# Mod 4 Project - Starter Notebook

# Step 1: Load the Data/Filtering for Chosen Zipcodes

93
```
import datetime
import itertools

import pandas as pd
import matplotlib
```

94
```
df = pd.read_csv("zillow_data.csv")
```

95
```
df.drop("SizeRank", axis=1, inplace=True)
```

96
```
df.columns
```

96
```
Index(['RegionID', 'RegionName', 'City', 'State', 'Metro', 'CountyName',
       '1996-04', '1996-05', '1996-06', '1996-07',
       ...
       '2017-07', '2017-08', '2017-09', '2017-10', '2017-11', '2017-12',
       '2018-01', '2018-02', '2018-03', '2018-04'],
      dtype='object', length=271)
```

97
```
df = df.loc[
    (df["State"] == "VA")
    & (df["Metro"] == "Washington")
].copy()
```

98
```
df
```

98

| | RegionID | RegionName | City | State | Metro | CountyName | 1996-04 |
|---|---|---|---|---|---|---|---|
| **193** | 67180 | 22191 | Woodbridge | VA | Washington | Prince William | 122600.0 |
| **247** | 67182 | 22193 | Woodbridge | VA | Washington | Prince William | 127700.0 |
| **290** | 66242 | 20147 | Ashburn | VA | Washington | Loudoun | 205400.0 |
| **359** | 67189 | 22204 | Arlington | VA | Washington | Arlington | 178400.0 |
| **570** | 67247 | 22407 | Fredericksburg | VA | Washington | Spotsylvania | 120400.0 |
| **...** | ... | ... | ... | ... | ... | ... | ... |

| | RegionID | RegionName | City | State | Metro | CountyName | 1996-04 |
|---|---|---|---|---|---|---|---|
| **13745** | 67381 | 22735 | Reva | VA | Washington | Culpeper | 101800.0 |
| **13752** | 66283 | 20197 | Waterford | VA | Washington | Loudoun | 283600.0 |
| **13934** | 66233 | 20137 | Broad Run | VA | Washington | Prince William | 200800.0 |
| **14274** | 67388 | 22742 | Sumerduck | VA | Washington | Fauquier | 128000.0 |
| **14490** | 67360 | 22713 | Boston | VA | Washington | Culpeper | 137900.0 |

105 rows × 271 columns

# Step 2: Reshape from Wide to Long Format

99
```
def get_datetimes(df):
        return pd.to_datetime(df.columns.values[1:], format='%Y-%m')
```

100
```
def melt_data(df):
    melted = pd.melt(df, id_vars=['RegionName', 'RegionID','City', 'State', 'Metro', 'CountyName'], var_n
    melted['time'] = pd.to_datetime(melted['time'], infer_datetime_format=True)
    melted = melted.dropna(subset=['value'])
    return melted.groupby(['time']).aggregate({'value':'mean'})
```

101
```
house_price_df = melt_data(df)
```

102
```
house_price_df
```

102

| | value |
|---|---|
| **time** | |
| **1996-04-01** | 199502.857143 |
| **1996-05-01** | 199369.523810 |
| **1996-06-01** | 199204.761905 |
| **1996-07-01** | 199049.523810 |
| **1996-08-01** | 198929.523810 |
| **...** | ... |
| **2017-12-01** | 514926.666667 |
| **2018-01-01** | 516926.666667 |

| | value |
|---|---|
| **time** | |
| **2018-02-01** | 520250.476190 |
| **2018-03-01** | 525317.142857 |
| **2018-04-01** | 528640.000000 |

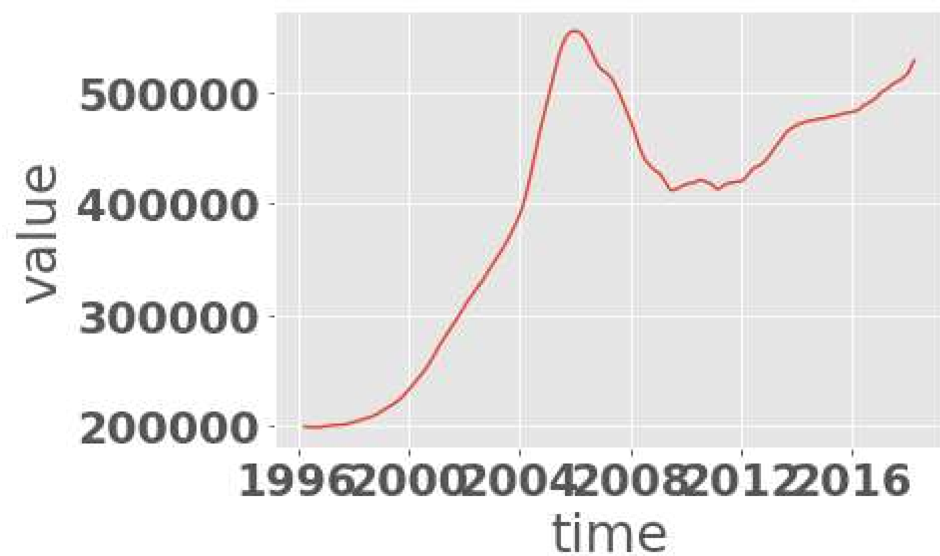
265 rows × 1 columns

# Step 3: EDA and Visualization

103
```
import seaborn as sns
import matplotlib.pyplot as plt
plt.style.use('ggplot')

font = {'family' : 'normal',
                'weight' : 'bold',
                'size'   : 22}

matplotlib.rc('font', **font)

# NOTE: if you visualizations are too cluttered to read, try calling 'plt.gcf().autofmt_xdate()'!
```

104
```
sns.lineplot(data=house_price_df["value"])
```

104 <AxesSubplot:xlabel='time', ylabel='value'>

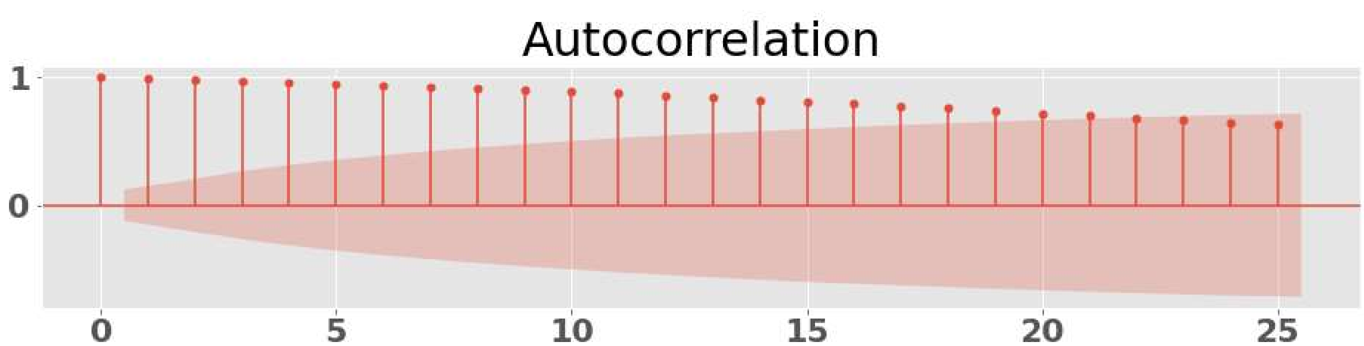


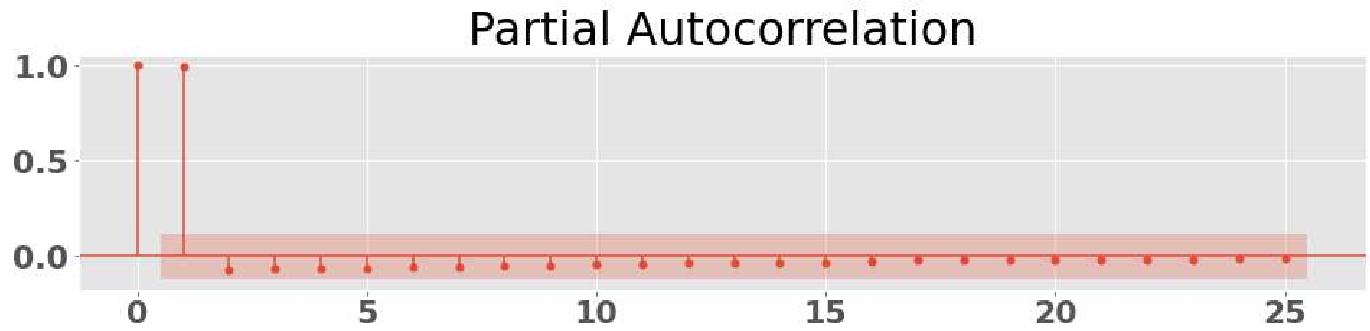

105
```
from statsmodels.graphics.tsaplots import plot_pacf
from statsmodels.graphics.tsaplots import plot_acf
from statsmodels.tsa.arima.model import ARIMA
```

106
```
import warnings
warnings.filterwarnings('ignore', 'statsmodels.tsa.arima_model.ARMA',
                        FutureWarning)
warnings.filterwarnings('ignore', 'statsmodels.tsa.arima_model.ARIMA',
                        FutureWarning)
```

107
```
fig, ax = plt.subplots(figsize=(16,3))
plot_acf(house_price_df['value'].dropna(axis=0), ax=ax)
fig2, ax2 = plt.subplots(figsize=(16,3))
plot_pacf(house_price_df['value'].dropna(axis=0), ax=ax2)

mod_arma = ARIMA(house_price_df["value"], order=(0, 0, 0), trend="c")
res_arma=mod_arma.fit()
print("New Best Summary:\n", res_arma.summary())
```

```
New Best Summary:
                                SARIMAX Results
==============================================================================
Dep. Variable:                  value   No. Observations:                  265
Model:                          ARIMA   Log Likelihood               -4064.851
Date:                Thu, 10 Jun 2021   AIC                           8133.702
Time:                        20:28:30   BIC                           8140.862
Sample:                    04-01-1996   HQIC                          8136.579
                         - 04-01-2018
Covariance Type:                  opg
==============================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------
const        3.95e+05   1.83e+06      0.216      0.829   -3.19e+06    3.98e+06
sigma2      3.338e+12   4.12e+11      8.109      0.000    2.53e+12    4.15e+12
===================================================================================
Ljung-Box (L1) (Q):                 263.31   Jarque-Bera (JB):                26.58
Prob(Q):                              0.00   Prob(JB):                         0.00
Heteroskedasticity (H):               0.27   Skew:                            -0.58
Prob(H) (two-sided):                  0.00   Kurtosis:                         1.96
===================================================================================

Warnings:
[1] Covariance matrix calculated using the outer product of gradients (complex-step).
c:\users\kiwini\.virtualenvs\dsc-phase-4-project\lib\site-packages\statsmodels\tsa\base\tsa_model.py:524:
  warnings.warn('No frequency information was'
c:\users\kiwini\.virtualenvs\dsc-phase-4-project\lib\site-packages\statsmodels\tsa\base\tsa_model.py:524:
  warnings.warn('No frequency information was'
c:\users\kiwini\.virtualenvs\dsc-phase-4-project\lib\site-packages\statsmodels\tsa\base\tsa_model.py:524:
  warnings.warn('No frequency information was'
```

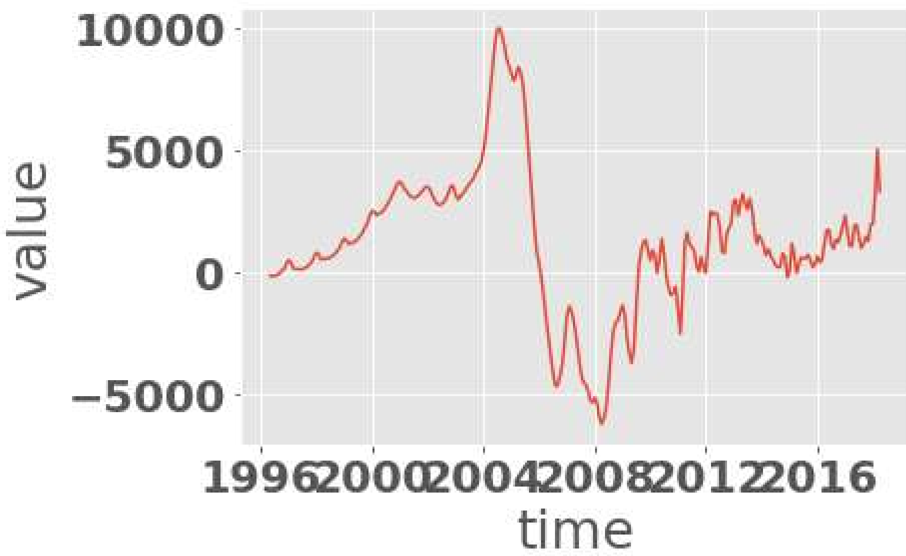


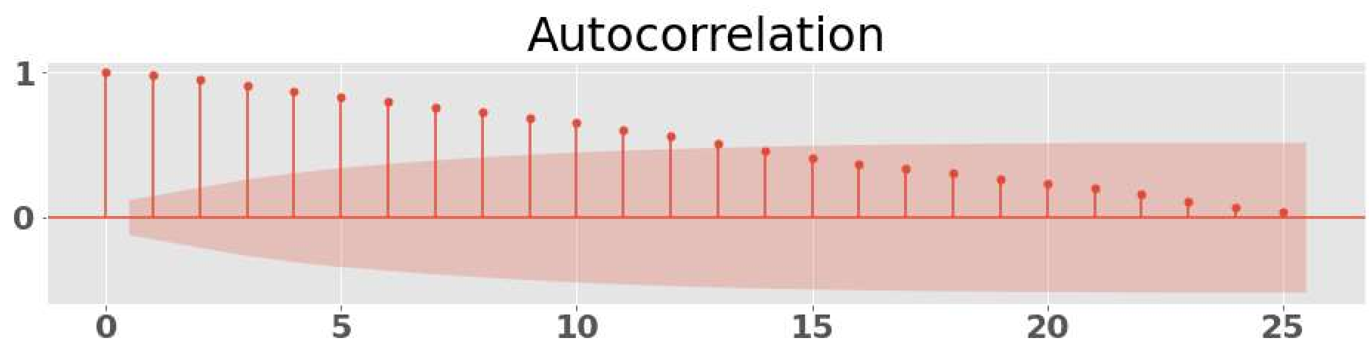


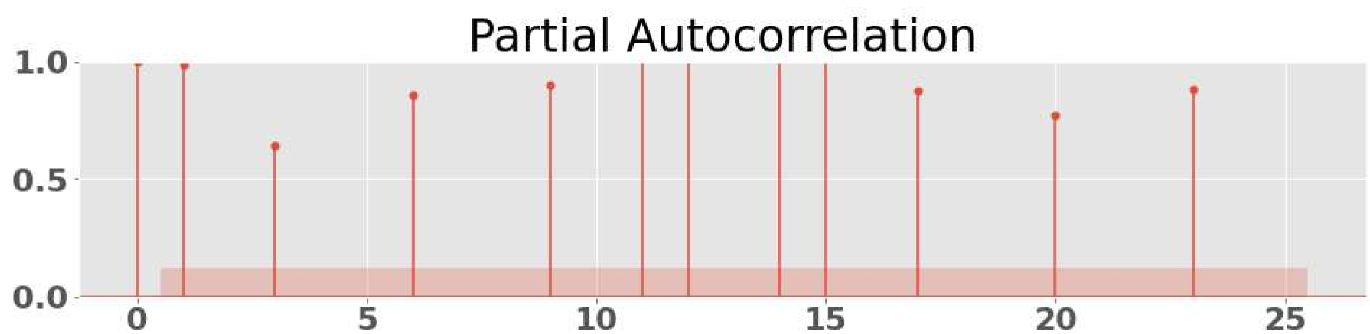

Autocorrelation is positive past 10 lags. Needs at least one difference.

108
```
house_price_diff = house_price_df.diff(periods=1)
sns.lineplot(data=house_price_diff["value"])

house_price_diff.dropna(axis=0, inplace=True)

fig3, ax3 = plt.subplots(figsize=(16,3))
plot_acf(house_price_diff, ax=ax3)
fig4, ax4 = plt.subplots(figsize=(16,3))
ax4.set_ylim(0,1)
plot_pacf(house_price_diff, ax=ax4, )

mod_arma = ARIMA(house_price_df["value"], order=(0, 1, 0))
res_arma=mod_arma.fit()
print("New Best Summary:\n", res_arma.summary())
```

```
New Best Summary:
                                SARIMAX Results
==============================================================================
Dep. Variable:                  value   No. Observations:                  265
Model:                 ARIMA(0, 1, 0)   Log Likelihood               -2507.660
Date:                Thu, 10 Jun 2021   AIC                           5017.320
Time:                        20:28:30   BIC                           5020.896
Sample:                    04-01-1996   HQIC                          5018.757
                         - 04-01-2018
Covariance Type:                  opg
==============================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------
sigma2      1.038e+07    7.2e+05     14.430      0.000    8.97e+06    1.18e+07
===================================================================================
Ljung-Box (L1) (Q):                 257.75   Jarque-Bera (JB):                18.85
Prob(Q):                              0.00   Prob(JB):                         0.00
Heteroskedasticity (H):               0.52   Skew:                             0.24
Prob(H) (two-sided):                  0.00   Kurtosis:                         4.21
===================================================================================

Warnings:
[1] Covariance matrix calculated using the outer product of gradients (complex-step).
c:\users\kiwini\.virtualenvs\dsc-phase-4-project\lib\site-packages\statsmodels\regression\linear_model.py
  return rho, np.sqrt(sigmasq)
c:\users\kiwini\.virtualenvs\dsc-phase-4-project\lib\site-packages\statsmodels\tsa\base\tsa_model.py:524:
  warnings.warn('No frequency information was'
c:\users\kiwini\.virtualenvs\dsc-phase-4-project\lib\site-packages\statsmodels\tsa\base\tsa_model.py:524:
  warnings.warn('No frequency information was'
c:\users\kiwini\.virtualenvs\dsc-phase-4-project\lib\site-packages\statsmodels\tsa\base\tsa_model.py:524:
  warnings.warn('No frequency information was'
```




Autocorrelation is positive past 10 lags. Needs another difference.

109
```
house_price_diff2 = house_price_diff.diff(periods=1)
sns.lineplot(data=house_price_diff2["value"])

house_price_diff2.dropna(axis=0, inplace=True)
house_price_diff2

fig5, ax5 = plt.subplots(figsize=(16,3))
plot_acf(house_price_diff2, ax=ax5)
fig6, ax6 = plt.subplots(figsize=(16,3))
plot_pacf(house_price_diff2, ax=ax6)

mod_arma = ARIMA(house_price_df["value"], order=(0, 2, 0))
res_arma=mod_arma.fit()
print("New Best Summary:\n", res_arma.summary())
```

```
New Best Summary:
                               SARIMAX Results
```

```
==============================================================================
Dep. Variable:                  value   No. Observations:                  265
Model:                 ARIMA(0, 2, 0)   Log Likelihood               -2026.174
Date:                Thu, 10 Jun 2021   AIC                           4054.347
Time:                        20:28:30   BIC                           4057.920
Sample:                    04-01-1996   HQIC                          4055.783
                         - 04-01-2018
Covariance Type:                  opg
==============================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------
sigma2      2.868e+05    1.8e+04     15.938      0.000    2.52e+05    3.22e+05
===================================================================================
Ljung-Box (L1) (Q):                  64.68   Jarque-Bera (JB):                44.02
Prob(Q):                              0.00   Prob(JB):                         0.00
Heteroskedasticity (H):              21.02   Skew:                             0.45
Prob(H) (two-sided):                  0.00   Kurtosis:                         4.79
===================================================================================

Warnings:
[1] Covariance matrix calculated using the outer product of gradients (complex-step).
```

```
c:\users\kiwini\.virtualenvs\dsc-phase-4-project\lib\site-packages\statsmodels\tsa\base\tsa_model.py:524:
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  warnings.warn('No frequency information was'
```
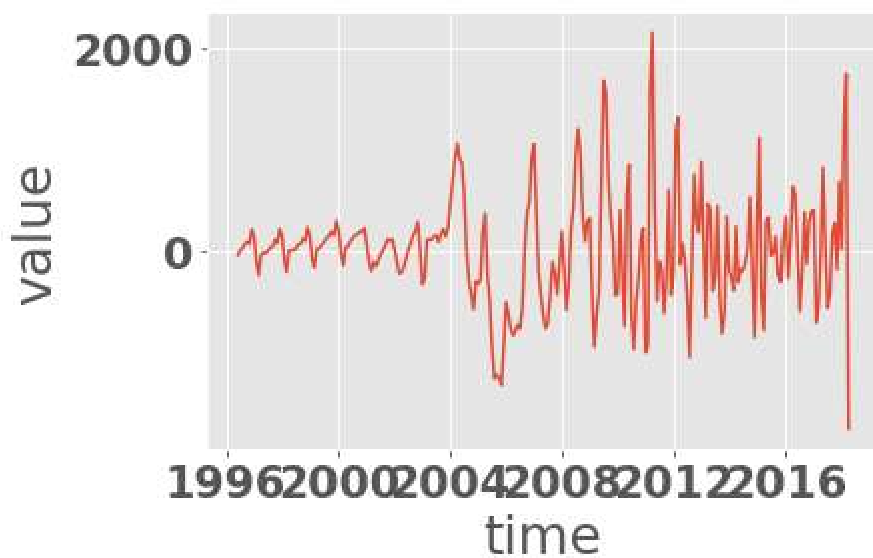
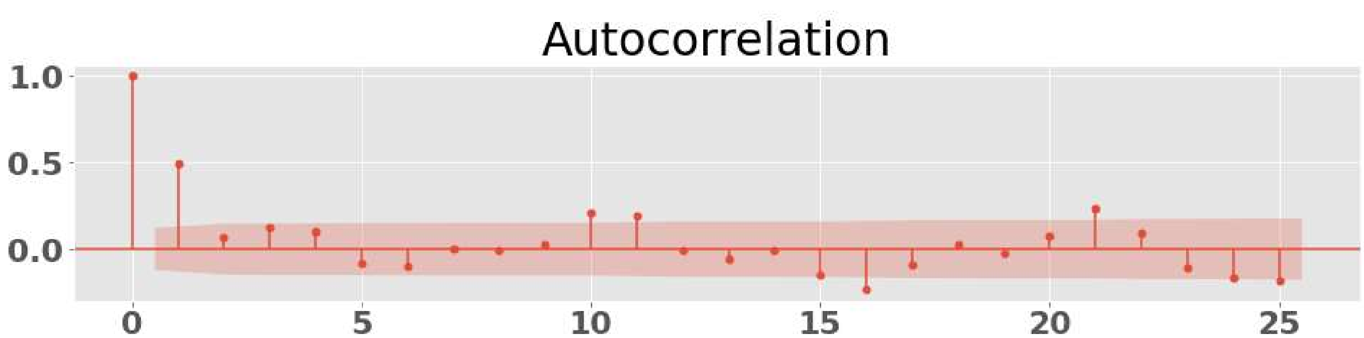
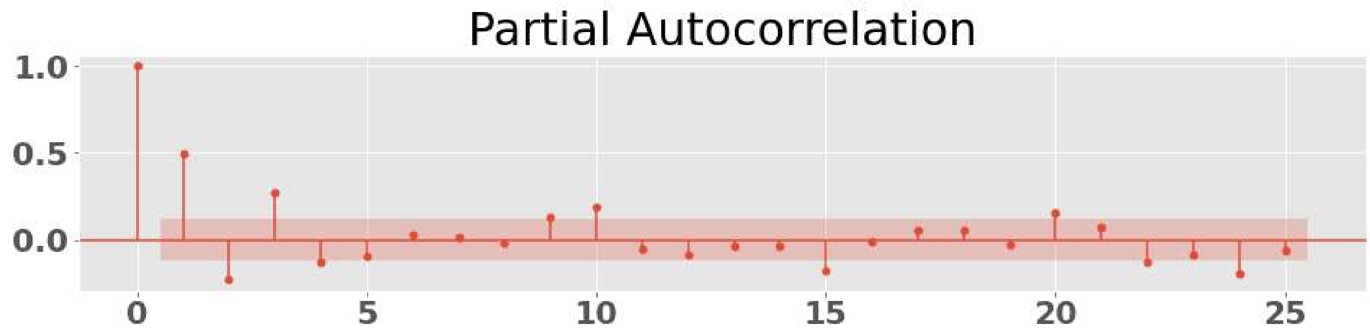



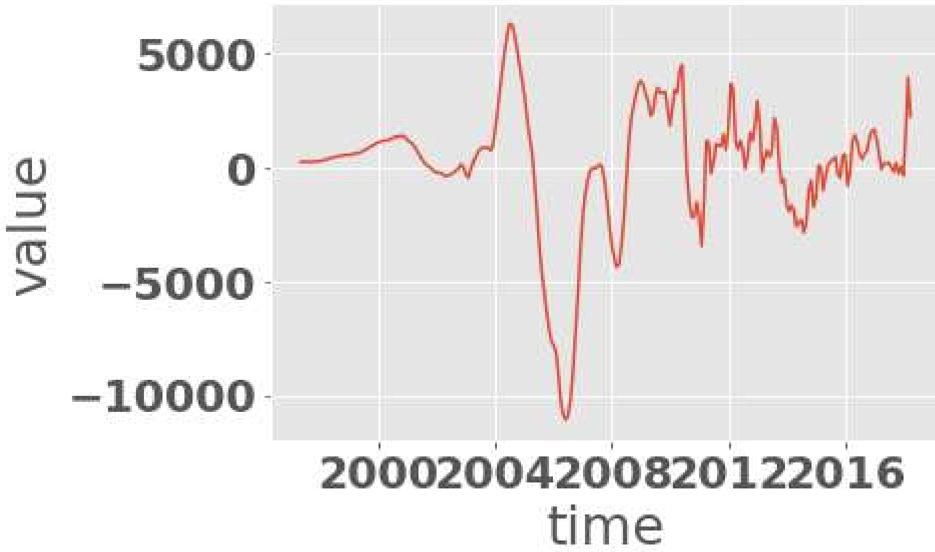



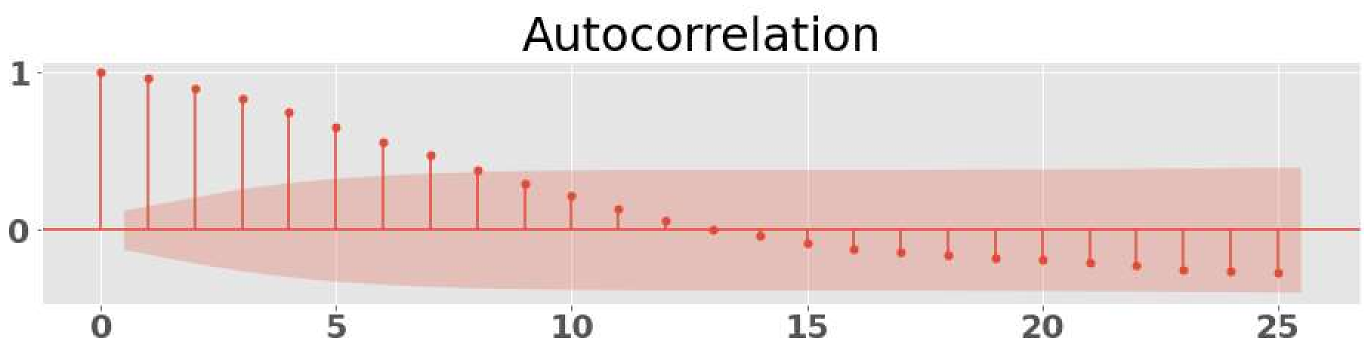


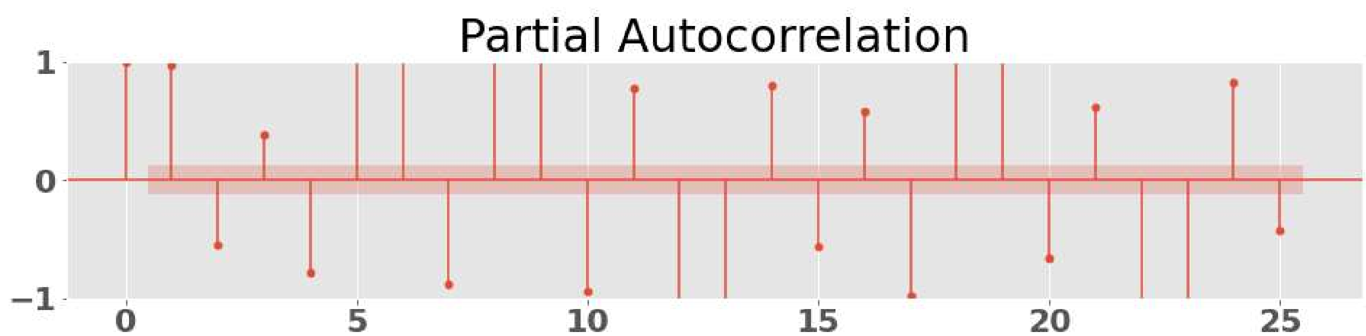

110
```
house_price_diffs = house_price_diff.diff(periods=12)
sns.lineplot(data=house_price_diffs["value"])

house_price_diffs.dropna(axis=0, inplace=True)
house_price_diffs

fig7, ax7 = plt.subplots(figsize=(16,3))
plot_acf(house_price_diffs, ax=ax7)
fig8, ax8 = plt.subplots(figsize=(16,3))
plot_pacf(house_price_diffs, ax=ax8)
ax8.set_ylim(-1,1)

mod_arma = ARIMA(house_price_df["value"], order=(0, 2, 0), trend=[0,0,1])
res_arma=mod_arma.fit()
print("New Best Summary:\n", res_arma.summary())
```

```
New Best Summary:
                                SARIMAX Results
==============================================================================
Dep. Variable:                  value   No. Observations:                  265
Model:                 ARIMA(0, 2, 0)   Log Likelihood               -2026.096
Date:                Thu, 10 Jun 2021   AIC                           4056.191
Time:                        20:28:31   BIC                           4063.335
Sample:                    04-01-1996   HQIC                          4059.062
                         - 04-01-2018
Covariance Type:                  opg
==============================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------
x1             6.5707     16.908      0.389      0.698     -26.568      39.710
sigma2      2.862e+05   1.85e+04     15.445      0.000     2.5e+05    3.23e+05
===================================================================================
Ljung-Box (L1) (Q):                  64.68   Jarque-Bera (JB):                44.02
Prob(Q):                              0.00   Prob(JB):                         0.00
Heteroskedasticity (H):              22.18   Skew:                             0.45
Prob(H) (two-sided):                  0.00   Kurtosis:                         4.79
===================================================================================

Warnings:
[1] Covariance matrix calculated using the outer product of gradients (complex-step).
```

```
c:\users\kiwini\.virtualenvs\dsc-phase-4-project\lib\site-packages\statsmodels\regression\linear_model.py
  return rho, np.sqrt(sigmasq)
c:\users\kiwini\.virtualenvs\dsc-phase-4-project\lib\site-packages\statsmodels\tsa\base\tsa_model.py:524:
  warnings.warn('No frequency information was'
c:\users\kiwini\.virtualenvs\dsc-phase-4-project\lib\site-packages\statsmodels\tsa\base\tsa_model.py:524:
  warnings.warn('No frequency information was'
c:\users\kiwini\.virtualenvs\dsc-phase-4-project\lib\site-packages\statsmodels\tsa\base\tsa_model.py:524:
  warnings.warn('No frequency information was'
```




## EDA + Visualization Analysis

### Graph

2 non-seasonal differences looks best. It looks most stationary, but variance seems to change over time.

### Heteroskedasticity

Negligible difference between seasonal + Non-seasonal models.

### ACF

2 non-seasonal differences looks best. There are still a number of significant lags, with no pattern.

### PACF

2 non-seasonal differences looks best. There are still a number of significant lags, with no pattern.

### Summary

The data is almost suitable for ARIMA analysis, but heteroskedasticity is too high.

The variance change looks like it is mostly the same between 1996-2004 and 2008-present. I will only use 2008+ data for the model.

## EDA + Visualization (2008+)

111
```
from dateutil.parser import isoparse
recent_house_price_df = house_price_df[house_price_df.index > isoparse('20071201')].copy()
recent_house_price_df
```

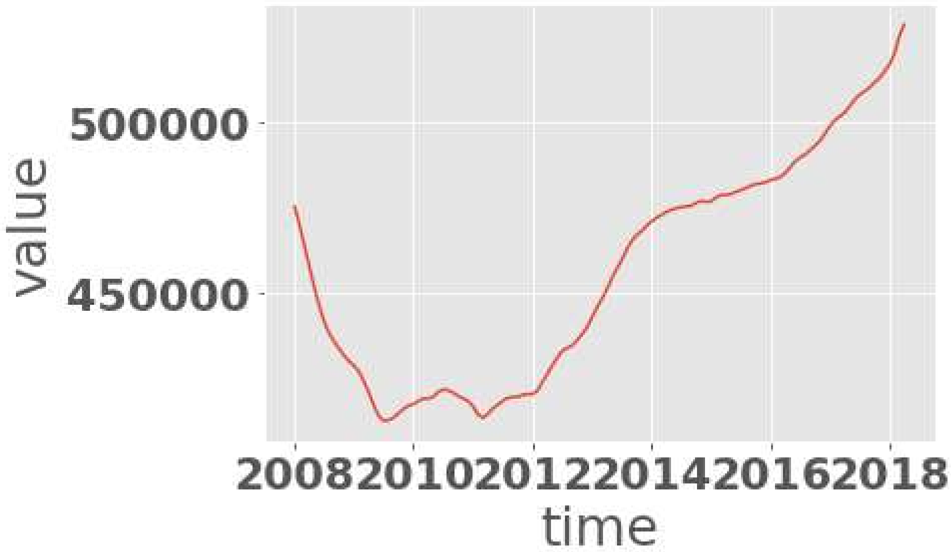
111

| | value |
|---|---|
| **time** | |
| **2008-01-01** | 475176.190476 |
| **2008-02-01** | 469799.047619 |
| **2008-03-01** | 463845.714286 |
| **2008-04-01** | 457592.380952 |
| **2008-05-01** | 451570.476190 |
| **...** | ... |
| **2017-12-01** | 514926.666667 |
| **2018-01-01** | 516926.666667 |
| **2018-02-01** | 520250.476190 |
| **2018-03-01** | 525317.142857 |
| **2018-04-01** | 528640.000000 |

124 rows × 1 columns

112
```
sns.lineplot(data=recent_house_price_df["value"])
```

112 <AxesSubplot:xlabel='time', ylabel='value'>

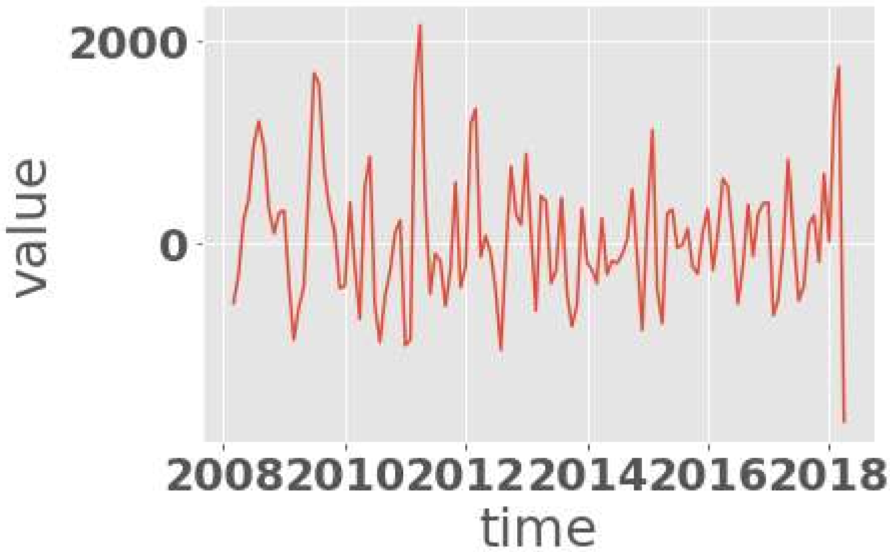


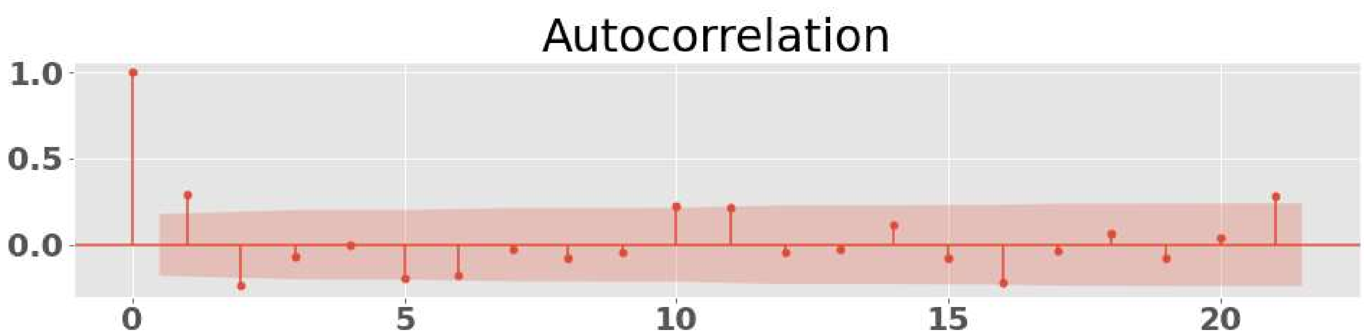

113
```
recent_house_price_diff = recent_house_price_df.diff(periods=1)
recent_house_price_diff2 = recent_house_price_diff.diff(periods=1)
sns.lineplot(data=recent_house_price_diff2["value"])

recent_house_price_diff2.dropna(axis=0, inplace=True)

fig9, ax9 = plt.subplots(figsize=(16,3))
plot_acf(recent_house_price_diff2, ax=ax9)
fig0, ax0 = plt.subplots(figsize=(16,3))
plot_pacf(recent_house_price_diff2, ax=ax0)

mod_arma = ARIMA(recent_house_price_diff2["value"], order=(0, 2, 0))
res_arma=mod_arma.fit()
print("Summary:\n", res_arma.summary())
```

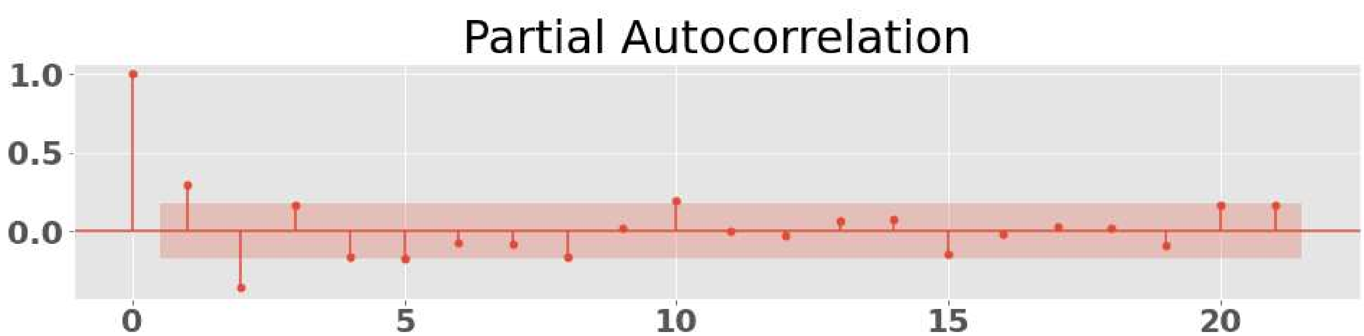
```
Summary:
                                SARIMAX Results
==============================================================================
Dep. Variable:                  value   No. Observations:                  122
Model:                 ARIMA(0, 2, 0)   Log Likelihood               -1003.339
Date:                Thu, 10 Jun 2021   AIC                           2008.679
Time:                        20:28:31   BIC                           2011.466
Sample:                    03-01-2008   HQIC                          2009.811
                         - 04-01-2018
Covariance Type:                  opg
==============================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------
sigma2      1.071e+06   1.17e+05      9.161      0.000    8.42e+05     1.3e+06
===================================================================================
Ljung-Box (L1) (Q):                   4.04   Jarque-Bera (JB):                 7.26
Prob(Q):                              0.04   Prob(JB):                         0.03
Heteroskedasticity (H):               1.33   Skew:                            -0.48
Prob(H) (two-sided):                  0.37   Kurtosis:                         3.74
===================================================================================

Warnings:
[1] Covariance matrix calculated using the outer product of gradients (complex-step).
```

```
c:\users\kiwini\.virtualenvs\dsc-phase-4-project\lib\site-packages\statsmodels\tsa\base\tsa_model.py:524:
  warnings.warn('No frequency information was'
c:\users\kiwini\.virtualenvs\dsc-phase-4-project\lib\site-packages\statsmodels\tsa\base\tsa_model.py:524:
  warnings.warn('No frequency information was'
```

```
c:\users\kiwini\.virtualenvs\dsc-phase-4-project\lib\site-packages\statsmodels\tsa\base\tsa_model.py:524:
  warnings.warn('No frequency information was'
```




114
```
recent_house_price_df = recent_house_price_df.asfreq("MS")
```

# EDA + Visualization Analysis (2008+ Data)

## Heteroscedasticity

Dropped from 20+ to 1.33. More appropriate for ARIMA modelling

## ACF

Most of the lags that were clearly "significant" before are now inside the shaded area. Looks easier to model!

### PACF

Most of the lags that were clearly "significant" before are now inside the shaded area. Looks easier to model!

# Step 5: ARIMA Modeling

The following code is adapted from a tutorial on Grid Searching, but changed to use Bayesian Search instead to better search a large state space in finite time.

115

```
from statsmodels.tsa.statespace.sarimax import SARIMAX
from sklearn.metrics import mean_squared_error

# Validation functions. Take in a model and return a "score" that can be used to compare models.
# measure_rmse + train_test_split + sarima_forecast are helper functions for walk_forward_validation

# root mean squared error or rmse
def measure_rmse(actual, predicted):
	return sqrt(mean_squared_error(actual, predicted))

# split a univariate dataset into train/test sets
def train_test_split(data, n_test):
	return data[:-n_test], data[-n_test:]

# one-step sarima forecast
def sarima_forecast(history, config, prior_arima_result=None):
	"""Train a model + make 1 month forecast"""
	order, sorder, trend = config
	# define model
	model = SARIMAX(history, order=order, seasonal_order=sorder, trend=trend, enforce_stationarity=Fa
	# fit model
	model_fit = model.fit(disp=False)

	# make one step forecast
	yhat = model_fit.predict(len(history), len(history))
	return yhat[0]

# walk-forward validation for univariate data
def walk_forward_validation(data, n_test, cfg):
	"""Return a score based on `n_test` one month forecasts.

	Model is retrained before each forecast on data up to the month of forecast.
	"""
	predictions = list()
	# split dataset
	train, test = train_test_split(data, n_test)
	# seed history with training dataset
	history = [x for x in train]

	# step over each time-step in the test set
	for i in range(len(test)):
		# fit model and make forecast for history
```

```
                yhat = sarima_forecast(history, cfg)
                # store forecast in list of predictions
                predictions.append(yhat)
                # add actual observation to history for the next loop
                history.append(test[i])
        # estimate prediction error
        error = measure_rmse(test, predictions)
        return error

def bic_validation(data, n_test, cfg):
        order, sorder, trend = cfg
        # define model
        model = SARIMAX(data, order=order, seasonal_order=sorder, trend=trend, enforce_stationarity=False
        # fit model
        model_fit = model.fit(disp=False)
        return model_fit.bic
```

155

```
from hyperopt import hp, fmin, tpe, Trials
# grid search sarima hyperparameters
from math import sqrt
import time
from warnings import catch_warnings
from warnings import filterwarnings

# score a model, return None on failure
def score_model(data, n_test, cfg, debug=False, score_func=bic_validation):
        start_time = time.time()
        result = None
        # convert config to a key
        key = str(cfg)
        # show all warnings and fail on exception if debugging
        if debug:
                result = score_func(data, n_test, cfg)
        else:
                # one failure during model validation suggests an unstable config
                try:
                        # never show warnings when grid searching, too noisy
                        with catch_warnings():
                                filterwarnings("ignore")
                                result = score_func(data, n_test, cfg)
                except Exception as e:
                        print("Error:", e)
                        error = None
        # check for an interesting result
        if result is not None:
                print(f'Model: {key} | Fit time (s): {time.time() - start_time} | RMSE: {result}')
        return (key, result)


def bayesian_search(data, timeout=5*60, n_test=6, score_func=bic_validation):
        """Bayesian search over a large state space.

        Explore p and q from 0 up to 30 (900 combinations).

    Tried extra configurations (Seasonal-MA + Seasonal-AR) because final model wasn't good, and wanted to
    everything I could think of to make it better.
    They're commented out because they fit slower and are worse. Uncomment to check them out.
    """

        space = hp.choice('seasonality', [
        #  {
    #     'type': "Seasonal-MA",
        #       'p': hp.randint('p_sma', 0, 10),
```

```
        #       'd': hp.choice('d_sma', [1]),
        #       'q': hp.randint('q_sma', 0, 10),
        #       't': hp.choice('t_sma', ['n', 'c', 't', 'ct']),
        #       'P': hp.choice('P_sma', [0]),
        #       'D': hp.choice('D_sma', [1]),
        #       'Q': hp.randint('Q_sma', 0, 10),
        #       'm': hp.choice('m_sma', [12]),
        # },
        # {
        #       'type': "Seasonal-AR",
        #        'p': hp.randint('p_sar', 0, 10),
        #               'd': hp.choice('d_sar', [1]),
        #               'q': hp.randint('q_sar', 0, 10),
        #               't': hp.choice('t_sar', ['n', 'c', 't', 'ct']),
        #               'P': hp.randint('Q_sar', 0, 10),
        #               'D': hp.choice('D_sar', [1]),
        #               'Q': hp.choice('P_sar', [0]),
        #               'm': hp.choice('m_sar', [12]),
        # },
        {
        'type': "Non-Seasonal AR",
                'p': hp.quniform('p_nar', 0, 31, 1),
                'd': hp.choice('d_nar', [2]),
                'q': hp.quniform('q_nar', 0, 3, 1),
                't': hp.choice('t_nar', [None]),
        },
        {
                'type': "Non-seasonal MA",
                'p': hp.quniform('p_nma', 0, 3, 1),
                'd': hp.choice('d_nma', [2]),
                'q': hp.quniform('q_nma', 0, 31, 1),
                't': hp.choice('t_nma', [None]),
        }]
        )
        def bayesian_objective_function(d):
                if 'm' in d.keys():
                        cfg = [(d['p'],d['d'], d['q']), (d['P'],d['D'],d['Q'],d['m']), d['t']]
                        #cfg = [(d['p'],d['d'], d['q']), (d['P'],d['D'],d['Q'],d['m']), None]
                else:
                        cfg = [(d['p'],d['d'], d['q']), None, d['t']]
                        #cfg = [(d['p'],d['d'], d['q']), None, None]
                key, result = score_model(data, n_test=n_test, cfg=cfg, score_func=score_func)
                if result is None:
                        return {
                                "key": key,
                                "status": "fail"
                        }
                else:
                        return {
                                "key": key,
                                "status": "ok",
                                "loss": result
                        }
        bayes_trials = Trials()
        best = fmin(
                bayesian_objective_function,
                space=space,
                algo=tpe.suggest,
                timeout=timeout,
                trials=bayes_trials,
                                )
        return best

# grid search configs
def grid_search(data, cfg_list, n_test, parallel=True, score_func=bic_validation):
```

```
    scores = [score_model(data, n_test, cfg, score_func=score_func) for cfg in cfg_list]
    # remove empty results
    scores = [r for r in scores if r[1] != None]
    # sort configs by error, asc
    scores.sort(key=lambda tup: tup[1])
    return scores
```

## ARIMA Model (Hand-selected Parameters)

With no obvious patterns in the ACF + PACF graphs, I tried a (0, 2, 0) model to start.

120
```
model = SARIMAX(recent_house_price_df["value"], order=(0,2,0))
model_fit = model.fit(disp=False)
```

121
```
model_fit.summary()
```

121

SARIMAX Results

| | | | |
|---|---|---|---|
| **Dep. Variable:** | value | **No. Observations:** | 124 |
| **Model:** | SARIMAX(0, 2, 0) | **Log Likelihood** | -963.100 |
| **Date:** | Thu, 10 Jun 2021 | **AIC** | 1928.200 |
| **Time:** | 20:41:20 | **BIC** | 1931.004 |
| **Sample:** | 01-01-2008 | **HQIC** | 1929.339 |
| | - 04-01-2018 | | |
| **Covariance Type:** | opg | | |

| | **coef** | **std err** | **z** | **P>\|z\|** | **[0.025** | **0.975]** |
|---|---|---|---|---|---|---|
| **sigma2** | 4.21e+05 | 4.46e+04 | 9.447 | 0.000 | 3.34e+05 | 5.08e+05 |

| | | | |
|---|---|---|---|
| **Ljung-Box (L1) (Q):** | 10.78 | **Jarque-Bera (JB):** | 8.65 |
| **Prob(Q):** | 0.00 | **Prob(JB):** | 0.01 |
| **Heteroskedasticity (H):** | 0.61 | **Skew:** | 0.55 |
| **Prob(H) (two-sided):** | 0.12 | **Kurtosis:** | 3.70 |

Warnings:

[1] Covariance matrix calculated using the outer product of gradients (complex-step).

122
```
model_fit.params
```

122
```
sigma2    420999.187472
dtype: float64
```

124
```
score_model(recent_house_price_df["value"], n_test=24, cfg=[(0,2,0), None, None], score_func=walk_forward
```

```
Model: [(0, 2, 0), None, None] | Fit time (s): 0.14162111282348633 | RMSE: 698.3075317645577
```

124
```
('[(0, 2, 0), None, None]', 698.3075317645577)
```

# ARIMA Results (Hand-selected Parameters)

RMSE of $698 BIC of 1931

# Grid Search Low p, q values

132
```
import itertools
cfg_list = list([(p, 2, q), None, None]
                                          for (p, q) in itertools.product(
                                                        range(11),
                                                        range(11)
                                          ))
grid_search(recent_house_price_df["value"], cfg_list, n_test=6, score_func=bic_validation)
```

```
Model: [(0, 2, 0), None, None] | Fit time (s): 0.012964010238647461 | RMSE: 1915.4188002935916
Model: [(0, 2, 1), None, None] | Fit time (s): 0.04188728332519531 | RMSE: 1891.8156660528407
Model: [(0, 2, 2), None, None] | Fit time (s): 0.028922557830810547 | RMSE: 1861.139409755614
Model: [(0, 2, 3), None, None] | Fit time (s): 0.031914710998535156 | RMSE: 1843.7158961250257
Model: [(0, 2, 4), None, None] | Fit time (s): 0.09474706649780273 | RMSE: 1814.7112661017152
Model: [(0, 2, 5), None, None] | Fit time (s): 0.06682229042053223 | RMSE: 1804.1935803535523
Model: [(0, 2, 6), None, None] | Fit time (s): 0.13267064094543457 | RMSE: 1788.7787528588044
Model: [(0, 2, 7), None, None] | Fit time (s): 0.24897146224975586 | RMSE: 1771.4900187136798
Model: [(0, 2, 8), None, None] | Fit time (s): 0.4258861541748047 | RMSE: 1764.9989074250389
Model: [(0, 2, 9), None, None] | Fit time (s): 0.33408212661743164 | RMSE: 1748.3110933603602
Model: [(0, 2, 10), None, None] | Fit time (s): 0.38796234130859375 | RMSE: 1741.6145241238994
Model: [(1, 2, 0), None, None] | Fit time (s): 0.009972333908081055 | RMSE: 1907.4835961618485
Model: [(1, 2, 1), None, None] | Fit time (s): 0.026928186416625977 | RMSE: 1874.6328208646255
Model: [(1, 2, 2), None, None] | Fit time (s): 0.05385637283325195 | RMSE: 1864.3291370505403
Model: [(1, 2, 3), None, None] | Fit time (s): 0.15358877182006836 | RMSE: 1845.188999877701
Model: [(1, 2, 4), None, None] | Fit time (s): 0.07380390167236328 | RMSE: 1819.7124102773075
Model: [(1, 2, 5), None, None] | Fit time (s): 0.1934819221496582 | RMSE: 1802.5511010100374
Model: [(1, 2, 6), None, None] | Fit time (s): 0.18251252174377441 | RMSE: 1791.9069772033108
Model: [(1, 2, 7), None, None] | Fit time (s): 0.26628899574279785 | RMSE: 1781.2746532262495
Model: [(1, 2, 8), None, None] | Fit time (s): 0.34407925605773926 | RMSE: 1768.7897016300146
Model: [(1, 2, 9), None, None] | Fit time (s): 0.35205888748168945 | RMSE: 1752.7150249608173
Model: [(1, 2, 10), None, None] | Fit time (s): 0.3969395160675049 | RMSE: 1745.6636269002163
Model: [(2, 2, 0), None, None] | Fit time (s): 0.008976221084594727 | RMSE: 1874.6980862378684
Model: [(2, 2, 1), None, None] | Fit time (s): 0.048868656158447266 | RMSE: 1879.7048344787515
Model: [(2, 2, 2), None, None] | Fit time (s): 0.16356348991394043 | RMSE: 1858.1979657199615
Model: [(2, 2, 3), None, None] | Fit time (s): 0.05983996391296387 | RMSE: 1841.4965338568513
Model: [(2, 2, 4), None, None] | Fit time (s): 0.19946718215942383 | RMSE: 1815.1639666832373
Model: [(2, 2, 5), None, None] | Fit time (s): 0.20046567916870117 | RMSE: 1803.7300843640955
Model: [(2, 2, 6), None, None] | Fit time (s): 0.25830817222595215 | RMSE: 1793.683945101899
```

```
Model: [(2, 2, 7), None, None] | Fit time (s): 0.2822446823120117 | RMSE: 1782.4482243804027
Model: [(2, 2, 8), None, None] | Fit time (s): 0.33211255073547363 | RMSE: 1770.4891402137528
Model: [(2, 2, 9), None, None] | Fit time (s): 0.4168858528137207 | RMSE: 1752.0969368864278
Model: [(2, 2, 10), None, None] | Fit time (s): 0.4777493476867676 | RMSE: 1738.8169638003285
Model: [(3, 2, 0), None, None] | Fit time (s): 0.009947061538696289 | RMSE: 1856.0158115197974
Model: [(3, 2, 1), None, None] | Fit time (s): 0.04191422462463379 | RMSE: 1860.3803069967228
Model: [(3, 2, 2), None, None] | Fit time (s): 0.05083727836608887 | RMSE: 1862.187840401688
Model: [(3, 2, 3), None, None] | Fit time (s): 0.1934833526611328 | RMSE: 1827.9574300819659
Model: [(3, 2, 4), None, None] | Fit time (s): 0.11269855499267578 | RMSE: 1827.8267222239908
Model: [(3, 2, 5), None, None] | Fit time (s): 0.10471963882446289 | RMSE: 1816.041335322133
Model: [(3, 2, 6), None, None] | Fit time (s): 0.3121926784515381 | RMSE: 1796.431206771017
Model: [(3, 2, 7), None, None] | Fit time (s): 0.19547677040100098 | RMSE: 1793.3530663516035
Model: [(3, 2, 8), None, None] | Fit time (s): 0.37998533248901367 | RMSE: 1770.566567595878
Model: [(3, 2, 9), None, None] | Fit time (s): 0.3979356288909912 | RMSE: 1761.6913078387092
Model: [(3, 2, 10), None, None] | Fit time (s): 0.4527637958526611 3 | RMSE: 1751.9307007097996
Model: [(4, 2, 0), None, None] | Fit time (s): 0.012964725494384766 | RMSE: 1837.5016211734398
Model: [(4, 2, 1), None, None] | Fit time (s): 0.042885541915893555 | RMSE: 1839.4520038226894
Model: [(4, 2, 2), None, None] | Fit time (s): 0.10372352600097656 | RMSE: 1838.106551047914
Model: [(4, 2, 3), None, None] | Fit time (s): 0.18450593948364258 | RMSE: 1845.3223832763329
Model: [(4, 2, 4), None, None] | Fit time (s): 0.1037225723266601 6 | RMSE: 1832.7080191124794
Model: [(4, 2, 5), None, None] | Fit time (s): 0.14261913299560547 | RMSE: 1820.5287466538934
Model: [(4, 2, 6), None, None] | Fit time (s): 0.32712674140930176 | RMSE: 1802.1397972799243
Model: [(4, 2, 7), None, None] | Fit time (s): 0.29122018814086914 | RMSE: 1795.0773339458538
Model: [(4, 2, 8), None, None] | Fit time (s): 0.4138941764831543 | RMSE: 1787.8218976774479
Model: [(4, 2, 9), None, None] | Fit time (s): 0.3011951446533203 | RMSE: 1772.2594961098016
Model: [(4, 2, 10), None, None] | Fit time (s): 0.5465383529663086 | RMSE: 1751.4904727012622
Model: [(5, 2, 0), None, None] | Fit time (s): 0.011968135833740234 | RMSE: 1823.0244500069412
Model: [(5, 2, 1), None, None] | Fit time (s): 0.09474778175354004 | RMSE: 1830.018249357578
Model: [(5, 2, 2), None, None] | Fit time (s): 0.11768436431884766 | RMSE: 1833.705239022815
Model: [(5, 2, 3), None, None] | Fit time (s): 0.2652912139892578 | RMSE: 1853.3333214324575
Model: [(5, 2, 4), None, None] | Fit time (s): 0.15857601165771484 | RMSE: 1837.0779430361906
Model: [(5, 2, 5), None, None] | Fit time (s): 0.2293863296508789 | RMSE: 1825.2676898177144
Model: [(5, 2, 6), None, None] | Fit time (s): 0.33310937881469727 | RMSE: 1807.7688180827945
Model: [(5, 2, 7), None, None] | Fit time (s): 0.30219221115112305 | RMSE: 1798.7811010541125
Model: [(5, 2, 8), None, None] | Fit time (s): 0.47074174880981445 | RMSE: 1789.8516690781798
Model: [(5, 2, 9), None, None] | Fit time (s): 0.4468059539794922 | RMSE: 1771.0620217996013
Model: [(5, 2, 10), None, None] | Fit time (s): 0.5505282878875732 | RMSE: 1756.2148121581345
Model: [(6, 2, 0), None, None] | Fit time (s): 0.011968612670898438 | RMSE: 1811.4947540966166
Model: [(6, 2, 1), None, None] | Fit time (s): 0.11170125007629395 | RMSE: 1814.229430114862
Model: [(6, 2, 2), None, None] | Fit time (s): 0.13962650299072266 | RMSE: 1818.3885527388302
Model: [(6, 2, 3), None, None] | Fit time (s): 0.43184590339660645 | RMSE: 1861.9273326567911
Model: [(6, 2, 4), None, None] | Fit time (s): 0.28324294090270996 | RMSE: 1821.6848918159092
Model: [(6, 2, 5), None, None] | Fit time (s): 0.2982029914855957 | RMSE: 1826.1043023878783
Model: [(6, 2, 6), None, None] | Fit time (s): 0.3510615825653076 | RMSE: 1814.7436379603914
Model: [(6, 2, 7), None, None] | Fit time (s): 0.3361015319824219 | RMSE: 1802.7750564282233
Model: [(6, 2, 8), None, None] | Fit time (s): 0.5156219005584717 | RMSE: 1794.3605029196428
Model: [(6, 2, 9), None, None] | Fit time (s): 0.4438135623931885 | RMSE: 1777.6677966384711
Model: [(6, 2, 10), None, None] | Fit time (s): 0.5146245956420898 | RMSE: 1758.4459609458816
Model: [(7, 2, 0), None, None] | Fit time (s): 0.013962507247924805 | RMSE: 1791.6364992599185
Model: [(7, 2, 1), None, None] | Fit time (s): 0.09574413299560547 | RMSE: 1795.8002453794168
Model: [(7, 2, 2), None, None] | Fit time (s): 0.2343735694885254 | RMSE: 1806.291560938126
Model: [(7, 2, 3), None, None] | Fit time (s): 0.40793275833129883 | RMSE: 1816.446765714729
Model: [(7, 2, 4), None, None] | Fit time (s): 0.2582864761352539 | RMSE: 1808.1061426942508
Model: [(7, 2, 5), None, None] | Fit time (s): 0.2563149929046631 | RMSE: 1812.0514695563043
Model: [(7, 2, 6), None, None] | Fit time (s): 0.4218740463256836 | RMSE: 1821.032824752019
Model: [(7, 2, 7), None, None] | Fit time (s): 0.43483662605285645 | RMSE: 1806.6253788388442
Model: [(7, 2, 8), None, None] | Fit time (s): 0.5116598606109619 | RMSE: 1792.868427501299
Model: [(7, 2, 9), None, None] | Fit time (s): 0.5993964672088623 | RMSE: 1773.795554550524
Model: [(7, 2, 10), None, None] | Fit time (s): 0.6203415393829346 | RMSE: 1772.5412679691813
Model: [(8, 2, 0), None, None] | Fit time (s): 0.017953157424926758 | RMSE: 1781.4651066047759
Model: [(8, 2, 1), None, None] | Fit time (s): 0.2513277530670166 | RMSE: 1784.756874556231
Model: [(8, 2, 2), None, None] | Fit time (s): 0.23038339614868164 | RMSE: 1790.1037879854507
Model: [(8, 2, 3), None, None] | Fit time (s): 0.3311154842376709 | RMSE: 1793.2248955057378
Model: [(8, 2, 4), None, None] | Fit time (s): 0.5206072330474854 | RMSE: 4199.602710919589
Model: [(8, 2, 5), None, None] | Fit time (s): 0.49271273612976074 | RMSE: 1805.5511098822478
```

```
Model: [(8, 2, 6), None, None] | Fit time (s): 0.4478003978729248 | RMSE: 1817.142192611169
Model: [(8, 2, 7), None, None] | Fit time (s): 0.4796907901763916 | RMSE: 1808.865596398107
Model: [(8, 2, 8), None, None] | Fit time (s): 0.5245988368988037 | RMSE: 1796.3383424013082
Model: [(8, 2, 9), None, None] | Fit time (s): 0.7360327243804932 | RMSE: 1784.615390410626
Model: [(8, 2, 10), None, None] | Fit time (s): 0.6133613586425781 | RMSE: 1768.3417536235027
Model: [(9, 2, 0), None, None] | Fit time (s): 0.016955137252807617 | RMSE: 1770.978443019545
Model: [(9, 2, 1), None, None] | Fit time (s): 0.24534201622009277 | RMSE: 1774.4099019735067
Model: [(9, 2, 2), None, None] | Fit time (s): 0.3610353469848633 | RMSE: 1779.5557911946132
Model: [(9, 2, 3), None, None] | Fit time (s): 0.40192604064941406 | RMSE: 1783.8352353612481
Model: [(9, 2, 4), None, None] | Fit time (s): 0.9165496826171875 | RMSE: 2166.5836433573922
Model: [(9, 2, 5), None, None] | Fit time (s): 0.5036530494689941 | RMSE: 1812.45825232441
Model: [(9, 2, 6), None, None] | Fit time (s): 0.6233346462249756 | RMSE: 1810.5776892524668
Model: [(9, 2, 7), None, None] | Fit time (s): 0.5285868644714355 | RMSE: 1792.2078408225782
Model: [(9, 2, 8), None, None] | Fit time (s): 0.5355944633483887 | RMSE: 1798.0400714747943
Model: [(9, 2, 9), None, None] | Fit time (s): 0.542525053024292 | RMSE: 1790.4378458049746
Model: [(9, 2, 10), None, None] | Fit time (s): 0.648292064666748 | RMSE: 1775.5599351892624
Model: [(10, 2, 0), None, None] | Fit time (s): 0.016928672790527344 | RMSE: 1757.4920831978673
Model: [(10, 2, 1), None, None] | Fit time (s): 0.2263965606689453 | RMSE: 1763.981547988379
Model: [(10, 2, 2), None, None] | Fit time (s): 0.22439908981323242 | RMSE: 1765.5679620921574
Model: [(10, 2, 3), None, None] | Fit time (s): 0.2952108383178711 | RMSE: 1769.832617345393
Model: [(10, 2, 4), None, None] | Fit time (s): 0.6492648124694824 | RMSE: 2224.129244729223
Model: [(10, 2, 5), None, None] | Fit time (s): 0.5445442199707031 | RMSE: 1790.643532672116
Model: [(10, 2, 6), None, None] | Fit time (s): 0.581446647644043 | RMSE: 1792.6936734098824
Model: [(10, 2, 7), None, None] | Fit time (s): 0.5176427364349365 | RMSE: 1773.5147568996542
Model: [(10, 2, 8), None, None] | Fit time (s): 0.4428415298461914 | RMSE: 1783.7267335129038
Model: [(10, 2, 9), None, None] | Fit time (s): 0.5794258117675781 | RMSE: 1801.0363023046473
Model: [(10, 2, 10), None, None] | Fit time (s): 0.6751933097839355 | RMSE: 1776.105474168479
```

132
```
[('[(2, 2, 10), None, None]', 1738.8169638003285),
 ('[(0, 2, 10), None, None]', 1741.6145241238994),
 ('[(1, 2, 10), None, None]', 1745.6636269002163),
 ('[(0, 2, 9), None, None]', 1748.3110933603602),
 ('[(4, 2, 10), None, None]', 1751.4904727012622),
 ('[(3, 2, 10), None, None]', 1751.9307007097996),
 ('[(2, 2, 9), None, None]', 1752.0969368864278),
 ('[(1, 2, 9), None, None]', 1752.7150249608173),
 ('[(5, 2, 10), None, None]', 1756.2148121581345),
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# ARIMA Results (low p,q grid search):

I started with grid searching p < 4 and q < 4. I expanded it when the best result came with max allowed p, q: (3, 2, 3). I made the grid bigger multiple times, but always the best result was biggest allowed p+q.

I stopped grid search after (10, 2, 10) and tried a bayesian search with bigger allowed parameters.

## Top 3 models (by BIC)

Model: [(2, 2, 10), None, None] | Fit time (s): <1 | BIC: 1738.8169638003285 Model: [(0, 2, 10), None, None] | Fit time (s): <1 | BIC: 1741.6145241238994 Model: [(1, 2, 10), None, None] | Fit time (s): <1 | BIC: 1745.6636269002163

156
```
best = bayesian_search(recent_house_price_df["value"], timeout=30 * 60, n_test=6)
print(best)
```

```
Model: [(5.0, 2, 2.0), None, None] | Fit time (s): 0.11269950866699219 | RMSE: 1833.705239022815
Model: [(2.0, 2, 25.0), None, None] | Fit time (s): 2.3238134384155273 | RMSE: 1554.0786600812817
Model: [(2.0, 2, 25.0), None, None] | Fit time (s): 2.1372878551483154 | RMSE: 1554.0786600812817
Model: [(0.0, 2, 15.0), None, None] | Fit time (s): 0.6462714672088623 | RMSE: 1673.2834959633158
Model: [(1.0, 2, 29.0), None, None] | Fit time (s): 3.1406290531158447 | RMSE: 1531.635063770194
Model: [(3.0, 2, 28.0), None, None] | Fit time (s): 3.136613607406616 | RMSE: 1520.7070317323107
Model: [(16.0, 2, 3.0), None, None] | Fit time (s): 0.6801817417144775 | RMSE: 1692.5542587480477
Model: [(2.0, 2, 11.0), None, None] | Fit time (s): 0.5236027240753174 | RMSE: 1732.0800952959826
Model: [(8.0, 2, 1.0), None, None] | Fit time (s): 0.22043633460998535 | RMSE: 1784.756874556231
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Model: [(0.0, 2, 30.0), None, None] | Fit time (s): 4.2386698722839355 | RMSE: 1607.1464879948294
Model: [(1.0, 2, 1.0), None, None] | Fit time (s): 0.02792525291442871 | RMSE: 1874.6328208646255
Model: [(2.0, 2, 19.0), None, None] | Fit time (s): 1.164888620376587 | RMSE: 1626.9209127167978
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Model: [(16.0, 2, 1.0), None, None] | Fit time (s): 0.6901295185089111 | RMSE: 1684.3145711161353
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Model: [(29.0, 2, 2.0), None, None] | Fit time (s): 3.08575177192688 | RMSE: 1529.3024077941368
Model: [(15.0, 2, 2.0), None, None] | Fit time (s): 0.6372966766357422 | RMSE: 1700.377377183027
```

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Model: [(29.0, 2, 3.0), None, None] | Fit time (s): 3.1665608882904053 | RMSE: 1531.5665678205773
Model: [(31.0, 2, 0.0), None, None] | Fit time (s): 0.7080850601196289 | RMSE: 1499.8009477407797
Model: [(3.0, 2, 8.0), None, None] | Fit time (s): 0.39594173431396484 | RMSE: 1770.566567595878
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Model: [(30.0, 2, 0.0), None, None] | Fit time (s): 0.17064404487609863 | RMSE: 1510.974495208657
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Model: [(28.0, 2, 1.0), None, None] | Fit time (s): 2.5763766765594482 | RMSE: 1537.9717274583368
Model: [(31.0, 2, 0.0), None, None] | Fit time (s): 0.7031269073486328 | RMSE: 1499.8009477407797
Model: [(0.0, 2, 21.0), None, None] | Fit time (s): 1.2302205562591553 | RMSE: 1604.5081032694284
Model: [(27.0, 2, 0.0), None, None] | Fit time (s): 0.128326416015625 | RMSE: 1543.3295510464977
Model: [(30.0, 2, 0.0), None, None] | Fit time (s): 0.16579365730285645 | RMSE: 1510.974495208657
```

```
Model: [(28.0, 2, 0.0), None, None] | Fit time (s): 0.13627886772155762 | RMSE: 1533.4682531051967
Model: [(15.0, 2, 0.0), None, None] | Fit time (s): 0.025904417037963867 | RMSE: 1701.0627600563698
Model: [(29.0, 2, 0.0), None, None] | Fit time (s): 0.16334176063537598 | RMSE: 1522.5682362457846
Model: [(3.0, 2, 0.0), None, None] | Fit time (s): 0.007035255432128906 | RMSE: 1856.0158115197974
Model: [(30.0, 2, 0.0), None, None] | Fit time (s): 0.1701664924621582 | RMSE: 1510.974495208657
Model: [(31.0, 2, 3.0), None, None] | Fit time (s): 4.368914604187012 | RMSE: 1506.427437772652
Model: [(26.0, 2, 0.0), None, None] | Fit time (s): 0.11006593704223633 | RMSE: 1554.0562906335576
Model: [(20.0, 2, 0.0), None, None] | Fit time (s): 0.05593156814575195 | RMSE: 1635.6118586680882
Model: [(1.0, 2, 8.0), None, None] | Fit time (s): 0.32665300369262695 | RMSE: 1768.7897016300146
Model: [(30.0, 2, 1.0), None, None] | Fit time (s): 2.68617582321167 | RMSE: 1513.8516877116163
Model: [(29.0, 2, 0.0), None, None] | Fit time (s): 0.15856242179870605 | RMSE: 1522.5682362457846
Model: [(27.0, 2, 0.0), None, None] | Fit time (s): 0.13189387321472168 | RMSE: 1543.3295510464977
Model: [(31.0, 2, 0.0), None, None] | Fit time (s): 0.7012951374053955 | RMSE: 1499.8009477407797
Model: [(28.0, 2, 0.0), None, None] | Fit time (s): 0.13790082931518555 | RMSE: 1533.4682531051967
Model: [(30.0, 2, 0.0), None, None] | Fit time (s): 0.16286873817443848 | RMSE: 1510.974495208657
Model: [(31.0, 2, 0.0), None, None] | Fit time (s): 0.6912674903869629 | RMSE: 1499.8009477407797
Model: [(25.0, 2, 0.0), None, None] | Fit time (s): 0.1061091423034668 | RMSE: 1567.36137852295
Model: [(0.0, 2, 27.0), None, None] | Fit time (s): 2.746605634689331 | RMSE: 1519.8374124101167
Model: [(29.0, 2, 1.0), None, None] | Fit time (s): 2.8726465702056885 | RMSE: 1526.0498090668952
Model: [(27.0, 2, 0.0), None, None] | Fit time (s): 0.12782955169677734 | RMSE: 1543.3295510464977
Model: [(28.0, 2, 0.0), None, None] | Fit time (s): 0.13589000701904297 | RMSE: 1533.4682531051967
Model: [(31.0, 2, 0.0), None, None] | Fit time (s): 0.6970891952514648 | RMSE: 1499.8009477407797
Model: [(31.0, 2, 0.0), None, None] | Fit time (s): 0.7066948413848877 | RMSE: 1499.8009477407797
Model: [(30.0, 2, 2.0), None, None] | Fit time (s): 2.7012264728546143 | RMSE: 1515.3528518681321
Model: [(30.0, 2, 0.0), None, None] | Fit time (s): 0.16655468940734863 | RMSE: 1510.974495208657
Model: [(21.0, 2, 0.0), None, None] | Fit time (s): 0.050864219665527344 | RMSE: 1621.4458626853818
Model: [(28.0, 2, 0.0), None, None] | Fit time (s): 0.15456104278564453 | RMSE: 1533.4682531051967
Model: [(24.0, 2, 0.0), None, None] | Fit time (s): 0.09275221824645996 | RMSE: 1578.6530615324136
Model: [(3.0, 2, 12.0), None, None] | Fit time (s): 0.6223366260528564 | RMSE: 1721.3292017034905
Model: [(29.0, 2, 0.0), None, None] | Fit time (s): 0.1605701446533203 | RMSE: 1522.5682362457846
Model: [(29.0, 2, 0.0), None, None] | Fit time (s): 0.16057062149047852 | RMSE: 1522.5682362457846
Model: [(26.0, 2, 0.0), None, None] | Fit time (s): 0.11469388008117676 | RMSE: 1554.0562906335576
Model: [(30.0, 2, 1.0), None, None] | Fit time (s): 2.7436673641204834 | RMSE: 1513.8516877116163
Model: [(31.0, 2, 0.0), None, None] | Fit time (s): 0.6961386203765869 | RMSE: 1499.8009477407797
Model: [(30.0, 2, 0.0), None, None] | Fit time (s): 0.16755223274230957 | RMSE: 1510.974495208657
Model: [(27.0, 2, 0.0), None, None] | Fit time (s): 0.13564038276672363 | RMSE: 1543.3295510464977
Model: [(29.0, 2, 0.0), None, None] | Fit time (s): 0.16456031799316406 | RMSE: 1522.5682362457846
Model: [(2.0, 2, 14.0), None, None] | Fit time (s): 0.6428406238555908 | RMSE: 1690.714074957991
Model: [(31.0, 2, 0.0), None, None] | Fit time (s): 0.694469690322876 | RMSE: 1499.8009477407797
Model: [(28.0, 2, 0.0), None, None] | Fit time (s): 0.1358191967010498 | RMSE: 1533.4682531051967
Model: [(25.0, 2, 0.0), None, None] | Fit time (s): 0.10689711570739746 | RMSE: 1567.36137852295
Model: [(31.0, 2, 0.0), None, None] | Fit time (s): 0.7062757015228271 | RMSE: 1499.8009477407797
Model: [(30.0, 2, 2.0), None, None] | Fit time (s): 2.7211337089538574 | RMSE: 1515.3528518681321
Model: [(26.0, 2, 0.0), None, None] | Fit time (s): 0.11584639549255371 | RMSE: 1554.0562906335576
Model: [(27.0, 2, 1.0), None, None] | Fit time (s): 2.2229840755462646 | RMSE: 1547.8883069210744
Model: [(29.0, 2, 0.0), None, None] | Fit time (s): 0.16901326179504395 | RMSE: 1522.5682362457846
Model: [(28.0, 2, 0.0), None, None] | Fit time (s): 0.13323163986206055 | RMSE: 1533.4682531051967
Model: [(31.0, 2, 0.0), None, None] | Fit time (s): 0.7012176513671875 | RMSE: 1499.8009477407797
Model: [(1.0, 2, 5.0), None, None] | Fit time (s): 0.19878745079040527 | RMSE: 1802.5511010100374
Model: [(30.0, 2, 0.0), None, None] | Fit time (s): 0.1658766269683838 | RMSE: 1510.974495208657
Model: [(29.0, 2, 0.0), None, None] | Fit time (s): 0.15647149085998535 | RMSE: 1522.5682362457846
Model: [(31.0, 2, 0.0), None, None] | Fit time (s): 0.6991615295410156 | RMSE: 1499.8009477407797
Model: [(28.0, 2, 0.0), None, None] | Fit time (s): 0.13585972785949707 | RMSE: 1533.4682531051967
Model: [(24.0, 2, 0.0), None, None] | Fit time (s): 0.09471392631530762 | RMSE: 1578.6530615324136
Model: [(30.0, 2, 0.0), None, None] | Fit time (s): 0.16583490371704102 | RMSE: 1510.974495208657
Model: [(31.0, 2, 0.0), None, None] | Fit time (s): 0.7069954872131348 | RMSE: 1499.8009477407797
Model: [(27.0, 2, 0.0), None, None] | Fit time (s): 0.12984275817871094 | RMSE: 1543.3295510464977
Model: [(29.0, 2, 1.0), None, None] | Fit time (s): 2.8282642364501953 | RMSE: 1526.0498090668952
Model: [(0.0, 2, 31.0), None, None] | Fit time (s): 1.893782615661621 | RMSE: nan
Model: [(0.0, 2, 18.0), None, None] | Fit time (s): 0.9349331855773926 | RMSE: 1640.018543322034
Model: [(26.0, 2, 0.0), None, None] | Fit time (s): 0.11390018463134766 | RMSE: 1554.0562906335576
Model: [(12.0, 2, 3.0), None, None] | Fit time (s): 0.42780518531799316 | RMSE: 1748.505632695454
Model: [(23.0, 2, 0.0), None, None] | Fit time (s): 0.07589888572692871 | RMSE: 1600.671095733694
Model: [(14.0, 2, 0.0), None, None] | Fit time (s): 0.029798030853271484 | RMSE: 1712.1907146922526
Model: [(28.0, 2, 0.0), None, None] | Fit time (s): 0.1398153305053711 | RMSE: 1533.4682531051967
```

```
Model: [(30.0, 2, 0.0), None, None] | Fit time (s): 0.1713564395904541 | RMSE: 1510.974495208657
Model: [(31.0, 2, 0.0), None, None] | Fit time (s): 0.712108850479126 | RMSE: 1499.8009477407797
Model: [(22.0, 2, 0.0), None, None] | Fit time (s): 0.0519251823425293 | RMSE: 1611.6777668028467
Model: [(29.0, 2, 0.0), None, None] | Fit time (s): 0.15992426872253418 | RMSE: 1522.5682362457846
Model: [(2.0, 2, 31.0), None, None] | Fit time (s): 2.1886253356933594 | RMSE: nan
Model: [(2.0, 2, 0.0), None, None] | Fit time (s): 0.023936033248901367 | RMSE: 1874.6980862378684
Model: [(31.0, 2, 0.0), None, None] | Fit time (s): 1.1680235862731934 | RMSE: 1499.8009477407797
Model: [(30.0, 2, 0.0), None, None] | Fit time (s): 0.19457435607910156 | RMSE: 1510.974495208657
Model: [(31.0, 2, 0.0), None, None] | Fit time (s): 0.7057220935821533 | RMSE: 1499.8009477407797
Model: [(30.0, 2, 0.0), None, None] | Fit time (s): 0.18316364288330078 | RMSE: 1510.974495208657
Model: [(31.0, 2, 0.0), None, None] | Fit time (s): 0.7099676132202148 | RMSE: 1499.8009477407797
Model: [(31.0, 2, 0.0), None, None] | Fit time (s): 0.6885013580322266 | RMSE: 1499.8009477407797
Model: [(30.0, 2, 0.0), None, None] | Fit time (s): 0.17248201370239258 | RMSE: 1510.974495208657
Model: [(30.0, 2, 0.0), None, None] | Fit time (s): 0.17217373847961426 | RMSE: 1510.974495208657
Model: [(31.0, 2, 0.0), None, None] | Fit time (s): 0.714496374130249 | RMSE: 1499.8009477407797
Model: [(31.0, 2, 0.0), None, None] | Fit time (s): 0.7005043029785156 | RMSE: 1499.8009477407797
Model: [(29.0, 2, 0.0), None, None] | Fit time (s): 0.16689276695251465 | RMSE: 1522.5682362457846
Model: [(30.0, 2, 0.0), None, None] | Fit time (s): 0.17214679718017578 | RMSE: 1510.974495208657
Model: [(29.0, 2, 0.0), None, None] | Fit time (s): 0.15961503982543945 | RMSE: 1522.5682362457846
Model: [(31.0, 2, 0.0), None, None] | Fit time (s): 0.6971402168273926 | RMSE: 1499.8009477407797
Model: [(30.0, 2, 0.0), None, None] | Fit time (s): 0.17052102088928223 | RMSE: 1510.974495208657
Model: [(30.0, 2, 0.0), None, None] | Fit time (s): 0.17418289184570312 | RMSE: 1510.974495208657
Model: [(29.0, 2, 0.0), None, None] | Fit time (s): 0.166581392288208 | RMSE: 1522.5682362457846
Model: [(31.0, 2, 0.0), None, None] | Fit time (s): 0.7068784236907959 | RMSE: 1499.8009477407797
Model: [(31.0, 2, 0.0), None, None] | Fit time (s): 0.7133607864379883 | RMSE: 1499.8009477407797
Model: [(31.0, 2, 0.0), None, None] | Fit time (s): 0.7087390422821045 | RMSE: 1499.8009477407797
Model: [(29.0, 2, 0.0), None, None] | Fit time (s): 0.16353058815002441 | RMSE: 1522.5682362457846
Model: [(30.0, 2, 0.0), None, None] | Fit time (s): 0.17054319381713867 | RMSE: 1510.974495208657
Model: [(30.0, 2, 0.0), None, None] | Fit time (s): 0.17553162574768066 | RMSE: 1510.974495208657
Model: [(28.0, 2, 0.0), None, None] | Fit time (s): 0.14250922203063965 | RMSE: 1533.4682531051967
Model: [(29.0, 2, 0.0), None, None] | Fit time (s): 0.17898774147033691 | RMSE: 1522.5682362457846
Model: [(31.0, 2, 0.0), None, None] | Fit time (s): 0.7157371044158936 | RMSE: 1499.8009477407797
Model: [(30.0, 2, 0.0), None, None] | Fit time (s): 0.1711573600769043 | RMSE: 1510.974495208657
Model: [(29.0, 2, 0.0), None, None] | Fit time (s): 0.16652774810791016 | RMSE: 1522.5682362457846
Model: [(31.0, 2, 0.0), None, None] | Fit time (s): 0.7042090892791748 | RMSE: 1499.8009477407797
Model: [(28.0, 2, 0.0), None, None] | Fit time (s): 0.14162135124206543 | RMSE: 1533.4682531051967
Model: [(31.0, 2, 0.0), None, None] | Fit time (s): 0.7182052135467529 | RMSE: 1499.8009477407797
Model: [(30.0, 2, 0.0), None, None] | Fit time (s): 0.1749744415283203 | RMSE: 1510.974495208657
Model: [(29.0, 2, 0.0), None, None] | Fit time (s): 0.1635432243347168 | RMSE: 1522.5682362457846
Model: [(30.0, 2, 0.0), None, None] | Fit time (s): 0.1707472801208496 | RMSE: 1510.974495208657
Model: [(31.0, 2, 0.0), None, None] | Fit time (s): 0.704993724822998 | RMSE: 1499.8009477407797
Model: [(31.0, 2, 0.0), None, None] | Fit time (s): 0.7081165313720703 | RMSE: 1499.8009477407797
Model: [(29.0, 2, 0.0), None, None] | Fit time (s): 0.16954779624938965 | RMSE: 1522.5682362457846
Model: [(28.0, 2, 0.0), None, None] | Fit time (s): 0.1441023349761963 | RMSE: 1533.4682531051967
Model: [(31.0, 2, 0.0), None, None] | Fit time (s): 0.7114052772521973 | RMSE: 1499.8009477407797
Model: [(30.0, 2, 0.0), None, None] | Fit time (s): 0.19054961204528809 | RMSE: 1510.974495208657
Model: [(28.0, 2, 0.0), None, None] | Fit time (s): 0.13984155654907227 | RMSE: 1533.4682531051967
Model: [(29.0, 2, 0.0), None, None] | Fit time (s): 0.15853190422058105 | RMSE: 1522.5682362457846
Model: [(30.0, 2, 0.0), None, None] | Fit time (s): 0.17388415336608887 | RMSE: 1510.974495208657
Model: [(30.0, 2, 0.0), None, None] | Fit time (s): 0.17470240592956543 | RMSE: 1510.974495208657
Model: [(31.0, 2, 0.0), None, None] | Fit time (s): 0.7021899223327637 | RMSE: 1499.8009477407797
  0%|          | 1110/9223372036854775807 [13:35<1883126147315763:29:04,  1.36trial/s, best loss: 1499.80
```

```
---------------------------------------------------------------------------
KeyboardInterrupt                         Traceback (most recent call last)
<ipython-input-156-d00ee31419cd> in <module>
----> 1 best = bayesian_search(recent_house_price_df["value"], timeout=30 * 60, n_test=6)
      2 print(best)
      3

<ipython-input-155-756aed49a9b2> in bayesian_search(data, timeout, n_test, score_func)
     99                         }
    100         bayes_trials = Trials()
```

```
--> 101         best = fmin(
    102                 bayesian_objective_function,
    103                 space=space,

c:\users\kiwini\.virtualenvs\dsc-phase-4-project\lib\site-packages\hyperopt\fmin.py in fmin(fn, space, al
    505
    506     if allow_trials_fmin and hasattr(trials, "fmin"):
--> 507         return trials.fmin(
    508             fn,
    509             space,

c:\users\kiwini\.virtualenvs\dsc-phase-4-project\lib\site-packages\hyperopt\base.py in fmin(self, fn, spa
    680         from .fmin import fmin
    681
--> 682         return fmin(
    683             fn,
    684             space,

c:\users\kiwini\.virtualenvs\dsc-phase-4-project\lib\site-packages\hyperopt\fmin.py in fmin(fn, space, al
    551
    552     # next line is where the fmin is actually executed
--> 553     rval.exhaust()
    554
    555     if return_argmin:

c:\users\kiwini\.virtualenvs\dsc-phase-4-project\lib\site-packages\hyperopt\fmin.py in exhaust(self)
    354     def exhaust(self):
    355         n_done = len(self.trials)
--> 356         self.run(self.max_evals - n_done, block_until_done=self.asynchronous)
    357         self.trials.refresh()
    358         return self

c:\users\kiwini\.virtualenvs\dsc-phase-4-project\lib\site-packages\hyperopt\fmin.py in run(self, N, block
    268                     # `new_trials`. This is the core of `run`, all the rest is just
    269                     # processes orchestration
--> 270                     new_trials = algo(
    271                         new_ids, self.domain, trials, self.rstate.randint(2 ** 31 - 1)
    272                     )

c:\users\kiwini\.virtualenvs\dsc-phase-4-project\lib\site-packages\hyperopt\tpe.py in suggest(new_ids, do
    942     # evaluate `n_EI_candidates` pyll nodes in `posterior` using `memo`
    943     # TODO: it seems to return idxs, vals, all the same. Is this correct?
--> 944     idxs, vals = pyll.rec_eval(posterior, memo=memo, print_node_on_error=False)
    945
    946     # hack to add offset again for randint params

c:\users\kiwini\.virtualenvs\dsc-phase-4-project\lib\site-packages\hyperopt\pyll\base.py in rec_eval(expr
    909
    910             try:
--> 911                 rval = scope._impls[node.name](*args, **kwargs)
    912
    913             except Exception as e:

c:\users\kiwini\.virtualenvs\dsc-phase-4-project\lib\site-packages\hyperopt\tpe.py in ap_split_trials(o_i
    638     # Splitting is done this way to cope with duplicate loss values.
    639     n_below = min(int(np.ceil(gamma * np.sqrt(len(l_vals)))), gamma_cap)
--> 640     l_order = np.argsort(l_vals)
    641
    642     keep_idxs = set(l_idxs[l_order[:n_below]])

<__array_function__ internals> in argsort(*args, **kwargs)

c:\users\kiwini\.virtualenvs\dsc-phase-4-project\lib\site-packages\numpy\core\fromnumeric.py in argsort(a
   1110
   1111     """
-> 1112     return _wrapfunc(a, 'argsort', axis=axis, kind=kind, order=order)
```

```
   1113
   1114

c:\users\kiwini\.virtualenvs\dsc-phase-4-project\lib\site-packages\numpy\core\fromnumeric.py in _wrapfunc
     56
     57     try:
---> 58         return bound(*args, **kwds)
     59     except TypeError:
     60         # A TypeError occurs if the object does have such a method in its

KeyboardInterrupt:
```

# ARIMA Results (2 Hr. Bayesian Search):

I used BIC to choose the best models to try to fit the smallest model possible to avoid overfitting. RMSE is too slow during the search, but I used it to compare models with different orders of difference and select a final model. BIC penalizes additional terms more heavily than AIC, but the best models

## Top 3 models (by BIC)

- Model: [(31.0, 2, 0.0), None, None] | Fit time (s): 0.7021899223327637 | BIC: 1499.8009477407797
- Model: [(30.0, 2, 0.0), None, None] | Fit time (s): 0.17470240592956543 | BIC: 1510.974495208657
- Model: [(3.0, 2, 28.0), None, None] | Fit time (s): 3.136613607406616 | BIC: 1520.7070317323107

The non-seasonal model uses the most AR terms allowed in our search (30), with 0 or a couple of MA terms.

## Comparison to Hand-Selected Model

BIC is higher for all 3 than our (0,2,0) model.

176
```
# Check RMSE for Bayesian models
top_configs = [
        # Worst config by BIC, just to see difference
        [(8, 2, 4), None, None],
        # From first grid search
        [(3, 2, 3), None, None],
        # From larger grid search
        [(2, 2, 10), None, None],
        [(0, 2, 10), None, None],
        [(1, 2, 10), None, None],
        # From bayesian_search
        [(31, 2, 0), None, None],
        [(30, 2, 0), None, None],
        [(3, 2, 28), None, None],
]
```

```
for cfg in top_configs:
        score_model(recent_house_price_df["value"], n_test=24, cfg=cfg, score_func=walk_forward_validatic
```

```
Model: [(8, 2, 4), None, None] | Fit time (s): 10.607648849487305 | RMSE: 3251742.5619525746
Model: [(3, 2, 3), None, None] | Fit time (s): 3.701350212097168 | RMSE: 689.8407717617903
Model: [(2, 2, 10), None, None] | Fit time (s): 7.394841432571411 | RMSE: 761.8897648927265
Model: [(0, 2, 10), None, None] | Fit time (s): 8.144782543182373 | RMSE: 770.9269503353206
Model: [(1, 2, 10), None, None] | Fit time (s): 9.16835355758667 | RMSE: 757.4968072990458
Model: [(31, 2, 0), None, None] | Fit time (s): 29.643099784851074 | RMSE: 766.3138167074713
Model: [(30, 2, 0), None, None] | Fit time (s): 15.25999116897583 | RMSE: 755.8501004825118
Error: Input contains NaN, infinity or a value too large for dtype('float64').
```

## Top models (RMSE)

- Model: [(3, 2, 3), None, None] | Fit time (s): 3.874885082244873 | RMSE: 689.8407717617903
- Model: [(2, 2, 10), None, None] | Fit time (s): 7.570343255996704 | RMSE: 761.8897648927265
- Model: [(0, 2, 10), None, None] | Fit time (s): 8.15896463394165 | RMSE: 770.9269503353206
- Model: [(1, 2, 10), None, None] | Fit time (s): 9.20403242111206 | RMSE: 757.4968072990458
- Model: [(31, 2, 0), None, None] | Fit time (s): 29.67447853088379 | RMSE: 766.3138167074713
- Model: [(30, 2, 0), None, None] | Fit time (s): 15.325401782989502 | RMSE: 755.8501004825118
- Model: [(3, 2, 28), None, None] | ERROR

## Analysis

BIC gets better and better with larger parameter sizes, but the prediction error does not improve over small p,q

I want to do one last small grid search directly optimizing RMSE

161
```
cfg_list = list([(p, 2, q), None, None]
                                          for (p, q) in itertools.product(
                                                        range(4),
                                                        range(4)
                                          ))
grid_search(recent_house_price_df["value"], cfg_list, n_test=24, score_func=walk_forward_validation)
```

```
Model: [(0, 2, 0), None, None] | Fit time (s): 0.13982772827148438 | RMSE: 698.3075317645577
Model: [(0, 2, 1), None, None] | Fit time (s): 0.7674069404602051 | RMSE: 700.7497223117985
Model: [(0, 2, 2), None, None] | Fit time (s): 0.6070120334625244 | RMSE: 735.7782893163704
Model: [(0, 2, 3), None, None] | Fit time (s): 1.3775203227996826 | RMSE: 722.6301848882089
Model: [(1, 2, 0), None, None] | Fit time (s): 0.1199331283569336 | RMSE: 743.9272698396367
Model: [(1, 2, 1), None, None] | Fit time (s): 0.8196494579315186 | RMSE: 699.6375025312204
Model: [(1, 2, 2), None, None] | Fit time (s): 0.6418993473052979 | RMSE: 732.547587699774
Model: [(1, 2, 3), None, None] | Fit time (s): 2.654660940170288 | RMSE: 709.8279926596362
Model: [(2, 2, 0), None, None] | Fit time (s): 0.13187003135681152 | RMSE: 695.0346788923246
Model: [(2, 2, 1), None, None] | Fit time (s): 0.958806037902832 | RMSE: 695.1955605367339
Model: [(2, 2, 2), None, None] | Fit time (s): 1.7949247360229492 | RMSE: 773.8336130022049
Model: [(2, 2, 3), None, None] | Fit time (s): 2.974283456802368 | RMSE: 715.096536300541
```

```
Model: [(3, 2, 0), None, None] | Fit time (s): 0.15184926986694336 | RMSE: 715.6670956939015
Model: [(3, 2, 1), None, None] | Fit time (s): 0.871971845626831 | RMSE: 715.8735032093646
Model: [(3, 2, 2), None, None] | Fit time (s): 2.0923759937286377 | RMSE: 708.02489574585
Model: [(3, 2, 3), None, None] | Fit time (s): 3.7220497131347656 | RMSE: 689.8407717617903
```

```
161 [('[(3, 2, 3), None, None]', 689.8407717617903),
 ('[(2, 2, 0), None, None]', 695.0346788923246),
 ('[(2, 2, 1), None, None]', 695.1955605367339),
 ('[(0, 2, 0), None, None]', 698.3075317645577),
 ('[(1, 2, 1), None, None]', 699.6375025312204),
 ('[(0, 2, 1), None, None]', 700.7497223117985),
 ('[(3, 2, 2), None, None]', 708.02489574585),
 ('[(1, 2, 3), None, None]', 709.8279926596362),
 ('[(2, 2, 3), None, None]', 715.096536300541),
 ('[(3, 2, 0), None, None]', 715.6670956939015),
 ('[(3, 2, 1), None, None]', 715.8735032093646),
 ('[(0, 2, 3), None, None]', 722.6301848882089),
 ('[(1, 2, 2), None, None]', 732.547587699774),
 ('[(0, 2, 2), None, None]', 735.7782893163704),
 ('[(1, 2, 0), None, None]', 743.9272698396367),
 ('[(2, 2, 2), None, None]', 773.8336130022049)]
```

## Final ARIMA Model

(0,2,0) is very close to the best model I found, with minimal overfitting risk. We will do some forecasting with this model.

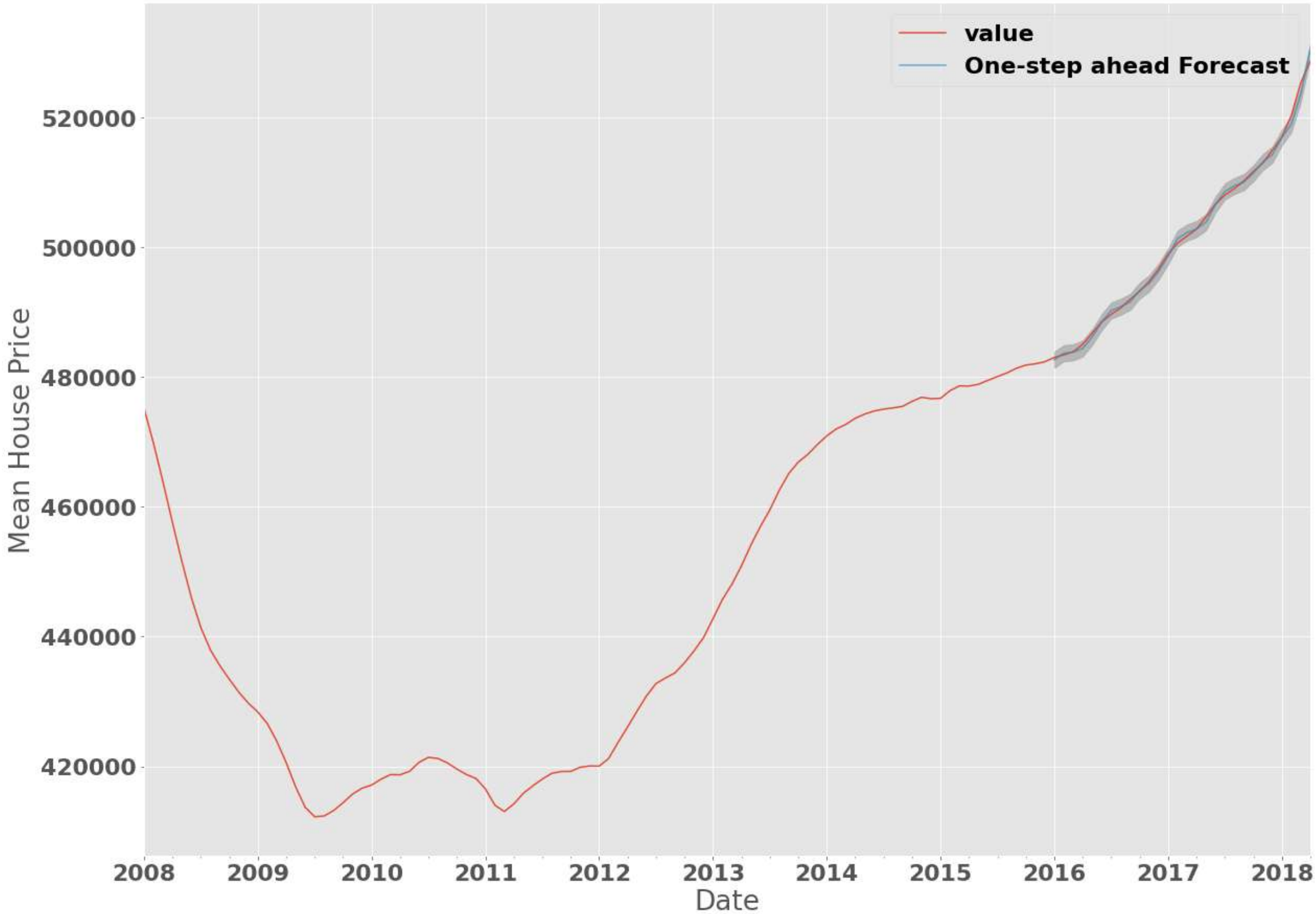
```
162 model = SARIMAX(recent_house_price_df["value"], order=(0,2,0))
```

# Step 6: Interpreting Results

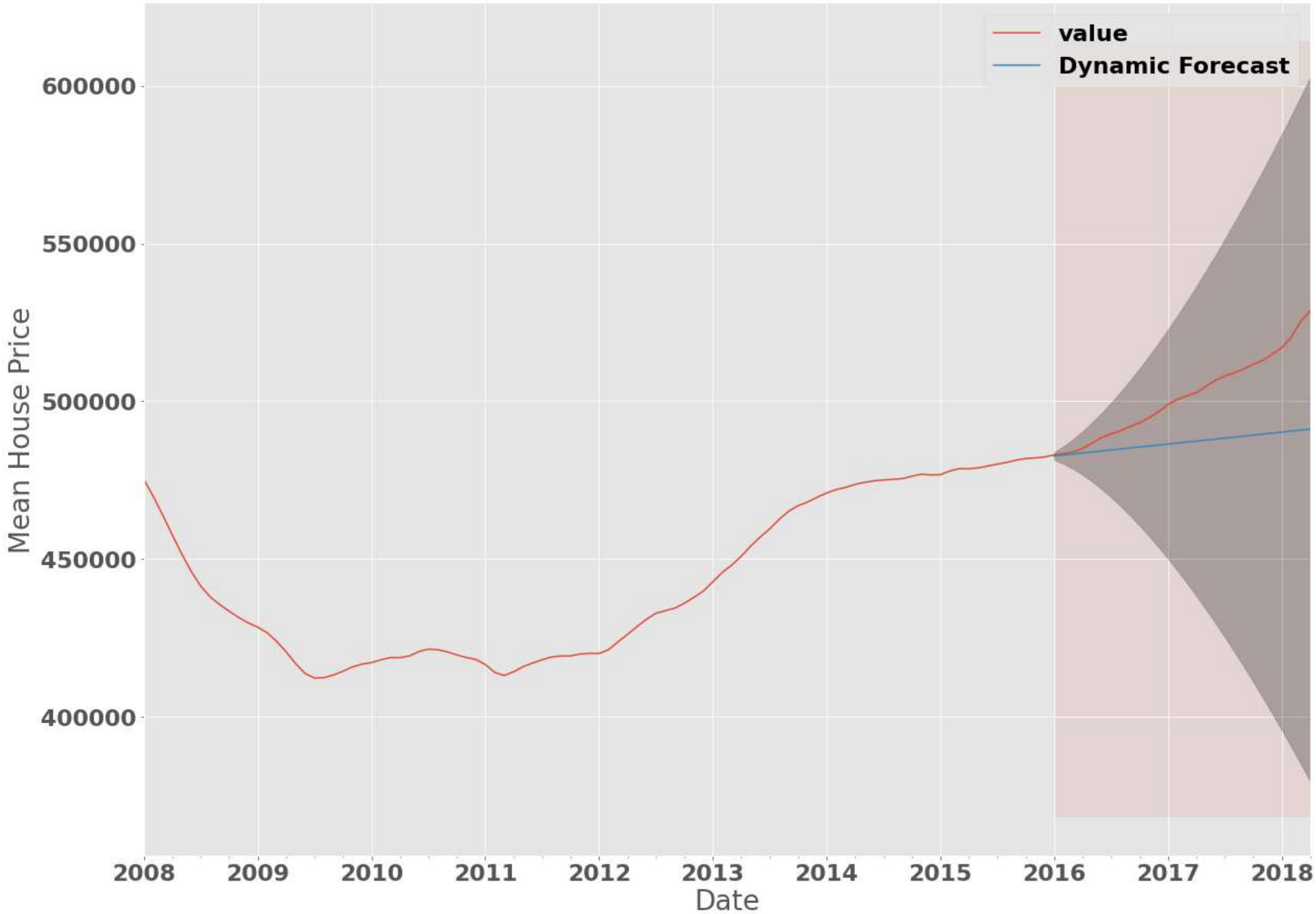
Let's use some visuals to see how our model is doing.

```
170 start_date = pd.to_datetime("2008-01-01")
pred_start_date = pd.to_datetime("2016-01-01")
#pred_start_date = pd.to_datetime("2017-07-01")
end_date = recent_house_price_df.index[-1]
observed= recent_house_price_df[recent_house_price_df.index >= start_date]
```

```
171 pred = model_fit.get_prediction(start=pred_start_date, dynamic=False)
pred_ci = pred.conf_int()
ax_static = observed.plot(label='observed', figsize=(20, 15))
pred.predicted_mean.plot(ax=ax_static, label='One-step ahead Forecast', alpha=.7)

ax_static.fill_between(pred_ci.index,
                pred_ci.iloc[:, 0],
                pred_ci.iloc[:, 1], color='k', alpha=.2)

ax_static.set_xlabel('Date')
ax_static.set_ylabel('Mean House Price')
plt.legend()

plt.show()
```

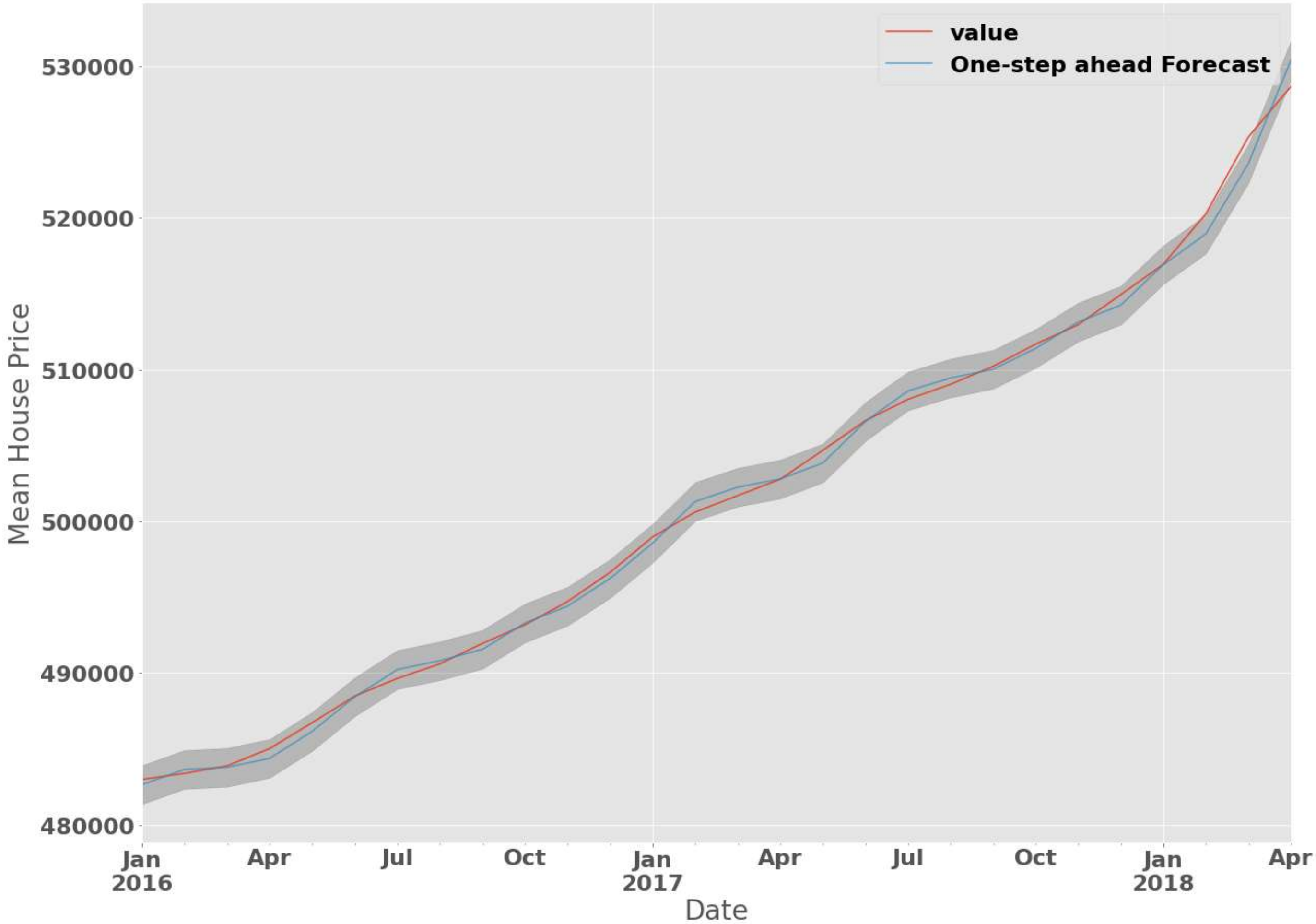



172
```
pred_dynamic = model_fit.get_prediction(start=pred_start_date, dynamic=True, full_results=True)
pred_dynamic_ci = pred_dynamic.conf_int()

ax_dyn = observed.plot(label='observed', figsize=(20, 15))
pred_dynamic.predicted_mean.plot(label='Dynamic Forecast', ax=ax_dyn)

ax_dyn.fill_between(pred_dynamic_ci.index,
                pred_dynamic_ci.iloc[:, 0],
                pred_dynamic_ci.iloc[:, 1], color='k', alpha=.25)

ax_dyn.fill_betweenx(ax_dyn.get_ylim(), pred_start_date, end_date,
                 alpha=.1, zorder=-1)


ax_dyn.set_xlabel('Date')
ax_dyn.set_ylabel('Mean House Price')
plt.legend()

plt.show()
```



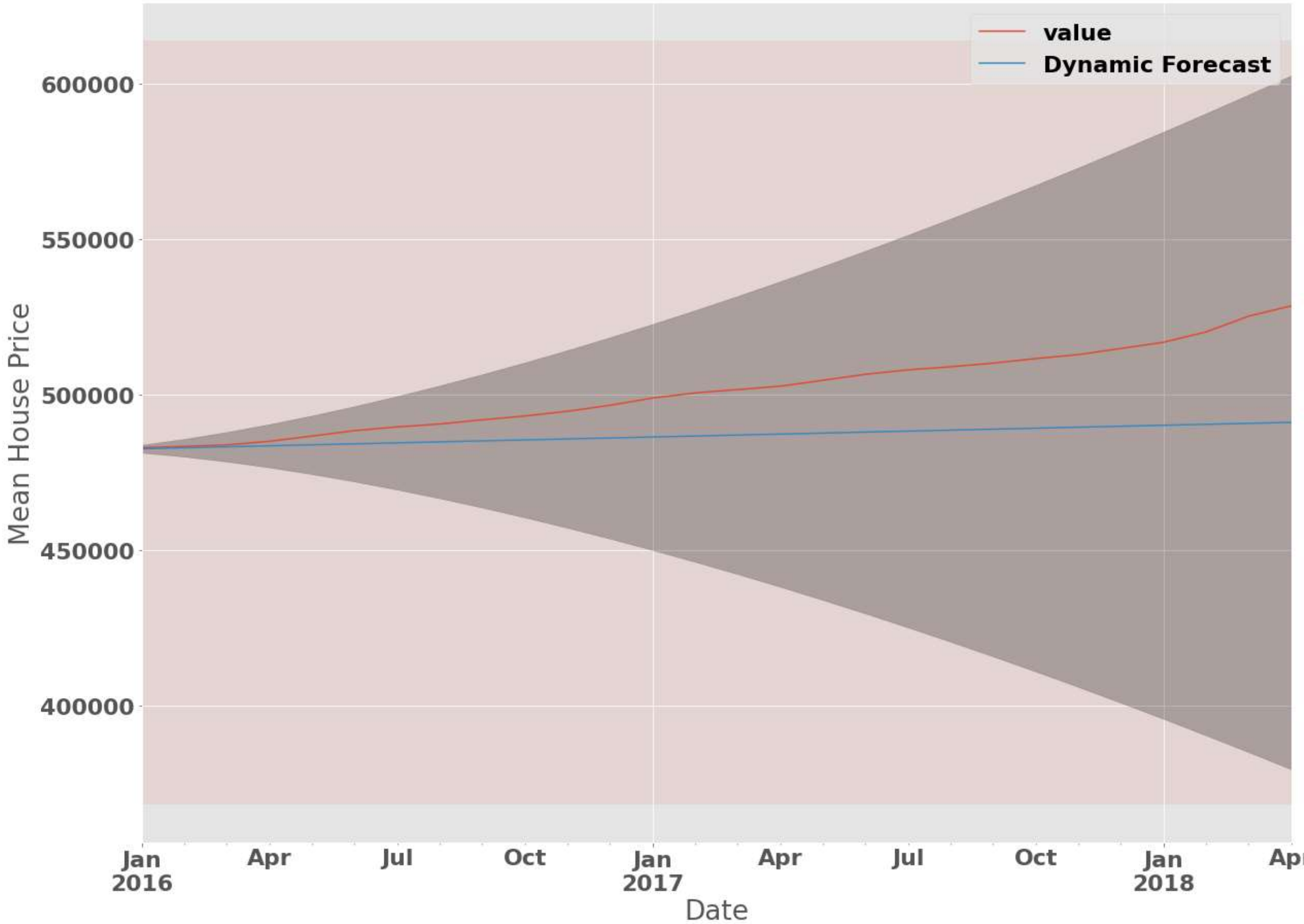

## Zoomed in

173
```
observed= recent_house_price_df[recent_house_price_df.index >= pred_start_date]
pred = model_fit.get_prediction(start=pred_start_date, dynamic=False)
pred_ci = pred.conf_int()
ax_static = observed.plot(label='observed', figsize=(20, 15))
pred.predicted_mean.plot(ax=ax_static, label='One-step ahead Forecast', alpha=.7)

ax_static.fill_between(pred_ci.index,
                                           pred_ci.iloc[:, 0],
                                           pred_ci.iloc[:, 1], color='k', alpha=.2)

ax_static.set_xlabel('Date')
ax_static.set_ylabel('Mean House Price')
plt.legend()

plt.show()
```




Only 1 out of 24 1-month predictions is out of the 95% confidence interval. The confidence interval seems accurate.

174
```
pred_dynamic = model_fit.get_prediction(start=pred_start_date, dynamic=True, full_results=True)
pred_dynamic_ci = pred_dynamic.conf_int()

ax_dyn = observed.plot(label='observed', figsize=(20, 15))
pred_dynamic.predicted_mean.plot(label='Dynamic Forecast', ax=ax_dyn)

ax_dyn.fill_between(pred_dynamic_ci.index,
                                        pred_dynamic_ci.iloc[:, 0],
                                        pred_dynamic_ci.iloc[:, 1], color='k', alpha=.25)

ax_dyn.fill_betweenx(ax_dyn.get_ylim(), pred_start_date, end_date,
                                         alpha=.1, zorder=-1)


ax_dyn.set_xlabel('Date')
ax_dyn.set_ylabel('Mean House Price')
plt.legend()

plt.show()
```




The 2 year prediction is off by almost $50,000. The confidence interval is more than$200,000.

Forecasts only seem useful for about 3-6 months for most applications: the confidence interval gets too big past that point.

# Final Result

The model is not great past 3 month forecasts. To get a better result, a different process (not ARIMA-based) or additional data is required. ARIMA has been fully tried on the current data. Potential data for improving future models: monthly unemployment rates, interest rates, stock index prices, house prices in nearby areas, etc.