Graphical and statistical analysis of intraday electricity prices for PHELIX, year 2015 (stochastic component)

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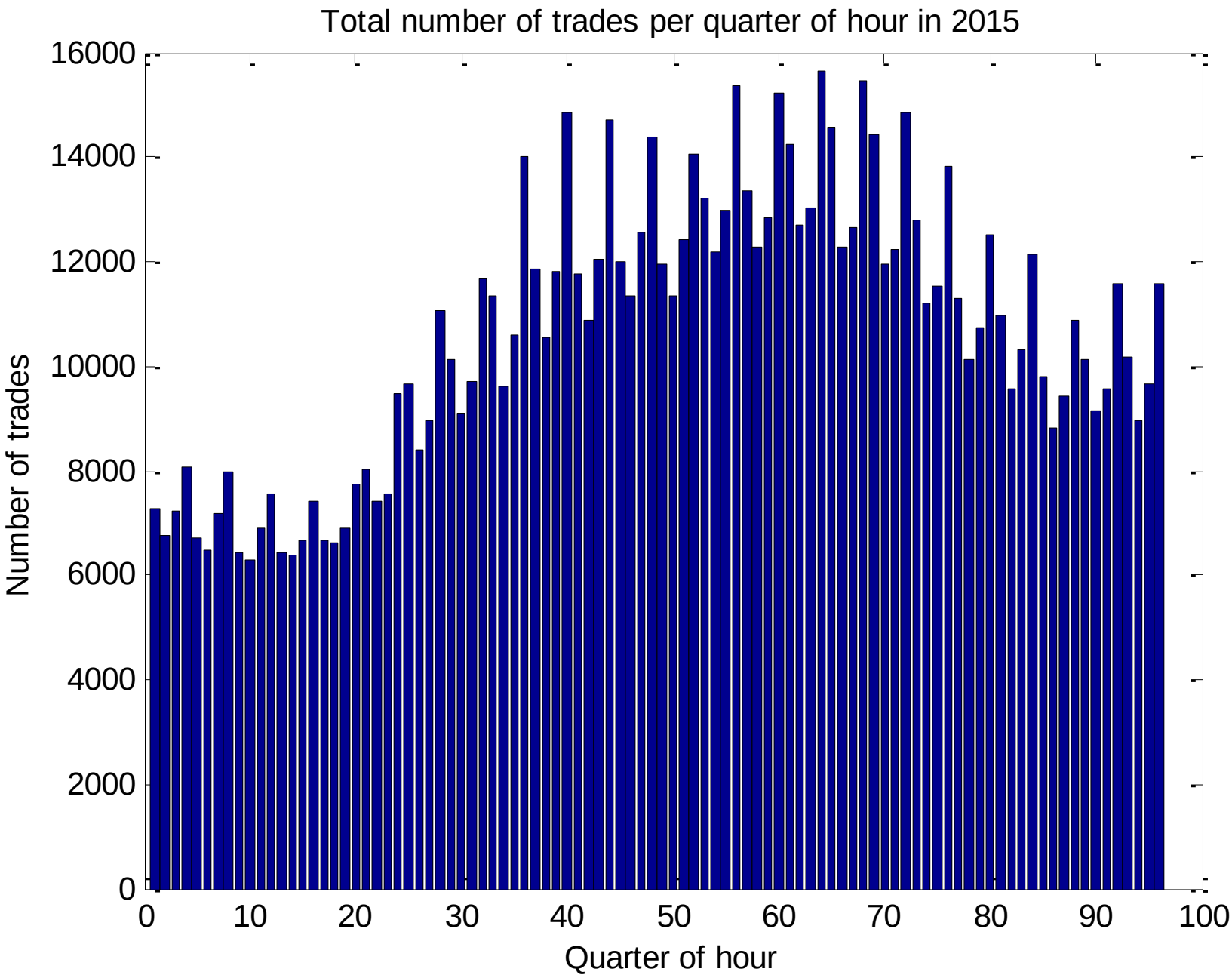
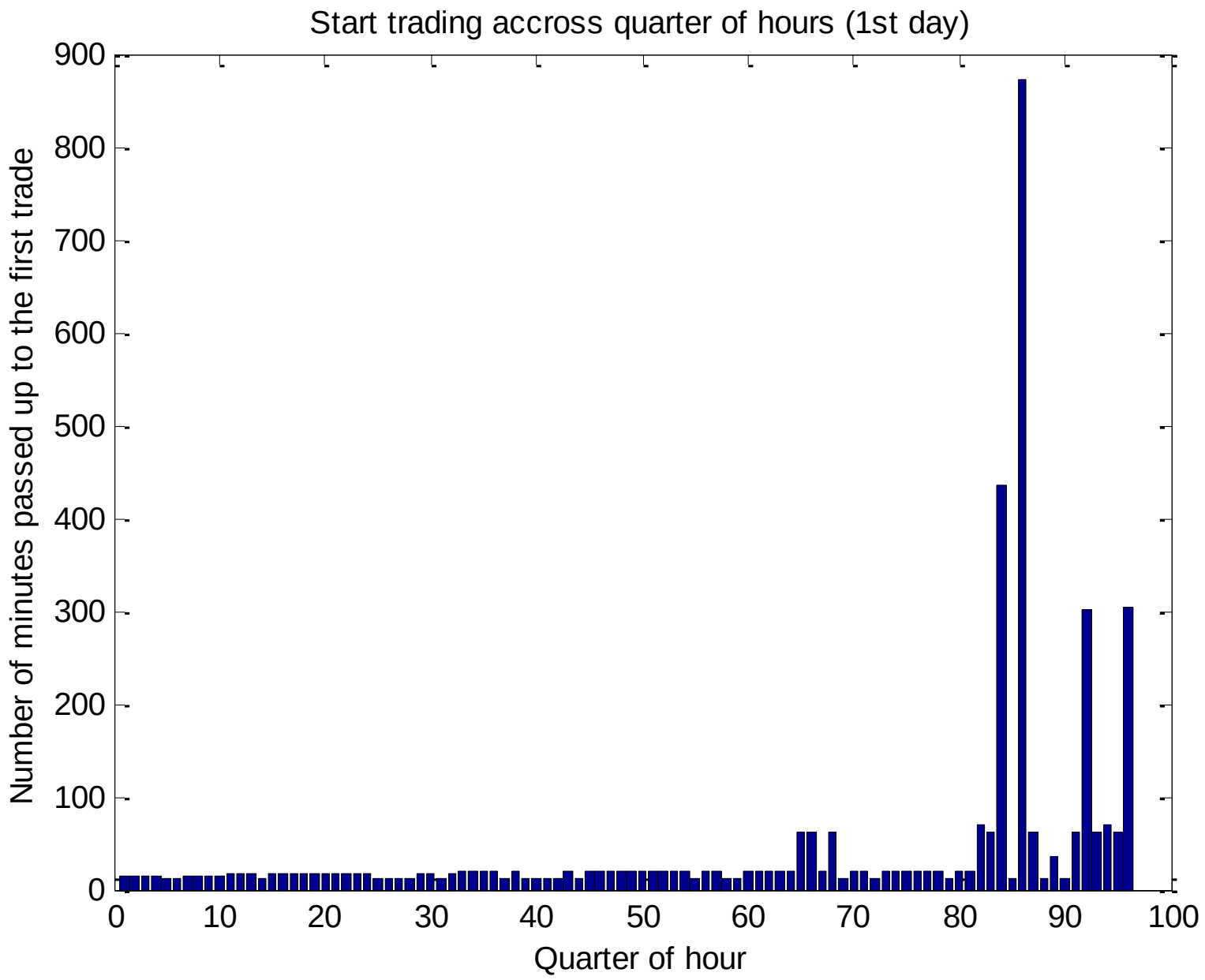
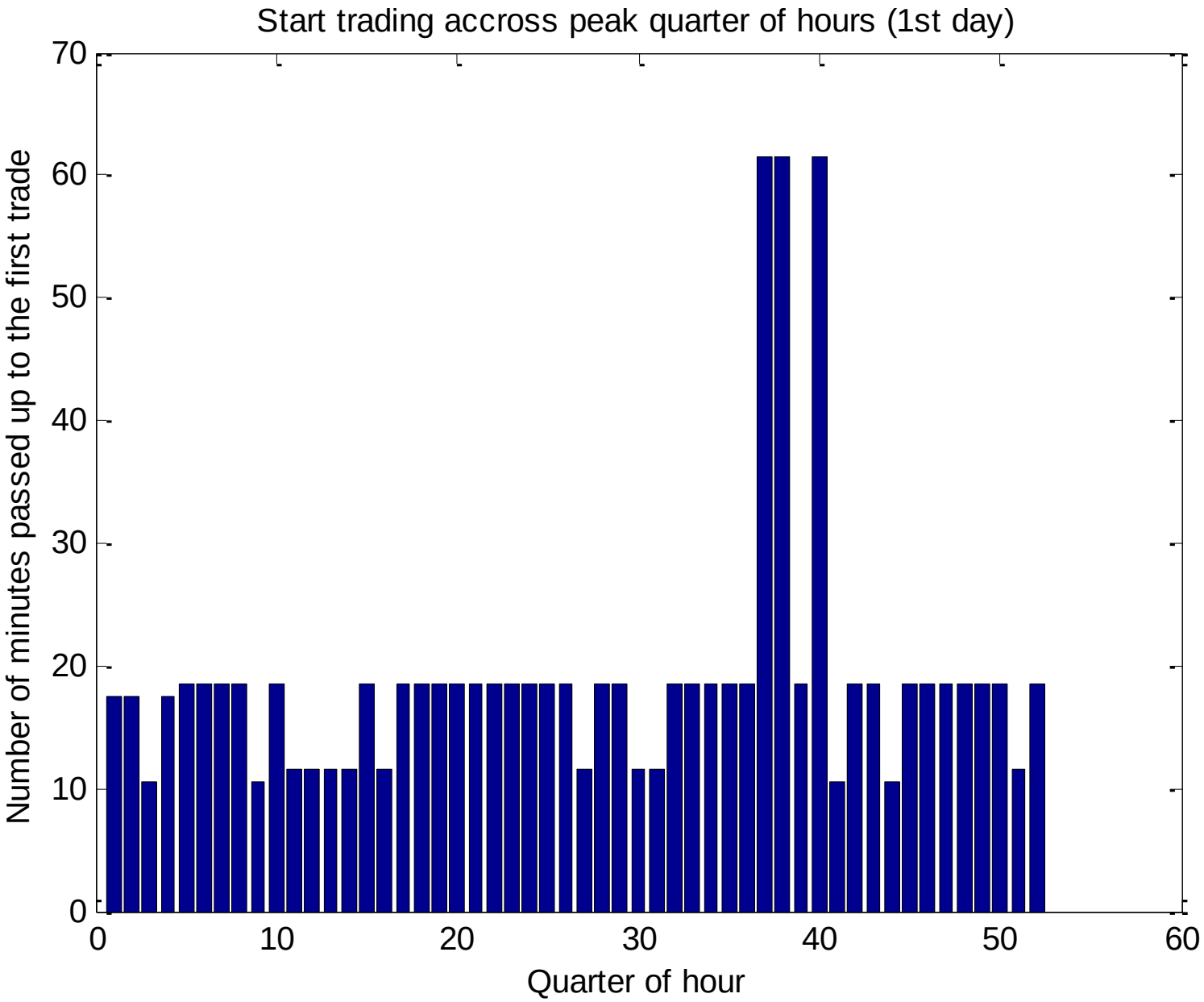
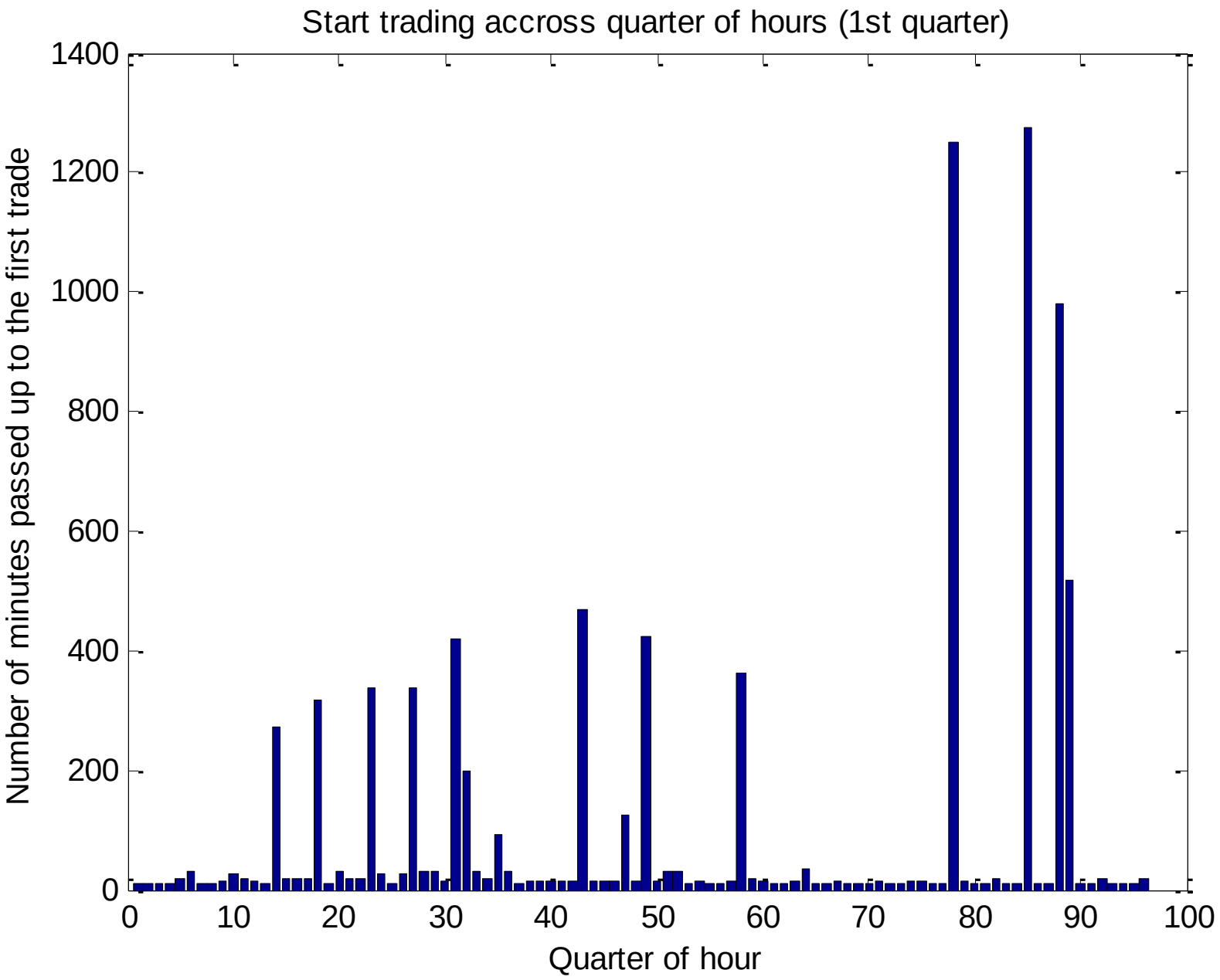
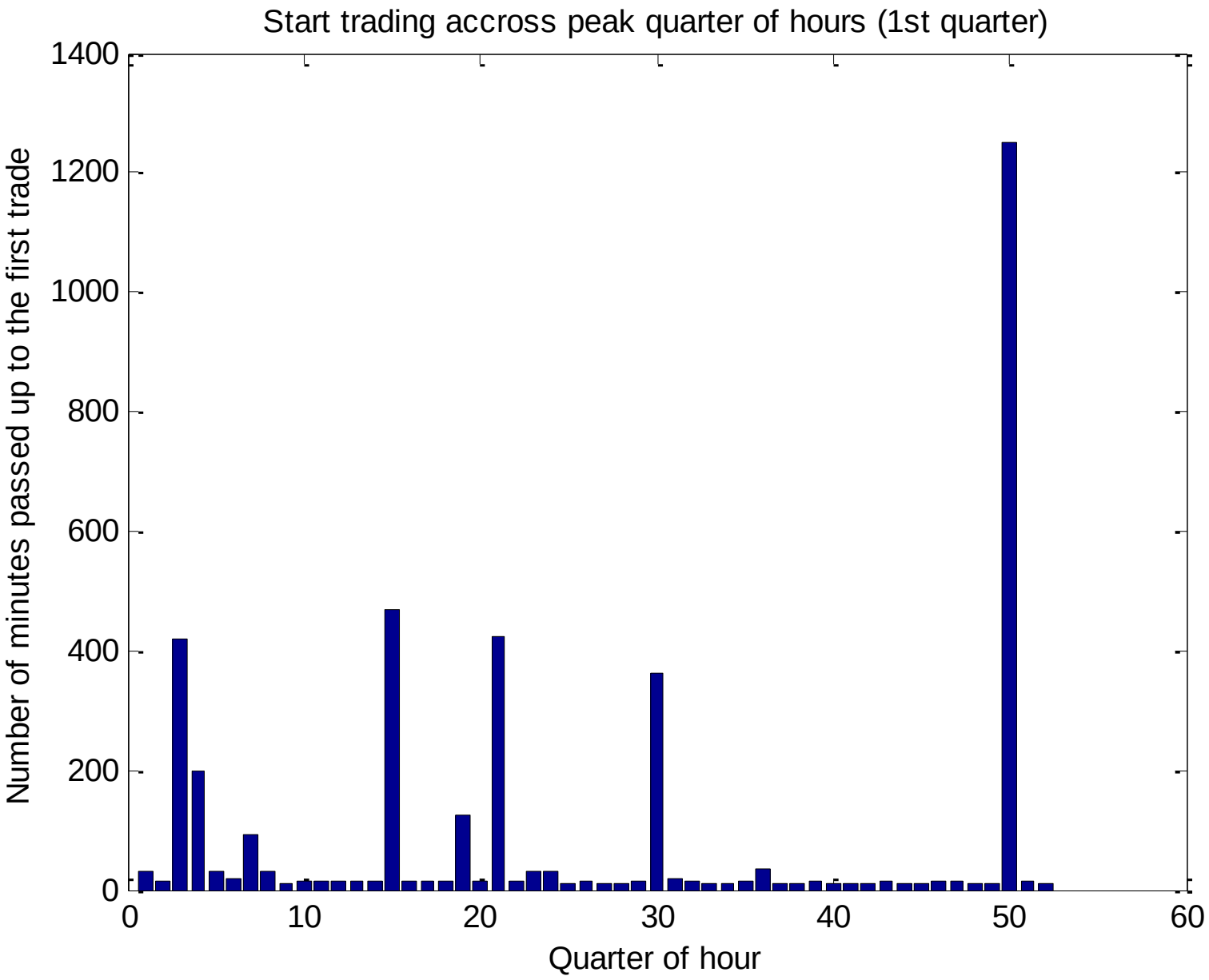
Oslo, August 2016

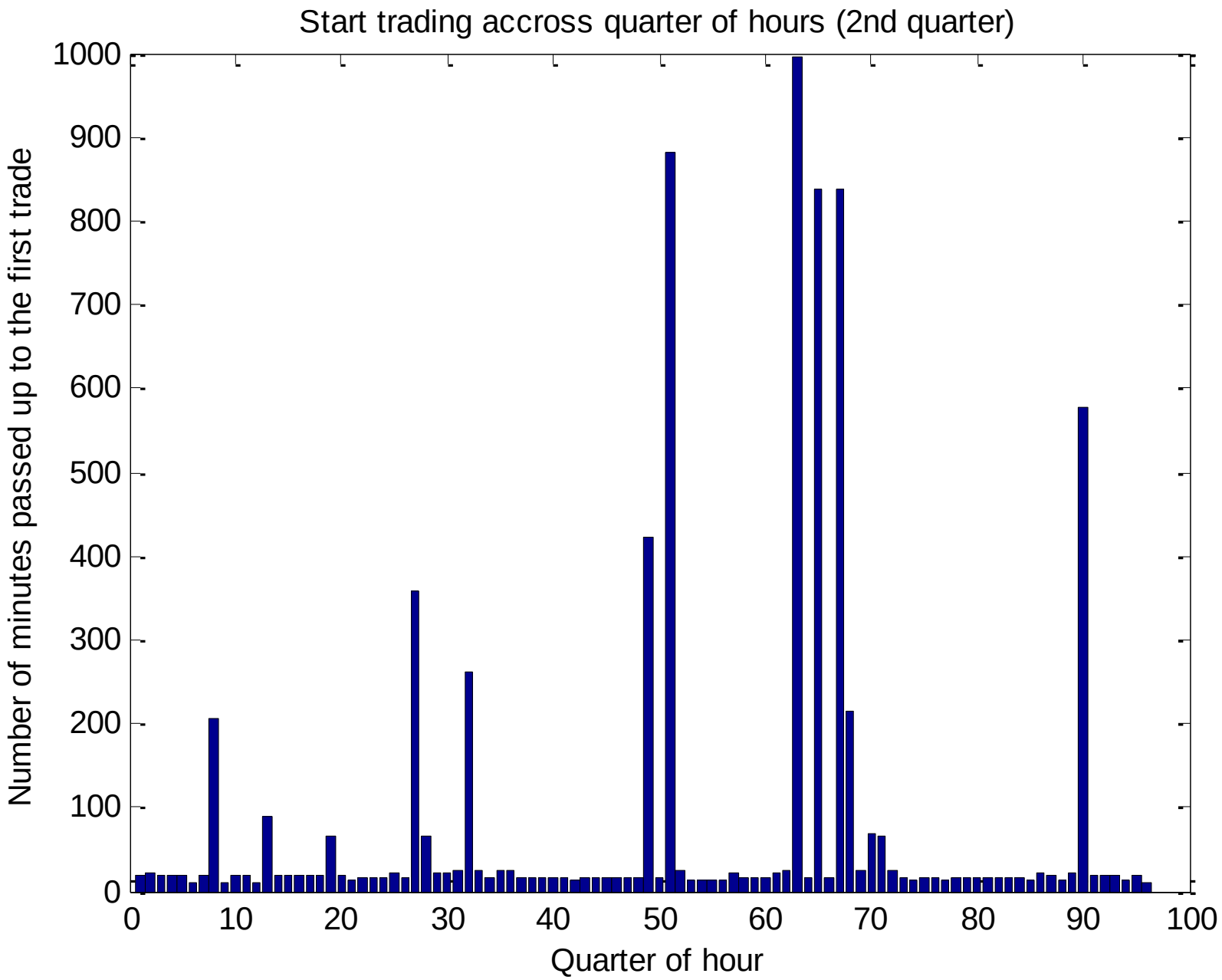

Total number of trades per quarter of hour in 2015
Number of trades
Quarter of hour
0
2000
4000
6000
8000
10000
12000
14000
16000
0
10
20
30
40
50
60
70
80
90
100

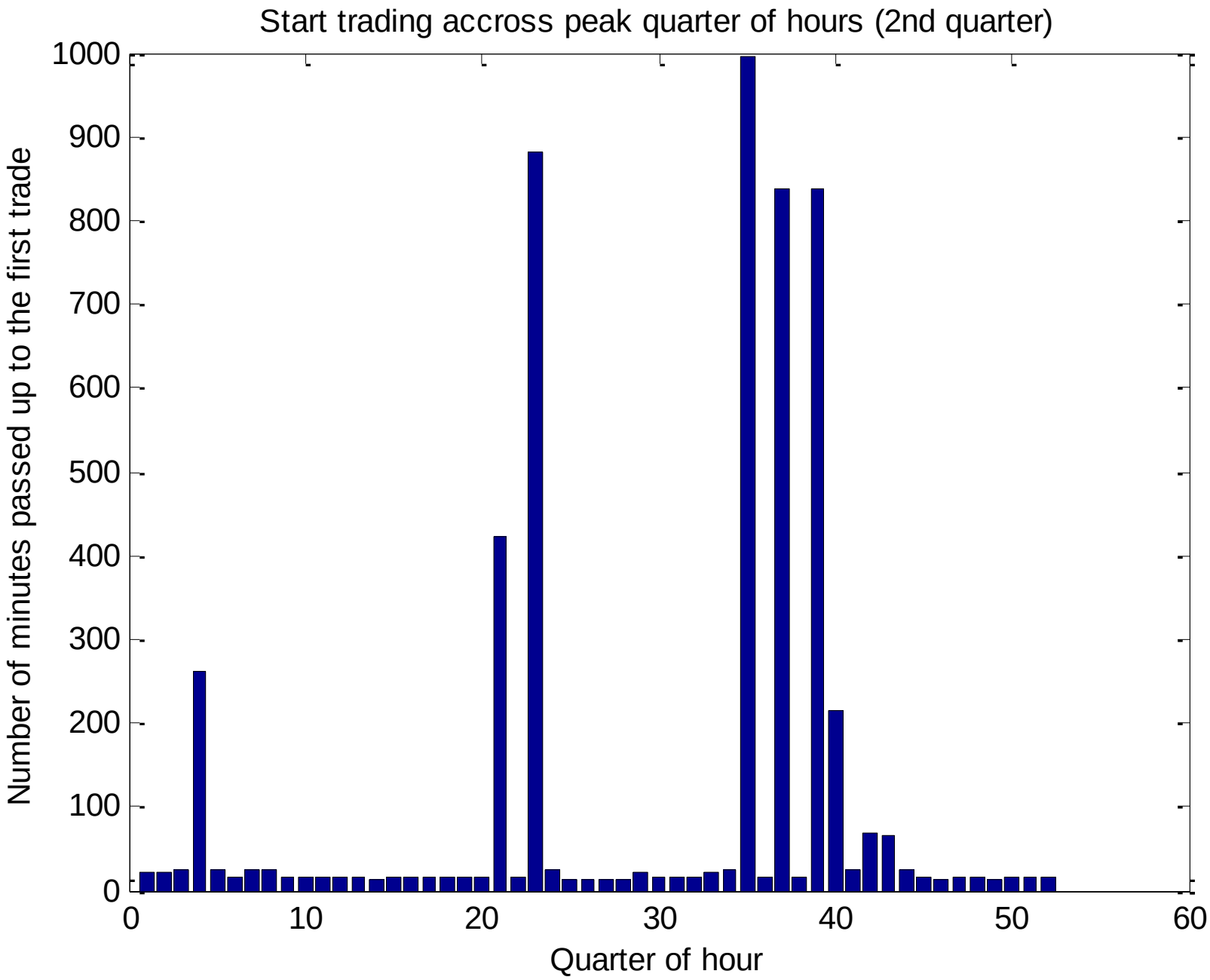

Start trading accross quarter of hours (1st day)
Number of minutes passed up to the first trade
Quarter of hour
0
100
200
300
400
500
600
700
800
900
0
10
20
30
40
50
60
70
80
90
100

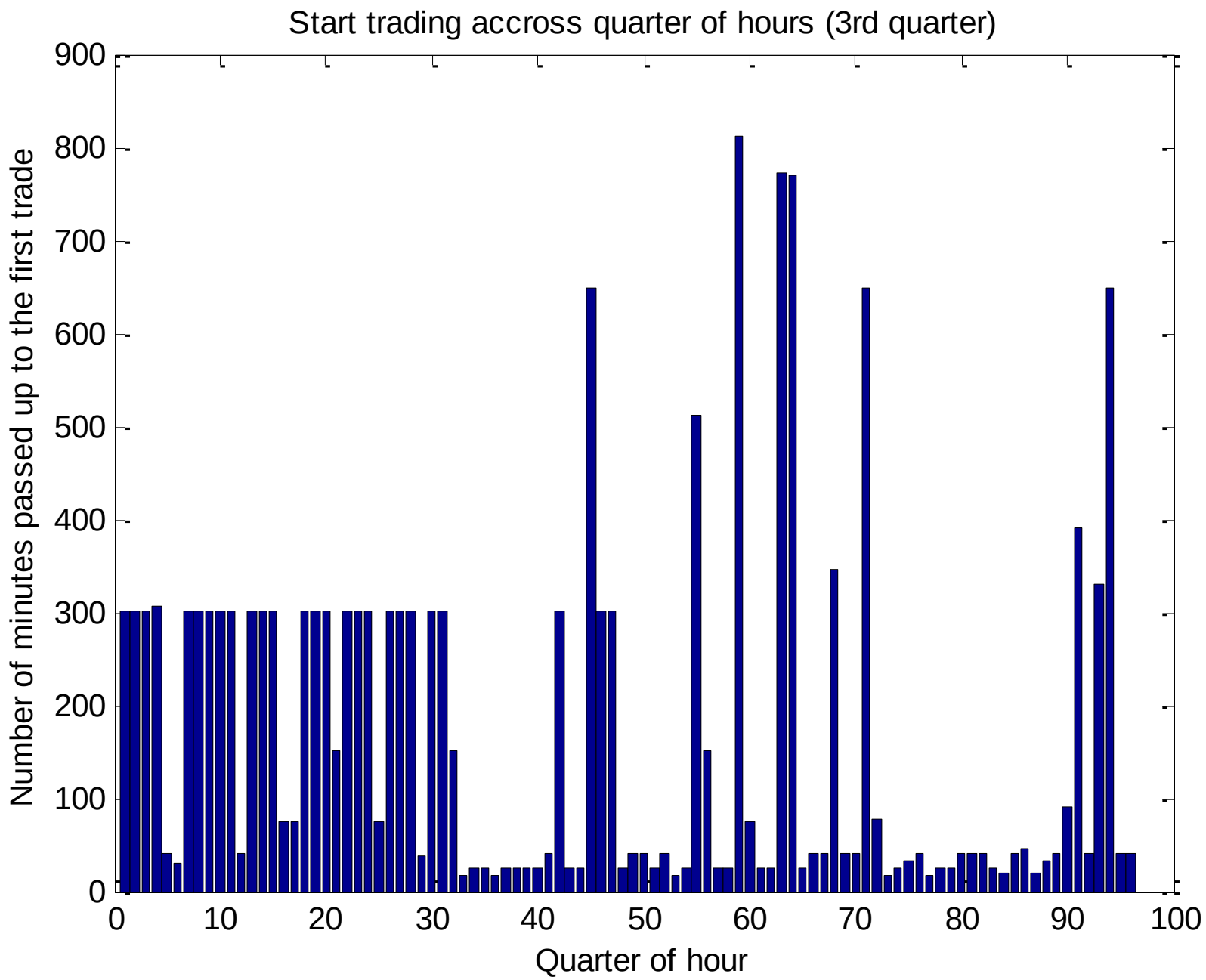

Start trading accross peak quarter of hours (1st day)
Number of minutes passed up to the first trade
Quarter of hour
0
10
20
30
40
50
60
70

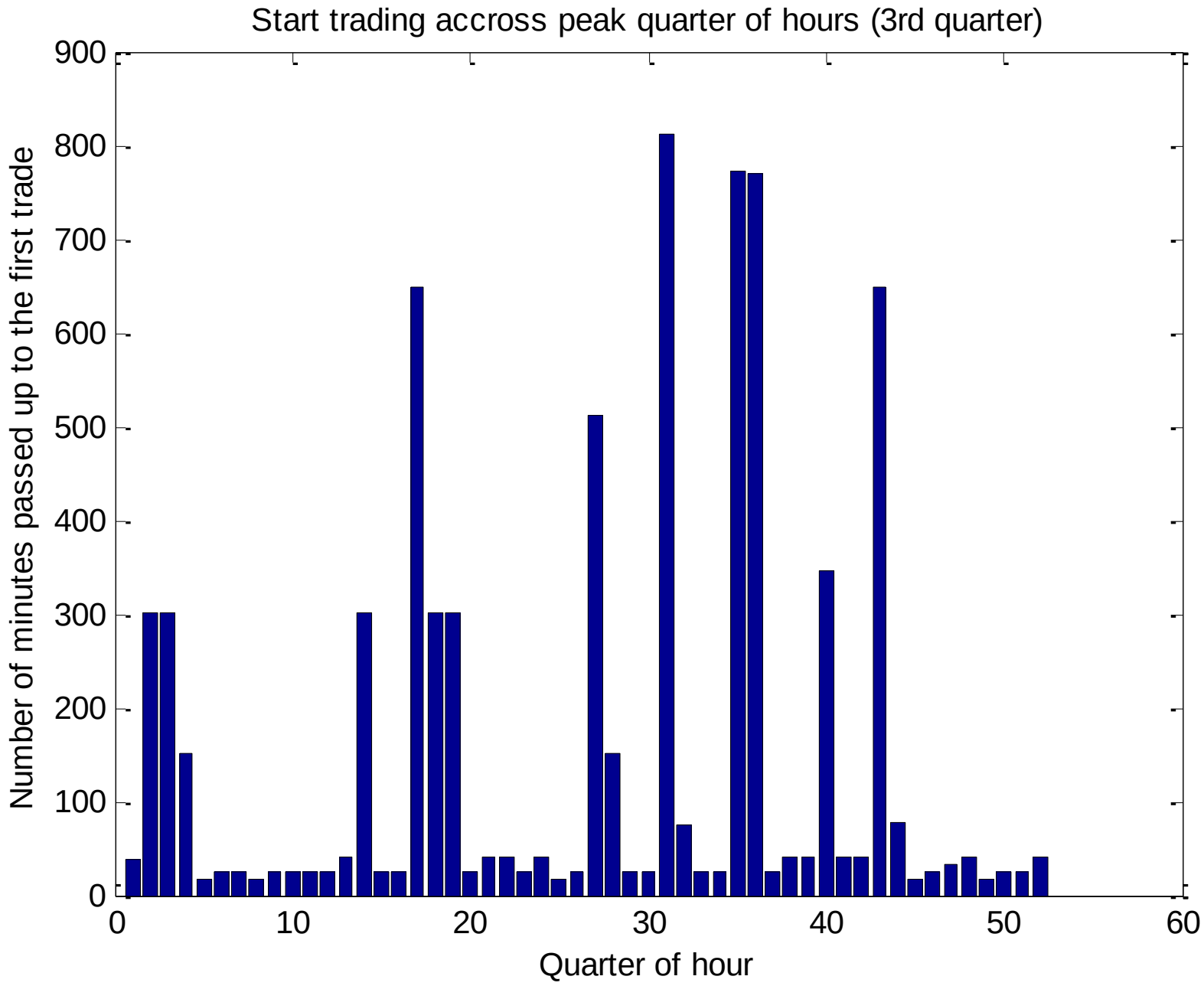

Start trading accross quarter of hours (1st quarter)
Number of minutes passed up to the first trade
Quarter of hour
0
200
400
600
800
1000
1200
1400
0
10
20
30
40
50
60
70
80
90
100


Start trading accross peak quarter of hours (1st quarter)
Number of minutes passed up to the first trade
Quarter of hour
0
200
400
600
800
1000
1200
1400
0
10
20
30
40
50
60


Start trading accross quarter of hours (2nd quarter)
Number of minutes passed up to the first trade
Quarter of hour
0
100
200
300
400
500
600
700
800
900
1000
0
10
20
30
40
50
60
70
80
90
100


Start trading accross peak quarter of hours (2nd quarter)
Number of minutes passed up to the first trade
Quarter of hour
0
100
200
300
400
500
600
700
800
900
1000
0
10
20
30
40
50
60

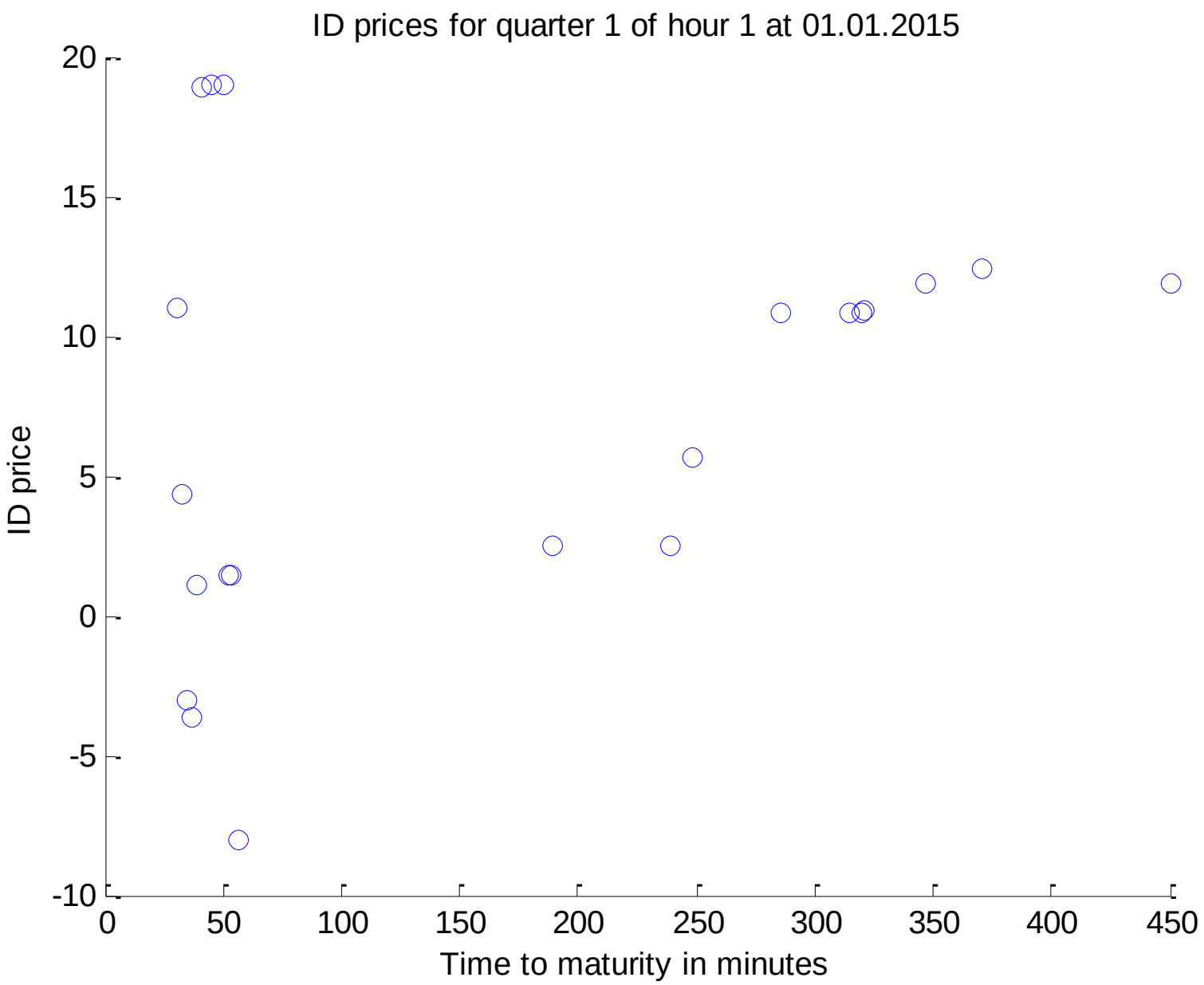

Start trading accross quarter of hours (3rd quarter)
Number of minutes passed up to the first trade
Quarter of hour
0
100
200
300
400
500
600
700
800
900
0
10
20
30
40
50
60
70
80
90
100

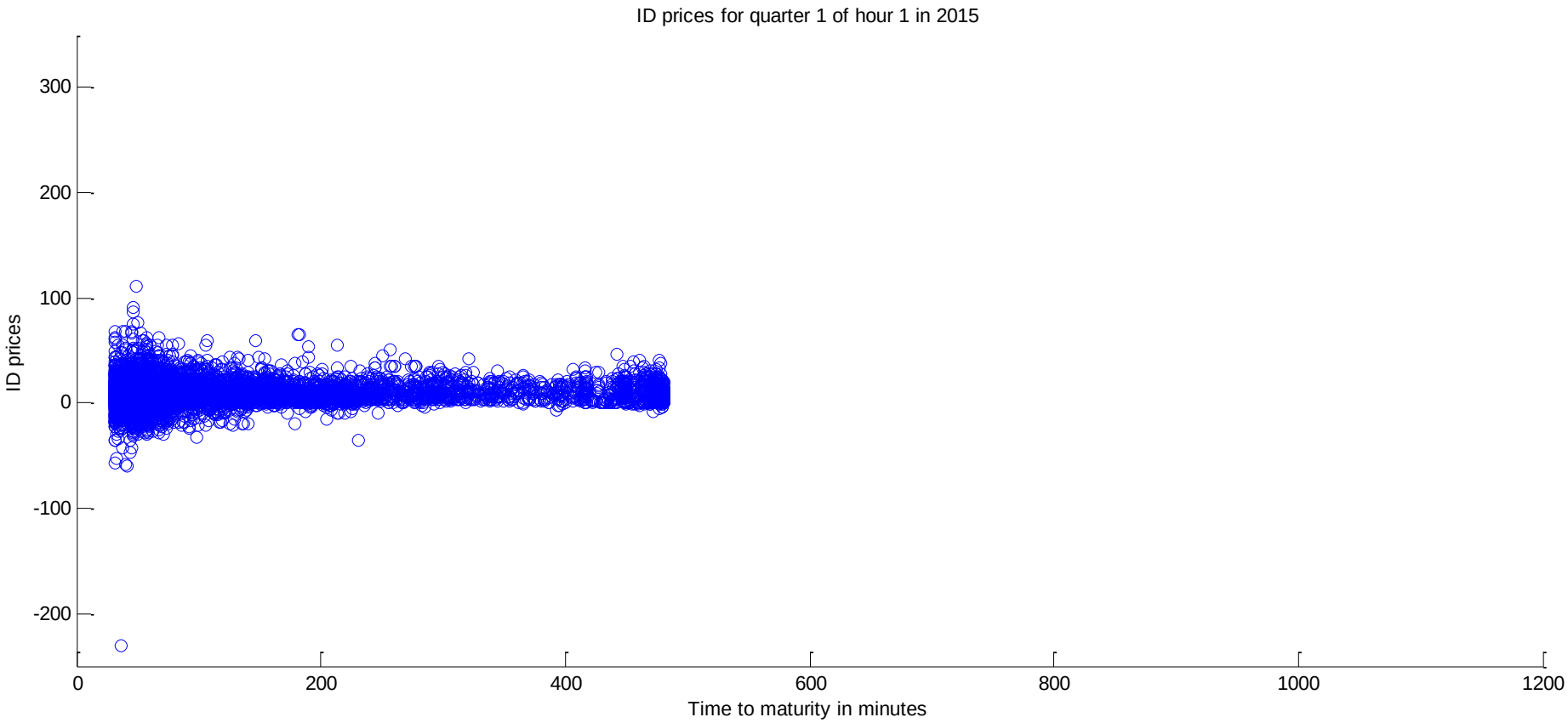

Start trading accross peak quarter of hours (3rd quarter)
Number of minutes passed up to the first trade
Quarter of hour
0
100
200
300
400
500
600
700
800
900
0
10
20
30
40
50
60

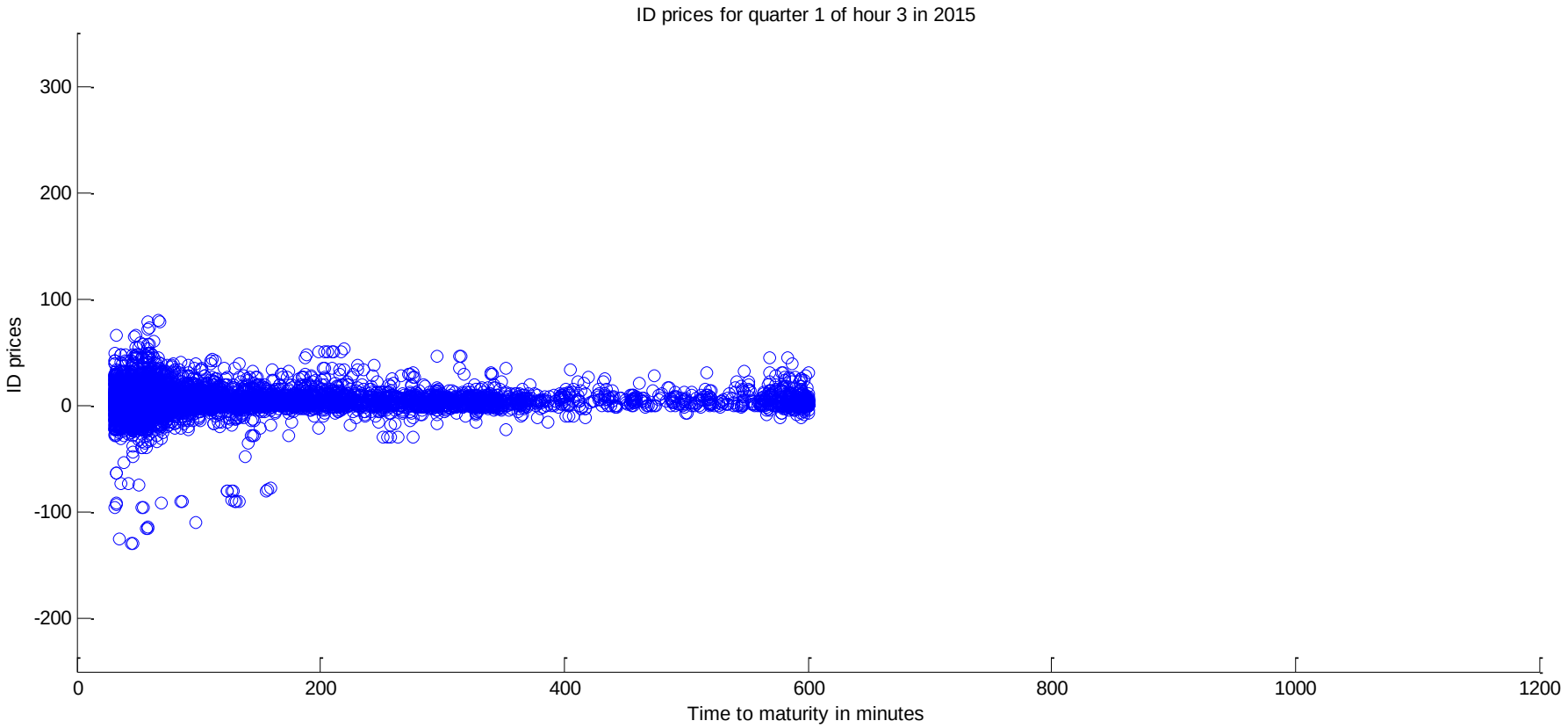
Observation

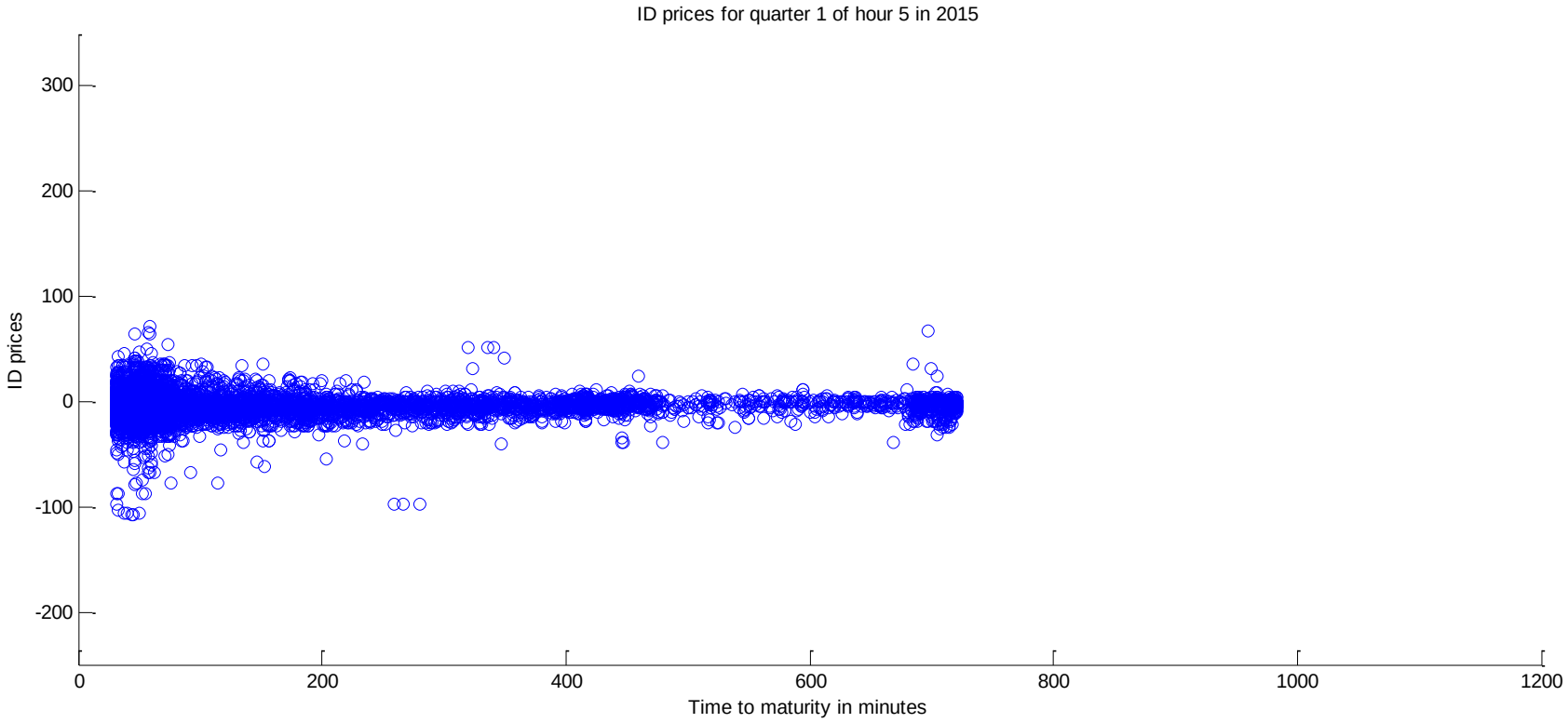
1. It is hard to grid all 96 hour-quarterly prices, as trading starts much later occasionally
2. We could grid the data for quarter-hourly prices belonging to the same trading block.

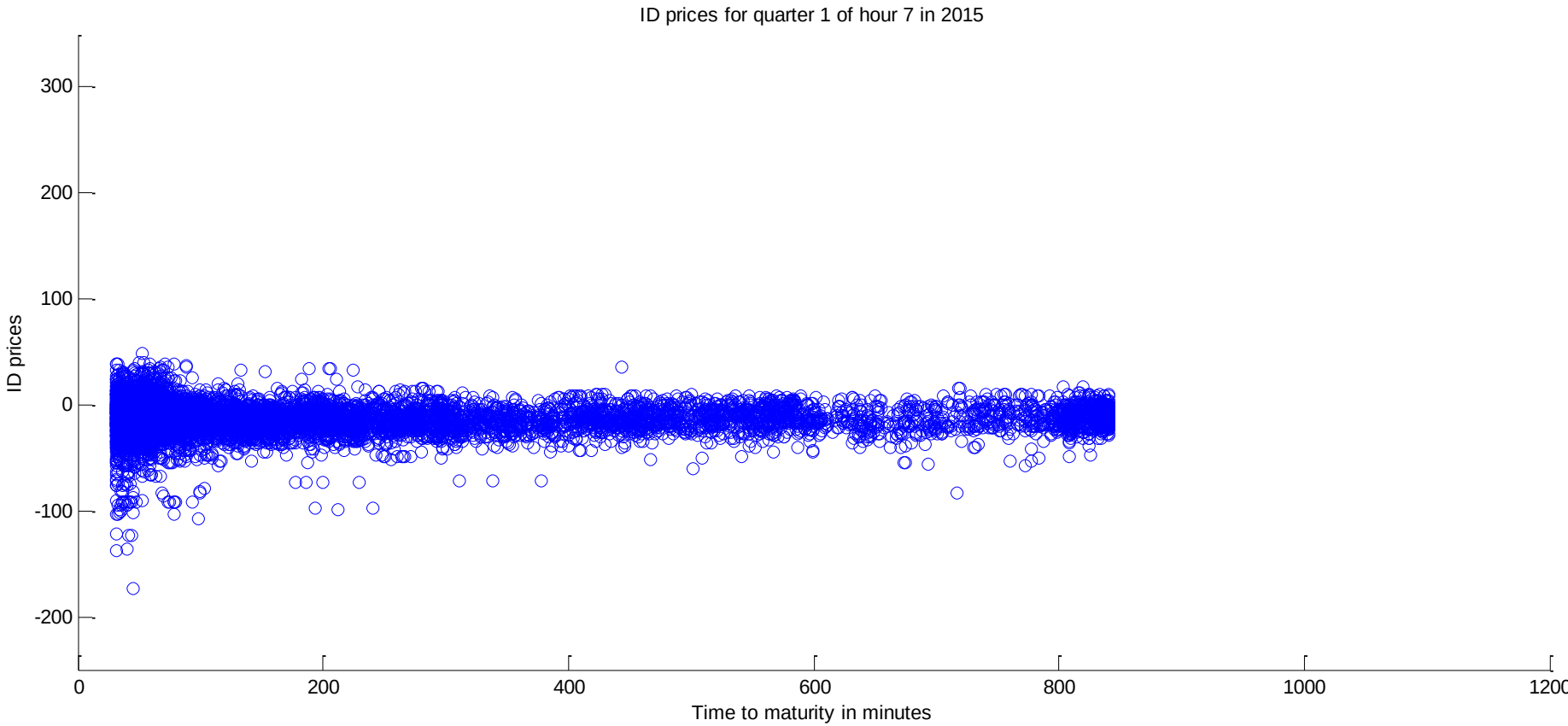
Vola patterns

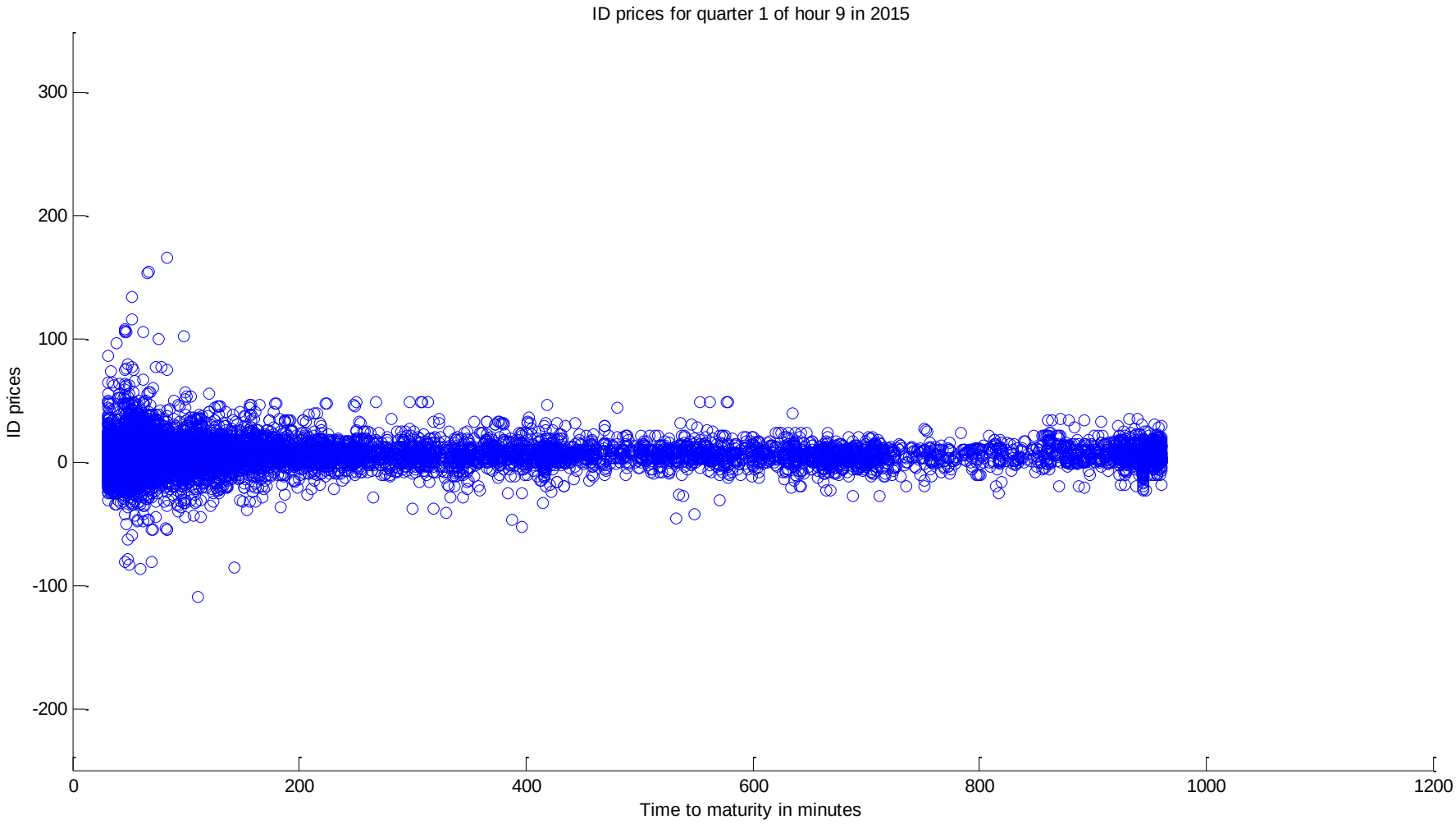

ID prices for quarter 1 of hour 1 at 01.01.2015
ID price
Time to maturity in minutes
20
15
10
5
0
-5
-10
0
50
100
150
200
250
300
350
400
450

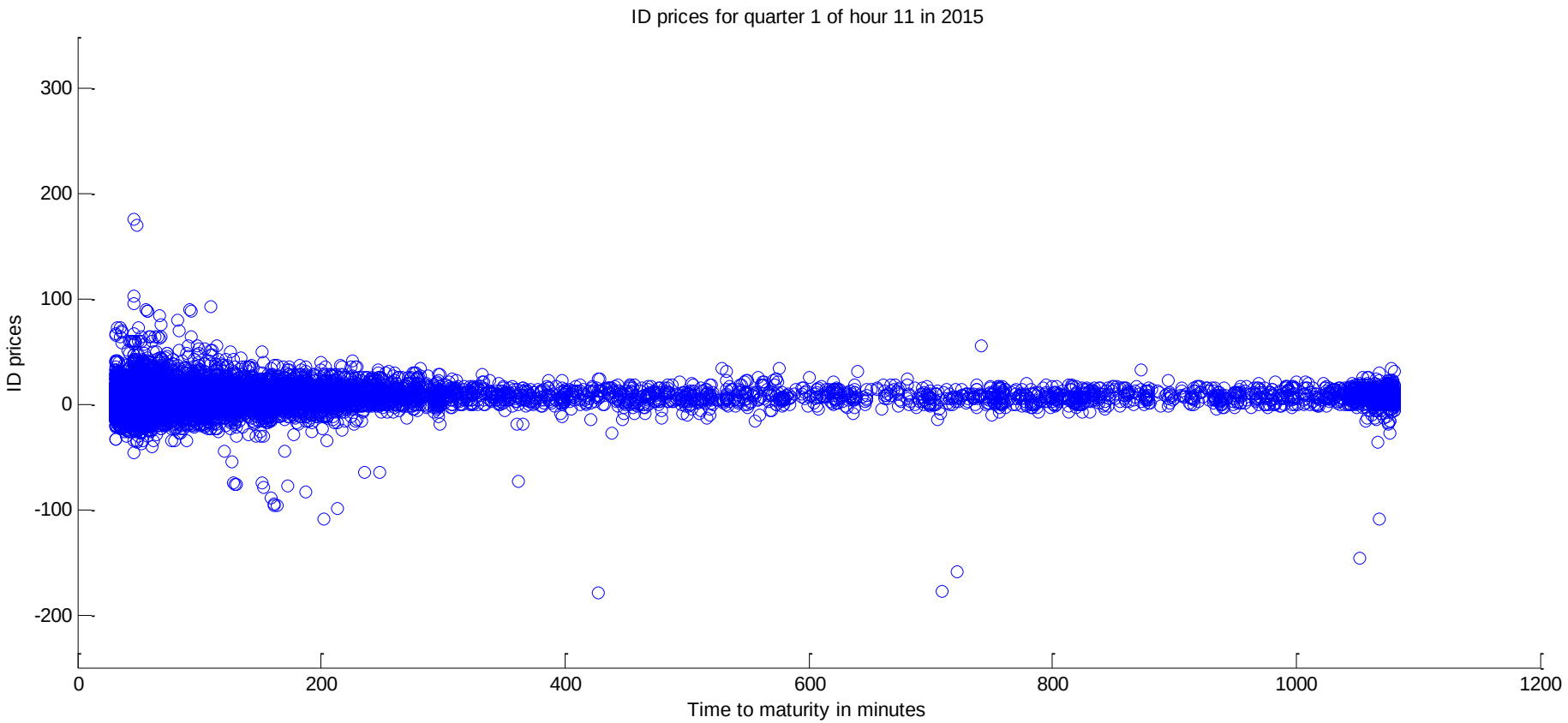

ID prices for quarter 1 of hour 1 in 2015
ID prices
300
200
100
0
-100
-200
0
200
400
600
800
1000
1200
Time to maturity in minutes

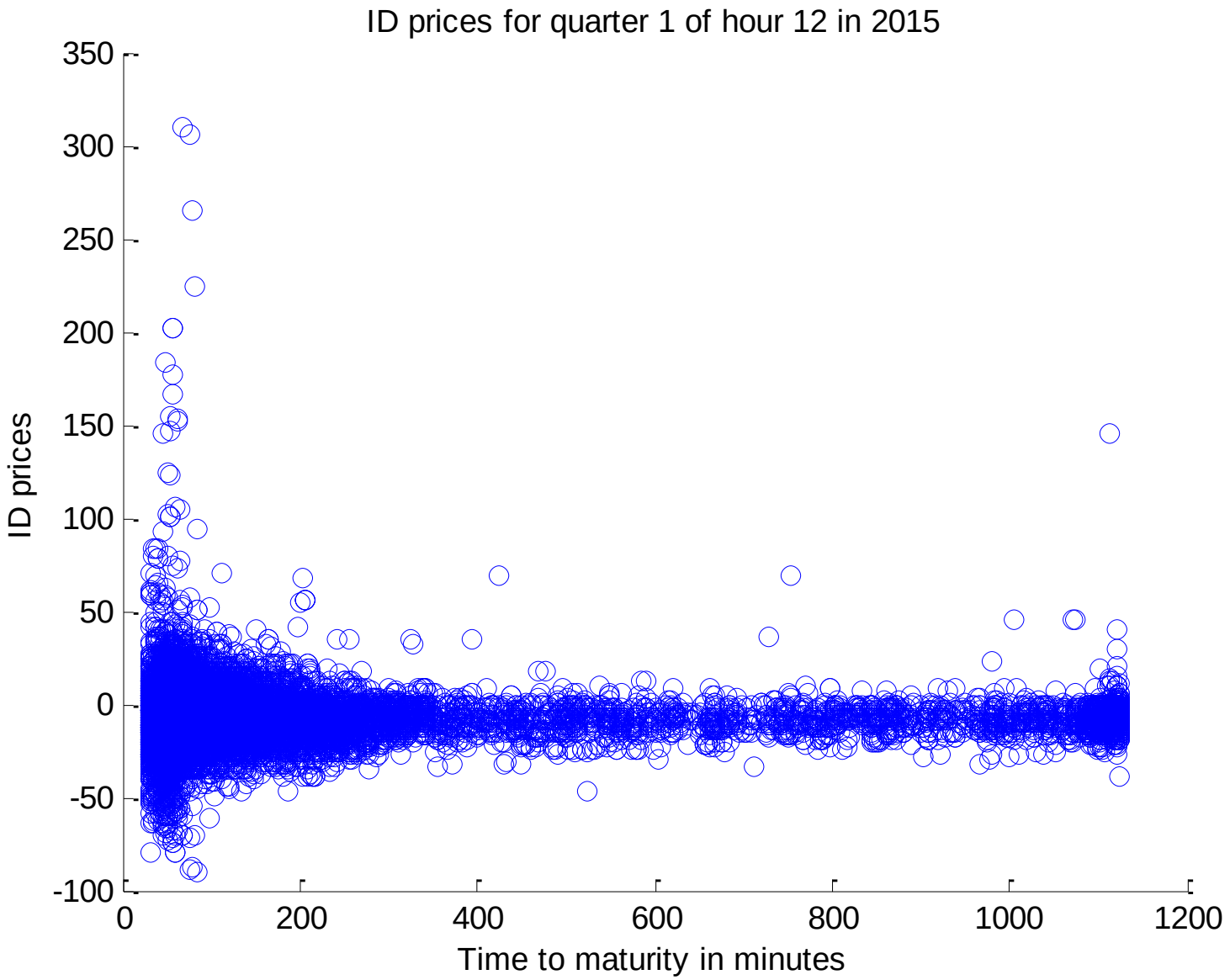

ID prices for quarter 1 of hour 3 in 2015
ID prices
300
200
100
0
-100
-200
0
200
400
600
800
1000
1200
Time to maturity in minutes

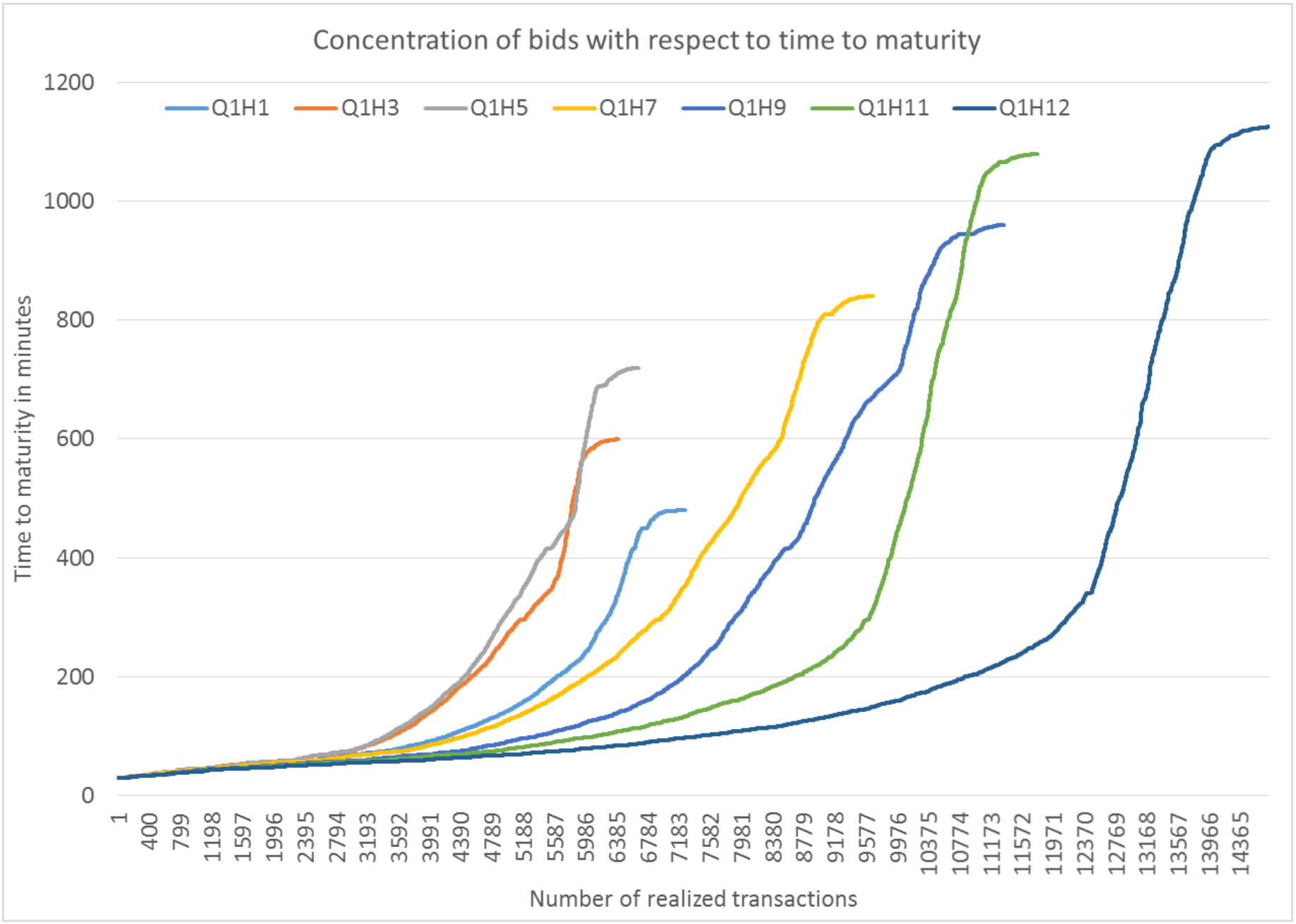

ID prices for quarter 1 of hour 5 in 2015
ID prices
300
200
100
0
-100
-200
0
200
400
600
800
1000
1200
Time to maturity in minutes

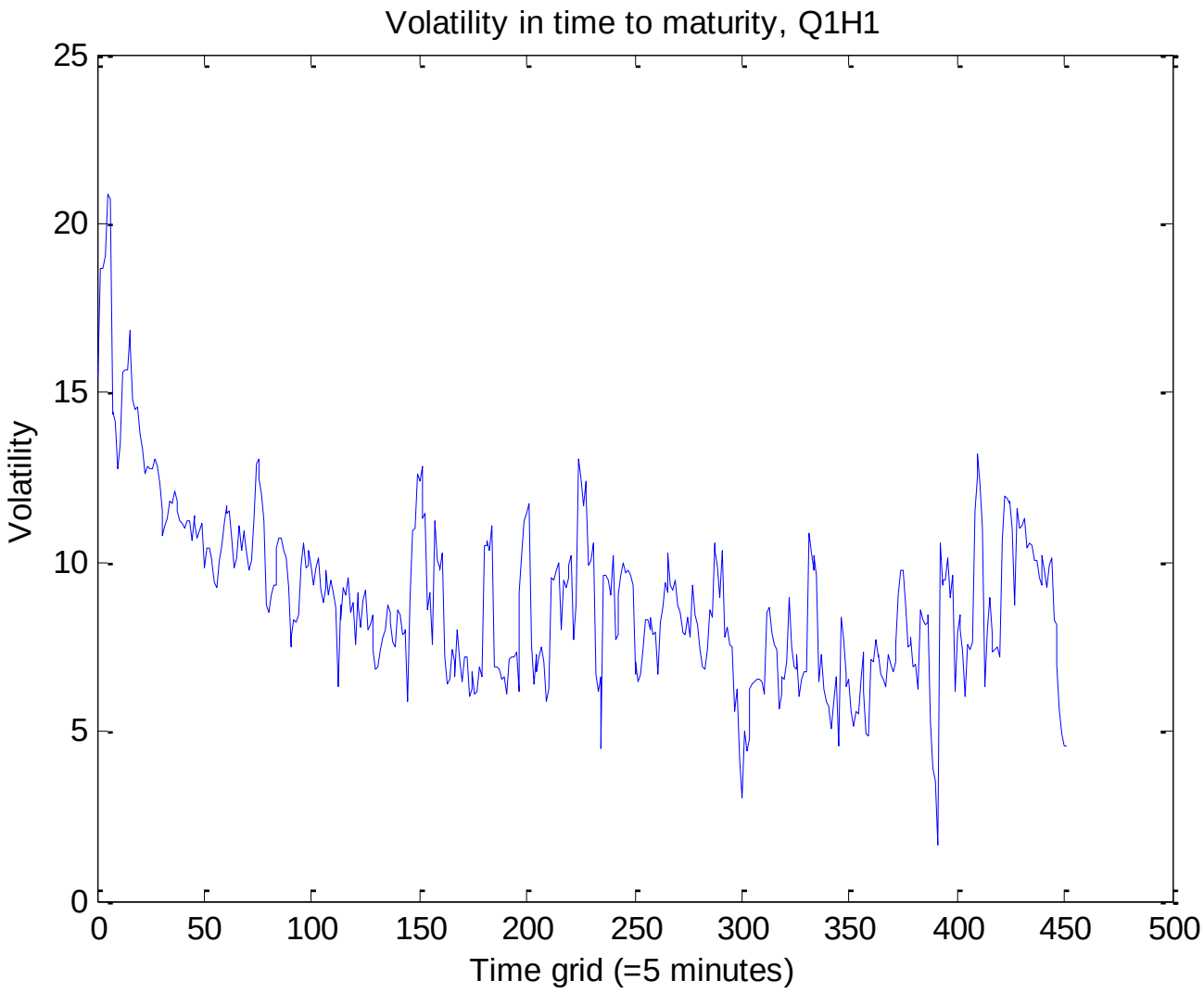

ID prices for quarter 1 of hour 7 in 2015
ID prices
300
200
100
0
-100
-200
0
200
400
600
800
1000
1200
Time to maturity in minutes

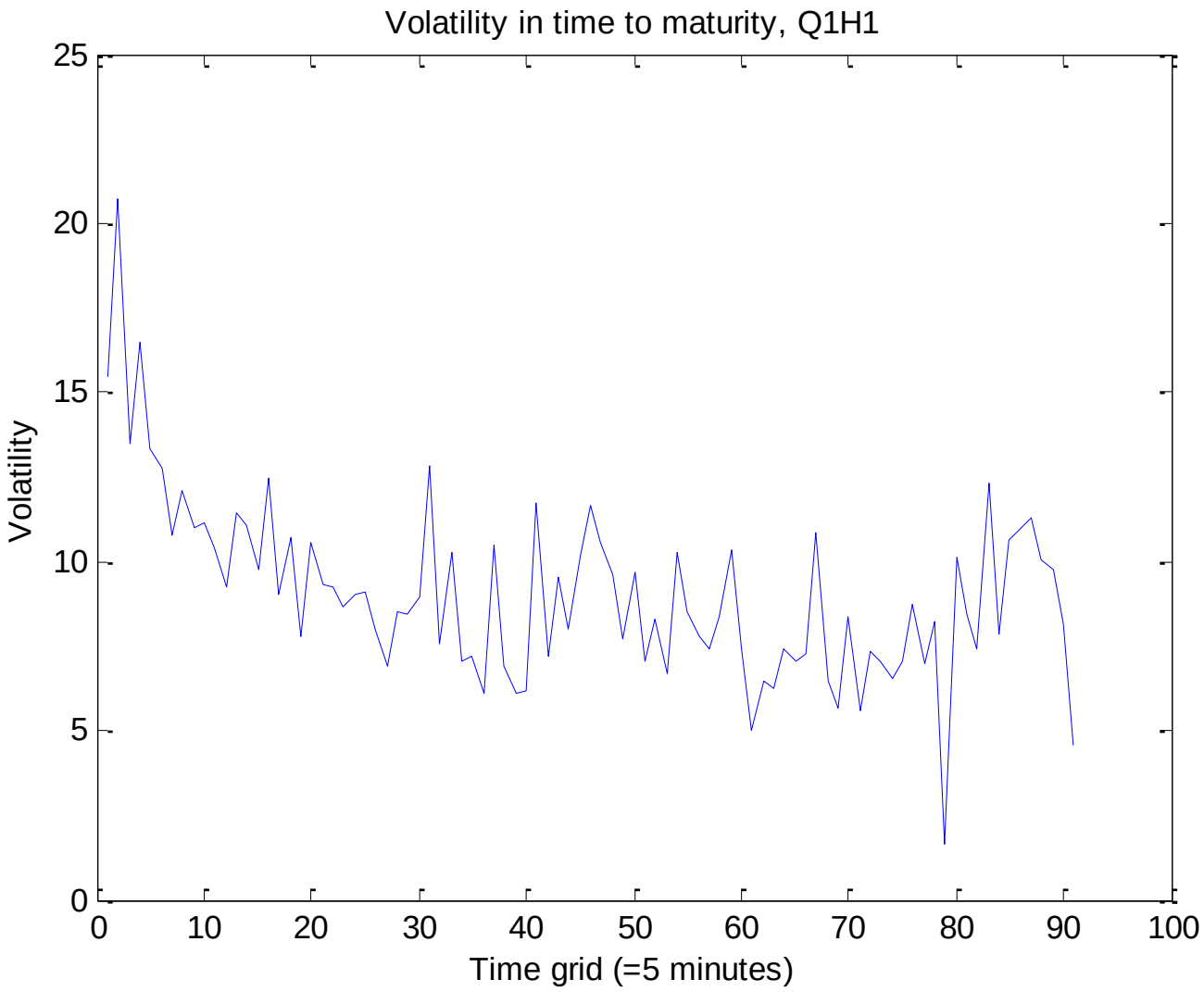

ID prices for quarter 1 of hour 9 in 2015
ID prices
300
200
100
0
-100
-200
0
200
400
600
800
1000
1200
Time to maturity in minutes

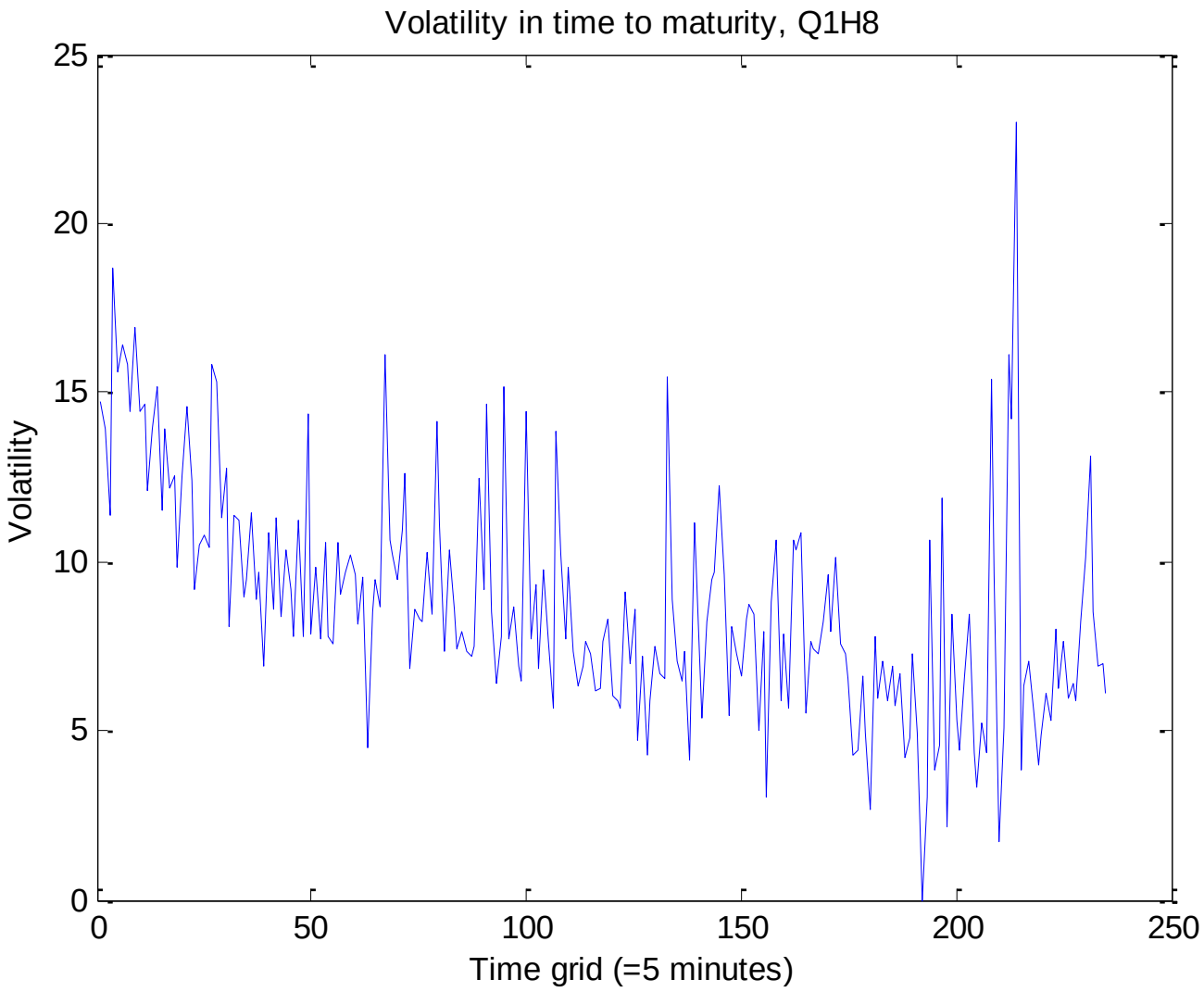

ID prices for quarter 1 of hour 11 in 2015
ID prices
300
200
100
0
-100
-200
0
200
400
600
800
1000
1200
Time to maturity in minutes

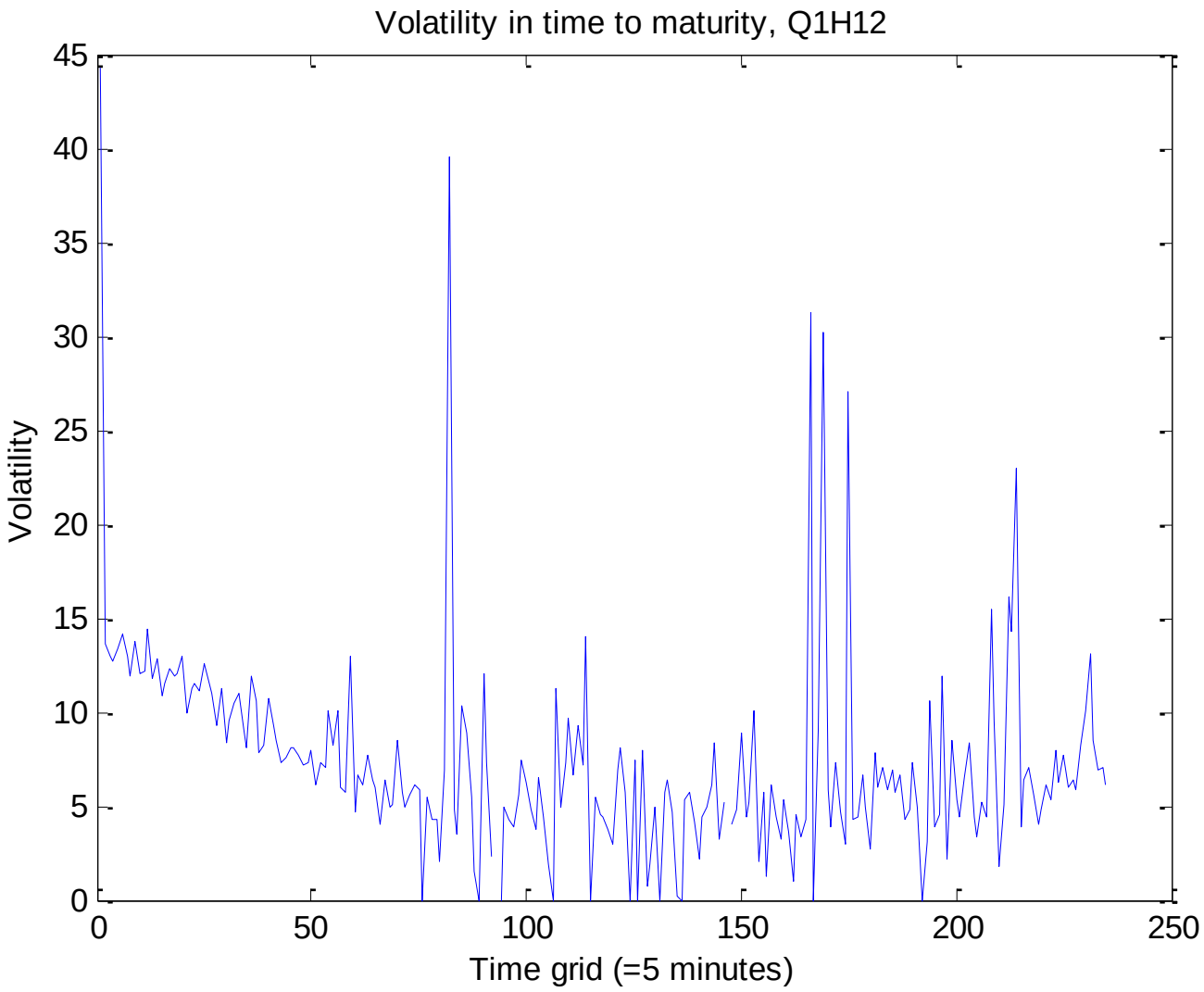

ID prices for quarter 1 of hour 12 in 2015
ID prices
Time to maturity in minutes
350
300
250
200
150
100
50
0
-50
-100
0
200
400
600
800
1000
1200

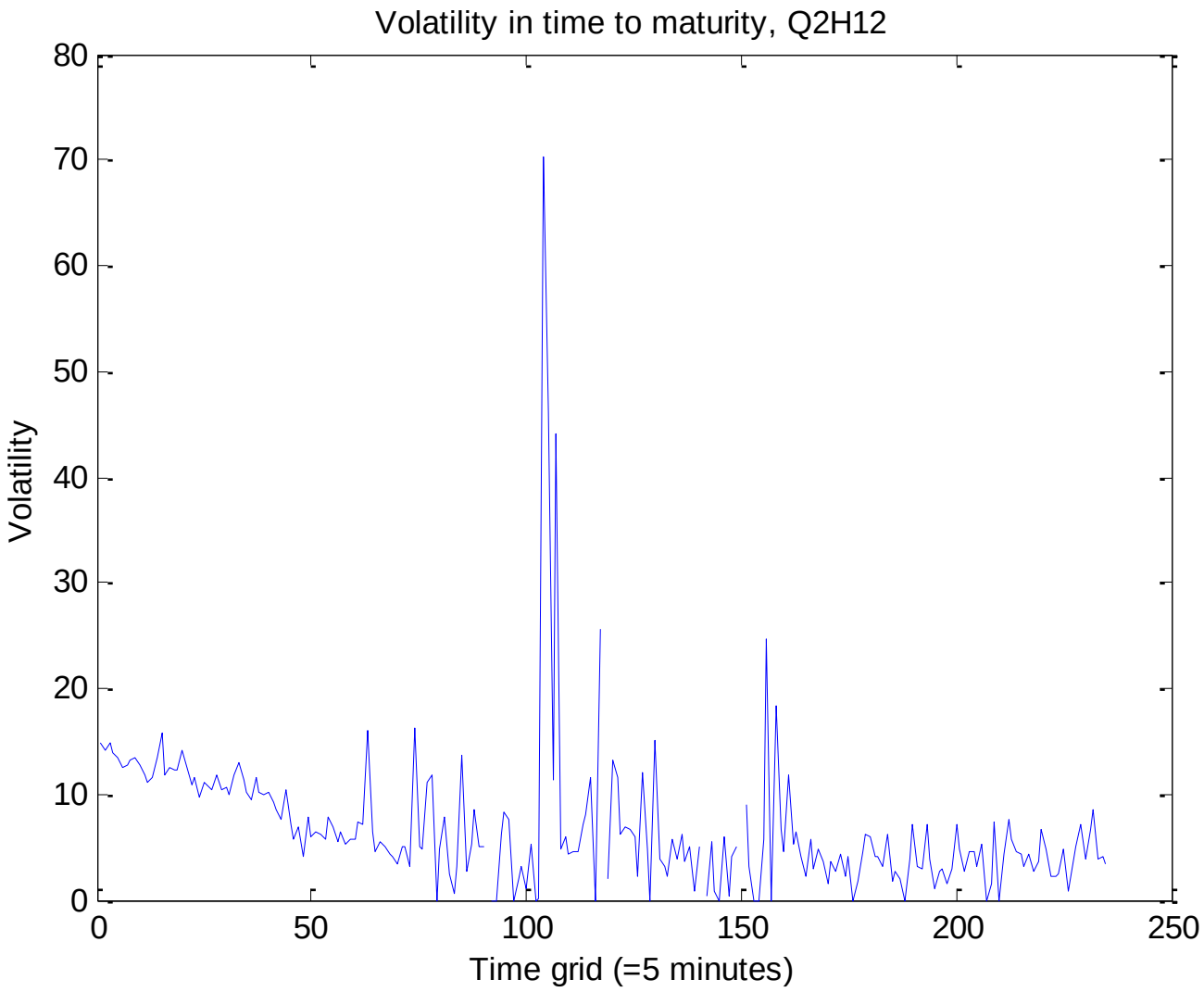

Concentration of bids with respect to time to maturity
Q1H1
Q1H3
Q1H5
Q1H7
Q1H9
Q1H11
Q1H12
Time to maturity in minutes
0
200
400
600
800
1000
1200
1
400
799
1198
1597
1996
2395
2794
3193
3592
3991
4390
4789
5188
5587
5986
6385
6784
7183
7582
7981
8380
8779
9178
9577
9976
10375
10774
11173
11572
11971
12370
12769
13168
13567
13966
14365
Number of realized transactions

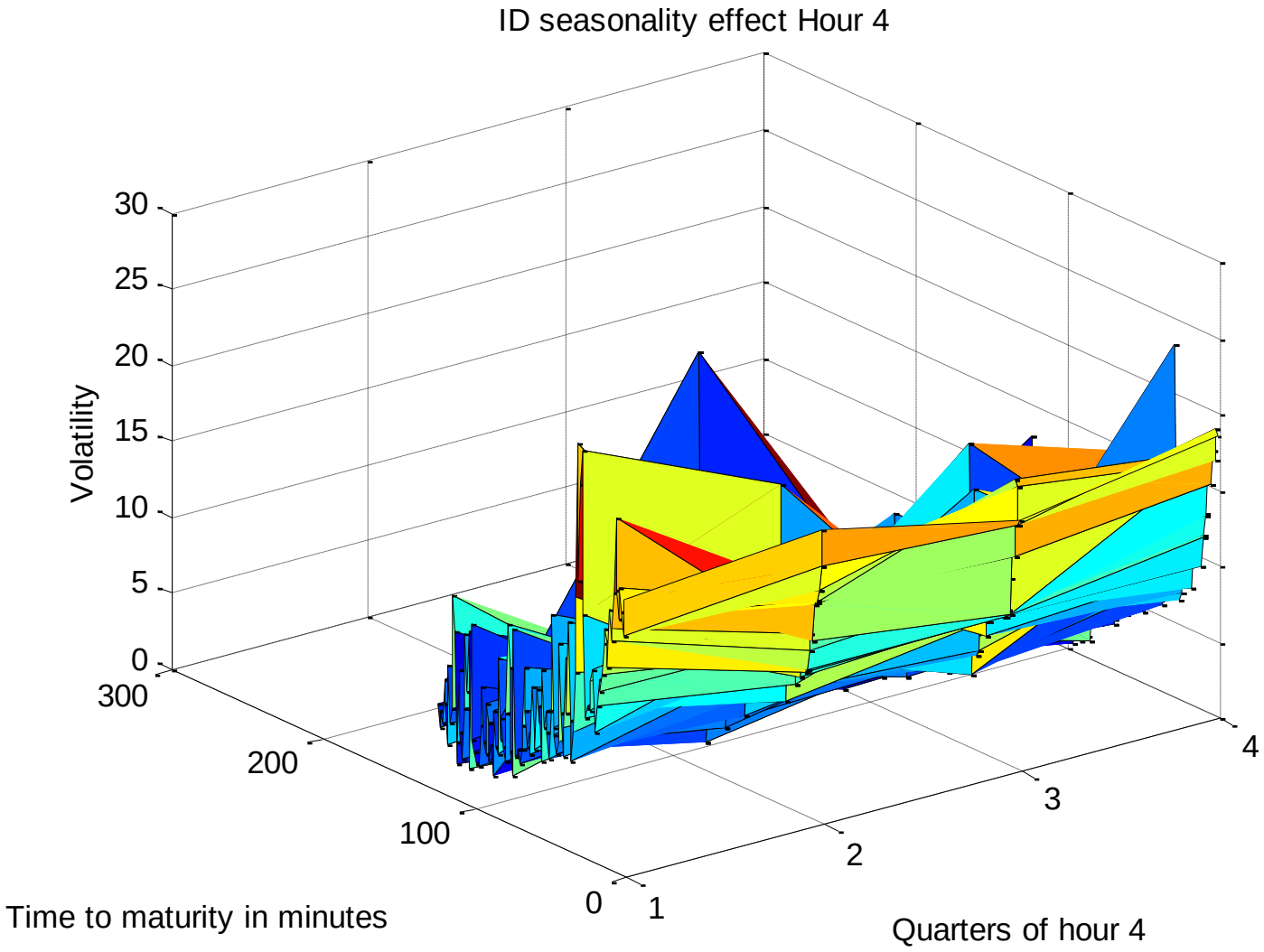

Volatility in time to maturity, Q1H1
Volatility
Time grid (=5 minutes)
0
5
10
15
20
25
0
50
100
150
200
250
300
350
400
450
500

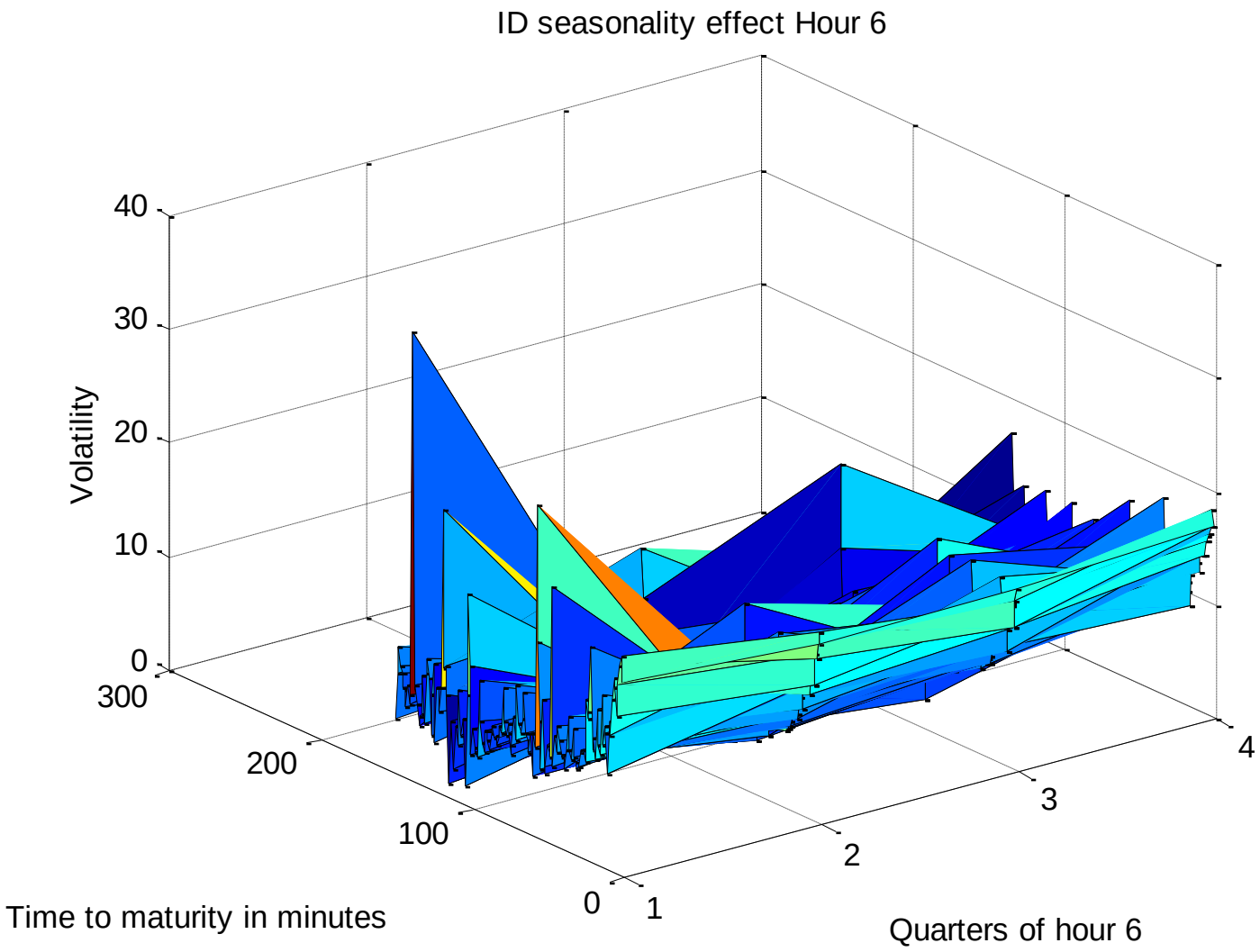

Volatility in time to maturity, Q1H1
Volatility
Time grid (=5 minutes)
0
5
10
15
20
25
0
10
20
30
40
50
60
70
80
90
100

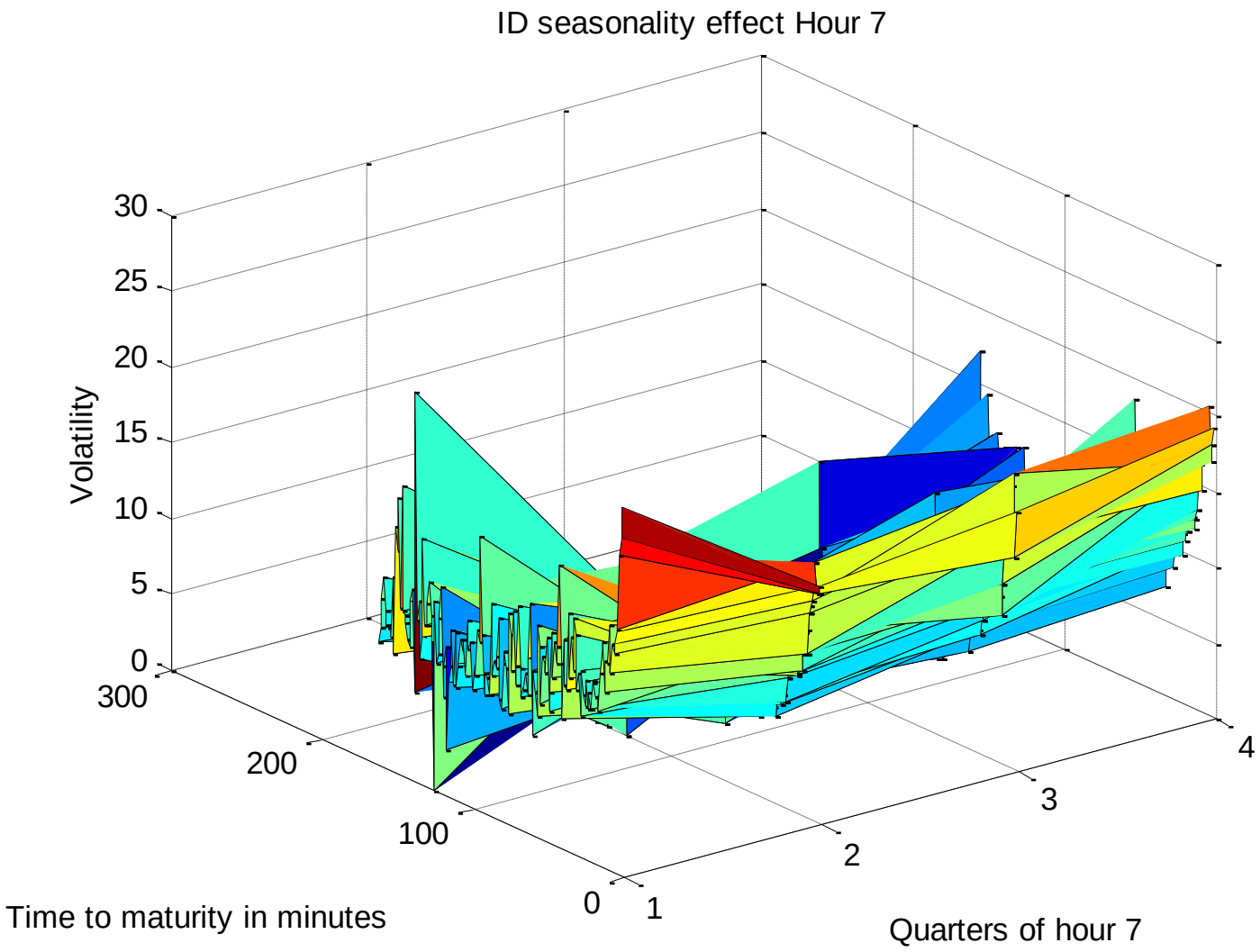

Volatility in time to maturity, Q1H8
Volatility
Time grid (=5 minutes)
0
5
10
15
20
25
0
50
100
150
200
250

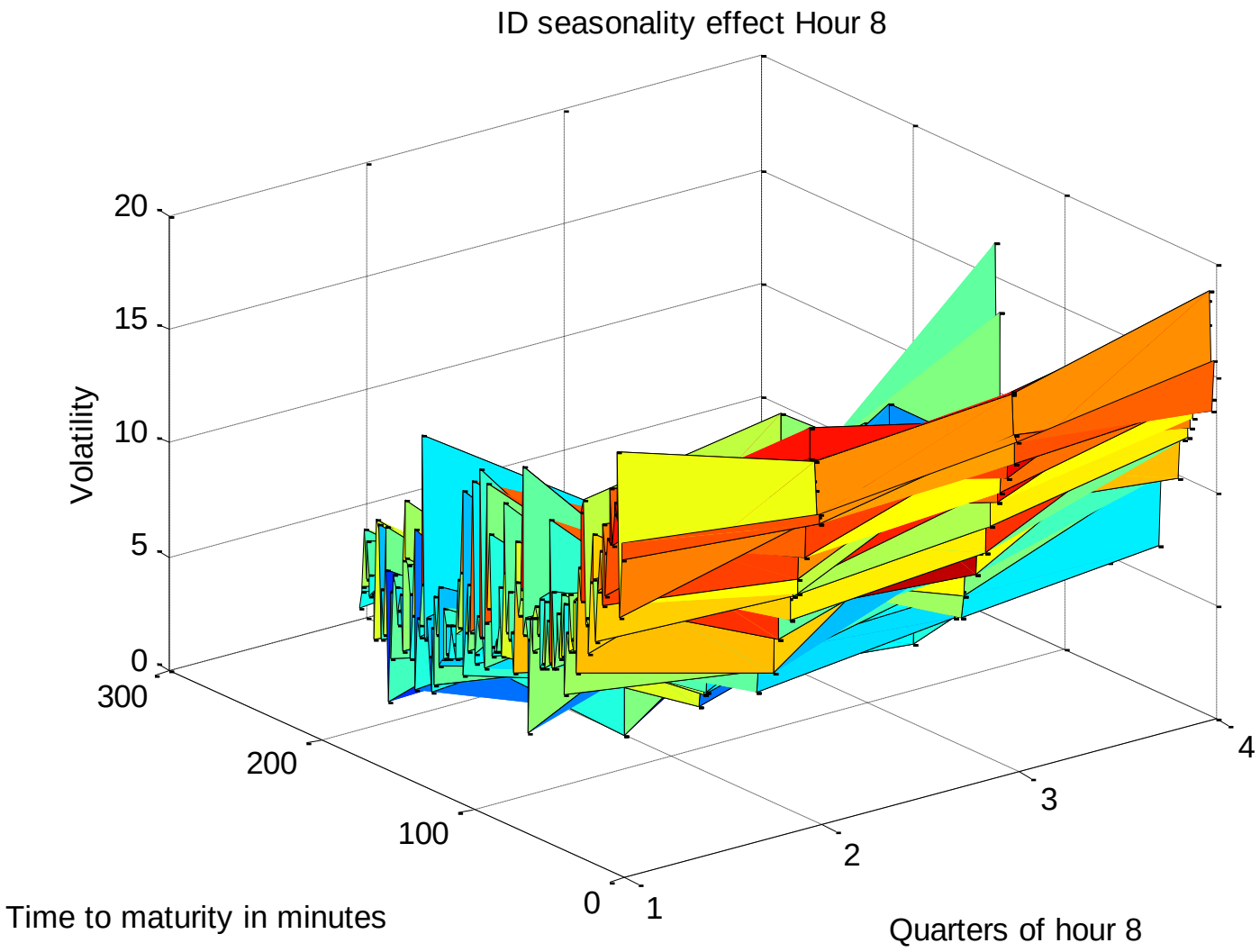

Volatility in time to maturity, Q1H12
Volatility
Time grid (=5 minutes)
0
5
10
15
20
25
30
35
40
45
0
50
100
150
200
250

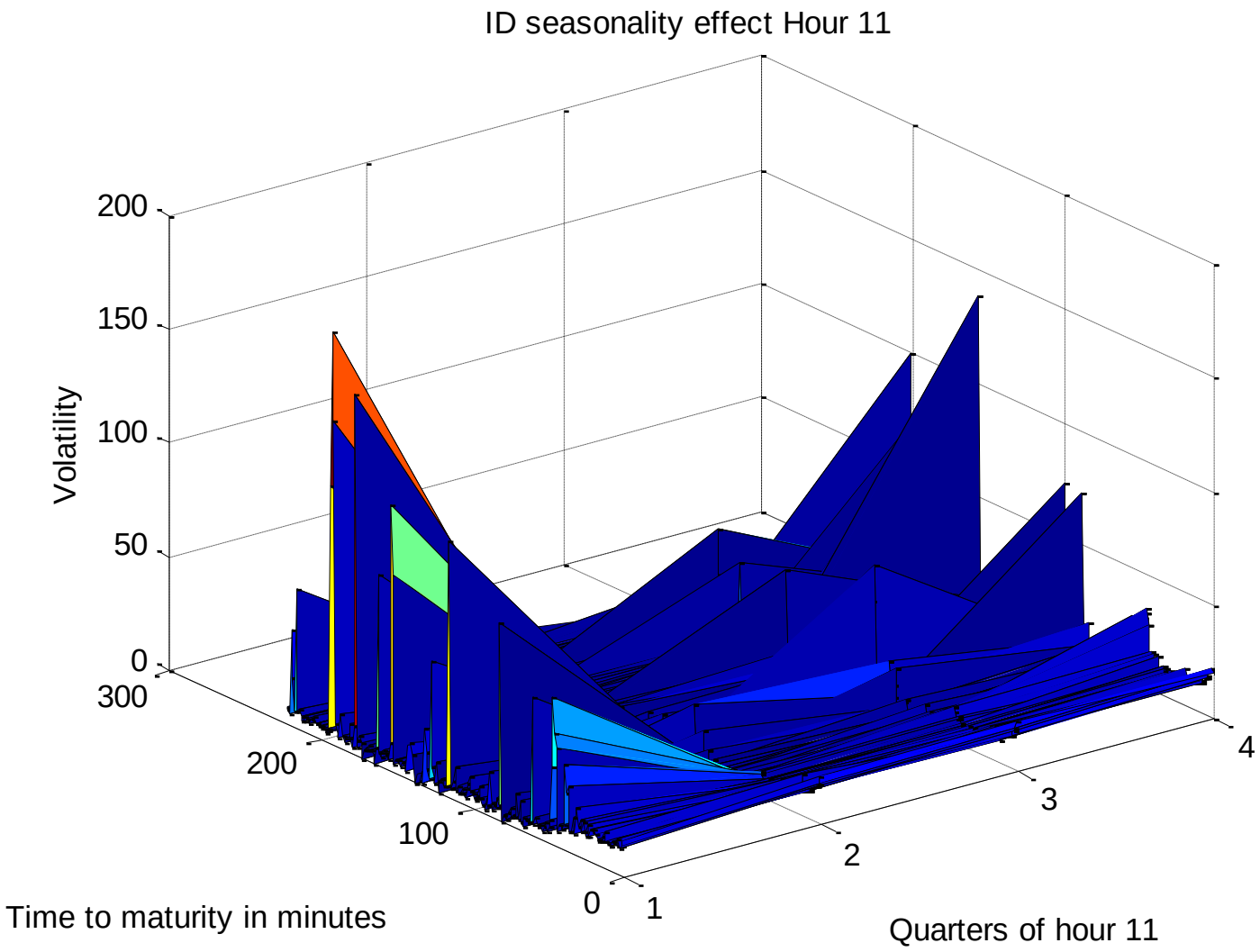

Volatility in time to maturity, Q2H12
Volatility
Time grid (=5 minutes)
0
10
20
30
40
50
60
70
80
0
50
100
150
200
250

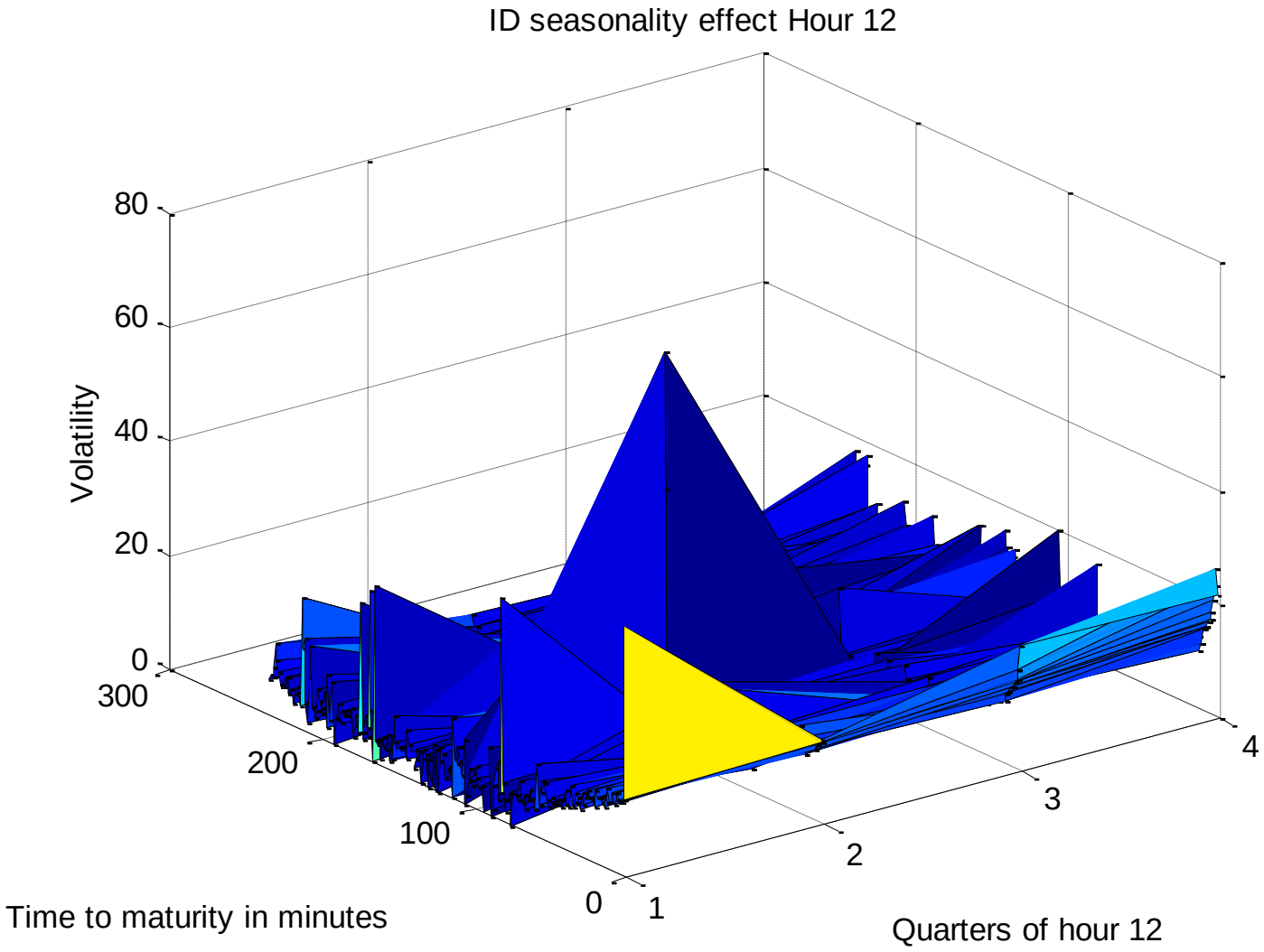

ID seasonality effect Hour 4
Volatility
30
25
20
15
10
5
0
300
200
100
0
Time to maturity in minutes
1
2
3
4
Quarters of hour 4

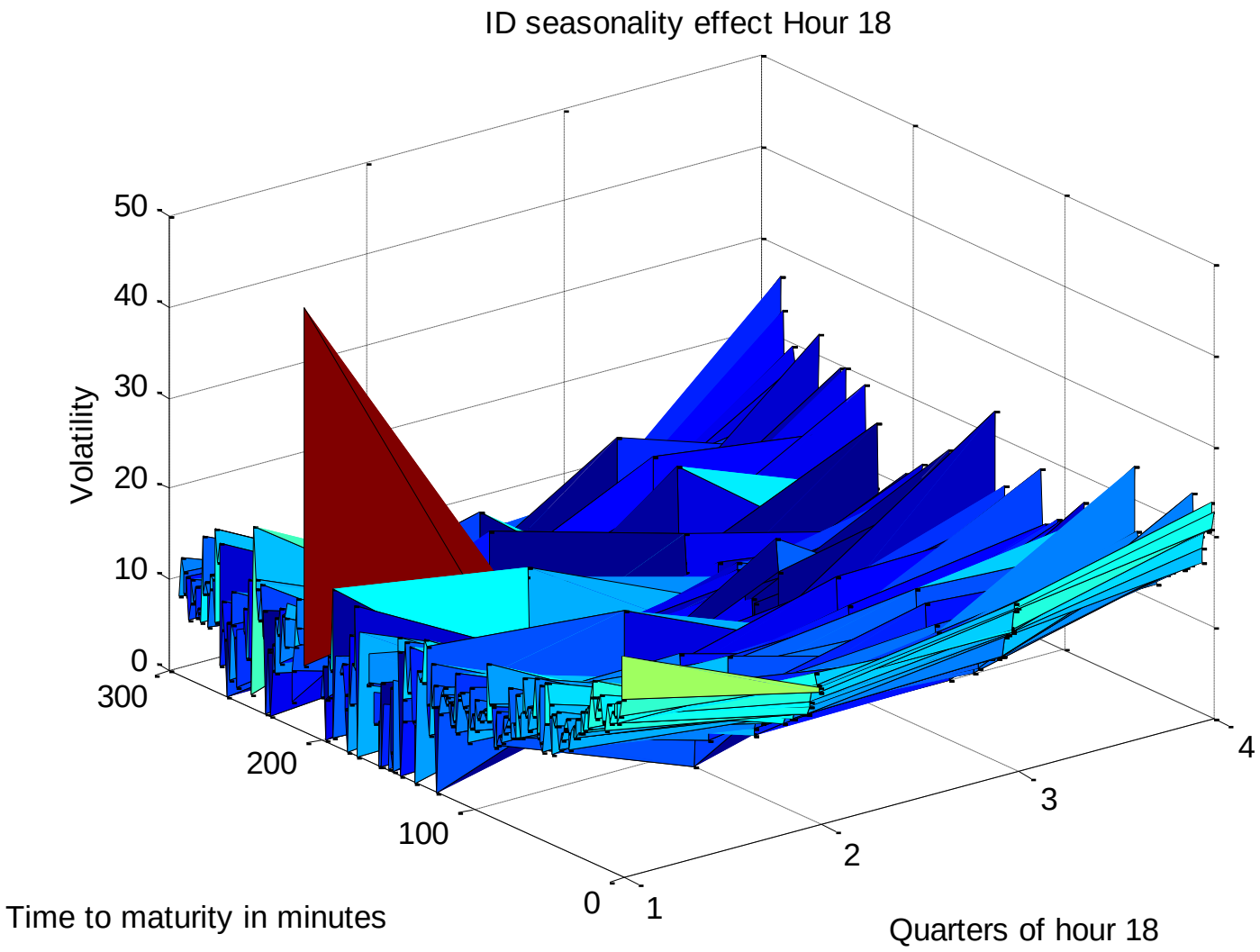

ID seasonality effect Hour 6
Volatility
40
30
20
10
0
300
200
100
0
Time to maturity in minutes
1
2
3
4
Quarters of hour 6

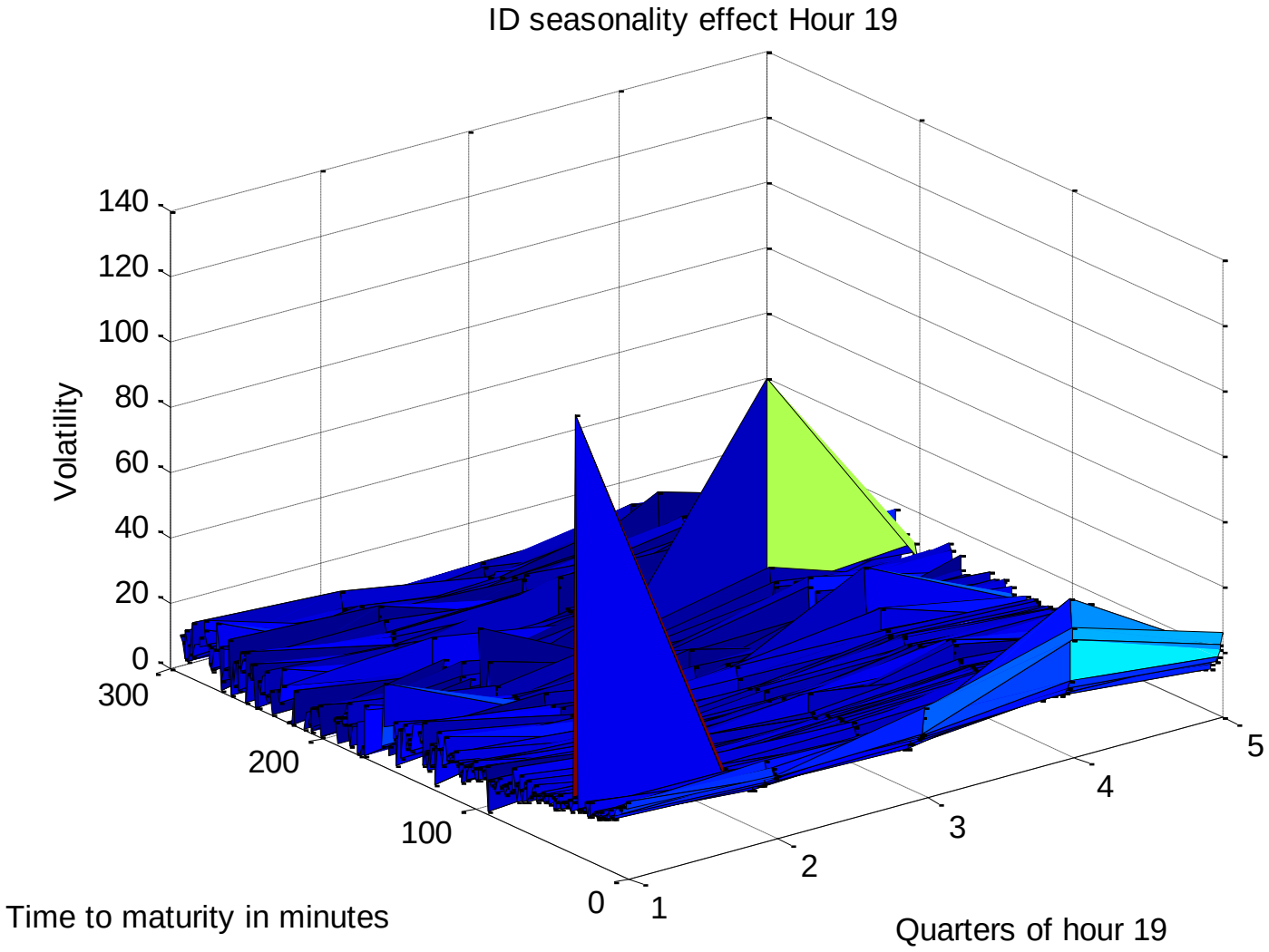

ID seasonality effect Hour 7
Volatility
30
25
20
15
10
5
0
300
200
100
0
Time to maturity in minutes
1
2
3
4
Quarters of hour 7

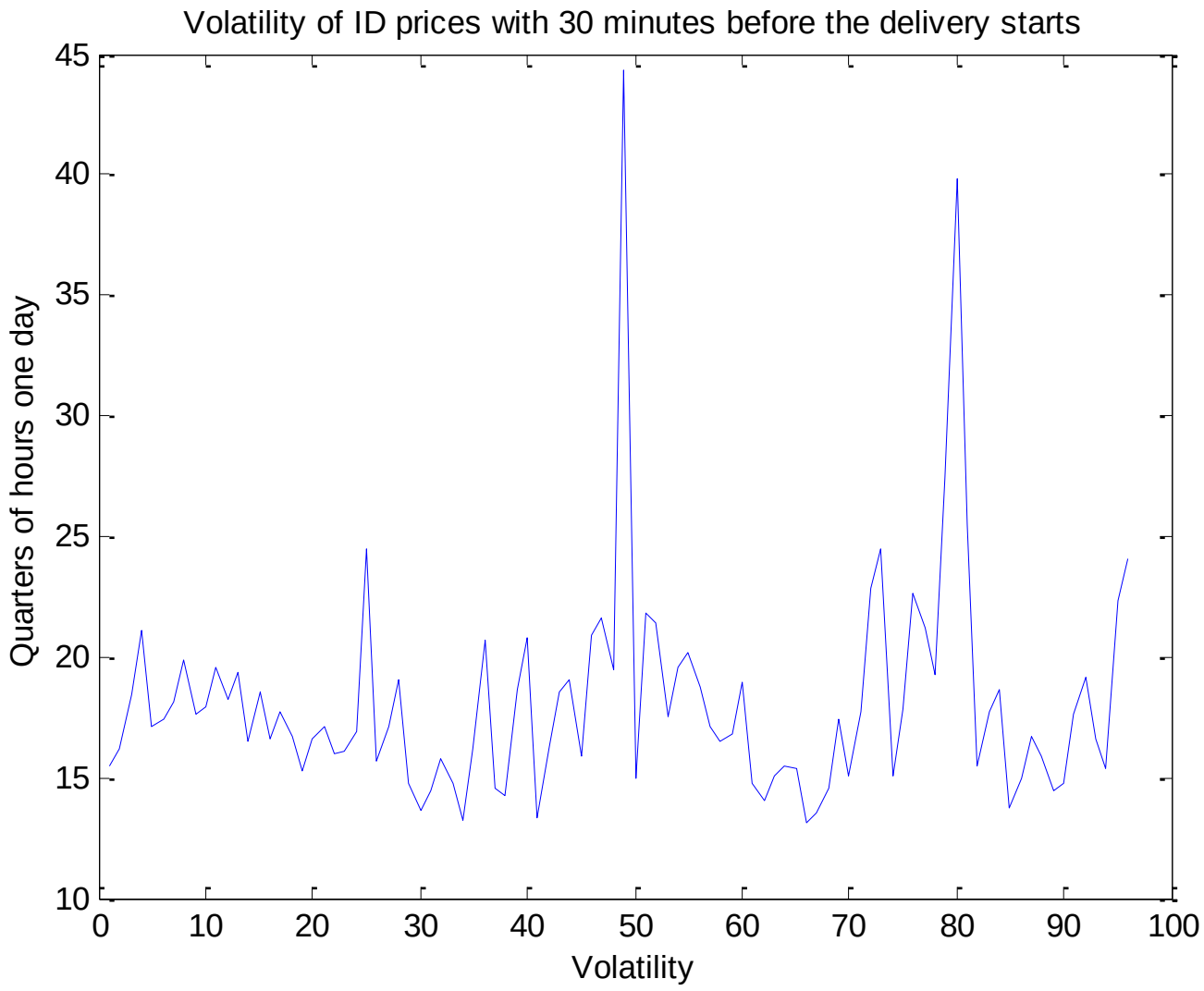

ID seasonality effect Hour 8
Volatility
20
15
10
5
0
300
200
100
0
Time to maturity in minutes
1
2
3
4
Quarters of hour 8


ID seasonality effect Hour 11
Volatility
200
150
100
50
0
300
200
100
0
Time to maturity in minutes
1
2
3
4
Quarters of hour 11

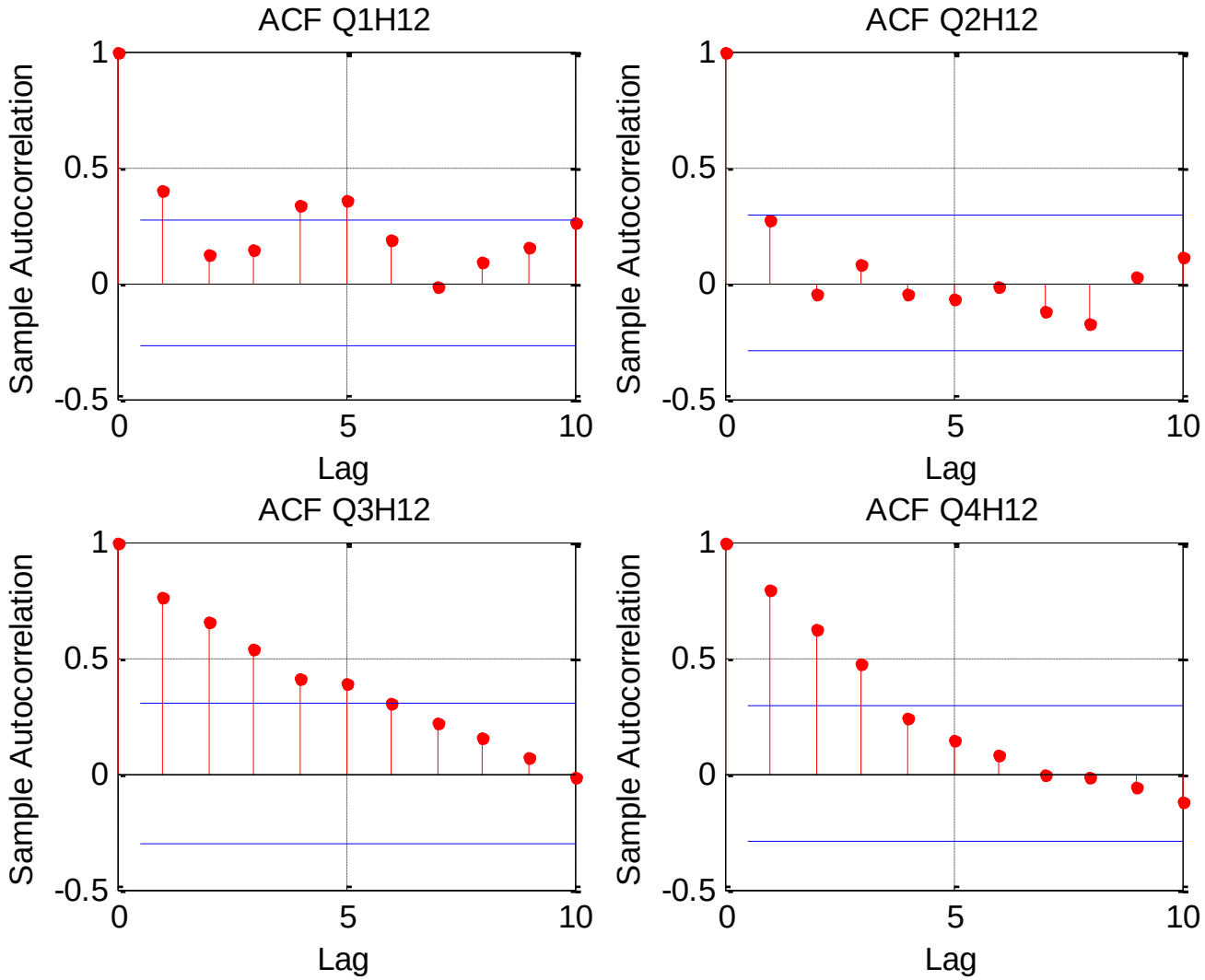

ID seasonality effect Hour 12
Volatility
80
60
40
20
0
300
200
100
0
Time to maturity in minutes
1
2
3
4
Quarters of hour 12

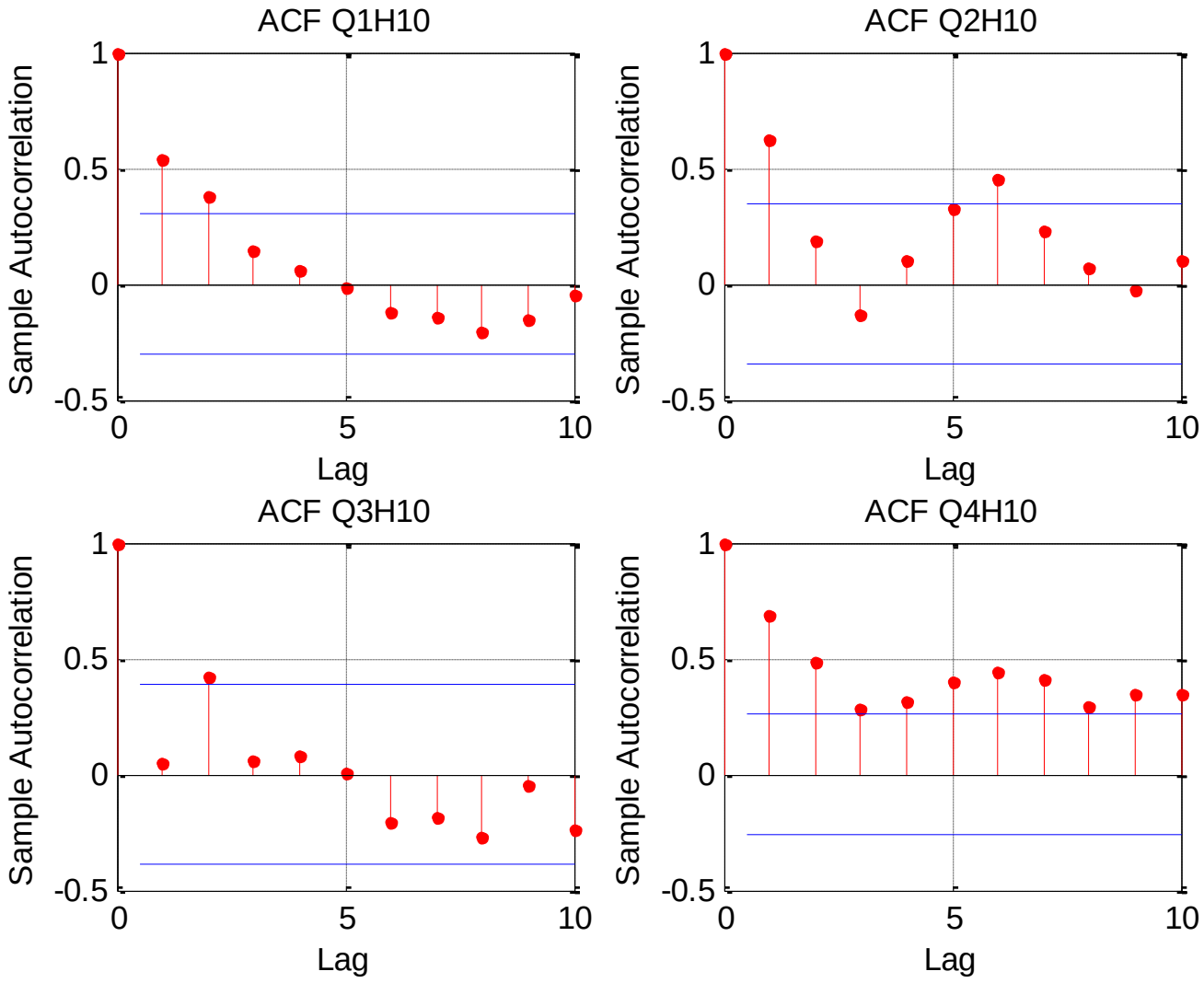

ID seasonality effect Hour 18
Volatility
50
40
30
20
10
0
300
200
100
0
Time to maturity in minutes
1
2
3
4
Quarters of hour 18

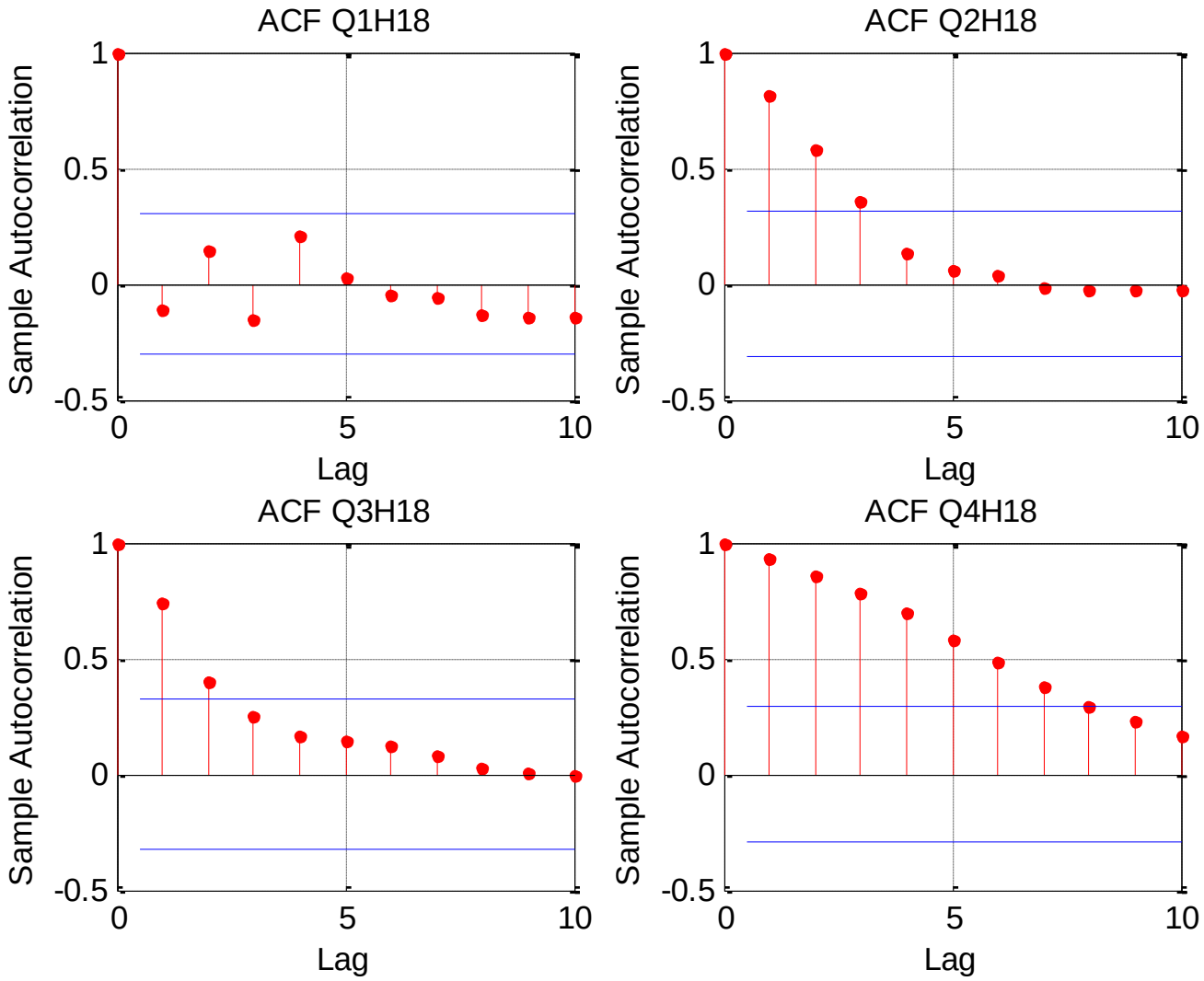

ID seasonality effect Hour 19
Volatility
140
120
100
80
60
40
20
0
300
200
100
0
Time to maturity in minutes
1
2
3
4
5
Quarters of hour 19

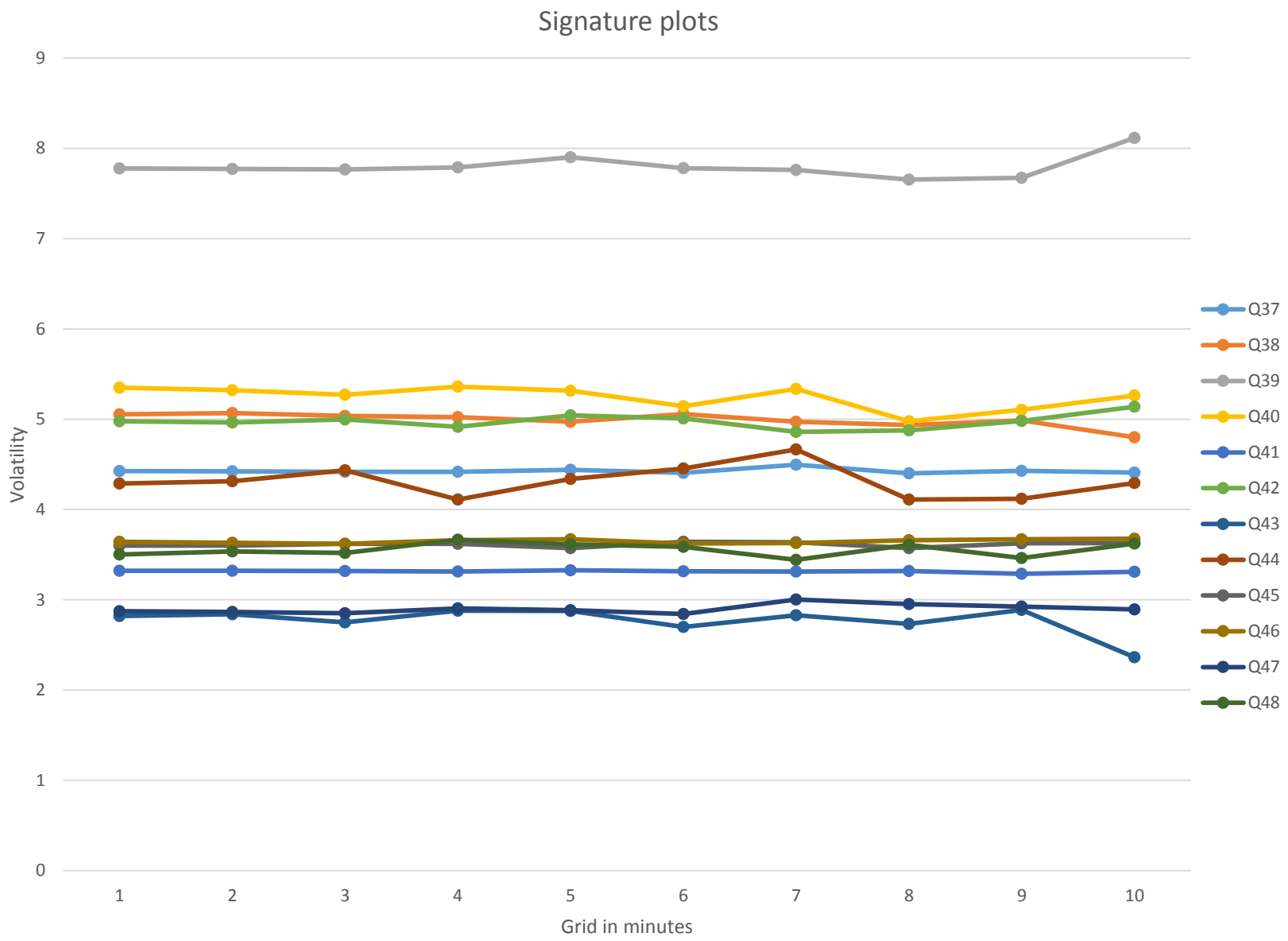

Volatility of ID prices with 30 minutes before the delivery starts
Quarters of hours one day
Volatility
45
40
35
30
25
20
15
10
0
10
20
30
40
50
60
70
80
90
100

Autocorrelation function of sqarred ID prices Series are stationary, autocorrelated and have ARCH/GARCH effects




ACF Q1H10
ACF Q2H10
ACF Q3H10
ACF Q4H10
Sample Autocorrelation
Lag
1
0.5
0
-0.5
0
5
10


ACF Q1H18
ACF Q2H18
ACF Q3H18
ACF Q4H18
Sample Autocorrelation
Lag
1
0.5
0
-0.5
0
5
10


Signature plots
Volatility
Grid in minutes
0
1
2
3
4
5
6
7
8
9
1
2
3
4
5
6
7
8
9
10
Q37
Q38
Q39
Q40
Q41
Q42
Q43
Q44
Q45
Q46
Q47
Q48

VAR analysis of block product late morning (10—12)

Main idea:

- We consider that intraday prices for a certain hourly block (as traded at EPEX) is a system in equilibrium;
- Thus, the price for a certain delivery period within one block is not exogenous, but it is the result of all other price dynamics for neighboring delivery periods (quarters of hours) within the block.
- The equilibrium of the block intraday system is given by common needs of market participants to balance out their production, given common weather condition and other factors which jointly impact the price level within the block
- We look at cross-section correlations between quarters within one block

VAR model formulation

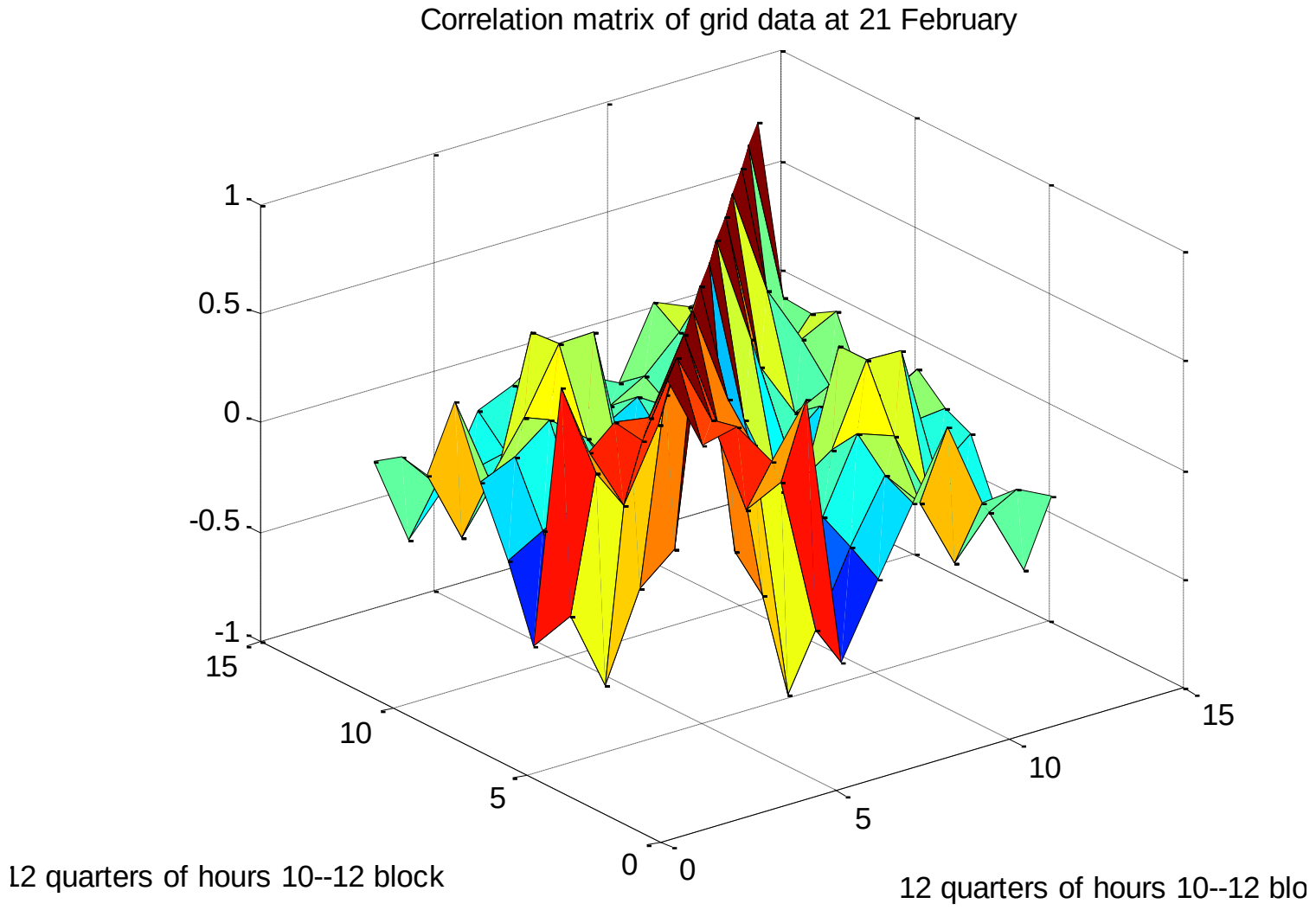
$$y_t = v + A_1 y_{t-1} + \ldots + A_p y_{t-p} + u_t, \quad t = 0,$$

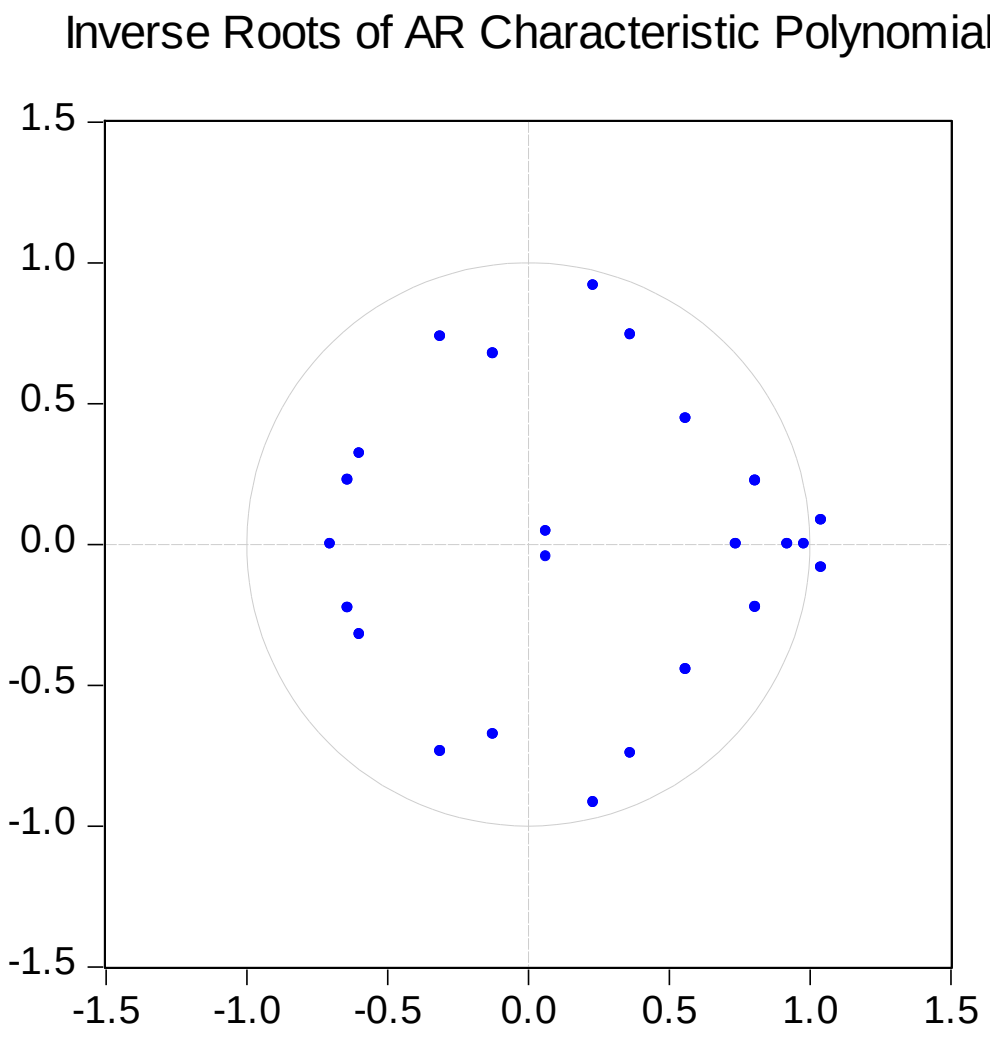
where $y_t = (Q4H12, Q3H12, \ldots, Q1H10)'$ is the vector of our intraday prices for each quarter of hour within one block.

Impulse response analysis:

- In case our VAR is stable, (polinomial roots lie inside the unit circle), we can employ the impulse-response analysis to produce the time path of teh dependent variables in the VAR to shocks from all other explanatory variables.

Winter February day


Correlation matrix of grid data at 21 February
1
0.5
0
-0.5
-1
15
10
5
0
0
5
10
15
l2 quarters of hours 10--12 block
12 quarters of hours 10--12 blo

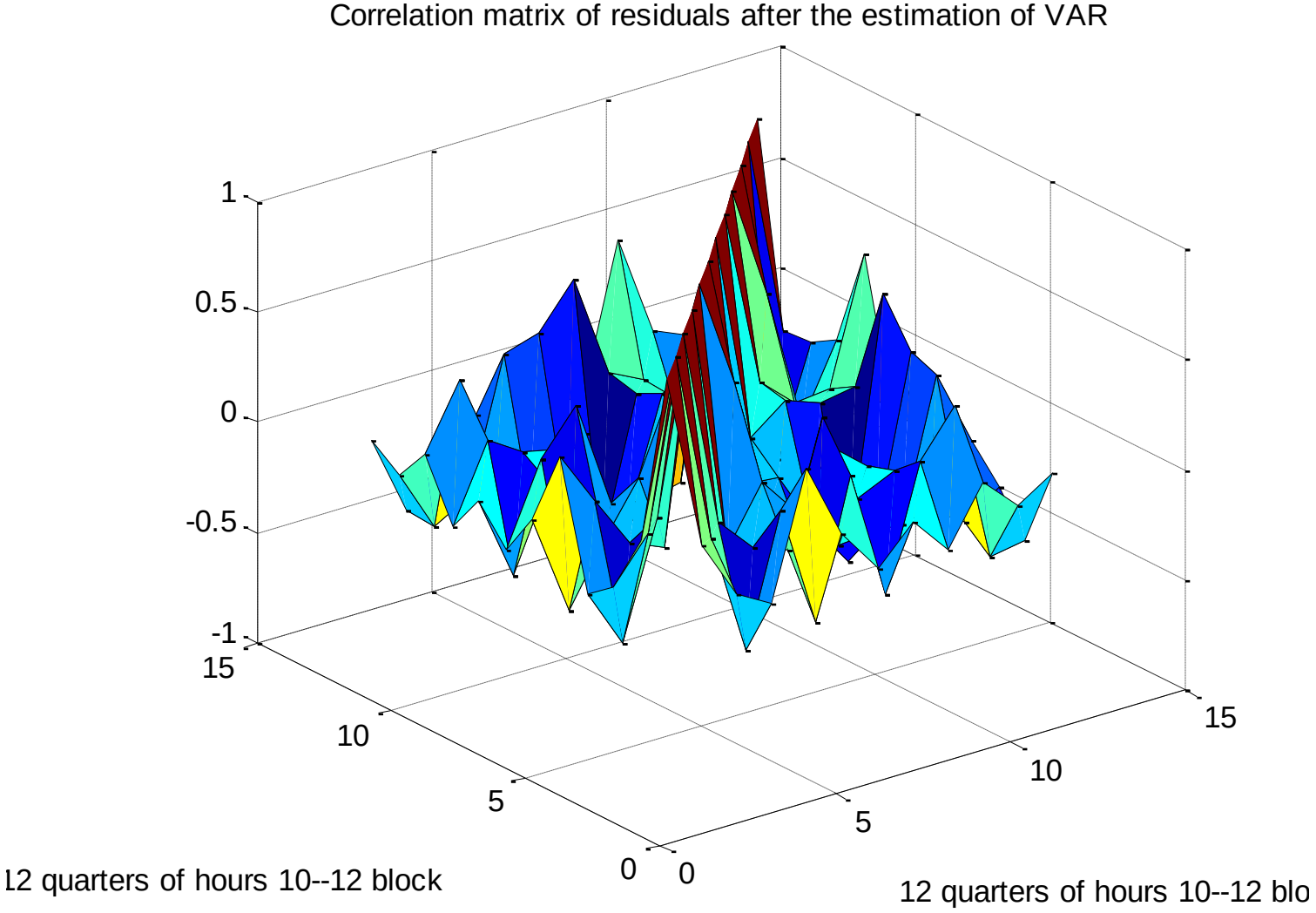

Inverse Roots of AR Characteristic Polynomial
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5

Multivariate autocorrelation test in residuals

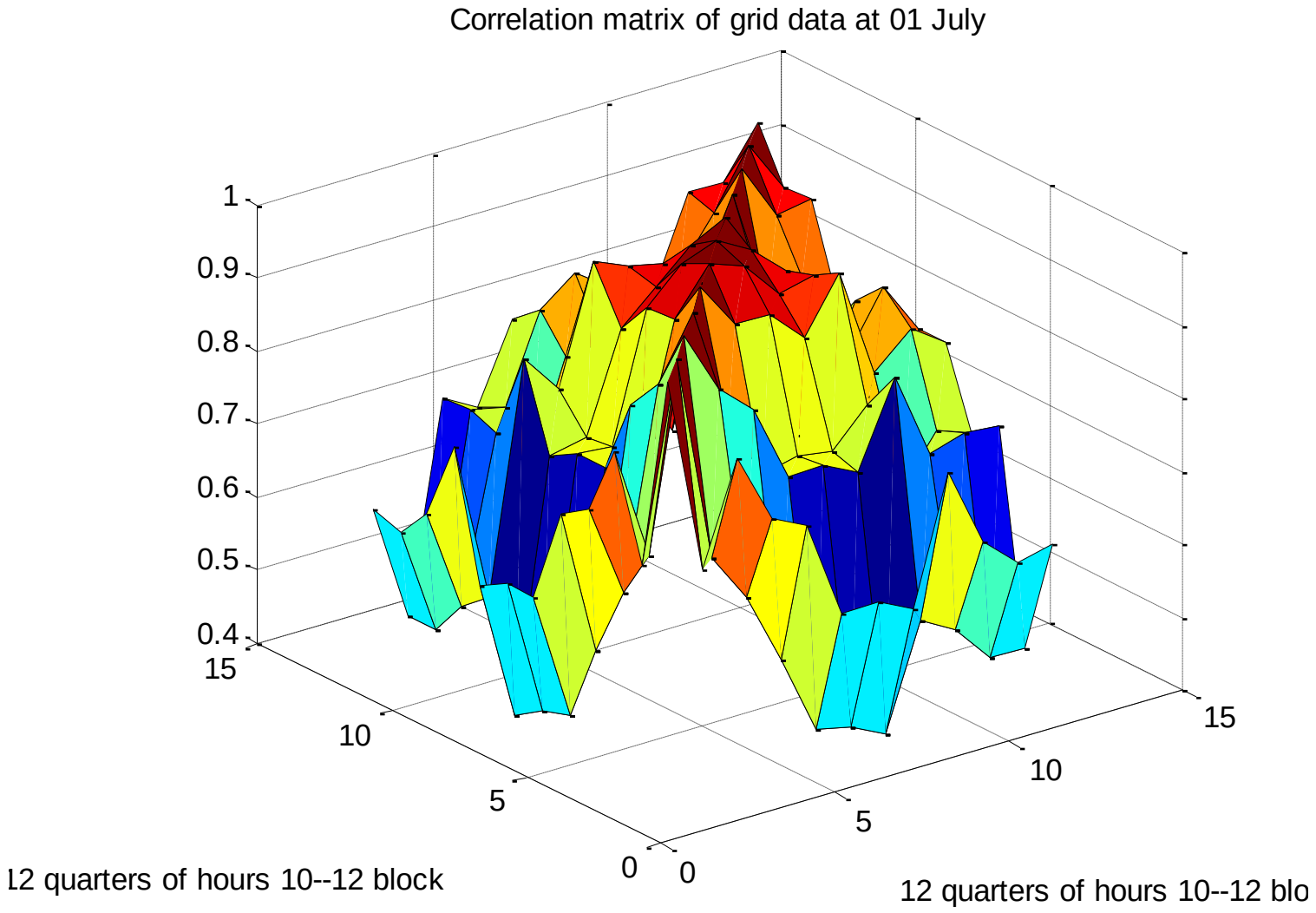
VAR Residual Portmanteau Tests for Autocorrelations
Null Hypothesis: no residual autocorrelations up to lag h
Date: 08/14/16 Time: 11:41
Sample: 1 105
Included observations: 102

Lags	Q-Stat	Prob.	Adj Q-Stat	Prob.	df
1	203.8990	NA*	205.9178	NA*	NA*
2	379.8293	NA*	385.3667	NA*	NA*
3	512.4958	0.0000	522.0534	0.0000	144
4	632.3793	0.0000	646.8301	0.0000	288
5	764.1359	0.0000	785.3783	0.0000	432
6	887.3018	0.0000	916.2421	0.0000	576
7	1026.081	0.0000	1065.247	0.0000	720
8	1157.764	0.0000	1208.137	0.0000	864
9	1255.921	0.0000	1315.793	0.0000	1008
10	1420.660	0.0000	1498.438	0.0000	1152
11	1533.092	0.0000	1624.461	0.0000	1296
12	1688.204	0.0000	1800.255	0.0000	1440

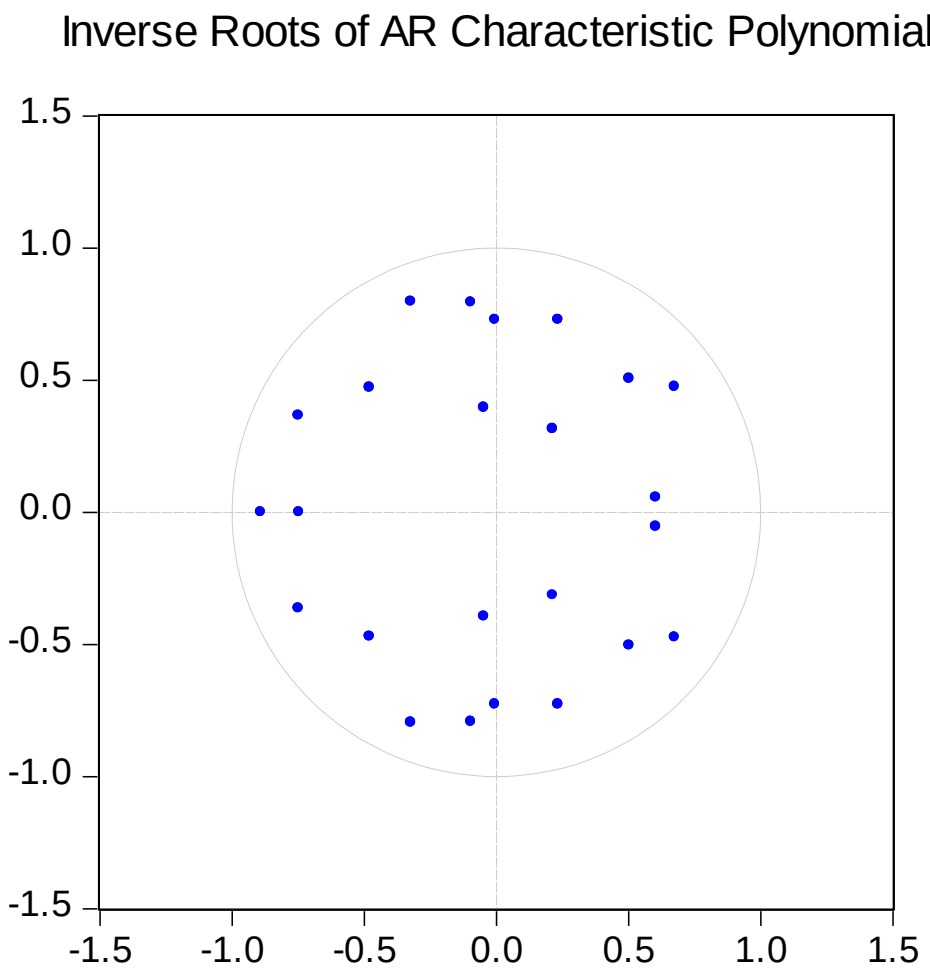
*The test is valid only for lags larger than the VAR lag order.
df is degrees of freedom for (approximate) chi-square distribution


Correlation matrix of residuals after the estimation of VAR
1
0.5
0
-0.5
-1
15
10
5
0
0
5
10
15
l2 quarters of hours 10--12 block
12 quarters of hours 10--12 blo

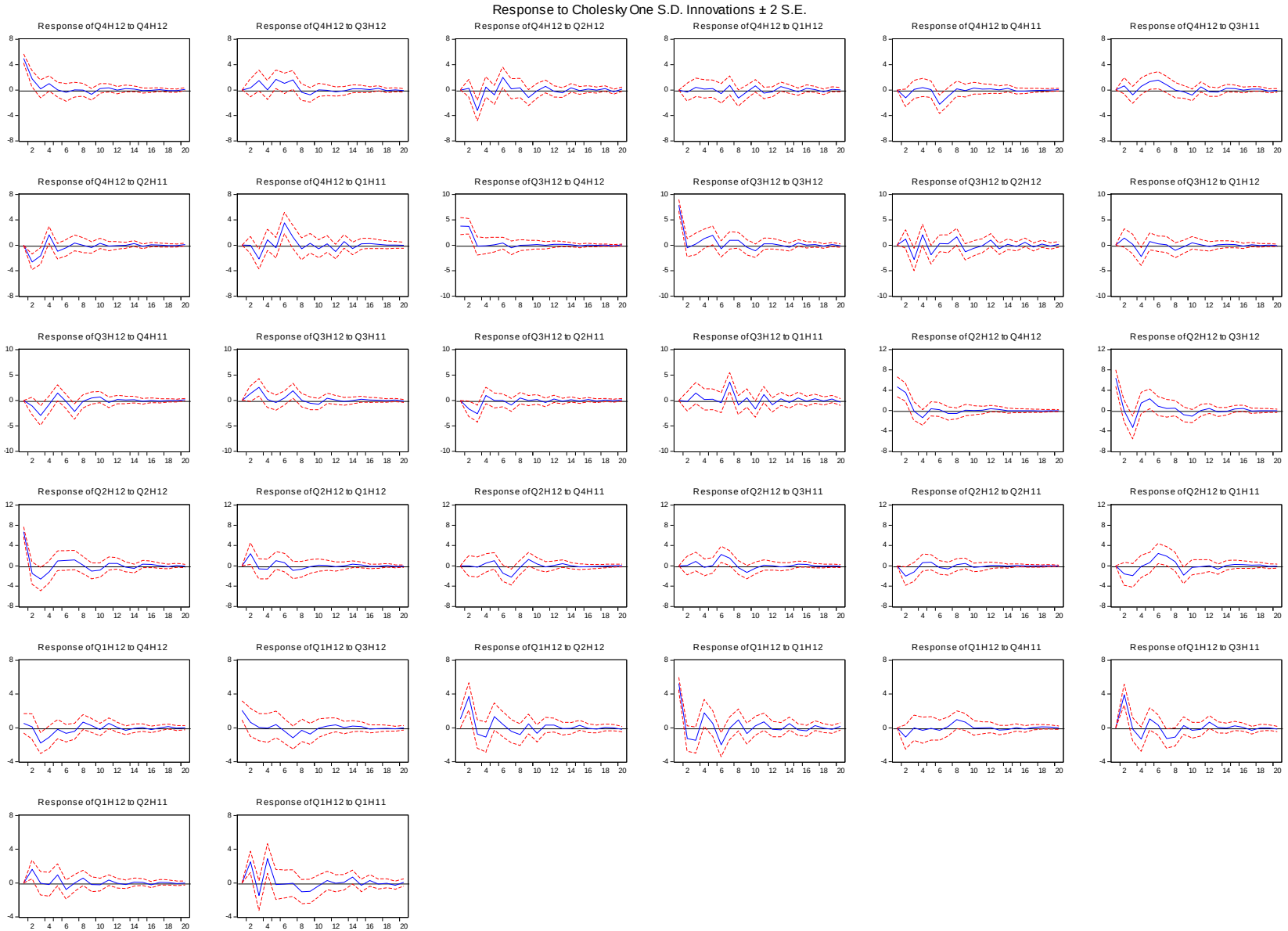
Summer July day


Correlation matrix of grid data at 01 July
1
0.9
0.8
0.7
0.6
0.5
0.4
15
10
5
0
0
5
10
15
l2 quarters of hours 10--12 block
12 quarters of hours 10--12 blo

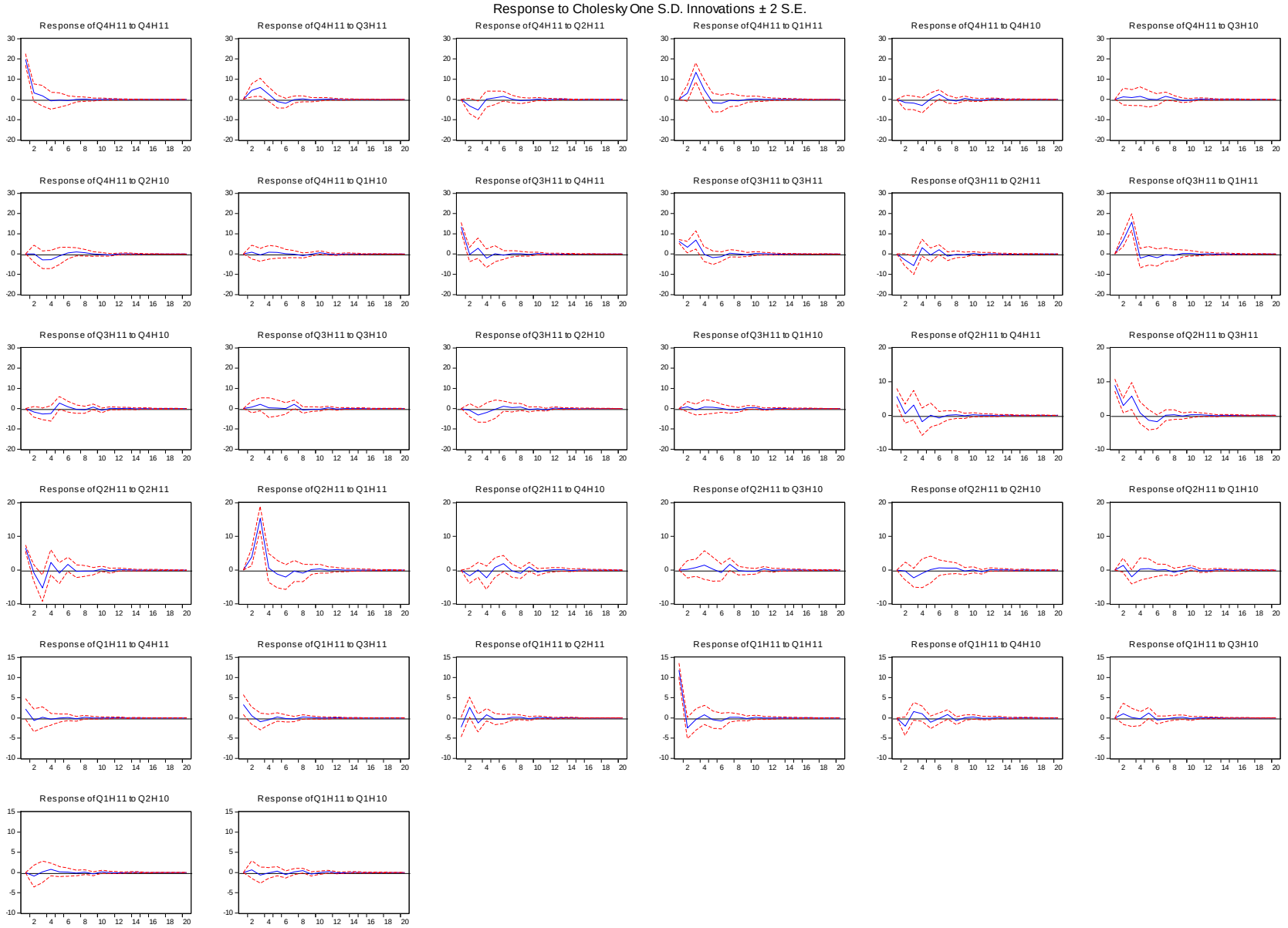
VAR is stable



VAR 12—11 reduced sample

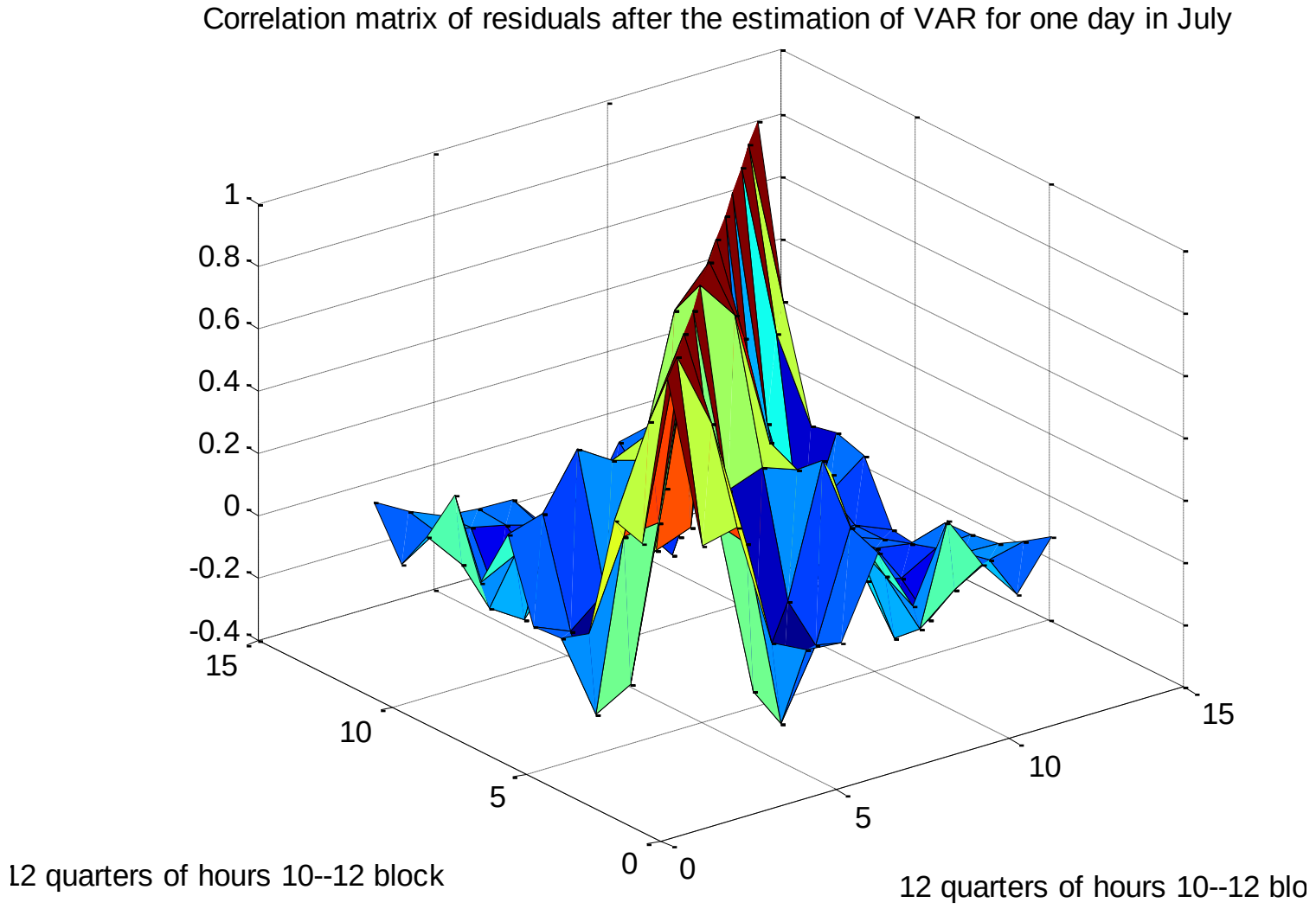


VAR 11—10 reduced sample

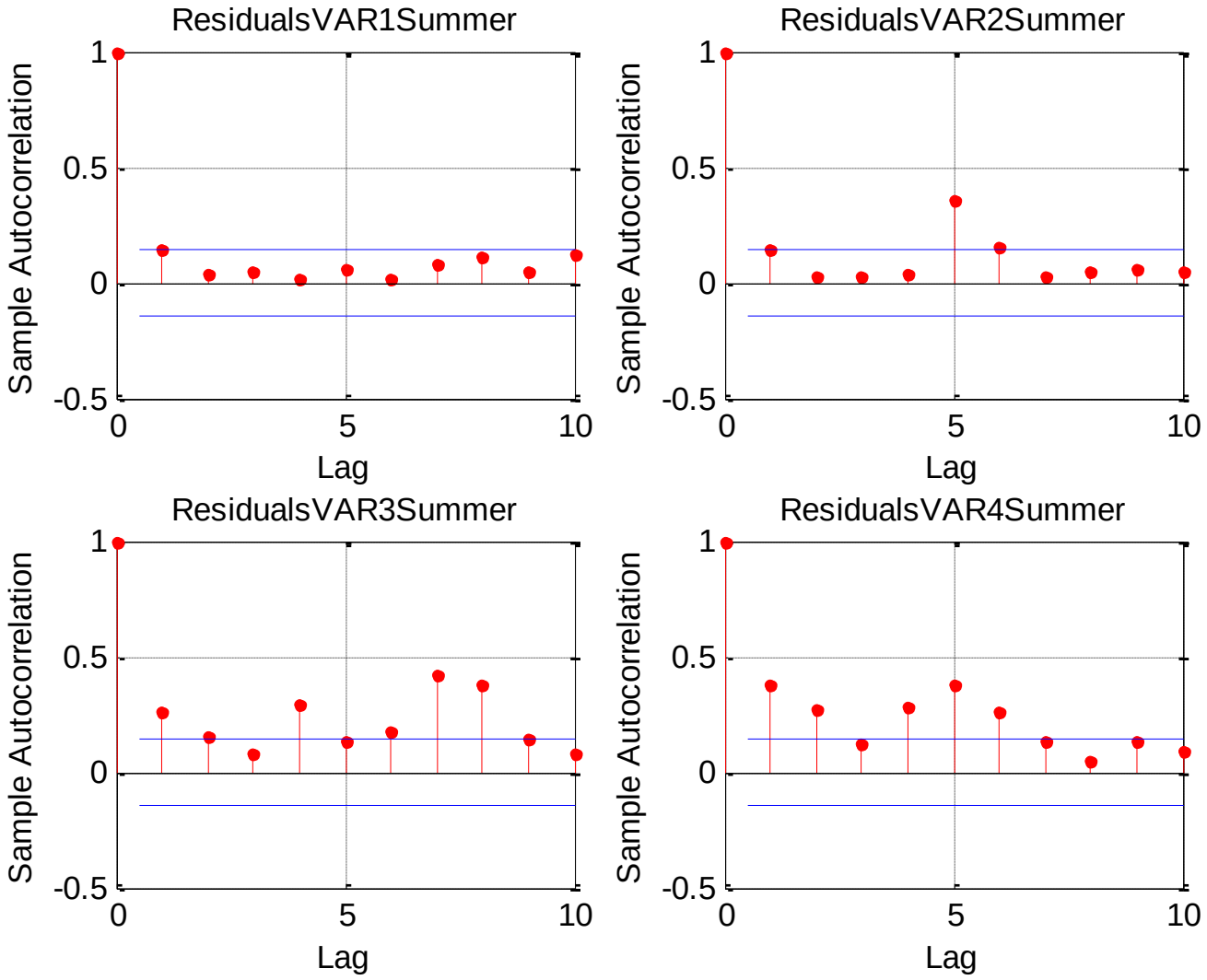


Observations

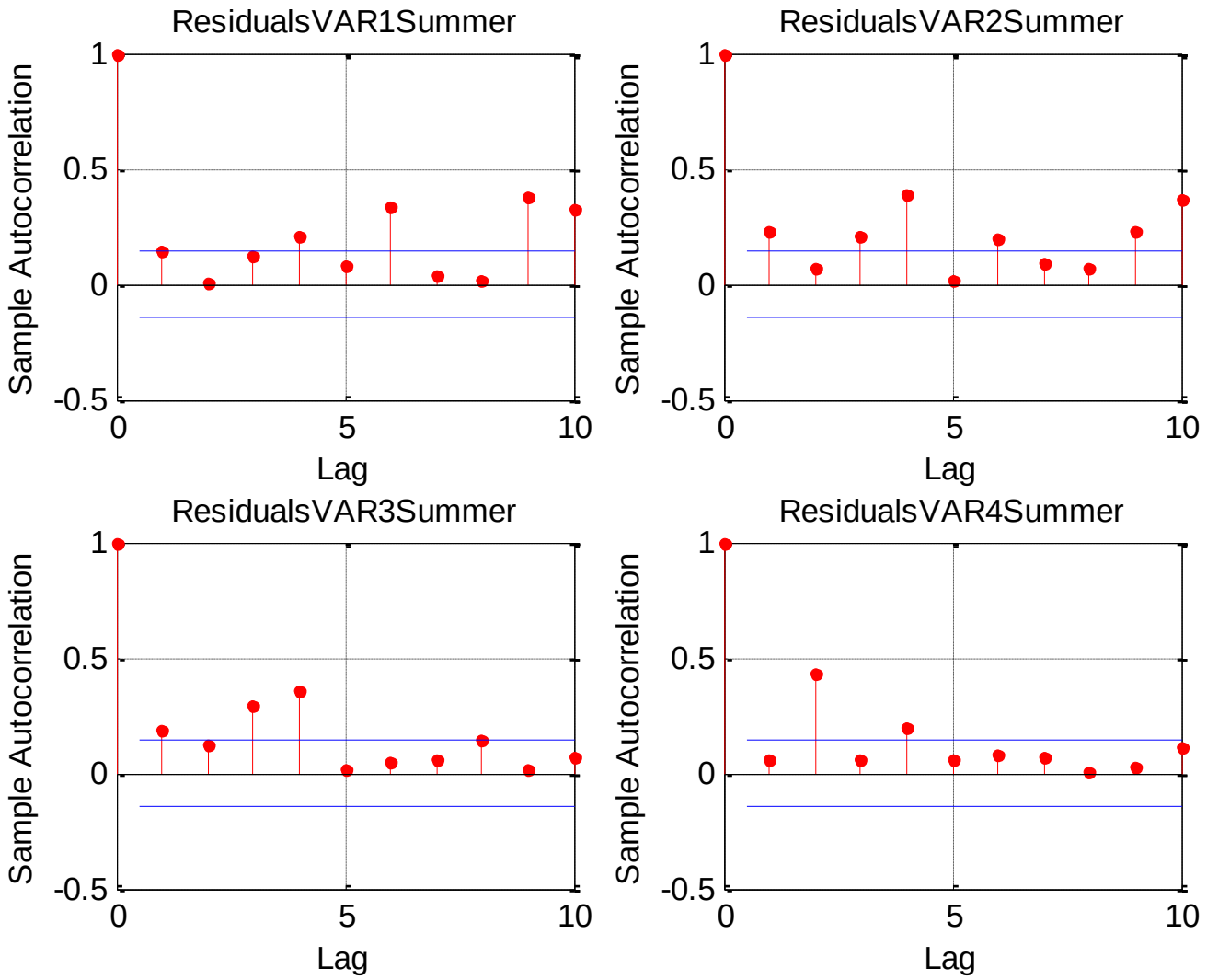
1. VAR 12—11 11—10 shows similar impulse-responses:
   - Bidding behavior for neighboring quarter-hourly products similar
   - Quarters 1 and 4: positive response in both directions; for both it is more difficult to balance out diseuqilibria (higher volumes of trades); mid-quarters have flatter responses (closer to the mean day-ahead price)
   - Neighboring hours: not significant responses


Correlation matrix of residuals after the estimation of VAR for one day in July
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
15
10
5
0
0
5
10
15
l2 quarters of hours 10--12 block
12 quarters of hours 10--12 blo

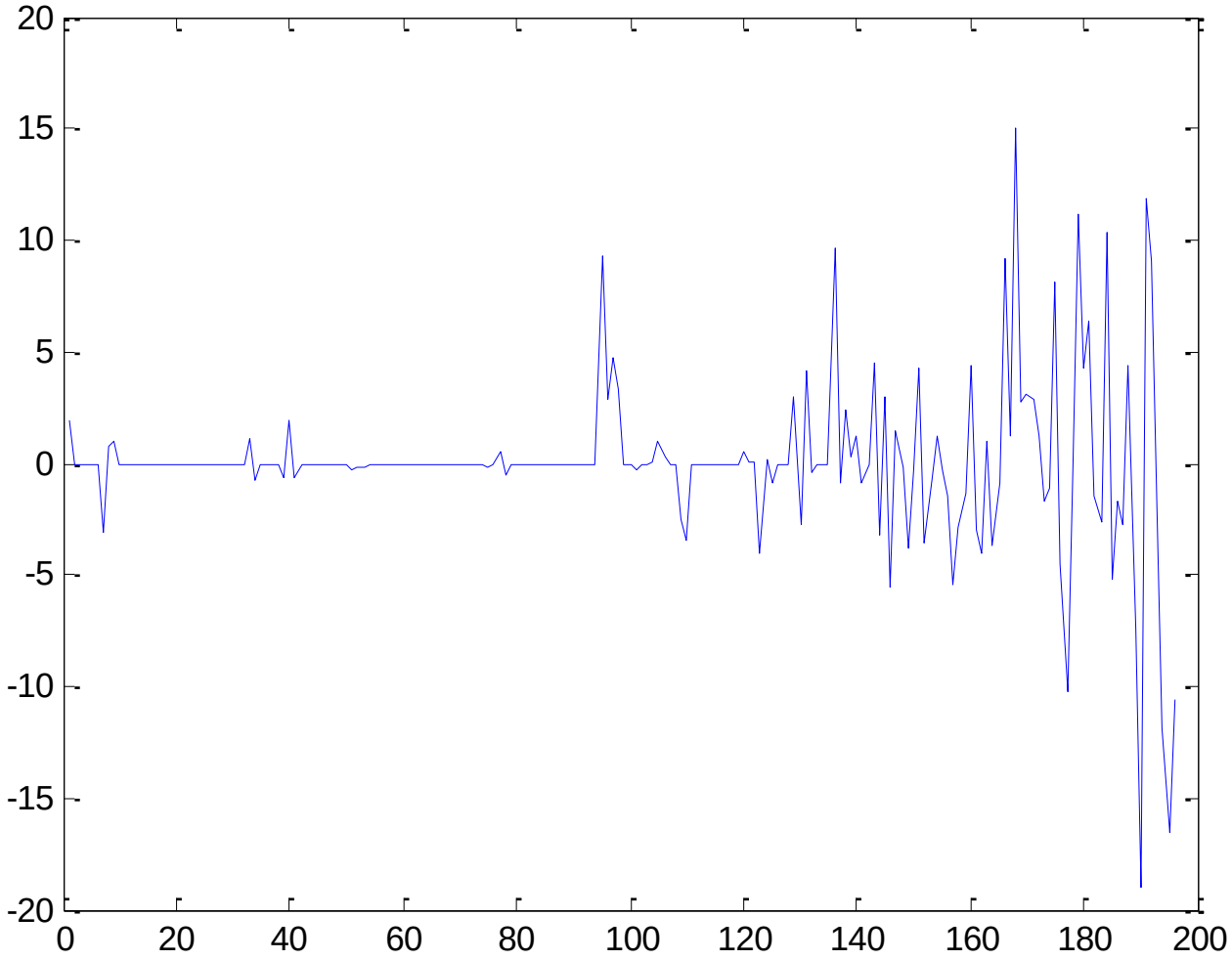
Autocorrelation function VAR (July intraday), Q1—4H10



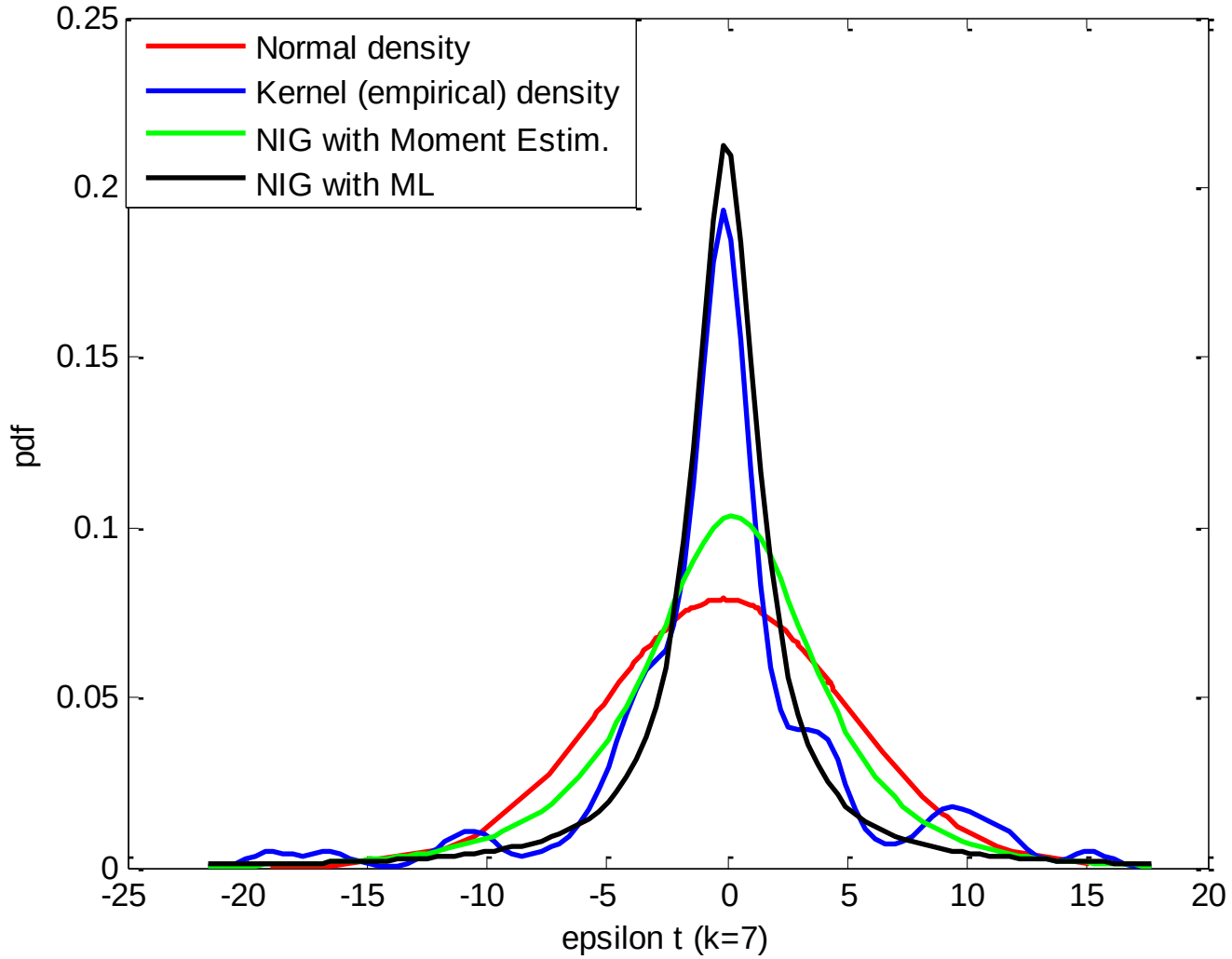
Autocorrelation function VAR (July intraday), Q1—4H11



Residuals VAR summer (4) Q4H10



NIG VAR summer 4 (focus only on high trading periods, exclude zeros) Q4H10



NIG VAR summer 4, include zeros Q4H10