</td>
<td>0.202</td>
<td>0.102</td>
<td>0.126</td>
<td>0.494</td>
<td></td>
</tr>
</tbody>
</table>

Note: Uses lagged price appreciation from the FHFA house price indices. Each coefficient is paired with a robust standard error in parentheses and the p-value from a test that the coefficient equals 1. Pooled regressions cluster standard errors at the metropolitan area level.

Table 1.9: Recent price appreciation

Dependent variable: Expected house price appreciation

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant 15-year appreciation to 1995</td>
<td>0.18*** (0.090)</td>
<td>0.33*** (0.12)</td>
<td>0.26** (0.11)</td>
<td>0.15* (0.10)</td>
<td>0.10 (0.16)</td>
<td>0.25 (0.19)</td>
<td>0.074 (0.21)</td>
<td>0.043 (0.25)</td>
<td>0.10 (0.12)</td>
</tr>
<tr>
<td>Lagged 5-year appreciation</td>
<td>0.31*** (0.082)</td>
<td>0.085 (0.057)</td>
<td>0.046 (0.032)</td>
<td>-0.078*** (0.033)</td>
<td>-0.18** (0.088)</td>
<td>-0.035 (0.092)</td>
<td>0.29*** (0.096)</td>
<td>0.31*** (0.10)</td>
<td>0.066*** (0.026)</td>
</tr>
<tr>
<td>Lagged 1-year appreciation</td>
<td>-0.14*** (0.035)</td>
<td>-0.032 (0.031)</td>
<td>-0.054* (0.028)</td>
<td>0.023 (0.025)</td>
<td>0.16*** (0.019)</td>
<td>0.30*** (0.049)</td>
<td>0.26*** (0.049)</td>
<td>0.16 (0.09)</td>
<td>0.087*** (0.014)</td>
</tr>
<tr>
<td>Constant</td>
<td>0.043*** (0.0042)</td>
<td>0.019*** (0.0060)</td>
<td>0.022*** (0.0056)</td>
<td>0.037*** (0.0057)</td>
<td>0.049*** (0.0095)</td>
<td>0.026*** (0.010)</td>
<td>0.023* (0.011)</td>
<td>0.042*** (0.014)</td>
<td>0.019 (0.0049)</td>
</tr>
<tr>
<td>Observations</td>
<td>163</td>
<td>163</td>
<td>163</td>
<td>163</td>
<td>163</td>
<td>163</td>
<td>163</td>
<td>163</td>
<td>1,304</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.110</td>
<td>0.089</td>
<td>0.064</td>
<td>0.048</td>
<td>0.207</td>
<td>0.237</td>
<td>0.225</td>
<td>0.152</td>
<td>0.207</td>
</tr>
</tbody>
</table>

Note: Uses lagged price appreciation from the FHFA house price indices. Robust standard errors in parentheses. Pooled regressions cluster standard errors at the metropolitan area level. *** p<0.01, ** p<0.05, * p<0.1.
Figure 1.1: Distribution of estimated house price trend breaks

Note: Breaks in price series estimated using quarterly zip code level house price indices from Zillow aggregated to the Census PUMA level.
Figure 1.2: Timing of mortgage market changes

Panel A:

Panel B:

Panel C:

Note: Credit market measures come from LPS mortgage level data. The data is aggregated from the zip code level to the Census PUMA.
Figure 1.3: Income growth staggered by price break year

Note: Geographic areas whose price breaks began in a given year are grouped together and average values for income growth in those areas over two different time horizons are provided. The circles give average income growth prior to the start of a price break, so there is a rolling window over which this is computed based on the price break year given on the x-axis. The intent is to demonstrate that variation in the timing of local income growth is consistent with the start of local house price cycles in 2000 and earlier, but not for areas whose house prices did not begin rapidly appreciating until 2001 or later. The x marks measure average income growth over a fixed window, corresponding to 1991 to 1998. The intent is to show that areas whose price booms began in 2000 or earlier were not atypical in their rate of income growth during the 1990s. Income growth is computed off of annual per capita income from IRS statistics of income data. The data is aggregated from the zip code level to the Census PUMA. Since data is only available in certain years, the closest match is used for income leading into the price break year: 1991 to 1998 growth for 1998-2000 breaks, 1998-2002 growth for 2001 and 2002 breaks, and growth since 2002 for 2003-2006 breaks.
Figure 1.4: Future house price appreciation
National distribution

Note: Each year’s distribution of expectations is across all metropolitan and state non-metropolitan areas and is weighted by the number of housing units in each area. The actual annual appreciation rate is the mean change across metropolitan areas in house prices from year t-1 to year t from the FHFA index, weighted by the number of housing units in each area.
Figure 1.5: Comparison to rent to price ratio implied expectations

Note: The rent to price ratio implied expectations are computed by solving equation (1.6) for the expected price appreciation term and using observed values for the other variables in the equation.
Figure 1.6: Comparison to survey expectations: National level

Note: The tenure choice expectation is computed from the tenure model estimates as the national mean weighted by the number of housing units in each area. The actual annual appreciation rate is the mean change across metropolitan areas in house prices from year t-1 to year t from the FHFA index, weighted by the number of housing units in each area. The survey expectations are national figures reported by the Michigan Survey of Consumers which asks respondents what they expect house price appreciation to be for houses like theirs per year over the next 1 and 5 years, respectively.
Figure 1.7: Comparison to survey expectations: Individual cities

Note: The tenure choice expectation is computed from the tenure model estimates for the relevant metropolitan area. The survey expectations are reported by Case, Shiller, and Thompson (2012). They ask recent home buyers in a given city or county what they expect home price appreciation to be per year over the next 1 and 10 years. Oakland survey responses are from Alameda County which is only a portion of the Oakland metropolitan division for which the tenure choice implied expectation is estimated.
Figure 1.8: Robustness to sample income cutoffs

Note: The national mean of expectations each year is weighted by the number of housing units in each area. Expectations are computed off of the tenure choice decisions of only those households whose income exceeds the given percentile of income in their metropolitan or non-metropolitan area.
House prices and expected capital gains: Evidence from the Massachusetts Anti-Snob Zoning Law
2.1 Introduction

Three years ago, households witnessed the end of housing bust marked by a drop in real house prices of more than a third nationally. While prices in some markets have begun appreciating again, at the end of 2013, more than 9 million homes remain yoked to underwater mortgages. Chastened by this very recent experience, one might predict that households would be turning to stocks, bonds, or even the safety of savings accounts for their investments. That prediction would be wrong. According to Gallup polling, nearly 1 in 3 Americans currently cites real estate as the best long-term investment, comfortably beating out stocks, bonds, savings accounts and gold. If this seems to denote a lack of financial sophistication, the preference for real estate actually peaks among the highest income individuals surveyed.

Housing is a unique asset in that it provides consumption and also serves as an investment vehicle. People anticipate using capital gains on their housing to fund both retirement and bequests. Whether house hunting or considering an investment property, people are always trying to suss out which neighborhood is poised to be the next hot location, where others will lament not getting in while prices were still low. Theoretical models of house prices have anticipation of future price growth as a direct driver of demand for housing. Testing for a causal link between expected future price appreciation and current price to rent ratios requires both a measure of expectations and exogenous variation in those expectations. In this paper I employ the expectations measure developed in Suher (2013), in conjunction with a quasi-experimental setting based on a policy relaxing housing supply restrictions, to produce causal estimates of the capitalization of capital gain expectations into current house prices. The measure itself is based on reconciling differences in propensity for ownership across geographic areas through variation in expectations for capital
gains on housing. The documented first stage relationship serves as a validation of the new expectations measure in that it responds as predicted to an expectations changing event. Two stage least squares estimates indicate capital gains expectations are capitalized into rent to price ratios. Further, the magnitude of capitalization is roughly one to one, consistent with a cost of capital model of house prices.

The source of exogenous variation in expectations exploited in this paper comes from a Massachusetts law which allows developers to circumvent local restrictions on construction of new housing units. The policy’s treatment is an increase in housing supply elasticity. It combines cross-sectional variation in exposure to the policy’s effects with a discrete increase in intensity of the treatment following a court ruling. Housing supply elasticity determines the extent to which future increases in demand show up as higher house prices or in greater construction of new housing units. This underpins why the policy provides a relevant instrument for cross-sectional variation in housing capital gains expectations. Further, it is plausibly exogenous as supply elasticity is not a direct determinant of current house prices. It only impacts them indirectly through capital gains expectations. This contrasts with a change in amenities or other housing demand drivers which would typically combine direct price impacts with indirect impacts through expectations.

The paper proceeds as follows. Section 2 summarizes the history and impact of the Chapter 40B Comprehensive Permit Act. Section 3 describes the theoretical framework behind the empirical strategy based on this law. Section 4 presents the results and Section 5 concludes.
2.2 Background

The Chapter 40B comprehensive permit act was passed in 1969 with the intent of increasing the supply of affordable housing in Massachusetts. The law allows developers of subsidized housing units to appeal local zoning board decisions to a state board if the construction is to be in towns with an insufficient stock of low income housing. Specifically, towns with fewer than 10% of total units in their subsidized housing inventory (SHI) are subject to the policy. As noted by Stanley (2004), “The way the statute works essentially gives developers tremendous leverage to secure comprehensive permits in communities with less than 10% subsidized housing and very little leverage in communities with more than 10%.” Furthermore, developments can include market rate owner-occupied or rental units as long as at least 25% of a project’s units are designated for lower-income residents.

During the 1990s comprehensive permit applications diminished as so called deep subsidy programs, large grants or loans to developers alongside significant control by regulatory authorities over the design and operation of low income housing, fell out of fashion. Shallow subsidy programs where subsidized loans or the combination of market rate and low income units were used as incentives to develop low-income housing became the dominant model. Such developments were initially considered ineligible for comprehensive permits (Forton 2001).

A 1999 court case significantly increased the intensity and nature of developments under Chapter 40B by changing the rules for qualified developments. In Stubborn Ltd. Partnership v. Barnstable Zoning Board of Appeals, developers receiving subsidized loans from the New England Fund of the Federal Home Loan Bank of Boston were deemed to have received a public subsidy and were thus eligible to
use the comprehensive permit process to circumvent local zoning board decisions (Krefetz 2001). This led to a dramatic increase in the pace of construction under the auspices of chapter 40B and hastened a shift towards maximizing the allowable number of market rate units. For the first 30 years of the program’s existence, from 1969 to 1999, an average of 933 units a year were built. From March 2001 to January 2004, the annual average number of permits issued was 10,000, a ten fold increase over the pace prior to the Stuborn decision. Further, while in the 1990s more than half of units were affordable, post 2000, only 27% were (Stanley 2004). This implies that developers were effectively maximizing the allowable number of market rate units (capped at 75%).

Figure 2.1 presents residential construction trends following the court decision, arrayed by a town’s initial SHI share. From 2000 to 2005, the stock of residential units in towns with SHI below the 10% threshold, who are subject to the policy, grew by more than 7% on average compared to less than 3% average growth in exempt towns. Clearly the increase in the forcefulness of the comprehensive permit law triggered by the Stuborn decision set exempt and non-exempt towns on significantly different housing supply paths. The next section describes how the change in supply elasticity brought on by the policy should impact expectations for future house price appreciation.

2.3 Theoretical framework

Housing supply elasticity determines the extent to which increases in housing demand result in either higher house prices and rents or an increase in the quantity of housing available. As detailed in, e.g. Poterba (1984), the extent of local supply
elasticity together with anticipated demand growth should guide current expectations for the future path of house prices. The degree of supply elasticity in a given housing market results from a combination of geographic constraints on construction and regulatory limits on land use. The empirical strategy employed in this paper exploits a policy which targets the latter constraint on housing supply, specifically exclusionary zoning. While in actuality the strategy relies on a significant intensification of an existing policy, the discussion that follows will treat it as a new policy for simplicity.

First, assume that households in all areas anticipate similar increases in future housing demand, and that housing supply is initially completely inelastic. Figure 3.5a diagrams this situation. Future house prices are initially expected to rise to \( p' \) to accommodate the increase in demand to \( D' \). Now a policy is implemented which removes some regulatory barriers to housing development in some areas but not others. In the treated areas, supply conditions are characterized by \( S' \) denoting some degree of supply elasticity. For the same anticipated increase in housing demand, future prices in the treated areas will now only rise to \( p'' \) in combination with an increase in the future housing stock. If households are forward looking, expectations for future house price appreciation in treated areas should fall relative to untreated areas. This is the typical case, as most housing markets will be characterized by positive demand growth and some degree of initial supply inelasticity. There are two caveats to the mechanism described. One is portrayed in Figure 3.5b where future housing demand is anticipated to decline (or stay constant). As explored in Glaeser and Gyourko (2005), due to the durable nature of housing, housing supply is asymmetric in that it is highly inelastic in the face of falling demand. Since this relationship is due to the nature of housing and not the presence of land use regulation, exposure to the treatment will have no impact on downward supply
elasticity, and so will not impact current expectations for the path of future house price declines. The other caveat is sketched in Figure 2.2c. In general, the impact of the treatment on expectations will be stronger the more initially inelastic an area’s housing supply. At the other extreme, an area whose pre-policy housing supply is completely elastic will also not be impacted by the policy, as no house price growth should have been anticipated to begin with. To summarize, areas with anticipated demand growth, which are also initially inelastically supplied, should have expectations altered if exposed to the policy. This motivates the use of the comprehensive permit act’s intensification as a source of variation in future house price expectations.

2.4 Empirical Analysis

The central specification of interest is the relation of the housing rent to price ratio in area $a$ at time $t$ to the expected price appreciation rate, $g$ and other local factors $X$:

$$\left(\frac{R}{P}\right)_{a,t} = \beta_0 + \beta_1 g_{a,t} + \beta_2 X_{a,t} + \epsilon_{a,t} \tag{2.1}$$

The prediction is that expectations are negatively linked to rent to price ratios, with capitalization at a one to one rate. Using the rent to price ratio, rather than just price, accounts for the direct impact of changes in the actual supply of units over time relative to anticipation of future supply increases. Still, the estimated $\beta_1$ coefficient may be biased. Measurement error is likely as the expectations measure is inferred indirectly from homeownership decisions, sometimes from fairly
small samples of households. Reverse causation is also possible. Prospective buyers may interpret high house price levels as indicating higher future capital gains on housing, a phenomenon documented from surveys of expected future stock market returns (Greenwood and Shleifer 2014). Rent to price ratios could also be driven by omitted variables correlated with expectations, particularly ones related to credit constraints. For example, Fostel and Geanakoplos (2012) postulate that house prices are driven by a small class of permanently optimistic investors whose only constraint is a downpayment requirement, which may tend to be looser in areas where the average expectation, the one captured by the measure used in this paper, is more optimistic.

Because of these concerns, an instrumental variables strategy will be used. As discussed above, the source of the instrument is a Massachusetts policy differentially altering supply elasticity, and thus in principle expectations for price appreciation, across different towns. The application of the policy is endogenous to local conditions, specifically the presence of subsidized housing, which may also be correlated with house prices. Because the policy employs a discontinuous threshold in its application though, there is some random variation in the intensity of the treatment conditional on the stock of subsidized housing. Since the expectations measure is at the PUMA level and because housing markets are not necessarily confined to single towns, the instrument is computed at the PUMA level as well. The instrument is the share of a PUMA’s housing units exposed to the policy. This measures the level of “risk” of future supply increases a PUMA faces, which is correlated with, but not identical to the share of subsidized housing units in a PUMA, so that the latter can be included directly as a control.

A constituent town of a given PUMA is exposed to the policy discontinuously if its SHI falls below 10%, whereas the share of subsidized housing is continuous
through the threshold. So for example, if one town with 10,000 housing units has 1% SHI and another has 9% SHI, they both contribute the same to the policy exposure variable, but the latter contributes much more to the subsidized housing share of a PUMA. This demonstrates how it is possible to control for the direct impact of subsidized housing on prices while still leaving some variation in treatment intensity. Additionally, since the 10% threshold is imposed statewide, and was chosen at the policy’s inception in 1969, it is likely to be exogenous to local housing market conditions in the 1990s and 2000s.

2.4.1 Data

The creation of the house price appreciation expectations measure used is detailed in Suher (2013). Here it is computed at the level of the Census public use microdata area (PUMA). PUMAs must encompass at least 100 thousand people, and are typically between 100 and 150 thousand people. In Massachusetts, PUMAs follow town boundaries, except in the city of Boston which is divided into five PUMAs. There are 351 towns and 52 PUMAs under 2000 Census geography. Because towns are nested into PUMAs in Massachusetts, PUMA geography from 1990 is matched to 2000, and expectations, property tax rates, rent and price data from 1990 is reweighted to match 2000 PUMA geography.

Quality adjusted rent to price ratios are computed from Census microdata. The procedure, described more fully in Suher (2013), estimates hedonic price and rent equations in each PUMA and year to extract house prices and rent with quantity and quality differences between the owned and rented stock removed. Annual house price data is constructed from administrative records collected by the Warren Group. Data on land cover comes from MassGIS. Following Hilber and Mayer (2009), resi-
dential developable land is computed as developed residential land plus agricultural and open land. Residential permit data is from the Census Bureau Construction Statistics. The subsidized housing inventory share (SHI) at the town level over time was obtained from the Massachusetts Department of Housing and Community Development.

Summary statistics are presented in table 2.2. The treatment variable, Policy Exposure, capturing susceptibility to comprehensive permit developments, ranges from 0 to 1 by design, with a mean of 0.7. The share of developable residential land in a PUMA which has been developed averages 79%, and ranges from 35 to 99%. The share of a PUMA's housing units which are subsidized (SHI share) averages 8% in 2000. It is growing over time with the completion of Chapter 40B developments, though relatively slowly. This is not surprising given that developers tended to build the minimum number of affordable units allowed following the Stubborn court decision discussed in Section 2. The next section turns to the empirical results.

2.4.2 Results

The estimates in Table 2.2 are for all U.S. metropolitan areas and divisions. Specifications one and two relate the rent to price ratio with current expected house price appreciation and the property tax rate in 2000 and 2005. As predicted, expected price appreciation, which should be positively related to prices, is negatively related to the rent to price ratio. These estimates are substantially below 1 in magnitude which may reflect attenuation bias from measurement error. Further, the estimates may suffer from reverse causation or omitted variable bias as discussed above.

Specifications three and four relate changes in the rent to price ratio with changes
in expected price appreciation and property tax rates over the 1990-2000 and 1990-2005 period. This should remove the influence of fixed factors correlated with both expected price appreciation and rent to price ratios. Such bias does not appear to be at play as the estimated impact of expected capital gains remains of similar magnitude.

Due to the likely presence of measurement error and other potential confounders, an instrument for expected house price appreciation is required. As laid out above, within the state of Massachusetts, exposure of local housing markets to the Chapter 40B comprehensive permit law provides some plausibly exogenous variation in anticipated housing capital gains.

Figure 2.3 summarizes the reduced form relationship between exposure to the policy and house prices. It uses administrative house price records to follow annual house price trends so that the exact timing of the policy’s impact can be seen. The relationship between house price appreciation relative to 1998, the year prior to the policy’s intensification, and the extent of an area’s exposure to the policy is presented. As outlined above, post-1999, exposure to the policy should result in lower expected price appreciation, and thus lower current house prices. Because over time the policy induces actual housing supply increases which should directly reduce prices, price appreciation is first regressed on the actual pace of local construction. Then the residuals from these regressions are used in the presented figure, so that only anticipated impacts of the policy should be present. As a check, price trends in 1999, largely prior to the policy’s intensification are presented. As should be the case, the policy has no effect, with in fact a slightly positive relationship between prices and exposure to policy. The impact of the policy does not actually appear to show up in 2000, instead not becoming apparent until 2001, when a substantial negative relationship between prices and the policy is evident. This could indicate some lag
in home buyers understanding of the policy’s intensification, which is reasonable as it was due not to new legislation but rather to a fairly technical court decision. The policy’s impact continues to exhibit itself in future years, though at a muted level relative to 2001. This may reflect the fact that public outcry over the policy resulted in some caps being placed on the size of housing developments using the law beginning in the last quarter of 2001.

Table 3.2 provides first stage estimates. Expected house price appreciation is regressed on the Policy Exposure instrument. The unconditional correlation between expectations and the intensity of the treatment in a PUMA is actually positive as seen in column one. The predicted negative sign appears though in column two, once the extent of local subsidized housing is controlled. The implication is that areas with less subsidized housing tend to have higher expected house price appreciation in general which is arguably not very surprising. All other specifications, whether in levels for 2000 and 2005, or in changes from 1990 to 2000 or 1990 to 2005 exhibit the predicted negative relationship between exposure to the policy and expectations. Only the specification with changes from 1990 to 2005 is statistically significant, which is in line with the reduced form relationship observed in figure 2.3, where the policy’s impact is somewhat delayed. While the relationship is otherwise statistically weak, its consistency across different years, and in levels and differences, is persuasive of the instrument’s relevance. Estimates are around -.005, indicating that expected price appreciation rates are 0.5% lower in areas fully exposed to the policy relative to ones which are completely exempt from it.

The estimates in Table 2.4 are for all Massachusetts PUMAs. OLS estimates in columns one through four, whether in levels or differences, are very similar to the national estimates, indicating that results from this one state are typical. Columns five through eight present two-stage least squares estimates where expected price
appreciation is instrumented with the Policy Exposure variable. Estimates tend to be less precise, but are consistently of a larger magnitude, implying that OLS estimates were likely attenuated by measurement error. Further, the estimated magnitudes are largely in line with the theoretical prediction that expected price appreciation rates should capitalize one-for-one into rent to price ratios.

As explained in section 3, the channel through which the policy exposure instrument impacts expectations is by increasing housing supply elasticity and thereby muting anticipated future house price increases. According to the diagram in figure 2.2, the impact of exposure to the policy should be increasing in the initial degree of supply inelasticity characterizing a local housing market, and should be nil in an area with completely elastic supply prior to the policy’s implementation. To verify that the policy is operating as theorized, the first stage is repeated with the sample split into inelastic and elastic housing markets, as determined by the share of land available for residential development. The estimates in Table 2.5 are consistent with the predicted behavior. Specifically, in Panel A, the impact of the policy on expected price appreciation in inelastic areas is negative in all specifications and for the relationship in levels, more than double the magnitude of the full sample first stage estimates. In contrast, in Panel B, which estimates the first stage relationship only for more elastically supplied markets, the estimated impact of the policy is statistically indistinguishable from zero. These split sample estimates are reassuring that the instrument used in this paper is impacting prices through an expectations channel as envisioned.
2.5 Conclusion

This paper exploits a quasi-experimental setting, based on altered housing supply elasticities across towns in Massachusetts, to produce causal estimates of the capitalization of capital gain expectations into housing rent to price ratios. Two stage least squares estimates demonstrate that expected rates of future price appreciation are capitalized into house prices at a rate close to one for one, or roughly five times the magnitude produced by OLS estimates. Additionally, the first stage estimation is itself useful validation that the measure developed in Suher (2013) is in fact isolating expectations, as its relationship to an expectations altering policy is as predicted. The use of a Massachusetts specific policy for identification means estimates are only for a relatively small piece of the national housing market. The similarity of OLS estimates to national figures though is supportive of external validity. It would be interesting to see whether findings are consistent in other states which may employ similar supply elasticity altering policies. Future work can use this framework, or similar expectation related policies, to investigate the extent to which the mechanism by which expectations drive current prices is through a direct demand shift or in part indirectly through a credit channel.

2.6 Tables and Figures
Figure 2.1: Residential construction relative to policy threshold

Note: Permit intensity is the number of permitted residential units from 2000 to 2005 scaled by the existing stock of units in 2000. The chapter 40B policy threshold is at 10% subsidized housing inventory (SHI). Town level permit intensity is averaged by 1% SHI bins.
Figure 2.2: Impact of change in supply elasticity

(a) Rising demand

(b) Falling demand

(c) Elastic supply
**Figure 2.3:** Reduced form evidence: Policy impact on house prices

Note: Variables are measured at the Census PUMA level. Annualized price appreciation is measured relative to 1998, and controls for the pace of construction of residential units over the corresponding time period. Policy exposure measures the share of a PUMA’s housing units in towns susceptible to comprehensive permit actions.
Table 2.1: Summary statistics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean (%)</th>
<th>Standard deviation (%)</th>
<th>Minimum (%)</th>
<th>Maximum (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Policy variables</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Policy exposure</td>
<td>70.4</td>
<td>40.1</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Developed land</td>
<td>79.4</td>
<td>16.7</td>
<td>35.0</td>
<td>98.7</td>
</tr>
<tr>
<td><strong>2000</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rent to price ratio</td>
<td>3.9</td>
<td>0.7</td>
<td>2.1</td>
<td>5.0</td>
</tr>
<tr>
<td>Expected price appreciation</td>
<td>6.8</td>
<td>1.0</td>
<td>4.1</td>
<td>8.7</td>
</tr>
<tr>
<td>Property tax rate</td>
<td>1.2</td>
<td>0.2</td>
<td>0.6</td>
<td>1.8</td>
</tr>
<tr>
<td>SHI share</td>
<td>8.2</td>
<td>4.8</td>
<td>3.1</td>
<td>19.4</td>
</tr>
<tr>
<td><strong>2005</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rent to price ratio</td>
<td>3.0</td>
<td>0.6</td>
<td>1.8</td>
<td>4.5</td>
</tr>
<tr>
<td>Expected price appreciation</td>
<td>6.1</td>
<td>1.0</td>
<td>4.2</td>
<td>9.5</td>
</tr>
<tr>
<td>Property tax rate</td>
<td>0.9</td>
<td>0.2</td>
<td>0.4</td>
<td>1.5</td>
</tr>
<tr>
<td>SHI share</td>
<td>8.8</td>
<td>4.5</td>
<td>3.8</td>
<td>18.9</td>
</tr>
<tr>
<td><strong>1990-2000</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rent to price ratio</td>
<td>1.2</td>
<td>0.5</td>
<td>0.2</td>
<td>2.3</td>
</tr>
<tr>
<td>Expected price appreciation</td>
<td>-2.1</td>
<td>0.7</td>
<td>-4.0</td>
<td>-0.6</td>
</tr>
<tr>
<td>Property tax rate</td>
<td>0.3</td>
<td>0.2</td>
<td>-0.2</td>
<td>1.0</td>
</tr>
<tr>
<td>SHI share</td>
<td>0.2</td>
<td>0.7</td>
<td>-1.5</td>
<td>2.1</td>
</tr>
<tr>
<td><strong>1990-2005</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rent to price ratio</td>
<td>-2.8</td>
<td>1.0</td>
<td>-5.2</td>
<td>-0.1</td>
</tr>
<tr>
<td>Expected price appreciation</td>
<td>0.0</td>
<td>0.2</td>
<td>-0.3</td>
<td>0.6</td>
</tr>
<tr>
<td>Property tax rate</td>
<td>0.8</td>
<td>1.0</td>
<td>-1.6</td>
<td>3.1</td>
</tr>
<tr>
<td>SHI share</td>
<td>1.2</td>
<td>0.5</td>
<td>0.2</td>
<td>2.3</td>
</tr>
</tbody>
</table>

Note: Variables are measured at the Census PUMA level.

Table 2.2: National estimates

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Expected price appreciation</td>
<td>-0.26***</td>
<td>-0.18***</td>
<td>-0.16</td>
<td>-0.13*</td>
</tr>
<tr>
<td></td>
<td>(0.082)</td>
<td>(0.043)</td>
<td>(0.11)</td>
<td>(0.067)</td>
</tr>
<tr>
<td>Property tax rate</td>
<td>0.64***</td>
<td>1.56***</td>
<td>0.91*</td>
<td>1.42***</td>
</tr>
<tr>
<td></td>
<td>(0.22)</td>
<td>(0.24)</td>
<td>(0.53)</td>
<td>(0.42)</td>
</tr>
<tr>
<td>Constant</td>
<td>0.058***</td>
<td>0.035***</td>
<td>0.0075***</td>
<td>0.00083</td>
</tr>
<tr>
<td></td>
<td>(0.0055)</td>
<td>(0.0044)</td>
<td>(0.0021)</td>
<td>(0.0030)</td>
</tr>
<tr>
<td>Observations</td>
<td>376</td>
<td>374</td>
<td>369</td>
<td>368</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.111</td>
<td>0.321</td>
<td>0.082</td>
<td>0.141</td>
</tr>
</tbody>
</table>

Note: Variables are measured at the metropolitan area or division level. Estimates are weighted by the number of households in each area. All variables enter in changes in specifications three and four. Robust standard errors in parentheses. 
*** p<0.01, ** p<0.05, * p<0.1.
### Table 2.3: First stage

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Policy Exposure</td>
<td>0.0063*</td>
<td>-0.0073</td>
<td>-0.0032</td>
<td>-0.0044</td>
<td>-0.0039</td>
<td>-0.0080***</td>
</tr>
<tr>
<td></td>
<td>(0.0037)</td>
<td>(0.0085)</td>
<td>(0.0074)</td>
<td>(0.0026)</td>
<td>(0.0033)</td>
<td>(0.0026)</td>
</tr>
<tr>
<td>SHI Share</td>
<td>-0.13*</td>
<td>-0.060</td>
<td>0.063</td>
<td>-0.20</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.068)</td>
<td>(0.066)</td>
<td></td>
<td>(0.16)</td>
<td></td>
<td>(0.13)</td>
</tr>
<tr>
<td>Constant</td>
<td>0.064***</td>
<td>0.083***</td>
<td>0.069***</td>
<td>-0.018***</td>
<td>-0.018***</td>
<td>-0.020***</td>
</tr>
<tr>
<td></td>
<td>(0.0032)</td>
<td>(0.011)</td>
<td>(0.011)</td>
<td>(0.0023)</td>
<td>(0.0030)</td>
<td>(0.0022)</td>
</tr>
<tr>
<td>Observations</td>
<td>52</td>
<td>52</td>
<td>52</td>
<td>52</td>
<td>52</td>
<td>52</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.062</td>
<td>0.133</td>
<td>0.026</td>
<td>0.065</td>
<td>0.068</td>
<td>0.126</td>
</tr>
</tbody>
</table>

Note: Variables are measured at the Census PUMA level. Policy Exposure measures the share of a PUMA’s housing units in towns susceptible to comprehensive permit actions. SHI share is the share of a PUMA’s housing units that are subsidized. SHI Share enters in changes in specifications five and six. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.
Table 2.4: Massachusetts estimates

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Expected price appreciation</td>
<td>-0.21***</td>
<td>-0.25***</td>
<td>-0.37***</td>
<td>-0.19***</td>
<td>-2.09</td>
<td>-1.11</td>
<td>-1.05</td>
<td>-0.52***</td>
</tr>
<tr>
<td></td>
<td>(0.063)</td>
<td>(0.065)</td>
<td>(0.080)</td>
<td>(0.037)</td>
<td>(6.51)</td>
<td>(2.79)</td>
<td>(0.80)</td>
<td>(0.19)</td>
</tr>
<tr>
<td>Property tax rate</td>
<td>2.28***</td>
<td>2.06***</td>
<td>1.22***</td>
<td>1.31**</td>
<td>5.15</td>
<td>3.77</td>
<td>1.52***</td>
<td>1.82***</td>
</tr>
<tr>
<td></td>
<td>(0.23)</td>
<td>(0.27)</td>
<td>(0.25)</td>
<td>(0.54)</td>
<td>(9.57)</td>
<td>(5.75)</td>
<td>(0.43)</td>
<td>(0.59)</td>
</tr>
<tr>
<td>SHI share</td>
<td>-0.026*</td>
<td>-0.027*</td>
<td>-0.057</td>
<td>0.13**</td>
<td>-0.11</td>
<td>-0.035</td>
<td>0.068</td>
<td>0.061</td>
</tr>
<tr>
<td></td>
<td>(0.015)</td>
<td>(0.014)</td>
<td>(0.073)</td>
<td>(0.062)</td>
<td>(0.32)</td>
<td>(0.032)</td>
<td>(0.20)</td>
<td>(0.087)</td>
</tr>
<tr>
<td>Constant</td>
<td>0.028***</td>
<td>0.030***</td>
<td>0.0014</td>
<td>-0.0023*</td>
<td>0.13</td>
<td>0.069</td>
<td>-0.014</td>
<td>-0.011**</td>
</tr>
<tr>
<td></td>
<td>(0.0053)</td>
<td>(0.0046)</td>
<td>(0.0020)</td>
<td>(0.0012)</td>
<td>(0.36)</td>
<td>(0.12)</td>
<td>(0.018)</td>
<td>(0.0048)</td>
</tr>
<tr>
<td>Observations</td>
<td>52</td>
<td>52</td>
<td>52</td>
<td>52</td>
<td>52</td>
<td>52</td>
<td>52</td>
<td>52</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.618</td>
<td>0.512</td>
<td>0.493</td>
<td>0.396</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: Variables are measured at the Census PUMA level. SHI share is the share of a PUMA’s housing units that are subsidized. All variables enter in changes in specifications three, four, seven, and eight. Two-stage least squares estimates instrument for expected house price appreciation with the Policy Exposure variable: the share of a PUMA’s housing units in towns susceptible to comprehensive permit actions. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.
Table 2.5: Role of initial supply elasticity

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Panel A: Inelastically supplied markets</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Policy Exposure</td>
<td>-0.019*</td>
<td>-0.012*</td>
<td>-0.0061</td>
<td>-0.0069*</td>
</tr>
<tr>
<td></td>
<td>(0.010)</td>
<td>(0.0063)</td>
<td>(0.0046)</td>
<td>(0.0039)</td>
</tr>
<tr>
<td>SHI Share</td>
<td>-0.17*</td>
<td>-0.099</td>
<td>0.0039</td>
<td>-0.22</td>
</tr>
<tr>
<td></td>
<td>(0.087)</td>
<td>(0.058)</td>
<td>(0.32)</td>
<td>(0.25)</td>
</tr>
<tr>
<td>Constant</td>
<td>0.091***</td>
<td>0.075***</td>
<td>-0.017***</td>
<td>-0.020***</td>
</tr>
<tr>
<td></td>
<td>(0.015)</td>
<td>(0.0091)</td>
<td>(0.0047)</td>
<td>(0.0032)</td>
</tr>
<tr>
<td>Observations</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>26</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.171</td>
<td>0.099</td>
<td>0.142</td>
<td>0.126</td>
</tr>
<tr>
<td><strong>Panel B: Elastically supplied markets</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Policy Exposure</td>
<td>0.012</td>
<td>0.0033</td>
<td>0.0039</td>
<td>-0.0098</td>
</tr>
<tr>
<td></td>
<td>(0.013)</td>
<td>(0.014)</td>
<td>(0.0039)</td>
<td>(0.0077)</td>
</tr>
<tr>
<td>SHI Share</td>
<td>0.012</td>
<td>0.11</td>
<td>0.084</td>
<td>-0.19</td>
</tr>
<tr>
<td></td>
<td>(0.100)</td>
<td>(0.100)</td>
<td>(0.21)</td>
<td>(0.15)</td>
</tr>
<tr>
<td>Constant</td>
<td>0.061***</td>
<td>0.055***</td>
<td>-0.025***</td>
<td>-0.019**</td>
</tr>
<tr>
<td></td>
<td>(0.017)</td>
<td>(0.018)</td>
<td>(0.0035)</td>
<td>(0.0069)</td>
</tr>
<tr>
<td>Observations</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>26</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.092</td>
<td>0.035</td>
<td>0.022</td>
<td>0.090</td>
</tr>
</tbody>
</table>

Note: Variables are measured at the Census PUMA level. Policy Exposure measures the share of a PUMA’s housing units in towns susceptible to comprehensive permit actions. SHI share is the share of a PUMA’s housing units that are subsidized. SHI Share enters in changes in specifications three and four. Supply inelasticity is proxied by the share of a PUMA’s potentially developable residential land which is developed, with the full sample split in half by values of this variable. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.
Chapter Three

Proximity and productivity: Localization economies in the office sectors
3.1 Introduction

The theoretical literature on the impact of agglomeration economies on firm productivity highlights the importance of spatial linkages operating at various geographic scales. Despite this, previous empirical work has mostly focused on the effects of firm and industry clustering at the city level. A better understanding of the role of distance in the strength of local interactions can illuminate the relative importance of the various mechanisms thought to be underpinning cross-city productivity and wage premia.

Estimating agglomeration economies with city level scale masks the possibility that these effects are partly or wholly an artifact of industry clustering at the sub-city level. The scarcity of research on within city density reflects a dearth of spatially disaggregated data as well as the difficulty in developing a research design which isolates exogenous variation in the density of economic activity at a smaller geographic scale. In this paper I attempt to address both of these issues. I also focus on firms in the office-based industries which have received less attention in the urban literature despite their increased importance for the economy. I observe establishment location at the zip code level and combine it with data describing the changing intra-city distribution of a city’s office stock over time. My research design exploits partially exogenous variation in the within city location of new office construction during a recent building boom to isolate shifts in firm location which are plausibly unrelated to changing production technology. Specifically, the empirical analysis jointly estimates the effects of scale externalities on firms in the office-based sectors resulting from the local scale of each sector in both the central business district as well as the entire metropolitan area. I find that productivity premiums, as reflected in wages, are driven by the scale of an industry in the central business district (CBD), while
being largely unrelated to the overall metropolitan area footprint of the industry.

The empirical strategy exploits a national shock to overall office construction which exhibited significant local variation in the extent to which new office space was delivered in the CBD or in suburban office submarkets. Cities whose office expansion was more suburban provided incentive for firms to relocate to, or be founded in, suburban office parks rather than downtown. If agglomeration effects derive at least in part from closer proximity in a CBD rather than just from colocation in the same metropolitan area, then operation in the suburbs will entail lower productivity. To the extent that denser CBDs provide greater agglomeration benefits than sparser suburban office parks, reduced CBD size will decrease the productivity of firms in the CBD and thus the average productivity across all firms in the metropolitan area.

I propose a set of instruments characterizing geographic land cover and land assembly difficulties as plausibly exogenous predictors of the spatial distribution of office construction during the boom and thus the resulting shifts in CBD relative to metropolitan scale. These instruments are then used to estimate the impact on productivity of localization economies in the office-based sectors at two different geographic scales. First, the presence of a significant wage premium in the office-based sector related to metropolitan scale is substantiated, confirming the presence of localization effects on productivity. This mirrors the findings of an extensive literature documenting such premia in the manufacturing sector. Joint estimates of the impact of sector localization at the metropolitan area level and CBD level are then performed. Two-stage least squares estimates demonstrate that observed wage premiums are in fact driven by the extent of a sector’s presence in the CBD, and unrelated to its overall metropolitan area footprint. The conclusion is that closer proximity of firms within the same CBD, rather than just within the same city, is the main driver of metropolitan wage premia in these sectors. Parallel estimates using
output per worker proved less precise, though were consistent with these findings.

The paper proceeds as follows: Section 2 provides the theoretical framework supporting the empirical strategy for estimating the magnitude and geographic scope of agglomeration economies. Section 3 describes the data. Section 4 discusses the office construction boom and presents the first stage estimations. Section 5 presents the estimates of agglomeration economies. Section 6 performs robustness checks. Section 7 concludes.

3.2 Estimating agglomeration economies

The existence of cities, industry clustering, and the productivity and wage premia associated with the density of economic activity all suggest an important role for interactions between firms in the production process. Isolating the impact of scale externalities on firm productivity or location decisions from alternative explanations faces a number of empirical challenges. A typical estimation of agglomeration economies takes the form of equation (3.1) where it is assumed that workers are paid their marginal product and thus wages reflect firm productivity. Productivity is in turn assumed to be partially a function of the extent of local economic activity, either overall or for a given firm’s own industry.

$$lnw_m = \beta_0 + \beta_1 lnE_m + \eta_m + \epsilon_m$$  \hspace{1cm} (3.1)

Here for city $m$, $w$ is the wage, $E$ is a measure of scale or density, and $\eta$ is a location specific fixed factor affecting wages directly through productivity or indirectly through the land market.
Combes, Duranton, and Gobillon (2010) outline the issues surrounding the identification of agglomeration effects in a specification like (3.1) and survey the approaches that have been used to address them. They classify the sources of estimation bias into three categories: endogenous quantity of labor, endogenous quality of labor, and shocks. The analysis in this paper employs time differencing and instrumental variables techniques to attempt to address these three sources of bias. While both of these techniques have been incorporated previously in estimates of agglomeration economies, this paper applies them to the question of the spatial extent of firm interactions.

In their review chapter on empirical investigation of agglomeration economies, Rosenthal and Strange (2004) discuss the geographic scope of different varieties of firm interactions. They speculate that knowledge spillovers likely operate at a very short distance while labor pooling might matter at multiple different geographic scales. The distance over which input sharing operates will likely depend on transport costs for the input in question. They conclude by noting that the question of the geographic scope of different sources of agglomeration economies has only occasionally been emphasized in prior research.

Two previous studies have investigated the geographic scope of agglomeration effects. Rosenthal and Strange (2003) restrict their analysis to six industries in both manufacturing and services. They look at the impact of own industry and overall scale on firm births at the zip code level. They find significant evidence of localization effects which tend to attenuate rapidly with distance. Arzaghi and Henderson (2008) also use data on firm births in addition to incorporating measured rent gradients. Looking at advertising agencies in Manhattan, they find strong evidence of information spillovers at very close range of a few hundred meters, but dissipating entirely within a 1 km distance.
In contrast to those two studies, this paper looks directly at the relation of wages and productivity to intra-metropolitan density, but has the drawback of using a coarser geography: MSAs are treated as offering only two location choices to office-based firms, the CBD and the suburbs. I assume that for firms located in a city’s CBD, productivity is a function of own industry scale within the closer confines of just the CBD, \( E_{mc,i} \) as well as the industry’s overall presence in the broader metropolitan area \( E_{m,i} \), and estimate the following specification:

\[
\ln w_{m,i} = \beta_0 + \beta_1 \ln E_{mc,i} + \beta_2 \ln E_{m,i} + \epsilon_{m,i} \quad (3.2)
\]

This means I will be measuring the impact of firm interactions within the CBD as reflected in the overall metropolitan wage for each sector.

Other recent work has used a similar geographic dichotomy. From a mostly theoretical perspective, Brinkman, Coen-Pirani, and Sieg (2010) consider intra-metropolitan firm location and relocation in the service sector in a model with two location choices: the CBD and the rest of the urban area. They note that high productivity firms are expected to outbid others for CBD space where they gain from higher agglomeration externalities. Baldwin and Okubo (2006) develop a similarly motivated model with heterogeneous firms choosing between operating in the core or periphery of a region. The core selects for more productive firms under the assumption that they gain more from spatial linkages. The presence of city or CBD unobserved fixed factors which drive firm productivity and are correlated with local scale, in addition to these selection concerns, suggest the use of time differencing.

Previous work estimating agglomeration effects has incorporated time differencing as a means of dealing with omitted variable bias.\(^1\) While time differencing can

\(^1\)Henderson (2003) constructs a panel of plant level data for machinery and high-tech manufacturing industries and looks for evidence of local scale externalities from own-industry, overall scale,
address the econometric problem of unobserved fixed factors in a regression of wages on local scale, it also implicitly removes the potential dynamic agglomeration benefits that accrue in larger cities. In a recent empirical study at the worker level, Baum-Snow and Pavan (2011) find that a significant driver of higher average wages in larger cities is faster wage growth due to some form of dynamic learning externality. To the extent that average metro wages reflect these accumulated experience effects, looking at changes in density over relatively short time periods will largely exclude the impact of larger scale on wage growth and only pick up the immediate level effects. So while a time differencing approach may deliver cleaner estimates of static agglomeration economies, it is not a direct substitute for the more common cross-sectional approach.

Time differencing likely increases the need for instruments to deal with the correlation between density changes and unobserved local shocks affecting both scale and wages. This is where the use of the quasi-experiment generated by the office construction boom comes into play. A decrease in the financing costs of commercial construction, which was largely national in nature, interacted with city specific differences in the elasticity of land supply in the CBD relative to the suburbs. The model below captures the impact of this construction boom on firm location decisions, productivity, and wages.

Each area $b$ of a city $m$ is populated with identical firms, each with production and diversity effects. He finds strong own-industry scale effects for the high-tech industry. Combes, Duranton, and Gobillon (2008) employ worker level data from France across all industries. Interestingly, when they estimate their aggregate model in first-differences, they get an almost identical estimate to the corresponding estimation at the worker level, implying that the effects of sorting by individual workers may be fairly stable over time at the aggregate level. Martin, Mayer, and Mayneris (2011) use year to year changes in plant-level productivity and find significant localization effects.
function:

\[ y_{mb}^i = A_{mb}^i \min \{l, kx \} \]  \hspace{1cm} (3.3)

where labor \( l \) and space \( x \) are used in fixed proportions. Firms can either operate in the CBD \((b = c)\) or Suburbs \((b = s)\).

Productivity \( A \) is a function of the city scale of the sector in which the firm operates, as well as potentially the scale of the CBD if the firm locates there:

\[ A_{ms}^i = f(E_m) \]
\[ A_{mc}^i = f(E_m, E_{mc}) \]  \hspace{1cm} (3.4)

Profit maximization with unit output price yields:

\[ w_m + q_{ms} = A_{ms}^i \]
\[ w_m + q_{mc} = A_{mc}^i \]  \hspace{1cm} (3.5)

In the long run, profits must be equal whether a firm operates in the CBD or Suburbs of the city, as well as across cities.

The supply curves characterizing developers’ supply of office space in the suburbs and CBD are:

\[ q_{ms} = d^0 + d_{ms}^1 X_{ms} \]
\[ q_{mc} = d^0 + d_{mc}^1 X_{mc} \]  \hspace{1cm} (3.6)

where \( d^1 \) determines the degree of supply elasticity in each area of the city.
In the long-run rent is fixed by the prevailing wage and productivity in a given area: \( \overline{q}_{mb} = A_{mb} - w. \)

The financially driven construction shock is captured by a decrease in the parameter \( d^0 \) everywhere. The result is an increase in the pace of construction to take advantage of construction costs being below market rent. The amount of new construction (the increase in the stock of space) driven by the fall in \( d^0 \) will be bigger the smaller is the parameter \( d^1 \). That is, more new space will be delivered in areas with more elastic supply conditions:

\[
\begin{align*}
X_{mb} &= \overline{q} - d^0 \\
\frac{\partial X_{mb}}{\partial d^0} &= -\frac{1}{d^1_{mb}}
\end{align*}
\]  

(3.7)

If productivity \( A \) is increasing in the local scale of a sector, than productivity should increase more in areas that grow more. CBD scale will increase more if supply elasticity is high in the CBD. Additionally, if supply elasticity is low in the suburbs, then general metropolitan growth in the stock of firms will be further biased towards the CBD. Thus I will estimate equation (3.2) by two stage least squares using as instruments a set of geographic variables characterizing different land cover types and a proxy for land assembly difficulties in the CBD to capture city level variation in the relative supply elasticity between the CBD and Suburbs. Additionally, a Bartik-type predicted growth variable based on local industrial composition will be used as an instrument driving overall metropolitan growth in each sector.

In summary, while a few previous studies have investigated agglomeration effects at sub-city scale, this is the first to do so using wages and productivity data directly. I draw on econometric techniques including time differencing and instrumental variables which have been proposed as appropriate ways to deal with the various sources
of bias which may plague the identification of agglomeration economies. In addition, I introduce a new measure of land assembly frictions in the CBD. Finally, my empirical framework utilizes a within city firm location choice set with two options, the CBD and the suburbs, which meshes with recent largely theoretical work on location choice within a city or region. In the next section I turn to a description of the data used in the analysis.

3.3 Data

Data on the office market is from CBRE Torto Wheaton Research (TWR). They collect data on stock, completions, rent, and vacancies for 57 self-defined markets in the U.S. The markets are similar in conception to metropolitan areas but do not directly follow census MSAs. The TWR markets are collapsed into Census metropolitan area definitions (MSAs for wages and CBSAs for output data) using constituent zip codes. TWR also designates a CBD in larger markets which generally spans multiple zip codes, and even multiple submarkets, but is contiguous. The designation of a CBD as well as suburban office employment clusters is not a trivial facet of this data. An entire literature exists which focuses on the issue of employment subcenter delineation. Without local knowledge of a city’s geography, it is difficult for a researcher to determine what constitutes dense and what local firms consider to be cohesive workplace locations. The TWR data relies on the expertise of commercial real estate brokers operating in each city to classify office employment submarkets. The dataset used in this study comprises the 44 MSAs for which TWR provides a CBD to zip code mapping. This sample encompasses the 30 largest MSAs by 2000

\[2\] See the data appendix for details of this process.
\[3\] See McMillen and Smith (2003) for an example of one of the few studies which identifies subcenters across multiple metropolitan areas with a consistent methodology.
population. The data is also provided by office quality class for class A and class B/C space.

The office-based sector is enumerated using the definition employed by TWR in their forecasting models (Jones and Shams (2008)). The sector is based on 2002 NAICS classifications with constituent two digit industries: Information (51), Finance and Insurance (52), Real Estate and Rental and Leasing (53), Professional, Scientific, and Technical Services (54), Management of Companies and Enterprises (55), Administrative and Support Services (56) and Other Services, except Public Administration (81). I exclude sector 55 which covers manufacturing and other industry’s headquarters and sector 81 as it is largely personal services and non-profit entities.

Local scale is measured using establishment counts from the Census Business Patterns data. These data are collected annually and since 1998 under the NAICS industrial classification system. The analysis focuses on data from 2002 and 2007 to coincide with the economic census. The ZIP Business patterns are used to populate the CBD of each metropolitan area, while the County Business Patterns data is aggregated to 1999 MSA or the more recent CBSA metro area definitions to yield overall city establishment counts. Wage data by industry is from County Business Patterns as well, which reports annual payroll and employment.

Output data is from the Bureau of Economic Analysis (BEA) regional accounts. Since 2001 the BEA has reported annual metro area output data (for CBSA metropolitan and micropolitan areas). This data is also provided by industry mostly at the 3-digit NAICS level, though the industry detail lines are frequently censored to avoid

---

4Some subsectors which are not office based are excluded. These are Broadcasting (515), Satellite Telecommunications (5174), Cable and Other Program Distribution (5175), Other Telecommunications (5179) and Rental and Leasing Services (532).
disclosure of confidential information. The output series is computed via a top down process, based both on county level personal income data and on state GDP which is a bottom up tabulation similar to that used for national GDP figures.

Table 3.1 reports summary statistics for the prevalence and composition of the office sector. Panel A gives the share of this sector in overall metropolitan employment as 32% with by far the largest component the Professional, Scientific, and Technical Services industry, comprising on average 12% of metro establishments. The small standard deviation of 4% shows that overall office establishments make up a fairly similar proportion of each MSAs economy. In Panel B we see that on average 15% of a MSAs office sector is located in its CBD. The component 2-digit industries closely follow this pattern as all have on average between 10% and 18% of their metro presence located in the CBD. There is significant variation across cities though, in the degree to which the office sector is CBD focused. Finally, Panel C shows that the overall office sector comprises nearly half of all establishments in the average CBD. In the next section I highlight salient features of the commercial construction boom, introduce the instruments, and present the results from the first stage.

3.4 Expansion in the office market and first stage results

3.4.1 The commercial construction boom

This study argues that partially exogenous differences in CBD expansion over time were driven by variation across cities in the degree to which new office completions
were suburban focused during the recent commercial construction boom. Commercial real estate in the U.S. including office construction has undergone two large booms since the late 1970s. Case (2001) argues that the cyclicality in this sector is in part due to the long lag between planning of production space and the opening of a new development, which can span from 5 to 10 years. Figure 3.1 plots the waves of construction and the resultant increase in overall office stock since 1980 in the 57 markets which TWR covers.

Garner (2008) attributes the start of the late 1970s-1980s expansion to a rapid shift of the economy into office-based industries, with employment growth in that sector exceeding 4% per year during the period. Despite the rapidly increasing demand for space, there was still a substantial amount of overbuilding, driven both by tax incentives for commercial development incorporated in the Economic Recovery Act of 1981 and a regulatory change allowing Savings and Loan institutions to lend in the commercial real estate arena. Garner points to supply side factors, particularly on the financing side, as the driver behind the more recent commercial construction boom beginning in 1996/97. During this latter expansion, office sector employment was growing at a much slower rate of about 1.5% per year. This belied significant increases in both securitization of commercial mortgages during this period, as well as the assets of tax-advantaged Real Estate Investment Trusts (REITs) which invest in commercial properties and commercial mortgages. Garner reports commercial mortgage securitization rates, which were below 10% in 1996, growing to above 25% by 2007.

Figure 3.2 plots annual issuance of commercial mortgage backed securities (CMBS). During the 2002 to 2007 period I focus on in the empirical results, US issuance grew starkly, increasing more than fourfold from $50 billion to over $200 billion by 2007. Caballero (2009) explains the global forces behind the increases in mortgage securi-
tization in this period. Growth in emerging economies combined with a commodity price boom lead to swelling sovereign wealth funds and thus a large increase in the pool of global savings with a directive to invest in safe assets. This increased demand faced a limited and relatively fixed supply of highly rated corporate debt. Thus the impetus was provided for the credit transformation made possible by the tranche structure of securitized assets. This process afforded a mechanism for funneling the increase in global savings earmarked for low-risk investments into riskier outlets like subprime residential loans and commercial mortgages.

The manifestation of these financial market effects were rising sale prices and increased construction of commercial properties. Gyourko (2009) surveys these trends, focusing on the 2003 to 2008 period. He attributes more than half the rise in commercial property prices to an increase in the multiplier investors placed on a dollar of rents, rather than on rising cash flows. In addition to investor exuberance, lenders showed deteriorating underwriting standards, including the proliferation of pro forma loans in which hoped for rent increases were credited as certainties. Local commercial and residential sectors are expected to experience similar changes, and Gyourko does find that office building prices rose relative to construction costs in concert with the same relation for a city’s house prices. Notably though, he finds that for commercial real estate two-thirds of the variation in asset values and total return are explained by a common national effect. This compares to the housing market where only 27% of the variation in price changes are attributable to a national factor.

In summary, the recent boom in office construction is heavily attributable to national and international currents in financial markets, with new development being supported by cheaper financing and increased investor interest in owning office buildings. This contrasts with the 1980s boom which, though later supported by over-lending, was initiated by rapid transformation of the economy into office-based
employment. Yet while all cities were experiencing expansion from this national office construction shock, the intra-metropolitan distribution of new development had a more local flavor.

The degree to which office completions were suburban focused across all cities during the recent boom is evident in Figure 3.3. Though this was not the whole story, the fastest growing areas in terms of office stock during the more recent boom did tend to be cities which were already heavily suburban. As a rough accounting for proportional growth, I apply 1996 levels of the suburban share of office stock in each city to the subsequent growth in suburban stock from 1996 to 2007. By this metric approximately 27% of the increase in the sample MSAs suburban stock was not accounted for by overall city expansion. The same figure computed for the pre-boom period of 1988 to 1996 was only 13%.

Lang (2000) shows that expansion of the urban fringe was a feature of the 1980s boom as well, rather than part of an unbroken trend of suburbanization. Instead of CBDs, his data compares primary central cities with suburbs. He finds that from 1979 to 1989 the share of metropolitan office space in primary central cities fell from 67% to 48%, but then barely gave up another 1% over the next 10 years. A potential explanation for this feature of commercial construction booms comes from the literature on land assembly. Inefficiencies in the market for urban land and its potential consequences for new development have long been considered from a theoretical perspective. The link between land assembly frictions and urban sprawl offer one explanation for the variation across cities in the degree to which recent commercial development has been suburban focused.

Office stock and completion figures understate suburban numbers. Buildings under 10,000 square feet (with higher limits in some bigger cities) are excluded so small office buildings in the suburbs are not counted.
Regulatory, technical and efficiency concerns can all militate for larger scale in the development of a new office property. Sufficiently large plots are rare so multiple smaller contiguous plots must be assembled. This process is costly and the cost is increasing in the number of distinct owners with whom the developer must bargain. Miceli and Sirmans (2007) model this situation as a holdout problem, where incumbent owners jockey to be the last to sell to the developer in order to reap the surplus from the land assembly, with this drawn out bargaining process leading to costly delays in development. They argue that nearer to the CBD, land ownership will be more dispersed as higher land prices drive smaller housing demand and substitution of capital for land. The inverse relationship between dispersion of ownership and distance from the CBD, combined with developers wish to avoid bargaining costs, will bias development toward the urban fringe where land ownership is more consolidated and assembly costs are thus lower. Colwell and Munneke (1999), using data from Cook County, Illinois, find that for commercial land, prices in the CBD are much less concave in lot size then in the rest of the county, and argue that this is indicative of more significant holdout problems in land assembly in the downtown area. Most recently, Brooks and Lutz (2010) conduct an empirical study of land sales using an 11 year panel from Los Angeles County. They find that parcels slated for assembly trade at a premium and that developers are more likely to assemble larger parcels. They interpret this as strongly rejecting the hypothesis of efficient operation of the market for urban land. Thus, theoretical and empirical work on land assembly highlights significant frictions that will bias development away from CBDs and towards the urban fringe. Further it suggests a source of variation across cities, unrelated to local industrial composition, in the extent to which new waves of commercial development will be channeled between CBDs and suburban areas: historical dispersion of ownership. This is the inspiration for one of the instruments I propose for explaining changes in CBD scale.
3.4.2 Instruments

Empirical work on land assembly has to date focused only on one city at a time, yielding no standard measure of cross-city differences in the difficulty of CBD land assembly. The literature suggests that the extent of historical dispersion of parcel ownership is a good gauge of the frictions facing a potential CBD development. As an indicator of this dispersed ownership I will use the initial share of a citys CBD office stock which is not Class A space as observed in the TWR data. Class A office buildings are marked by better exterior facades and interior common spaces, as well as more extensive building services like security and maintenance. As seen in Figure 3.4, while new class B/C buildings are sometimes built in suburban areas, only new class A space is delivered in CBDs. In fact, CBD class B space typically results from pre-war buildings which have filtered down in quality over time. As discussed in Willis (1995), office buildings built at that time had much smaller footprints for technological reasons: prior to cooler fluorescent lighting and the advent of air conditioning, office dwellers needed to be fairly close to windows for the natural light, limiting the usability of interior space. In short, a CBDs share of sub class A space will proxy for land assembly difficulties to the extent that more class B/C space is indicative of smaller plots and greater dispersion of ownership resulting from the age of the CBDs office stock. The CBD share of class B/C office space averages 43%, though ranging greatly across cities from 7 to 79%.

Geographic restrictions on development are the source for the other instruments used in this analysis. I use the land cover measures made available by the work of Saiz (2010). He computes the share of land unusable for residential or commercial development within a 50 km radius of the central city of each metropolitan area. The measure is a combination of unusable land cover types: land with unbuildably steep
slope (above 15%), wetlands, lakes, rivers, and other internal bodies of water, plus the oceans and great lakes. Saiz finds that geographic constraints decrease housing supply elasticity and drive higher house prices and house price growth over time. It is plausible that variation across cities in the spatial distribution of its buildable land will mediate where geographically a commercial construction shock will play out. For example, cities which are near the ocean or great lakes generally have their downtown directly on the water. This is also true for rivers which frequently divide central cities. In contrast, nearby mountains or otherwise rugged terrain would tend to constrain suburban expansion. To the extent that these different land cover types are correlated with the degree to which new office space is delivered in the suburbs rather than downtown, they will be relevant predictors of changes in CBD scale during the construction boom.

The end goal is to jointly estimate the effects of CBD scale and metropolitan scale on firm productivity to compare the relative magnitudes of agglomeration effects for the two different measures of geographic proximity. The land cover and land assembly variables are proposed as predictors of changes in the intra-metropolitan distribution of office establishments over time, distinct from overall growth effects. In order to separately predict changes in overall metropolitan office sector scale I will use a measure of predicted growth as an additional instrument. This measure is motivated by Bartik (1991) and relies on changes in the relative prominence of industries nationally outside the target city. These changes are then interacted with the initial share of each of these sectors locally. Specifically, the measure of metropolitan predicted establishment growth I compute is:

\[ \text{pred} \Delta \ln E_c = \ln \gamma_{c,t} - \ln E_{c,t} \]  

(3.8)
where for the sum over all 2-digit industries $k$:

$$\gamma_{c,t} = \sum_k \rho_{c,k,t} \left( \frac{\rho_{c,k,t+1} - \rho_{c,k,t}}{\rho_{c,k,t}} \right)$$  \hspace{1cm} (3.9)

Here $\rho_{c,k,t}$ is the national share of industry $k$ at time $t$ excluding city $c$. This is a relevant instrument if cities with larger shares of growing national industries expand more, and that this overall expansion in metropolitan size is correlated with growth in the office-based sector. By excluding the own-city impact on national changes in relative industry prominence, the measure is plausibly unrelated to any factors besides scale changes which are affecting firm productivity locally.

The variation in the suburban focus of construction across cities is evidenced in Figure 3.5. At any point in time, different cities exist with substantially different orientations towards their CBDs, with New York having nearly 80% of its office stock downtown, and a city like Los Angeles having more than 80% in the suburbs. Panel A shows changes in each sample MSAs suburban share of office stock during the pre-boom period. Interestingly, a number of cities were becoming less suburban focused over this span, particularly those that began the period with a large share of their office stock in the suburbs. During the construction boom, presented in Panel B, almost all cities were becoming increasingly suburban, but with substantial variation in the degree, ranging from almost no change to a nearly 15% shift into suburban stock. As discussed above, the literature on urban sprawl predicts this suburb biased growth during periods of rapid development. The evident cross-city variation at the heart of the empirical analysis will be shown, in the first stage results presented below, to be partially attributable to plausibly exogenous geographic and land assembly characteristics particular to each metropolitan area.
3.4.3 First stage results

The results of this study's central first stage are reported Table 3.2, where changes in the scale of CBD and Metropolitan area office sectors are regressed on the land cover variables and land assembly proxy.

As seen in column 2, three of the six instruments are significant predictors of changes in CBD scale. Internal water share (rivers and lakes) is negatively associated with changes in CBD scale. This may reflect the fact that CBDs are often traversed by rivers which could constrain expansion. Wetlands is a positive predictor which likely reflects constraints on suburban expansion from lack of land or environmental restrictions. The proxy for CBD land assembly frictions, share of office stock which is not class A, is a negative predictor of CBD expansion as expected. The overall shift share variable is added in column 3. It is positively related to CBD expansion, though is not statistically significant, and does not impact the relationship of the other instruments.

For comparison purposes, column (1) reproduces the first stage in levels for 2002. Recall that the motivation for the instruments relevance in explaining changes in CBD scale are based on their interaction with a period of rapid commercial development. The instruments do have some predictive power for the cross-section of CBD scale, but mostly in different direction than in the changes specification. Internal water share is associated with larger CBDs. Non-ocean share is also a strong negative predictor of CBD scale which may reflect the historical centralizing of development around ports. Finally, column 4 presents the other first stage for changes in the overall metropolitan scale of each sector. The overall shift share variable, the predicted change in overall metropolitan size, is a strong positive predictor. While some of the land cover variables also predict changes in metropolitan area scale, the
shift share instrument and land assembly proxy in particular are picking out separate variation in the two endogenous variables. The next section incorporates these first stage specifications into two stage least squares estimates of agglomeration effects from CBD and metropolitan scale.

### 3.5 Results

I assess the effects of localization economies on productivity in the office sectors as reflected in wages. The analysis is performed first for metropolitan scale only and then jointly with both CBD scale and metropolitan scale treated as endogenous. Table 3.3 contains summary statistics for the 44 MSAs used in the wage regressions. Panel A, which reports 2002 levels, shows the sample cities range widely in terms of CBD and overall metro office sector scale. Unsurprisingly, in the cross-section, CBD scale is strongly related to metropolitan scale, with a correlation of about 0.72.

The estimates in Table 3.4 consider overall metropolitan scale of the office sector. Without the need to define CBDs, this specification can be estimated across all 316 MSAs. This is more in the spirit of past studies of agglomeration economies, which seek to estimate the impact of industry localization on wages for an entire city or region. It differs in that most previous studies have not considered office based service sectors, nor made use of a Bartik-type instrument for changes in local scale. Column 1 based on 2002 levels yield a coefficient of 0.15. Column 2 is for an estimate in changes which is implemented to address bias from any unobserved local fixed factors affecting productivity and scale as well as partially addressing the effects of worker sorting. The coefficient on metro scale remains similar at 0.13. Column 3 instruments for changes in office sector scale using predicted metropolitan
growth for all sectors based on initial local industrial composition interacted with national growth in each 2-digit industry. The result is a larger point estimate for localization economies in this sector of 0.29. This implies a very significant role for local interaction in this sectors productivity, above even previous estimates for high tech manufacturing.

Table 3.5 reports results for the effects of CBD and metropolitan scale estimated simultaneously. Column 1 shows the results based on 2002 levels of metropolitan area wages, CBD scale, and metropolitan scale disaggregated into the five office-based sectors in the 44 cities with delineated CBDs. All specifications include industry fixed effects and standard errors are clustered at the metropolitan area level. Wages are increasing in both a sector’s CBD and metropolitan scale, though only CBD is statistically significant. The coefficient on CBD scale implies a 1% increase in wages for a 10% increase in CBD scale, holding metropolitan scale constant. Column 2 is estimated in changes. In addition to addressing fixed sources of bias as discussed above, changes in CBD and metropolitan office sector scale are less codetermined than are levels: the correlation between changes in the two scale measures is about 0.52. The CBD coefficient is similar in magnitude though imprecisely estimated, while the coefficient on metropolitan scale is negative. Column 3 presents the two stage least squares estimates, where both CBD and metropolitan scale change variables are instrumented with the shift share predicted growth variable, the land cover measures, and the proxy for CBD land assembly difficulties. Assuming the instruments are valid, these coefficients represent the causal effect of local scale in the office based sectors on productivity as measured through wages. The estimated impact of CBD scale on wages is larger than the OLS estimates and is marginally statistically significant. It implies a 5% increase in wages for a 10% increase in CBD scale, holding metropolitan scale constant. The coefficient on metropolitan scale is negative,
though statistically insignificant. There is a consistent pattern when these two geographic units are considered jointly: the effect of CBD scale remains while that of metropolitan scale is substantially diminished. This suggests that close proximity in the core sub-city level cluster matters more than overall city presence, and in fact largely drives results from estimates performed only at the aggregate city level. In the next section I perform some robustness checks and further probe the validity of the instruments.

3.6 Robustness

While wage premia have been frequently used in previous studies to discern agglomeration effects, theoretical models of urban land use point to rents as the more natural place to look for the capitalization of agglomeration benefits in productivity. In one of the few studies to incorporate rents, Arzaghi and Henderson (2008) find evidence that agglomeration economies are predominately compounded into rents. This questions the sole use of wage data to infer agglomeration benefits, particularly within a single city where similar workers will command equal wages but large spatial disparities in rents, reflecting the existence of more productive locations within a city, can persist.

Figure 3.6 plots the downtown office rent premium for the metropolitan areas used in this study. At the start of the commercial construction boom, CBDs exhibited a rent premium of about 33% over the rest of the metro area. This figure grew significantly over the course of the boom, with a particularly precipitous increase during the 2002 to 2007 window which is the focus of the current study. By the peak in 2008, downtown rents were on average nearly 80% higher than in the
The framework used in this paper assumed that CBDs offered additional local agglomeration benefits while the suburbs offered only access to externalities from overall city scale. Further, development of new suburban office space driven by cheaper financing was depressing suburban rents even further relative to the CBD and thus luring relocations to, and new firm births in, the suburbs. An alternative explanation for this observed rent trend is that initially existing suburban submarkets offer some degree of local scale externalities, but that new office space during the boom was being delivered in increasingly remote locations. These new suburban locations provided less scope for local interaction then older suburban clusters and thus commanded lower rents, driving down average suburban office rents relative to CBD rents.

If within city differences in agglomeration effects are revealed mostly through rents rather than wages, one solution is to look directly at output. The results from such an exercise are shown in Table 3.6. As discussed in section 3, I collected metropolitan area output data from the BEA. This data is reported with some industrial detail, but in practice these figures are heavily censored, so sample size is smaller than with the wage regressions. The outcome variable here is log GDP per worker. In column 1, which is in levels, GDP per worker is increasing in CBD and metropolitan scale, but the CBD coefficient is larger and more statistically significant as with the wage specifications. Column 2 is estimated in changes, while column 3 presents two-stage least squares estimates using the aforementioned instruments. The estimated coefficients are not statistically significant owing to the smaller sample size, but do consistently show that the positive relationship between changes in CBD scale and output per worker remains, while that between metropolitan scale

---

6 The rent indices used are constructed by TWR using hedonic regressions at the building level. The intent is to extract a rent figure which is independent of the characteristics of the stock of office buildings at a particular location or point in time.
is actually negative. In general, these results reinforce the message of the more precisely estimated findings from wages.

The relevance of the instruments is predicated on the assumption that greater expansion in suburban office stock relative to CBD stock drives up the relative rent premium between the two locations. This begs the question of whether firms were actually enticed into the new suburban developments and whether factors related to changing production technology in the office-based sector independent of rent differentials were changing demand for suburban space. Figure 3.7 plots the history of vacancy rates at the metropolitan and CBD level.\textsuperscript{7} Vacancy rates had declined to about 10\% at the start of the construction boom, but begin rising in 2000. For the 2002 to 2007 period used in this paper's analysis the rate remains elevated, oscillating around 15\%. Most notably, CBD and metro vacancy rates remain very similar, implying that firms were in fact occupying the new suburban space.

The specific form that suburban development takes is considered in McDonald and McMillen (2000) who look at patterns of decentralization in Chicago from 1990 to 1996 including for commercial space. They find that commercial development is attracted to traditional measures of access to the urban transportation network, including O'Hare Airport and highway interchanges, as well as being more likely in locations with more land devoted to agriculture. They cite earlier patterns of development as taking place along traditional highway and rail spokes, with more recent expansion now filling in the gaps at a lower density. Existing employment subcenters are also magnets for commercial development. They note that suburban areas now often have large subcenters with significant density, and argue that a city

\footnote{Metro vacancy data for the entire span and CBD vacancy rates since 1988 are from the TWR data described in section 3. For comparison purposes data on CBD vacancy for the earlier period was collected. This data is from Coldwell Banker but the cities over which it is computed are not known. The data series is printed in Hester (2002).}
which expands via subcenters is more centralized than one that expands by pushing firms and households to the urban periphery.

Table 3.7 looks at the possible determinants of the expansion of individual suburban submarkets over the 2002 to 2007 study period for the sample MSAs. The change in log office space for a given suburban submarket is estimated as a function of 2002 office stock, class B/C share, vacancy rate, and rent level. The only variable consistently associated with growth rates is the initial size of the stock, which is a strong negative predictor of submarket expansion. So new development was proportionally more likely in initially less developed submarkets, but was otherwise not being drawn by areas with growing locational advantage which would be expected to show up in initially lower vacancy rates or higher rents. Additionally, initial class B/C stock share is unrelated to new development, implying that there are not significant differences in land assembly constraints across the different suburban submarkets.

Regarding productivity based sorting, ideally I would base estimates on individual firms which could be observed over time and use firm fixed effects. Though the fact that this study uses average wages and productivity across the entire metropolitan area, rather than just in the CBD, means that a finding of a lack of agglomeration externalities would not be an artifact of the relocation of the least productive firms to the suburbs. If firms do experience heterogeneous agglomeration externalities, and sorting on productivity occurs, than the agglomeration effects estimated in this study will be identified off of those firms who gain the most from the close proximity of firms in the CBD, implying a higher estimate than what the average firm would experience.

One final issue is the potential for higher CBD rents to drive factor input substitution. Brinkman, Coen-Pirani, and Sieg (2010) find evidence of firms operating
with less office space per employee in the CBD relative to the rest of the metropolitan area. This follows on Robacks work which envisions the potential productivity depressing effects of such substitution driven by differences across cities in overall land price level. Factor input substitution could bias estimates in this papers empirical framework if migration of firms to the suburbs holds down rent appreciation in the CBD, which in turn allows firms to operate with more space per worker. That said, within the office-based sector, the role of space per employee in the production function, at least within some reasonable range, is not plainly apparent. In fact, some firms even institute open floor plans, without offices or cubicles, intimating that the relationship between office space and worker productivity is not necessarily always positive. Another possibility is that firms use additional office space as a non-pecuniary form of remuneration. The data collected for this study are not appropriate for addressing this issue so it is left as a question for future research.

3.7 Conclusion

In this paper I sought to discern the geographic scope of agglomeration economies in the office-based sector. I collected establishment counts over time at the zip code level as a measure of the potential for interactions among nearby firms. This local scale data was combined with data describing the arrangement and evolution of the office market across a sample of cities. I described the financially driven recent boom in commercial construction and demonstrated how it differentially altered the spatial distribution of office stock between the CBD and the suburbs across metropolitan areas. A set of instruments characterizing local geographic constraints to development as well as a proxy measure of land assembly frictions in the CBD

\footnote{See e.g., Levitt, David M. Manhattan Builders Plan Biggest Decade for Towers Since 80s. Bloomberg News (May 20, 2011).}
were introduced and their relevance for predicting changes in CBD office sector scale were presented. These instruments, along with a standard predicted growth measure based on local industrial composition, were employed through two stage least squares to estimate the causal effect of CBD and metropolitan scale on productivity as reflected in wages. Joint estimates of the effect of firm proximity measured for the two geographic scales demonstrated that the close proximity of firms within the CBD, rather than just within the same city, underpins metropolitan wage premia in the office-based sectors. Parallel estimations using GDP per worker in place of wages were less precise though still consistent with this interpretation.

Understanding the role of within city differences in employment density on local interactions is useful both for measuring the size and geographic scope of agglomeration effects, as well as for assessing the relative importance of the different mechanisms thought to underpin the existence of scale externalities. The fact that firms in these office-based sectors only receive the productivity enhancing benefits of external scale economies from very nearby establishments highlights the role of knowledge spillovers. Given the increased importance of office-based industries in the economy, it is worthwhile for researchers to gain a better grasp on the strength and nature of agglomeration economies for these firms. Future work can improve understanding of agglomeration linkages in these sectors with the use of firm and worker level data.

3.8 Tables and Figures
Figure 3.1: Office stock and completions

Note: For 57 TWR markets
Figure 3.2: Commercial mortgage backed security issuance

Source: Commercial Mortgage Alert
Figure 3.3: Office completions - CBD vs. Suburbs
Figure 3.4: Office stock by class and location

Note: Data restricted to sample MSAs
Figure 3.5: Changing intra-MSA office space allocation
Figure 3.6: Downtown rent premium

Note: Weighted average of MSA rent indices weighted by total MSA space
Figure 3.7: Office vacancy history
Table 3.1: Office sector statistics

Panel A: Office sector share of overall metro establishments

<table>
<thead>
<tr>
<th>2-digit industry</th>
<th>Mean</th>
<th>SD</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Information</td>
<td>0.02</td>
<td>0.00</td>
<td>0.01</td>
<td>0.03</td>
</tr>
<tr>
<td>Finance</td>
<td>0.06</td>
<td>0.01</td>
<td>0.05</td>
<td>0.08</td>
</tr>
<tr>
<td>Real Estate</td>
<td>0.04</td>
<td>0.01</td>
<td>0.02</td>
<td>0.08</td>
</tr>
<tr>
<td>Prof. and Tech. Services</td>
<td>0.12</td>
<td>0.02</td>
<td>0.07</td>
<td>0.18</td>
</tr>
<tr>
<td>Management of companies</td>
<td>0.01</td>
<td>0.01</td>
<td>0.00</td>
<td>0.11</td>
</tr>
<tr>
<td>Administrative and support</td>
<td>0.06</td>
<td>0.01</td>
<td>0.04</td>
<td>0.08</td>
</tr>
<tr>
<td>Other services</td>
<td>0.02</td>
<td>0.01</td>
<td>0.01</td>
<td>0.04</td>
</tr>
<tr>
<td>Total office sectors</td>
<td>0.32</td>
<td>0.04</td>
<td>0.24</td>
<td>0.42</td>
</tr>
</tbody>
</table>

Panel B: Proportion of a metro’s office sector establishments located in the CBD

<table>
<thead>
<tr>
<th>2-digit industry</th>
<th>Mean</th>
<th>SD</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Information</td>
<td>0.15</td>
<td>0.14</td>
<td>0.02</td>
<td>0.68</td>
</tr>
<tr>
<td>Finance</td>
<td>0.14</td>
<td>0.12</td>
<td>0.03</td>
<td>0.60</td>
</tr>
<tr>
<td>Real Estate</td>
<td>0.12</td>
<td>0.11</td>
<td>0.01</td>
<td>0.61</td>
</tr>
<tr>
<td>Prof. and Tech. Services</td>
<td>0.17</td>
<td>0.12</td>
<td>0.04</td>
<td>0.65</td>
</tr>
<tr>
<td>Management of companies</td>
<td>0.16</td>
<td>0.15</td>
<td>0.03</td>
<td>0.75</td>
</tr>
<tr>
<td>Administrative and support</td>
<td>0.10</td>
<td>0.10</td>
<td>0.02</td>
<td>0.57</td>
</tr>
<tr>
<td>Other services</td>
<td>0.18</td>
<td>0.12</td>
<td>0.03</td>
<td>0.59</td>
</tr>
<tr>
<td>Total office sectors</td>
<td>0.15</td>
<td>0.12</td>
<td>0.03</td>
<td>0.62</td>
</tr>
</tbody>
</table>

Panel C: Office sector share of overall CBD establishments

<table>
<thead>
<tr>
<th>2-digit industry</th>
<th>Mean</th>
<th>SD</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Information</td>
<td>0.02</td>
<td>0.01</td>
<td>0.01</td>
<td>0.05</td>
</tr>
<tr>
<td>Finance</td>
<td>0.09</td>
<td>0.05</td>
<td>0.04</td>
<td>0.35</td>
</tr>
<tr>
<td>Real Estate</td>
<td>0.04</td>
<td>0.01</td>
<td>0.02</td>
<td>0.07</td>
</tr>
<tr>
<td>Prof. and Tech. Services</td>
<td>0.22</td>
<td>0.07</td>
<td>0.07</td>
<td>0.40</td>
</tr>
<tr>
<td>Management of companies</td>
<td>0.02</td>
<td>0.05</td>
<td>0.00</td>
<td>0.39</td>
</tr>
<tr>
<td>Administrative and support</td>
<td>0.05</td>
<td>0.01</td>
<td>0.03</td>
<td>0.07</td>
</tr>
<tr>
<td>Other services</td>
<td>0.04</td>
<td>0.02</td>
<td>0.01</td>
<td>0.12</td>
</tr>
<tr>
<td>Total office sectors</td>
<td>0.48</td>
<td>0.12</td>
<td>0.24</td>
<td>0.74</td>
</tr>
</tbody>
</table>
Table 3.2: First stage

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Predicted $\Delta \ln(\text{Metro establishments})$</td>
<td>2.24 (3.13)</td>
<td>9.19*** (2.58)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flat share</td>
<td>0.32 (0.52)</td>
<td>0.051 (0.064)</td>
<td>0.066 (0.058)</td>
<td>-0.013 (0.062)</td>
</tr>
<tr>
<td>Internal water share</td>
<td>12.6* (6.42)</td>
<td>-1.26** (0.62)</td>
<td>-1.28** (0.62)</td>
<td>-1.53*** (0.40)</td>
</tr>
<tr>
<td>Wetlands1 share</td>
<td>-1.32 (1.04)</td>
<td>0.11 (0.10)</td>
<td>0.12 (0.10)</td>
<td>0.30*** (0.076)</td>
</tr>
<tr>
<td>Wetlands2 share</td>
<td>-3.38 (2.42)</td>
<td>0.41** (0.18)</td>
<td>0.39** (0.18)</td>
<td>0.63*** (0.17)</td>
</tr>
<tr>
<td>Non-ocean/great lakes share</td>
<td>-1.42** (0.59)</td>
<td>-0.025 (0.070)</td>
<td>-0.026 (0.066)</td>
<td>0.18*** (0.049)</td>
</tr>
<tr>
<td>CBD class B share</td>
<td>0.13 (0.56)</td>
<td>-0.17** (0.076)</td>
<td>-0.17** (0.074)</td>
<td>-0.064 (0.043)</td>
</tr>
<tr>
<td>Constant</td>
<td>-1.38 (1.27)</td>
<td>0.0025 (0.070)</td>
<td>-0.013 (0.069)</td>
<td>-0.033 (0.058)</td>
</tr>
<tr>
<td>Observations</td>
<td>220</td>
<td>220</td>
<td>220</td>
<td>220</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.808</td>
<td>0.258</td>
<td>0.259</td>
<td>0.551</td>
</tr>
<tr>
<td>F-stat</td>
<td>2.76</td>
<td>4.09</td>
<td>4.25</td>
<td>9.00</td>
</tr>
</tbody>
</table>

Note: All specifications include industry fixed effects. Robust standard errors clustered by MSA in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 3.3: Summary statistics

Panel A: 2002 levels

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Mean</th>
<th>SD</th>
<th>Min</th>
<th>P5</th>
<th>P95</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wage(metro office sector) $000s</td>
<td>44</td>
<td>48.1</td>
<td>11.9</td>
<td>33.1</td>
<td>34.2</td>
<td>78.8</td>
<td>88.9</td>
</tr>
<tr>
<td>CBD office establishments</td>
<td>44</td>
<td>3,273</td>
<td>6,333</td>
<td>384</td>
<td>478</td>
<td>9,205</td>
<td>41,528</td>
</tr>
<tr>
<td>Metro office establishments</td>
<td>44</td>
<td>23,929</td>
<td>18,707</td>
<td>4,016</td>
<td>6,180</td>
<td>70,863</td>
<td>88,658</td>
</tr>
</tbody>
</table>

Panel B: 2002-2007 percent changes

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Mean</th>
<th>SD</th>
<th>Min</th>
<th>P5</th>
<th>P95</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wage(metro office sector)</td>
<td>44</td>
<td>0.29</td>
<td>0.08</td>
<td>0.14</td>
<td>0.19</td>
<td>0.43</td>
<td>0.46</td>
</tr>
<tr>
<td>CBD office establishments</td>
<td>44</td>
<td>0.01</td>
<td>0.07</td>
<td>-0.20</td>
<td>-0.07</td>
<td>0.12</td>
<td>0.13</td>
</tr>
<tr>
<td>Metro office establishments</td>
<td>44</td>
<td>0.13</td>
<td>0.08</td>
<td>-0.01</td>
<td>0.03</td>
<td>0.24</td>
<td>0.32</td>
</tr>
</tbody>
</table>

Note: All specifications include industry fixed effects. Robust standard errors clustered by MSA in parentheses. *** p<0.01, ** p<0.05, * p<0.1.
### Table 3.4: Metro level estimates

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>ln(Metro establishments)</td>
<td>0.15***</td>
<td>0.13*</td>
<td>0.29*</td>
</tr>
<tr>
<td></td>
<td>(0.0083)</td>
<td>(0.077)</td>
<td>(0.17)</td>
</tr>
<tr>
<td>Constant</td>
<td>2.27***</td>
<td>0.20***</td>
<td>0.18***</td>
</tr>
<tr>
<td></td>
<td>(0.064)</td>
<td>(0.011)</td>
<td>(0.020)</td>
</tr>
<tr>
<td>Observations</td>
<td>316</td>
<td>316</td>
<td>316</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.563</td>
<td>0.011</td>
<td></td>
</tr>
</tbody>
</table>

Note: Robust standard errors clustered by MSA in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

### Table 3.5: Joint CBD and Metro level estimates

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>ln(CBD establishments)</td>
<td>0.090***</td>
<td>0.15</td>
<td>0.50*</td>
</tr>
<tr>
<td></td>
<td>(0.028)</td>
<td>(0.12)</td>
<td>(0.26)</td>
</tr>
<tr>
<td>ln(Metro establishments)</td>
<td>0.055</td>
<td>-0.11</td>
<td>-0.20</td>
</tr>
<tr>
<td></td>
<td>(0.034)</td>
<td>(0.11)</td>
<td>(0.21)</td>
</tr>
<tr>
<td>Constant</td>
<td>2.37***</td>
<td>0.16***</td>
<td>0.19***</td>
</tr>
<tr>
<td></td>
<td>(0.18)</td>
<td>(0.020)</td>
<td>(0.035)</td>
</tr>
<tr>
<td>Observations</td>
<td>220</td>
<td>220</td>
<td>220</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.757</td>
<td>0.155</td>
<td>0.017</td>
</tr>
</tbody>
</table>

Note: All specifications include industry fixed effects. Robust standard errors clustered by MSA in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

### Table 3.6: Output estimates

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>ln(CBD establishments)</td>
<td>0.086*</td>
<td>0.036</td>
<td>0.041</td>
</tr>
<tr>
<td></td>
<td>(0.044)</td>
<td>(0.050)</td>
<td>(0.15)</td>
</tr>
<tr>
<td>ln(Metro establishments)</td>
<td>0.060</td>
<td>-0.12</td>
<td>-0.044</td>
</tr>
<tr>
<td></td>
<td>(0.043)</td>
<td>(0.10)</td>
<td>(0.13)</td>
</tr>
<tr>
<td>Constant</td>
<td>-4.29***</td>
<td>0.10***</td>
<td>0.096***</td>
</tr>
<tr>
<td></td>
<td>(0.25)</td>
<td>(0.014)</td>
<td>(0.021)</td>
</tr>
<tr>
<td>Observations</td>
<td>123</td>
<td>114</td>
<td>114</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.900</td>
<td>0.798</td>
<td>0.797</td>
</tr>
</tbody>
</table>

Note: All specifications include industry fixed effects. Robust standard errors clustered by CBSA in parentheses. *** p<0.01, ** p<0.05, * p<0.1.
Table 3.7: Suburban submarket growth

<table>
<thead>
<tr>
<th>Dependent Variable: Δ ln(Office stock)</th>
<th>2002-2007</th>
</tr>
</thead>
<tbody>
<tr>
<td>ln(Office stock)</td>
<td>-0.11***</td>
</tr>
<tr>
<td></td>
<td>(0.023)</td>
</tr>
<tr>
<td>Class B/C share</td>
<td>-0.0069</td>
</tr>
<tr>
<td></td>
<td>(0.063)</td>
</tr>
<tr>
<td>Vacancy rate</td>
<td>0.0029*</td>
</tr>
<tr>
<td></td>
<td>(0.0015)</td>
</tr>
<tr>
<td>Gross asking rent</td>
<td>-0.0019</td>
</tr>
<tr>
<td></td>
<td>(0.0024)</td>
</tr>
<tr>
<td>Constant</td>
<td>0.96***</td>
</tr>
<tr>
<td></td>
<td>(0.21)</td>
</tr>
<tr>
<td>Observations</td>
<td>551</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.224</td>
</tr>
</tbody>
</table>

Robust standard errors clustered by MSA in parentheses. *** p<0.01, ** p<0.05, * p<0.1.
APPENDIX A

Derivation of multi-period tenure choice decision
This section works through the derivation of the relative owner cost expression used in the tenure choice regressions. It is adapted from the model used in Glaeser, Gottlieb, and Gyourko (2013). First I show how the downpayment term drops out of the user cost of owning expression for non-credit constrained households. Then I show that under certain assumptions, a model where households have uncertain duration in their housing unit yields the same financial comparison at the time of a move as the one period model used in the body of the paper.

An owner occupier household is assumed to make its house payments at the end of the period, covering the mortgage, property tax at a rate $h_m$, and depreciation payments at a rate $d$. The mortgage interest rate $r_t$ is applied to the loan balance $(1-\gamma)p_{m,t}^\circ$ where $\gamma$ is the downpayment proportion. Mortgage interest and property tax payments are tax deductible at the household’s tax rate of $\tau^i$.

The one period user cost of owning for a household who sells at the end of the period is:

$$c_{m,t}^i p_{m,t}^\circ = \gamma p_{m,t}^\circ + \frac{1}{1 + \rho^i} \left\{ [(1-\tau^i)(1-\gamma)r_t + (1-\tau^i)h_m + d]p_{m,t}^\circ - [p_{m,t+1}^\circ - (1-\gamma)p_{m,t}^\circ] \right\}$$

$$= \frac{p_{m,t}^\circ}{1 + \rho^i} \left[ \rho^i \gamma + (1-\tau^i)(1-\gamma)r_t + (1-\tau^i)h_m + d - g_{m,t} \right] \tag{A.1}$$

where $\rho^i$ is a household’s discount rate and expected house price growth at a rate of $g_{m,t}$ gives $p_{m,t+1}^\circ = (1 + g_{m,t})p_{m,t}^\circ$.

This expression simplifies, with the downpayment parameter dropping out, if it is assumed that a household’s discount rate is equal to the interest rate net of taxes,
\[ \rho^i = (1 - \tau^i) r_t; \]

\[ c_{m,t}^i p_{m,t}^o = \frac{p_{m,t}^o}{1 + (1 - \tau^i) r_t} \left[ (1 - \tau^i)(r_t + h_m) + d - g_{m,t} \right] \quad (A.2) \]

Such a discount rate is appropriate for households who have sufficient savings for a downpayment and thus are not forced to reduce current consumption to purchase a home.

More realistically, households will anticipate staying in a new housing unit for multiple years, and so will make the tenure choice decision based on a present value comparison of the potential future stream of ownership user costs versus rental payments. Under certain assumptions laid out below, the multi-period decision will be an identical comparison of ownership and rental costs as the one-period decision described above.

Mortgage payments are assumed fixed for each period: the nominal amount of the mortgage stays constant and there is no refinancing. The property tax rate \( h_m \) and depreciation costs at a rate \( d \) are applied to the current period’s home value \( p_{m,t+j}^o \). The household has an uncertain duration in the unit which is captured by a fixed per period probability \( \phi \) of leaving the unit.

The probability that a given household will choose to owner occupy its unit is then the result of an expected utility comparison in present value terms denoted by the tildes:

\[ Pr(Own)_{m,t}^i = Pr\{\tilde{U}(Own)_{m,t}^i > \tilde{U}(Rent)_{m,t}^i \} \times Pr(Mortgage)_t^i \quad (A.3) \]

where the probability of securing a mortgage, \( Pr(Mortgage)_t^i \), is assumed to be
independent of the tenure choice utility comparison.

The expected present value of rental payments is computed assuming rents are paid at the end of each period and that rents grow in tandem with housing prices:

\[
P_{m,t}^\rho = \sum_{j=1}^{\infty} \left( \frac{1-\phi}{1+\rho^i} \right)^j \left( \frac{1}{1-\phi} \right) p_{m,t+j-1}^\rho
\]

\[
= \frac{p_{m,t}^\rho}{\rho^i + \phi + \phi g_{m,t} - g_{m,t}} \tag{A.4}
\]

The expected present value of the user cost of owner occupying is similarly given by:

\[
\bar{c}_{m,t}^i p_{m,t}^o = \gamma p_{m,t}^o + \sum_{j=1}^{\infty} \left( \frac{1-\phi}{1+\rho^i} \right)^j \left( \frac{1}{1-\phi} \right) \left\{ r_t (1-\gamma^i) (1-\gamma) p_{m,t+j-1}^o + [h_{m,t}(1-\tau^i) +d] p_{m,t+j-1}^o - \phi[p_{m,t+j-1}^o - (1-\gamma) p_{m,t+j-1}^o] \right\}
\]

\[
= p_{m,t}^o \left\{ \gamma \rho^i + (1-\gamma)(1-\tau^i) r_t + (1-\tau^i) h_m + d - g_{m,t} \left[ 1 - (1-\gamma)(1-\rho^i) \left[ \frac{\rho^i - (1-\tau^i) r_t}{\rho^i + \phi} \right] \right] \right\}
\]

\[
/ \{ \rho^i + \phi + \phi g_{m,t} - g_{m,t} \} \tag{A.5}
\]

Making the same assumption as above, that the household’s discount rate is equal to the interest rate net of taxes, simplifies the expression to:

\[
\bar{c}_{m,t}^i p_{m,t}^o = p_{m,t}^o \left\{ \frac{c_{m,t}^i - g_{m,t}}{\rho^i + \phi + \phi g_{m,t} - g_{m,t}} \right\} \tag{A.6}
\]

where \( c_{m,t}^i = (1-\tau^i)(r_t + h_m) + d. \)
Finally, the individual preference for owner occupancy denoted by $\tilde{\alpha}^i_{m,t}$ is received at the end of each period and is also assumed to grow at a rate $g_{m,t}$ per period, so that $\tilde{\alpha}^i_{m,t} = (1 + g_{m,t})^j \alpha^i_{m,t}$. So as with the rents and user costs, the present value of the flow of ownership benefits is given by:

$$\tilde{\alpha}^i_{m,t} = \frac{\alpha^i_{m,t}}{\rho^i + \phi + \phi g_{m,t} - g_{m,t}}$$ (A.7)

Substituting in the utility expressions and expected present values of the constituent terms derived above into equation (1.8) gives:

$$Pr(Own)_{m,t}^i = Pr\{\tilde{\alpha}^i_{m,t} - \beta_1 \bar{c}^i_{m,t} \rho^o_{m,t} > -\beta_1 \bar{p}^r_{m,t}\} \times Pr(Mortgage)_{t}^i$$

$$\frac{Pr(Own)_{m,t}^i}{Pr(Mortgage)_{t}^i} = Pr\left\{\frac{\alpha^i_{m,t}}{\rho^i + \phi + \phi g_{m,t} - g_{m,t}} - \beta_1 \rho^o_{m,t} \bar{c}^i_{m,t} - g_{m,t} > -\beta_1 \rho^p_{m,t}\right\}$$

$$= Pr\{\alpha^i_{m,t} - \beta_1 (\bar{c}^i_{m,t} - g_{m,t}) \rho^o_{m,t} > -\beta_1 \rho^p_{m,t}\}$$ (A.8)

This is the same as equation (1.11), the tenure choice comparison made by households in a one-period model.

---

1This could reflect increased aptitude for maintenance of the house with longer duration in the unit.
Appendix B

Data appendix
B.1 Office market data

B.1.1 Office submarket definitions

Data on the office market comes from Torto Wheaton Research (TWR). They collect data via their parent company CB Richard Ellis (CBRE), a large national commercial property broker and investor. They have built a proprietary database of office buildings covering 57 self-defined markets. A market is akin to a metropolitan area though is not based on Census definitions (MSA classification is described below). The office building database is updated with the completion of new office buildings over time to create a time series of the stock of office space in the covered markets. TWR subdivides each market into major markets and even smaller submarkets, of which there are 132 and 775 respectively across all markets. For example within the New York market, Midtown Manhattan is a major market, while Rockefeller Center is a submarket. TWR also identifies a CBD in most markets which is a collection of one or more submarkets. A CBD is only identified for the downtown of the principal city of a given market. So for example, the submarket within the New York market known as White Plains CBD within the Westchester County major market is not identified as a CBD, only Downtown and Midtown Manhattan submarkets are classified as a CBD. Further, nine TWR markets are not assigned a CBD: Edison, Long Island, Newark, Orange County, Oxnard, Riverside, Stamford, Trenton, and West Palm Beach, even though in the 1982 Census of Retail Trade, the principal city within these markets has a CBD identified. Further these CBD definitions are static.
B.1.2 TWR Submarkets and ZIP codes

Each submarket is linked to current zip codes, though they are not nested: more than one submarket can cross into the same zip code. About 20% of zip codes host more than one submarket. When combined with Census ZIP business patterns establishment data, figures must be apportioned to submarkets. This is done by computing the proportion of the total submarket net rentable area (NRA) in a zip code attributed to each defined submarket and applying this to the establishment figures.

B.1.3 TWR markets and metropolitan areas

TWR submarkets are assigned to census defined 1999 metropolitan statistical areas (MSAs) and 2002 core-based statistical areas (CBSAs) via ZIP codes. Some metros encompass more than one TWR defined office market, e.g. New York, Long Island, Newark, and Edison TWR markets are all within the New York CBSA. I use the metropolitan area as the relevant market, so TWR office markets are combined when within the same MSA or CBSA.

B.2 Metropolitan areas and ZIP codes

The key linking metropolitan areas to zip codes is from the MABLE geocorr database. This actually matches to ZIP code Census tabulation areas (ZCTAs), the attempt to mesh Census geography with zip codes performed for the 2000 Census. Though USPS ZIP codes are collections of addresses, not polygons like the ZCTAs, for the
dense areas used in this analysis there should be no important distinction between 2000 ZCTAs and 2000 ZIP codes.

Instead, the main issue is with changes in USPS zip codes over time. In particular, as an area grows it is often split into multiple zip codes. Since the submarket definitions use 2010 ZIP codes, not all are found in the MSA or CBSA to 2000 ZCTA key file. When this happens, the matched metropolitan area for another zip code in the same submarket is used. If a submarket straddles more than one metro, the MSA match for the constituent ZIP code with the most office stock is used to project the MSA definitions where missing.

B.3 Census ZIP Business Patterns

The Census ZIP business patterns (ZBP) data provides establishment counts for employment by industry code. These ZIP codes are reported by the establishment so correspond to USPS ZIP codes for the year of data collection.

Correspondence files are used to apply consistent 2002 NAICS industry definitions to 1998-2002 data which follow 1997 NAICS definitions and to 2008 data which follows 2007 NAICS definitions.

To match each years ZBP data into current submarket boundaries, ZIP codes must be traced back over time. Unfortunately, there is no freely available zip code master equivalency file from year to year. Visual inspection via GIS of changes in ZIP code boundaries show that new ZIPs are generally carved out of existing ZIP codes and one piece of the old geographic unit persists with the old code. This means that applying current ZIP code boundaries back in time will tend not to lose any
substantial portions of the intended coverage area.

**B.4 BEA metropolitan area GDP data**

Beginning in 2001, the BEA generates a GDP series at the metropolitan area level (CBSA). They provide real and nominal GDP, with some industrial breakdown (approximately the 3-digit level). There are also worker counts by industry for the same metro areas, though at a coarser industrial level (approximately the 2-digit level). Both series industrial categories are derived from NAICS definitions or combinations of these definitions, but use a different coding system. I construct a key linking the worker, GDP, and NAICS industrial classifications for use with the data from Census Business Patterns.
Bibliography


