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Abstract

The U.S. housing collapse in 2007 is widely blamed for inducing a financial crisis that spread to the real economy and caused a severe and prolonged downturn. This paper investigates the role of rising gas prices and a dramatic gas price shock in triggering the housing market collapse. Specifically, we develop a parsimonious model of housing demand that integrates the Alonso-Muth model of urban form and the Poterba model of housing investment in order to demonstrate that unanticipated increases in gas prices increased the cost of work commutes, lowering the value of homes away from the city center and increasing foreclosure rates.

1 Introduction

In the fall of 2008, the United States suffered arguably the worst financial meltdown in its history and entered a period of economic decline second only to the Great Depression. Two years after the financial collapse, four million families had lost their homes to foreclosure and another four million were seriously delinquent on payments. As many as 26 million Americans—17% of the population—were underemployed and $11 trillion of household wealth was destroyed (FCIC 2011). The U.S. government's Financial Crisis Inquiry Commission (FCIC) concluded that the financial crisis was precipitated by the collapse of a housing bubble that had been fueled by low interest rates, new mortgage products, and easy credit (FCIC 2011). After the housing bubble burst, with

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nearly one in four households owing more on mortgages than the market value of their homes, delinquencies rose and financial institutions suffered huge losses that shook confidence in credit markets. According to the FCIC, as credit markets seized, trading slowed, the stock market fell, consumption declined, and the economy dived into recession.[1]

There is near-universal agreement that the proximate cause of the 2007 financial crisis was the collapse of the housing market (e.g. Mayer 2011, Acharya and Richardson 2010, Mian and Sufi 2010, Acharya, Philippon, Richardson, and Roubini 2009, and Caballero and Krishnamurthy 2009). But our understanding of what triggered the housing market collapse is more limited (Mayer 2011). Considerable research has posited that the housing boom was fueled variably by new mortgage products, lax lending practices, monetary easing, and federal housing policy–factors that extended home ownership to a new class of borrowers characterized by low incomes, high leverage, and low credit worthiness (see Mayer 2011 for a survey). They produced a housing market that by 2005 was susceptible to collapse. But if housing prices had continued to climb instead of turning down, they would have concealed weaknesses in the market as homeowners could have withdrawn equity from their homes to finance debt obligations. Easy credit, then, could not have triggered the collapse.

Taylor (2009), Hubbard and Mayer (2009), and others argued that a monetary contraction in 2005 induced the housing bust, which followed a boom caused by excessive monetary easing earlier in the decade. Glaeser, Gottlieb, and Gyourko (2010), however, showed that low interest rates could explain only a fraction of the 67% increase in home prices over eight years. Greenspan (2010) and Bernanke (2010) further contended that the Federal Funds rate controlled by the central bank should have only a modest impact on the housing market, which is more likely driven by long-term interest rates charged on mortgages. Bernanke (2010) also observed that high rates of housing price

[1] The role of asset price bubbles in financial crises is well documented (e.g. Reinhart and Rogoff 2008; Borio and Lowe 2002; Bernanke and Gertler 2000; Allen and Gale 1999; Kaminsky and Reinhart 1999), as is the spread of financial crises to the real economy (e.g. Reinhart and Rogoff 2009; Bordo 2009; Allen and Gale 1999; Bernanke 1983b; Friedman 1984; Kindleberger 1978; Mishkin 1978; Friedman and Schwartz 1963; Hart 1938; Fisher 1933). As Bordo (2009) explained, a displacement spurs a boom in investment financed by bank money and new credit instruments. The investment boom can lead to bubble-inducing euphoria among investors who have difficulty discerning the riskiness of assets. Asset prices rise faster than fundamentals suggest they should and investors become over-indebted. When the asset bubble reverses, a crisis "can lead to fire-sales of assets, declining net worths, bankruptcies, bank failures, and an ensuing recession" (p. 40). Housing bubbles preceded economic decline in each of the major bank-centered crises of the post-war industrialized world, including the crises in Spain in 1977, Norway in 1987, Finland and Sweden in 1991, and Japan in 1992. Based on a comparison of asset prices, real economic growth, and public debt across 18 post-war financial crises in industrialized countries, Reinhart and Rogoff (2008) contended that the U.S. crisis in 2007 was archetypal except to the degree that home prices escalated before the crisis.

The crisis of 2007 is understood as the consequence of aggressive lending behavior that left the U.S. banking sector ill-prepared for a reversal in the housing boom. Starting in about 2000, the U.S. experienced large and sustained capital inflows from foreigners seeking risk-less assets (Caballero 2010, Caballero and Krishnamurthy 2009). Banks used securitization to meet demand and avoid regulation-induced capital-adequacy constraints. But the securitization boom concentrated risk on the balance sheets of U.S. financial institutions so that, as Caballero and Krishnamurthy (2009) noted, the U.S. "increasingly specializes in holding its own toxic waste." When housing prices turned, the capital of financial institutions eroded and lending standards and margins tightened. Fire sales ensued and credit dried up (**?**).

appreciation predated monetary easing by several years. Apart from theories that blame monetary policy, we are aware of no explanation in the literature for what triggered the housing market collapse.

Shiller (2009, 2008, and 2007)) pointed to market psychology as the cause of dramatic housing appreciation that could not be supported by market fundamentals alone. Shiller (2009) described "an epidemic of irrational public enthusiasm for housing investments" that fueled a classic speculative bubble. A bubble, by definition, must burst, but Shiller conceded that it is unknown what caused this bubble to burst when it did. The bubble theory is supported by Case and Shiller (1989 and 2006), who showed that expectations about future price changes are highly correlated with lagged price changes, a central ingredient for irrational exuberance. Mayer and Sinai (2009) showed that medium-term, backward-looking expectations are significant determinants of the deviation of home prices from rental value.[2] Ferreira and Gyourko (2011) found that the geography, timing and magnitude of local housing booms is "suggestive of a role for contagion in explaining the spread of the boom across markets."

In this paper, we develop a theory that unanticipated gas price increases triggered the housing crisis in 2007. For much of the housing boom in the 1990s and early 2000s, and indeed since the mid-1980s, world oil prices remained relatively flat at $30 per barrel in constant 2011 dollars; U.S. retail gasoline prices were typically below $2.00 per gallon in real terms. In nominal terms, gas prices were below $1.50 per gallon from January 1976 to March 2000. Low energy prices during the housing boom, in combination with lax lending practices and new mortgage products, made suburban houses affordable to a new class of homeowners characterized by low incomes, high leverage, low credit worthiness, and long work commutes. As a result, housing markets by 2005 were fragile. When oil prices more than doubled between late 2005 and mid-2008, peaking at a record high $129 per barrel in July and sending gas prices to $4.15 per gallon, the calculus of suburban living changed. High commute costs made typical homes less valuable and mortgages less affordable for homeowners characterized by lower average incomes than urban counterparts. Some households could no longer meet mortgage obligations and others walked away from mortgage debt that exceeded the deflated market values of their homes.

The theory of this paper holds regardless of whether the housing boom was justified by fundamentals or based on market psychology. In a bubble, however, location-specific murmurs of a weakening market can be sufficient to end the cycle of price escalation and trigger falling prices

[2]Gerardi, Willen, Sherlund, and Lehnert (2009) showed that irrational exuberance caused homebuyers to be surprised by the housing market collapse; investment banks also did not anticipate the precipitous decline in housing prices that began in 2006.

throughout the market, including urban centers (e.g. Bikhchandani, Hirshleifer, and Welch 1992, Banerjee 1993, and Shiller 1995). Low mortgage rates, preferential tax treatment of mortgage payments, and high expectations for home price appreciation made homeownership cheap, opening the market to households that were typically priced out and fueling housing demand that was accommodated on the edge of cities. Low housing costs didn't just fuel housing demand; they also rendered home prices particularly sensitive to commute costs and generated conditions whereby those most exposed to shocks were also least able to absorb them. This theory explains the disproportionate decline in suburban housing markets while maintaining the rationality of homeowners conditional on their expectations.

The role of energy prices in the 2008 recession has been virtually ignored even though an extensive literature has documented the link between energy prices and economic growth (e.g. Hamilton 2009, Kilian 2008, Edelstein and Kilian 2009, Edelstein and Kilian 2007, Herrera and Pesavento 2009, Davis and Haltiwanger 2001, Pindyck 1991, Davis 1987, and Bernanke 1983a). The literature has identified now-standard channels by which energy price increases are transmitted throughout the economy to affect macroeconomic aggregates like unemployment and GDP, but the magnitude of impacts is bounded by the share of energy in consumption or production costs. Hamilton (2009), for instance, concluded that the dramatic energy price shock of 2007-08 caused a modest drag on the economy without which the dip into negative growth in 2008 might have been avoided. But energy market dynamics were insufficient to explain the dramatic decline in growth and employment. Our theory is compatible with both theories that lay blame for the economic downturn on oil prices and those that point to the bursting of the housing bubble. It posits a new channel by which energy shocks indirectly impact macroeconomic aggregates: they are transmitted through and amplified by imperfect financial markets. Thus, this paper links urban and energy economics to analysis of macroeconomic cycles and presents evidence as to the trigger of the housing market collapse, a topic that has been under-explored to date.

This paper proceeds in Section 2 by characterizing the evolution of the housing stock and urban form in the context of the Alonso-Muth mono-centric city model, which has become the workhorse of urban economics. We focus, in particular, on describing features of the housing market that make it vulnerable to unexpected gas price increases. In Section 3, we formalize our theory of the housing market collapse in a parsimonious model that integrates the mono-centric city model of Alonso and Muth with the Poterba (1984) model of housing investment decisions. We also present empirical evidence to support the relevancy of theoretical predictions in the context of the 1998-2006 housing boom and subsequent collapse. In Section 4, we simulate the housing market impacts of gas price shocks by parameterizing the model presented in Section 3. Section 5 discusses the implications of this analysis for policies relating to housing, energy, and the environment, and it concludes.

2 Commute Costs and Urban Form

Until 2007, post-war housing growth in the United States was characterized by the dramatic decline in center city population density and expansion of the urban fringe. Before World War II, most Americans lived in cities and only 25% of the population resided in suburbs. But by 1950, half the population lived in suburbs. The U.S. migration away from city centers is typically understood in the context of the mono-centric city model of Alonso (1964) and Muth (1969), in which employment is located exclusively at the city center in a central business district (CBD) and housing values decline with distance from the CBD to compensate for time-inclusive commute costs. Alonso (1964), Jackson (1987), Brueckner (2000) and others understood that reduced transportation costs permitted greater distances of travel from home to work. Transportation costs are central to the widely accepted "natural evolution theory" of urban form in which sprawl and gentrification are the inevitable consequences of innovations in intra-urban transportation, transportation infrastructure improvements, growing demand for housing and land, and changes over time in the relative advantage of different income groups to travel farther to work (Mieszkowski and Mills 1993).

LeRoy and Sonstelie (1983) documented the evolution of cities from before the 1900s through the 1970s and showed that as transportation technology advanced from walking to horse-drawn carriages to automobiles, neighborhoods pushed farther from city centers. They also explained the observed pattern of income stratification in which the wealthy were first to locate in the suburbs but returned to the cities starting in the 1970s. They extended the Alonso-Muth model to consider two modes of transportation (instead of just one): one fast and one slow. The fast mode is initially affordable only by the wealthy, who consequently enjoy a comparative advantage in commuting and move out of the city. But as the fast mode of technology becomes affordable to all income groups due to declining technology costs and rising incomes, the wealthy are relatively disadvantaged by commutes because of their higher valuations of time. Hence, they move back to the city.

Glaeser and Kahn (2004) described sprawl as the "natural, inexorable result of the technological dominance of the automobile." While the pecuniary cost of single car commutes (inclusive of fixed costs) almost always exceeds the pecuniary cost of public transit commutes regardless of distance, the time savings from commuting by car are dramatic: In 2000, the median car commute took 24.1 minutes, whereas the median transit commute took 47.7 minutes (Glaeser and Kahn 2004).

After accounting for a fixed time cost associated with transit trips of 16-20 minutes, cars are 50% faster than buses and roughly as fast as trains (Glaeser, Kahn, and Rappaport 2008). Thus, sprawl is strongly correlated with car ownership rates in both longitudinal and cross-sectional analyses (Glaeser and Kahn 2004).

Post-war investment in a national highway system is also expected to have reduced commute costs by improving the ease of travel across jurisdictions into the CBD. Baum-Snow (2007) tested for the impact of new highways on central city population and found that each new highway caused central city population to decline 18%. Had the interstate highway system not been built, center city population would have grown 8% rather than declining 17%.

Important to the hypothesis of this paper, there is some empirical evidence that gas prices directly influence urban form. Gas expenditures constitute a small but non-trivial component of annual household expenditure. For low-income, highly leveraged households, large unanticipated increases in gas prices can lead to cash shortages. Gasoline expenditures constituted 5.4% of average total household expenditures in 2008 (BLS 2011). In 2000, annual household gas expenditures averaged $1,700 (in constant 2011 dollars) with gas prices at an average $1.91 (in constant 2011 dollars). By 2008, however, with an average gas price of $3.35, the average American household spent $2,700 on gas—a 59% increase (BLS 2011). More relevant to the analysis of this paper, however, are the implications of rising gas prices on the marginal household, not the average household. The most gas-dependent households–those with long commutes or low-fuel-economy vehicles–saw their gas expenditures grow considerably. The average commuter in Antioch, California, for instance, experienced a $1,258 increase in annual costs associated with his 19-mile trip to work. But the Antioch resident who commuted to downtown San Francisco for work paid $2,979 more in constant 2011 dollars for his 45-mile trip to work. His $9,231 annual commute cost constituted 18% of total expenditure for the average American household in 2008, and 41% of total expenditure among households in the lowest income quartile.[3] Antioch is among the cities in California that suffered most as a consequence of the 2007-08 housing collapse.

While gas price shocks are expected to impact homeowners and consumers across the country, the impacts should not be homogeneous. Instead, those who reside in communities characterized by relatively high gas consumption should suffer the most. Suburban communities, then, are impacted by gas price increases to a greater degree than cities because of higher "trip to work" demand. Even for other trips, suburban households consume more energy because they are more reliant on travel

[3] Assumes 250 commute days per year and fuel economy of 21.75 miles per gallon. Also includes $0.05 in maintenance costs per mile.

by car and travel greater distances for each trip. For instance, in high sprawl cities, 78% of trips less than one mile long is made by private car, compared to 62% in low sprawl cities (Glaeser and Kahn 2004).

Coulson and Engle (1987) showed that gas price increases from 1974-1979 boosted the price difference between urban and suburban homes in the six cities studied. Molloy and Shan (2010) compared the response of home construction to gas price changes in close-in communities and those farther away from city centers, finding that a 10% increase in gasoline prices caused a four-year 10% decline in home construction in suburban neighborhoods relative to urban neighborhoods. Glaeser, Kolko, and Saiz (2001) used cross-country comparisons of urban density and tax-inclusive gasoline price to estimate a gasoline price elasticity of urban density equal to 1.10, suggesting that as gas prices double, density also doubles.

The housing boom from 1998-2006, and the half-century of suburbanization that preceded it, produced a housing stock that by 2006 was particularly vulnerable to energy price shocks: homes were more likely to be located away from CBDs and occupied by households of limited means than at any other time in U.S. history. And they tended to be in excess supply. During the boom, the U.S. housing stock added 15.8 million units, but households in the U.S. only grew by 9.8 million (U.S. Census Bureau 2010). At the height of the boom in 2005, 2.0 million new homes were built—33% more than the long run average annual growth in housing since 1959. In contrast, only one half million homes were built amid the housing bust in 2010.

Exurban areas grew twice as fast as metropolitan areas and were home to 10.8 million people by 2000 (Berube, Singer, Wilson, and Frey 2006). As a consequence, commute durations grew and vehicle miles traveled (VMT) increased steadily until 2006. From 1970-2006, VMT climbed 177%, including a 15% increase during the housing boom from 1998-2006.

Finally, a generous housing stock, federal housing policies, new mortgage products, low interest rates, and a general decline in underwriting practices made home ownership an affordable and seemingly attractive alternative to renting for households that had historically been priced out of the market. Homeownership reached record levels in each year from 1994-2006, peaking at 69%. For much of the 1980s and 1990s, the rate had hovered at 64% (U.S. Census Bureau 2011). The median down payment on home mortgages declined throughout the housing boom from around 20% in 1998 to 4% in 2006 (WSJ 2011). The median down payment fell to 0% in a number of cities, including San Francisco, Los Angeles, Las Vegas, and Washington, D.C. Nationwide, one in four borrowers took out interest-only mortgages in 2005 (FCIC 2011).

Subprime mortgage originations climbed from 1.1 million in 2003 to 1.9 million in 2005. Nearprime Alt-A loans grew faster, from 304,000 in 2003 to 1.1 million in 2005. And together, non-prime lending rose from ten percent of all originations in dollar terms to 32% in 2005 (Inside Mortgage Finance Publications 2008). Flexible rate mortgages that leave borrowers vulnerable to future rate increases constituted 75% of all subprime loans. The decline in underwriting standards and the ease of credit dramatically improved mortgage accessibility, but generated a borrowing class characterized by historically low credit-worthiness that had relatively little to lose in the event of foreclosure (Shiller 2008, FCIC 2011, and Acharya and Richardson 2010). Cheap and easy credit increased the susceptibility of the housing market to a crisis, and increased the severity of the crisis that ensued. But there is no reason to suspect that mortgage affordability triggered the crisis. Indeed, had housing prices continued to rise, poor lending and borrowing decisions would have been concealed by increasing home equity.

3 A Model of Gas Prices and Housing Market Outcomes

Motivated by the spatial pattern of decline following the collapse of the housing market, the central argument of this paper is that the housing bust was triggered by rising gas prices generally, and the gas price shock of 2008, in particular, altering the calculus of suburban living, which relied implicitly on low and declining real transportation costs. Specifically, we contend that a doubling of gas prices relative to long-run averages made mortgage payments unaffordable for some households, leading to "true" default. Still other households found their homes underwater as a reappraisal of transportation cost expectations caused the value of suburban and exurban homes to fall. Some of these households preferred strategic default to an alternative of incurring further losses. As discussed later in this section, this theory relies on an assumption that homebuyers either failed to forecast rising gas prices or did not incorporate those expectations into their housing investment decisions.

To formalize this argument, we incorporate the central features of the Alonso-Muth mono-centric city model into the Poterba (1984) model of housing investment. Specifically, consider a metropolitan area that includes a city and a suburb. All land within the city has been developed, and the total stock of housing in the city is fixed.[4] The outer boundary of the suburb, however, can expand in response to increasing demand for housing. There are N households living in the metropolitan area, with the income of household i denoted by y_i. The households are indexed such that $y_1 \geq \ldots \geq y_n$. Households can obtain housing services by renting in the city or by purchasing an owner-occupied

[4]This assumption is a reasonable simplification as cities traditionally grow from the inside-out, so that land in the city is scarce (Glaeser and Kahn 2004). Furthermore, local zoning regulations and political pressures often preclude cities from growing taller (e.g. Glaeser and Kahn 2010, Katz and Rosen 1987, Fischel 2000 and Fischel 1987). The urban theories of Moss (1977), Sheppard (1988), and Turnbull (1991) determined that growth controls induce sprawl.

house throughout the metro area. All households commute to the city center to work.[5]

Home ownership has been modeled as an investment decision dating at least to Kearl (1979). This approach recognizes the opportunity cost of funds allocated to the purchase of homes and is, perhaps, more applicable to the period leading to the 2007 housing market crisis than any period before. Accommodative monetary policies made loans cheaper, refinancing easier, and housing a more liquid asset (Diamond and Rajan 2009; Taylor 2009); and they fueled speculative interest. It is estimated that 27.7% of all homes purchased in 2005, for example, were for investment; another 12.2% were vacation homes (National Association of Realtors 2006).

Following Poterba (1984) and Poterba (1991), we require that the return on housing investments equals the "user cost" of homeownership, c, i.e.:

$$\frac{R}{P} = (1-\theta)(r+t) + \delta + \alpha + m - \pi^e = c \tag{1}$$

where P is the house price, R is the per-period value of rental services of the house, θ is the marginal tax rate, r is the nominal mortgage interest rate, t is the property tax rate as a share of house value, δ is the depreciation rate on housing capital, α is the risk premium required on assets with the risk characteristics of housing, m is the maintenance cost per unit value, and π^e is the expected rate of nominal housing appreciation (i.e., capital gains).

We extend this model to consider location-specific returns on housing investment. Let R_i^0 denote the value of a unit of housing services in the city for household i. It is determined by the total housing stock in the city and the total demand for rental housing in the city. Housing services have the same quality everywhere; however, to obtain housing services located farther away from the city center, households must incur higher commuting costs. Thus, household i's willingness to pay for a unit of housing services at location x in the suburb is $R_i(x) = R_i^0 - \tau_i x$, where x is the commuting distance and τ_i is the commuting cost per unit of distance, including the opportunity cost of commuting time. Following LeRoy and Sonstelie (1983) and De Bartolome and Ross (2003), among others, τ_i is assumed to be larger for households with higher income because they have a higher opportunity cost of commuting.

In spatial equilibrium, homeowners, as investors, must earn the same return on housing investments everywhere. Given household i's value of housing services at location x, $R_i(x) = R_i^0 - \tau_i x$,

[5] This is, admittedly, a simplification. Employment density has declined in the past several decades amid considerable innovation in telecommunication technologies. Still, as Glaeser (2011) and others have argued, the agglomeration benefits of cities remain large and are potentially enhanced by new telecommunications technologies. Thus, employment density remains greatest at city centers and is negatively correlated with distance from the city center, according to data from the U.S. Census Bureau's Zip Code Business Patterns survey.

household i's personal return on housing investment at location x is $\frac{R_i(x)}{P(x)}$ when the house price is $P(x)$ per unit of housing services. When $P(x) > \frac{R_i(x)}{c_i}$, household i's expected return on housing investments is lower than its expected return on other assets, where $c_i = (1-\theta_i)(r+t)+\delta+\alpha+m+\pi^e$ denotes household i's user cost of homeownership.[6] Thus, household i's maximum willingness to pay, or bid-price for housing at location x is:

$$P_i(x) = \frac{R_i^0(x) - \tau_i(x)}{(1-\theta_i)(r+t)+\delta+\alpha+m-\pi^e}. \tag{2}$$

The bid price is increasing in expected housing price appreciation and decreasing in commute cost, the mortgage interest rate, and the property tax rate.

Equation (2) shows that the user cost of homeownership magnifies the effect of commuting costs on the bid price for housing. Specifically, a one-dollar increase in commuting costs reduces the bid price for housing by $1/c_i$ dollars. The real user costs of homeownership varied from 0.0506 to 0.1324 during the period 1970-1990, depending on household income, mortgage interest rates and other parameters in the user cost (Poterba 1991). User costs during the boom are thought to have been even lower because of high expectations for home price appreciation, magnifying the sensitivity of home prices to changes in commute costs.

3.1 Gentrification and Exposure to Gas Price Shocks

The impact of energy price shocks on the housing market is exacerbated by gentrification. If housing is allocated to those who bid the highest price, then households with higher incomes are located closer to the city center because their bid-price functions are steeper and have a larger intercept on the vertical axis (i.e., both (R_i/c_i) and (τ_i/c_i) are larger for households with higher incomes). Intuitively, households with higher income have a higher opportunity cost of commuting and thus value accessibility to the city center more than low-income households. Assume land is developed when a household's bid price is above a reservation price, A (Capozza and Li 1994). Then, at the suburban boundary, b_s, $P_i(x) = A$. Using (2), b_s can be derived as:

$$b_s^* = \frac{1}{\tau_{\hat{i}}}\left\{R_i^0 - A\left[(1-\theta_{\hat{i}})(r+t)+\delta+\alpha+m-\pi^e\right]\right\}, \tag{3}$$

where $\hat{i} < N$ denotes the household living at the suburban boundary. Household $\hat{i}$ has the lowest income in the suburb. Any households with income below $y_{\hat{i}}$ cannot afford a house in the suburb

[6] For simplicity, all parameters in c_i are assumed to be same for all households except for the marginal tax rate θ_i, which is higher for households with higher income.

and must rent in the city. Differentiating (3) with $\tau_{\hat{i}}$, r, π^e, and $\theta_{\hat{i}}$ gives:

$$\frac{\partial b_s^*}{\partial \tau_{\hat{i}}} < 0,\ \frac{\partial b_s^*}{\partial r} < 0,\ \frac{\partial b_s^*}{\partial \pi^e} > 0,\ \text{and}\ \frac{\partial b_s^*}{\partial \theta_{\hat{i}}} > 0, \tag{4}$$

respectively. That is, the urban fringe expands and land is developed as the commuting cost and the mortgage interest rate decrease or as speculation about housing appreciation increases. Some low-income households that rent in the city before such changes will purchase houses in the suburb. Because these households commute the longest distance and have the lowest income in the suburb, they are most vulnerable to gas price increases. Accommodative monetary policies that lower the mortgage interest rates and give tax deductions to mortgage interest payments exacerbate the vulnerability because they encourage low-income households to purchase houses located farther away from the city.

The foregoing results are summarized in the following proposition.

Proposition 1. *Households most exposed to energy price shocks are also the least able to absorb the shocks.*

a) *Households with lowest income live in the city center as renters. However, among the homeowners, those with lower incomes live farther away from the city center.*

b) *More houses are built in the suburb when the commuting cost is lower and the expected housing price appreciation rate is higher. Households living there have the lowest income and the highest commuting costs and therefore are most vulnerable to an energy price shock.*

c) *By reducing the user cost of homeownership, accommodative monetary policies that lower the mortgage interest rate and tax policies that give deductions for mortgage interest payments and local property taxes encourage low-income households to purchase houses located farther away from the city and exacerbate the housing market vulnerability to energy price shocks.*

The location pattern suggested by proposition 1 is consistent with patterns observed in American cities. As shown in figure 1, the median household income and the poverty rate in a county are strongly related to the county location in a metropolitan area. According to the 2000 census, central counties of large metro areas had the highest average median household income, but also had a much higher average poverty rate than the fringe counties of large metro areas. Metro counties located farther away from a city center had the lowest median household income and the highest poverty rate. Likewise, Figure 2 shows the spatial pattern of median household income by zip code in the

United States; high income zip codes are concentrated near major metropolitan centers. Based on 2000 Census data, it is estimated that median household income of households located within 120 kilometers of a high employment density city declines one-tenth of one percent per kilometer of distance from the CBD.

As shown in (4), the model predicts that an increase in gasoline prices causes a contraction of the suburban boundary, b_s^*. This prediction was confirmed by a November 2011 article in the *Wall Street Journal,* which reported that raw land destined for residential development is being reverted to agricultural uses. Whereas U.S. Department of Agriculture surveys showed cropland declining by 2-4 million acres per year between 2000 and 2007, cropland stopped shrinking in 2007. The changing dynamics have turned farmers into land speculators as they are buying back at a fraction of the price land they had sold before the housing bust (Wall Street Journal 2011). This marks a reversal of the post-World War II trend of sprawl to suburbs and then exurbs that was predicated on cheap transportation fuels and declining costs of commutes.

3.2 Gasoline price shocks and home values

In response to the energy price shock, the value of household i's home declines, as reflected in the bid price function after the energy price shock:

$$\tilde{P}_i(x) = \frac{R_i^0 - \tilde{\tau}_i x}{(1-\theta_i)(r+t) + \delta + \alpha + m - \tilde{\pi^e}}, \tag{5}$$

where $\tilde{\tau}_i$ and $\tilde{\pi^e}$ denote the commuting cost and the homeowners' expected rate of nominal house price appreciation after the shock.

Each homeowner has four potential options in response to this shock: stay put, sell and move to another location in the suburb, sell and move to the city, or default and face foreclosure. However, selling is not a viable option because each homeowner is still the highest bidder for his own house. Because the energy price shock does not change the relative magnitudes of slopes and intercepts of the households' bid price functions, the current owners still value their own houses more than any other potential buyers. Thus, no homeowner receives an offer on his home to induce him to sell. This suggests the following result:

Proposition 2. *Each homeowner has only two viable options in response to the energy price shock: stay put or default.*

Because the current owners still bid the highest prices for their own houses, the equilibrium house price after the energy price shock is given by (5). This leads to the following proposition:

Proposition 3. *A gasoline price shock causes home values to decline at every distance from the CBD greater than zero. The magnitude of home value declines is increasing in*

a) *the length of the work commute, i.e., x; and*

b) *the magnitude of the increase in gas prices, i.e., $(\tilde{\tau}_i - \tau_i)$.*

Corollary. Because initial home values, $P_i(x)$, are decreasing in distance from the CBD and home value declines are increasing in distance from the CBD, the percent decline in home values is increasing in distance from the CBD at an increasing rate.

Proposition 3 predicts that suburban households should suffer from gas price shock more than urban households. This result is consistent with the observed pattern of housing market decline following the collapse of the market in 2007. On average, the losses in home values and the rate of foreclosures increased with distance. In five representative metropolitan regions across the country, neighborhoods located three miles from city centers suffered less deep housing price declines than neighborhoods located 13 miles from city centers (Cortright 2008). Home values in close-in neighborhoods in Pittsburgh and Portland increased from 2005 to 2006, while prices in more-distant neighborhoods fell 5% in each city.

More detailed analysis of the market collapse in California reveals a similar pattern. California was among the hardest hit regions in the country when the housing bubble burst; one-third of all mortgages were underwater in 2009. California represents 25% of all housing value in the country (Case and Quigley 2008) and accounted for 19% of the 2.9 million foreclosure filings across the country in 2010 (RealtyTrac 2011b). Of the 20 metropolitan areas with the highest rates of foreclosure activity in 2010, seven were located in California, in outlying areas like Modesto (3rd highest foreclosure rate in the U.S.), Riverside-San Bernardino-Ontario (6th), Stockton (7th) and Merced (8th) (RealtyTrac 2011a). A similar pattern was observed in 2009, with California being home to nine of the 20 metros with the highest foreclosure rate.

We analyzed the spatial distribution of home price declines in California using zip code-level data on prices from DataQuick.[7] Cities that experienced the highest percentage declines in median home price from 2007-2010 tended to be located farther from major cities and characterized by longer commutes, higher gas expenditures and more VMT compared to cities with the smallest drop in home

[7]We obtained monthly median home price data covering 1,505 zip codes in California from 2007-2010. DataQuick manages a comprehensive national database of real estate information obtained directly from county assessors.

prices (see table 1). In fact, the 15 cities that fared the best in the collapse were, on average, only 16 miles from a major city, 74% closer than the cities that fared the worst. Households in these resilient cities had incomes that averaged 125% higher than households in the least resilient communities. Their transportation costs as a percent of income were 23% lower; their gas expenditures in 2008 were 31% lower and they had twice as many public transit riders as a percent of population. Figures 4 and 5 show the percent change in median homes prices from 2007-2010 by zip code for California and the Los Angeles and San Francisco metropolitan areas, respectively. In the figures, darker colors indicate greater decline from the collapse. As is shown in the figures, the areas in the central valley and Inland Empire region of southern California fared worst, whereas communities near San Francisco and Los Angeles tended to withstand the collapse relatively well.

Finally, analysis of Zillow Home Value Index data for 30,434 zip codes covering 269 metropolitan statistical areas across the United States reveals that the housing market collapse disproportionately impacted suburban communities. The loss in home value from peak to trough as a percent of peak home value is positively correlated with distance from the CBD for communities within 120 kilometers of a CBD. An examination of the timing of local housing market collapses also supports the hypothesis of this paper: the suburbs should have been the first to fall and should be the last to recover. Zillow data show that home values started to turn down first in distant zip codes. Additionally, suburban communities had recovered less from their lows by summer 2011 than close-in communities.

3.3 Gasoline price shocks and mortgage defaults

The collapse of the housing market was characterized by high rates of loan defaults that jeopardized banks. The impact of a gas price shock on strategic foreclosures is, therefore, considered. In particular, household i will be "underwater" after the energy price shock if and only if the value of the household's home falls below its outstanding balance of mortgage debt:

$$\tilde{P}_i(x_i) < \psi_i P_i(x_i), \tag{6}$$

where ψ_i denotes household i's outstanding balance of mortgage debt as a percent of the purchase price immediately after the energy price shock.

Suppose household i purchased its house T_i periods before the energy price shock with a standard fixed-rate mortgage loan of $\bar{T}_i$ periods and a down payment of ρ_i percent of the purchasing price, then we have:

$$\psi_i = \frac{(1-\rho_i)\left[1-(1+r)^{-(\bar{T}_i - T_i)}\right]}{1-(1+r)^{-\bar{T}_i}}. \tag{7}$$

Rearranging (6) and substituting in (2), (5) and (7), we obtain that household i is underwater if and only if:

$$\frac{c_i(R_i^0 - \tilde{\tau}_i x_i)}{\tilde{c_i}(R_i^0 - \tau_i x_i)} < \psi_i, \tag{8}$$

where $\tilde{c_i}$ denotes the user cost of housing after the shock.

Condition (8) impacts current home owners through an intensive margin effect by determining the distance at which households with given mortgage characteristics are under water after a given gas price shock. The following results follow directly from (8).

Proposition 4. *Household i is more likely to be underwater after the energy price shock if*

a) *the home is located farther from the city (i.e., x is larger);*

b) *the gas price increase is larger (i.e., $(\tilde{\tau}_i - \tau_i)$ is larger);*

c) *the down payment is smaller (i.e., ρ_i is smaller);*

d) *the term of mortgage loan is longer (i.e., $\bar{T}_i$ is larger);*

e) *tenure in the home is shorter (i.e., T_i is smaller);*

f) *the decrease in expected appreciation rate of house value after the energy price shock, $\pi_i^e - \tilde{\pi_i^e}$ is greater; and*

g) *the rental rate in the city is lower (i.e., R_i^0 is smaller).*

Corollary. If household i is underwater, all households living farther away are also underwater if they have at least as large of a mortgage debt as a percent of purchase price, i.e., if $\psi_j \geq \psi_i$ for $j > i$.

All results in proposition 4 are intuitive and follow directly from (8). Importantly, the likelihood that a household is underwater after an energy price shock is increasing in the magnitude of the energy price shock and in distance from the CBD. Households are also more likely to be underwater after an energy price shock the greater is their outstanding balances of mortgage debt, which means households with smaller down payments, longer loan terms, and short tenures in their homes are at greater risk. A household that made a smaller down payment, had a longer term of loan and shorter tenure in the home, had a larger outstanding balance of mortgage debt. Furthermore, when the rental rate in the city is lower, the energy price shock induces greater losses in home value relative to pre-shock levels, increasing the risk of default.

Analysis of the spatial pattern of foreclosures in California supports the prediction of Proposition 4. Examining foreclosure rate data from CoreLogic for California zip codes, we find that the change in foreclosure rates from 2007-2010 tended to be greatest in suburbs.[8] In fact, 12 of the 15 cities with the largest increase in foreclosure rates from 2007-2010 were located 50 miles or more from a major city (see table 2). The mean distance to a city center for these 15 cities was 67 miles. The 15 most resilient cities (with the smallest increase in foreclosure rates), on the other hand, were, on average, located only 29 miles from a major city. The mean household income in the least resilient cities was 37% of the mean household income in the most resilient communities. The duration of their mean work commute was 50% longer.

Figures 6 and 7 show the difference in foreclosure rates from 2007-2010 by zip code, respectively, for California and the Los Angeles and San Francisco metropolitan areas. As is also reflected in figures depicting the percentage change in home prices, outlying areas of the Los Angeles and San Francisco metro areas tended to suffer the most in the housing collapse.

3.4 Housing Affordability, Policy, and the Magnitude of the Foreclosure Crisis

The severity of the housing crisis induced by a gas price shock is a function not just of mortgage interest rates (and, indirectly, monetary policy), but also fiscal and housing policies that promote home ownership. Policies that affect the user cost of housing influence the quantity of underwater homes along intensive and extensive margins under certain conditions. Turning first to extensive margin effects, policies that alter the user cost of home ownership can impact the magnitude of the housing crisis regardless of whether or not expectations change. As shown in figure 3a, policies that lower mortgage interest rates and increase the tax advantage of housing relative to other investments shift the suburban boundary from $x = b_s^*$ to $x = b_s^{**}$ by lowering the user cost of homeownership, and thereby encouraging low-income households to purchase houses located farther away from the city center. Thus, such policies effectively shift the spatial distribution of households away from the city center, causing there to be more underwater homes at the extensive margin following a gas price

[8] We obtained monthly data on foreclosure rates across 2,706 zip codes in California from 2007-2010. CoreLogic maintains a comprehensive database of real estate and mortgage data.

shock. Monetary, fiscal and housing policy during the boom, then, are likely to have worsened the housing collapse by inducing growth in suburbs to house highly leveraged, risky homeowners.

On the intensive margin, the user cost of home ownership is increasing in the property tax rate just as it is increasing in the mortgage interest rate. It is decreasing in the marginal income tax rate because the mortgage payment deduction becomes more valuable as the tax rate climbs. Thus, policies that lower mortgage interest rates, reduce property taxes and increase income tax rates increase the likelihood that households are underwater following a gas price shock that lowers expectations for home price appreciation. That is, conditional on the magnitude of the gas price shock, they shift the break-even curve down: $\frac{\partial}{\partial r}\left(\frac{c_i}{\tilde{c}_i}\right) > 0$, $\frac{\partial}{\partial t}\left(\frac{c_i}{\tilde{c}_i}\right) > 0$, and $\frac{\partial}{\partial \theta_i}\left(\frac{c_i}{\tilde{c}_i}\right) < 0$. Intuitively, the smaller is the user cost of housing before a change in expectations, the greater is the percentage increase in the user cost when expectations fall. This intensive margin effect is illustrated in figure 3b. If the energy price shock did not affect expectations for home prices in the future, then monetary policies related to interest rates and fiscal policies related to tax rates would have no effect on the break-even curve, as shown by (8). That is, they do not impact the distance from the CBD at which households are just underwater, conditional on mortgage characteristics.

3.5 The role of mortgage rates in the foreclosure crisis

The relationship between mortgage rates and the likelihood of default is not straightforward. If expectations over housing appreciation are unchanged following an energy price shock, then the user cost of housing is unchanged and the mortgage rate has no impact on the ratio of pre-shock and post-shock prices, i.e., the percentage change in home price following the shock is not impacted by the mortgage rate (see RHS of (8); c_i and $\tilde{c}_i$ cancel out). However, a lower mortgage interest rate reduces a current homeowner's outstanding mortgage debt, reducing the likelihood that the household is underwater.

If, instead, expected housing price appreciation falls after the energy price shock, then the mortgage interest rate *does* impact the relative prices of homes before and after the shock. Specifically, a lower mortgage interest rate makes the user cost more responsive to changes in housing appreciation expectations. That is, for a given decrease in expectations, the percent increase in user cost, and hence the percent decline in home prices due to the change in expectations, is decreasing in the mortgage rate. The greater decline in home prices after the energy price shock increases the likelihood that a household is underwater. Thus, if expected housing appreciation falls after the energy price shock, then the effect of low mortgage interest rates depends on the relative magnitudes of the effects of the mortgage rate on relative house prices and outstanding mortgage debt. A household with a young mortgage is more likely to be underwater with a high mortgage interest rate, whereas a household that has only a few remaining mortgage payments is less likely to be underwater with a high mortgage interest rate.

In addition, if expected housing appreciation falls after an energy price shock, then the fall in expected returns to housing investments after the energy price shock is increasing in the property tax rate and the marginal tax rate. Therefore, a homeowner is more likely to be underwater after the energy price shock with a lower property tax rate and a higher marginal tax rate. These results are summarized in the following proposition.

Proposition 5. *Suppose the expected appreciation rate of housing value decreases after the energy price shock, then:*

a) *A lower property tax rate and a higher marginal tax rate make current homeowners more likely to be underwater.*

b) *The effect of the mortgage interest rate on current homeowners depends on $(T_i/\bar{T}_i)$ and $(c_i/\tilde{c}_i)$. If $(T_i/\bar{T}_i)$ is close to zero and $(c_i/\tilde{c}_i)$ to one, then the current homeowners are less likely underwater after the energy price shock with a lower mortgage interest rate; on the other hand, if $(T_i/\bar{T}_i)$ is close to one and $(c_i/\tilde{c}_i)$ to zero, the current homeowners are more likely underwater with a lower mortgage interest rate.*

3.6 Expectations for Housing Price Appreciation

Much as Shiller and others contended that the housing bubble was not fully a consequence of market fundamentals and that market psychology played a role, so, too, do we allow that the market collapse was not exclusively the consequence of high gas prices, which, in the context of this model, might rightly be considered fundamental to the housing market. Rather, we hypothesize that the gas price shock caused house prices to decline, which caused homeowners and investors to lower expectations for housing appreciation. If homeowners expect the appreciation rate of house value to decrease after the energy price shock (i.e., $\tilde{\pi}_i^e$ is smaller than π_i^e), then home values fall even farther than expected on the basis of gas price increases alone. Indeed, Case and Shiller (2010) documented the evolution of homebuyer expectations throughout the boom and bust, showing that they are backward looking, a result confirmed by Mayer and Sinai (2009). Among homebuyers in Boston, Los Angeles, Milwaukee, and San Francisco in 1988, the mean expected annual price appreciation rates over ten years were 8.7%, 14.3%, 7.3% and 14.8%, respectively. In 2005, at the height of the housing boom, those expectations rose to 12.4% in Boston, 22% in Los Angeles and 13.5% in Milwaukee and fell slightly to 13.9% in San Francisco (Case and Shiller 2010). But by 2011, after the collapse, homebuyer expectations had fallen markedly to 3% on average across the four cities, suggesting expectations of roughly 1% growth net of inflation.

A lowering of expected home price appreciation drives home prices down everywhere. But a re-evaluation of home prices due to an energy price shock should cause a heterogeneous response in expectations. Expectations for suburban homes should clearly fall, where as expectations for urban homes should fall less, and may, in fact, rise in response to increased demand for urban homes. Such an adjustment in home price appreciation expectations is the consequence of decision-making errors on the part of consumers who either did not anticipate rising gas prices or did not consider gas price expectations in their home purchase decisions. Anderson, Kellogg, and Sallee (2011) provided evidence that following decades of relatively stable gasoline prices, consumers would not have anticipated the run-up in prices that began in 2002. They showed that consumers have "no change" expectations about the rate of change in gasoline prices; that is they expect that gas prices follow a martingale process.

In the context of other behavioral theories of consumer behavior (e.g. bounded rationality), it is also possible, if not probable, that gas prices were not a salient component of home purchase decisions during much of the housing boom because gas prices were low and stable. The energy price shock of 2008, however, likely increased the salience of gas prices, causing consumers to incorporate gas costs into their home purchase decisions. A 2005 Harris Interactive survey for the Urban Land Institute, for instance, showed that 21% of individuals had responded to high gas prices by looking for homes closer to work (ULI 2005). A 2011 survey of its realtors by Coldwell Banker found that 75% reported the gas price spike in spring 2011 had influenced their clients' decisions about where to live. And 93% reported that if gas prices remained high, their clients would choose to live closer to work (Coldwell Banker 2011).

If homeowners either did not anticipate increasing gas prices or did not consider the implications of rising gas prices in home location decisions before the energy price shock, then they made decisions that are suboptimal in a high-gas-price future. The decline in expectations about housing appreciation should be larger for suburban households and, according to (6), cause a greater decline in home prices in the suburbs than in the city.

4 Simulations

In this section, we simulate housing market outcomes derived by parameterizing the model to reflect conditions during the housing boom and bust. These simulations demonstrate the degree to which gas price changes can cause housing prices to fall in suburban and exurban communities, inducing strategic foreclosures, and deflating the housing market. They also show the role excessive monetary easing played in exacerbating the gas price shock. In this analysis, we variably consider changes in gas prices, mortgage interest rates, and expected home price appreciation, while holding constant property tax rates, maintenance costs, depreciation, and marginal income tax rates over the relevant period. We report results given a marginal tax rate of 0.28, which is the rate of the third-highest federal tax bracket in the U.S. and governs joint incomes of \$139,250 to \$212,300. We assume that the value of annual rental services for a single-family unit at the CBD, R_0, is \$48,000, which reflects the mean rent for a 3 bedroom unit in downtown San Francisco in 2011.[9]

During the housing boom, gas prices were relatively low, averaging \$2.00 nationally from 2000-2005. In 2008, during the most precipitous declines in home prices, gas prices averaged \$3.35, or 68% higher than the first half of the decade. Annual smoothing, however, conceals a more dramatic change in prices. Because house prices and expectations over future home price appreciation can adjust to instantaneous changes in gas prices, such fluctuations are also relevant to our analysis. In the first quarter of 2002, for instance, real gas prices were as low as \$1.38 and averaged \$1.44. In 2004, gas prices nationally were as low as \$1.87. But by 2007 they had broached the three-dollar mark for the first time since the early 1980s. In June 2008, they peaked at \$4.15.

Table 3 shows how the model is parameterized with respect to commute costs in order to consider several scenarios of gas price changes. Scenario 1 is a conservative case, representing the change from the five-year average gas price from 2000-2005 (\$2.00) to the average price in 2008 (\$3.35). Scenario 2 represents an intermediate case for a gas price shock from the lowest gas price just before the collapse (\$1.87) to the average over six months in 2008 during the collapse (\$3.54). Scenario 3 demonstrates the impacts of the greatest swing in gas prices—from the lowest price during the boom (\$1.38) to the highest price during the collapse (\$4.15). As throughout, we abstract from time costs associated with commutes, but we do include the variable costs associated with car trips, including maintenance costs and tire wear, in addition to fuel costs.[10]

[9] Computed from RentalHousehunter.com. Rental prices did not collapse with the housing market collapse, and, in fact, have remained stable and increased slightly in some markets. Thus, this estimate is likely a reasonable estimate of the rental rate in San Francisco during the boom.

[10] Estimated costs related to maintenance and tire wear are from AAA's "Your Driving Costs 2010" available online at www.aaaexchange.com. We assume the median gas mileage for medium-sized cars of 21.75 miles per gallon. Maintenance cost per unit distance and the cost of tire wear per unit distance are, respectively \$0.042 and \$0.0091.

For much of the housing boom, mortgage interest rates on a 15-year fixed rate loan were below 5.50%. We assume a mortgage rate of 5.42%, the rate that obtained in 2005. In some simulations, we allow expected home price appreciation to decline after the gas price shock, from 5.3% to 3% annually. This change in expectations is conservative. Case and Shiller (2010) showed that homeowners expected annual appreciation of 10-15% in the medium-term before the collapse, and only 3% appreciation per year after the collapse. The changes in expectations are simulated in order to demonstrate that declining expectations cause home prices to fall universally. The impact of a uniform change in expectations does not differentially effect suburban households, though as the user cost rises amid declining expectations, the responsiveness of home prices to commute costs is diminished, i.e., the penalty of suburban living declines amid higher user cost, as noted in Section 3. As the model in Section 3 suggests that urban housing demand grows relative to suburban housing as gas prices increase, one might consider a heterogeneous change in home price expectations that would cause home prices to fall more in the suburbs. There is no theory to inform such location-specific changes in expectations, however. Nevertheless, it is worthwhile to observe that such a change would increase the disproportional impact of a gas price shock on suburbs relative to urban communities.

Figure 8 shows the percent change in home prices for each scenario. Because home prices are *decreasing* in distance from the CBD and because the loss in value from a gas price shock is *increasing* in distance from the CBD, this function is increasing at an increasing rate in distance from the CBD. Under Scenario 1a, the most conservative, home prices decline by $7,900 (1.33%), $15,800 (2.75%), $39,500, (7.60%), $59,200 (12.49%), and 79,000 (18.42%) for homes at distances of 10, 20, 50, 75 and 100 miles from the CBD, respectively. Under Scenario 1b, which incorporates changes in the user cost of housing, home prices fall by $158,735 (26.79%), $159,900 (27.84%), $163,395 (31.43%), $166,307 (35.07%), and $169,219 (39.49%), respectively. Under Scenario 3a, which considers a 200% increase in gas prices (a 111% increase in commute costs), homes lose $16,206 (2.72%), $32,412 (5.57%), $81,031 (15.06%), $121,548 (24.24%), and $162,064 (34.85%), respectively. Figure 8 also depicts how home prices are less responsive to gas prices as the user cost increases; each of scenarios 1b, 2b, and 3b is characterized by higher user costs than 1a, 2a, and 3a because expected housing appreciation declines.

We also consider the impact of gas price changes on foreclosure rates. Because households that owe more on their mortgages than the current value of their homes (i.e., those that are underwater)

We assume 250 work days per year and two commuters per household. Though in many households only one individual may regularly commute to work, a non-commuting individual in the household is likely also to incur costs associated with transportation that are positively correlated with distance from the CBD (Glaeser and Kahn 2010).

are more likely to pursue a strategic default by walking away from their homes in order to avoid additional losses, we focus our analysis on underwater homes. As shown in (8), whether or not a household is underwater depends on the terms of the mortgage (i.e., when the mortgage was originated relative to the shock, the length of the mortgage, the mortgage rate, and the magnitude of the down payment as a share of the total mortgage value) and on the changes in commute costs and user costs. Figure 9 plots the "break-even curve" when condition 8 holds with equality for each scenario. That is, for homes located along the curves, the post-shock home price just equals the outstanding debt. All homes at points lying above the curves are underwater, as indicated by the gray shaded regions in the figure. The areas between curves 1a and 1b, 2a and 2b, and 3a and 3b measures the impact of a reduction in housing appreciation expectations following the gas price shock.

Under Scenario 1a, a household located at 20 miles from the CBD could have paid down only 3% of the mortgage and remained above water, but under Scenario 3a, the household would be underwater unless it paid down at least 5% of its mortgage. Under Scenario 3b, it would have had to pay down 30% of the loan to be above water. A household 50 miles from the CBD would have needed to pay down 8% and 16% of its mortgage to be above water under Scenarios 1a and 3a, respectively. Figure 9 shows that the likelihood that households are underwater is increasing in distance at an increasing rate. Thus, low gas prices, in combination with lax lending practices and mortgage innovations greatly expanded the "homeownership society" by recruiting low-income, high-risk households that purchase in the suburbs and, thus, are most vulnerable to price shocks.

Finally, figure 10 presents, as a function of distance, the magnitude of down payment required to keep a household above water on a 15-year mortgage at the prevailing mortgage rate. Each panel in the figure depicts a different scenario. Within each panel, several plots are represented for each of $T = j$ for $j \in \{1, 2, 3, 4, 5, 10\}$, where as before, T denotes tenure in the home. In 2006, the median downpayment in the country was 4%, with 0% down payments constituting the median in some cities. Under scenario 3a, homes as close as 20 miles from the CBD with no downpayment and one-year old mortgages would be underwater. Homes at 50 miles would be underwater with less than a 10% downpayment. Under scenario 1a, homes at 30 miles would be underwater. Homes at 50 miles would also be underwater with a three-year-old mortgage and no downpayment. Under scenarios 1b, 2b, and 3b, all homes with less than four-year-old mortgages and less than 10% down payments would be underwater. Thus, new homeowners posed considerable risk of default at the time of the housing collapse as they had paid off only a small share of home loans.

5 Conclusion and implications

Traditionally, economists have understood the macroeconomic impacts of rising oil prices to be constrained by the relatively small share of energy in production costs and household consumption. But this paper identifies a new link between energy prices and the macroeconomy through housing and financial markets. It shows that energy price shocks can have outsized effects on the macroeconomy that exceed those predicated on the traditional supply and demand channels if the shocks are transmitted through and amplified by imperfect financial markets characterized by excessive leverage. By integrating the foundational Alonso-Muth and Poterba models of urban economics, this paper provides microeconomic foundations for a macro phenomenon that generated considerable research interest following the housing market collapse in 2007. We show that while cheap fuel prices led to urban sprawl and the expansion of homeownership to low-income households that settled in the suburbs, dramatic increases in fuel prices disproportionately impacted suburban homeowners who suffered the greatest commute cost increases and home value declines. Mortgages became unaffordable for some households and imprudent for others, leading to unavoidable and strategic defaults. High rates of default induced shocks in financial markets characterized by excessive leverage. Data from the housing crisis of 2007-08 were used to illustrate the theory of this paper. They showed that the earliest and most significant reductions in home values occurred in suburbs with relatively low median household incomes. The rate of foreclosure increased with distance from the city center.

This analysis has implications for housing policy and consumer finance. First, it underscores the peril of loose credit policies in the housing market that generate a highly leveraged borrowing class with little incentive or ability to make loan payments when commute costs rise and home equity falls. Furthermore, easy credit and low interest rates heighten the responsiveness of home values to energy prices, making the housing market more vulnerable to energy price shocks. Second, our analysis suggests that unexpected price inflation in markets for inelastically demanded goods, like energy and food, can impact the ability of households to meet debt obligations. Failure to recognize this impact may lead to excessive risk taking in consumer finance. Third, while this paper has focused on the role of a gas price shock on housing market outcomes, energy price shocks more generally may disproportionately penalize suburban homeowners who tend to consume more energy not just in commutes, but also in home heating and cooling (Glaeser and Kahn 2010). The decline in housing market conditions in suburbs, then, is exacerbated by correlated shocks in prices for energy products besides transportation fuel, like electricity and natural gas.

This research also has implications for energy and climate change policy. Irrespective of energy market dynamics, policies to mitigate anthropogenic climate change, like gasoline taxes and renewable fuel standards, raise transportation costs that are borne disproportionately by subsurban homeowners. They lower home values in suburbs while increasing home values in city centers. Fuel economy standards, like the Corporate Average Fuel Economy (CAFE) standard in the U.S., however, lower the variable cost of commutes. The dispirate impact of the two types of policies on suburbanites may explain the political success of the latter relative to the former.

Finally, the theory of this paper yields predictions for the future of the housing market and for the broader economic recovery from the collapse. By 2012, a vast literature spanning at least a half-century had analyzed the implications of the seemingly perpetual decline of commute costs. But the consequences of a reversal of that trend had largely been ignored. Amid expectations of a high energy-price future, suburban housing markets are expected to languish as high commute costs fundamentally alter the calculus of living away from city centers. In contrast, urban home prices are expected to recover more quickly from collapse as demand for proximity to the central business district increases. High commute costs shift the suburban boundary inward, meaning homes on the suburban fringe are likely to be abandoned and future housing development is likely to be vertical rather than horizontal. The slow economic recovery following the 2007-08 housing market collapse can be explained, in part, by the slow recovery of the housing market, which remained depressed below pre-boom levels in 2012. With one in four homeowners underwater, many homeowners and small business owners could not withdraw home equity to finance consumption.

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Tables

Tables 1 and 2 follow table 3 due to space constraints.

Table 3: Simulation scenarios

	Case 1		Case 2		Case 3	
	a	b	a	b	a	b
Initial gas price (in dollars)	2.00	2.00	1.87	1.87	1.38	1.38
Change in gas price (in dollars)	1.35	1.35	1.67	1.67	2.77	2.77
Percent change in gas price	67.5	67.5	89.3	89.3	200.7	200.7
Percent change in commute cost	43.4	43.4	56.1	56.1	111.2	111.2
Changes in user cost (π and r)	No	Yes	No	Yes	No	Yes

Table 1: California city characteristics by fall in median price

(a) Largest price fall

Rank	City	Dist. to Nearest City (in miles)	Mean Commute (in min.)	Price fall as share of pre-shock price	Nearest City	Unemp. Rate	Mean Income ($)	Transpo. Cost as Percent Income	Gas Cost (2000) ($)	Gas Cost (2008) ($)
1	Richmond	18.2	35.02	0.6625	S. Francisco	7.86	41,584	18.1	1,643	5,370
2	S. Bernardino	54.7	28.90	0.6124	Los Angeles	9.86	33,471	23.2	1,469	3,911
3	Desert H. Spr.	109	28.56	0.6064	Los Angeles	10.34	31,753	25.8	1,902	5,065
4	Los Banos	79.7	39.20	0.5839	San Jose	14.43	43,370	28.9	1,701	4,528
5	S.J. Capistrano	54.9	25.17	0.5710	Los Angeles	6.70	101,991	19.2	1,733	4,614
6	San Pablo	19.6	36.48	0.5702	S. Francisco	7.86	39,618	17.8	1,607	4,278
7	Stockton	49.2	32.56	0.5676	Sacramento	12.40	40,722	24	1,457	3,879
8	Antioch	45.3	42.06	0.5607	S. Francisco	7.86	45,953	19.7	1,898	5,054
9	Hesperia	79.5	37.30	0.5602	Los Angeles	9.86	39,018	26	1,954	5,203
10	Atwater	121	22.47	0.5580	San Jose	14.43	40,677	28.2	1,535	4,086
11	Colton	55.7	27.74	0.5557	Los Angeles	9.86	35,575	23.1	1,397	3,718
12	Perris	72.2	36.74	0.5506	Los Angeles	10.34	36,056	24.7	1,788	4,761
13	Hemet	83.3	37.27	0.5430	San Diego	8.51	46,525	24.3	1,598	4,256
14	Moreno Valley	64.1	38.29	0.5420	Los Angeles	7.86	42,115	24.1	1,635	4,353
15	Vallejo	31.8	33.72	0.5390	S. Francisco	9.86	42,485	23.3	1,797	4,785

(b) Smallest price fall

Rank	City	Dist. to Nearest City (in miles)	Mean Commute (in min.)	Price fall as share of pre-shock price	Nearest City	Unemp. Rate	Mean Income ($)	Transpo. Cost as Percent Income	Gas Cost (2000) ($)	Gas Cost (2008) ($)
1	Cupertino	10.3	25.81	-0.0135	San Jose	7.97	126,859	14.1	1,350	3,594
2	Menlo Park	20.4	24.34	0.0051	San Jose	6.37	204,574	16.6	1,459	3,541
3	Mtn. View	12.9	24.01	0.0283	San Jose	7.97	95,252	12.9	1,130	3,009
4	So. Pasadena	8.6	27.44	0.0528	Los Angeles	8.85	91,396	21.2	961	2,743
5	Arcadia	18.3	31.25	0.0540	Los Angeles	8.85	82,367	22.5	1,156	3,299
6	Belmont	23.3	28.37	0.0583	S. Francisco	6.37	103,908	17.8	1,627	3,947
7	Temple City	14.1	31.03	0.0658	Los Angeles	8.85	46,843	22.2	1,080	3,083
8	San Francisco	1	28.37	0.0747	S. Francisco	6.81	87,099	12.5	1,110	2,693
9	Santa Monica	15.8	24.92	0.0790	Los Angeles	8.85	101,401	18.5	809	2,310
10	Venice	17.9	26.12	0.0793	Los Angeles	8.85	73,979	19.1	923	2,634
11	W. Hollywood	8.3	24.69	0.0818	Los Angeles	8.85	115,190	16.6	710	2,028
12	Sunnyvale	11.8	23.86	0.0842	San Jose	7.97	89,544	12.8	1,089	2,900
13	Hermosa Bea.	22.2	33.04	0.0861	Los Angeles	8.85	125,797	20.2	992	2,833
14	Seal Beach	29.6	30.63	0.0865	Los Angeles	6.70	70,675	17.2	1,334	3,552
15	Walnut	25.7	36.53	0.0896	Los Angeles	8.85	76,845	23.9	1,377	3,931

Note: Data based on original analysis of data from RealtyTrac and CoreLogic. Transportation and gas costs from the Center for Neighborhood Technology's Housing + Transportation Affordability Index.

Table 2: California city characteristics by foreclosure rate

(a) Highest rates of foreclosure

Rank	City	Dist. to Nearest City (in miles)	Mean Commute (in min.)	Forecl. Rate	Nearest City	Unemp. Rate	Mean Income ($)	Transpo. Cost as Percent Income	Gas Cost (2000) ($)	Gas Cost (2008) ($)
1	Victorville	84.8	33.72	0.0170	Los Angeles	9.86	42,485	25.3	1,835	4,886
2	Murrieta	65.4	35.99	0.0158	San Diego	10.34	72,422	25.2	1,751	4,661
3	Los Banos	79.7	39.20	0.0154	San Jose	14.43	43,370	28.9	1,701	4,528
4	San Jacinto	85.2	31.62	0.0145	Los Angeles	10.34	35,600	25.5	1,798	4,787
5	Palmdale	62.6	42.48	0.0144	Los Angeles	8.85	47,699	24.7	1,652	4,717
6	Elk Grove	16.7	30.75	0.0141	Sacramento	8.85	59,878	22.2	1,660	4,419
7	Lake Elsinore	70.6	39.78	0.0139	Los Angeles	10.34	42,111	25.2	1,879	5,003
8	Tracy	63	40.43	0.0138	S. Francisco	12.40	49,207	25.2	1,698	4,521
9	Perris	72.2	36.74	0.0137	Los Angeles	10.34	36,056	24.7	1,788	4,761
10	Lancaster	69.5	33.57	0.0120	Los Angeles	8.85	42,657	24.8	1,556	4,442
11	Fontana	49.8	37.80	0.0115	Los Angeles	9.86	38,347	23.5	1,506	4,010
12	Moreno Valley	64.4	33.91	0.0114	Los Angeles	10.34	38,358	24.1	1,635	4,353
13	Antioch	45.3	42.06	0.0104	S. Francisco	7.86	45,953	19.7	1,898	5,054
14	Ceres	94.6	26.99	0.0101	San Jose	12.98	37,184	25.3	1,527	4,065
15	Hesperia	79.5	37.30	0.0093	Los Angeles	9.86	39,018	26	1,954	5,203

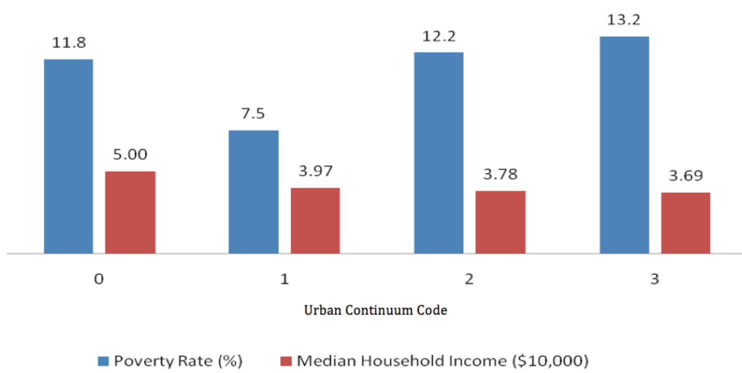
(b) Lowest rates of foreclosure

Rank	City	Dist. to Nearest City (in miles)	Mean Commute (in min.)	Forecl. Rate	Nearest City	Unemp. Rate	Mean Income ($)	Transpo. Cost as Percent Income	Gas Cost (2000) ($)	Gas Cost (2008) ($)
1	Davis	15.3	20.75	0.0004	Sacramento	8.99	63,478	22.9	1,330	3,541
2	Cupertino	48	25.81	0.0004	S. Francisco	7.97	126,859	14.1	1,350	3,594
3	Seal Beach	29.6	30.63	0.0005	Los Angeles	6.70	70,675	17.2	1,334	3,552
4	Mtn. View	12.9	20.91	0.0005	San Jose	7.97	95,252	12.9	1,130	3,009
5	Santa Monica	15.8	25.00	0.0005	Los Angeles	8.85	101,401	18.5	809	2,310
6	Burlingame	15.8	27.06	0.0006	S. Francisco	6.37	218,989	16.2	1,505	3,651
7	Manhat. Bea.	21.1	29.20	0.0006	Los Angeles	8.85	204,052	21.4	955	2,727
8	Coronado	6.4	17.39	0.0006	San Diego	7.45	99,032	25	1,703	4,534
9	S. Luis Obispo	185	15.60	0.0007	San Jose	7.03	61,319	22.9	1,281	3,411
10	San Carlos	24.4	26.69	0.0007	S. Francisco	6.37	131,613	17.2	1,579	3,831
11	Saratoga	13.4	26.40	0.0007	San Jose	7.97	260,549	15.5	1,691	4,503
12	So. Pasadena	8.6	27.44	0.0007	Los Angeles	8.85	91,396	21.2	961	2,743
13	San Francisco	1	26.16	0.0008	S. Francisco	6.81	87,099	12.5	1,110	2,693
14	Sunnyvale	11.8	23.86	0.0008	San Jose	7.97	89,544	12.8	1,089	2,900
15	Belmont	23.3	28.37	0.0008	S. Francisco	6.37	103,908	17.8	1,627	3,947

Note: Data based on original analysis of data from RealtyTrac and CoreLogic. Transportation and gas costs from the Center for Neighborhood Technology's Housing + Transportation Affordability Index.

Figures

Figure 1: Poverty rate and average median household income by urban continuum code, 2000



Notes: Code 0 - Central counties of metro areas with population of one million or more; 1 - Fringe counties of metro areas with populations of one million or more; 2 - Counties in metro areas with populations of 250,000 to 1 million; 3 - Counties in metro areas with populations less than 250,000.

Figure 2: Median household income by zip code, 2000

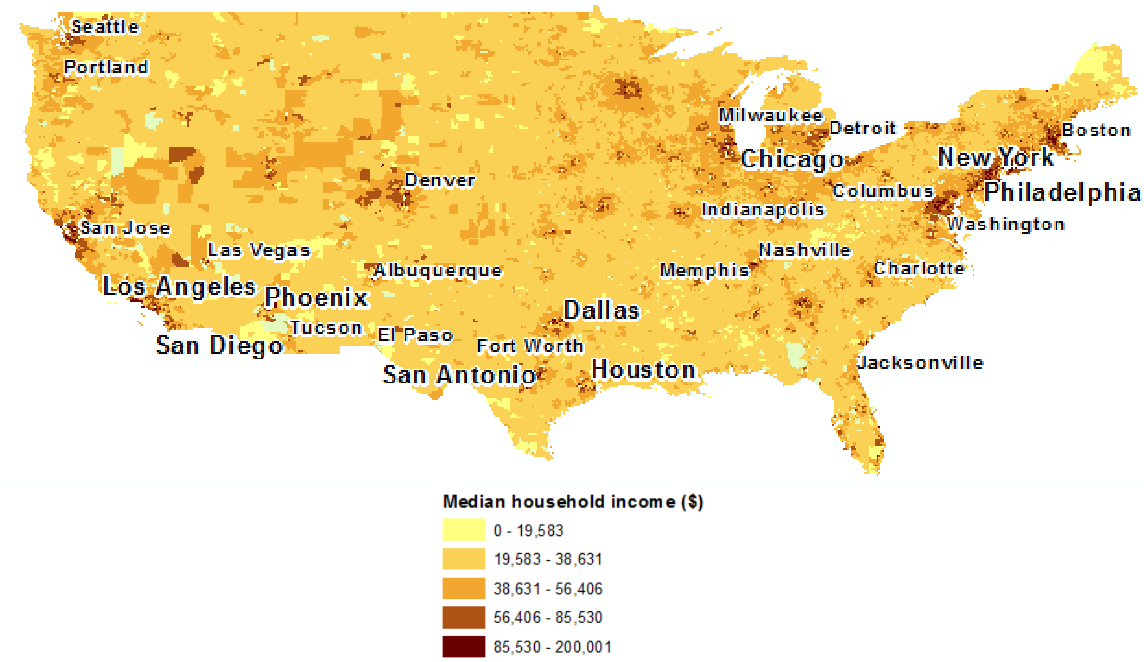
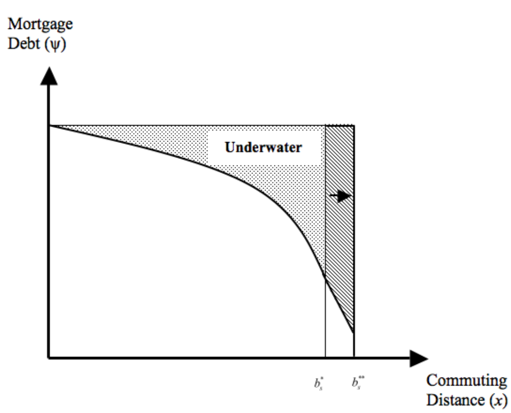


Figure 3: Accommodative monetary policy exacerbated the housing market crisis, but did not trigger it.

(a) Low mortgage rates and tax deductions shift out the suburban boundary.



(b) Accommodative policy shifts the break-even curve down when expectations change.

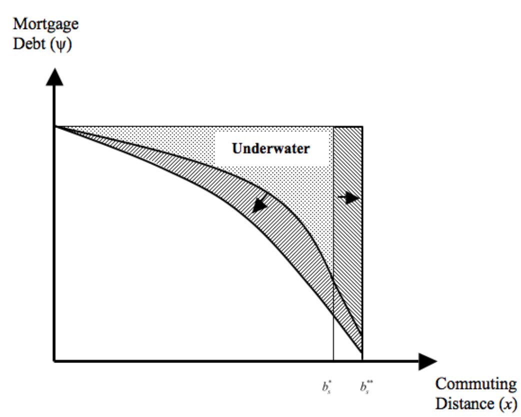


Figure 4: Percent change in median home prices after housing market collapse: California

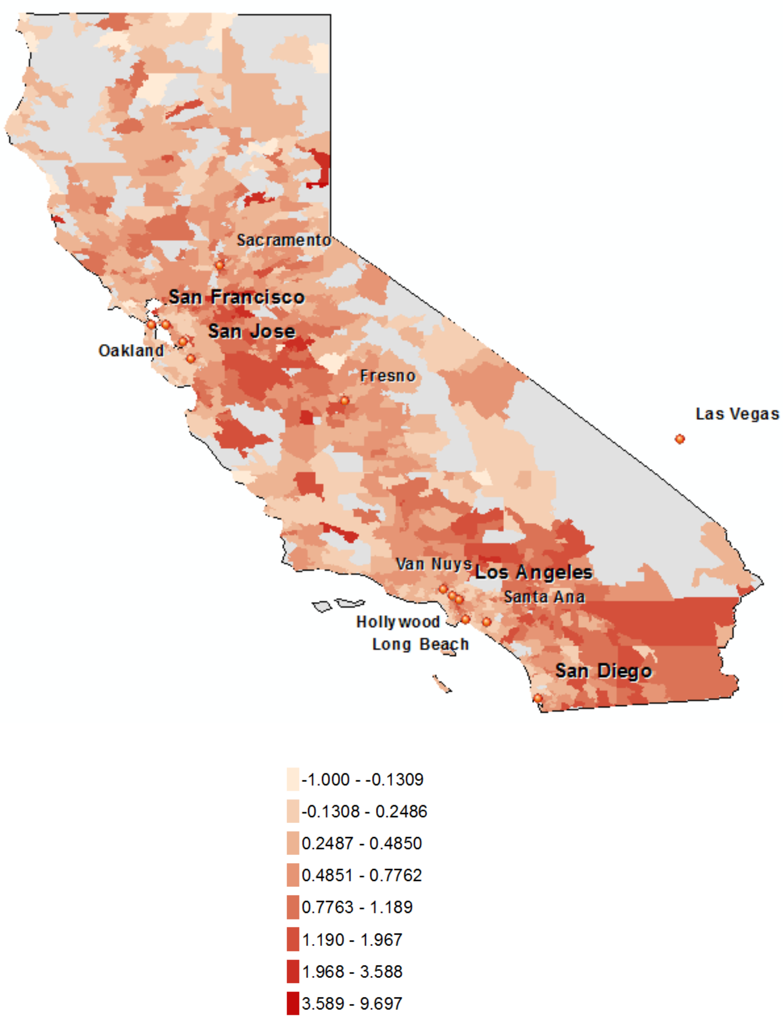


Figure 5: Percent change in median home prices after housing market collapse: Los Angeles and San Francisco metro areas

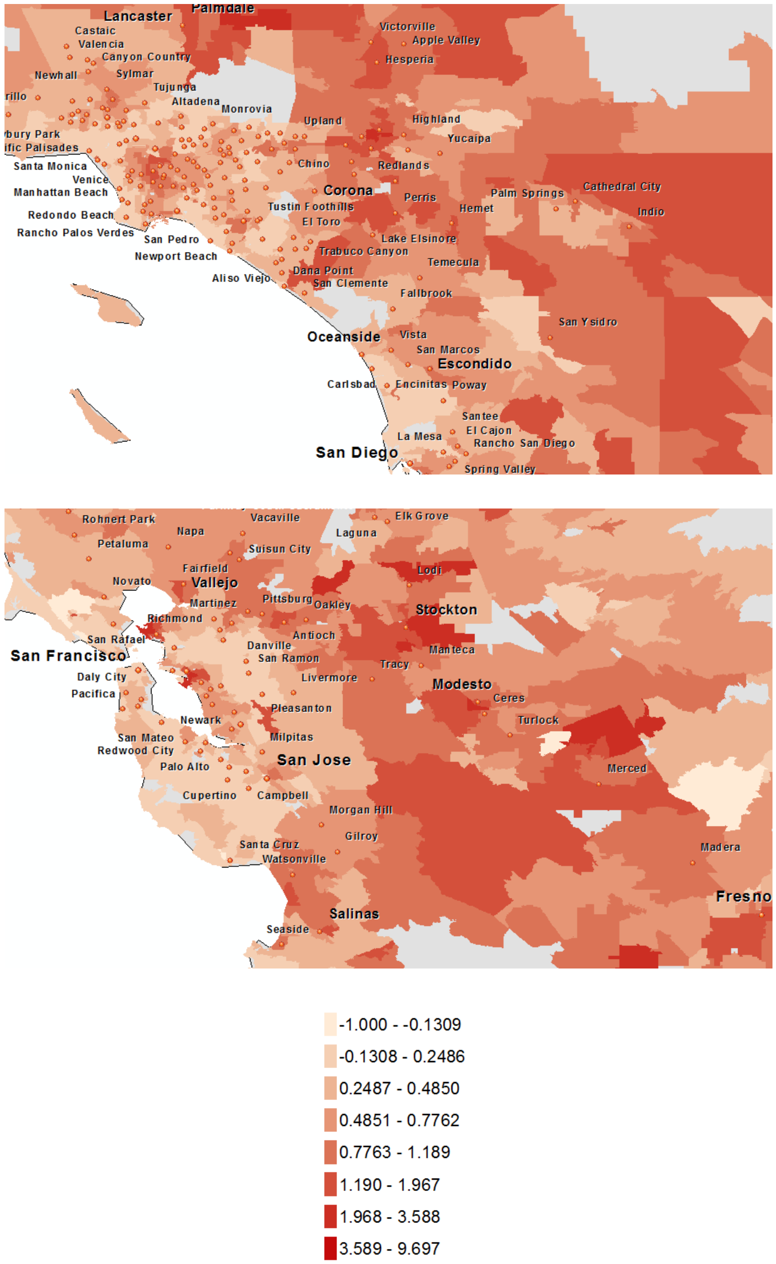


Figure 6: Change in foreclosure rates after housing market collapse: California

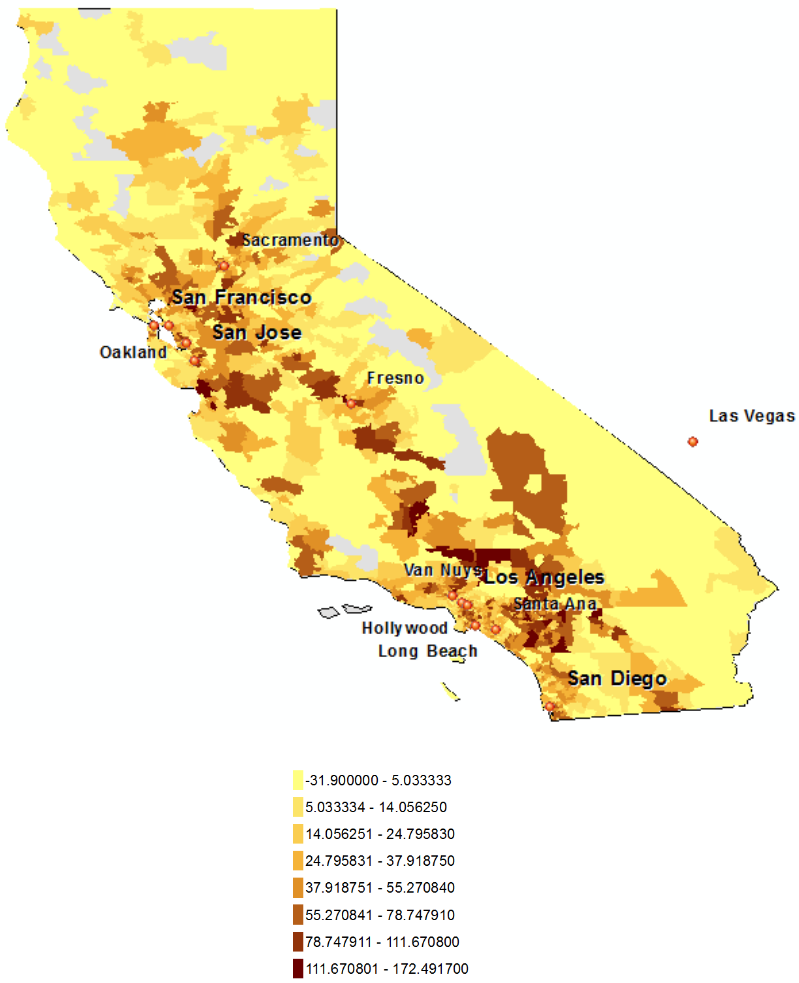


Figure 7: Change in foreclosure rates after housing market collapse: Los Angeles and San Francisco metro areas

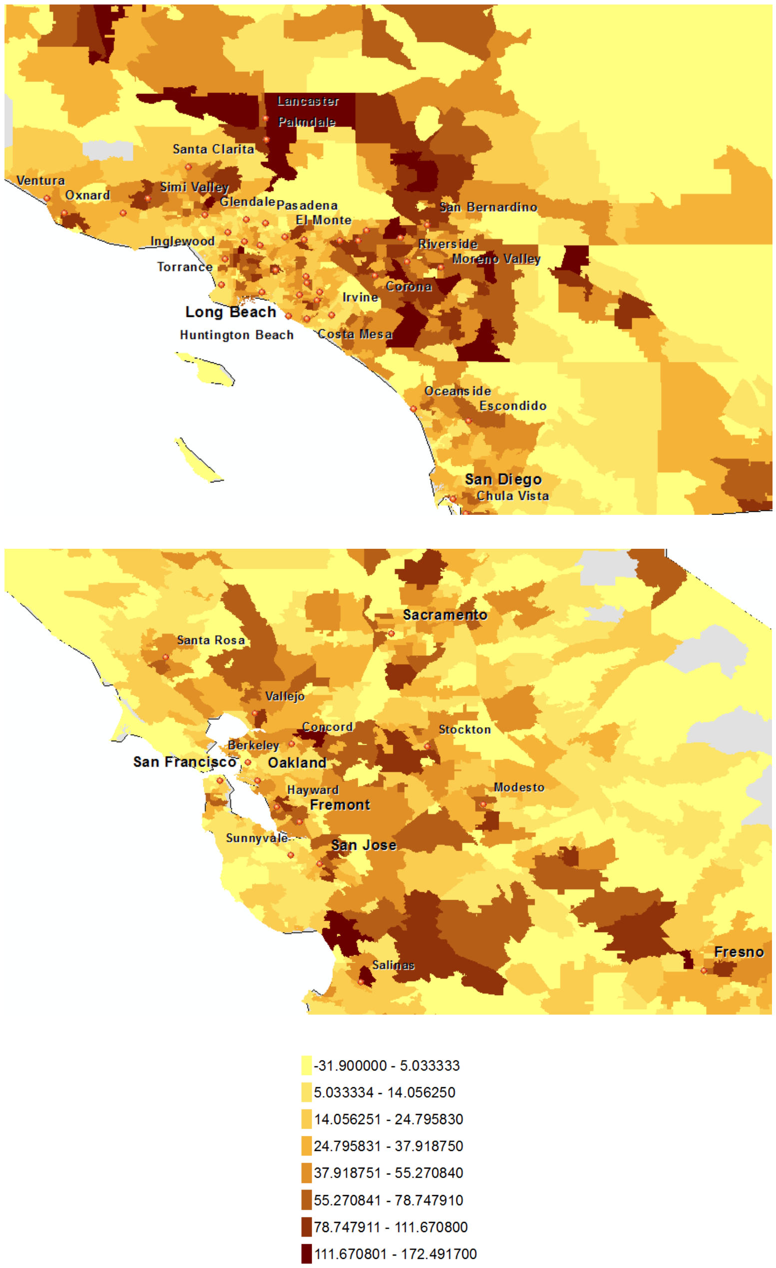


Figure 8: Simulated percent loss in home price for six scenarios as a function of distance to the CBD

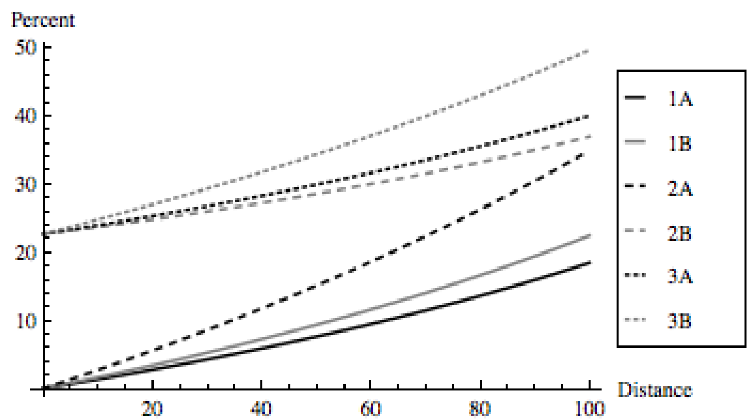
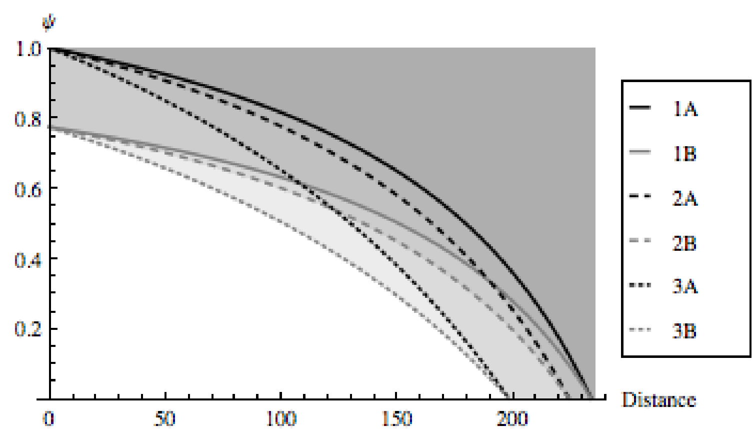


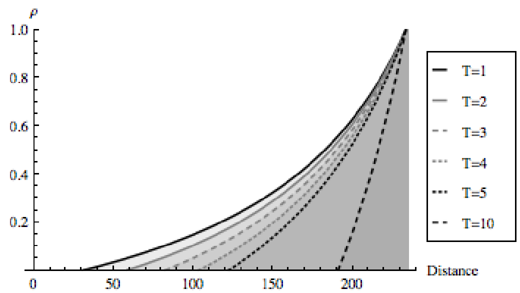
Figure 9: By distance to the CBD, outstanding mortgage debt as a share of purchase price at which homes are underwater for six scenarios.



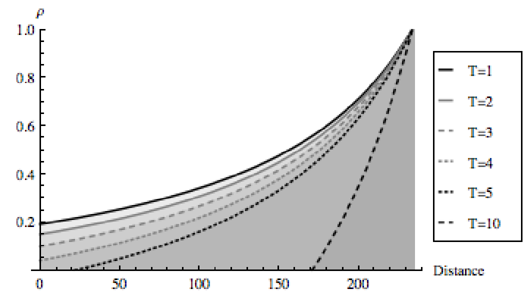
Note: Areas above the "break-even" curves (and shaded in gray) represent properties that are underwater.

Figure 10: Downpayment required to remain above water as a function of distance and mortgage age to gas price shock.

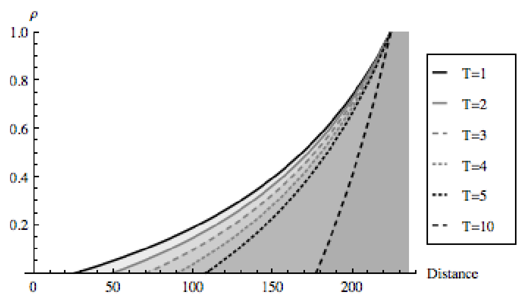
(a) Scenario 1a



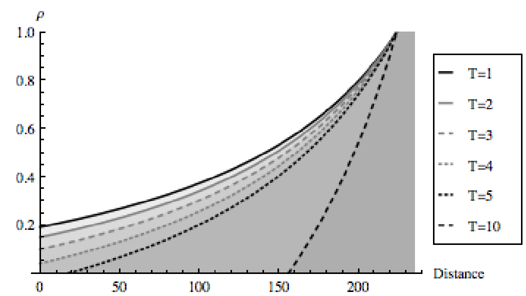
(b) Scenario 1b



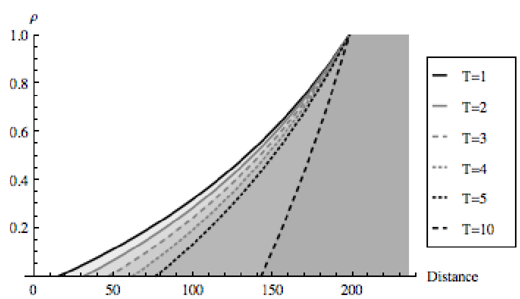
(c) Scenario 2a



(d) Scenario 2b



(e) Scenario 3a



(f) Scenario 3b