Currencies_1_2014_to_2015_in_sample

November 12, 2018

1 Pair Trading:

1.0.1 This project is to extract potential opportunities of pair trading for varies futures.

1.0.2 Data is based on minute prices from Quantopian. This Python code is for Quantopian.

1.0.3 Steps:

1. Compute sample correlation of in-sample future returns.

2. Compute and plot simple price spreads of any two futures for further observations. For example, for futures X and Y, if series of (X's returns - Y's retuns) looks like a stable series, then this implies that it is possible for us to generate stable returns by going long a share of X and going short a share of Y.

3. Compute and plot division price spreads of any two futures for further observations.

4. Find pairs with significant (p-value < 0.05) co-integration.

5. If future X and future Y has a significant in-sample co-integration, apply OLS regression model to get coefficients between X's returns and Y's returns during in-sample periods. For example, in-sample period is 2014-2015. Then, get coefficient and intercept between X's returns and Y's returns in 2014-2015, such as (Y'sreturn = 0.1 + 0.5 * X's return).

6. Compute, plot and check residules in validation period. For example, for future X and future Y, compute residules as (Y's return - 0.1 - 0.5 * X's return) in validation period, 2016-2017.

If the residules look like stable series, this further confirms that we may make use of the pair relationships to form a pair trading strategy.

2 Currency Futures

2.1 In-sample: 2014-2015 validation: 2016-2017

```
In [2]: import pandas as pd
        import numpy as np
        import matplotlib.pyplot as plt
        import statsmodels.api as sm
```

```
from quantopian.research.experimental import continuous_future, history
import statsmodels.tsa.stattools as ts
from statsmodels.tsa.stattools import adfuller
import seaborn as sns
```

In [3]:
```
Currencies={
    'currencies': {
        'jpy': continuous_future('JY'),
        'jpy_emini': continuous_future('JE'),
        'cad': continuous_future('CD'),
        'mxn': continuous_future('ME'),
        'aud': continuous_future('AD'),
        'nzd': continuous_future('NZ'),
        'gbp': continuous_future('BP'),
        'chf': continuous_future('SF'),
        'eur_emicro': continuous_future('EU'),
        'euro_fx': continuous_future('EC'),
        'euro_fx_emini': continuous_future('EE')
    }}
```

In [12]:
```
# Get data of different futures
def get_data(future_dic,start_date, end_date,fields_type='price',frequency_type='minu
    df = pd.DataFrame()
    future_list = future_dic.values()[0]
    for future_name, future_data in future_list.items():

        data = history(future_data, start = start_date, end = end_date, fields = fiel
        data = pd.DataFrame(data)
        data.columns=[future_name+'_'+'_'+frequency_type]
        df = pd.concat([df,data],axis=1)
    return df

# Calculate simple price spread
def spread_subtraction(df,times=1):
    future_name = df.columns

    delta_df = pd.DataFrame()

    for i in range(len(future_name)):
        for j in range(i+1,len(future_name)):
            y_future = future_name[i]
            x_future = future_name[j]

            delta_df[y_future+' - '+x_future] = df[y_future] - times*df[x_future]

    return delta_df
```

```
# Calculate price division
def spread_division(df):
    future_name = df.columns
    delta_df = pd.DataFrame()

    for i in range(len(future_name)):
        for j in range(i+1,len(future_name)):
            y_future = future_name[i]
            x_future = future_name[j]

            delta_df[y_future+' / '+x_future] = df[y_future] / df[x_future]

    return delta_df


# Plot time series
def plotting(df):
    future_name = df.columns
    num = len(future_name)

    for i in future_name:
        plt.figure(figsize=(10,3))
        plt.plot(df[i])
        plt.title(i)
    plt.show()

# Get adf test results to determine whether time series is stationary
def adf_test(df):
    future_name = df.columns
    adf_df = pd.DataFrame()

    for i in future_name:
        adftest = adfuller(df[i])
        adf_df.ix[i,'Test Statistic'] = adf_test[0]
        adf_df.ix[i,'p-value'] = adf_test[1]
        adf_df.ix[i,'Test Statistic'] = adf_test[0]

        for key, value in adftest[4].items():
            adf_df[i,'Critical Value (%s)'% key] = value

    return adf_test


# Find paris with significant cointegration
def find_cointegrated_paris(df,pvalue_level=0.05):
    future_name = df.columns
    n = len(future_name)
    pvalue_matrix = np.ones((n,n))
```

```
    pairs = []

    for i in range(len(future_name)):
        for j in range(i+1,len(future_name)):
            y_future = future_name[i]
            x_future = future_name[j]

            result = ts.coint(df[y_future],df[x_future])

            pvalue = result[1]
            pvalue_matrix[i,j] = pvalue

            if pvalue < pvalue_level:
                pairs.append((y_future,x_future))
    return pvalue_matrix, pairs

# Get ols parameters
def ols_in_sample(df,pairs):
    future_name = df.columns
    ols_df = pd.DataFrame()

    for i in range(len(future_name)):
        for j in range(i+1,len(future_name)):
            y_future = future_name[i]
            x_future = future_name[j]

            if (y_future,x_future) in pairs:
                reg = sm.add_constant(df[x_future])
                results = sm.OLS(df[y_future], reg).fit()

                name = str(y_future+' vs '+x_future)

                ols_df.loc[name,'cons'] = results.params[0]
                ols_df.loc[name,'coef'] = results.params[1]

    return ols_df

# Get residules of validation data based on in-sample ols parameters
def ols_validation(df, ols_df,pairs):
    future_name = df.columns
    ols_validation_df = pd.DataFrame()
    for i in range(len(future_name)):
        for j in range(i+1,len(future_name)):
            y_future = future_name[i]
            x_future = future_name[j]

            if (y_future,x_future) in pairs:
```

```
                    name = str(y_future+' vs '+x_future)

                    cons = ols_df.loc[name,'cons']
                    coef = ols_df.loc[name,'coef']
                    ols_validation_df[y_future+' vs '+x_future+'_residules'] = df[y_future

        return ols_validation_df
```

2.2 1. In-sample Period: 2014-2015 Validation Period: 2016-2017

```
In [5]: future_list = Currencies.values()[0].keys()
```

```
In [6]: data = get_data(Currencies,'2014-01-01','2015-12-31')
```

2.2.1 1.1 Correlation: 2014-01-01 to 2015-12-31

```
In [7]: correlation =data.corr()
        correlation
```

Out[7]:

	eur_emicro__minute	nzd__minute	jpy__minute	\
eur_emicro__minute	1.000000	0.871055	0.958945	
nzd__minute	0.871055	1.000000	0.875685	
jpy__minute	0.958945	0.875685	1.000000	
euro_fx__minute	0.999996	0.871235	0.958669	
mxn__minute	0.915263	0.943894	0.898045	
aud__minute	0.927362	0.956298	0.915378	
chf__minute	0.804660	0.764675	0.815733	
euro_fx_emini__minute	0.999971	0.871314	0.958730	
gbp__minute	0.931758	0.783519	0.917068	
jpy_emini__minute	0.959213	0.875957	0.999990	
cad__minute	0.925965	0.932713	0.886450	

	euro_fx__minute	mxn__minute	aud__minute	chf__minute	\
eur_emicro__minute	0.999996	0.915263	0.927362	0.804660	
nzd__minute	0.871235	0.943894	0.956298	0.764675	
jpy__minute	0.958669	0.898045	0.915378	0.815733	
euro_fx__minute	1.000000	0.915755	0.927524	0.804652	
mxn__minute	0.915755	1.000000	0.980788	0.766600	
aud__minute	0.927524	0.980788	1.000000	0.774723	
chf__minute	0.804652	0.766600	0.774723	1.000000	
euro_fx_emini__minute	0.999971	0.915594	0.927641	0.804832	
gbp__minute	0.931424	0.846321	0.881833	0.792271	
jpy_emini__minute	0.958941	0.898460	0.915519	0.815446	
cad__minute	0.926494	0.978414	0.973001	0.752621	

	euro_fx_emini__minute	gbp__minute	jpy_emini__minute	\
eur_emicro__minute	0.999971	0.931758	0.959213	
nzd__minute	0.871314	0.783519	0.875957	
jpy__minute	0.958730	0.917068	0.999990	

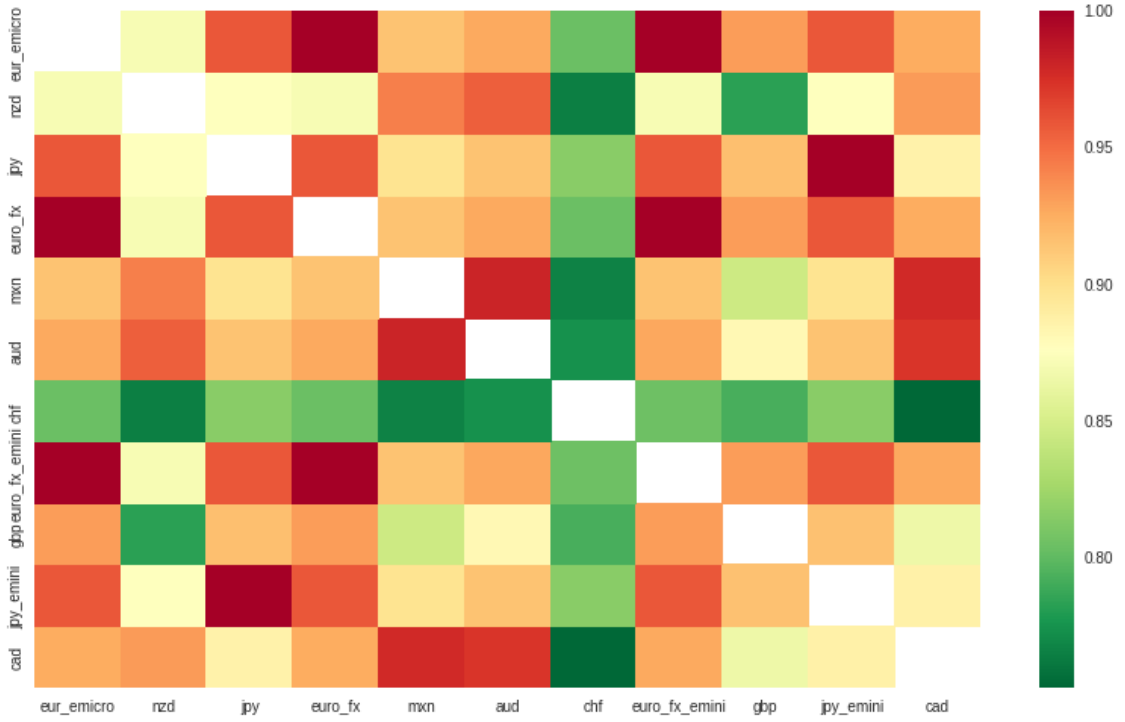
euro_fx__minute	0.999971	0.931424	0.958941
mxn__minute	0.915594	0.846321	0.898460
aud__minute	0.927641	0.881833	0.915519
chf__minute	0.804832	0.792271	0.815446
euro_fx_emini__minute	1.000000	0.932270	0.958997
gbp__minute	0.932270	1.000000	0.916705
jpy_emini__minute	0.958997	0.916705	1.000000
cad__minute	0.926645	0.865113	0.886955

	cad__minute
eur_emicro__minute	0.925965
nzd__minute	0.932713
jpy__minute	0.886450
euro_fx__minute	0.926494
mxn__minute	0.978414
aud__minute	0.973001
chf__minute	0.752621
euro_fx_emini__minute	0.926645
gbp__minute	0.865113
jpy_emini__minute	0.886955
cad__minute	1.000000

2.2.2 Heatmap of correlation: Red High correlation

```
In [8]: sns.heatmap(correlation,xticklabels=future_list, yticklabels=future_list,cmap = 'RdYlGr
```

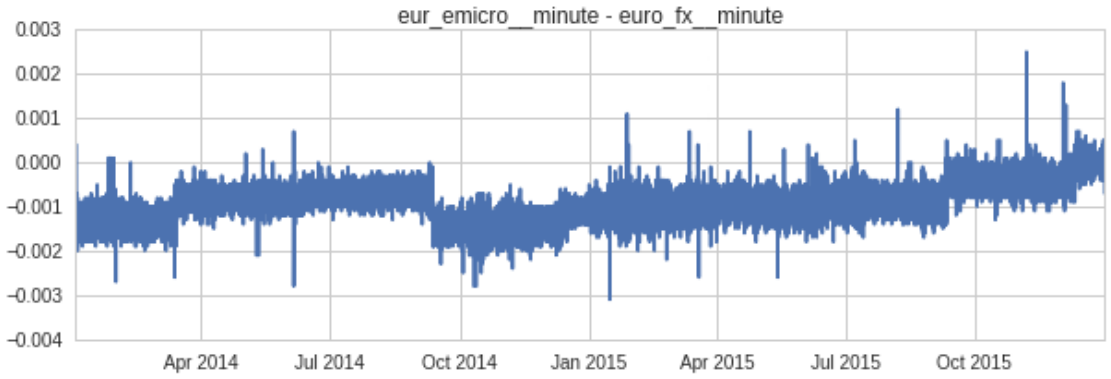
```
Out[8]: <matplotlib.axes._subplots.AxesSubplot at 0x7fdc2447fbd0>
```



2.2.3 1.2 Price Speard

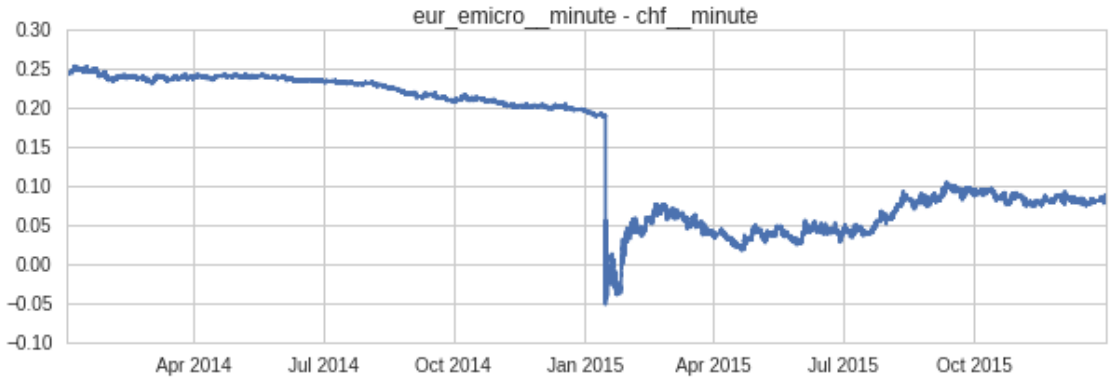
In [9]:
```
a = spread_subtraction(data)
plotting(a)
```

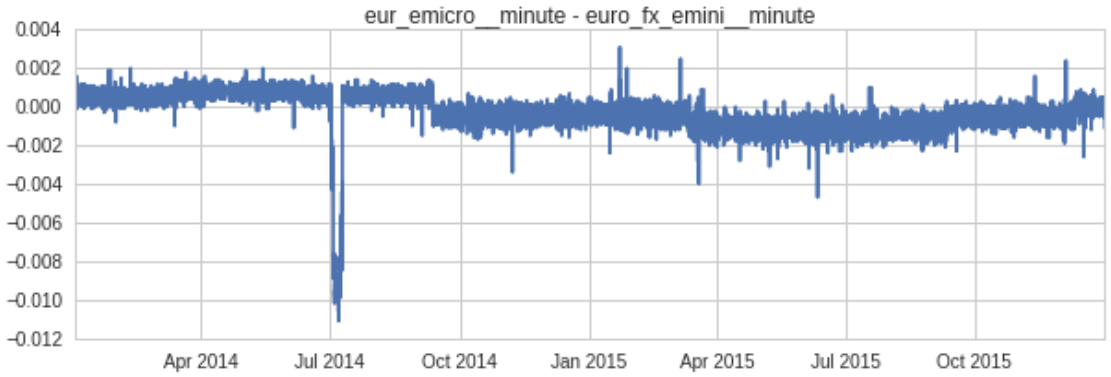
```
/usr/local/lib/python2.7/dist-packages/matplotlib/pyplot.py:516: RuntimeWarning: More than 20 f
  max_open_warning, RuntimeWarning)
```


eur_emicro__minute - euro_fx__minute
0.003
0.002
0.001
0.000
−0.001
−0.002
−0.003
−0.004
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015

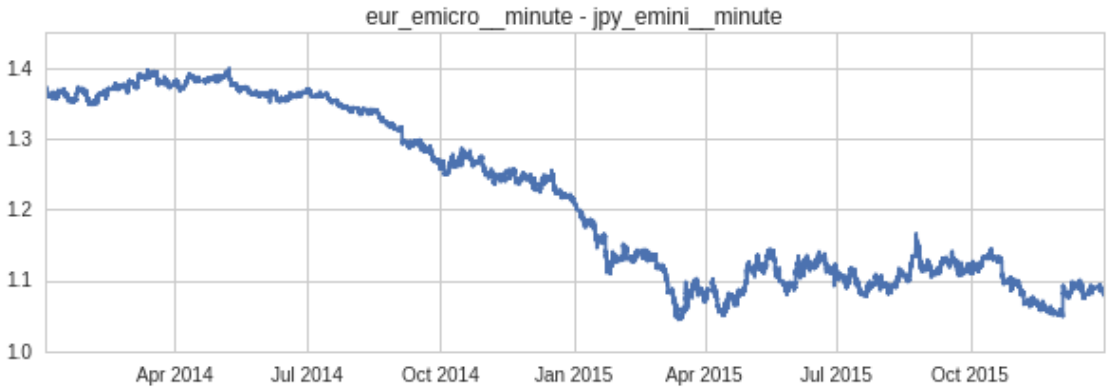

eur_emicro__minute - mxn__minute
1.35
1.30
1.25
1.20
1.15
1.10
1.05
1.00
0.95
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


eur_emicro__minute - aud__minute
0.60
0.55
0.50
0.45
0.40
0.35
0.30
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


eur_emicro__minute - chf__minute
0.30
0.25
0.20
0.15
0.10
0.05
0.00
−0.05
−0.10
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


eur_emicro__minute - euro_fx_emini__minute
0.004
0.002
0.000
−0.002
−0.004
−0.006
−0.008
−0.010
−0.012
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


eur_emicro__minute - gbp__minute
−0.20
−0.25
−0.30
−0.35
−0.40
−0.45
−0.50
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


eur_emicro__minute - jpy_emini__minute
1.4
1.3
1.2
1.1
1.0
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


eur_emicro__minute - cad__minute
0.55
0.50
0.45
0.40
0.35
0.30
0.25
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


nzd__minute - jpy__minute
0.85
0.80
0.75
0.70
0.65
0.60
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


nzd__minute - euro_fx__minute
−0.30
−0.35
−0.40
−0.45
−0.50
−0.55
−0.60
−0.65
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


nzd__minute - mxn__minute
0.80
0.75
0.70
0.65
0.60
0.55
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


nzd__minute - aud__minute
0.00
−0.02
−0.04
−0.06
−0.08
−0.10
−0.12
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


nzd__minute - chf__minute
−0.20
−0.25
−0.30
−0.35
−0.40
−0.45
−0.50
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


nzd__minute - euro_fx_emini__minute
−0.30
−0.35
−0.40
−0.45
−0.50
−0.55
−0.60
−0.65
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


nzd__minute - gbp__minute
−0.70
−0.75
−0.80
−0.85
−0.90
−0.95
−1.00
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


nzd__minute - jpy_emini__minute
0.85
0.80
0.75
0.70
0.65
0.60
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


nzd__minute - cad__minute
−0.02
−0.04
−0.06
−0.08
−0.10
−0.12
−0.14
−0.16
−0.18
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


jpy__minute - euro_fx__minute
−1.0
−1.1
−1.2
−1.3
−1.4
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015

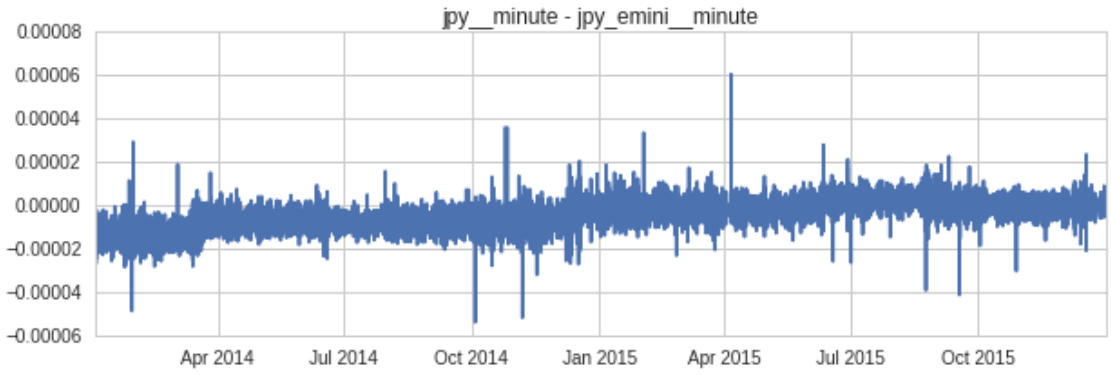

jpy__minute - mxn__minute
−0.045
−0.050
−0.055
−0.060
−0.065
−0.070
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


jpy__minute - aud__minute
−0.65
−0.70
−0.75
−0.80
−0.85
−0.90
−0.95
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


jpy__minute - chf__minute
−0.95
−1.00
−1.05
−1.10
−1.15
−1.20
−1.25
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


jpy__minute - euro_fx_emini__minute
−1.0
−1.1
−1.2
−1.3
−1.4
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


jpy__minute - gbp__minute
−1.40
−1.45
−1.50
−1.55
−1.60
−1.65
−1.70
−1.75
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015

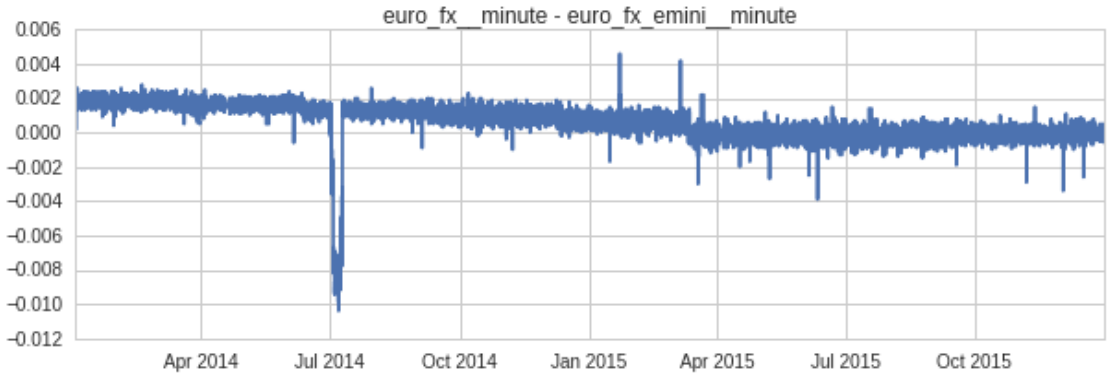

jpy__minute - jpy_emini__minute
0.00008
0.00006
0.00004
0.00002
0.00000
−0.00002
−0.00004
−0.00006
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


jpy__minute - cad__minute
−0.70
−0.75
−0.80
−0.85
−0.90
−0.95
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


euro_fx__minute - mxn__minute
1.35
1.30
1.25
1.20
1.15
1.10
1.05
1.00
0.95
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


euro_fx__minute - aud__minute
0.60
0.55
0.50
0.45
0.40
0.35
0.30
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


euro_fx__minute - chf__minute
0.30
0.25
0.20
0.15
0.10
0.05
0.00
−0.05
−0.10
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


euro_fx__minute - euro_fx_emini__minute
0.006
0.004
0.002
0.000
−0.002
−0.004
−0.006
−0.008
−0.010
−0.012
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


euro_fx__minute - gbp__minute
−0.20
−0.25
−0.30
−0.35
−0.40
−0.45
−0.50
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


euro_fx__minute - jpy_emini__minute
1.4
1.3
1.2
1.1
1.0
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


euro_fx__minute - cad__minute
0.55
0.50
0.45
0.40
0.35
0.30
0.25
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015

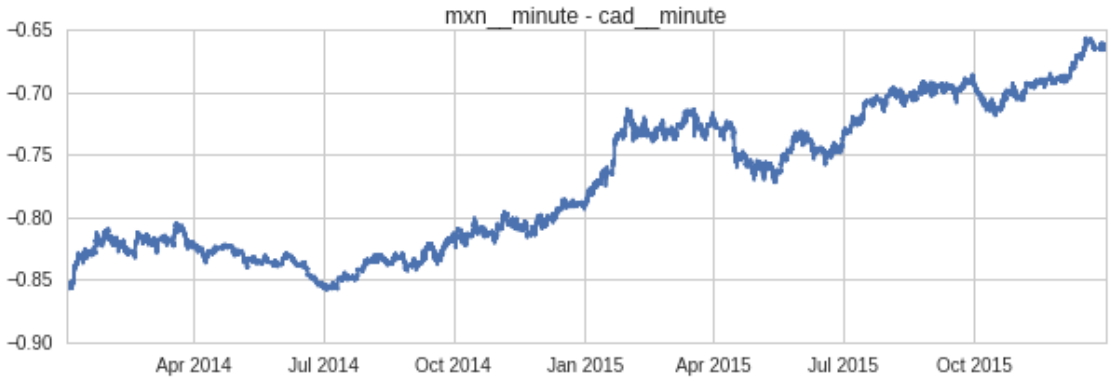

mxn__minute - aud__minute
−0.60
−0.65
−0.70
−0.75
−0.80
−0.85
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


mxn__minute - chf__minute
−0.90
−0.95
−1.00
−1.05
−1.10
−1.15
−1.20
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


mxn__minute - euro_fx_emini__minute
−1.0
−1.1
−1.2
−1.3
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015

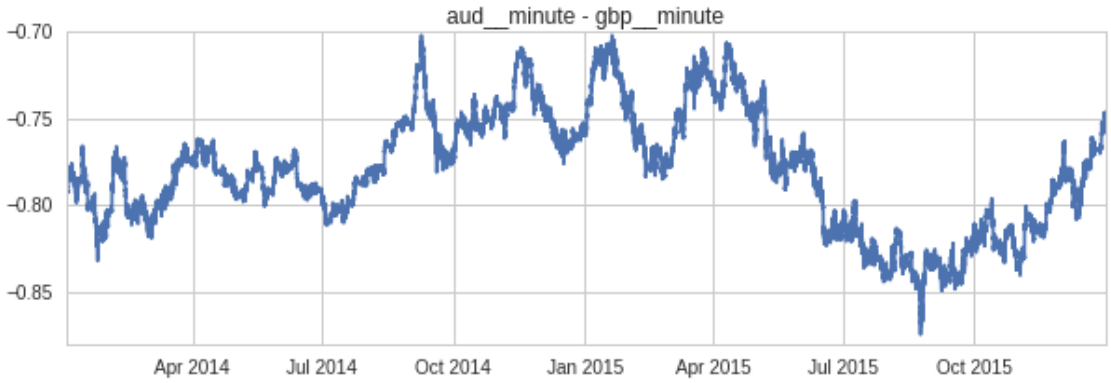

mxn__minute - gbp__minute
−1.35
−1.40
−1.45
−1.50
−1.55
−1.60
−1.65
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015

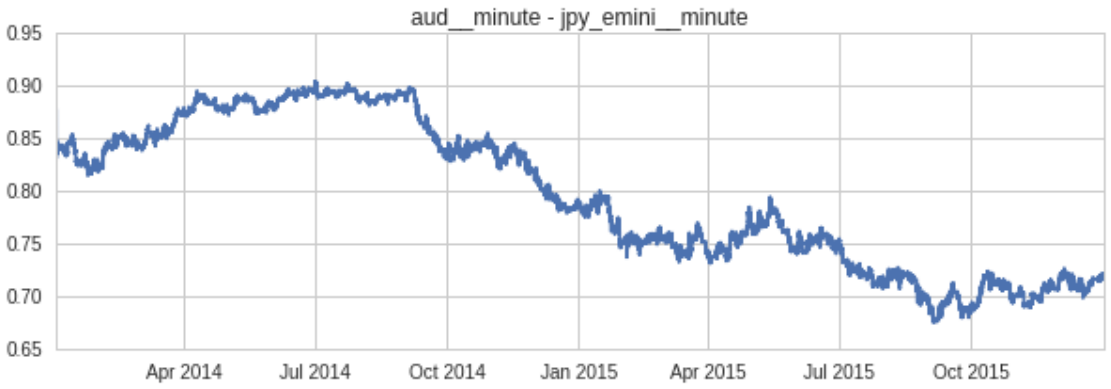

mxn__minute - jpy_emini__minute
0.070
0.065
0.060
0.055
0.050
0.045
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


mxn__minute - cad__minute
−0.65
−0.70
−0.75
−0.80
−0.85
−0.90
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


aud__minute - chf__minute
−0.15
−0.20
−0.25
−0.30
−0.35
−0.40
−0.45
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


aud__minute - euro_fx_emini__minute
−0.30
−0.35
−0.40
−0.45
−0.50
−0.55
−0.60
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015

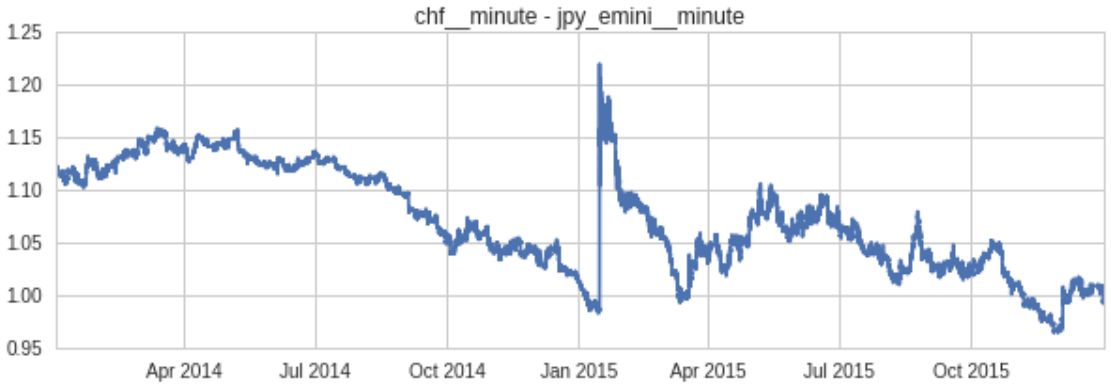

aud__minute - gbp__minute
−0.70
−0.75
−0.80
−0.85
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


aud__minute - jpy_emini__minute
0.95
0.90
0.85
0.80
0.75
0.70
0.65
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


aud__minute - cad__minute
0.02
0.00
−0.02
−0.04
−0.06
−0.08
−0.10
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015

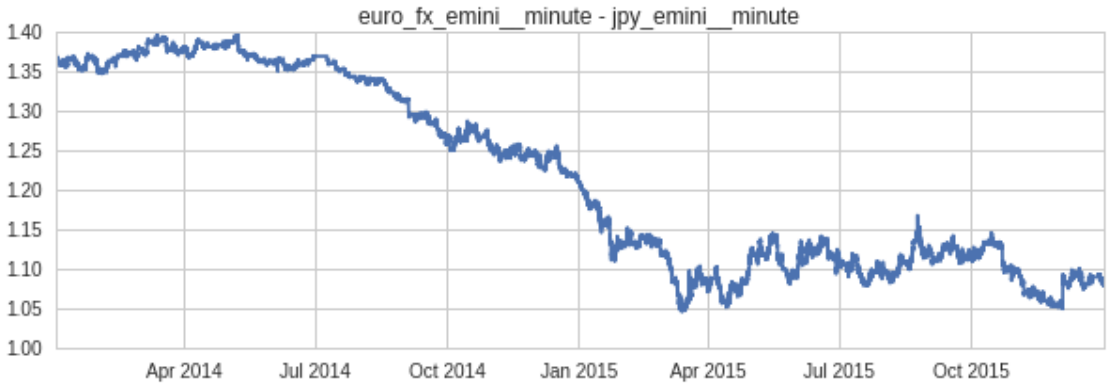

chf__minute - euro_fx_emini__minute
0.10
0.05
0.00
−0.05
−0.10
−0.15
−0.20
−0.25
−0.30
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


chf__minute - gbp__minute
−0.25
−0.30
−0.35
−0.40
−0.45
−0.50
−0.55
−0.60
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


chf__minute - jpy_emini__minute
1.25
1.20
1.15
1.10
1.05
1.00
0.95
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015

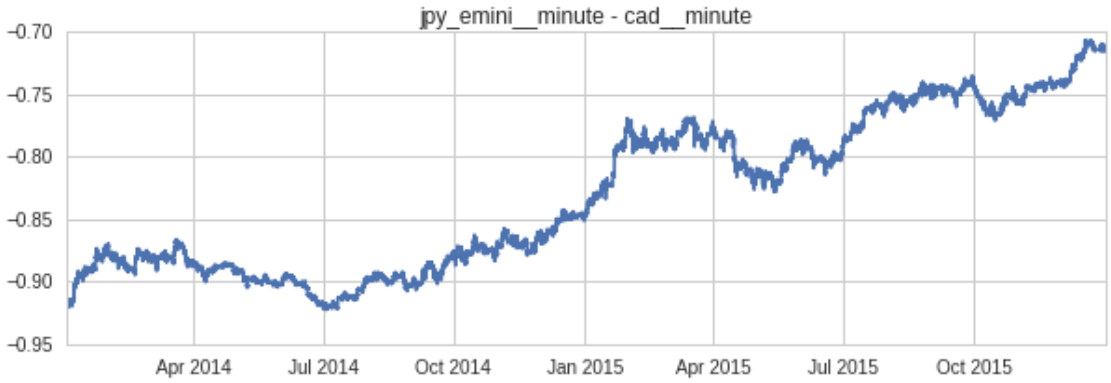

chf__minute - cad__minute
0.40
0.35
0.30
0.25
0.20
0.15
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


euro_fx_emini__minute - gbp__minute
−0.20
−0.25
−0.30
−0.35
−0.40
−0.45
−0.50
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


euro_fx_emini__minute - jpy_emini__minute
1.40
1.35
1.30
1.25
1.20
1.15
1.10
1.05
1.00
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


euro_fx_emini__minute - cad__minute
0.55
0.50
0.45
0.40
0.35
0.30
0.25
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


gbp__minute - jpy_emini__minute
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015

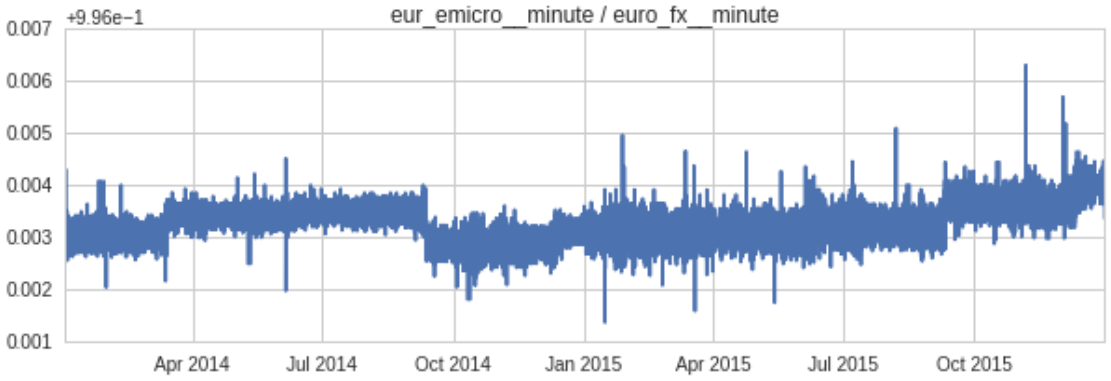


2.2.4 1.3 Price Division

```
In [7]: b = spread_division(data)
        plotting(b)
```

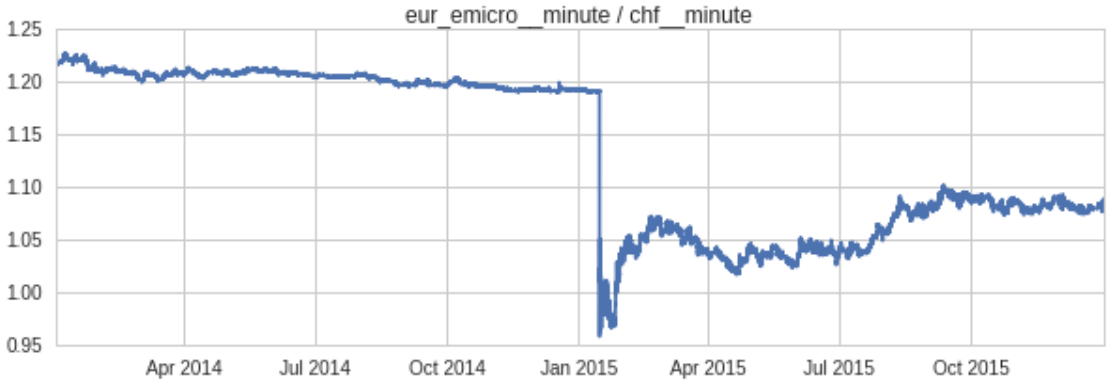
```
/usr/local/lib/python2.7/dist-packages/matplotlib/pyplot.py:516: RuntimeWarning: More than 20 f
  max_open_warning, RuntimeWarning)
```

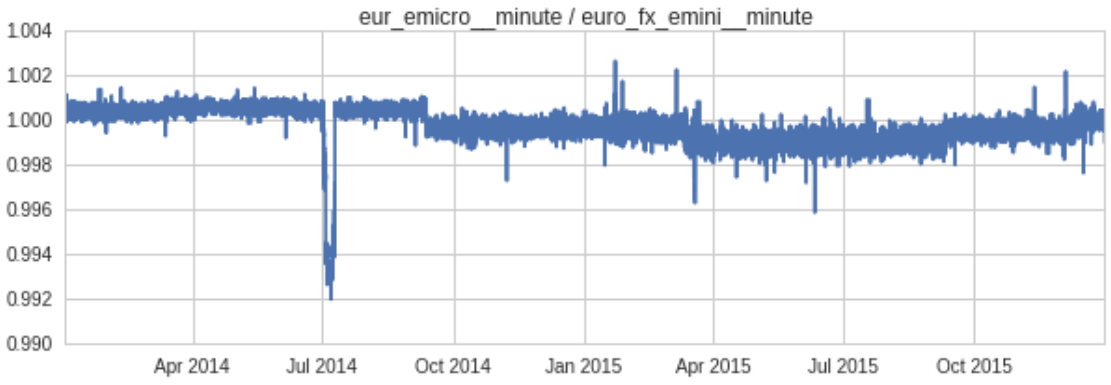

eur_emicro__minute / jpy__minute
150
145
140
135
130
125
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


+9.96e−1
eur_emicro__minute / euro_fx__minute
0.007
0.006
0.005
0.004
0.003
0.002
0.001
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


eur_emicro__minute / mxn__minute
21
20
19
18
17
16
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


eur_emicro__minute / aud__minute
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


eur_emicro__minute / chf__minute
1.25
1.20
1.15
1.10
1.05
1.00
0.95
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


eur_emicro__minute / euro_fx_emini__minute
1.004
1.002
1.000
0.998
0.996
0.994
0.992
0.990
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


eur_emicro__minute / gbp__minute
0.85
0.80
0.75
0.70
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


eur_emicro__minute / jpy_emini__minute
150
145
140
135
130
125
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


eur_emicro__minute / cad__minute
1.60
1.55
1.50
1.45
1.40
1.35
1.30
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


nzd__minute / jpy__minute
95
90
85
80
75
70
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


nzd__minute / euro_fx__minute
0.70
0.68
0.66
0.64
0.62
0.60
0.58
0.56
0.54
0.52
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015

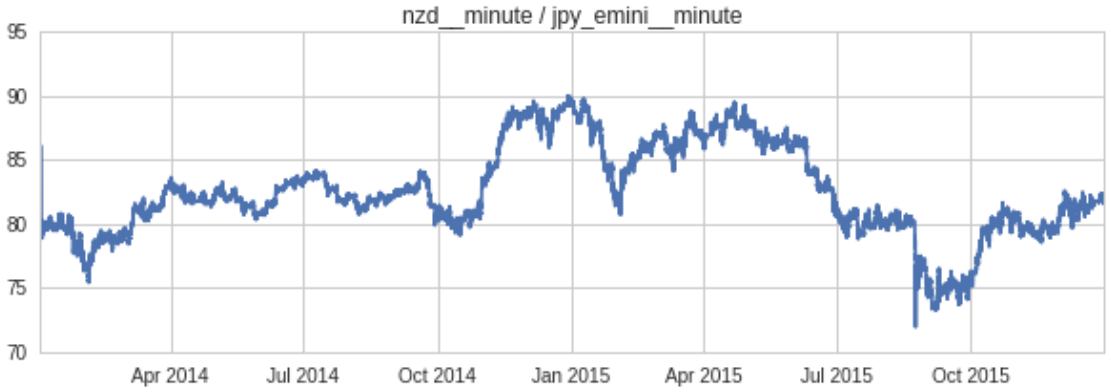

nzd__minute / mxn__minute
12.0
11.5
11.0
10.5
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


nzd__minute / aud__minute
1.00
0.98
0.96
0.94
0.92
0.90
0.88
0.86
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


nzd__minute / chf__minute
0.80
0.75
0.70
0.65
0.60
0.55
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


nzd__minute / euro_fx_emini__minute
0.70
0.68
0.66
0.64
0.62
0.60
0.58
0.56
0.54
0.52
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


nzd__minute / gbp__minute
0.52
0.50
0.48
0.46
0.44
0.42
0.40
0.38
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


nzd__minute / jpy_emini__minute
95
90
85
80
75
70
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


nzd__minute / cad__minute
0.96
0.94
0.92
0.90
0.88
0.86
0.84
0.82
0.80
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


jpy__minute / euro_fx__minute
0.0080
0.0078
0.0076
0.0074
0.0072
0.0070
0.0068
0.0066
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015

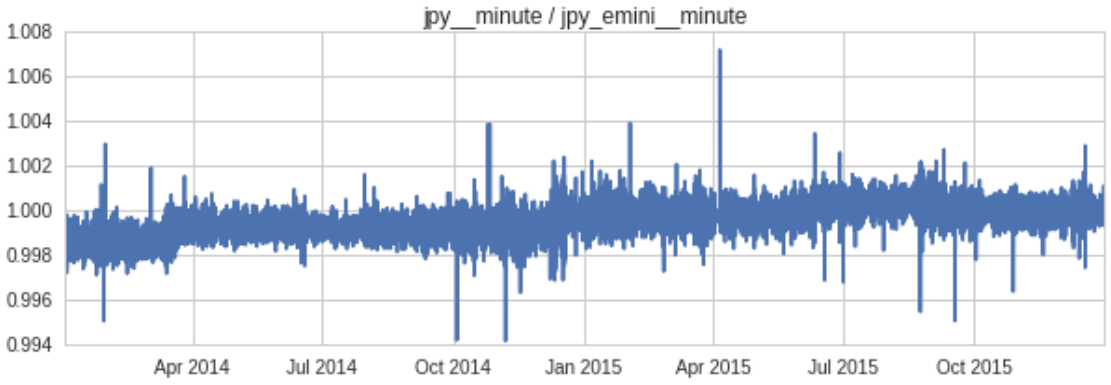

jpy__minute / mxn__minute
0.150
0.145
0.140
0.135
0.130
0.125
0.120
0.115
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015

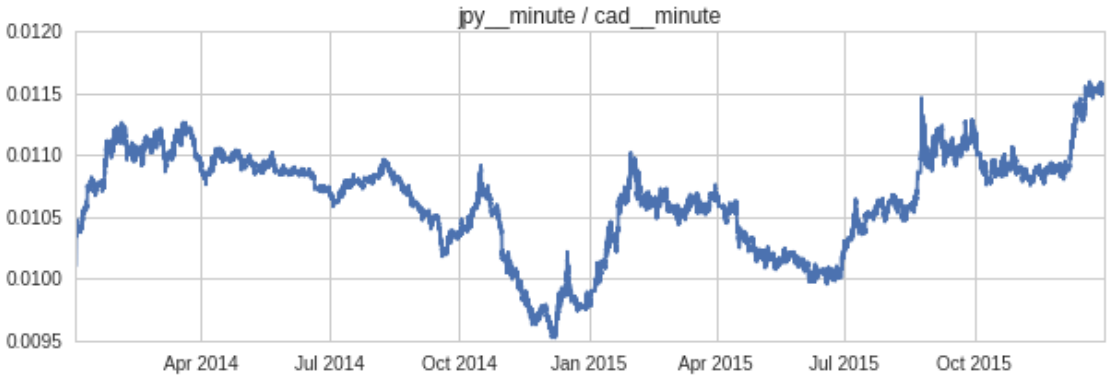

jpy__minute / aud__minute
0.0125
0.0120
0.0115
0.0110
0.0105
0.0100
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


jpy__minute / chf__minute
0.0090
0.0085
0.0080
0.0075
0.0070
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


jpy__minute / euro_fx_emini__minute
0.0080
0.0078
0.0076
0.0074
0.0072
0.0070
0.0068
0.0066
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


jpy__minute / gbp__minute
0.0062
0.0060
0.0058
0.0056
0.0054
0.0052
0.0050
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015

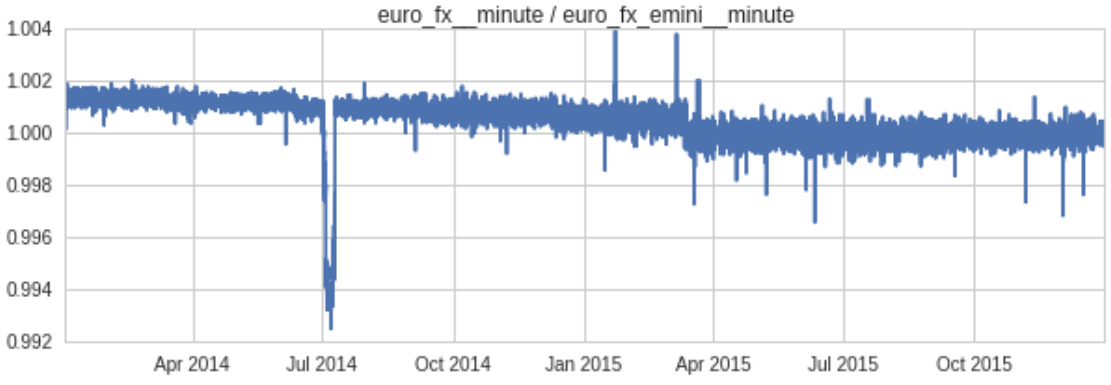

jpy__minute / jpy_emini__minute
1.008
1.006
1.004
1.002
1.000
0.998
0.996
0.994
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


jpy__minute / cad__minute
0.0120
0.0115
0.0110
0.0105
0.0100
0.0095
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


euro_fx__minute / mxn__minute
21
20
19
18
17
16
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


euro_fx__minute / aud__minute
1.70
1.65
1.60
1.55
1.50
1.45
1.40
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


euro_fx__minute / chf__minute
1.25
1.20
1.15
1.10
1.05
1.00
0.95
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


euro_fx__minute / euro_fx_emini__minute
1.004
1.002
1.000
0.998
0.996
0.994
0.992
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


euro_fx__minute / gbp__minute
0.85
0.80
0.75
0.70
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


euro_fx__minute / jpy_emini__minute
150
145
140
135
130
125
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


euro_fx__minute / cad__minute
1.60
1.55
1.50
1.45
1.40
1.35
1.30
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015

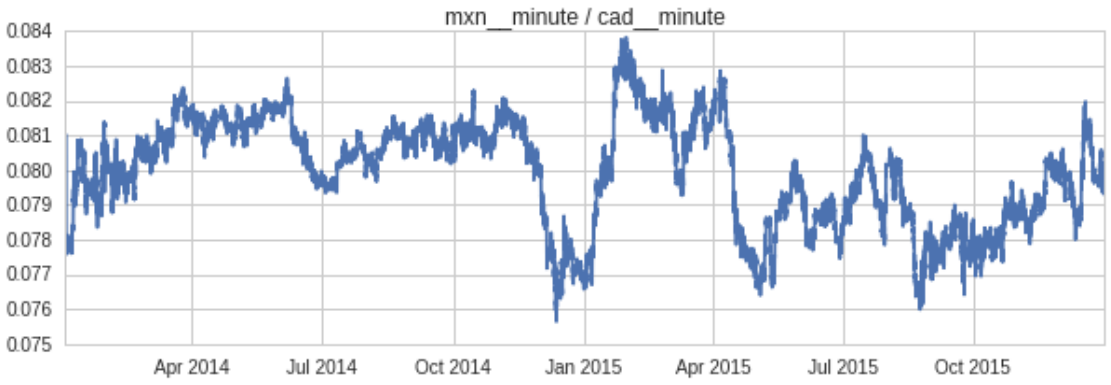

mxn__minute / aud__minute
0.090
0.088
0.086
0.084
0.082
0.080
0.078
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


mxn__minute / chf__minute
0.070
0.068
0.066
0.064
0.062
0.060
0.058
0.056
0.054
0.052
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


mxn__minute / euro_fx_emini__minute
0.062
0.060
0.058
0.056
0.054
0.052
0.050
0.048
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


mxn__minute / gbp__minute
0.048
0.046
0.044
0.042
0.040
0.038
0.036
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015

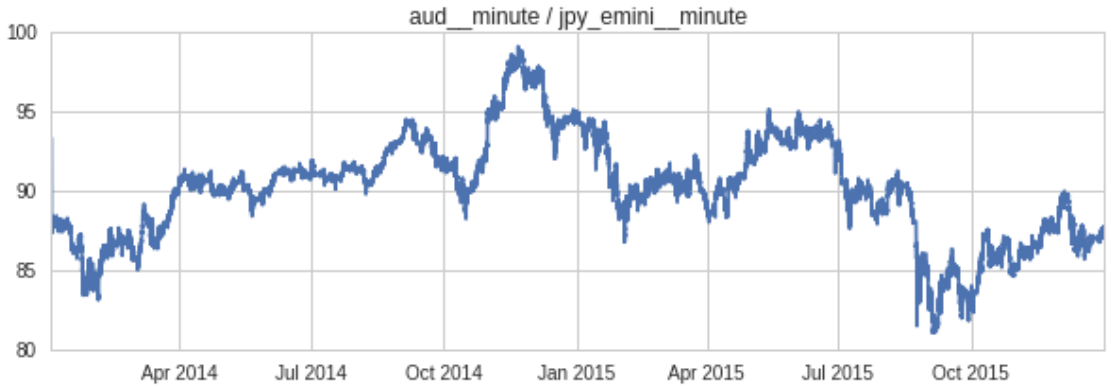

mxn__minute / jpy_emini__minute
8.4
8.2
8.0
7.8
7.6
7.4
7.2
7.0
6.8
6.6
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015

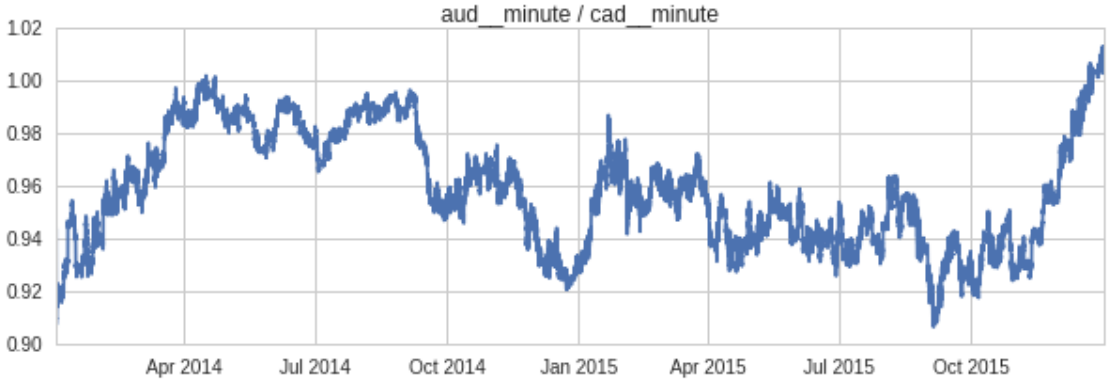

mxn__minute / cad__minute
0.084
0.083
0.082
0.081
0.080
0.079
0.078
0.077
0.076
0.075
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


aud__minute / chf__minute
0.85
0.80
0.75
0.70
0.65
0.60
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


aud__minute / euro_fx_emini__minute
0.72
0.70
0.68
0.66
0.64
0.62
0.60
0.58
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015

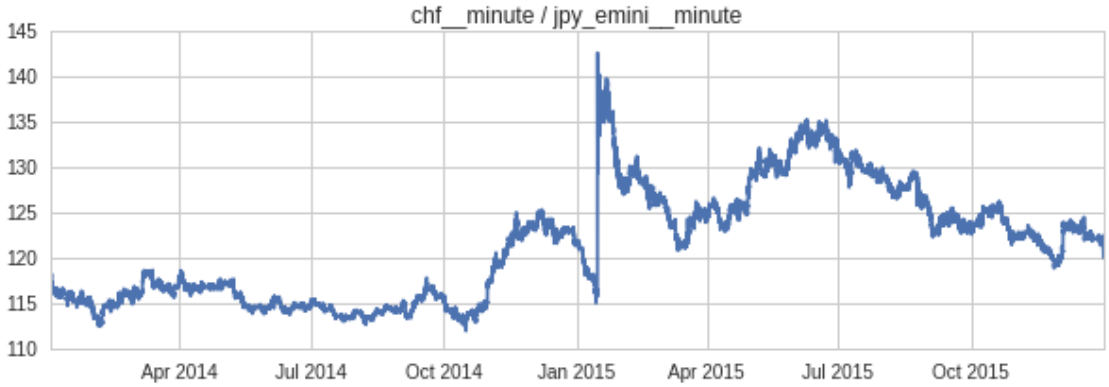

aud__minute / gbp__minute
0.58
0.56
0.54
0.52
0.50
0.48
0.46
0.44
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


aud__minute / jpy_emini__minute
100
95
90
85
80
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


aud__minute / cad__minute
1.02
1.00
0.98
0.96
0.94
0.92
0.90
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


chf__minute / euro_fx_emini__minute
1.05
1.00
0.95
0.90
0.85
0.80
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


chf__minute / gbp__minute
0.80
0.75
0.70
0.65
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015

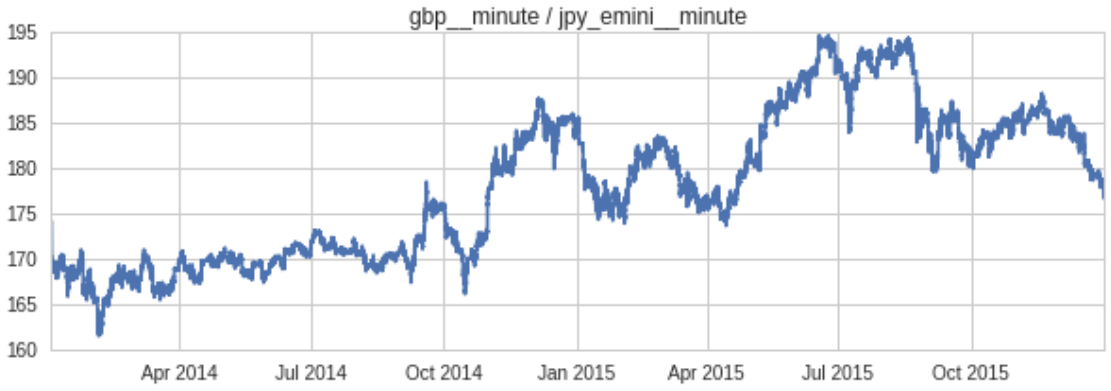

chf__minute / jpy_emini__minute
145
140
135
130
125
120
115
110
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015

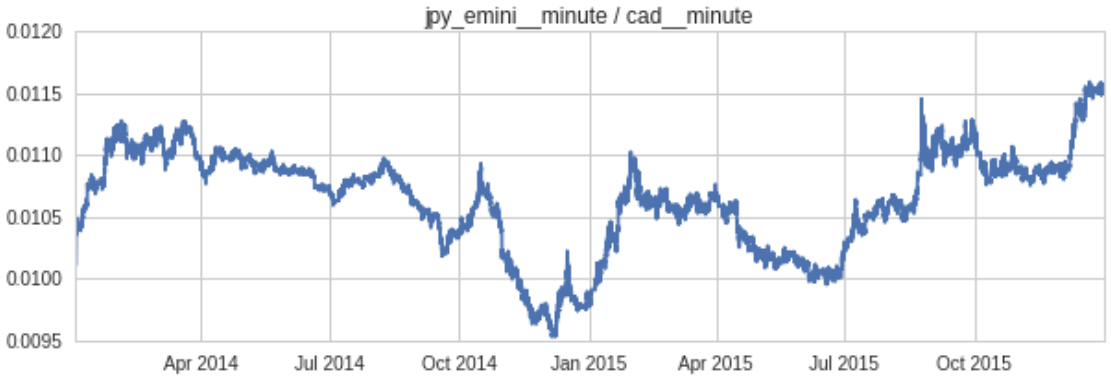

chf__minute / cad__minute
1.50
1.45
1.40
1.35
1.30
1.25
1.20
1.15
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


euro_fx_emini__minute / gbp__minute
0.85
0.80
0.75
0.70
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


euro_fx_emini__minute / jpy_emini__minute
150
145
140
135
130
125
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015


euro_fx_emini__minute / cad__minute
1.60
1.55
1.50
1.45
1.40
1.35
1.30
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015





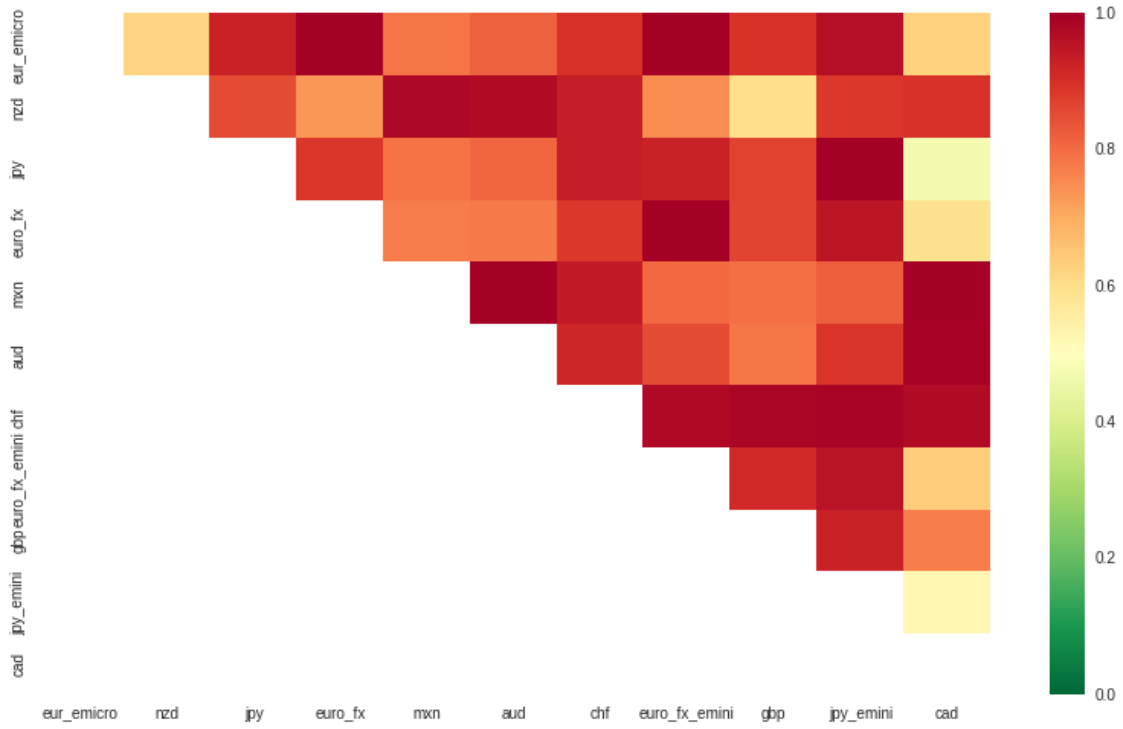
2.2.5 1.4 Cointegration (Green color squares imply lowest p-value and significant cointegration)

```
In [8]: pvalues, pairs =  find_cointegrated_paris(data)
```

2.2.6 Heatmap of cointegration: Green Significant cointegration

```
In [9]: sns.heatmap(1-pvalues,xticklabels=future_list, yticklabels=future_list,cmap = 'RdYlGn_
```

```
Out[9]: <matplotlib.axes._subplots.AxesSubplot at 0x7fde095718d0>
```



2.2.7 1.5 Pairs with significant cointegration

```
In [10]: pd.DataFrame(pairs)
```

Out[10]:

	0	1
0	eur_emicro__minute	euro_fx__minute
1	eur_emicro__minute	euro_fx_emini__minute
2	eur_emicro__minute	jpy_emini__minute
3	nzd__minute	mxn__minute
4	nzd__minute	aud__minute
5	jpy__minute	jpy_emini__minute
6	euro_fx__minute	euro_fx_emini__minute
7	euro_fx__minute	jpy_emini__minute
8	mxn__minute	aud__minute
9	mxn__minute	cad__minute
10	aud__minute	cad__minute
11	chf__minute	euro_fx_emini__minute
12	chf__minute	gbp__minute
13	chf__minute	jpy_emini__minute

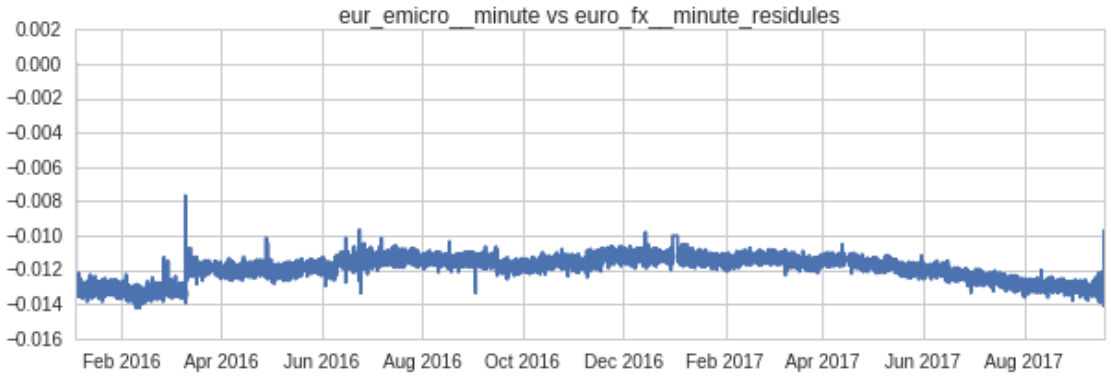
```
14            chf__minute            cad__minute
15  euro_fx_emini__minute      jpy_emini__minute
```

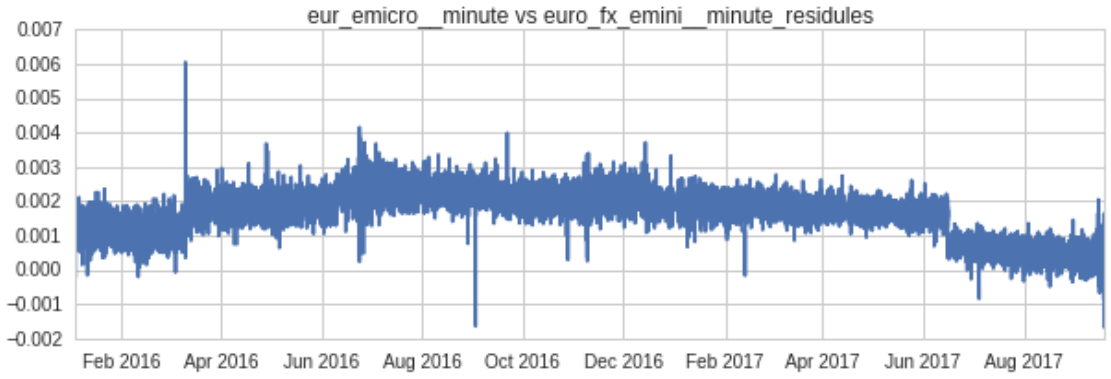
2.2.8 1.6 OLS In-sample: 2014-2015, Validation:2016-2017

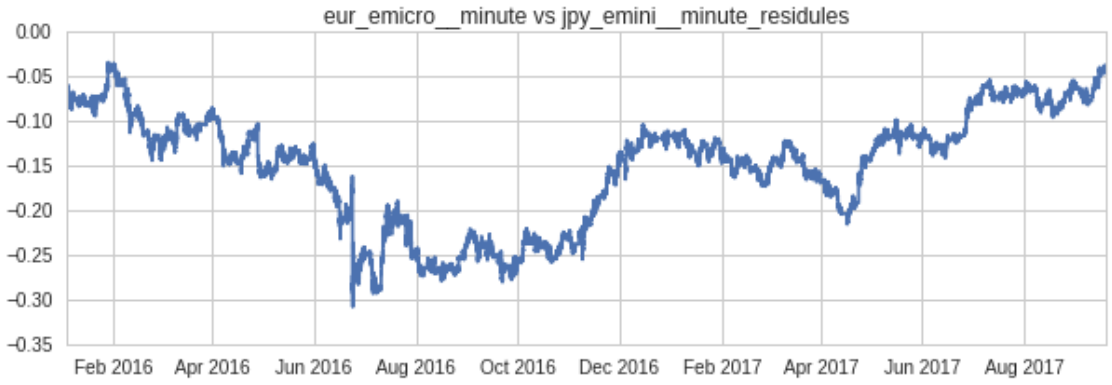
2.2.9 (Only pairs with significant cointegration are included)

In [13]:
```
# Get ols parameters using in-sample data
ols_result = ols_in_sample(data,pairs)

# Get residules using validation data based on in-sample ols parameters
validation_data = get_data(Currencies,start_date='2016-01-01', end_date='2017-12-31')
n=ols_validation(validation_data, ols_result,pairs)
plotting(n)
```

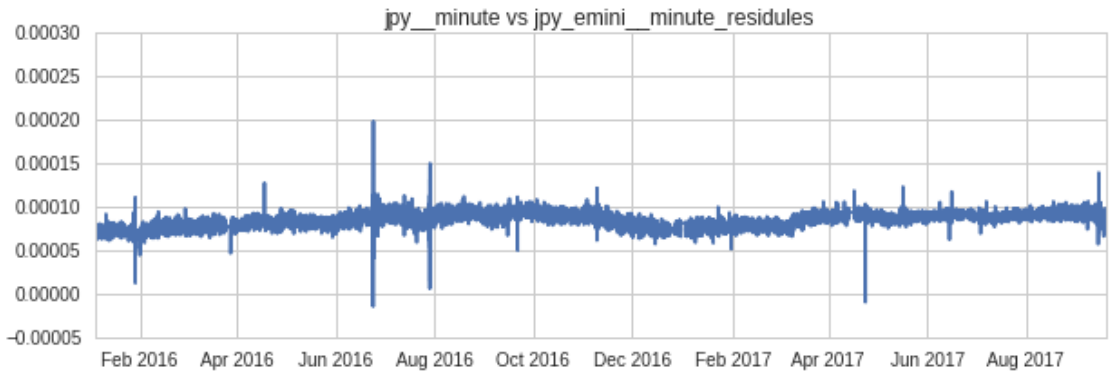


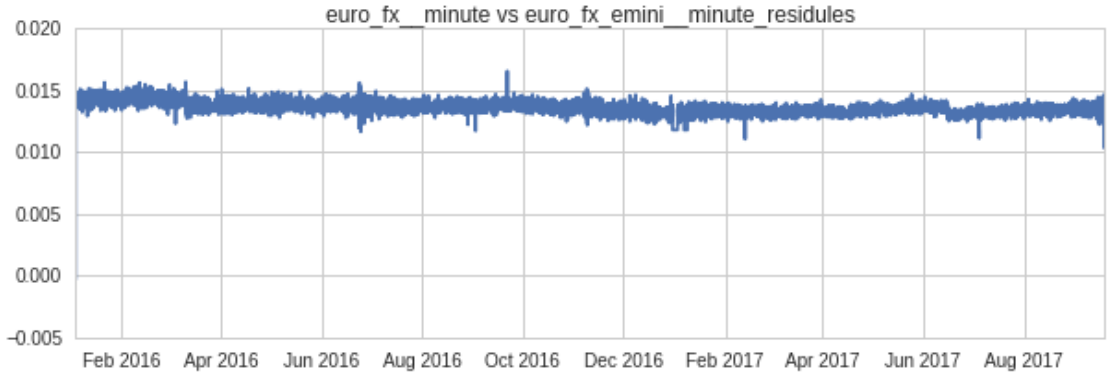



eur_emicro__minute vs jpy_emini__minute_residules
0.00
−0.05
−0.10
−0.15
−0.20
−0.25
−0.30
−0.35
Feb 2016
Apr 2016
Jun 2016
Aug 2016
Oct 2016
Dec 2016
Feb 2017
Apr 2017
Jun 2017
Aug 2017


nzd__minute vs mxn__minute_residules
0.25
0.20
0.15
0.10
0.05
0.00
Apr 2016
Jul 2016
Oct 2016
Jan 2017
Apr 2017
Jul 2017
Oct 2017


nzd__minute vs aud__minute_residules
0.04
0.03
0.02
0.01
0.00
−0.01
−0.02
−0.03
−0.04
Apr 2016
Jul 2016
Oct 2016
Jan 2017
Apr 2017
Jul 2017
Oct 2017


jpy__minute vs jpy_emini__minute_residules
0.00030
0.00025
0.00020
0.00015
0.00010
0.00005
0.00000
−0.00005
Feb 2016
Apr 2016
Jun 2016
Aug 2016
Oct 2016
Dec 2016
Feb 2017
Apr 2017
Jun 2017
Aug 2017

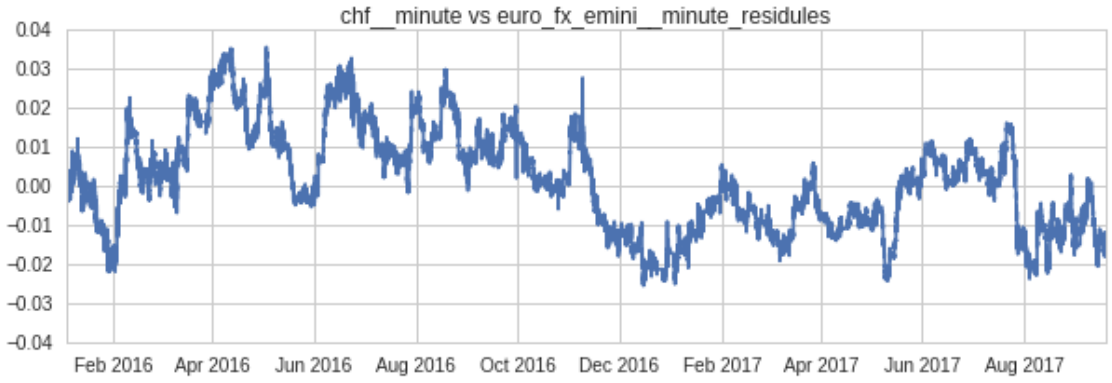

euro_fx__minute vs euro_fx_emini__minute_residules
0.020
0.015
0.010
0.005
0.000
−0.005
Feb 2016
Apr 2016
Jun 2016
Aug 2016
Oct 2016
Dec 2016
Feb 2017
Apr 2017
Jun 2017
Aug 2017


euro_fx__minute vs jpy_emini__minute_residules
0.00
−0.05
−0.10
−0.15
−0.20
−0.25
−0.30
Feb 2016
Apr 2016
Jun 2016
Aug 2016
Oct 2016
Dec 2016
Feb 2017
Apr 2017
Jun 2017
Aug 2017

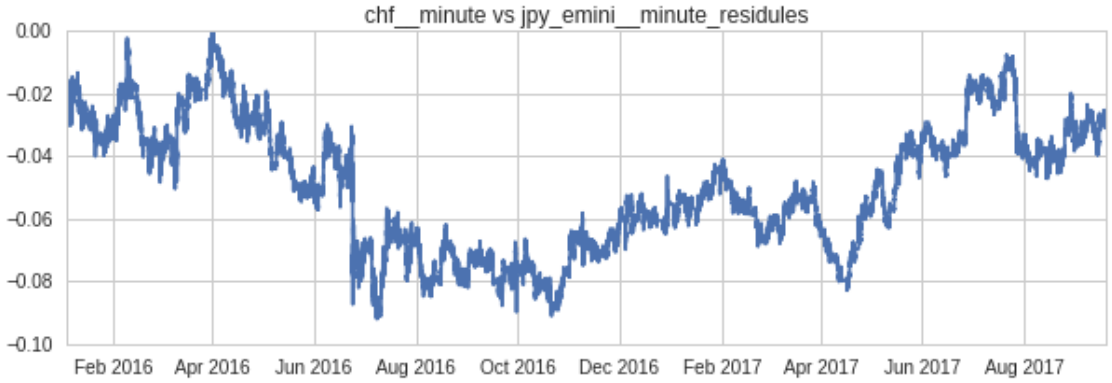

mxn__minute vs aud__minute_residules
0.000
−0.005
−0.010
−0.015
−0.020
−0.025
Apr 2016
Jul 2016
Oct 2016
Jan 2017
Apr 2017
Jul 2017
Oct 2017


mxn__minute vs cad__minute_residules
0.005
0.000
−0.005
−0.010
−0.015
−0.020
Apr 2016
Jul 2016
Oct 2016
Jan 2017
Apr 2017
Jul 2017
Oct 2017

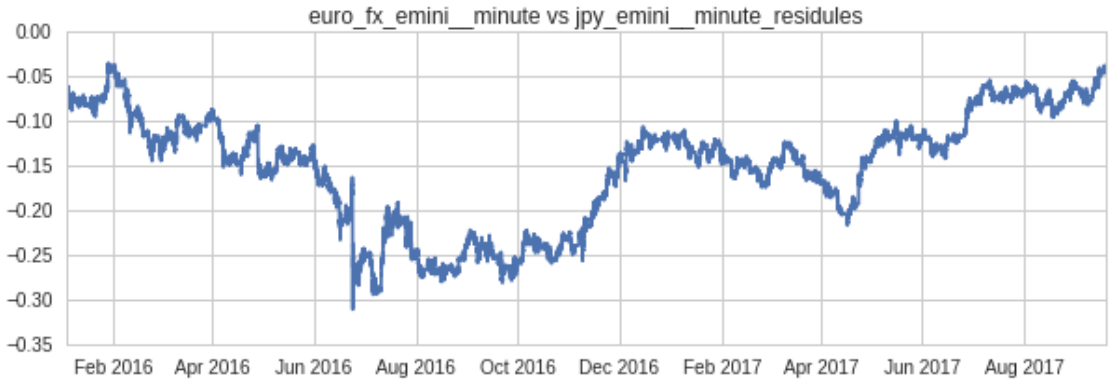

aud__minute vs cad__minute_residules
0.06
0.04
0.02
0.00
−0.02
Apr 2016
Jul 2016
Oct 2016
Jan 2017
Apr 2017
Jul 2017
Oct 2017


chf__minute vs euro_fx_emini__minute_residules
0.04
0.03
0.02
0.01
0.00
−0.01
−0.02
−0.03
−0.04
Feb 2016
Apr 2016
Jun 2016
Aug 2016
Oct 2016
Dec 2016
Feb 2017
Apr 2017
Jun 2017
Aug 2017


chf__minute vs gbp__minute_residules
0.20
0.15
0.10
0.05
0.00
−0.05
Apr 2016
Jul 2016
Oct 2016
Jan 2017
Apr 2017
Jul 2017
Oct 2017


chf__minute vs jpy_emini__minute_residules
0.00
−0.02
−0.04
−0.06
−0.08
−0.10
Feb 2016
Apr 2016
Jun 2016
Aug 2016
Oct 2016
Dec 2016
Feb 2017
Apr 2017
Jun 2017
Aug 2017


chf__minute vs cad__minute_residules
0.08
0.06
0.04
0.02
0.00
−0.02
−0.04
−0.06
Apr 2016
Jul 2016
Oct 2016
Jan 2017
Apr 2017
Jul 2017
Oct 2017


euro_fx_emini__minute vs jpy_emini__minute_residules
0.00
−0.05
−0.10
−0.15
−0.20
−0.25
−0.30
−0.35
Feb 2016
Apr 2016
Jun 2016
Aug 2016
Oct 2016
Dec 2016
Feb 2017
Apr 2017
Jun 2017
Aug 2017