How to time a Dispersion Strategy

First some setup

Entrée [1]:

```
# Indicate here the folders where you want the intraday quotes to be stored
# and the calibration result (folder 2)

folder1 = 'D:/Users/GitHub/Dispersion Volatility/processed'
folder2 = 'D:/Users/GitHub/Dispersion Volatility/parameters'

import os
os.makedirs(folder1, exist_ok=True)
os.makedirs(folder2, exist_ok=True)
```

Entrée [2]:

```
# We are now importing public libraries
import numpy as np
import pandas as pd
import QuantLib as ql
import math
import datetime
import matplotlib.pyplot as plt
import requests
import warnings
from IPython.display import display, HTML

pd.set_option('display.width', 200)
pd.set_option('display.max_columns', 30)
```

Entrée [3]:

```
# ...and specific libraries available in this git

from DateAndTime import DateAndTime
# uses QuantLib to calculate numbers of business day between dates and gener

from PricingAndCalibration import Pricing
# uses Quantlib to price European and American options with continuous divid

from PricingAndCalibration import FittingSpline
# uses scipy-UnivariateSpline to fit a 2nd degree spline through the implici
```

Entrée [4]:

```
# Choose here the time frame and the maturity to retrieve
from_date='20200310'
until_date='20200321'
chosen_matu = ['20201218']

#And now the underlyings with index weight
# [A7 option code, Spot whern weight in % was observed, Weight in %, Isin co
index_list = [('OESX', 3655.77, '', '', 'FESX')]

#you can reduce this stock list in ordre to save time...
udl_list = [
    ('SAP', 108.47, 6.17, 'DE0007164600', ''),
    ('ASM', 460, 5.69, 'NL0010273215', ''),
    ('LIN', 257.37, 4.69, 'IE00BZ12WP82', ''),
    ('MOH', 528.7, 4.58, 'FR0000121014', ''),
    ('SNW', 80.01, 4.13, 'FR0000120578', ''),
    ('SIE', 133.06, 3.42, 'DE0007236101', ''),
    ('TOTB', 35.07, 3.16, 'FR0000120271', ''),
    ('ALV', 195.77, 2.89, 'DE0008404005', ''),
    ('LOR', 305.6,2.89, 'FR0000120321', ''),
    ('AIR', 136.25, 2.74, 'FR0000120073', ''),
    ('IBE', 11.26, 2.57, 'ES0144580Y14', ''),
    ('SND', 124.6, 2.52, 'FR0000121972', ''),
    ('ENL5', 8.439, 2.45, 'IT0003128367', ''),
    ('BAY', 56.15, 2.21, 'DE000BAY0017', ''),
    ('ADS', 278, 2.2, 'DE000A1EWWW0', ''),
    ('BAS', 66.86, 2.02, 'DE000BASF111', ''),
    ('ADY', 1884.5, 1.86, 'NL0012969182', ''),
    ('PPX', 549, 1.81, 'FR0000121485', ''),
    ('SQU', 86, 1.71, 'FR0000125486', ''),
    ('ITK', 54.78, 1.64, 'BE0974293251', ''),
    ('DPW', 42.165, 1.63, 'DE0005552004', ''),
    ('DAI', 66.9, 1.61, 'DE0007100000', ''),
    ('PHI1', 47.08, 1.54, 'NL0000009538', ''),
    ('EAD', 93.42, 1.53, 'NL0000235190', ''),
    ('BSN', 53.34, 1.5, 'FR0000120644', ''),
    ('BNP', 53.595, 1.5, 'FR0000131104', ''),
#     ('PROSUS', 100.05, 1.44, 'NL0013654783', ''),
#     ('ESL', 128.75, 1.44, 'FR0000121667', 'no stock on Xetra'),
    ('AXA', 19.204, 1.37, 'FR0000120628', ''),
#      ('KONE', 66.03, 1.29, 'FI0009013403', ''),
    ('MUV2', 233.5, 1.58, 'DE0008430026', ''),
#     ('SEJ', 112.2, 1.26, 'FR0000073272', 'no stock on Xetra'),
    ('ANN', 55.53, 1.26, 'DE000A1ML7J1', ''),
    ('IES5', 2.059, 1.22, 'IT0000072618', ''),
    ('DB1', 136.4, 1.21, 'DE0005810055', ''),
    ('AHO', 23.35, 1.18, 'NL0011794037', ''),
    ('PER', 163.2, 1.15, 'FR0000120693', ''),
    ('IXD', 26.115, 1.12, 'ES0148396007', ''),
    ('BSD2', 2.774, 1.11, 'ES0113900J37', ''),
    ('VO3', 162.35, 1.07, 'DE0007664039', ''),
#     ('CRG', 35.51, 1.05, 'US12626K2033', 'no stock on Xetra'),
    ('INN', 7.766, 0.99, 'NL0011821202', ''),
#     ('AI3A', 56.37, 0.9, 'ES0109067019', 'no stock on Xetra'),
    ('VVU', 25.92, 0.87, 'FR0000127771', ''),
    ('BMW', 70.295, 0.83, 'DE0005190003', ''),
```

```
    ('NOA3', 3.495, 0.8, 'FI0009000681', ''),
    ('ENT5', 8.645, 0.7, 'IT0003132476', '')]
```

Entrée [5]:

```
#indicate your A7 credentials :
owner = 'your A7 username here'

API_TOKEN = "Bearer " + "your A7 API token here"
# The API token is obtained by clicking on your name in the upper right corn

proxies = {
    "http": "",  # Enter http Proxy if needed",
    "https": ""  # Enter https Proxy if needed",
}
```

Entrée [6]:

```
# Select an algo to retrieve quotes on A7.
# 'minsize_level_tb' allows you to look into the orderbook until finding a m
# 'minsize_level_fast' goes faster by looking only at the top level
# Both algos are given in this git as a .yml file
# They must be loaded first in your A7 account.
algo = 'minsize_level_tb'

# If you have chosen the 'minsize_level' algo :
min_lots = 1
```

Entrée [7]:

```
# Filter settings to speed up the process since we are only interested in At
# Levels are indicated for 1 year maturity option with an adjustment in sqrt
moneyness_range_call = (-0.025, 0.15)
moneyness_range_put = (-0.15, 0.025)

# Create instances of DateAndTime both for italian and other underlyings
DT = DateAndTime(from_date, until_date, force_matu=chosen_matu)
DTi = DateAndTime(from_date, until_date, force_matu=chosen_matu, ital_rule=T
```

The next function retrieves the intraday quotes given an option code

Entrée [8]:

```
def get_quotes(opt):
    if opt['PutOrCall'] == 'S':
        market = 'XETR'
    else:
        market = 'XEUR'

    url = 'https://a7.deutsche-boerse.com/api/v1/algo/{}/{}/'.format(owner,
    url = url + "run?marketId={}&date={}&marketSegmentId={}&securityId={}&fr
        market, reference_date, opt['SegmentID'], opt['SecurityID'], min_lot

    r = requests.get(url=url, headers={'Authorization': API_TOKEN}, proxies=
    res = r.json()

    if type(res) == list:
        df_opt = pd.DataFrame.from_dict(res[0]['series'][0]['content'])
        df_opt.ts = df_opt.ts.astype(np.int64)
        df_opt.ts = pd.to_datetime(df_opt.ts)
        df_opt.set_index('ts', inplace=True)

        df_opt[selected_fields_desc] = opt[selected_fields_desc]
        return (df_opt)
```

This function retrieves instruments from A7 in the res* lists,

It also gets segment codes in segment*,

and fills the matu_list* with relevant maturities

Entrée [9]:

```
def retrieve_instruments_from_A7():

    global res_u, res_f, res_i
    global segmentIDudl, segmentIDfut, segmentIDopt, security
    global matu_list_Stk, matu_list_Fut, matu_list_Opt

    # stock
    if (udl_p not in index_list) and (udl_p[4] != 'no stock on Xetra'):
        lst_ms = np.array([x['MarketSegment'] for x in res_gu['MarketSegment
        indx = np.where(lst_ms == isin)[0][0]
        segmentIDudl = res_gu['MarketSegments'][indx]['MarketSegmentID']

        url = 'https://a7.deutsche-boerse.com/api/v1/rdi/XETR/{}/{}?mode=det

        r = requests.get(url=url, headers={'Authorization': API_TOKEN}, prox
        res_u = r.json()
        security = res_u['Securities'][0]

        matu_list_Stk = ['UDL']
    else:
        matu_list_Stk = []

    # Futures
    if (udl_p in index_list):
        udl_f = udl_p[4]

        lst_ms = np.array([x['MarketSegment'] for x in res_go['MarketSegment
        indx = np.where(lst_ms == udl_f)[0][0]
        segmentIDfut = res_go['MarketSegments'][indx]['MarketSegmentID']

        url = 'https://a7.deutsche-boerse.com/api/v1/rdi/XEUR/{}/{}?mode=det
            reference_date,
            segmentIDfut)
        r = requests.get(url=url, headers={'Authorization': API_TOKEN}, prox
        res_f = r.json()

        matu_list_Fut = DT_u.get_matu_list(reference_date, trim=True)[:2]
    else:
        matu_list_Fut = []

    # Options

    lst_ms = np.array([x['MarketSegment'] for x in res_go['MarketSegments']]
    indx = np.where(lst_ms == udl)[0][0]
    segmentIDopt = res_go['MarketSegments'][indx]['MarketSegmentID']

    url = 'https://a7.deutsche-boerse.com/api/v1/rdi/XEUR/{}/{}?mode=detaile

    r = requests.get(url=url, headers={'Authorization': API_TOKEN}, proxies=
    res_i = r.json()

    matu_list_Opt = DT_u.get_matu_list(reference_date)
```

The next function transforms raw A7 output int dataframe of instrument to be retrieved.

It first tackles underlying (stock of futures) because it needs a underlying price to select "in_range" (ie. around the money) option to be put in df.

Entrée [10]:

```
def build_options_list():

    global df_orderbook

    df_u = pd.DataFrame(columns=['SegmentID'] + selected_fields + selected_f

    i = 0
    for matu in matu_list_Stk:
        df_u.loc[i] = [segmentIDudl, security['SecurityDesc'], security['Sec
        df_opt = get_quotes(df_u.loc[i])
        df_opt['matu'] = matu
        df_opt['udl'] = udl
        df_opt = df_opt.loc[(df_opt.bid > 0) & (df_opt.ask > 0)]
        df_orderbook = df_orderbook.append(df_opt)
        i += 1

    for c, matu in enumerate(matu_list_Fut):
        for x in [x for x in res_f['Securities'] if (str(x['MaturityDate'])
            df_u.loc[i] = [segmentIDfut] + [x[elt] for elt in selected_field
                x['DerivativesDescriptorGroup']['SimpleInstrumentDescriptorG
            df_u.loc[i]['PutOrCall'] = 'FUT' + str(c)
            df_opt = get_quotes(df_u.loc[i])
            df_opt['matu'] = matu
            df_opt['udl'] = udl
            df_opt = df_opt.loc[(df_opt.bid > 0) & (df_opt.ask > 0)]
            df_orderbook = df_orderbook.append(df_opt)
            i += 1

    FVUmin = (df_opt.bid.min() + df_orderbook.ask.min()) / 2
    FVUmax = (df_opt.bid.max() + df_orderbook.ask.max()) / 2

    for matu in matu_list_Opt:

        i = 0
        df = pd.DataFrame(columns=['SegmentID'] + selected_fields + selected

        for x in [x for x in res_i['Securities'] if
                  (str(x['MaturityDate']) == matu) and (x['SecurityType'] ==
            df.loc[i] = [segmentIDopt] + [x[elt] for elt in selected_fields]
                         [x['DerivativesDescriptorGroup']['SimpleInstrumentDe
                          in selected_fields_desc]
            i += 1

        df.sort_values(by=['StrikePrice', 'PutOrCall'], ascending=[True, Tru

        TTM = DT_u.time_between(pd.Timestamp(reference_date), pd.Timestamp(m
        df['matu'] = matu
        df['moneyness_T_min'] = df.apply(
            lambda opt: math.log(opt.StrikePrice / FVUmax) / (max(3.0 / 12.0
        # we consider that div max is 8%
        df['moneyness_T_max'] = df.apply(
            lambda opt: math.log(opt.StrikePrice / (FVUmin * 0.92)) / (max(3

        df['in_range'] = df.apply(lambda opt: (opt.moneyness_T_max > moneyne
                opt.moneyness_T_min < moneyness_range_call[1]) \
            if opt.PutOrCall == '1' else \
```

```
            (opt.moneyness_T_max > moneyness_range_put[0]) and (
                    opt.moneyness_T_min < moneyness_range_put[1]),
                                    axis='columns')

    return (df.loc[df.in_range])
```

Let's now use these functions to retrieve the intraday quotes data and save them in the df_ordebook dataframe

Entrée [11]:

```
a = datetime.datetime.now()  # time check

for reference_date in DT.dates_list:
    print(reference_date)

    # retrieve all instruments (stocks the options) from A7

    url = 'https://a7.deutsche-boerse.com/api/v1/rdi/XETR/{}?mode=detailed'.
    r = requests.get(url=url, headers={'Authorization': API_TOKEN}, proxies=
    res_gu = r.json()

    url = 'https://a7.deutsche-boerse.com/api/v1/rdi/XEUR/{}?mode=detailed'.
    r = requests.get(url=url, headers={'Authorization': API_TOKEN}, proxies=
    res_go = r.json()

    for udl_p in index_list + udl_list:
        udl = udl_p[0]
        isin = udl_p[3]

        # Determine which instance of DT class : the normal one (DT)
        # or the one giving thursday expiry dor italian stocks (DTi)
        if isin[:2] == 'IT':
            DT_u = DTi
        else:
            DT_u = DT

        try:
            df_orderbook = pd.read_pickle(folder1 + '/Quotes_' + udl + '.pkl
        except:
            df_orderbook = pd.DataFrame()

        if df_orderbook.shape[0] > 0:
            done_already = [elt.strftime('%Y%m%d') for elt in set([elt.date(
        else:
            done_already = []

        if reference_date not in done_already:

            try:

                retrieve_instruments_from_A7()

                # retrieves quotes

                selected_fields = ['SecurityDesc', 'SecurityID']
                selected_fields_desc = ['PutOrCall', 'StrikePrice', 'Contrac

                df = build_options_list()

                for index, opt in df.iterrows():
                    df_opt = get_quotes(opt)
                    df_opt['matu'] = opt.matu
                    df_opt['udl'] = udl
                    df_opt = df_opt.loc[(df_opt.bid > 0) & (df_opt.ask > 0)]
                    df_orderbook = df_orderbook.append(df_opt)

```

```
            except:
                print('\n\n\n fail for : {}, {}\n\n\n\n'.format(reference_date

        df_orderbook.to_pickle(folder1 + '/Quotes_' + udl + '.pkl')

for udl_p in index_list + udl_list:
    print(display(HTML(df_orderbook.head().to_html())))
    print('')
```

```
20200310
20200311
20200312
20200313
20200316
20200317
20200318
20200319
20200320
```

ts	ask	bid	PutOrCall	StrikePrice	ContractMultiplier	ExerciseStyle	matu	udl
2020-03-10 10:10:00	8.842	8.827	S	None	1	None	UDL	ENT5
2020-03-10 12:10:00	8.639	8.627	S	None	1	None	UDL	ENT5
2020-03-10 14:10:00	8.381	8.367	S	None	1	None	UDL	ENT5

At this stage, you have created a df_orderbook dataframe and saved it in folder1.
We are now going to fit a vol curve on these quotes using the FittingSpline class.

Entrée [16]:

```
for udl_p in index_list + udl_list:
    udl = udl_p[0]
    isin = udl_p[3]
    print(udl)

    if isin[:2] == 'IT':
        FS = FittingSpline(udl, DTi, folder1, folder2)
    else:
        FS = FittingSpline(udl, DT, folder1, folder2)

    if FS.data_found:
        FS.fit_all()

print(display(HTML(FS.df_params.head().to_html())))
```

```
OESX
SAP
ASM
LIN
MOH
SNW
SIE
TOTB
ALV
LOR
AIR
IBE
SND
ENL5
BAY
ADS
BAS
ADY
20200310
20200311
20200312
20200313
20200316
20200317
PPX
SQU
ITK
DPW
DAI
PHI1
EAD
BSN
BNP
AXA
MUV2
ANN
IES5
DB1
AHO
PER
IXD
BSD2
```

```
VO3
INN
VVU
BMW
NOA3
ENT5
```

ts	matu	spline_bid	spline
2020-03-10 10:10:00	20201217	<scipy.interpolate.fitpack2.LSQUnivariateSpline object at 0x000002A1719C22E0>	<scipy.interpolate.fitpack2.LSQUnivariateS object at 0x000002A17507(
2020-03-10 12:10:00	20201217	<scipy.interpolate.fitpack2.LSQUnivariateSpline object at 0x000002A17827F2E0>	<scipy.interpolate.fitpack2.LSQUnivariateS object at 0x000002A17507(
2020-03-10 14:10:00	20201217	<scipy.interpolate.fitpack2.LSQUnivariateSpline object at 0x000002A17827F9D0>	<scipy.interpolate.fitpack2.LSQUnivariateS object at 0x000002A17507(
2020-03-10 16:10:00	20201217	<scipy.interpolate.fitpack2.LSQUnivariateSpline object at 0x000002A171479AC0>	<scipy.interpolate.fitpack2.LSQUnivariateS object at 0x000002A17507(
2020-03-10 16:25:00	20201217	<scipy.interpolate.fitpack2.LSQUnivariateSpline object at 0x000002A1714794C0>	<scipy.interpolate.fitpack2.LSQUnivariateS object at 0x000002A17507(

```
None
```

The partameters have been saved in folder2.

We are now going to compute the dispersion volatility defined as :

Dispersion Vol = (Sum(i=1..50, Wi * ATFi^2) - (1+Leverage) * ATFindex^2) / Normalisation_factor

where

- ATFi is the ATM implicit vol of the ith stock in the index
- ATFindex is the ATM implicit vol of the index
- Leverage is the additional notional of index varswap to sell in order to get a vega neutral dispersion.
- Wi is the weight of the ith component in the index
- Normalisation_factor is a factor to apply to get a vega of 1 on the index so : 2 * (1+Leverage) * ATFindex

The index weight are calculated based on a "photo" taken on a specific date. Ref spot have been saved soi that %weight can be adjusted depending of relative stock fluctuations.

Entrée [13]:

```
def pick_hour(df_d):
    i = df_d.Error.idxmin()
    return(df.loc[i,:])

def compute_dispvol(df_d):
    W = df_d.W.sum()
    res = df_d.loc[df_d.udl == 'OESX']
    res['W'] = W * res.RefSpot / res.Spot
    res['DispVolbid'] = (df_d.DispVolbid.sum() / W - (1+Leverage) * res.ATFb
    res['DispVolask'] = (df_d.DispVolask.sum() / W - (1 + Leverage) * res.AT
    return(res)


matu = chosen_matu[0][:-2]
# udl_dic = dict([(elt[0], (elt[1], elt[2])) for elt in udl_list])
Leverage = 0.2

df = pd.DataFrame()
for udl_p in index_list + udl_list:
    udl = udl_p[0]
    try:
        df_udl = pd.read_pickle(folder2 + '/Params_' + udl + '.pkl')
    except:
        df_udl = pd.DataFrame()

    if df_udl.shape[0] > 0:
        df_udl['udl'] = udl
        df_udl['ATFbid'] = df_udl.spline_bid.apply(lambda x: x(0))
        df_udl['ATFask'] = df_udl.spline_ask.apply(lambda x: x(0))
        s = df_udl.index.levels[1].to_series()
        df_udl.index = df_udl.index.set_levels(s.map(lambda x: x[:-2]).filln
        df_udl = df_udl.xs(matu, level=1, drop_level=True)
        df_udl = df_udl[['udl', 'ATFbid', 'ATFask', 'Spot', 'Error']]
        df_udl.index = df_udl.index.map(lambda x: x.date())
        df_udl.sort_values(by=['ts', 'Error'], inplace=True)
        df_udl = df_udl.groupby(df_udl.index).first()
        df = df.append(df_udl)


dW = pd.DataFrame(index_list + udl_list, columns=['udl', 'RefSpot', 'W', 'is
df = pd.merge(df, dW, left_on='udl', right_on='udl', how='left').set_index(d
df['W'] = df.apply(lambda x: 0 if x.udl == 'OESX' else x.W / 100 * (x.Spot /
df['DispVolbid'] = df.apply(lambda x: x.W * x.ATFbid ** 2, axis='columns')
df['DispVolask'] = df.apply(lambda x: x.W * x.ATFask ** 2, axis='columns')
df = df.groupby(df.index, group_keys=False).apply(compute_dispvol)

print(df.head())
```

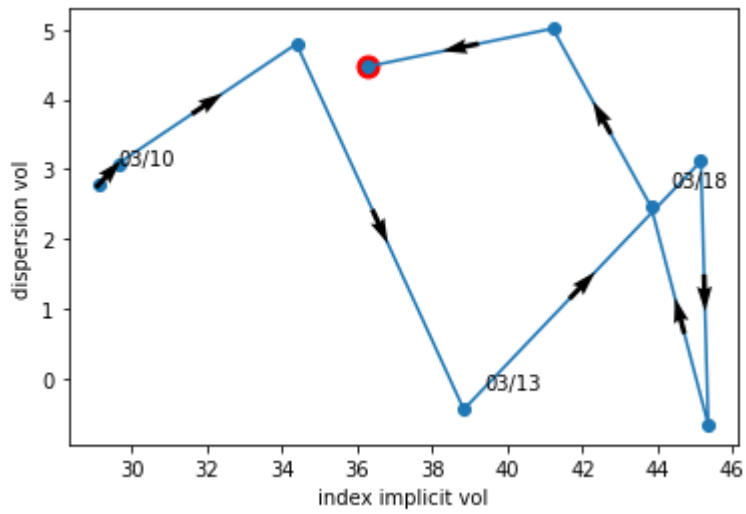
```
             udl     ATFbid     ATFask    Spot     Error  RefSpot         W i
sin  info  DispVolbid  DispVolask
ts
2020-03-10  OESX  28.754499  29.468070  3071.5  1.418594  3655.77  0.837895
FESX    1.591197    3.967912
2020-03-11  OESX  29.319411  29.947383  2957.5  2.512380  3655.77  0.838896
FESX    2.008498    4.158529
2020-03-12  OESX  33.981621  34.776443  2732.5  2.409569  3655.77  0.842498
```

```
FESX    2.178010    7.415036
2020-03-13  OESX  37.930204  39.741945  2630.5  3.310121  3655.77  0.830927
FESX   -1.736319    0.853326
2020-03-16  OESX  44.207588  46.098708  2360.5  4.703373  3655.77  0.840752
FESX    0.007350    6.221516
```

Finally, we will graph the DispVol vs the index vol to exhibit circular patterns as describes in the README file.

Entrée [14]:

```
x = ((df['ATFbid'] + df['ATFask'])/2).values
y = ((df['DispVolbid'] + df['DispVolask'])/2).values
dates = [elt.strftime('%m/%d') for elt in df.index.values]

u = np.diff(x)
v = np.diff(y)
pos_x = x[:-1] + u/2
pos_y = y[:-1] + v/2
norm = np.sqrt(u**2+v**2)

fig, ax = plt.subplots()
ax.plot(x,y, marker="o")
ax.quiver(pos_x, pos_y, u/norm, v/norm, angles="xy", zorder=5, pivot="mid")

for i, txt in enumerate(dates):
    if i%3==0:
        # ax.annotate(txt, (x[i], y[i]))
        ax.annotate(txt, (x[i], y[i]), xytext=(10, 10), textcoords='offset p

plt.scatter([x[-1]], [y[-1]], c='#ff0000', s=120)

plt.xlabel("index implicit vol")
plt.ylabel("dispersion vol")
plt.show()
```



This graph shows the evolution of the Dispersion Volatility (Y) vs the straight Implicit Volatility (X) of the index during the march 2020 market meltdown. It shows a classical example of index vol raising faster than it's components then a catch up. (See the README file of this Git for more details.)