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Determinants of Housing Supply Expansion in the Western United States

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Abstract

New residential construction is an important indicator of economic health. Previous empirical work demonstrates the profound power of housing starts in forecasting recession. Theoretical research, backed by empirical study, suggests that home prices and interest rates are closely related to the amount of residential investment. This paper attempts to better understand the complex relationship between various factors that influence the supply and demand of new housing; what information do suppliers and regulators use to determine how many new units of housing will be constructed? Specifically, we will look at the respective state housing markets of California, Oregon, and Washington by constructing an empirical model of the number of housing permits issued. Our findings suggest that during the period from 2005 to 2019, the number of annual housing permits issued, as a proxy for housing starts, is related negatively to increases in, and higher levels of, 30-year mortgage rates and positively to increases in, and higher levels of, 2-year Treasury bill rates. Short-term interest rates may have been a special signalling mechanism for the health of the overall economy.

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Introduction

New residential construction is an important indicator of economic health. Not only as a sign of a growing population, which might indicate future economic growth to come, new construction also affects the ability for people to afford new homes. Builders and developers willing to invest in constructing new housing units is an indicator of confidence in the economy going forward.

Prior to 2009, the United States as a whole averaged roughly 1.5 million housing starts annually, with a range from about 1 million in 1982 and 1991 up to 2.4 million in 1972. While past recessions had been a result of bank runs, market crashes, oil price swings, or tech busts, the Great Financial Crisis was directly tied to the housing market. Securities dependent upon mortgages as the underlying asset became incredibly popular, and "insurance" in the form of credit default swaps helped to magnify the eventual crash when the housing market went under. The effective federal funds rate hit 1% in periods of 2003 to 2004. Before that, the last time the federal funds rate was under 1% was from May to July of 1958, where it dropped to 0.63% in May. From July 2007 to December 2008, the federal funds rate dropped from 5.26% to 0.16%. While other recessions saw the federal funds rate cut for a few months, to have it rebound shortly after, the federal funds rate did not surpass 0.2% from December 2008 to November 2015. The federal funds rate began to rise again, and hit around 2.4% during the summer of 2019, and was already going down before the COVID-19 pandemic, which caused rates to be cut to under 0.1% in March 2020. It seems fair to say, then, that the period from 2005 to 2019 that is the focus of this paper might be seen as an exceptional period in history, as the market has been under expansionary policy for an extensive period of time to get the economy up and running again.

We often hear complaints of skyrocketing home prices, particularly in booming cities like San Francisco, Portland, and Seattle. Table 1 shows that, in both Oregon and Washington, home values over the last 15 years have grown at a faster rate on average than personal income has grown. Since 1960, median home prices have increased 121% nationally, while median household income has increased only 29% (Tekin 2020). Additionally, all three of the top three MSA's in terms of the percentage of median income spent on mortgage payments are in California (Lattice).

One might expect that the housing market could correct itself, or at least slow down the increase in prices, by expanding the stock of housing. However, there are multiple parties and factors involved in the expansion of housing stock. Firstly, housing is not a pure commodity that is divisible, meaning that more than one housing unit cannot take up the same physical space. The proximity of a unit to desirable environmental features, like jobs, good schools, etc. can drive up the price of a home, so to prevent the upward spiral of prices in a competitive market, builders would have to increase local density, creating externalities for those already in the area. Essentially, new units will only be produced if builders believe the project will be profitable in terms of net present value, and if the local government approves applications for construction. Suppliers of new housing, then, must predict what their returns will be based on the price of housing, ability of home-buyers to pay, and the number of homes that will be demanded. Local governments presumably do not want unhappy citizens, and so must manage the addition of new homes to their locale.

This paper attempts to better understand the complex relationship between various factors that influence the supply and demand of new housing; what information do suppliers and regulators use to determine how many new units of housing will be constructed? Specifically, we

will look at the respective state housing markets of California, Oregon, and Washington by constructing an empirical model of the number of housing permits issued.

When approaching the subject of housing starts or residential investment, research is often conducted at the national level, and treated as a national indicator like GDP. For instance, Leamer (2007) inspects the role of residential investment to macroeconomic recession as a leading indicator of recession.

Mayer and Somerville (2000) use MSA-level data, but attempt to explain variation in single-family permits by home prices with multiple lags, measures of regulatory delay in the process, the change in the real prime rate, and the population.

This paper, alternatively, attempts to implement an expanded form of the theoretical model using difference equations presented by Chiang (2005) in Chapter 17.5. I rearrange and expand the "Market Model with Inventory", then apply it to empirical data.

Literature Review

Leamer (2007) postulates that housing starts, the number of dwelling units upon which construction has begun, and the change in housing starts are the prime predictors of the business cycle phase that he has come across. It seems to me that if housing starts are a strong leading indicator of recession, and we can determine the leading indicators of changes in housing starts, then we can have an even better understanding of oncoming downturns, and potentially see them coming further in advance. Out of ten recessions between World War II and 2007, eight have been "preceded by substantial problems in housing and consumer durables"(Leamer). He recommends a tighter monetary policy upon initial ascent of the cycle to avoid eventual catastrophic crash, citing cyclical inertia as a powerful enough force to allow booms to ride

themselves out while minimizing eventual busts. During expansions, while housing is not maximally responsive to changes in interest rates, is a period in which monetary policy can be enacted preventatively.

Leamer (2007) contends that, given the wide range of policies tested from 1972 to 2007, the fact that the economy has reliably grown at roughly 3% per year, give or take 3% in either direction, is an indicator that our focus should be upon addressing the cyclical nature of the economy. He presents figures and data regarding the different contributors to this growth in real GDP as a fraction of the overall rate. Residential Investment contributes a small percentage of real GDP growth (leading up to 2007, around 4.2% out of 3.1% annual real GDP growth).

Leamer (2007) first subtracts the normal contribution of Residential Investment to growth from the observed data, then cumulates the resulting "abnormal" contributions. By removing data surrounding recessions, and subtracting the value of contribution to growth from residential investment at cycle peaks, he presents an impressive set of figures. Reliably, we see a consistent trend of residential investment contributing abnormally less to growth leading up to cycle peaks. Chillingly, the steepest downward slope presented over the period post-World War II occurs leading up to and during 2007, the time of publication of his paper.

Furthermore, measuring the cumulative contribution to weakness in GDP in the year before recession, Leamer (2007) finds that six out of ten recessions have Residential Investment as the leading contributor. On average, Residential Investment cumulatively contributes 22% to weakness in GDP the year before these ten recessions, the highest contribution amongst Durables, Exports, Equipment and Software, Nondurables, Federal Defense, Services, State and Local, and Structures. Examining the seven "normal" recessions, excluding "the 1953 Defense Downturn, the 2001 Internet Comeuppance and the ancient 1948 recession," Leamer (2007)

finds that contributions to GDP weakness the year before recessions changes dramatically. Residential Investment then increases in average cumulative contribution from 22% to 25%, Durables remains at 20%, and Services takes the third place spot at 11%. From this, Leamer (2007) concludes that "it's weakness in consumer spending that is a symptom of an oncoming recessions."

As the population of an area increases, it seems logical that the demand for new housing would increase as well. While net migration rates have propped up residential investment in the past, they "fell by more than 40% between 2016 and 2019. Indeed, in 2019 America's population grew at its slowest pace in a century"(The Economist).

Interest rates and house prices have been found to be influential over residential investment. In this paper, we will study the relationship of both long-term 30-year rates and shorter-term 2-year rates with the number of housing permits issued. House prices are also found to be responsive to short-term interest rates, with Sutton et. al. (2017) finding a 5% increase in home prices expected over time following a 1 percentage point cut to short-term interest rates. While the connection between mortgage rates and residential investment might be more obvious, in that higher rates for home-buyers should decrease demand for new homes, the short-term interest rate is highly sensitive to the state of the general economy.

It is important to understand that the relationship between new supply and home prices is dynamic, in that new supply is both in part determined and a determinant of prices. McCarthy and Peach (2002) put forth a model describing long-term home prices from the supply side as a function of the log investment rate and the construction cost index for single-family homes. The demand curve describes long-term price as a function of the log of stock of housing, the log of nondurables and services consumption, and the log of the user cost of holding the housing asset..

Their short run supply equation describes the change in the investment rate as a function of a number of variables: the difference between the actual home price and the theoretical price given the supply function from the last period, the change in price, the change in construction costs, the change in the short-term interest rate, the change in the price of land relative to the PCE deflator, and the log of the quantity of new homes for sale. McCarthy and Peach (2002) find that after 1985, following deregulation of the mortgage market and an expansion of access to capital, the coefficient of home price inflation when regressed on the investment rate becomes larger and becomes statistically significant. Of the other independent variables, the real interest rate was found to be the only other statistically significant variable, other than the error-correction term.

Continuing with our study of the relationship between new supply and home prices, Mayer and Sommerville (2000) estimate that a one percent increase in home prices is followed over the next 5 quarters by a 15 percent increase in new construction. They find that the steady state level of construction is decreased by land use regulations. While development or impact fees were shown to have a small negative effect on construction levels, regulations that delay construction time or cause uncertainty with regards to permit and zoning approval were shown to have a more significant negative impact on construction.

This paper attempts to apply a theoretical supply-demand framework to determine the relationship between a number of different factors with the number of housing permits issued at the state level, specifically for California, Oregon, and Washington. Study of new residential construction is typically done at the national level, as an indicator of macroeconomic health. Mayer and Somerville (2000) apply their model to MSA data, but are focused on the effect of regulation on new construction. This paper, instead, includes explanatory variables like the

vacancy rate and the lumber price index, as a proxy for construction costs, thus focusing more upon housing market-specific factors.

Theory and Hypothesis Development

In *Fundamentals of Economic Analysis*, Chiang presents a framework for the relationship between supply and demand as follows in Equations 1 and 2:

$$Equation\ 1:\ Q_{dt} = \alpha - \beta P_t \qquad (\alpha, \beta > 0)$$

$$Equation\ 2:\ Q_{st} = -\gamma + \delta P_{t-1} \qquad (\gamma, \delta > 0)$$

Q_{dt} is the quantity demanded at time t, α is the intercept, β is the price elasticity of demand, and P_t is the price at time t. Q_{st} is the quantity supplied at time t, $-\gamma$ is the intercept, δ is the price elasticity of supply, and P_{t-1} is the price at time t-1. Without regulation or other impediments to market efficiency, markets are expected to reach equilibrium in the long-run. However, because homes are a commodity that cannot be produced in real time to meet the demand for housing, there exists a temporal gap between the supply of housing and the demand of housing. Suppliers of housing, then, must react to the disequilibrium by increasing or decreasing the production of new houses. Suppliers will react by producing X quantity of homes, then the price of housing will adjust, causing the following period's production to adjust, and so on.

Chiang goes on to describe a model of Prices as a function of Prices of the previous period, as well as the Inventory, as in Equation 3:

$$Equation\ 3:\ P_{t+1} = P_t - \sigma(Q_{st} - Q_{dt})$$

Logically, it makes sense that the housing inventory will be represented by how much larger the quantity supplied is relative to the quantity demanded. However, in this paper, we are attempting

to describe the reverse: how much larger is the quantity demanded than the quantity supplied? It stands to reason that the number of new units produced will be influenced by the number of units that already exist. Why go to the trouble of getting legal authorization and investing time and money building new units, when the price of new units produced will be reduced by the presence of existing, unoccupied housing?

We must also recognize that equilibrium in a growing and changing country is not stationary, and that the quantity demanded and quantity supplied are influenced by more factors than just the price. Factors like the price of housing, a growing population, growing income, and the 30 year mortgage rate should have a relationship with the quantity of homes demanded, as shown in Equation 4.

$$Equation\ 4:\ Q_{dt} = f(P_t,\ Pop_t,\ Inc_t,\ 30\,yr\ I/R_t)$$

Knowing that homes will not be ready for purchase for some period of time after starting construction, housing suppliers must estimate demand during the period in which their product will become available on the market.

As mentioned above, the price of housing, which is a determinant of the expected return of suppliers, the vacancy rate, the cost of capital for suppliers, and the construction costs are relevant considerations related to the supply of housing, as shown in Equation 5.

$$Equation\ 5:\ Q_{st} = f(P_{t-1},\ VacancyRate_{t-1},\ 2\,yr\ I/R_{t-1},\ LPI_{t-1})$$

More accurately, the amount of new housing supply is a function of what suppliers expected market conditions to be when the new supply hit the market. Suppliers are looking to take advantage of an undersupply of housing by producing more housing, collecting the difference between the price at which houses are sold and the cost to produce such housing. In reality,

suppliers of housing want to take advantage of future conditions, such that the price of housing they produce will be sufficiently high when the housing is ready for sale.

As the numbers of new units supplied and demanded are a response to changes in these other factors, and that the equilibrium at time *t* is moving along with these other variables, our model may resemble Equation 6.

$$Equation\ 6: \ ln(PermsIss)_{t+1} = \alpha_t + \beta_1 \Delta Price_t + \beta_2 \Delta Pop_t + \beta_3 \Delta Inc_t + \beta_4 \Delta 30yrI/R_t + \beta_5 \Delta VacancyRate_t + \beta_6 \Delta 2yrI/R_t + \beta_7 ln(LPI_t) + \beta_8 30yrI/R_t + \beta_9 VacancyRate_t + \beta_{10} 2yrI/R_t + \beta_{11} ln(PermsIss_t)$$

Definitions can be found in the 'Variable Definitions' table in the appendix. In a totally efficient market, the number of permits issued authorizing construction should represent how much larger the quantity demanded is than the quantity supplied. However, because the government can determine how many units can be produced via limiting access to building permits, the number of units authorized by building permits may not cover the excess demand. Additionally, firms in the short-run are not incentivized to completely close the gap between the quantity demanded and quantity supplied, as this would reduce the price, and therefore returns per unit.

Due to price being a force driving supply upwards and demand downwards, it seems difficult to hypothesize about the coefficient the change in price would have. With more people entering a state, we would expect demand for housing to increase, necessitating the construction of new housing units authorized by building permits, resulting in a positive value for β_2. Similarly, with more income available, we should expect demand for new housing to increase, and thus a positive coefficient on β_3. As mortgage rates rise, we would expect a decrease in demand for new housing, resulting in a negative β_4 and β_8. With a higher percentage of vacant

homes, we should expect suppliers to restrict production of new housing, so we should expect a negative value for β_5 and β_9. As 2-year interest rates rise, we might expect a smaller amount of new housing production, as the cost of debt for suppliers is higher, resulting in a negative value for β_6 and β_9. As the price of lumber increases, we should expect a decrease in supply, as costs to builders increases, resulting in a negative value for β_7. If when controlling for the rest of these variables, the relationship between the number of permits issued from the previous period to the current period is positive, this might suggest that the limitations the state is placing on construction are not allowing for the market to adequately meet demand.

Data

The panel data collected is from 2005 to 2019 (n=15) at an annual frequency for the states of California, Washington, Oregon, and the United States as a whole. While mortgage rates vary by state, the variance between states in a given year is much smaller than the amount of variance seen over time. For instance, in 2019 California, Oregon, and Washington had average APR rates of 4.83%, 4.85%, and 4.89% respectively.[1] In addition, the data for the annual nationwide average data for mortgage rates was available, while historical state data was not available. The number of building permits issued annually in the United States, California, Oregon, and Washington for the period are from the Census Bureau website. Home prices by region and year are sourced from Zillow. Population data is sourced from FRED St. Louis Fed. Per capita personal income is sourced from FRED St. Louis Fed. The real interest rate of 30-year mortgages and 2-year Treasury notes were sourced from FRED St. Louis Fed. The vacancy rate is sourced from FRED St. Louis Fed. The price of lumber index is sourced from FRED St. Louis Fed.

[1] Guerin, Jessica. "This Is How Mortgage Rates Vary by State." *HousingWire* (blog), February 12, 2019. https://www.housingwire.com/articles/48165-this-is-how-mortgage-rates-vary-by-state/.

Summary Statistics

Table 1 shows the summary statistics by state for the growth rate of the home value index, population, and personal income. Table 2 shows the levels of the number of permits issued, the home value index, population, personal income, and the vacancy rate. Table 3 shows the summary statistics for the variables that are considered consistent across different states, being the real 30-year interest rate and its change, the real 2-year interest rate and its change, and the lumber price index. While there may be differences in mortgage and interest rates between states in a given period, the differences between periods are generally much larger than those between states. Additionally, California, Oregon, and Washington are of a similar region and thus deviation in terms of the cost of producing and transporting lumber could be expected to be relatively small. Graphs visualizing different relevant data can be found in the 'Data Visualization' section.

Results

We regress the panel data upon the natural log of the number of permits issued the following year using fixed effects. Table 4 shows the results. When the natural log of permits issued the current year is omitted, as shown in Model 1, the growth rate of prices, the natural log of the lumber price index, the real 30-year mortgage rate, the change in the real 30-year mortgage rate, and the change in the real two-year interest rate have statistically significant relationships with the natural log of permits issued the following year. For a 1 percentage point increase in the growth rate of prices, we find a 0.973% increase in the number of permits issued

the following year. This suggests that as developers see prices increasing, they tend to make more investments in housing. For a 1% increase in the lumber price index, we find roughly a 0.815% increase in the number of permits issued. This is surprising, as we would expect higher construction costs to decrease the number of housing starts. For a one percentage point increase in the real 30-year mortgage rate, we find roughly a 11.2% decrease in the number of permits issued the following year. For a one percentage point increase in the change in the real 30-year mortgage rate, we find roughly a 18% decrease in the number of permits issued the following year. As mortgage rates increase, it seems that developers expect demand for housing to decrease, reducing developer incentive to invest in new construction. For a one percentage point increase in the change in the real two-year interest rate, we find roughly a 23% increase in the number of permits issued the following year. This is somewhat surprising, given that a higher cost of debt for borrowers would intuitively reduce the number of new housing supplied, as interest expense would increase.

In Model 2, which omits the growth rate of income and the change in the vacancy rate which were insignificant in Model 1, coefficients were quite similar to their value in Model 1. The vacancy rate now became statistically significant. For a one percentage point increase in the vacancy rate, we find roughly a 12.5% decrease in the number of permits issued the following year.

In Model 3, once adding the natural log of the number of permits issued the current year to the model, we find relatively similar results. The growth rate of prices and the level of the 30-year mortgage rate become no longer statistically significant. However, the level of the two-year rate becomes significant, but with quite a small negative coefficient.

Model 4 represents Model 3 with the growth rate of the population, the growth rate of income, the natural log of the lumber price index, the level of the 30-year mortgage rate, and the change in the vacancy rate omitted, as they were not statistically significant in Model 3. Again, we see that the vacancy rate shows a statistically significant relationship with the natural log of the number of permits issued the following year. The growth rate of prices becomes slightly statistically significant, but has a relatively small coefficient; for a 1 percentage point increase in the growth rate of prices, we find roughly a 0.458% increase in the number of permits issued.

Model 5 represents a similar panel fixed-effects regression model, but regressed upon the natural log of the number of permits issued in the current year. We find that the growth rate of prices, the real 30-year interest rate, and the real two-year interest rate have a statistically significant relationship with the natural log of the number of permits issued in the current year. For a one percentage point increase in the growth rate of home prices, we find roughly a 1.7% increase in the number of permits issued during that year. For a one percentage point increase in the real 30-year mortgage rate, the number of permits issued the following year decreases by 26%. For a one percentage point increase in the real two-year interest rate, we find a 25.4% increase in the number of permits issued the following year.

Conclusion

Housing starts are an important indicator of economic health and growth. Intuitively, if fewer new homes are being bought, the labor force is seeing relatively little expansion, while the lack of new supply can drive up prices in crowded urban areas. If people are not confident in their ability to take on a mortgage, there will be less demand for new housing, and it seems less likely that people are doing well financially.

Using panel regression with state fixed effects, we find that home prices, interest rates, and changes in interest rates are the main drivers of the number of housing permits issued. However, the constant was comparatively quite large, and the number of permits issued the previous year had a strong relationship with the number of permits issued the following year, suggesting that much of the variation in housing permits is not captured by our models. As the growth rate of prices increases, the number of permits issued increases as well, as the expected return for developers increases. The 30-year mortgage rate had negative relationships with the number of permits issued the following year, as expected.

However, the more interesting findings lie with the two-year interest rate and the change in the two-year interest rate. We find that for a one percentage point increase in the change in the two-year interest rate, the number of permits issued the following year increases by roughly 0.25%. Yet, for a one percentage point increase in the level of the two-year interest rate, the number of permits issued in the current year increases by 0.25% as well. While we had initially expected the two-year rate to capture the cost of debt to builders, we found it to have a positive effect during this period, possibly signalling strong demand for housing in the future. Interest rates were significantly cut from 2008 to 2009, and housing starts plummeted along with them. So, interpreted differently, our results show that in years where interest rates are low, housing permits issued are also low. When short-term interest rates are cut, housing permits the following year decreases as well. As was mentioned earlier in this paper, the federal funds rate was kept incredibly low from 2008 to 2015, which makes up a significant portion of our data set. Our data begins in 2005 at the peak of the housing bubble, and its rapid decline contributed strongly to our results. While normally, low interest rates stimulate residential investment, as McCarthy and Peach (2002) found, this period of time is simply unprecedented. Developers have been wary of

investing in new construction, as the recent crash was the direct result of over-issuing mortgages, and over-supplying homes. Interest rates acted as a signaling mechanism of macroeconomic health during this time period.

Due to data availability, we were limited to the years from 2005-2019, which featured the largest boom-bust period of housing in American history. While it does seem possible that cuts to interest rates would be associated with declining numbers of permits issued, as interest rate cuts tend to coincide with bad macroeconomic conditions, we would likely see that cuts to interest rates are followed by increasing numbers of permits issued over the next few years, as the economy has time to pick back up again. If historical housing starts data becomes available, it would be quite interesting to see whether the results my study found regarding short-term interest rates are obtained in other periods, or whether they would support the findings of McCarthy and Peach (2002).

Appendix

Table 1

	California (N=15)	Oregon (N=15)	Washington (N=15)	Overall (N=45)
Home Value Index Growth Rate				
Mean (SD)	0.0297 (0.128)	0.0423 (0.0863)	0.0415 (0.0890)	0.0378 (0.101)
Median [Min, Max]	0.0457 [-0.282, 0.223]	0.0584 [-0.0944, 0.185]	0.0650 [-0.104, 0.171]	0.0593 [-0.282, 0.223]
Population Growth Rate				
Mean (SD)	0.00700 (0.00256)	0.0111 (0.00343)	0.0139 (0.00271)	0.0107 (0.00406)
Median [Min, Max]	0.00819 [0.00128, 0.00972]	0.0105 [0.00600, 0.0183]	0.0134 [0.00966, 0.0181]	0.0103 [0.00128, 0.0183]
Personal Income Growth Rate				
Mean (SD)	0.0385 (0.0287)	0.0355 (0.0275)	0.0380 (0.0326)	0.0373 (0.0290)
Median [Min, Max]	0.0445 [-0.0430, 0.0691]	0.0395 [-0.0437, 0.0716]	0.0450 [-0.0601, 0.0685]	0.0445 [-0.0601, 0.0716]

Table 1 shows the mean, standard deviation, median, minimum, and maximum values for the respective growth rates of Zillow's Home Value Index, population, and personal income in California, Washington, and Oregon for the years 2005-2019.

Table 2

	California (N=15)	Oregon (N=15)	Washington (N=15)	Overall (N=45)
Permits Issued				
Mean (SD)	95000 (45500)	16900 (7170)	37300 (12000)	49700 (42900)
Median [Min, Max]	98200 [35100, 205000]	17500 [6870, 31000]	40400 [17000, 53000]	35100 [6870, 205000]
Home Value Index				
Mean (SD)	424000 (83100)	260000 (45300)	285000 (50500)	323000 (95000)
Median [Min, Max]	435000 [299000, 544000]	254000 [202000, 350000]	279000 [219000, 393000]	299000 [202000, 544000]
Population				
Mean (SD)	37900000 (1310000)	3920000 (186000)	6920000 (423000)	16200000 (15500000)
Median [Min, Max]	37900000 [35800000, 39500000]	3900000 [3610000, 4220000]	6900000 [6260000, 7610000]	6900000 [3610000, 39500000]
Personal Income				
Mean (SD)	50400 (8670)	41100 (6470)	49200 (8260)	46900 (8730)
Median [Min, Max]	48800 [39300, 66600]	39600 [32500, 53200]	47700 [37700, 64800]	44700 [32500, 66600]
Vacancy Rate				
Mean (SD)	1.64 (0.665)	1.89 (0.679)	1.58 (0.600)	1.70 (0.648)
Median [Min, Max]	1.20 [1.00, 3.10]	1.80 [1.00, 3.30]	1.50 [0.800, 2.70]	1.60 [0.800, 3.30]

Table 2 describes the mean, standard deviation, median, minimum and maximum values for the number of housing permits issued, Zillow's Home Value Index, the population, personal income, and the vacancy rate in California, Oregon, and Washington for the years 2005-2019.

Table 3

	Overall (N=15)
Real 30 yr. Rate	
Mean (SD)	2.66 (1.01)
Median [Min, Max]	2.47 [1.29, 5.39]
Real 2 yr. rate	
Mean (SD)	-0.337 (1.30)
Median [Min, Max]	-0.427 [-2.71, 1.59]
Lumber Price Index	
Mean (SD)	190 (23.7)
Median [Min, Max]	199 [149, 232]
Change in real 30 yr. Rate	
Mean (SD)	0.142 (1.50)
Median [Min, Max]	0.242 [-2.34, 3.20]
Change in real 2 yr. rate	
Mean (SD)	0.0104 (1.62)
Median [Min, Max]	0.0721 [-3.34, 3.14]

Table 3 shows the mean, standard deviation, median, minimum and maximum values of the real 30-year mortgage rate and its change from the previous period, the 2-year Treasury bill rate and its change from the previous period, and the Lumber Price Index.

Table 4: Regression results, dependent variable: ln(permits issued the following year), fixed effects

Model ->	1	2	3	4
lnperm			0.451*** (0.09)	0.438*** (0.07)
pricegrowthr	0.00973*** (0.0035)	0.00932*** (0.29)	0.00246 (0.0029)	0.00458* (0.0027)
popgrowthr	0.07314 (7.61)	0.070 (0.07)	0.08671 (0.06)	
incgrowthr	0.00043 (0.0089)		0.314 (0.65)	
vacr	-0.107 (0.08)	-0.125** (0.06)	-0.052 (0.06)	-0.165*** (0.04)
lnlpi	0.815*** (0.30)	0.783*** (0.27)	0.711*** (0.22)	
realthirty	-0.112** (0.05)	-0.110*** (0.04)	0.011 (0.04)	
realtwo	0.037 (0.03)	0.033 (0.28)	-0.084** (0.03)	-0.083*** (0.02)
drthirty	-0.180*** (0.03)	-0.185*** (0.03)	-0.193*** (0.03)	-0.206*** (0.02)
drtwo	0.228*** (0.03)	0.231*** (0.027)	0.244*** (0.02)	0.252*** (0.02)
dvr	-0.020 (0.06)		-0.040 (0.05)	
_cons	6.539*** (1.66)	6.738*** (1.51)	1.886 (1.53)	6.075*** (0.80)
Within R^2	0.9539	0.9537	0.9760	0.9662
Between R^2	0.0358	0.0066	0.9963	0.9991
Overall R^2	0.2308	0.2372	0.8466	0.8624
Fixed Effects	Yes	Yes	Yes	Yes

Table 4 shows regression results with the natural log of the number of permits issued the following period as the dependent variable.

Table 5: Regression results, dependent variable: ln(permits issued the current year), fixed effects

Model	**5**
pricegrowthr	**0.017*** (.005)**
popgrowthr	**0.011 (0.10)**
incgrowthr	**-0.005 (0.01)**
vacr	**-0.090 (.11)**
lnlpi	**0.251 (0.44)**
realthirty	**-0.263*** (0.07)**
realtwo	**0.254*** (0.04)**
drthirty	**0.0210 (0.05)**
drtwo	**-0.022 (0.04)**
dvr	**0.041 (0.09)**
_cons	**10.052*** (2.44)**
Within R^2	**0.9086**
Between R^2	**0.0137**
Overall R^2	**0.2487**
Fixed Effects	**Yes**

Table 5 shows regression results with the natural log of the number of permits issued the contemporaneous period as the dependent variable.

Variable Definitions

Variable	Definition
PermsIss	The number of new housing units authorized by building permits
lnperm	The natural log of the number of units authorized by housing permits
leadlnp	lnperm of period t+1
HomePrice	Zillow Home Value Index for homes in the 35th to 65th percentile range
lnprice	The natural log of home price index
Pricegrowthr	The percentage change in the Zillow Home Value Index from the previous year
Population	The number of people by state/country
lnpop	The natural log of the population
Popgrowthr	The percentage change in population from the previous period
Income	Per Capita Personal Income
lninc	The natural log of per capita personal income
Incgrowthr	The percentage change in income from the previous period
realthirty	The real 30 year mortgage interest rate
thirtyyr	The nominal 30 year mortgage interest rate
drthirty	The change in the 30 year mortgage interest rate from the previous period
realtwo	The real 2 year note interest rate
twoyr	The nominal 2 year note interest rate
drtwo	The change in the 2 year note interest rate from the previous period
Vacr	The percentage of homes that are vacant
dvr	The change in the vacancy rate from the previous period
LumberPrice	The Lumber Price Index
lnlpi	The natural log of the lumber price index
dLPI	The change in the Lumber Price Index

Data Visualization

Figure 1

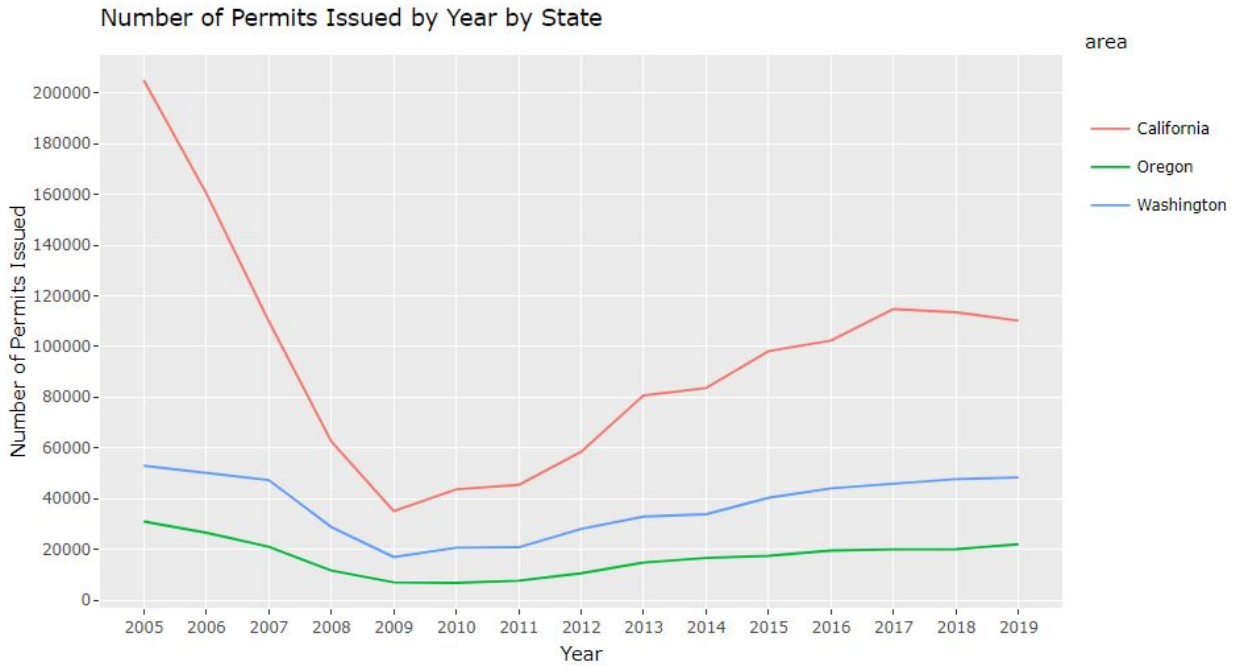

Figure 1 shows the number of housing permits issued annually in California, Oregon, and Washington for the years 2005-2019.

Figure 2

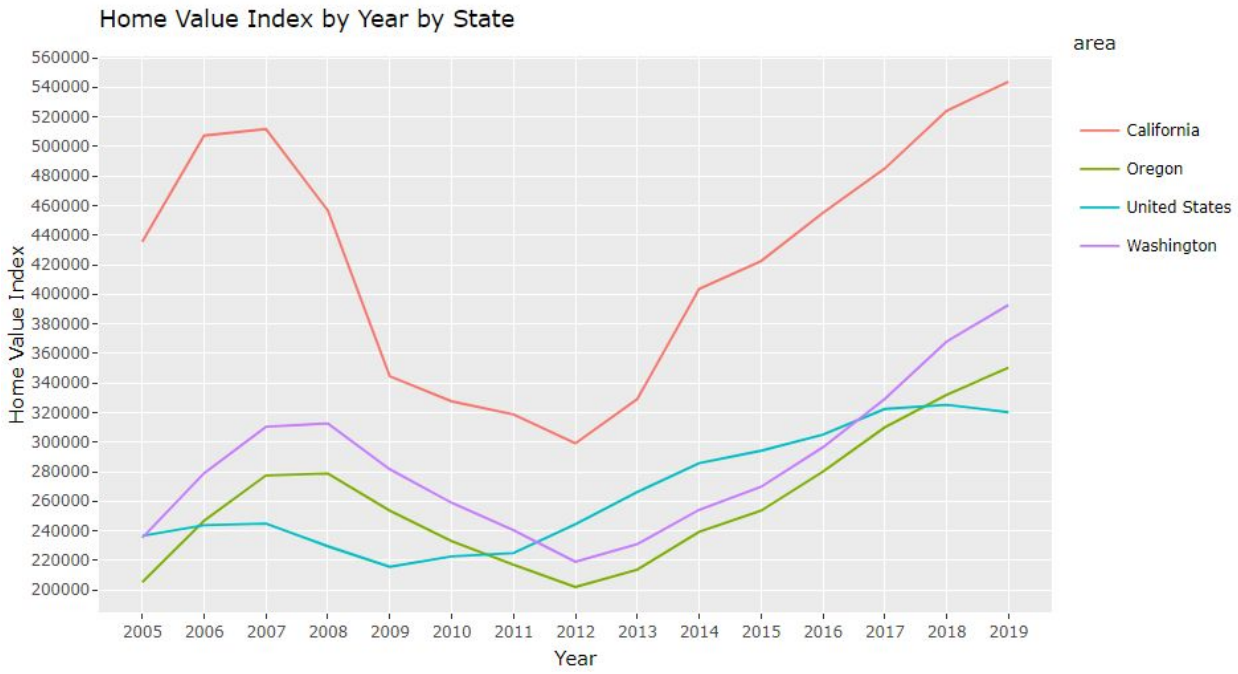

Figure 2 shows the Zillow Home Value Index for California, Oregon, and Washington for the years 2005-2019.

Figure 3

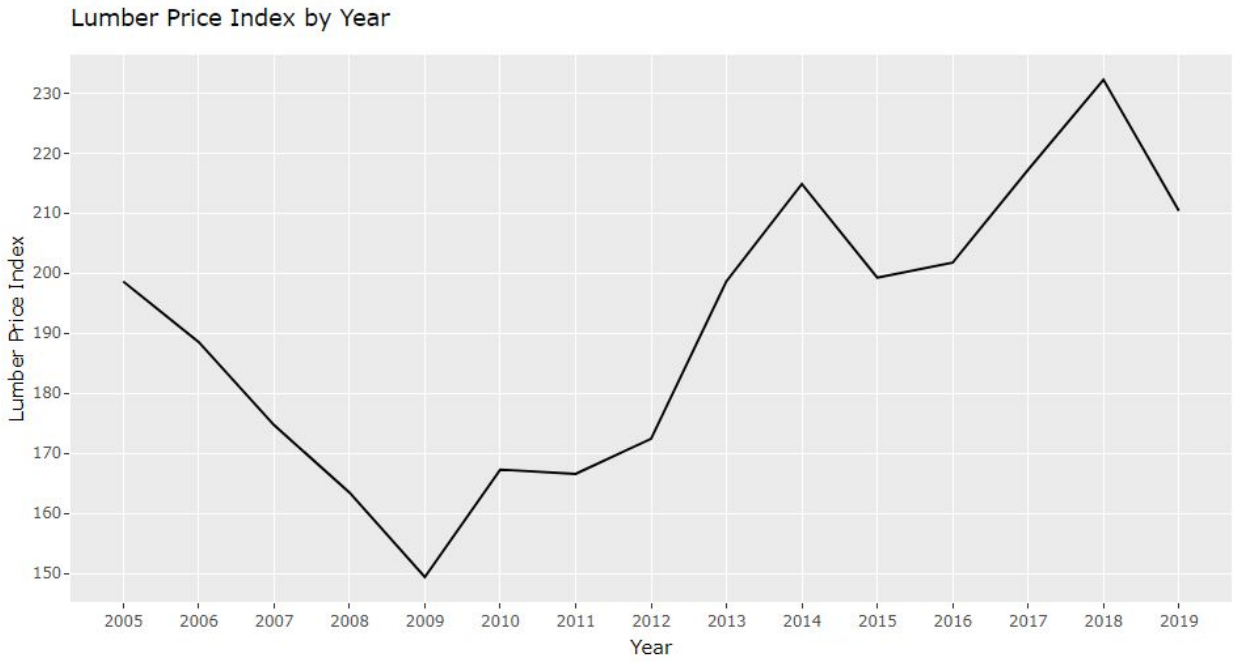

Figure 3 shows the annual Lumber Price Index for the years 2005-2019.

Figure 4

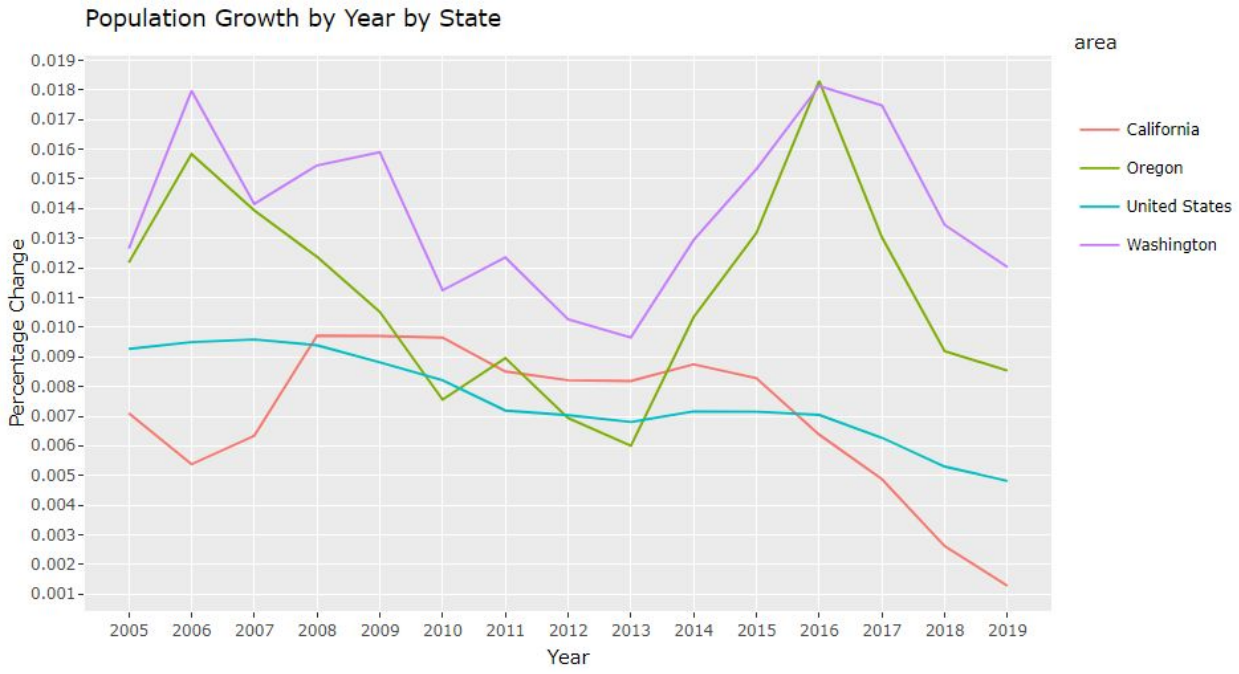

Figure 4 shows the annual population growth rate in California, Oregon, Washington, and the United States for the years 2005-2019.

Figure 5

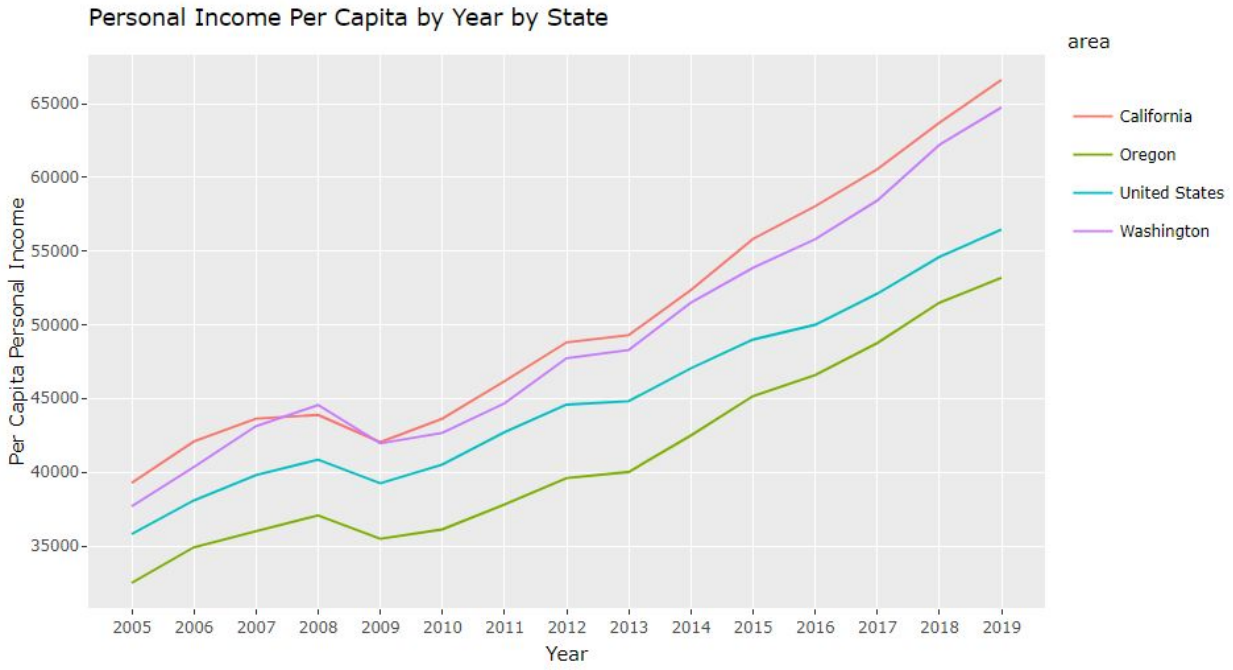

Figure 5 shows Personal Income Per Capita in California, Oregon, Washington, and the United States for the years 2005-2019.

Figure 6

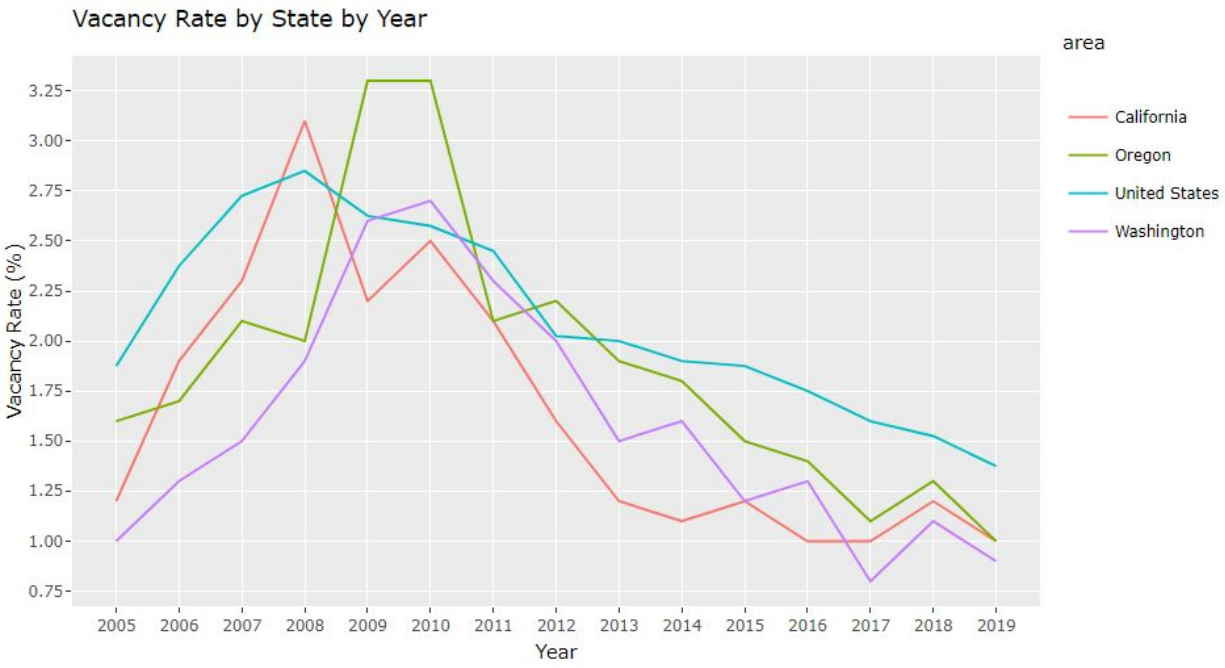

Figure 6 shows the Vacancy Rate in California, Oregon, Washington, and the United States for the years 2005-2019.

Figure 7

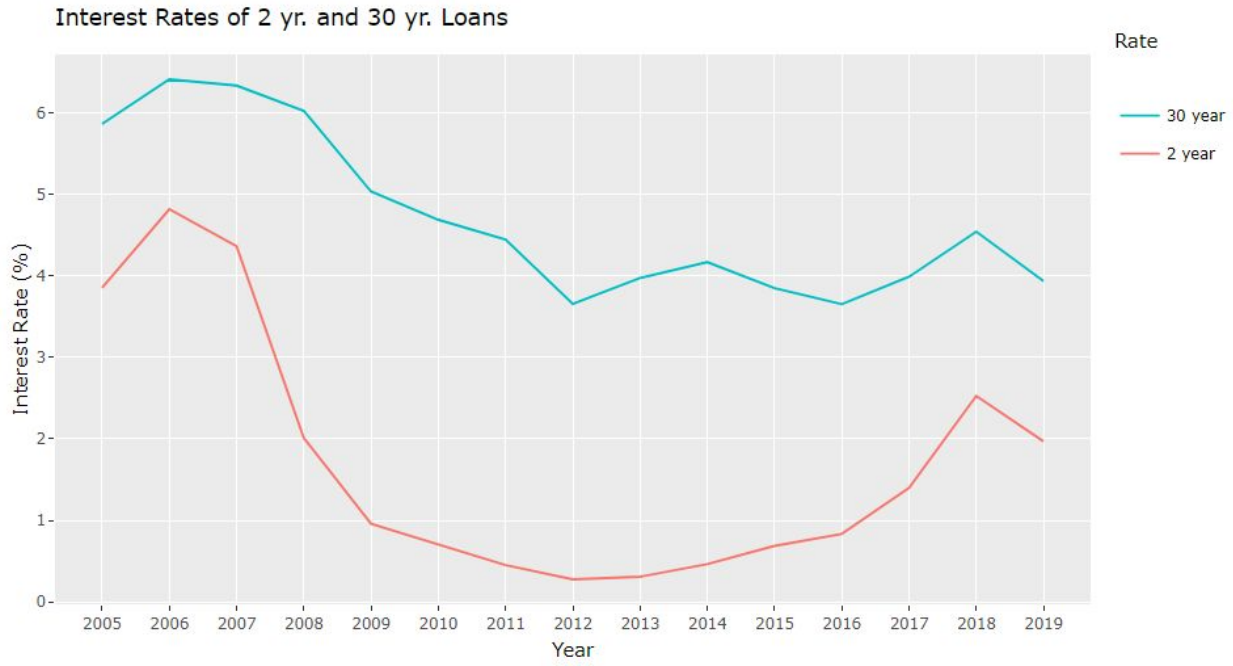

Figure 7 shows the nominal 30-year mortgage and 2-year interest rates in the United States for the years 2005-2019.

Figure 8

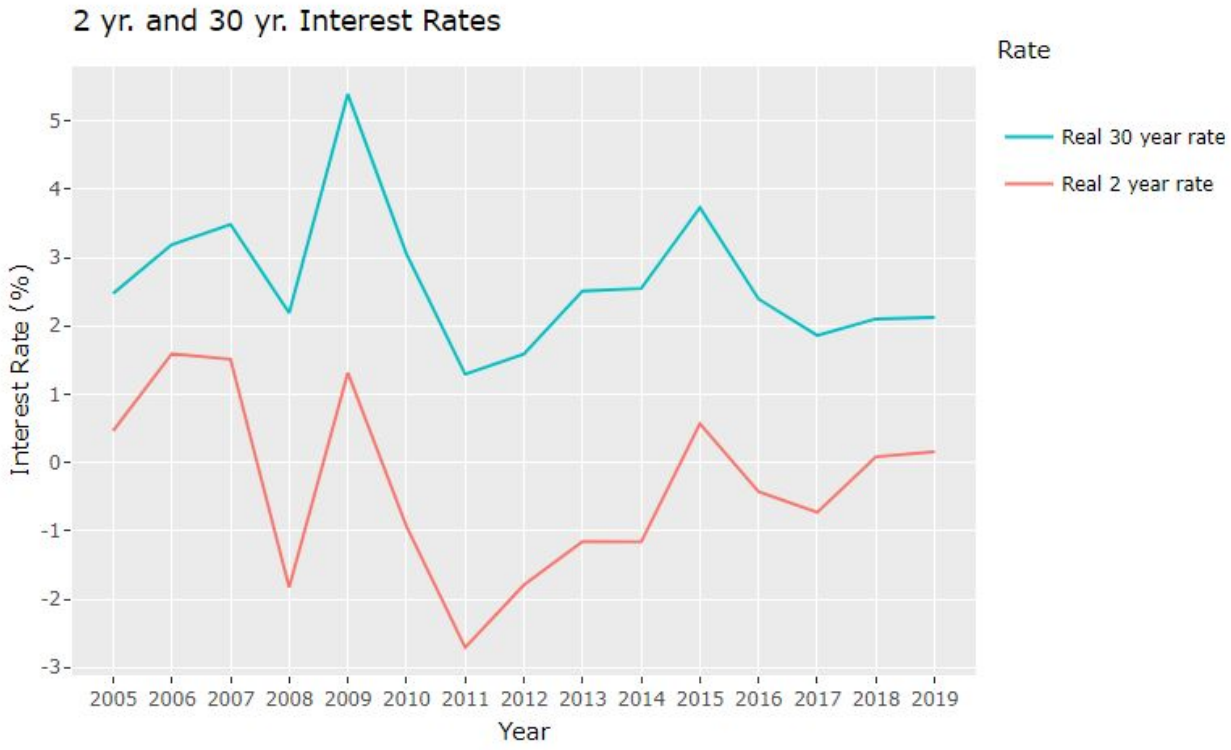

Figure 7 shows the nominal 30-year mortgage and 2-year interest rates in the United States for the years 2005-2019.

Figure 9

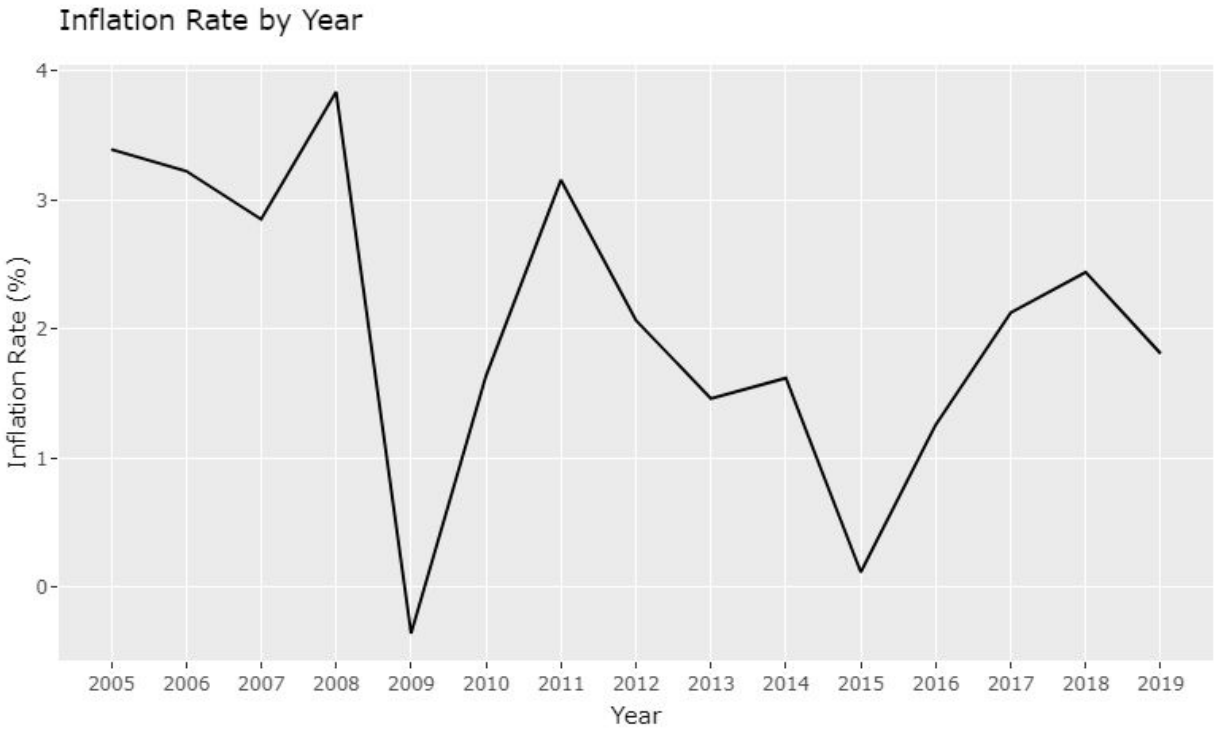

Figure 9 shows the inflation rate in the United States for the years 2005-2019.

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