Speculating on Home Improvements*

Hyun-Soo Choi† Harrison Hong‡ Jose Scheinkman§

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Abstract

We develop a speculation-based theory of home improvements. Housing services are produced from a mix of land and structures. Homeowners optimistic about future prices for these services speculate by making improvements, which we model as them increasing their structures holding fixed their land. The recoup value (the difference between the resale value of improvements and construction costs) is simultaneously increasing in home price appreciation and falls with construction cost growth. This prediction stands in contrast to a consumption-cum-financial constraints motive in which rising home prices loosen financial constraints and lead to lower recoup values. We provide evidence consistent with a speculative motive using data on the costs and recoup values of remodeling projects across U.S. cities.

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†Singapore Management University (e-mail: hschoi@smu.edu.sg)

‡Princeton University, NBER, and China Academy of Financial Research (e-mail: hhong@princeton.edu)

§Princeton University, Columbia University, and NBER (e-mail: joses@princeton.edu)

1. Introduction

We seek to develop a theory of home improvements—a little-studied but important economic activity. While the significance of new home constructions for economic growth during the housing bubble years of 2003-2007 is well-documented, the contributions of home remodeling expenditures, though less heralded, are no less impressive. The Joint Center for Housing Studies of Harvard University reports that home improvement expenditures on, for instance, a new bathroom or a new deck, jumped from around 1% of GDP ($229 billion) in 2003 to 2% of GDP ($326 billion) in 2007.[1] Spending on remodeling projects then dropped precipitously after 2007 with falling home prices, thereby exacerbating the Great Recession of 2008. These figures suggest that home remodeling is an important industry for the U.S. economy and the pro-cyclicality of these expenditures contributes to business cycle fluctuations.

A consumption-cum-financial constraints motive is a natural way to rationalize remodeling activity. Rising home values loosen financial constraints as banks are more apt to lend to homeowners who might want to indulge in home improvements as a form of pleasure. Remodeling as consumption is consistent with the prevailing professional view that such activities are typically not profitable as the value-added of the improvements is often less than the construction cost. For instance, homeowners who install pink tile in their bathrooms to satisfy their idiosyncratic tastes decrease the recoup value of their improvements. Indeed, an eminently reasonable additional assumption of moving costs would reinforce the consumption motive as remodeling becomes a substitute for moving to a newer or nicer place.

However, there are a number of other stylized patterns regarding remodeling which suggest that speculation in addition to consumption may be an important economic force behind home improvements. First, there is significant anecdotal evidence that homeowners think of improvements as an investment in the same way they think about the purchase of a home. For instance, "fix it and flip it" is a phrase often associated with real estate investing in

[1]These figures include professional remodeling projects and do-it-yourself (DIY) jobs. The purchase of raw materials from companies like Home Depot for DIY jobs are accounted for in these GDP figures but not the opportunity costs of DIY labor.

which it is thought that the completion of a few choice remodeling projects will add significant value to the price of a home.[2] Thus homeowners undertake major renovation projects with the *mistaken* belief that improving the place will result in big profits. Instead, they often end up not realizing these gains. Second, home improvements are more likely to be undertaken by sellers or households planning to move (see Joint Center for Housing Studies of Harvard University) and remodeling activity picks up when moving costs are low as opposed to being high in the time series.

And third, rapid price appreciation during the recent housing bubble years and the potential for quick capital gains no doubt reinforced the "fix it and flip it" mentality. Indeed, McQueen (Apr 24, 2010) reports that the forces driving home improvements during the previous housing-boom decade could not be more different than the ones driving home improvements after the collapse of home prices: "Back then, people wanted to renovate their places so that they could trade up to bigger homes, or because their home equity was soaring and they wanted to reinvest some of the spoils. Now, the opposite is happening: Many people who bought during the boom years are accepting the reality that they won't soon be swapping up for a sybaritic spread. Their mortgages may remain above water, but after years of falling home prices, their equity is so low that the transaction costs of buying a new house would leave little for a down payment."

As such, we pursue in this paper a speculation-based theory of home improvements. We first develop a model with a pure speculative motive for home improvements and then expand it to also account for a consumption-cum-financial constraints motive to highlight a key testable prediction that differs across these two motives. Our model has the following features. A unit of housing services is given by a Cobb-Douglas production function of land and structures with constant returns to scale. We fix the supply of land but assume that there is an upward sloping supply curve for structures. Homeowners have an option to build additional structures.

[2]Google search "fix it and flip it" and many housing sites discuss this phenomenon.

Housing unit prices are determined by the beliefs of the homeowners regarding the level of future prices. Homeowners have an equal chance of becoming optimistic or pessimistic. In other words, homeowners are hit by a sentiment shock. When homeowners receive the positive shock, they will undertake home remodeling, whereas they will not when they receive a negative shock.

We derive three key results. The first result is that a larger growth in home prices is correlated with home improvement activity. To the extent home prices are correlated with optimism among homeowners, this will naturally increase the optimal amount of structures in a given plot of land. This effect is partially moderated by an increase in the cost of structures. Our model generates the exaggerated pro-cyclical pattern in remodeling expenditures with home prices. The reason is that home improvement is a homogeneous function of degree larger than one in the beliefs of the optimistic homeowners. We perform a simple calibration that shows that the kind of mistakes we attribute to homeowners can explain in part the high level of improvements relative to GDP during the main bubble years of 2003-2007 in contrast to the relatively low levels over the previous decade (1993-2003), when prices grew just as much in total but over a longer period of time.

The second result is that there is on average excessive investment in improvements by optimistic homeowners, which can be measured by either the recoup value, defined as the difference between resale value of improvements and construct costs or the recoup ratio, which is the resale value over the construction costs. We show that the expected recoup ratio is less than one on average and the expected recoup ratio is lower the higher is the level of home improvements. This result is consistent with the view among professionals that such activities are on average not profitable. The prevailing view is that this is because home improvements are consumption. But this second result suggests that it might also be driven by speculative forces.

The third result is that the realized recoup ratio is positively correlated with realized home price appreciation, controlling for construction cost growth. Even though homeowners are too optimistic about future home prices and do too much remodeling, this speculation can be profitable when realized home prices meet or exceed these expectations. But their optimism leads to losses when construction cost growth is high controlling for home price appreciation. Hence, the recoup ratio increases with home price growth controlling for construction cost growth and decreases with construction cost growth controlling for home price appreciation.

The third result is particularly interesting because it cuts against the consumption-cum-financial-constraints motive. To see why, we extend our pure speculation model to also allow for a consumption-cum-financial constraints motive. A bank with rational beliefs (which we assume to be perfect foresight on the path of home prices) lends to homeowners who are financially constrained. The key assumption is that financial constraints are always binding for homeowners. As such, homeowners' recoup values are too high since they would like to indulge in more pink tile but cannot. But higher home prices, which banks can rationally anticipate, loosen financial constraints and allows homeowners to borrow and hence consume more pink tile which will lead to lower recoup values. Under a consumption-cum-financial constraints motive, we show that recoup values and home price appreciation are negatively correlated.

We conduct a test of this prediction using data on construction costs and resale value of home improvement projects across the U.S. The data comes from *Realtor Magazine* which collects surveys of construction cost and resale value for a basket of home remodeling projects. We use cross-sectional variation to test the third hypothesis by regressing recoup values in different cities on realized home price appreciation and construction cost growth. The main idea of our exercise is that there is cross-city variation in home price growth and we use this variation to test our third prediction. During the housing boom years of 2003 to 2009, there were significant home improvements made. We expect to find higher recoup values over this period in cities where home prices performed relatively well, controlling for construction cost growth, than in cities where home prices performed relatively poorly.

In the cross-section, we find that cities with more home price appreciation indeed have higher recoup ratios during the period of the housing boom period 2003 to 2009. Moreover, we find that those with higher construction cost growth have actually witnessed a fall in recoup ratio. These relationships are statistically and economically significant. We conduct a series of robustness checks to verify that these relationships are robust. The negative relationship between the recoup ratio and cost growth is consistent with our model since excessive speculation drives up the cost of construction and lowers the recoup ratio. But this result can also be consistent with a consumption motive since more remodeling for pleasure delivers lower recoup values and at the same time also drives up high construction costs. It is really the home price comparative static that pins down the speculation motive and rules out the consumption-cum-financial constraints one.

Our paper is related to work on home improvements including Montgomery (1992), Helms (2003) and Gyourko and Saiz (2004). Importantly, Gyourko and Saiz (2004) find that home improvements cease when the value of the home is low relative to construction costs, suggesting a rational investment motive consistent with our premise. Our paper is also related to a recent interesting paper by Glaeser, Gyourko, and Saiz (2008) who argue that home prices went up more in low supply elasticity states (such as New York and California where land is limited and zoning and development rules are stricter) because supply could not quickly adjust to the rising home prices. Indeed, we can use their work to motivate a further test of our model, which is to see if the effect of the change in home prices on the change in recoup value is greater in low as opposed to high elasticity cities. After all, we know from their work that much of the speculation in the purchase of homes occurs in low elasticity areas. It stands to reason that if our regression specification is picking up speculative remodeling effects, then the change in home prices ought to have more of an effect on change in recoup values in low elasticity areas. We confirm this prediction in the data.

Our theory and empirical analysis contributes to the burgeoning literature of household finance (see Campbell (2006) and Barber and Odean (2011) for surveys). Much of this literature has focused on the financial decisions of households such as stock market participation or financial products such as types of mortgages that are used and whether the appropriate decisions are made. There is a consensus that at least poor and uneducated households do not make appropriate decisions. But this literature has entirely ignored home improvement decisions and whether the right level of remodeling is undertaken. These economic decisions as we pointed out above account for an enormous industry that extends to even wealthy households, with consequences for the macro-economy. Our paper suggests that there are excessive expenditures on home remodeling.

Our paper also adds to the burgeoning literature on the effect of asset prices or bubbles on real investments. This literature examines whether capital investments by firms are influenced are stock price bubbles, with the dot-com bubble being the primary object of focus (see, e.g., Polk and Sapienza (2008), Gilchrist, Himmelberg, and Huberman (2005), and Farhi and Panageas (2004)).

We present our model and derive the key comparative statics results in Section 2. We expand our model for a consumption-cum-financial constraints motive in Section 3. We discuss the empirical work regarding home improvement projects in Section 4. We conclude in Section 5.

2. Model

2.1. Set-up

Our model has three dates $t = 0, 1, 2$. The interest rate is set to zero. A housing unit or service H_t is derived from two inputs: land L_t and structure (i.e. construction) S_t. In particular, we assume that the units of housing H_t is given by a Cobb-Douglas production function with constant returns to scale:

$$H_t = L_t^{\alpha} S_t^{1-\alpha}, \tag{1}$$

where α is the share of land in housing.

Let

$$\bar{P}_1^o > \bar{P}_1^p > 0. \tag{2}$$

At time 1, with probability 1/2, homeowners become optimistic and believe that P_2, the price of a housing unit at $t = 2$, which includes both rents and capital gains associated with one unit of housing, has the following distribution

$$P_2 \sim \text{Uniform}[\bar{P}_1{}^o - K, \bar{P}_1{}^o + K]. \tag{3}$$

That is

$$E_1[P_2|Optimism] = \bar{P}_1^o. \tag{4}$$

With a probability 1/2, they become pessimistic and believe that P_2 is distributed as

$$P_2 \sim \text{Uniform}[\bar{P}_1{}^p - K, \bar{P}_1{}^p + K]. \tag{5}$$

That is

$$E_1[P_2|Pessimism] = \bar{P}_1^p. \tag{6}$$

We assume agents are risk-neutral so that the price P_1 of housing at time 1 is equal to either $\bar{P}_1^o$ or $\bar{P}_1^p$ with equal probability. At $t = 0$, the price of housing units equals these homeowners' expectations on P_1 given by:

$$E_0[P_1] = \frac{1}{2}\bar{P}_1^o + \frac{1}{2}\bar{P}_1^p = \bar{P}_0 \tag{7}$$

Homeowners are endowed with H_0 housing units at $t = 0$ and so have identical wealth of $\bar{P}_0 H_0$.

This set-up is a simple way to capture the following scenario. The economy is in steady-state at $t = 0$ and the price of a housing unit at $t = 0$ is given by $\bar{P}_0$. At $t = 1$, there is a shock to agents' expectations regarding the price of housing unit at $t = 2$. At $t = 1$, homeowners have an option to add structures depending on their expectations to maximize the expected home value (i.e. choosing S on a fixed land size L_0). More formally, they maximize expected profits depending on the draw to their expectations:

$$\text{Max}_S \left\{ \bar{P}_1^i L_0^\alpha S^{1-\alpha} - \omega(S - S_0) \right\} \tag{8}$$

subject to the constraint that

$$S \geq S_0, \tag{9}$$

and where $i \in \{o, p\}$. The constraint is an irreversibility constraint that says that homeowners cannot decrease their structures. The homeowners who resell their housing units at $t = 2$ then expect a payoff of $\bar{P}_1^i L_0^\alpha S^{1-\alpha}$ and their cost is $\omega(S - S_0)$.

To close the model, we assume that there is an upward sloping supply curve for structures given by

$$\omega = (\frac{S}{S_0})^\beta. \tag{10}$$

β measures the elasticity of the supply curve.

2.2. Equilibrium at $t = 1$

The key outcome of interest is how home improvements depend on the shock to the expectations of the homeowners at $t = 1$. The following proposition characterizes the equilibrium at $t = 1$.

Proposition 1. *If $P_1 = \bar{P}_1^p$, then $S = S_0$. If $P_1 = \bar{P}_1^o$, then homeowners' optimal choice of structures at $t = 1$ is simply*

$$S = [(1 - \alpha)\bar{P}_1^o L_0^\alpha S_0^\beta]^{\frac{1}{\alpha+\beta}}. \tag{11}$$

If homeowners are pessimistic at $t = 1$, they simply stay with their old structure S_0. If homeowners are optimistic at $t = 1$, they naturally add structures $S - S_0 > 0$.

Proposition 2. *When there is home price appreciation, $\bar{P}_1^o > \bar{P}_0$, the equilibrium level of structure at t=1, S is greater than S_0, the equilibrium level of structure at t=0. And the equilibrium cost of structure at t=1 is greater than the equilibrium cost of structure at t=0.*

Indeed, it is easy to see that the higher is their expectation $\bar{P}_1^o$ relative to P_0, the more structures they add.

2.3. Comparative Statics

In this section, we use the equilibrium results from the previous section to derive some comparative statics.

2.3.1. Improvements Are a Homogenous Function of Degree Bigger than One of Home Price Appreciation

The first result concerns the relationship between the growth of structures that result from home improvement and home price appreciation. Recall that the price in period 1, P_1, is either $\bar{P}_1^0 > P_0$ or $\bar{P}_1^p < P_0$, and that if $P_1 > P_0$, $S > S_0$ in equilibrium. The following result relates the growth of structures that result from home improvement $\frac{S}{S_0}$ to home price appreciation $\frac{P_1}{P_0}$.

Proposition 3. *Home improvement is a homogeneous function of degree $\frac{1}{\alpha+\beta}$ in home price increase, that is:*

$$\frac{S}{S_0} = (\frac{\bar{P}_1^o}{\bar{P}_0})^{\frac{1}{\alpha+\beta}}. \tag{12}$$

The result follows from the expression for the S that solves the homeowners' problem. The sensitivity of home improvement to price appreciation depends on the share of land in the value of houses (α) and the slope of the supply curve in structures (β). If, for instance, $\alpha = 1/2$ and $\beta = 1/4$ (i.e. land is half of the value of homes), than the degree of homogeneity is 4/3.

The first implication of the proposition is that an increase in home prices leads to a higher optimal amount of structures in a given plot of land. This is consistent with the pro-cyclical pattern in remodeling expenditures with home prices. The second implication of the proposition is the homogeneity of degree $\frac{1}{\alpha+\beta}$. If α is not near one and β is not large, then we can have the case where $\frac{1}{\alpha+\beta} > 1$.

Using this observation, a simple calibration then shows that the economic forces we highlight here can explain in part the high level of improvements relative to GDP during the recent housing bubble (2003-2007) in contrast to the relatively low levels over the previous decade (1993-2003). Recall that the cumulative house price increase between the ten-year period of 1993 to 2003 is roughly equal to that of the five-year period of 2003 to 2007 - both are around 100%. This means that the home price appreciation per year during the latter 5 year period is roughly double that of the per year appreciation in the earlier decade. Remodeling also nearly doubled during the five-year period of 2003 to 2007 (rising from 1% of GDP to 2% to GDP as we discussed in the introduction).

Our model can rationalize this fact. A large price change in a given year engenders a bigger response in remodeling investments than do a series of small increases across many years when $\frac{1}{\alpha+\beta}$ is large. For instance, say $\alpha + \beta = 0.5$, then the homogeneity is of degree 2. Then, if the annual price change in the 1993-2003 period is 1.1, this will mean remodeling of S/S_0 of 1.21. But if the annual price change in the 2003-2007 period is 1.2, this will lead to a 1.4 in remodeling. Depending on the degree of homogeneity, one can get significant differences in remodeling with home price appreciation. Of course, this calibration is necessarily rough and should be taken with a grain of salt as many other factors also changed during this period.

2.3.2. Excessive Remodeling

Moreover, when investors are optimistic, they will on average lose from these improvements. One way to measure this is to look at the recoup ratio, defined as the ratio of resale value or value-added to construction costs of improvements. The recoup ratio depends on the realization of the price P_2 at $t = 2$ and the cost of the improvements $S - S_0$ which are incurred at $t = 1$.

Importantly, we can calculate the value-added of additional structure, which is given by

$$P_2 L_0^\alpha S^{1-\alpha} - P_2 L_0^\alpha S_0^{1-\alpha} = P_2 L_0^\alpha S_0^{1-\alpha}[(\frac{S}{S_0})^{1-\alpha} - 1] \tag{13}$$

The cost of additional structure is given by

$$\omega(S - S_0) = (\frac{S}{S_0})^\beta (S - S_0) = S_0 (\frac{S}{S_0})^\beta (\frac{S}{S_0} - 1) \tag{14}$$

Using these two quantities, we can calculate in closed form the recoup ratio, which is simply the ratio of value-added of additional structures to the cost of additional structures:

$$R = \frac{P_2 L_0^\alpha S^{1-\alpha} - P_2 L_0^\alpha S_0^{1-\alpha}}{\omega(S - S_0)} = \frac{P_2 L_0^\alpha S_0^{1-\alpha}[(\frac{S}{S_0})^{1-\alpha} - 1]}{S_0(\frac{S}{S_0})^\beta (\frac{S}{S_0} - 1)} = \frac{1}{1-\alpha} \frac{P_2}{\bar{P}_0} \frac{(\frac{S}{S_0})^{1-\alpha} - 1}{(\frac{S}{S_0})^\beta (\frac{S}{S_0} - 1)} \tag{15}$$

The expected recoup ratio is given by

$$\frac{1}{1-\alpha} \frac{(\frac{S}{S_0})^{1-\alpha} - 1}{(\frac{S}{S_0})^\beta (\frac{S}{S_0} - 1)}. \tag{16}$$

Proposition 4. *Expected recoup ratio is less than or equal to 1 and the greater the structure growth, the lower is the recoup ratio.*

Let $\frac{S}{S_0}$ be X. Then

$$\frac{1}{1-\alpha} \frac{(\frac{S}{S_0})^{1-\alpha} - 1}{(\frac{S}{S_0})^\beta (\frac{S}{S_0} - 1))} = \frac{1}{1-\alpha} \frac{X^{1-\alpha} - 1}{X^\beta (X - 1)}. \tag{17}$$

Applying L'Hopital's Rule allows us to show that the expected recoup ratio is one when

$X \to 1$, i.e. when there is no home improvement. We also can show that

$$\frac{\partial}{\partial X}[\frac{1}{1-\alpha}\frac{X^{1-\alpha}-1}{X^{\beta}(X-1)}] < 0. \tag{18}$$

That is, the more home improvements there are, the lower the recoup ratio on average. Because investors are optimistic at $t = 1$, there is too much remodeling in equilibrium and the degree to which the expected recoup ratio is below 1 is an ex-ante measure of this.

In Figure 1, we consider a simple calibration of how the expected recoup value varies with the optimism bias of homeowners. The optimism bias, defined as $\frac{\bar{P}_1^o}{P_0} - 1$, lies in the interior of $]0, 2[$ in the calibration. The share of land in housing services α is set at 0.25 and the slope of the supply curve for construction β is set at 0.25. These two parameters are set to give a degree of homogeneity to the growth of structures or improvements equal to 2. In this example, an optimism bias of 50% leads to an expected recoup value of 0.729. In the data below, the expected recoup value is 0.78. So our model can easily match the low expected recoup value and the high growth rate of structures during the sample period.

2.3.3. Price Appreciation, Construction Costs and Recoup Value

The third result we derive, which is testable and that is the focus of our empirical work below, is that the recoup ratio is positively related to realized price P_2 and negatively related with $\bar{P}_1^o$ (optimist's expectation) and $S - S_0$ (additional remodeling due to optimistic view).

As such we can formally state the following result which is the focus of our empirical work. This discussion assumes that in period 1, investors are optimists and there is actual remodeling.

Proposition 5. *The recoup ratio is positively correlated with home price appreciation $P_2 - P_1$ and negatively correlated with construction cost ω.*

A related quantity to the recoup ratio is the recoup value

$$P_2 L_0^{\alpha} S^{1-\alpha} - P_2 L_0^{\alpha} S_0^{1-\alpha} - \omega(S - S_0). \tag{19}$$

The recoup value also increases with $P_2 - P_1$. In addition, when recoup ratios are below one, a decrease in recoup ratios implies a decrease in recoup values. Thus, since recoup ratios are negatively correlated with construction costs ω and typically below unity, recoup values are also negatively correlated with construction costs ω.

Notice that the speculation on home improvements can pay off for homeowners depending on how much appreciation occurs between periods 1 and 2. This depends on the draw of the uniform distribution for P_2. When there are positive draws in P_2, the speculation pays off as the above proposition shows. This is a natural outcome of speculation assuming no financing constraints whatsoever.

2.4. Overconfidence on Construction Costs Instead of Optimistic Beliefs about Home Prices

In our current set-up, we have assumed that home improvers are optimistic about the path of home prices to get excessive home remodeling. Alternatively, we can also model homeowners as being overconfident about their ability to install structures.[3] They think they can do the improvements at the time-0 cost ($w_{S,0}$) when it fact the time-1 cost ($w_{S,1}$) will prevail. This is a way of modeling that with higher cost growth, improvers are overconfident about the cost at which they can install new structures. Either modeling choice (mistaken beliefs on path of home prices or overconfidence on cost of remodeling) yields similar economics, which is an excessive amount of structures that get built. We provide details of this alternative model in the Appendix. We also generalize the set-up to allow for flexible land prices in

[3]There is now plentiful evidence on retail trading behavior which indicates that the typical retail investor trades on noise and loses money to trading cost as a result of this noise trading (see, e.g., Barber and Odean (2001) and Odean (1999)). The poor performance of small business owners is documented by Moskowitz and Vissing-Jorgensen (2002), who suggest that either overconfidence or tax evasion are plausible explanations.

addition to flexible structure prices and show that we get similar results.

3. Adding a Consumption-cum-Financial-Constraints Motive

In this section, we extend our pure speculation model to allow for a consumption-cum-financial-constraint motive. That is, homeowners also derive utility from housing units as opposed to purely benefiting from profit. They are financially constrained and have to borrow from competitive banks to finance their investments. Otherwise, the model set-up is the same as before.

To model the consumption motive, we assume that homeowner utility is quasi-linear in housing units, h and c, where c is some other consumption basket:

$$u(c,h) = u(L^{\alpha}S^{1-\alpha}) + c \tag{20}$$

At $t = 0$, homeowners start with housing unit $L_0^{\alpha}S_0^{1-\alpha}$. They have to borrow an amount $\lambda\bar{P}_0L_0^{\alpha}S_0^{1-\alpha}$ to finance their purchase, where λ represents their loan-to-equity value. The loan is obtained from competitive banks who we assume to have perfect foresight about P_2 at $t = 1$: $\bar{P}_1^b = P_2$.

At $t = 1$, homeowners maximize expected home value by adding more structure on a fixed land size: They choose S to maximize

$$U = u(L_0^{\alpha}S^{1-\alpha}) + \bar{P}_1^iL_0^{\alpha}S^{1-\alpha} - \bar{P}_1^iL_0^{\alpha}S_0^{1-\alpha} - \omega(S - S_0) \tag{21}$$

subject to a irreversibility constraint $S \geq S_0$ and a credit constraint:

$$w(S - S_0) \leq \bar{P}_1^bL_0^{\alpha}S^{1-\alpha} - \lambda\bar{P}_0L_0^{\alpha}S_0^{1-\alpha}, \tag{22}$$

and where $i \in \{o, p\}$.

The objective function includes both consumption utility and profits from these investments. The credit constraint means that the cost of remodeling cannot exceed banks' expected value of remodeled house subtracting pre-existing debt.

Suppose the credit constraint binds. Since the bank has perfect foresight, i.e. $\bar{P}_1^b = P_2$, we can write the credit constraint as

$$w(S - S_0) = P_2 L_0^\alpha S^{1-\alpha} - \lambda \bar{P}_0 L_0^\alpha S_0^{1-\alpha}. \tag{23}$$

Then recall that the recoup value is given by $R = P_2 L_0^\alpha S^{1-\alpha} - P_2 L_0^\alpha S_0^{1-\alpha} - \omega(S - S_0)$. We can rewrite the recoup value by substituting in the credit constraint:

$$R = \lambda \bar{P}_0 L_0^\alpha S_0^{1-\alpha} - P_2 L_0^\alpha S_0^{1-\alpha}. \tag{24}$$

The recoup value decreases in P_2. Because the credit constraint binds, this means the higher is P_2, the bank's perfect foresight expectation, the more they are willing to lend for the homeowner to do home improvements, the more these homeowners can scale their improvements and hence the lower is the recoup value. This result concerns the recoup value as opposed to the recoup ratio. However, a decline in the recoup value implies a decline in the recoup ratio, provided the recoup ratio is not too much below 1.

The recoup value is negatively associated with construction cost. For each P_2, S in equilibrium will be determined by equation (23). Let

$$F(P_2, S) = w(S - S_0) - P_2 L_0^\alpha S^{1-\alpha} + \lambda \bar{P}_0 L_0^\alpha S_0^{1-\alpha}. \tag{25}$$

Since $\frac{\partial F}{\partial P_2} < 0$ and $\frac{\partial F}{\partial S} > 0$, we get

$$\frac{\partial S}{\partial P_2} = -\frac{\partial F}{\partial P_2} / \frac{\partial F}{\partial S} > 0. \tag{26}$$

The equilibrium structure increases with P_2 and construction cost, $\omega = (\frac{S}{S_0})^\beta$, also increases with the P_2.

4. Empirical Work

Our empirical analysis centers on testing our theory's prediction regarding the change in the recoup value of remodeling projects being positively correlated with the percentage change in home prices and negatively correlated with construction cost growth. We test this prediction using data across US cities and regressing the percentage change in recoup value of projects in each city on the percentage change in construction cost of these projects and the percentage change in home prices.

4.1. Data

Our data on home improvement projects comes from the *Cost vs. Value Report* provided by *Realtor Magazine*, which is the official monthly magazine of the National Association of Realtors. It provides information regarding costs and resale value (value added to home) for a range of major home improvement projects across many cities starting in 1998 and ending in 2009. (Note that magazine did not conduct a survey in 2006 and hence data is missing for this year.) The projects and cities are listed in Table 1. Panel A lists the projects covered ranging from attic bedroom remodel to deck addition. For some of the projects on this list, starting in 2002, the magazine separated the projects into a mid-scale and an up-scale version that differ in terms of square footage and use of high-end finishes. The core projects covered have increased slightly from 12 in 1998 to 14 in 2009. So the set of projects has remained relatively stable over time. These projects represent major remodeling as opposed to small ones such as replacing a door which would more appropriately be labeled as maintenance. Panel B lists the cities surveyed. The magazine started with 60 cities in 1998 and increased the coverage to 80 cities in 2009. The list of cities includes the 35 metro markets listed as the top remodeling markets by the Harvard Joint Center for Housing Studies.

For each remodeling project in each city, the database reports for each year its cost, resale value and recoup value, which is simply the resale value divided by the cost. The cost and resale figures in the annual reports are compiled separately. The cost figures come from HomeTech Information Systems, a remodeling estimating software company in Bethesda, Maryland. HomeTech collects current cost information quarterly from thousands of contractors nationwide. The project costs are based on estimates for hypothetical projects made by the firm based on their information of the real costs of projects actually undertaken. The figures include markup and are adjusted to account for pricing variations in different parts of the country. The construction cost figures include labor, material, subtrades, and contractor overhead and profit. The cost data in the early years of the sample were split among various firms but for most of the sample since, it has been completed by HomeTech Information Systems.[4] HomeTech is a leading provider of construction cost estimates for various projects across the country.

It is interesting to consider what is driving differences in home improvement costs across different cities. We gathered anecdotal evidence on this issue by reading material provided by HomeTech on their website and various sources in the internet media regarding home remodeling. Interestingly, wages in different cities accounts for only a fraction of the differences in costs. There are also variations in lumber and materials prices in different cities depending on factors such as the number of lumber suppliers in that city according to HomeTech. Moreover, a bigger source of cost inflation that is often reported for the high-end improvement projects that are at the center for our data set is that there is a trade-off in terms of the speed of construction and cost. For instance, consider the cost of an Italian marble bathroom. The biggest cost is procuring the Italian marble and depending on search time the cost differences can be substantial. In cities in which people are in a rush to build, busy

[4]For 1998, cost estimates for projects were from three publishers of construction cost estimating guides and software: Craftsman Books, Carlsbad, CA; HomeTech Information Systems, Bethesda, MD; and R.S. Means, Kingston, MA. For 1999, R.S. Means, Kingston, MA was the only source for the cost estimates.

contractors are less picky about how much such quality items cost. Instead of searching for an extra month to find the same quality at a lower price, the contractor uses the most expensive one. This is the big cost difference across cities and over time between building during the bubble years versus the non-bubble years.[5] So one should think of variations in remodeling costs from this database across cities as driven by these local supply factors in addition to any wage differences. We look at this issue of wages in residential construction more closely and relate it to our model in the robustness sub-section below.

Resale values (or value-added) of these home improvements are based on the professional judgment of members of the National Association of Realtor (NAR). To obtain these judgments, the magazine sent out surveys containing customized cost-to-construct data for each city, as well as information on median house prices, via e-mail to appraisers, sales agents, and brokers. The magazine gives instructions in the survey for the respondents not to make judgments about the motivation of the homeowner in either the decision to undertake the remodeling project or to sell the house. The real estate professionals then responded with dollar figures for each remodeling project that represent the value the completed project would add to the selling price of the house under current market conditions. The surveys are obtained from hundreds of real estate professionals and aggregated to provide the resale values in the magazine.

We construct for each city by year a COST variable which is simply the equal weighted average of the costs of the projects in that city. We construct a similar variable RESALE which is the average of the resale values for the projects in that city. We divided RESALE by COST to obtain RECOUP, which corresponds to recoup value in our theoretical analysis and is our main dependent variable of interest. Our home price index for each city obtained from the Federal Housing Finance Agency is HPI. Data for HPI is defined at the level of the Metropolitan Statistical Area. So we use as the home price for each city the price of the

[5]See for instance coverage on this issue at the following site: http://moneywatch.bnet.com/saving-money/article/five-home-renovations-that-pay-off/353008/. See also the description in http://www.remodeling.hw.net/remodeling/cost-vs-value-report-2006.aspx.

MSA that it belongs to.

Our analysis largely focuses on the three variables of RECOUP, HPI, and COST. Indeed, our theory can be completely summarized by these variables. To test our theory, we really do not need to look at any other variables. But for completeness of analysis, we include demographic variables in our robustness checks. They should have no material impact on the relationships we are predicting. As such, we will not have many comments regarding the demographic variables. The relationships of these demographic variables to our variables of interest in all likelihood are determined by complicated equilibrium effects.

The demographic variables are as follows. INC is income per capita in the city. POP is population in the city. We do not have data for INC and POP for 2009 yet and so in our analyses involving these variables we can only look at changes in INC and POP up to 2008 instead. These two latter variables are from the Bureau of Economic Analysis. UNEMP is the unemployment rate in a city, which is provided by the Bureau of Labor Statistics.

Table 2 provides the summary statistics for our main variables of interest. In Panel A, we report the time series average (across years) of the cross-sectional (across cities for each year) means and standard deviations for the following variables. The mean COST of a typical project in a typical city is $39,189 with a standard deviation of $4193. As these numbers attest, the projects are major remodeling undertakings and most of them have roughly the same average value. The mean RESALE is $29428 with a standard deviation of $7959. The recoup value is 0.78 with a standard deviation of 0.18. The recoup value is on average less than one and there is a reasonable difference in recoup values across cities. The mean HPI is 162 with a standard deviation of 26. The per capita income (INC) is $35,437 with a standard deviation of $6319. The population of a typical city in our sample is around 1.2 million people with a standard deviation of around 1.5 million people. The unemployment rate (UNEMP) is around 6% with a standard deviation of 2%.

Panel B provides the time-series average of the cross-sectional correlations of these variables of interest. The key things to observe from this panel are the following. COST and

RESALE are positively correlated with a correlation coefficient of 0.61 and COST and RECOUP are also positively correlated with a coefficient of 0.23. In other words, cities with higher COST also have higher RESALE and RECOUP values. This positive correlation is in levels and captures potentially many unobservables. Hence, COST and RECOUP need not be mechanically hardwired to be negatively correlated since RESALE also adjusts. Our theory does not have much to say about levels since it is geared to understanding the implications of how a change in home prices stimulates home improvements. When we look at changes in these variables, the comment regarding the hard-wiring of COST and RECOUP in levels applies to changes—that is, the correlation of changes in these two quantities need not be hard-wired to have a particular sign. Moreover, the correlation of HPI with COST, RESALE and RECOUP are all positive. Hence, cities with higher home prices captured by HPI also have higher COST, RESALE and RECOUP values.

4.2. Baseline Results

Our theory is concerned with the relationship between changes in RECOUP associated with a change in home prices HPI and changes in COST. To this extent, our empirical design is centered around looking at how COST and RECOUP values, and HPI changed during the bubble period of 2003-2009. Figure 2 plots the time series for the average RECOUP, HPI, and COST across cities in each year. COST has gone up substantially from a low of around $20000 in 1998 to around $60000 in 2009. These are nominal levels and reflect the inflation in wages, material costs and potentially other types of zoning and regulatory costs. RECOUP starts at 0.8 in 1998 and rose to a high of 0.9 in 2005 and then decreases with the collapse of housing prices starting in 2007 and into 2009. HPI starts at 118 in 1998 and rose to a high of 210 in 2007 and falls from 2007 to 185 in 2009. The year 2003 or 2004 is generally viewed as the beginning of the housing bubble period. Any strong inference here is impossible given the limited time series.

Hence we will try to test our prediction by looking at the correlation of changes in recoup values with changes in HPI and changes in construction costs across cities. We now turn to our first set of results, reported in Table 3, concerning the relationships between changes in recoup value, %ΔRECOUP, and changes in %ΔHPI and changes in cost %ΔCOST, respectively. We focus our analysis here on the changes in these variables during the period of 2003 to 2009. This is our baseline sample period. We will consider robustness checks below for sub-periods.

Panel A reports the summary statistics for changes in our variables of interest over this period. Construction cost grew by about 57% with a standard deviation of 7%. Recoup values fell on average by 14.6% with a standard deviation of 21.2%. Home prices rose on average by about 20.8% with a standard deviation of 15.9%. Income and population also expanded and so did unemployment since we have 2009 in our sample. The income and population numbers are calculated from 2003 to 2008 since we do not yet have data for 2009 for these two variables.

Panel B reports the correlation of these variables over this period. The key take-aways are the following. The percentage changes in COST and RECOUP are negatively correlated across cities. Higher HPI is correlated with higher RECOUP. These correlations are consistent with our theory. Home improvers gain from their improvements when home prices are higher and lose when construction costs growth are higher. But only the correlation of RECOUP and HPI is distinct to a speculative motive, whereas the negative correlation of RECOUP with COST might also be consumption driven.

Panel C reports the results for our main regression of interest: the percentage change in recoup value on percentage change in HPI. In column (1), we report the simple univariate regression with only the percentage change in HPI on the right hand side. The regression has 35 cities as observations. The coefficient of interest is 0.320 with a t-statistic of 2.0. A standard deviation of %ΔHPI is 0.16. So a one standard deviation increase in %ΔHPI is associated with an increase in %ΔRECOUP of 0.05 (0.32*0.16=0.05) which is about a 24% of a standard deviation of %ΔRECOUP. The economic significance is clearly very sizeable.

The corresponding plot of this regression is shown in Figure 3 with the fitted line of this regression plotted against the scattered observations. It clearly shows a prominent positive sloping relationship between these two variables of interest that does not seem to be driven by outliers.

In column (2), we add in %ΔCOST and a host of demographic variables. The coefficient in front of %ΔCOST is -1.174 with a t-statistic of 2.38. Importantly, the coefficient now in front of price change increases to 0.563 with a t-statistic now of 5.034. This specification represents the strongest evidence of our model in which both of our variables of interest are economic and statistically significant as predicted. Of the control variables, only the percentage change in income comes in with a statistically significant effect but interestingly, it attracts a counter-intuitive negative sign. Our model is silent on what to expect from this change in income variable and this variable probably is better interpreted in a consumption-based model. It appears this percentage change in per capita income variable is correlated with the percentage change in home prices variable and its addition to the regression specification boosts the explanatory power of home price changes. The main take-away for us is that our two variables of interest, cost growth and home price change both attract the predicted coefficients even with the inclusion with a number of demographic variables.

In Table 4, we consider a number of robustness exercises. In Panel A, we look at the results when we break them down by midrange and upscale projects. The results are similar across these two types of projects. In Panel B, we briefly summarize our analysis when we look at the results project by project. The coefficients for all the projects have the right signs.

In Panel C, we focus on the period 2001 to 2007 and 1998-2009. We consider this exercise to see if the collapse of home prices during the years of 2008 and 2009 are driving all our results. Even if this were the case, it would not necessarily be inconsistent with our model. It turns out, however, that the results are largely similar. Another reason we consider this robustness check is the timing of the survey results. If homeowners' beliefs as proxied by the surveys of realtors on resale values are forward looking while the surveys of contractors are backward looking or stale, then this might explain why resale did not keep up with construction cost growth during the crash of home prices from 2007-2009. This issue of timing is less critical when we consider long horizon periods. Even if the construction cost estimates are stale, they will eventually catch up to the resale values over longer periods. In Panel D, we consider what happens when we cluster the standard errors by region instead of by divisions. The results are similar.

4.3. Results By Housing Supply Elasticity

Having established our baseline regression specification and result, we turn to testing an auxiliary implication of our model. Namely, the effect of home prices on recoup values ought to be stronger in cities with a low as opposed to a high housing supply elasticity index of Saiz (2010). In other words, if we re-run our preferred regression specification separately for low versus high housing supply elasticity areas, we expect a larger economic effect for the low supply elasticity areas.

The reason we expect this is that Glaeser, Gyourko, and Saiz (2008) show that low supply elasticity states (such as New York and California where land is limited and zoning and development rules are stricter) in which supply could not quickly adjust to the rising home prices are more prone to bubbles than high elasticity areas where supply can adjust quickly. One can think of low elasticity areas as cities with limited supply and limited supply is a strong determinant of speculative behavior (Hong, Scheinkman, and Xiong (2006)). When there is too much supply, it is difficult perhaps for households to believe that prices can rise enough to justify their speculative behavior. One only needs to recall the dot-com bubble in which the vast majority of the speculative trading during the 1996-2000 period was concentrated in a small group of internet stocks (Ofek and Richardson (2003)).

As for how the cost growth should affect recoup values in these two sub-samples, we do not have a clear prediction. The reason is that only the home price growth part has an unambiguous prediction in our model compared with the consumption-cum-financial constraints story. Cost growth could influence recoup values negatively for both consumption and speculation reasons. So the sign we expect to see for cost growth depends on how important remodeling is for consumption reasons across these areas, which would of course depend on potentially other unobservable factors.

In Table 5 Panel A, we report the housing Supply Elasticity index for the cities in our sample along with %ΔCOST and %ΔHPI in each city. We sort the cities by Supply Elasticity from low to high. The low elasticity or difficult-to-build places are Miami, Los Angeles, San Francisco and San Diego. The high elasticity or easy-to-build places are Columbus, San Antonio, Kansas City and Indianapolis. The index goes from a low of 0.6 for Miami to a high of 4 for Indianapolis. In Panel B, we calculate the correlation with Supply Elasticity with %ΔCOST and %ΔHPI. As we would expect, low elasticity places have experienced higher cost growth and higher home price appreciation.

In Panel C, we divide up our sample into two groups, low versus high elasticity cities and we report the summary statistics for our key variables of interest. The split is down the middle, 17 cities in the low and 17 cities in the high elasticity group. Two things stand out from the summary statistics. First, the low elasticity areas have experienced a bigger decline in recoup values, much higher home price appreciation and somewhat higher cost growth than the high elasticity areas.

In Panel D, we then run our baseline regression specification of change in recoup values on change in home prices and cost growth separately for low versus high elasticity areas. The first column reports the results for the low elasticity cities. The coefficient in front of %ΔHPI is 0.841 with a t-statistic of 5.9 The coefficient in front of %ΔCOST is -1.4 with a t-statistic of 1.5. The second column reports the results for the high elasticity cities. The coefficient in front of %ΔHPI is 0.410 with a t-statistic of 1.05 and the coefficient in front of %ΔCOST is -1.6 with a t-statistic of 2.75. The economic effect of home price changes on recoup values is much greater for low than high elasticity cities, consistent with our model.

The economic effect for cost growth is only slightly larger for high elasticity cities than low elasticity cities. The unambiguous difference for the home price change coefficients across these two sub-groups compared to the ambiguous difference for cost growth coefficients is very much in line with our theory.

4.4. Additional Robustness Checks and Alternative Interpretations

In this section, we discuss a number of robustness checks we have done but which we do not report for brevity. First, we have chosen to focus on recoup values in Table 3 which is the most natural quantity that encompasses both mistakes in resale value or in construction costs. We could have also focused on resale values and redone Table 3 with resale values and obtained similar results. In other words, our results are robust to the choice of recoup or resale values, very much in line with the economics of our model and the alternative set-up discussion.

Second, several caveats are warranted for the data. The methodology used to compiled this database was changed slightly in 2007. In 2007, the magazine gave clearer guidelines on the projects. They argue that this led to more accurate construction costs estimates. In 2009, the Home Valuation Code of Conduct (HVCC) took effect on May 1, 2009. The effect is to try to bring more fairness into appraisals by having the appraiser of a home be randomly chosen from a pool. To the extent that the respondents of the resale surveys are influenced by observed appraisals, this might have had an effect on their responses. We dealt with this issue using various beginning and end dates for the regression sample and found roughly similar results. The recoup value results are robust to these perturbations—some of these results are presented in the earlier robustness check table.

We also gather residential construction wage data for counties from the Bureau of Labor Statistics and find that wages in this industry are correlated with the costs of the improvements in the city and that changes in these costs and changes in these wages over time are also correlated. This provides a check as to the accuracy of the cost data, though of course, other factors like zoning or regulatory rules and the other local supply factors discussed above which vary across cities might also impact substantially improvement costs.

However, our cost data is better than wage growth to test our theory for a few reasons. The first is that wage growth in the residential construction sector is correlated with wage growth in the city. Hence, wage growth also behaves like an income effect in the city, and a consumption theory predicts that cities with higher wage or income growth actually should have higher recoup values since households will want more amenities. We find that this type of an effect is not very significant, however, in the data. Hence, our change in cost variable is robust to the addition of a wage growth variable and suggests that the part of the cost variable that is picking up supply factors like lumber or the cost of Italian marble seems to be, consistent with our priors and discussion above, the dominant variation influencing our regressions.

4.5. Potential Extensions and Comments

Our model is very stylized and there are potentially interesting extensions to it that might generate more testable implications of interest to the household finance literature. The first is modeling moving and moving costs. In our pure speculation model, moving costs do not matter since households want to take remodeling investments regardless of whether they plan to move or not. The relevant margin in the speculation decision is really the opportunity cost of what else the household would do with their time or money. In the dot-com period, it would have been in our model to trade dot-com stocks instead of doing remodeling.

This observation gives an interesting prediction which might be testable which is to see if households in fact substitute day-trading for home improvements. For instance, of the households who engaged in speculative home improvements during the houseing bubble, what fraction were also day traders during the internet bubble period? This would require both remodeling activity data at the household level and also trading data for the household's portfolio. This seems a tall order but these variables might be attainable at the city or zip code level.

As we pointed out in the introduction, anecdotal evidence suggests that people do remodeling before moving, which is a sign that the remodeling is for resale value as opposed to consumption. However, introducing moving and moving costs would be interesting in our consumption-cum-financial constraints model. Here, households do face a trade-off in terms of remodeling their home or buying a new place. Buying a new place in our model means that the household could have the flexibility of optimizing over both both land L and structures S as opposed to remodeling, which is simply to optimize over S holding fixed their endowed L. We would see in this scenario remodeling be less correlated with moving. In other words, if we had remodeling data, we could try to discriminate between the speculative and consumption hypotheses by seeing if remodeling and moving are positively correlated as in the speculative scenario or negatively correlated as in the consumption scenario.

We have described the speculative remodeling impulse as being tied to owners being overly-optimistic about the recoup values of their investments. Another way this speculative motive is manifested is in the belief among homeowners that remodels cut down the time their home stays on the market when they sell. They believe that cutting down time on the market is valuable since they will get much higher prices as a result. There is a belief among homeowners and real estate agents, true or not, that the longer a house sits on the market, the lower the price it will receive because buyers will become suspicious that there is something wrong with the house. We can then think of over-optimism about remodeling as owners over-estimating the degree to which improvements reduce the time their homes sit on the market.

5. Conclusion

Home improvements are an important economic activity. Such activity accounts from around 1 to 2% of GDP each year and this is not even accounting for the opportunity cost of time of many homeowners who tend to under-take these efforts by themselves. This tremendously important economic activity has been, with a few exceptions, largely neglected by researchers. We believe that this topic deserves the same amount of attention that economists have given to consumption and investment decisions in financial markets. We develop a theory of home improvements in which optimistic homeowners speculate on future home prices by engaging in remodeling. This theory yields a number of results including convexity of improvement expenditures to home price changes, over-investment in home remodeling, and higher growth in recoup values in areas with higher home price appreciation controlling for construction cost growth. We test this last prediction using data on home improvement costs and resale values across US cities. This prediction also cuts against a consumption-cum-financial constraints motive in which higher home prices should be correlated with lower recoup values. Consistent with our theory, we find that cities with higher home price appreciation experience higher recoup value growth during the recent housing bubble period of 2003-2009.

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A. Proofs of Proposition

Proof of Proposition 1. Homeowners choose S($S \geq S_0$) to maximize

$$\bar{P}_1^i L_0^\alpha S^{1-\alpha} - \omega(S - S_0). \tag{A-1}$$

If P_1=$\bar{P}_1^o$, homeowners solve

$$0 = (1-\alpha)\bar{P}_1^o L_0^\alpha S^{-\alpha} - (\frac{S}{S_0})^\beta \tag{A-2}$$

to get

$$S = [(1-\alpha)\bar{P}_1^o L_0^\alpha S_0^\beta]^{\frac{1}{\alpha+\beta}} > 0. \tag{A-3}$$

If P_1=$\bar{P}_1^p$, homeowners don't change their structure since they cannot decrease the structure. Thus, $S = S_0$. □

Proof of Proposition 2. S_0 is the optimal level of structure when the price of housing units is $\bar{P}_0$. Homeowners solve

$$(1-\alpha)\bar{P}_0 L_0^\alpha S_0^{-\alpha} = \omega = 1. \tag{A-4}$$

We normalize the cost of structure with the cost at t=0. From (A-3) and (A-4), we get

$$S = (\frac{\bar{P}_1^o}{\bar{P}_0})^{\frac{1}{\alpha+\beta}} S_0. \tag{A-5}$$

When $\bar{P}_1^o > \bar{P}_0$, S is greater than S_0. The equilibrium cost of structure, $\omega = (\frac{S}{S_0})^\beta$, is greater than 1, which is the equilibrium cost of structure at $t = 0$. □

Proof of Proposition 3. From (A-5), we get

$$\frac{S}{S_0} = (\frac{\bar{P}_1^o}{\bar{P}_0})^{\frac{1}{\alpha+\beta}}. \tag{A-6}$$

□

Proof of Proposition 4. Let $X = \frac{S}{S_0}$. Then

$$\frac{1}{1-\alpha}\frac{(\frac{S}{S_0})^{1-\alpha}-1}{(\frac{S}{S_0})^{\beta}(\frac{S}{S_0}-1)} = \frac{1}{1-\alpha}\frac{X^{1-\alpha}-1}{X^{\beta}(X-1)}. \tag{A-7}$$

Since $X \geq 1$,

$$\frac{\partial}{\partial X}\frac{X^{1-\alpha}-1}{X^{\beta}(X-1)} \leq 0 \tag{A-8}$$

where the equality holds with $X = 1$. Note that

$$\lim_{x\to 1}[\frac{1}{1-\alpha}\frac{X^{1-\alpha}-1}{X^{\beta}(X-1)}] = \lim_{x\to 1}[\frac{X^{-\alpha}}{(1+\beta)X^{\beta}-\beta X^{\beta-1}}] = 1 \tag{A-9}$$

by l'Hospital's rule. Thus, expected recoup ratio is less than 1 and the greater the structure growth ($X = \frac{S}{S_0}$), the lower the expected recoup ratio. □

Proof of Proposition 5. Recoup ratio is

$$\frac{P_2 L_0^{\alpha} S^{1-\alpha} - P_2 L_0^{\alpha} S_0^{1-\alpha}}{\omega(S-S_0)} = \frac{1}{1-\alpha}\frac{P_2}{\bar{P}_0}\frac{(\frac{S}{S_0})^{1-\alpha}-1}{(\frac{S}{S_0})^{\beta}(\frac{S}{S_0}-1)}. \tag{A-10}$$

Recoup ratio is positively correlated with home price appreciation, $P_2 - P_1 = P_2 - \bar{P}_1^o$. From (A-8),

$$\frac{\partial}{\partial X}\frac{X^{1-\alpha}-1}{X^{\beta}(X-1)} < 0 \tag{A-11}$$

with $X > 1$. Conditional on there being remodeling at $t = 1$ ($X > 1$), recoup ratio is negatively correlated with X and $\omega = X^{\beta}$. □

Table 1: List of Projects and Cities

The Cost vs. Value Report provides cost, resale value and recoup ratio by project and city. Panel A gives a list of projects that are covered at various point in time. Projects without sufficient data were dropped. Panel B gives a list of cities that are covered at various point of time. Note that Virginia Beach, VA was reported as Norfolk, VA before 2007.

Panel A : *List of Projects*

Attic Bedroom Remodel	Basement Remodel
Bathroom Addition	Bathroom Remodel
Deck Addition	Family Room Addition
Major Kitchen Remodel	Master Suite Addition
Minor Kitchen Remodel	Roofing Replacement
Siding Replacement	Sunroom Addition
Two-Story Addition	Window Replacement

Panel B : *List of Cities*

Albany,NY	Dayton,OH	Manchester,NH	Richmond,VA
Albuquerque,NM	Denver,CO	Memphis,TN	Riverside,CA
Allentown,PA	Des Moines,IA	Miami,FL	Rochester,NY
Anchorage,AK	Detroit,MI	Milwaukee,WI	Sacramento,CA
Atlanta,GA	El Paso,TX	Minneapolis,MN	Salt Lake City,UT
Austin,TX	Fargo,ND	Nashua,NH	San Antonio,TX
Baltimore,MD	Garden City,NY	Nassau-Suffolk,NY	San Diego,CA
Billings,MT	Grand Rapids,MI	New Haven,CT	San Francisco,CA
Birmingham,AL	Harrisburg,PA	New Orleans,LA	Seattle,WA
Boise,ID	Hartford,CT	New York,NY	Sioux Falls,SD
Boston,MA	Honolulu,HI	Oakland,CA	Spokane,WA
Buffalo,NY	Houston,TX	Oklahoma City,OK	Springfield,MA
Burlington,VT	Indianapolis,IN	Omaha,NE	St. Louis,MO
Charleston,SC	Jackson,MS	Orange City,CA	Tampa,FL
Charleston,WV	Jacksonville,FL	Orlando,FL	Tulsa,OK
Charlotte,NC	Kansas City,MO	Passaic,NJ	Ventura,CA
Chicago,IL	Knoxville,TN	Philadelphia,PA	Virginia Beach,VA
Cincinnati,OH	Lancaster,PA	Phoenix,AZ	Washington,DC
Cleveland,OH	Las Vegas,NV	Pittsburgh,PA	Westchester,NY
Colorado Springs,CO	Little Rock,AR	Portland,ME	Wichita,KS
Columbia,SC	Los Angeles,CA	Portland,OR	Wilmington,DE
Columbus,OH	Louisville,KY	Providence,RI	Worcester,MA
Dallas,TX	Madison,WI	Raleigh,NC	

Table 2: Summary Statistics

Panel A reports the time series average of cross-sectional means and standard deviations for the variables of interest. Panel B reports the time series average of correlation matrix for the variables of interest. COST and RESALE are the equal-weighted measures across different projects by year and city. RECOUP is the recoup ratio by year and city defined as RESALE/COST. HPI is the house price index by Federal Housing Finance Agency. HPI is defined at the level of Metropolitan Statistical Area(MSA). The HPI of MSA is used when the city belongs to the MSA. INC is income per capita and POP is population size by year and city. INC and POP for 2009 are excluded due to the data availability from Bureau of Economic Analysis. UNEMP is the unemployment rate by year and city from Bureau of Labor Statistics.

Panel A : *Means and standard deviations*

Variable	Mean	Std.dev.
COST	39189.3	4193.0
RESALE	29428.2	7958.7
RECOUP	0.78	0.18
HPI	162	26.6
INC	35436.9	6319.4
POP	1181105	1506280
UNEMP	0.06	0.02

Panel B : *Correlation Matrix*

	COST	RESALE	RECOUP	HPI	INC	POP	UNEMP
COST	1						
RESALE	0.61	1					
RECOUP	0.23	0.88	1				
HPI	0.29	0.50	0.45	1			
INC	0.40	0.52	0.40	0.41	1		
POP	0.33	0.29	0.18	0.24	0.11	1	
UNEMP	0.28	-0.01	-0.13	-0.11	-0.24	0.20	1

Table 3: %ΔRECOUP on %ΔHPI and %ΔCOST

Panel A reports the mean and standard deviation of percentage change(%Δ) in variables from 2003 to 2009. Panel B reports the correlation matrix of %Δ in variables from 2003 to 2009. Panel C reports regressions of %ΔRECOUP on %ΔHPI from 2003 to 2009. In column (1), univariate regression of %ΔRECOUP on %ΔHPI is reported. Column (2) reports the regression of %ΔRECOUP on %ΔHPI with %ΔCOST and %Δ of demographic control variables. The table reports point estimates with t-statistics in parentheses. Standard errors are clustered by the U.S. Census division. ***, **, * denotes 1%, 5%, and 10% statistical significance.

Panel A : *Means and standard deviations*

	Mean	Std.dev.
%ΔCOST	0.572	0.071
%ΔRECOUP	-0.146	0.212
%ΔHPI	0.208	0.159
%ΔINC	0.245	0.078
%ΔPOP	0.034	0.077
%ΔUNEMP	0.424	0.285

Panel B : *Correlations*

	%ΔCOST	%ΔRECOUP	%ΔHPI	%ΔINC	%ΔPOP	%ΔUNEMP
%ΔCOST	1					
%ΔRECOUP	-0.47	1				
%ΔHPI	-0.04	0.24	1			
%ΔINC	0.26	-0.18	0.51	1		
%ΔPOP	-0.31	0.10	0.06	-0.42	1	
%ΔUNEMP	0.34	-0.20	-0.29	-0.24	-0.16	1

Panel C : *%ΔRECOUP on %ΔHPI and %ΔCOST*

	(1)	(2)
Variables	%ΔRECOUP	
%ΔHPI	0.320*	0.563***
	(2.038)	(5.034)
%ΔCOST		-1.174*
		(-2.328)
%ΔINC		-1.109**
		(-2.549)
%ΔPOP		-0.635
		(-1.298)
%ΔUNEMP		-0.0572
		(-0.899)
Constant	-0.212***	0.726**
	(-3.646)	(2.597)
Observations	35	35
R^2	0.058	0.354

Table 4: Robustness

For certain projects in the list, projects are broken down by midrange and upscale level. Panel A reports regressions of %ΔRECOUP on %ΔHPI and %ΔCOST within midrange and upscale projects. The dependent variable is %ΔRECOUP, the percentage change from 2003 to 2009 in RECOUP which is equal-weighted measure across different midrange projects by year and city. In columns (1)-(2), %ΔRECOUP is regressed on %ΔHPI and %ΔCOST with %Δ of demographic variables controlled. Column (1) reports the regression of midrange projects and column (2) reports the regression of upscale projects. COST is equal-weighted measure across different midrange projects by year and city. Panel B reports the regression of %ΔRECOUP on %ΔHPI and %ΔCOST for individual projects with %Δ of demographic variables controlled. The dependent variable is %ΔRECOUP, the percentage change from 2003 to 2009 in RECOUP of the project by year and city. %ΔCOST is the percentage change from 2003 to 2009 in COST of the project by year and city. Only the coefficient and t-statistics for %ΔHPI and %ΔCOST are reported for brevity. Panel C reports the regressions of %ΔRECOUP on %ΔHPI and %ΔCOST for different time horizons, from 2001 to 2007 and from 1998 to 2009. Panel D reports the regression in Table 3 with standard error clustered by the U.S. region. The table reports point estimates with t-statistics in parentheses. Other than Panel D, standard errors are clustered by the U.S. Census division. ***, **, * denotes 1%, 5%, and 10% statistical significance.

Panel A : *By Projects' Quality Level*

Variable	(1) *Midrange Projects* %ΔRECOUP	(2) *Upscale Projects* %ΔRECOUP
%ΔHPI	0.599***	0.521*
	(6.955)	(2.023)
%ΔCOST	-1.201**	-1.753**
	(-2.741)	(-2.481)
%ΔUNEMP	-0.00539	-0.0497
	(-0.0748)	(-0.423)
%ΔINC	-1.122**	-0.967
	(-2.676)	(-1.618)
%ΔPOP	-0.551	-0.456
	(-1.336)	(-0.744)
Constant	0.696**	0.547**
	(3.491)	(3.075)
Observations	35	35
R^2	0.328	0.415

Table 4 (continued)

Panel B : *By Individual Project*

Project	%ΔHPI	*t-stats*	%ΔCOST	*t-stats*
Basement Remodel (M)	0.409*	(2.250)	-1.100**	(-2.683)
Bathroom Addition (M)	0.347**	(2.870)	-0.603**	(-3.236)
Bathroom Addition (U)	0.418	(1.810)	-0.733**	(-2.776)
Bathroom Remodel (M)	0.606**	(2.602)	-1.313*	(-2.157)
Bathroom Remodel (U)	0.322	(1.682)	-0.706	(-1.821)
Family Room Addition (M)	0.652***	(6.365)	-0.852	(-1.630)
Major Kitchen Remodel (M)	0.891***	(4.915)	-2.120**	(-2.581)
Major Kitchen Remodel (U)	1.235	(1.442)	0.349	(0.218)
Master Suite Addition (M)	0.762***	(4.661)	-0.836**	(-2.456)
Master Suite Addition (U)	0.555**	(2.925)	-1.851**	(-3.268)
Window Replacement (M)	0.327	(0.724)	-1.508*	(-2.355)
Window Replacement (U)	0.233	(0.893)	-1.534	(-1.807)

Panel C : *By Different Sample Periods*

	(1)	(2)
	From 2001 to 2007	*From 1998 to 2009*
Variables	%ΔRECOUP	%ΔRECOUP
%ΔHPI	0.118	0.162
	(1.362)	(1.339)
%ΔCOST	0.257	-0.444**
	(0.491)	(-3.112)
Constant	-0.324	0.602*
	(-0.643)	(1.884)
Observations	50	52
R^2	0.050	0.099

Panel D : *Clustering Standard Errors by the U.S. Region*

	(1)	(2)
Variables	%ΔRECOUP	
%ΔHPI	0.320	0.563**
	(2.205)	(3.365)
%ΔCOST		-1.174**
		(-5.538)
%ΔUNEMP		-1.109
		(-1.975)
%ΔINC		-0.635
		(-0.942)
%ΔPOP		-0.0572
		(-0.741)
Constant	-0.212***	0.726**
	(-6.827)	(3.316)
Observations	35	35
R^2	0.058	0.354

Table 5: %ΔRECOUP on %ΔHPI by Housing Supply Elasticity

Panel A reports the housing supply elasticity from Saiz(2010), %ΔCOST, and %ΔHPI from 2003 to 2009 across different cities. Panel B reports the correlation matrix between supply elasticity, %ΔCOST, and %ΔHPI with heteroskedasticity-consistent t-statistics in parentheses. Panel C reports the summary statistics by supply elasticity. Panel D reports regressions of %ΔRECOUP on %ΔHPI, %ΔCOST by supply elasticity from 2003 to 2009. Column (1) reports the regression results using the cities with low supply elasticity and column (2) report the regression results using cities with high supply elasticity. The table reports point estimates with t-statistics in parentheses. Standard errors are clustered by the U.S. division. ***, **, * denotes 1%, 5%, and 10% statistical significance.

Panel A : *Housing Supply Elasticity, %ΔCOST, and %ΔHPI*

City	Housing Supply Elasticity	%ΔCOST	%ΔHPI
Miami, FL	0.60	0.57	0.24
Los Angeles, CA	0.63	0.65	0.32
San Francisco, CA	0.66	0.59	0.21
San Diego, CA	0.67	0.60	0.08
Salt Lake City, UT	0.75	0.51	0.40
New York, NY	0.76	0.74	0.34
Chicago, IL	0.81	0.67	0.18
New Orleans, LA	0.81	0.60	0.32
Virginia Beach, VA	0.82	0.56	0.64
Boston, MA	0.86	0.65	0.09
Seattle, WA	0.88	0.54	0.40
Tampa, FL	1.00	0.62	0.22
Cleveland, OH	1.02	0.50	0.00
Milwaukee, WI	1.03	0.57	0.22
Portland, OR	1.07	0.57	0.42
Orlando, FL	1.12	0.57	0.28
Pittsburgh, PA	1.20	0.53	0.20
Detroit, MI	1.24	0.61	-0.25
Minneapolis, MN	1.45	0.65	0.08
Denver, CO	1.53	0.52	0.07
Phoenix, AZ	1.61	0.47	0.23
Providence, RI	1.61	0.62	0.16
Washington, DC	1.61	0.62	0.36
Philadelphia, PA	1.65	0.58	0.40
Buffalo, NY	1.83	0.56	0.24
Dallas, TX	2.18	0.46	0.16
Houston, TX	2.30	0.47	0.28
St. Louis, MO	2.36	0.54	0.20
Cincinnati, OH	2.46	0.50	0.09
Atlanta, GA	2.55	0.48	0.09
Columbus, OH	2.71	0.51	0.08
San Antonio, TX	2.98	0.50	0.34
Kansas City, MO	3.19	0.69	0.11
Indianapolis, IN	4.00	0.53	0.07

Panel B : *Correlation Matrix*

Housing Supply Elasticity	1	-0.377 (-1.97)	-0.27 (-2.11)
%ΔCOST		1	0.02 (0.16)
%ΔHPI			1

Table 5 (continued)

Panel C : *Summary Statistics by Housing Supply Elasticity*

	Low Supply Elasticity			*High Supply Elasticity*		
Variables	Obs	Mean	Std. dev.	Obs	Mean	Std. dev.
%ΔRECOUP	17	-0.179	0.218	17	-0.121	0.211
%ΔHPI	17	0.267	0.150	17	0.160	0.151
%ΔCOST	17	0.590	0.062	17	0.547	0.069
%ΔINC	17	0.278	0.074	17	0.213	0.073
%ΔPOP	17	0.016	0.089	17	0.052	0.062
%ΔUNEMP	17	0.418	0.270	17	0.401	0.291

Panel D : *%ΔRECOUP on %ΔHPI and %ΔCOST by Housing Supply Elasticity*

	(1)	(2)
	Low Supply Elasticity	*High Supply Elasticity*
Variables	%ΔRECOUP	%ΔRECOUP
%ΔHPI	0.841***	0.410
	(5.892)	(1.055)
%ΔCOST	-1.419	-1.626**
	(-1.542)	(-2.750)
%ΔINC	-1.214	-0.873
	(-1.450)	(-1.057)
%ΔPOP	-0.769	-1.376
	(-1.031)	(-0.751)
%ΔUNEMP	-0.0832	-0.228
	(-0.651)	(-0.737)
Constant	0.817*	1.052**
	(2.028)	(2.456)
Observations	17	17
R^2	0.644	0.350

Figure 1: Optimism bias and expected recoup ratio

The figure plots expected recoup ratio and optimism bias. Optimism bias is defined as $\frac{\bar{P}_1^O}{\bar{P}_0} - 1$, where $\bar{P}_1^O$ is the expected home price by optimistic homeowners. For the calibration, following parameters are used: $\alpha = 0.25$ and $\beta = 0.25$.

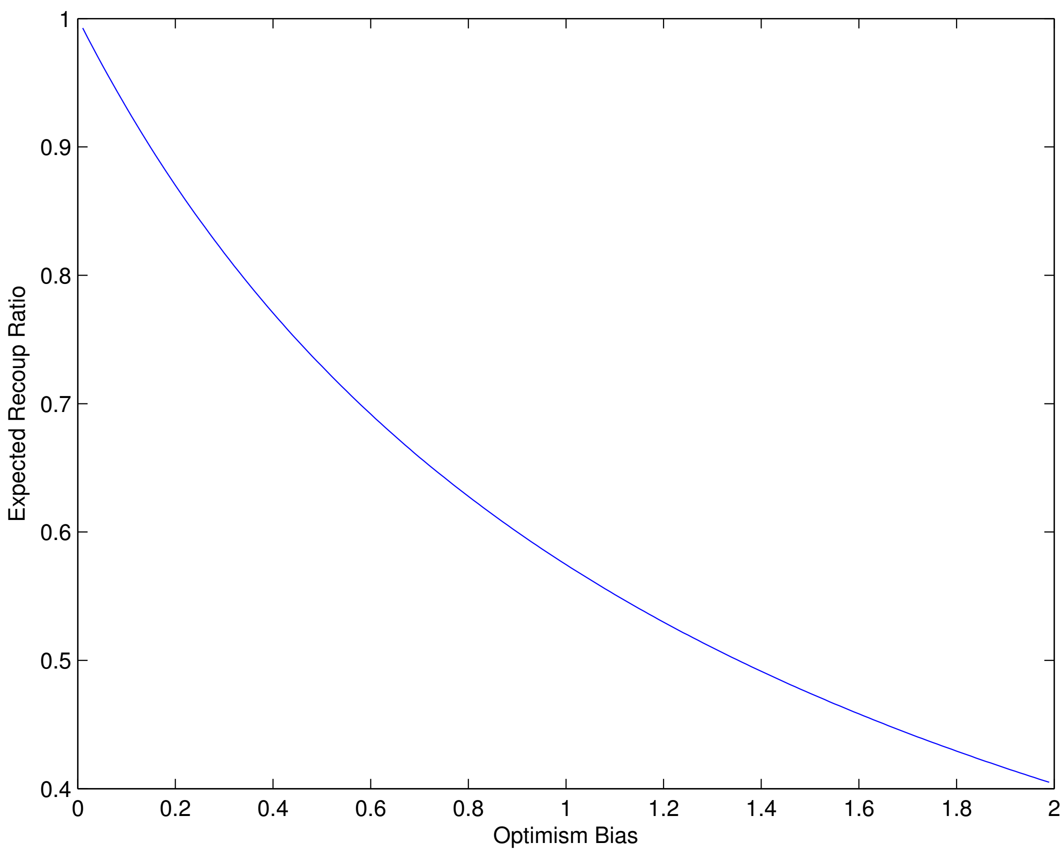
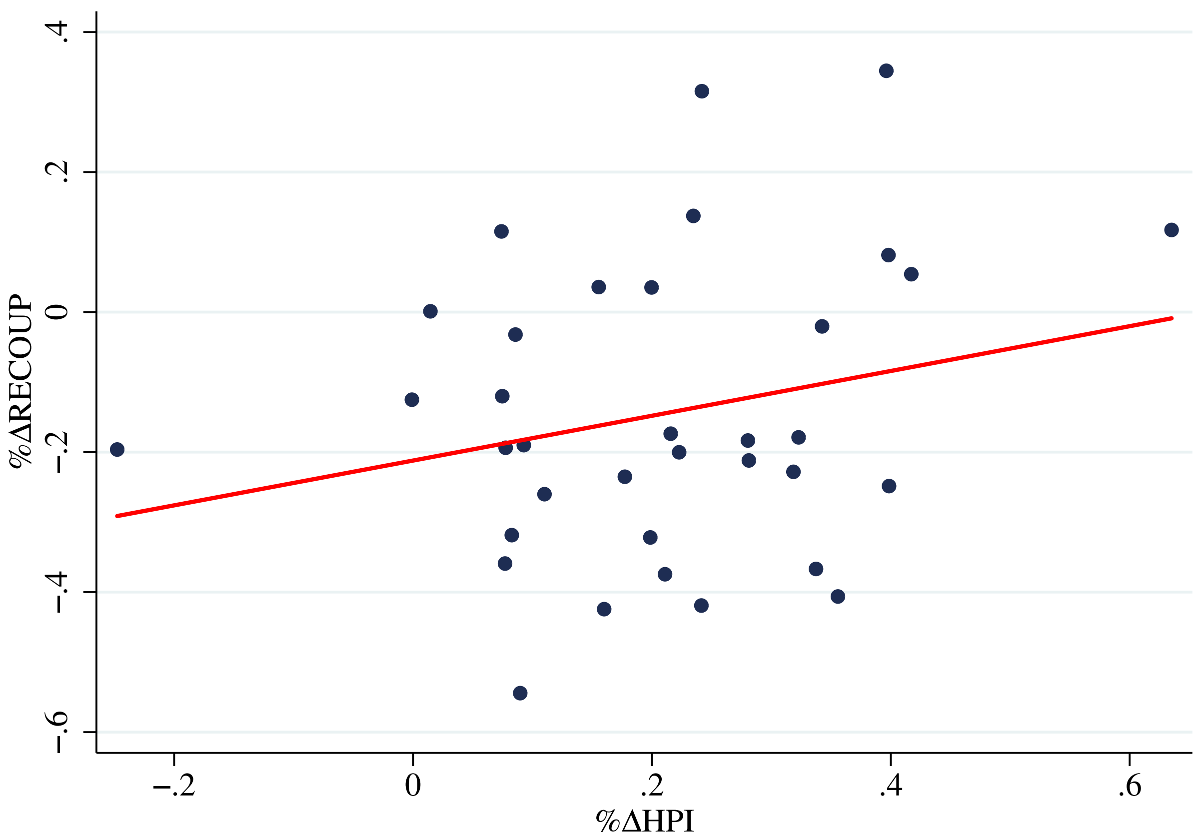


Figure 2: Average RECOUP, HPI, and COST

The figure plots RECOUP, HPI and COST averaged across cities for various years. RESALE and COST are the equal-weighted measures across different projects by year and city and RECOUP is the recoup ratio by year and city defined as RESALE/COST.

Figure 3: %ΔHPI and %ΔRECOUP

The figure plots %ΔRECOUP and %ΔHPI across cities. %ΔRECOUP is the percentage change in RECOUP from 2003 to 2009. %ΔHPI is the percentage change in HPI from 2003 to 2009.



B. Internet Appendix

Overconfidence on Construction Costs: There are three dates $t = 0, 1, 2$. The interest rate is zero. At $t = 0$, competitive (price-taking) home builders make new homes from two inputs: land L_0 and structure (i.e. construction) S_0. The units of housing H_0 is given by:

$$H_0 = L_0^{\alpha} S_0^{1-\alpha}, \tag{B-1}$$

where α is the share of land in housing. Let p_0 be the expected value of the home at $t = 1$. Let $w_{L,0}$ be the price of land and $w_{S,0}$ be the price of structure (including the cost of labor and materials) at $t = 0$. Builders maximize profits per house taking as given the price of homes and the costs of the two inputs:

$$\text{Max}_{S_0,L_0} \left(p_0 L_0^{\alpha} S_0^{1-\alpha} - w_{L,0} L_0 - w_{S,0} S_0 \right). \tag{B-2}$$

A δ fraction of the houses vanish each period.[6] Given the (unique and optimal) choice of inputs S_0 and L_0 for each house, the total demand for land and structures are given by δL_0 and δS_0, respectively. There are upward-sloping supply curves for land and structures of the form:

$$w_{L,0} = (\delta L_0)^{\gamma}, \tag{B-3}$$

$$w_{S,0} = (\delta S_0)^{\beta}, \tag{B-4}$$

where γ and β capture the sensitivity of the prices of land and structures to demand for them, respectively. There is free-entry, which gives a zero-profit condition for this competitive home-building industry.

[6] We assume this for tractability. We can also model it as new homes built each period.

Homeowners live one-period and re-sell their homes the next period to new homeowners. There is no population growth. At $t = 1$, existing homeowners have the option to do home improvements before selling to future homeowners at $t = 2$. Let p_1 be the present value of rents and capital gains associated with house (i.e. the expected price at $t = 2$). And let $w_{L,1}$ and $w_{S,1}$ be the prices of land and structure at $t = 1$, respectively.

Existing homeowners then maximize

$$\text{Max}_{X_1} \left(p_1 L_0^{\alpha} (X_1 + S_0)^{1-\alpha} - w_{S,0} X_1 \right), \tag{B-5}$$

subject to the constraint that $X_1 \geq 0$. X_1 is the addition to structure above the initial amount of structure S_0. All homeowners have the same initial L_0. They take $w_{S,0}$ as the price of their structure in their optimization problem because they are overconfident that they can build quality additions or structures at the old prices or for a price lower than the competitive building industry.

Professional home builders are also active at time 1 to build new homes. Let $w_{L,1}$ be the price of land and $w_{S,1}$ be the price of structure. The builders again maximize profits taking as given the price of homes and the costs of inputs.

$$\text{Max}_{S_1, L_1} \left(p_1 L_1^{\alpha} S_1^{1-\alpha} - w_{L,1} L_1 - w_{S,1} S_1 \right). \tag{B-6}$$

Again, we assume upward sloping supply curves for land and structure of the form:

$$w_{L,1} = (\delta L_1)^{\gamma}, \tag{B-7}$$

$$w_{S,1} = (\delta S_1 + (1 - \delta) X_1)^{\beta}. \tag{B-8}$$

Notice that there are only $1 - \delta$ old houses left, and so the total demand for structure at

$t = 1$ is $\delta S_1 + (1-\delta)X_1$.[7] We then impose the same competitive zero profit condition as in time 0.

The Equilibrium at $t = 0$: The first-order conditions from the home builders' maximization problem with a Cobb-Douglas production function yield the optimal proportions of land and structure as a function of the relative factor prices $\frac{w_{S,0}}{w_{L,0}}$ and factor shares $\frac{\alpha}{1-\alpha}$:

$$L_0 = \frac{w_{S,0}}{w_{L,0}} \frac{\alpha}{1-\alpha} S_0. \tag{B-9}$$

The relationship is the usual one: the ratio of land to structure is higher the higher is the relative cost of structure to land and the higher is the share of land in value relative to structure.

Imposing zero-profit for homebuilders yields:

$$\frac{p_0}{w_{L,0}^{\alpha}} (\frac{\alpha}{1-\alpha})^{\alpha}(1-\alpha) = w_{S,0}^{1-\alpha}. \tag{B-10}$$

And adding the two supply functions then gives four equations in four unknowns for L_0, S_0, $w_{S,0}$, $w_{L,0}$.

To solve for these four quantities, we first plug the two supply functions into the first-order condition of the homebuilders to give

$$w_{L,0} = w_{S,0}^{\frac{1+\beta}{\beta}\frac{\gamma}{1+\gamma}} (\frac{\alpha}{1-\alpha})^{\frac{\gamma}{1+\gamma}}. \tag{B-11}$$

Intuitively, the bigger is β, the more inelastic the supply curve of construction, the higher the wage of construction relative to wage of land.

We then plug $w_{L,0}$ into the zero-profit condition to give

$$w_{S,0} = [p_0(\frac{\alpha}{1-\alpha})^{\frac{\alpha}{1+\gamma}}(1-\alpha)]^{\frac{1}{(1-\alpha)+\alpha(\frac{1+\beta}{\beta}\frac{\gamma}{1+\gamma})}}. \tag{B-12}$$

[7] Since δL_0 land would become vacant, we could alternatively have written $w_{L,1} = \max\{0, (\delta(L_1 - L^0)^{\gamma})\}$. However this only leads to minor algebraic changes.

We will get $w_{L,0}$ as a result. Then we can use the supply function for $w_{S,0}$ to obtain the equilibrium amount of structure as

$$S_0 = \delta^{-1}[p_0(\frac{\alpha}{1-\alpha})^{\frac{\alpha}{1+\gamma}}(1-\alpha)]^{\frac{1}{(1-\alpha)+\alpha(\frac{1+\beta}{\beta}\frac{\gamma}{1+\gamma})}\frac{1}{\beta}}, \tag{B-13}$$

which will then allow us to obtain L_0. Note L_0 will also be proportional to δ^{-1}. We will focus on the equilibrium S_0.

The Equilibrium at $t = 1$: Since homeowners believe they can add structure at the previous price $w_{S,0}$, the first-order condition of the home improvement optimization problem is given by

$$p_1 L_0^{\alpha}(1-\alpha)(X_1 + S_0)^{-\alpha} - w_{S,0} = 0, \tag{B-14}$$

or

$$(X_1 + S_0)^{-\alpha} = \frac{w_{S,0}}{p_1}\frac{1}{1-\alpha}\frac{1}{L_0^{\alpha}}, \tag{B-15}$$

assuming $X_1 \geq 0$. Notice that if $p_1 = p_0$, then $X_1 = 0$ since at the old home price level of p_0, S_0 was the optimal amount of structure.

The first-order condition of home builders at $t = 1$ is given by

$$L_1 = \frac{w_{S,1}}{w_{L,1}}\frac{\alpha}{1-\alpha}S_1. \tag{B-16}$$

And imposing the zero profit condition of homebuilders yields

$$\frac{p_1}{w_{L,1}^{\alpha}}(\frac{\alpha}{1-\alpha})^{\alpha}(1-\alpha) = w_{S,1}^{1-\alpha}. \tag{B-17}$$

We then plug in the two supply functions into the first-order condition of the homebuilder to write $w_{L,1}$ as function of $w_{S,1}$ and X_1:

$$w_{L,1}^{\frac{1+\gamma}{\gamma}} = w_{S,1}(\frac{\alpha}{1-\alpha})[w_{S,1}^{\frac{1}{\beta}} - (1-\delta)X_1]. \tag{B-18}$$

Note that $S_1 = \delta^{-1}[w_{S,1}^{\frac{1}{\beta}} - (1-\delta)X_1]$ and so δ^{-1} cancels from the first-order condition.

Then plug $w_{L,1}$ into the zero-profit condition for equation in $w_{S,1}$ to get

$$p_1\{w_{S,1}\frac{\alpha}{1-\alpha}[w_{S,1}^{\frac{1}{\beta}} - (1-\delta)X_1]\}^{-\alpha(\frac{\gamma}{1+\gamma})}(\frac{\alpha}{1-\alpha})^{\alpha}(1-\alpha) - w_{S,1}^{1-\alpha} = 0. \tag{B-19}$$

Let $x = (1-\delta)X_1$ and $w = w_{S,1}$ and write equation (B-19) as $F(x,w) = 0$.

If $p_1 > p_0$, $X_1 > 0$. To show that $w_{S,1} > w_{S,0}$ amounts to showing that $dw/dx > 0$. By the implicit function theorem, $dw/dx = -F_x/F_w$. It is easy to show that that $F_x > 0$ and $F_w < 0$ and hence $dw/dx > 0$. Hence, we have the following result:

Proposition B-1. *If $p_1 > p_0$, the equilibrium cost of structure at $t = 1$, $w_{S,1}$, is greater than $w_{S,0}$, the equilibrium cost of structure at $t = 0$.*

We now show that we can derive analogous results to the three predictions in our baseline model.

The first result is the convexity of home improvements in home price increases.

Proposition B-2. *The growth of structures that results from home improvement is a homogeneous function of degree $\frac{1}{\alpha} > 1$ of home price increases, that is:*

$$\frac{X_1 + S_0}{S_0} = \left(\frac{p_1}{p_0}\right)^{\frac{1}{\alpha}}. \tag{B-20}$$

To see this, note that from the profit maximization of the professional home builders at $t = 0$

$$p_0 L_0^{\alpha}(1-\alpha)S_0^{-\alpha} - w_{S,0} = 0. \tag{B-21}$$

Because S_0 was optimal and so we have

$$S_0^{-\alpha} = \frac{w_{S,0}}{p_0} \frac{1}{1-\alpha} \frac{1}{L_0^\alpha}. \tag{B-22}$$

The result follows from the expression for the X_1 that solves the homeowners' problem.

The second result is over-investment in structures by existing homeowners. Notice that we have shown that if $p_1 > p_0$ than $w_{S,1} > w_{S,0}$.

Proposition B-3. *Let $\hat{X}_1$ be the investment of the homeowner at the right equilibrium price $w_{S,1}$ (as opposed to the old construction cost of $w_{S,0}$). Then,*

$$\frac{X_1 + S_0}{\hat{X}_1 + S_0} = \left(\frac{w_{S,1}}{w_{S,0}}\right)^{\frac{1}{\alpha}}, \tag{B-23}$$

that is, there is is excessive investment in structure at $t = 1$ and the percentage of excessive investments is a function of the growth in the price of structures that is homogenous of degree $\frac{1}{\alpha} > 1$.

Equation (B-23) follows immediately from Equation (B-15), the first-order condition for the homeowner's home improvement problem.

The third result we derive is to characterize recoup value as a function of home prices and construction cost growth. Homeowner's gains from the added investment are thus

$$p_1 L_0^\alpha (X_1 + S_0)^{1-\alpha} - p_1 L_0^\alpha S_0^{1-\alpha}.$$

The recoup value is the ratio of gains to cost that is:

$$R := \frac{p_1 L_0^\alpha (X_1 + S_0)^{1-\alpha} - p_1 L_0^\alpha S_0^{1-\alpha}}{w_{S,1} X_1}.$$

A *lower bound* for the recoup value is $\frac{w_{S,0}}{w_{S,1}} < 1$. To derive an upper bound, notice that since for any concave function f, $f(y) - f(x) \leq f'(x)(y - x)$ we have:

$$\begin{aligned} R &\leq \frac{p_1(1-\alpha)L_0^{\alpha}S_0^{-\alpha}X_1}{w_{S,1}X_1} \\ &= \frac{p_1}{p_0}\frac{p_0(1-\alpha)L_0^{\alpha}S_0^{-\alpha}}{w_{S,1}} = \frac{p_1}{p_0}\frac{w_{S,0}}{w_{S,1}}, \end{aligned}$$

where the last equality comes from the first order condition at time zero.