INVESTIGATING FILTERING THEORY IN US HOUSING POLICY

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ABSTRACT

This study investigates the concept of "filtering" as a process with the potential to lessen housing unaffordability in the United States. Through statistical analysis, the study compares the relationship between housing production and rent prices, while considering historical information and contemporary academic analysis. Using Python and Excel, data at the census tract level across the United States was analyzed, illuminating housing availability and affordability disparities while controlling for socioeconomic factors. Findings suggested that increases in the housing supply are associated with increases in the percent of rent charged on average across a neighborhood, which is antithetical to filtering theory. This paper does, however, find instances where the relationship is reversed. This suggests that for filtering theory to be effective, during the observed time range of approximately 15 years, on the neighborhood level, the percent change in supply must exceed a certain threshold.

BIOGRAPHICAL SKETCH

Stella Borovska Frank is a fourth-year undergraduate at Cornell University majoring in Urban and Regional Studies. Her academic interests center on housing affordability, neighborhood change, and equitable planning policy. This thesis stems from her interest in the limitations of supply-side strategies in solving the housing crisis, particularly the use of filtering theory. During her time at Cornell, she conducted research examining disparities in health outcomes correlated to spatial segregation utilizing GIS and Python. She worked with multiple surrounding local governments to update transportation and comprehensive plans as well as redesign an affordable senior living facility. She was also a founding member of Cornell's Homelessness Action Project Club. She has previously worked as a GIS analyst at the Urban Data Lab and interned with the City of Ithaca, Town of Ithaca, and Fairfax County's planning departments. After graduation, she plans to continue working in planning policy in Washington, D.C.

This thesis is dedicated to those facing housing insecurity, and to the individuals shaping policy in the pursuit of lasting solutions.

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LIST OF ABBREVIATIONS

ACS (American Community Survey)

FHA (Federal Housing Administration)

HUD (U.S. Department of Housing and Urban Development)

NOAH (Naturally occurring affordable housing)

OLS (Ordinary least squares)

VIF (Variable Inflation Factors)

INTRODUCTION

Housing affordability has remained one of the average American's main financial struggles across a lifetime. Although homeownership is a keystone goal for most working-class Americans to access financial stability and accumulate generational wealth, it is becoming increasingly out of reach for greater proportions of the population. It has been found that more than half of the nation's workers cannot afford a one-bedroom apartment at a fair market rate in their area ("Out of Reach," 2024). Likewise, a quarter of all homeowners and half of all renters in the United States were cost-burdened as of 2022 ("State of The Nation's Housing," 2024).

Over the last century, the U.S. federal government has addressed these living conditions through initiatives aimed at improving the quality, supply, and accessibility of housing across the nation. While a wide variety of methods have been implemented, contemporary housing policy has increasingly relied on the private sector to provide housing at all cost levels. As economist Stuart Rosenthal describes, "private markets are thought to provide low-income housing primarily through a dynamic process in which homes built for higher income families slowly deteriorate and filter down to lower-income households" (Rosenthal, 2014) This process, termed "filtering", theorizes that construction of new high-quality housing units would raise the standard across the municipality, causing wealthy residents to leave their current comparatively older units, thereby opening up the previously occupied supply to new less wealthy inhabitants.

There has, however, been some divergence between the stance of the Federal government and academics on the efficacy of filtering. The National Multifamily Housing Council cited that, "HUD declares filtering is the traditional means of creating Naturally

Occurring Affordable Housing (NOAH) for lower-income families in the United States," in 2016 (Myers, 2020). Harvard University's "State of the Nation's Housing" report found that in the last decade, the supply of high-cost rental housing has increased significantly while the supply of low-cost rental housing has continued to decline (2024).

This paper aims to further investigate the efficacy of filtering by comparing the percent change of housing prices in an area to the percent change of units on the market, while controlling for other socioeconomic factors like race and vacancy rates. In doing so, it seeks to understand the viability of policymakers relying on filtering as a means of creating NOAH across time and in differing market contexts. OLS regression analysis in Python revealed a nonlinear relationship between the percent change in price of a unit and the percent change in the quantity built in both a national model and a smaller model based on San Francisco County.

LITERATURE REVIEW

PT. 1: HISTORICAL ORIGINS OF FILTERING THEORY IN PUBLIC POLICY

Although contemporary literature acknowledges the popular term “filtering,” it is less known that this concept stems from the early 1900s and precedes the Great Depression. The process was inspired by the Progressive Party in England, which developed high-quality municipal housing along urban peripheries for middle-class workers as an attractant so they would vacate older inner city units and lessen their demand (Dolbeare, 1992).

It wasn't long until neoclassical economic theories like these were applied to the housing market in federal U.S. policy. Authors of appraisal manuals during the Great Depression were quoted with reference to the “filtration” process. Stanley McMichael, author of McMichael’s appraising manual, said that, “these districts, passing from a higher to a lower use... are accompanied by infiltration of a lower social type.’’ In 1932, Fredrick Babcock, the Director of the FHA’s Underwriting Division, clearly described in his book, “The Valuation of Real Estate,” that the calculation of depreciation was not solely based on physical deterioration but also social changes. Babcock was quoted arguing that a “gradual infiltration” which ‘‘carries all residential areas not capable of other use downward in quality and value,” also contributed to such conditions. Continuing that, “given time, all such areas become decadent districts or slums occupied by the poorest, most incompetent, and least desirable groups in the city. He concluded that, “ragged urchins play on marquetry floors” (Harris, 2012).

In retrospect, the idea that home values have historically been tied solely to the physical structure of the building could have been missing the larger picture. Anticipated home value changes were also tied to social changes, which some government officials at

the time perceived as negative. The term ‘filtering’ became established in housing market discourse in the United States around the Civil Rights Era. In 1955, the director of the University of Chicago’s planning program deduced that residents of a declining neighborhood had no choice but to rely on the ‘filter-down process’ to provide housing to low-income families. By this time, the FHA had begun to refer to the filtering process as a politically neutral concept based on economic science and objectivity (Harris, 2012).

Shortly after the Fair Housing Act was passed in 1968, the Housing and Community Development Act of 1974 was passed, establishing the Section 8 housing voucher program. Increasingly, reliance on private market housing supply, instead of programs like public housing, became the primary political means of attaining housing affordability over time. Simultaneously, in the two decades between 1970 and 1989, the rate of subsidized housing occupancy for those in the bottom 25th percentile went from 10 to 74%, alluding to a drastic decrease in the number of NOAH (Dolbeare, 1992). In 1998, the Faircloth Amendment was passed, capping the number of allowed public housing units in the United States so that no more could be built, cementing this shift in public policy reliance on the private housing market to ultimately deliver affordable housing supply.

PT 2: ECONOMIC THEORY UNDERPINNING FILTERING AS AN AFFORDABILITY STRATEGY

Supply-side filtering theory in housing is rooted in neoclassical economic assumptions, including perfect information, rational behavior, elastic supply, and utility maximization through substitution. Due to the real-world limitations and factors swaying the housing market, this section of the literature review aims to describe how the theoretical economic framework giving way to filtering theory may not be practical before using statistical analysis to further investigate. As Maurie et al argues:

> "Filtering is an idealised conception of the operation of the housing market under certain conditions. As those conditions do not obtain in practice, filtering ceases to be a representation of what happens in the housing market. The implication that filtering does or can occur becomes an untestable assertion, which is inseparable from the political associations of the idea. In other words, it becomes an assertion used to justify a reliance on the market" (Maurie et al, 1976).

Some of the core neoclassical economic principles, like the availability of information and the rationality of the actors involved, are naturally intended to have variance amongst the individuals making up the larger group. Filtering, in theory, assumes that all households have full market knowledge of the real estate available to them and that as a household makes more money, they would predictably move to more expensive units. Recently conducted research has shown that poor renters in particular often lack knowledge of local real estate markets, even when households do know about opportunities. This is, in part, due to the way housing market information is spread in the 21st century. While historically information about sales has been available via yard signs or newspaper ads, contemporarily this information is largely spread through the internet.

While at first glance the convenience of the internet seems like a potential benefit to the free spread of information, in reality, this shift creates a twofold impact on the fair spread of information. Access to the internet is not universal, and communities that are heavily impoverished or marginalized have physical and economic barriers to accessing information. Research conducted by Boeing found that higher rates of internet usage have consistently been observed among wealthier, highly educated, and younger populations as compared to their counterparts. This level of informational asymmetry has also been shown to induce excess costs among the afflicted populations as well (2019).

On the supply side, a study comparing search results for apartments on Craigslist, Apartments.com, Zillow, and GoSection8 found that different online platforms would heavily advertise units in certain areas over others, regardless of affordability. While some platforms avoided advertising areas that had high densities of low-income individuals and people of color, others, like GoSection8, would over-advertise in these areas (Hess et al, 2022).

Once a household has access to information about more cost-effective housing options, the notion that the household would elect to move, following the principle of utility maximization through substitution, does not entirely hold. Households actually often elect to remain in their current home due to family, community connection, access to job opportunities, school districts, or more. Skobba and Goetz explain that:

> "Relationships, rather than neighborhoods, appear to be the driving factor in residential mobility and decision making for the low-income families in our study. In the absence of financial resources, people are an essential source of capital. For very low-income households, support networks become an important way for families to meet basic needs. The use of informal support networks to meet housing needs is no exception" (2013).

The last economic principle to be addressed in this section is the question of supply and demand elasticity in the housing market. Elasticity refers to the ability of either the supply-side or demand-side of a market to adjust accordingly when conditions change. When the market is graphed, elasticity allows for shifts in the demand curve to be met with a less volatile supply curve, meaning that while prices may increase slightly, the units provided will experience the most dramatic increase, making filtering possible. If the supply curve is instead inelastic, increased demand cannot be met as much, and the price will increase more drastically. While inelastic supply and demand do not constitute a market

failure on their own, they certainly can contribute to or give way to a market failure happening.

PT. 3 PREVIOUS EMPIRICAL EVALUATIONS ON FILTERING

Research seeking to evaluate the elasticity of supply and demand within the housing market has found that both the supply and demand curves in the housing market are inelastic. Elasticity is essential to filtering theory as high elasticity dictates that price is responsive to changes in supply. However, consensus around the inelasticity of demand is strong both theoretically and empirically, in 1979 the average renter income-elasticity and owner income-elasticity was highly inelastic and some suggest that these findings illustrate households may choose to allocate additional income to other basic needs before moving (Mulford, 1979). Rosenthal expounded on this work by also finding that the elasticity of demand for rental and for-sale housing over the last 30 years has been highly inelastic and consistent with other findings (2014).

On the other hand, consensus around inelastic supply is still somewhat contested in contemporary research. In California in 2016, the Legislative Analysts' Office released a report suggesting that “Increasing the supply of housing can help alleviate this competition and, in turn, place downward pressure on housing costs. Building new housing indirectly adds to the supply of housing at the lower end of the market” (Taylor, 2016). In theory, developers should be able to build more to meet increasing demand, but cities have the constraint of land on housing supply; eventually, more densification is not possible. As hot markets get closer to this threshold, the market becomes more volatile, impacting the cost of housing development and therefore what final product can be afforded.

Nathanson and Zwick argue that this may be because of the impact land speculation has on the private markets' ability to provide low- to moderate-income housing (2013). Land allotments are finite resources, so we have a tragedy of the commons effect where actors that want to maximize profits buy up a lot of land and overproduce a supply of luxury-priced housing. Then the unmet demand at lower income levels continues to grow as people move into the city. This is further enforced by the government as local municipalities have to make decisions about how their remaining land is best used while facing incentives to grow their tax base. These internal pressures, combined with many constituents and homeowners looking towards their home values for guidance, leave local governments little room in negotiating with developers to get a deal done.

Supply elasticity is only one piece of the puzzle. Nathanson and Zwink found that during the 2000-2006 housing boom, cities where the housing supply was more elastic actually saw the greatest increase in housing prices (2013). Developers are naturally inclined towards increasing profits, meaning they are most keen to invest in the hottest markets to increase their chances of a good return. As Zuk and Chapple find:

> "Market-rate development in the 2000s is associated with higher rents, which could be expected as areas with higher rents are more lucrative places for developers to build housing. Furthermore, development in both the 1990s and 2000s is positively associated with housing cost burden for low-income households. Thus, while filtering may eventually help lower rents decades later, these units may still not be affordable to low-income households" (2016).

How housing is used as an investment, rather than just a commodity, at all levels impairs the filtering process from coming to fruition. Many homeowners do not want their largest asset to depreciate in value, as home ownership has become akin to building generational wealth in the United States. Nygaard et al explain that recurrent investment in

properties, through renovations, updates, or conversion to alternate uses, all disrupt the filtering process and can potentially prevent it or create a reversed impact (2022). Over the short term and in the hottest markets in the U.S., where prices are rapidly increasing and there is little affordable stock, it has been found that filtering is ineffective and takes decades to come to fruition. Sometimes, a reverse-filtering effect is observed where desirable older units increase in prices (Chapple and Song, 2024). Interestingly, Damiano and Fenier argue that while prior research has suggested the filtering process successfully produces more affordable housing in the long run, their analysis showed that while new construction has an immediate effect of decreasing high-priced rental housing, it increases low-priced rental housing over nearly two decades (2020).

Taken together, the literature reviewed suggests that while filtering theory offers a plausible framework for understanding how new housing might lead to greater affordability over time, however, its assumptions are often too idealized to hold in practice. Multiple scholars have highlighted that filtering occurs slowly, unevenly, and is frequently overpowered by local demand-side forces. The efficacy of filtering appears to depend not only on the quantity of housing added, but also on where that housing is built. Informed by this literature, my statistical analysis tests whether changes in housing supply at the census tract level are associated with changes in rental prices. By comparing a national model to San Francisco County we can narrow in on a high demand area where filtering theory has been employed to compare to the national average. In doing so, I control for variables like median age of the housing stock, racial composition, educational attainment, vacancy rates, and unit characteristics which are all factors the literature identifies as shaping how supply interacts with affordability.

METHODOLOGY

The motivation behind this paper is to investigate a counter-hypothesis to traditional filtering theory by quantifying what effect a percent change of units in a census tract has on the average inflation-adjusted change of price a unit goes for in the same area. This paper uses the empirical approach of conducting a series of Ordinary Least Squares (OLS) Regression analyses on both the housing market of the United States overall and San Francisco County..

Using data from the 2000 decennial census and 2016 ACS 5-year estimates at the census tract level for the United States, the dependent variable tested in the regression is the percent change in price for the average rental unit, and the primary independent variable investigated is the percent change in housing price for the average rental unit of the same area. Variables controlled for include the percent of the population that is White, the percent that holds a bachelor's degree, the median age of the population, the median year of construction for housing stock, the vacancy rate, the average number of rooms per unit, and the cumulative commute time (measured in minutes).

Table 1: Descriptive Statistics: National and San Francisco Samples

Variable	Mean (Nat)	SD (Nat)	Min (Nat)	Max (Nat)	N (Nat)	Mean (SF)	SD (SF)	Min (SF)	Max (SF)	N (SF)
% Change in Rent	54.881	92.288	-88.239	2436.394	54689	68.009	85.528	-43.754	646.453	161
% Change in Units	82.319	2067.204	-99.140	258000.000	54689	16.768	94.543	-83.256	532.500	161
% White	0.733	0.251	0.001	1.000	54689	0.751	0.139	0.227	0.983	161
% w/Bachelor's Degree	0.193	0.104	0.001	0.769	54689	0.279	0.090	0.073	0.480	161
Median Age	40.183	8.184	11.400	85.700	54689	42.550	7.718	23.200	61.700	161
Median Year Built	1975.621	15.961	1940.000	2014.000	54689	1976.801	12.482	1940.000	2005.000	161
% Vacancy	9.300	8.925	0.098	97.529	54689	5.609	8.706	0.339	68.828	161
Avg. Rooms per Unit	5.569	1.128	1.300	10.000	54689	5.737	1.102	3.100	10.000	161
Commute Time (Cumulative Min)	1743.406	783.338	22.000	24550.000	54689	2089.075	861.597	372.000	5028.000	161

Controlling for the percentage of the census tract that is White examines potential racial disparities. Descriptive statistics show that San Francisco has a less diverse population

than the average nationally, though both models show tracts with most of the population being white. San Francisco has a less extreme minimum, with Table 1 showing the least White tract still having 23% of their population reported as white, whereas across the nation, the least white tract was found to have 0.01% of the population reported as White. Research has shown that Black households experience housing cost burdens at a higher rate than their White counterparts, even after controlling for other factors (Hess et al, 2020).

The portion of the population holding a bachelor's degree is used as a proxy for households with high-paying jobs in a neighborhood. Previous research has used this metric to proxy for the skill level of an area and has found that places declining in this metric are highly correlated with a declining population (Glaeser and Gyourko, 2005). The San Francisco data from Table 1 shows more census tracts having a higher portion of people with bachelor's degrees, and a much higher minimum than seen in the national data.

Since demand for housing varies based on age demographics, this factor was controlled for as it could impact the efficacy of supply-side theory in each area (Francke and Korevaar, 2022). For example, while housing demand is high for people in adulthood, as some people age, we may see a tendency for housing demand to lower as children move out and retirement or medical costs start to be a burden. In Table 1 the average age was similar across the nation as it was in San Francisco, but the nation as a whole saw higher variance.

Considering the median year of structures built in a tract can provide insight into areas that may be more prone to filtering with aging stock. Due to the slow-moving nature of filtering, other studies have shown that this process can take generations to come to fruition (Zuk and Chapple, 2016). Likewise, examining patterns across this metric can provide valuable insights to this study. However, it is important to note that this metric is limited in

that cells containing values in the 1800's was cleaned as the nature they were reported was incomplete and inaccurate due to technical limitations of the time. On the other hand, including this variable can also reduce the potential of omitted-variable bias, as otherwise the model may attribute rent increases to unit growth when there is unaccounted underlying value in historic or new luxury stock composition.

Controlling for the vacancy rate captures how hot the market is in each census tract, which directly impacts the asking price for housing units. This will aid the model in being able to capture the impact of supply growth alone rather than being swayed significantly by outlying demand inputs. The San Francisco datasets in Table 1 showed characteristics of higher demand than the national average, as the mean and minimum vacancy rates are both lower, however, the standard deviation across the two locations is very similar.

The location housing is developed can also impact the price and demand for it, therefore, controlling for total commute time to work allows the model to account for another element of spatial variability. Naturally, developments near job sites may be higher in price more than those that are not. The data showed that San Francisco tracts had a longer cumulative commute time than the national average, another indicator of the demand present in that market.

All data was tested for Variable Inflation Factors (VIF), and all variables tested had scores around one, showing low multicollinearity concern. Additionally, all tracts with missing cells of data or zero values were cleaned from the dataset. As Table 2 and Table 3 show, a correlation matrix was created for both sets of data, revealing that most variables are weakly correlated with a few that stand out as moderately correlated. After the data was fully refined, two OLS regressions were run. The linear regression function was then

modified to a quadratic regression function to test for a nonlinear relationship for both models (Wooldridge, 2016).

DISCUSSION

For the United States overall, the dependent variable–percent change in rent price–was positively correlated with the percent of population with a bachelor's degree at .39 as seen in Table 2. The percent of the population that is White is correlated with both average age and average rooms per unit in a tract at .37 and .33, respectively. Average age is correlated with the vacancy rate across U.S. Census tracts at .31. On the other hand, the vacancy rate is negatively correlated with commute time at -.39.

Table 2: Correlation Matrix: National Sample

	% Rent	% Units	% White	BA Deg.	Age	Yr Built	Vacancy	Rooms	Commute
% Rent	1.000	0.015	-0.053	0.392	0.053	0.093	-0.129	0.143	0.148
% Units	0.015	1.000	0.011	0.014	0.005	0.012	0.007	0.009	0.022
% White	-0.053	0.011	1.000	0.171	0.367	0.144	0.111	0.333	0.016
BA Degree	0.392	0.014	0.171	1.000	0.106	0.162	-0.120	0.217	0.222
Median Age	0.053	0.005	0.367	0.106	1.000	0.021	0.306	0.226	-0.229
Year Built	0.093	0.012	0.144	0.162	0.021	1.000	0.006	0.155	0.179
Vacancy Rate	-0.129	0.007	0.111	-0.120	0.306	0.006	1.000	-0.211	-0.385
Avg. Rooms	0.143	0.009	0.333	0.217	0.226	0.155	-0.211	1.000	0.127
Commute Time	0.148	0.022	0.016	0.222	-0.229	0.179	-0.385	0.127	1.000

Table 3: Correlation Matrix: San Francisco Sample

	% Rent	% Units	% White	BA Deg.	Age	Yr Built	Vacancy	Rooms	Commute
% Rent	1.000	0.267	0.079	0.246	0.136	0.313	-0.158	0.386	0.017
% Units	0.267	1.000	-0.022	0.101	0.054	0.229	-0.082	0.132	0.260
% White	0.079	-0.022	1.000	0.042	0.051	0.056	0.312	0.174	-0.309
BA Degree	0.246	0.101	0.042	1.000	0.245	-0.025	0.073	0.549	-0.076
Median Age	0.136	0.054	0.051	0.245	1.000	0.201	0.228	0.466	-0.438
Year Built	0.313	0.229	0.056	-0.025	0.201	1.000	0.019	0.328	0.192
Vacancy Rate	-0.158	-0.082	0.312	0.073	0.228	0.019	1.000	-0.134	-0.310
Avg. Rooms	0.386	0.132	0.174	0.549	0.466	0.328	-0.134	1.000	-0.076
Commute Time	0.017	0.260	-0.309	-0.076	-0.438	0.192	-0.310	-0.076	1.000

For the San Francisco County model, as seen in Table 3, there were more variables moderately correlated to each other. The percentage of the population with a bachelor's degree and the average rooms per unit in a tract had a correlation of 0.55. The average

number of rooms also had a significant correlation with the average age of the population in a tract at 0.47. On the other hand, the average age of the population also had a negative correlation with the cumulative commute time at -0.44. The dependent variable, the percent change in rent in a tract, was most strongly correlated with the average rooms per unit, at .39.

In both models, cumulative commute times were negatively correlated with both vacancy rates and age. As Tables 2 and 3 illustrate, in the San Francisco model, the dependent variable was most strongly correlated with the average number of rooms in a unit, whereas in the national sample, the percent change in rent had a significant correlation with the percentage of the population holding a bachelor's degree. Also worth noting is that for the San Francisco sample, the dependent variable and primary independent variable had a correlation of .27 between percent change in rent and percent change in units, whereas in the national sample, a very weak correlation of 0.02 was observed.

Table 4: Regression Results: National and San Francisco Models

Variable	Nat. Linear	Nat. Nonlinear	SF Linear	SF Nonlinear
% Change in Units	0.000**	0.002***	0.188***	0.092
Units Squared	—	0.000***	—	0.000
Percent White	-63.816***	-63.845***	52.046	53.256
Bachelor's Degree	328.832***	328.805***	-37.986	-36.584
Median Age	0.986***	0.984***	-1.458	-1.371
Median Year Built	0.197***	0.197***	1.578**	1.590**
Vacancy Rate	-0.578***	-0.584***	-1.334	-1.323
Avg. Rooms per Unit	6.273***	6.287***	25.093***	25.291***
Commute Time	0.006***	0.006***	-0.013	-0.010
Constant	-431.103	-430.281	-3130.224	-3167.509
R^2	0.188	0.189	0.250	0.253
Adj. R^2	0.188	0.189	0.211	0.209
N	54689	54689	161	161

Notes: Coefficients shown with significance stars. ** $p < 0.05$, *** $p < 0.01$.

In the analysis of the regression results, we find that the dependent variable, percent change in rent, has a statistically significant, positive association with the percent change of units in both the national and localized models. It is important to note that the true results of the national nonlinear model, as depicted in the chart, do not fully represent findings from data analysis. As the chart is rounded to the thousandth value, the national nonlinear model's chart as shown here does not indicate an extremely small, yet highly statistically significant detail sitting at the crux of this topic - an association with a value of -1.103e-08 compared to the linear output of 0.0004313 as a non rounded number. The negative value sign change on the directionality of the association here shows that as the percent change in units increases, so does the percent change in rent up until a point of ~90,662% after which the price begins to fall.

The threshold point is calculated from the quadratic regression equation wherein the primary independent variable was squared and stored in a new field, then incorporated into a standard quadratic regression function. Drawing on Wooldridge's equation ("Introductory Econometrics*"* 2016)*:*

The turning point (threshold) in a quadratic regression model of the form:

$$\hat{y} = \beta_2 \cdot x^2 + \beta_1 \cdot x + \beta_0 \qquad \text{(Equation 1)}$$

is given by:

$$x^* = -\beta_1 / (2 \cdot \beta_2). \qquad \text{(Equation 2)}$$

so for the national model the turning point is given by:

$$x^* = -0.002 / (2 \cdot (-1.103 \times 10^{-8})) \approx 90{,}662 \qquad \text{(Equation 3)}$$

This threshold point, while large, is not only statistically significant but also within the observed range of the data. The national model, according to Table 1, observed up to a

258,000% increase for this metric, however, this is representative of a tract that had only one unit of housing reported in the year 2000, so this represents unique growth characteristics that are hard to replicate. In fact, the data set had 160 of the 50,000 tracts report five or fewer units in the year 2000; the average tract saw a growth of 82%, but the standard deviation among the data was high at around 2,000. Further investigation reveals that 77 tracts in the national sample, representing 0.014% of the national sample, performed above this threshold of unit growth and saw an association between this amount of increase in supply and an eventual decline in price.

For both national regression models in Table 4, the highest associations found were between the percent change in price and the percent of the population that has a bachelor's degree or is White. The directionality of the association shows that as the share of a population with a bachelor's degree increases, so does the percent change in average rental price, and that, oppositely, as the share of a population is increasingly White, the average rental price decreases. In the San Francisco models, the variables accounting for race and educational attainment lacked a statistically significant relationship with the dependent variable.

The median year built showed some level of significant positive association with the increase in rents, which is supportive of supply-side theory, as is the consistently negative yet less significant association observed between vacancy rates and rental price increases. Another consistently significant variable found was, unsurprisingly, the average number of rooms per unit, which held a very significant positive association across all regressions. In fact this was the only variable with a highly significant association between the San Francisco regressions, both reporting an association coefficient of around 25. Overall, the

national regression returned more variables that were highly significant yet had smaller R-squared values than the San Francisco counterparts.

IMPLICATIONS

Analysis reveals a small but statistically significant nonlinear relationship between the percent change in housing supply and the percent change in average rent in an area at the national level. Meaning that while none of the models examined showed a truly strong relationship between the two variables in most tracts, those with low numbers of starting housing stock and extremely high percent changes in unit supply (at least ~90,600%) did see a statistically significant trend in lowering prices, which falls in line with filtering theory. As depicted by the national model, when the percent change of units falls below this threshold point, increases in supply are associated with price increases, which is antithetical to filtering theory.

The analysis showed a positive relationship between the two primary variables in San Francisco County, which is also antithetical to filtering theory. Overall, the San Francisco model showed a stronger relationship of prices increasing as supply increases past a certain threshold but lacked the statistical significance to validate the association. The deviation observed between the national model and San Francisco could be potentially explained by other factors contributing to the local housing market dynamics in the area.

For example, the median year housing stock was built showed a positive relationship with the change in rental prices, meaning that newer stock was priced higher than older counterparts. This association suggests that for every year increase in the median age of housing stock in a census tract, the rent would rise 1.58-1.59%, which is in support of filtering theory (Table 4). However, this association was less significant and of a smaller strength than in the national average, so there is still plausible room in the market for some reverse filtering effect due to the high values of historic housing stock in San Francisco.

On the other hand, the variable that the San Francisco model produced its strongest and most significant relationship with was the average number of rooms per unit. The relationship between these variables was even stronger in the San Francisco model than in the national model, indicating that as the average number of rooms increases by 1, the percent change in rent observed in about 15 years is 25% (Table 4). While this effect is most strong in San Francisco, it is still present and significant on the national model, just to a lesser extent. These results can be interpreted as San Francisco housing stock having concentrations of rental price increases in areas with larger housing stock available. Secondly, it suggests that average rental prices increase along with newer, potentially larger luxury developments.

For the national model, the two variables that stood out as most impactful and statistically significant were the percentage of the population that is White and the percentage of the population with a bachelor's degree. These variables tested returned values of around -64 and 329, respectively, both at the 0.01 significance level. So, if a census tract hypothetically saw a tract go from 0-100% White, it would be associated with a 64 percentage point decrease in rent. On the other hand, if the population of a tract changes such that there is an increase in the people holding bachelor's degrees from 0-100%, it is associated with a 329-percentage point increase in average rent in the area (Table 4). Taking these two factors from the national model into account simultaneously suggests that rent increases were seen in pockets of the nation that were concentrated in highly educated and racially diverse areas. Resembling Boeing's (2019) research, these statistics align with the idea of a lack of access to information via the internet, or potentially also varied educational levels, creating information asymmetry in housing markets and therefore producing atypical

characteristics of market failure. These results also support Rosenthal's caution that filtering may occur at to slow a rate to be effective as a policy strategy. Adding to this perspective, Zuk and Chapple (2016) found that filtering occurs at to slow a rate to meet current housing demand levels. However, Rosental (2014) finds individual home depreciation to occur at a rate of 0.5% a year. Similarly, I find in Table 4 that for every year the median housing development is younger in a census tract, it attracts a 0.197 percentage point higher rent than its counterparts.

By comparing these two results, it could be extrapolated that while individual homes may have some effect where their value filters down if they age, new development may just be concentrated in high-demand neighborhoods where rent levels are rising quickly enough to counteract this filtering effect for the housing market dynamics of the area. While Rosenthal's methods for examining filtering assume that this phenomenon would be observed at the individual unit level in isolation, this research suggests that, in practice, rent growth at the neighborhood level is too strong to see a significant impact due to other demand factors. This dynamic would suggest that filtering theory, while having true theoretical framework, is too small of a practical effect to significantly impact the modern-day appreciating housing market. Seeing as housing development ostensibly happens in areas that are already experiencing high levels of demand, these neighborhood-level dynamics can reverse or neutralize the outcome expected to be produced by filtering theory when adding units to a market.

The findings presented in this paper are consistent with Zuk and Chapple (2016) and Nathonson and Zwick's (2013) as discussed in the literature review section, assuming that the percent change of units in an area and market rate development are signifiers of supply

elasticity. This metric has been found to have a very small, but positive impact on the average housing cost, which is antithetical to filtering theory. Evidence pointing to the observation of some form of reversed filtering effect mentioned in these papers is consistent with the findings here. This paper specifically finds the relationship between housing price and supply growth to be negative only past a very high and uniquely occurring level of unit growth that is only seen in census tracts initially reporting with next to no stock.

CONCLUSION

This thesis set out to investigate whether growth of the housing supply in census tracts is associated with the average housing cost change observed in that tract over the same time period in a way that is indicative of filtering theory. Using data from the U.S. Census from 2000 and the ACS from 2016 I conducted a linear and nonlinear regression analysis for both a national sample and a San Francisco sample. To find if supply growth meaningfully impacts housing prices, the models were made to account for a variety of other socioeconomic factors that could be contributing to the primary investigated relationship. Adopting a mixed methods approach allows this paper to directly connect filtering theory and its historical roots in policy to a quantitative analysis.

The national model reveals a very small, but highly statistically significant nonlinear relationship showing that below a certain level of development, a reversal of the typical filtering relationship is observed. After the threshold is reached, there is some filtering effect shown however, only a very small number of census tracts across the entire country fit into this category. Census tracts that did see a typical filtering effect all started with five or fewer units at the first point of data collection, making a larger percent change in unit supply feasible in these areas. These trends directly contradict what proponents of filtering theory would suggest in most census tracts in the nation.

In the San Francisco model, the non-linear regression showed a highly significant positive relationship between the percent change of units in an area and the percent change in price of a rental. This result goes even further to oppose what filtering theory would suggest than the national model did, perhaps due to limited land left to build on, high levels of demand, and other factors leading to homes there appreciating too fast for a filtering

effect to be observed. In the nonlinear regression, no statistically significant relationship was found between the primary variables. However, other factors like the percentage of the population that is white and high levels of educational attainment had far larger effects on rental growth than the percentage change in supply.

In both models, the median year a structure was built is correlated with the percent change in rent, such that areas with younger housing stock show larger growth in rental prices than their counterparts. This further complicates the notion that adding supply to an area would work to alleviate rising affordability pressures. These findings challenge the efficacy of using filtering theory as a policy strategy to address affordability concerns, as has been promoted by HUD to create more NOAH (Myers, 2020). This paper argues that while filtering may occur at the unit level over a long time, it is too weak an effect to produce neighborhood-level progress in making affordable housing units naturally occur. As opposed to the classical supply-side model wherein increasing housing units leads to alleviating pressures on housing prices, these results may suggest that construction predominantly occurs in tracts that are already in high demand with appreciating markets.

Therefore, relying on market-rate private housing development alone is not likely to create a meaningful reduction in rents or alleviate the rate at which housing costs are growing, especially in areas of high demand or areas that have already experienced substantial development. While housing production is still an important sector for policy to shape, who the production serves and where it is built is shown to have drastic impacts on the efficacy of filtering theory. Supply-driven policies for targeting affordability measures should be tailored such that market rate development is a tool for the appropriate tracts, and

where inappropriate, strong affordability requirements are required of developers. This may be the difference between creating an affordable opportunity and squandering it.

For planners and policymakers, implications from this research can allow filtering theory to be seen through a more nuanced lens and applied where appropriate. Often, other pressures in markets render filtering an insufficient strategy for indirectly developing affordable housing opportunities. In rare cases, such as undeveloped census tracts, perhaps filtering theory should be examined.

This study has limitations due to its reliance on census-based tract-level data, meaning some level of granularity cannot be captured. The models shown in this paper also cannot account for unobserved factors like political or financial conditions shaping housing markets on an individual scale. Moreover, the cross-sectional aspect of this form of analysis means that while associations can be investigated, causality cannot be established definitively. Further research should continue to investigate these relationships over longer time horizons and with more granular data.

This thesis adds to a growing body of literature that challenges the assumptions of supply-side housing market dynamics, such that they question the efficacy of filtering as a strategy. I find that while filtering theory may hold under certain ideal conditions, empirical analysis suggests that for many census tracts across the U.S., a filtering effect may be outpaced by other market forces. Therefore, addressing housing affordability will require more thought and intentional policy considerations to prioritize efficacy in providing affordable housing opportunities alongside typical production methods.

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