

# Financial Data Analysis

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## Contents

<b>1</b>	<b>Introduction</b>	<b>2</b>
<b>2</b>	<b>Literature Review</b>	<b>2</b>
<b>3</b>	<b>Data source and data description</b>	<b>3</b>
3.1	Data source . . . . .	3
3.2	Data description . . . . .	3
<b>4</b>	<b>Model Specification</b>	<b>4</b>
4.1	Autoregressive model . . . . .	4
4.2	Autoregressive Integrated Moving Average model . . . . .	4
4.3	General Autoregressive conditional heteroskedasticity model . . . . .	5
<b>5</b>	<b>Empirical Results</b>	<b>5</b>
<b>6</b>	<b>Discussion of Linear Model</b>	<b>7</b>
6.1	Reasons for this Bad Estimation . . . . .	7
6.2	Trend of the Difference . . . . .	9
<b>7</b>	<b>Conclusion</b>	<b>9</b>

# 1 Introduction

Real estate economics is gradually becoming an irreplaceable facet of the social topic in the metropolis. The captivate of the preemption of real estate is a double-edged sword that not only polarizes the rich and the poor but also contains the incentives of the middle-class people of having house possession. One preponderant element of this trading is the house price, while the much latent compounds lying behind it could be the mortgage rate of this particular kind of housing loan. We are considering the mortgage rate in that the central government executes the management control system of the monetary market through various policy tool, the mortgage rate occupies an important position. Common sense makes it possible that the influence of the mortgage rate on the housing price is undeniable, but we still curious about the range of this effect.

In our analysis of the relationship between the housing price index and mortgage rate, the Autoregressive (AR) model fits the data by the order 12. Although this recognizable 12 provides no evidence to quarrel with, the Autoregressive Integrated Moving Average (ARIMA) Model illustrates the connection by more explanatory variables, especially the one from the error term in AR model. Also, the General Autoregressive conditional heteroskedasticity (GARCH) model is used, but it does not yield the significance contribution on data fitting.

The analysis of the dataset of housing price index and mortgage rate provides a good estimation process to their relationship. They are negatively related, and we have given the linear model as the most efficient and simplest model.

# 2 Literature Review

In recent years, the housing price and the lending rate have gained many peoples attention. Researchers study them and want to find the relationship between this two index. The brief definition of housing price index(HPI) is the price changes of residential housing. Lending rate, also called the mortgage rate, is the rate of interest charged on a mortgage. Mortgage rates are determined by the lender in most cases. Since the 1970s of last century, the relationship between housing price and mortgage rate has drawn many real estate researchers attention in aboard. In a paper called MORTGAGE RATE BUYDOWNS: IMPLICATIONS FOR HOUSING PRICE INDEXES (VB Agarwal RA Phillips,Social Science Quarterly,1984 ,65 (3) :868-875) using FHA-VA transaction to show that the prices of buydown homes tend to be elevated as compared to other properties, and the housing price index are likely to be distorted by the influence of mortgage rate. In paper Do lower mortgage rates mean higher housing prices? (JAMES M. MCGIBANY\* and FARROKH NOURZAD, Applied Economics,2004 ,36 (4) :305-313) analyzes the housing price index and mortgage rate in both long run and short run, compared with each other finds that in long run, they have a negative relationship, but in short run there is no influence from mortgage rate to housing price index. The previous research gives us a brief idea that we want to analyze the long run HPI and mortgage rate with real estate. Relationship between Hong Kong house prices and mortgage flows (RYC Tse, Journal of Property Finance,1996 ,7 (4) :54-63) indicates the price for housing units in Hong Kong

is distorted by mortgage constraint, any changes house prices will have a feedback on mortgage lending, and thus tend to iron out the housing demand. The data in Visually shows the mortgage rate and housing price in Canada. Home price in Toronto rose 5.4% in 2013 and the mortgage rate fallen to historical lows  $< 3\%$ . This data told us the negative relationship between HPI and Mortgage rate in Canada. However, in the US, one of the world biggest real estate trade market, the relationship between this two index may have a more remarkable result. So we decide to analyze HPI and mortgage rate in the US during recent 30 years using ARMA, ARIMA and GRACH model.

## 3 Data source and data description

### 3.1 Data source

The data we choose are US National Housing Price Index with a base of 100 in 1975 and 30-Year Conventional MortgageRate(DISCONTINUED). We download the two data from the website “FRED” which is free. Both of the two data are monthly recorded and not seasonally adjusted. We use monthly-based data mainly because two reason: the first one is that we want to make our sample big enough to assure the accuracy of our estimated results; the other one is that we want to find the monthly characteristic of our data by ARIMA model and that is also why we choose the data which is not seasonal adjusted. The time span of our sample data is during 1975.Jan. and 2016.Sep. which is the only period we could find that contains both the two types of data.

```
1 library(readxl)
2 data <- read_excel("data.xlsx")
3 head(data)
4      v1 v2 v3      v4      v5
5 1 1975  1  1 25.25  9.43
6 2 1975  2  1 25.29  9.11
7 3 1975  3  1 25.36  8.90
8 4 1975  4  1 25.40  8.82
9 5 1975  5  1 25.48  8.91
10 6 1975  6  1 25.46  8.89
```

### 3.2 Data description

We download the data from FRED by Excel form. One is about US National Housing Price Index and the other one is 30-Year Conventional MortgageRate(DISCONTINUED). We combine the excel into one in order to make the process of importing data more easily. Therefore, there are 501 rows and 5 columns contained in the final data excel. The 501 rows represent the 501 different months we contained in our sample, from 1975.Jan to 2016.Sep. The first column represents YEAR, the second is MONTH and the third is DATE. The fourth column is the data of US National Housing Price Index Value and the last one is of 30-Year Conventional MortgageRate(DISCONTINUED), which we use v4 and v5 to stand for the two columns in our code. We did some basic analysis for the data as followed:

```

1 hpi=data$V4 % US National Housing Price Index Value
2 mort=data$V5 % 30-Year Conventional MortgageRate
3 summary(hpi)
4      Min. 1st Qu.  Median      Mean 3rd Qu.      Max.
5  25.25   55.72   81.66   97.76  144.00  184.60
6 summary(mort)
7      Min. 1st Qu.  Median      Mean 3rd Qu.      Max.
8   3.350   5.970   7.910   8.294  10.080  18.450

```

## 4 Model Specification

### 4.1 Autoregressive model

An autoregressive (AR) model describes the time-varying processes of some specific variables, and it focuses especially on the relationship among the localized data, always the data before time  $t$ . Intuitively speaking, given a time series data  $\{x_i\}$ , for each  $x_t$ , we believe that  $x_{t-1}$ ,  $x_{t-2}$ ,  $x_{t-3}$  ... have the predictive power that can somewhat explain main portion of  $x_t$  as an linear combination. Also, AR model contains a white noise series or a stochastic term that can be imperfectly predicted. And with the time variant assumption,  $x_t$  has a statistically significant lag-n autocorrelation, the lagged value  $x_{t-1}$  might be the most powerful explanatory variable. In the model specification, R program helps us with the order that has the significant influence on our AR regression.

```

1 > ml=ar(dhpi, method="mle")
2 > ml$order
3 [1] 12

```

And AR(12) is used in our model:

$$(1 - \phi_1 B + \phi_2 B^2 + \cdots + \phi_{12} B^{12})x_t = a_t. \quad (1)$$

### 4.2 Autoregressive Integrated Moving Average model

An autoregressive integrated moving average (ARIMA) model provide a parsimonious description of the stochastic process. The AR part is regressed on its own lagged, the (moving average) MA part is a linear combination of lagged error term occurring contemporaneously, the I part illustrates the difference of the value and their previous value. One leading transmutation of ARIMA cut down the burdensome variables used in AR model and MA models, but it still adequate to simulate the data with dynamic structure in our analysis. With the spurn of high order model, some insignificant terms can be removed, the number of parameters used is sharply reduced, and the structure of the estimating model becomes parsimony. Also, as the model comprise three frames, these features should fit the data as well as possible, and we are expecting that the ARIMA model would afford a better interpretation for the interconnection of housing price index.

```

1 > tsdhpi=ts(dhpi)

```

```

2 > auto.arima(tsdhpi)
3 Series: tsdhpi
4 ARIMA(5,0,4) with non-zero mean
5 sigma^2 estimated as 0.06933: log likelihood=-39.09
6 AIC=100.18 AICc=100.72 BIC=146.54
7 > m4=arima(dhpi, order = c(5,1,4))
8 > m4
9 Call:
10 arima(x = dhpi, order = c(5, 1, 4))
11 sigma^2 estimated as 0.04959: log likelihood = 39.46,
12 aic = -58.93

```

This time we are using the ARIMA(5,1,4):

$$\begin{aligned}
(1 - \phi_1 B + \phi_2 B^2 - \phi_3 B^3 - \phi_4 B^4 + \phi_5 B^5)x_t \\
= a_t - \theta_1 a_{t-1} + \theta_2 a_{t-2} - \theta_3 a_{t-3} + \theta_4 a_{t-4}.
\end{aligned} \tag{2}$$

### 4.3 General Autoregressive conditional heteroskedasticity model

First, if an autoregressive moving average model (ARMA) model is assumed for the error variance, the model is a generalized autoregressive conditional heteroscedasticity (GARCH) model. Second, if we look at the basic autoregressive conditional heteroskedasticity (ARCH) model, the variance of the current term is a function of the previous time series' error term. The assumption of the time series data is serially uncorrelated but they are dependent, this time variant data is split into a stochastic piece which is a strong white noise and a time-dependent standard deviation. And in the GARCH ( $p, q$ ) model,  $p$  indicates the order of  $\sigma^2$ ,  $q$  indicates the order of the stochastic series. One thing needs to mention is that the model is highly relevant in volatility modeling, which means the GARCH model is the best method to test the volatility, for now. The tail distribution of GARCH is heavier than normal, but it still provides a simple parametric function that can be used to describe the volatility evolution.

## 5 Empirical Results

In this section, we apply the proposed estimation method to the housing price index and mortgage rate to demonstrate its fitness. In the empirical, we target at investigating the following question. (1) How effective is the proposed method? (2) How consilient does the representing formulation describe the data relationship?

First, let's take a look at the inter-correlation within the housing price index. The left picture of figure 1 provides a strong evidence for the trending of this time variant data, we can mainly predicate that this is a unit root process, and it is also stationary. The right picture of figure 1 is the ACF after we have made one difference on the data, it is so clearly that the differenced data has seasonal adjusting and about 12 months as a cycle. That makes sense to us because this 12 months' cycle reflects indirectly the varying of one year's preference for the housing.

Then we have the sense that we can try the AR(12) model with differentiating for once. From the code, we see 11 of the 12 coefficient is significant and the aic is small, so

[b]0.4

[b]0.4

Figure 1: ACF and PACF of housing price index fitted from 1975. Jan to 2016. Sep.

we cannot deny that model is a good fit for our data. We use the ‘tsdiag’ command in the RStudio (see the results in the graph), and it gives much information so that we can have the AR(12) model as:

$$(1 - 1.234B + 0.283B^2 + \cdots + 0.233B^{12})x_t = a_t. \quad (3)$$

```
1 > m2=arima(hpi, order=c(12,1,0))
2 > m2
3 Call:
4 arima(x = hpi, order = c(12,1,0))
5 Coefficients:
6          ar1          ar2          ar3          ar4          ar5          ar6          ar7
7          1.2343   -0.2827   -0.3300   0.3316   -0.0762   -0.1727   0.1563
8 s.e.    0.0434    0.0687    0.0696    0.0710    0.0725    0.0725    0.0724
9          ar8          ar9          ar10         ar11         ar12
10         0.0020   -0.0972    0.1159    0.3202   -0.2325
11 s.e.    0.0729    0.0713    0.0698    0.0689    0.0436
12 sigma^2 estimated as 0.04963: log likelihood = 38.27, aic = -50.54
```

We also tried the MA(12) model, but unfortunately, this MA(12) model has  $aic = 110.58$  and  $loglikelihood = -42.29$ . We do not think that it is a good model for predicting this housing price index dataset, and we do not give the representation of it here.

After the AR and MA model, we think the combination of these two will also make sense, so we tried the ARIMA model. Before we do the simulation, we transform the data into a time series one by using the ‘ts’ command in RStudio. The ‘auto.arima’ command gives us the automatic simulation of these housing price index data on the ARIMA model, and it provides the ARIMA(5,0,4) for the data which has been differentiating for once. That is equivalent to the result that we would have an ARIMA(5,1,4) for the original data, the data without differentiating. And the model is:

$$(1 + 0.220B + 0.05B^2 - 0.726B^3 - 0.004B^4 + 0.163B^5)x_t = a_t + 1.728a_{t-1} + 2.145a_{t-2} + 1.184a_{t-3} + 0.429a_{t-4}. \quad (4)$$

```
1 > m4=arima(hpi, order = c(5,1,4))
2 > m4
3 Call:
4 arima(x = hpi, order = c(5, 1, 4))
5 Coefficients:
6          ar1          ar2          ar3          ar4          ar5          ma1          ma2          ma3
7         -0.2191   -0.0476    0.7262    0.0043   -0.1634    1.7278    2.1454    1.1841
8 s.e.    0.1095    0.0829    0.0678    0.0886    0.0760    0.1066    0.1708    0.1561
9          ma4
```

```

10      0.4289
11 s.e.  0.0874
12 sigma^2 estimated as 0.0693:  log likelihood = -44.05,  aic = 108.09
13 > Box.test(m4$residuals)
14      Box-Pierce test
15 data:  m4$residuals
16 X-squared = 0.34351, df = 1, p-value = 0.5578
17 > pp=1-pchisq(0.34,12)
18 > pp
19 [1] 1

```

We also have a basic analysis of the mortgage rate, see Figure 2. The ACF shows a strong serial correlation, and the PACF only significant on 1,2,3. And we can conclude that the mortgage rate is almost a stationary data.

[b]0.4

[b]0.4

Figure 2: ACF and PACF of mortgage rate fitted from 1975. Jan to 2016. Sep.

Here comes the most focused part of our analysis on the relationship between the housing price index and mortgage rate. By using the ‘plot’ command in RStudio, we have an intuitively negative relationship, see the following picture.

And we are also wondering if we could just do it using a basic linear model. We think it provides bad estimation because the t-test of both the intercept and coefficient is significant at 99% confidence interval and the adjusted R-squared equals 0.603. And also because we see the steep change both in the mortgage rate in about 1980 and the housing price index in about 2008. But we here still give the function of this linear regression:

$$hpi = 193.19 - 11.48 \text{ mort.} \quad (5)$$

3.738   0.418

## 6 Discussion of Linear Model

In our paper, the basic topic is the relationship between housing price index and the mortgage rate, so we will have a deeper discussion in this section.

### 6.1 Reasons for this Bad Estimation

As we have mentioned before, we do not think that the linear model is a good estimation to relate housing price index with the mortgage rate. Because we see the steep change both in the mortgage rate in about 1980s and the housing price index in about 2008, it

is reasonable to think about the expectations. Would it be the residual that made that bad estimation? Or would there be some special cases in this time period?

First, consider the residuals' part. The ACF of our linear residuals shows a stationary trend in this relationship between housing price index and mortgage rate. The PACF of our linear residuals in the right graph in Figure 3 shows significance in the first two lags. We use this information to further discuss the residuals in our linear regression model.

[b]0.4

[b]0.4

Figure 3: ACF and PACF of linear residuals fitted from 1975. Jan to 2016. Sep.

The residuals form an AR(2) model with housing price index on the left side of the equation, while mortgage rate on the right. The equation is:

$$(1 - 1.473B + 0.601B^2)hpi = 0.075mort. \quad (6)$$

```

1 > m5=arima(hpi, order=c(2,0,0), include.mean=F, xreg=mort)
2 > m5
3 Call:
4 arima(x = hpi, order = c(2, 0, 0), xreg = mort, include.mean = F)
5 Coefficients:
6             ar1             ar2             mort
7             1.4729          -0.6005           0.0748
8 s.e.          0.0356           0.0356           0.0340
9 sigma^2 estimated as 0.07448: log likelihood = -61.54, aic = 131.08

```

But it's not a good explanation, the aic is big and the t-test is significant.

Second, consider the information part. All of us think this part makes more sense to the reason that the steep change in both datasets. The financial crisis in about 1980 and 2008 obviously make the change in the housing price index and the mortgage rate.

But why the financial crisis in about 1980 have such huge impact on the mortgage rate, but almost no change in housing price? It has some issue rooted in history, like the baby boomers. Baby boomers in the United States, those born in the post-war generation over the 19 year period between 1946 and 1965, has become to the age of marriage. And that has the significant increase in the demand of the house because we know that most of them moved out from their parents' house after marriage. We do not know the most exactly why the housing price does not change that much, but we can guess that it is for some reality reasons.

And if we look at the financial crisis in 2008, it provides enough information for the suddenly climb. In 2003, the federal fund rate is about 1.01%, and after considering the inflation, it was actually a negative interest. This breaks the balance of the prudent savings and speculative risk, and it stimulates the opportunist in housing markets. That drives the housing price up in a very short period. We see the final results of this



property bubble, it's the 2008 Financial Crisis. And that makes our regression model more reasonable for it does not fit the data that much.

## 6.2 Trend of the Difference

In this section, we talk about the variance in the dataset. To be specific, we are analysis the relationship between the  $hpi_n - phi_{n-1}$  and  $mort_n - nort_{n-1}$ . We are curious that the difference in the dataset will following which trend? Will they have the positive relationship? The code provides the answer:

$$\begin{matrix} dhpi = & 0.322 & -0.275 & dmort \\ & 0.037 & & 0.126 \end{matrix} \quad (7)$$

```

1 > y=dhpi[2:500]; x=dmort[1:499];
2 > n2=lm(y~x)
3 > n2
4 lm(formula = y ~ x)
5 Coefficients:
6             Estimate Std. Error t value Pr(>|t|)
7 (Intercept)  0.32190    0.03661   8.794  <2e-16 ***
8 x            0.27533    0.12558   2.193   0.0288  *

```

Now we can conclude that the t-test of the coefficient is significant at 95% confidence interval, and the intercept is significant on 99% confidence interval. As we just did to the linear regression for the non-differentiated term, we take a look at the linear residuals. The ACF provides the evidence that there exists a seasonal trend in the residuals, that may explain the model.

[b]0.4

[b]0.4

Figure 4: ACF and PACF of n2 residuals fitted from 1975. Jan to 2016. Sep.

## 7 Conclusion

We choose the housing price index and mortgage rate to do the research because we are concerned about the relationship between these two data and the influence to the real estate market, also the data resources are reliable. The relationship between housing price index and the mortgage rate have gained many researchers attention in recent years. There are many research paper about this topic, so it has the abundant background for us to consult and meaningful for us to analyze. Our research using many models to study the data. For basic analysis, it is easy for readers to understand our fundamental idea. The advanced models are using to prove our data result and make our research more

convincing. What we have done in our research paper, first, we find the relationship between housing price index and mortgage rate is linear, which is necessary and undoubted. Second, there are some outliers because of the economic influence such as economic crisis. If there is not a economic crisis, we think that the linear relationship between these two data is totally appropriate. The constrain is the data only fit in US, in other countries the status are different. We can not predict that the result is fitted in all situations. The weakness of our research is still have endogenous variable in error term influence the result and have noise to our research. This state is inevitable. In the future, we decide to study more about the cross influence of inflation rate and government policy to the housing price and mortgage rate. For example, the effects of inflation rate mortgage on house price inflation. Monetary policy cause the mortgage boom and housing price increase, because real estate plays a major role in the global crisis, and some worry that the low interest rate environment causes by government policy is inflating new housing bubbles, which is also a valuable aspect for us to analyze.