Guidelines for determining the useable range of thresholds for Directional Change profiling

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Abstract

Price changes in a financial market are typically summarised by time series, which sample transaction prices at fixed intervals, but this paper draws on Directional Change (DC) as an alternative, data-driven way to effectively sample date points. This is where data points are sampled at peaks and troughs when the financial market changes its direction. However, the observer has to determine how big a percentage makes up a significant price change in the opposite direction to determine a directional change has taken place. This percentage is called a threshold in DC research. In this paper, we argue that if we want to collect statistical information for profiling a market-period, then the threshold cannot be too small or too big. When the threshold is too small, every transaction in the opposite direction constitutes a Directional Change, and such profiles may capture a lot of noise. On the other hand, when the threshold is too big, there will be too few trends in the profile to make its statistical properties meaningful. In this paper, we are proposing research into data-driven guidelines for determining when the threshold is too small, or too big, for effectively profiling a chosen market-period.

1 Introduction

Time Series (TS) is the main stream in the study of financial analysis. But Directional Change（DC）has been proposed as an alternative way to effectively describe the movement of the financial market (Guillaume et al. 1997). The idea of DC is that each observer pays attention to what he/she considers a "significant change" – which is called his/her threshold – in the market. And with Directional Change, Tsang et al (2017), has further proposed the use of statistical information which is needed to profile a market over a particular period (which we shall refer to as a market-period). This paper argues that if statistical information is to be used, one should be careful with one's choice of thresholds. One should avoid thresholds which are too small or too big.

1.1 What is Directional Change (DC)

Firstly, to briefly explain what makes up Directional Change, briefly it can be seen as an alternative concept which is used by researchers and analysts to summarise price movements in financial markets. But compared to Time Series, a DC-based analysis looks at the same data from another angle, and provides different perspectives of what is happening to the same data. In time series (TS), analysts determine how often the data is sampled, this means that observers determine the time-scale of the x-axis and observe price changes in the y-axis. In DC-based analysis, observers can determine how big a change in the market is considered to be significant, and this means that we can determine the price-scale of the y-axis, and let the data alone indicate when to record prices. In TS, observers normally sample data at irregular time intervals, which is not the method used to sample the data under DC. In contrast, in DC, we are therefore using different indicators for DC-based sampling.

Guillaume et al. (1997) introduced the concept of Directional Change (DC) as a new approach to sample data for analysis. It was originally used to study data from the FX, and to estimate the average number of directional price changes that were made, using a chosen threshold for the data sample, to be able to interpret an alternative measure of risk. Tsang (2011), went on to further define the concept of Directional Change. According to Tsang, in DC, sample points are all data-driven, which means the observer lets the data determine when to sample the market. The observer decides the threshold of price changes that he/she considers to be significant, which could be 5% or 0.5%, this is completely a personal choice. The market is next partitioned into alternating uptrends and downtrends. A change from a downtrend (uptrend) to an uptrend (downtrend) is recorded when the market price changes direction by the predefined threshold. And, Tsang makes the observation that the advantage of Directional Change is that extreme points reached by the financial market are always sampled, and not missed, as they can be under TS (Tsang, 2010).

1.2 Objective of this paper

In general, an observer may choose to use any threshold to observe the market. However, if our aim is to collect statistical measures to profile a market over a period, as proposed by Tsang et al (2017), then we have to be careful in choosing the thresholds. A threshold that is too big will not produce enough number of observable directional changes for statistical purposes. On the other hand, if a threshold is too small, any small shift in the opposite direction will be observed as a directional change for the observer. This introduces the problem of 'noise' into our statistical measures, as we shall elaborate below.

The objective of this research is to develop measures to determine when the threshold is too big or too small. However, we emphasise that our objective is not to identify what an "optimal" threshold is for profiling a market-period, as it is unlikely that a one size fits all approach would be appropriate to our research . Instead, our objective is to identify the range of usable thresholds for profiling. In this paper, we propose a method which will let the data tell us what thresholds are too big, or too small, for profiling a market-period.

2 Literature Survey

2.1 Directional Change (DC)

Tsang et al (2017) has introduced further definitions of Directional Change. Firstly, Tsang et al (2017) defined that Directional Change Extreme Point (EXT) is the starting point. The starting point means it is the point of where a DC trend starts with, the start point can either be an Upturn Point or Downturn Point. It can be also seen as the end of one TM event. This is where a TM event is a total price movement, which is constituted by a downturn event, and a downward overshoot event follows, or an upturn event and an upward overshoot event follows (Glattfelder et al, 2011). Directional Change Confirmation Point (DCC) is the point at which to confirm one DC event. The Theoretical Directional Change Confirmation Point (DCC*) is the minimal or maximum directional change confirmation price for an upturn or downturn directional change event.

Overshoot is the price change from the last directional change confirmation price (DCC) to the current price. Tsang et al (2017) define Overshoot Value (OSV) for measuring the value of an overshoot. Instead of using the absolute value of the price change as in time series, the value of OSV is relative to the threshold, that have been chosen by the observer. Therefore, we define OSV as follows:

$OSV = ((P_c - P_{DCC}) \div P_{DCC}) \div \theta$

Here P_c is the current price, P_{DCC} is the last directional change confirmation price, θ is the threshold.

Overshoot values at extreme points (OSV_{EXT}) is an indicator for measuring the value of an overshoot based on the price distance between fixed points. It measures how far the overshoot goes from the theoretical directional change confirmation point (DCC*) to the next extreme point (EXT). We define OSV_{EXT} as follows:

$OSV_{EXT} = ((P_{EXT} - P_{DCC*}) \div P_{DCC*}) \div \theta$

Here P_{EXT} is the price at the extreme point that ends the current trend, P_{DCC*} is the price of the theoretical directional change confirmation point of the current trend, θ is the threshold.

Glattfelder et al. (2011), discovered 12 new scaling laws in foreign exchange markets, which were established using the DC approach, which was used to study stylised facts in FX markets. Gillaume et al. (1997) had proposed a new scaling law for DC, to be considered as a new way to measure volatility and the description of the evolution of financial prices.

The idea of the use of Directional Change (DC) as an alternative way to summarise price changes in the financial market, is illustrated in Figure 1, which shows (in black) the minute-by-minute exchange rates between US Dollars and Japanese Yen (USD/JPY) from July to August 2017. A change of direction is said to have taken place, if the price has risen from a trough by a predefined threshold.

Figure 1 shows two directional change events (in red). The first DC took place when price rose from the first trough (just above 100.0) by 6% (to just above 106.0). The second DC took place when the price dropped from the peak (around 107.5) by 6% (to around 101). The movement from 106.0 to 107.5 is called an overshoot. Thus, DC partitions the market into alternating Upward trends and Downward trends.

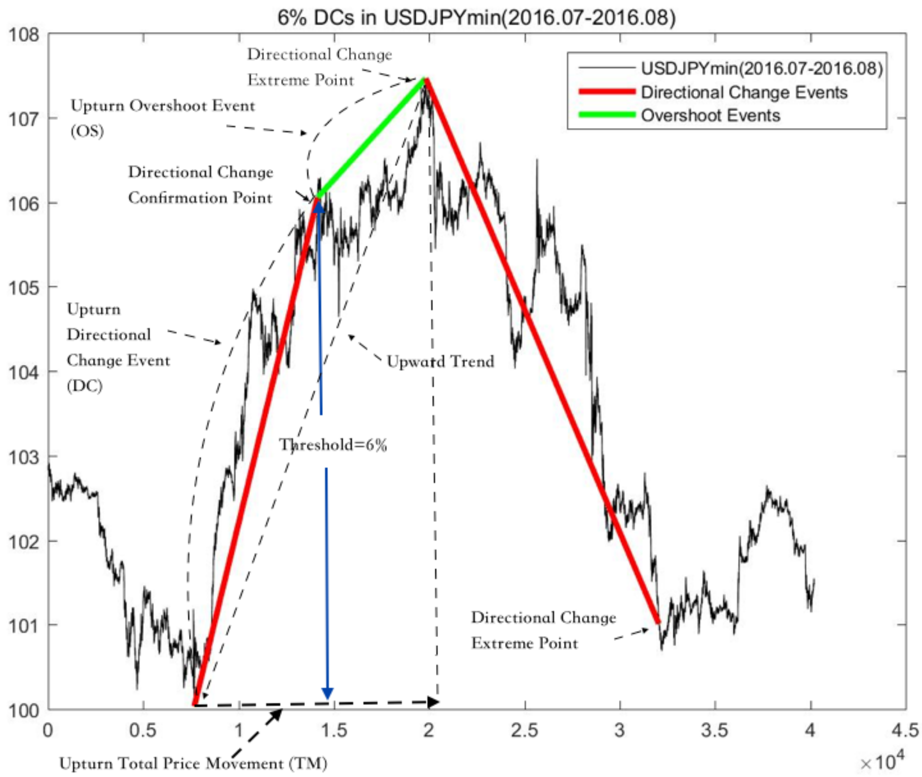

Figure 1: Directional Changes in foreign exchange rates between US Dollars and Japanese Yen (USD/JPY); here the threshold = 6%

2.2 TMV, a DC indicator on volatility

Under time series (TS), people often use the standard deviation of log returns under a fixed time interval, to measure the volatility of the market, in that time period. With DC, we need a new vocabulary to describe volatility.

Here we introduce TMV, a volatility measures proposed in Tsang et al (2017) that is relevant to this research.

Under the DC framework, the market is technically either in a downtrend (bear market) or an uptrend (bull market). A downtrend ends at P_{trough} if prices have risen from P_{trough} by a threshold; in other words, if there exist a price $P_{DCC\uparrow}$ such that:

$$P_{DCC\uparrow} \geq P_{trough} \times (1 + \theta).$$

$P_{DCC\uparrow}$ is called the DC confirmation point. P_{trough} is confirmed to be a trough at $P_{DCC\uparrow}$ (i.e. confirmation in hindsight). Similarly, an uptrend ends at P_{peak} if prices have dropped from P_{peak} by a threshold, in other words, if there exist a price $P_{DCC\downarrow}$ such that:

$$P_{DCC\downarrow} \leq P_{peak} \times (1 - \theta)$$

P_{peak} is confirmed to be a peak at the DC confirmed point $P_{DCC\downarrow}$ (in hindsight).

The market is thus partitioned into uptrends and downtrends. Each trend comprises a DC event and an overshoot event.

The total price movement in a trend, TMV, is price changes from the beginning to the end of the trend, normalized by the threshold:

$$TMV = (|P_{EXT\_Start} - P_{EXT\_End}| \div P_{EXT\_Start}) \div \theta$$

Where P_{EXT_Start} and P_{EXT_End} are the prices at the start and end, respectively, of the trend. The division by θ makes in this definition makes TMV threshold-independent. This allows us to compare TMV observed under different thresholds.

2.3 DC Profiling – descriptive statistics of a market-period

Tsang et al (2017) proposed to capture market information in a market-period using DC. They introduced a set of indicators, including TMV (described above), in DC for each trend. Each period is made up of a number of trends in DC. Tsang et al (2017) proposed to use the statistical values of those indicators collected over the trends in the period to profile the market-period. It is worth emphasising that, as profiling is based on statistical measures, the trend must be made up of enough of a number of trends for profiling to be meaningful. So, given the definition of DC, we would argue that the number of trends one observes in a period is inversely proportional to the size of the threshold: the bigger the threshold one uses, the fewer trends one should expect to observe.

3 Methodology

In this section, we propose guidelines to determine the range of useable thresholds for a given data set.

3.1 Overview of the methodology

To decide what thresholds are usable for profiling a data set, we summarise the data as sequence of trends in DC with a range of thresholds. We compute the mean, maximum and minimum TMVs of the trends.

Based on Guillaume et al (1997), the minimum TMV observed should be close to 1 (to be explained below). Therefore, we propose to use the minimum TMV as an indicator of whether the threshold used is too small.

As explained in Section 2.2.1, TMV are normalized by the threshold by definition, hence TMV is threshold-independent. Therefore, if we observe a sharp change in the mean TMV when we increment the threshold, it signals the danger of using too few trends for profiling. This is the sign of using a threshold that is too big.

3.2 When is the threshold too small?

As we explained in Section 2, an uptrend is confirmed when there exists a price $P_{DCC\uparrow}$ such that:

$$P_{DCC\uparrow} \geq P_{trough} \times (1 + \theta).$$

The minimum price for an uptrend to be confirmed is $P_{DCC\uparrow*}$, where:

$$P_{DCC\uparrow*} = P_{trough} \times (1 + \theta)$$

Similarly, the maximum price for a downtrend confirmation is $P_{DCC\downarrow*}$:

$$P_{DCC\downarrow*} = P_{peak} \times (1 - \theta)$$

According to Tsang et al (2017), the Overshoot Value (OSV) at an upward DC confirmation point $DCC_{\uparrow}$ is as:

$$OSV_{DCC\uparrow} = ((P_{DCC\uparrow} - P_{DCC\uparrow *}) \div P_{DCC\uparrow *}) \div \theta$$

$P_{DCC\uparrow}$ is normally close to $P_{DCC\uparrow *}$ in practice. If that is the case, then $OSV_{DCC\uparrow}$ is close to 0. However, if we use a very small threshold, $P_{DCC\uparrow}$ could be significantly larger than $P_{DCC\uparrow *}$. To take an extreme example, suppose price normally moves by steps of 0.001% in a particular market. If we use a threshold of 0.0001%, then $OSV_{DCC\uparrow}$ could become very big:

$$OSV_{DCC\uparrow} = 0.001\% \div 0.0001\% = 10$$

If the trend reverses immediately at $DCC_{\uparrow}$, TMV of this trend is equal to 10. Empirical studies (Guillaume et al 1997) shows that this is a very big TMV. However, this big TMV is only observed because we chose an unreasonably small threshold for this market.

Guillaume et al (1997) showed that, regardless of the threshold used, TMVs follow a power law decade: many trends reverse immediately after DCC. As explained above, TMVs of these trends are close to 1. Therefore, we expect the minimum TMV is close to 1. Should the minimum TMV observed in a market-period be significantly greater than 1, it is likely to be caused by the fact that we have chosen a threshold that is too small. This forms the basis of our first guideline for establishing a threshold.

Guideline 1: We should reject a threshold for being too small for profiling if the minimum TMV in the market-period is significantly greater than 1.

3.3 When is the threshold too big?

According to Olsen's observation (Guillaume et al 1997), markets exhibit a fractal phenomenon under DC. This means we observe similar profiles under different thresholds. The TMV definition above is normalized by the threshold use. Therefore, according to Olsen's observation, we should observe similar TMV values under different thresholds. If the mean TMV changes dramatically as we increment the threshold, then it is likely that the new profile offers as too few (assimilar) trends. In other words, the new threshold used is too big. This is the basis of our second guideline.

Guideline 2: We should reject a threshold for being too big for profiling if the mean TMV increases dramatically when we increment the threshold.

4 Example One: EUR/USD Period One

In this section, we used an example to explain the guidelines that we proposed above to identify the useable range of thresholds for a given data set.

4.1 Data selected and range of thresholds to examine

In this section, we use tick data in EUR/USD exchange market from 06/05/2016 14:32:16 to 25/05/2016 06:59:21.

We named this dataset EUR/USD Period One.

In order to decide what threshold are useable, we summarised the data in section 3.1, by using DC with a range of thresholds. We use 28 thresholds in this paper. The thresholds and their indices are shown in Table 1.

Index(n)/ Threshold	1	2	3	4	5	6	7
	0.00001	0.00002	0.00003	0.00004	0.00005	0.00006	0.00007
	8	9	10	11	12	13	14
	0.00008	0.00009	0.0001	0.0002	0.0003	0.0004	0.0005
	15	16	17	18	19	20	21
	0.0006	0.0007	0.0008	0.0009	0.001	0.002	0.003
	22	23	24	25	26	27	28
	0.004	0005	0.006	0.007	0.008	0.009	0.01

Table 1: Index of (n) and Threshold (Th) used for in this paper

4.2 Results for Period One

Index	Threshold	Mean TMV	Min TMV
1	0.00001	4.42728192	1.261447637
2	0.00002	3.951849541	1.261415813
3	0.00003	3.596183487	1.261590866
4	0.00004	3.359168984	1.261495377
5	0.00005	2.687335187	1.009196301
6	0.00006	2.675828519	1.051445106
7	0.00007	2.670469684	1.08154098
8	0.00008	2.666903475	1.104128811
9	0.00009	2.51458287	1.000730533
10	0.0001	2.383306516	1.00913265
11	0.0002	2.1908594	1.010126518
12	0.0003	2.088427744	1.000321843

13	0.0004	2.045122883	1.000296862
14	0.0005	2.022096672	1.006685424
15	0.0006	2.014058484	1.000361
16	0.0007	2.016866655	1.00089339
17	0.0008	2.038527943	1.012530059
18	0.0009	2.016789033	1.000374053
19	0.001	2.072359721	1.002703492
20	0.002	2.194055054	1.003699913
21	0.003	2.210405732	1.023351009
22	0.004	2.096681185	1.011487374
23	0.005	2.064840761	1.218470794
24	0.006	1.720700634	1.015392328
25	0.007	2.363148902	1.010859414
26	0.008	2.851425636	1.704359762
27	0.009	2.534600565	1.514986455
28	0.01	2.281140509	1.36348781

Table 2: EUR/USD Period One's mean TMV and minimum TMV under different threshold.

4.3 When is a threshold too small for profiling Period One?

As we mentioned in Section 3.1, from Table 2, we can see that the value of minimum TMV (the rightmost column) under thresholds from 0.004 to 0.00005 are all around 1. At Threshold=0.00005, the minimum TMV is 1.009196301. However, when the threshold value drops to 0.00004, the value of minimum TMV rises sharply to 1.261495377. In this case, we see any threshold below 0.00005 unsuitable for profiling EUR/USE Period One.

4.4 When is a threshold too big for profiling Period One?

Table 2 shows that in EUR/USE Period one, when the threshold is between 0.0002 and 0.005, the mean TMV values are around 2.0 (column 3). Once the threshold increased to 0.006, the value of mean TMV sharply decreases to 1.720700634. Mean TMV increases to 2.363148902 under threshold 0.007. Under the circumstances, we define that any threshold larger than 0.005 is unsuitable for profiling EUR/USE Period One.

In conclusion, we defined that the usable range of thresholds for this data set is between 0.00005 and 0.005, both numbers included.

5 Example Two: EUR/USD Period Two

In this section, we use another example to demonstrate the proposed methodology for threshold selection.

5.1 Data selected range of thresholds to examine

In this section, we use tick data in EUR/USD exchange market from 29/03/2016 13:29:42 to 13/04/2016 10:19:18.

We named this dataset EUR/USD Period Two.

We used the same threshold as we introduced in Section 4.

5.2 Results for Period Two

Index	Threshold	Mean TMV	Min TMV
1	0.00001	4.73054856	1.232119
2	0.00002	4.0040592	1.232013
3	0.00003	3.59096243	1.232544
4	0.00004	3.3717238	1.232438
5	0.00005	2.93279468	1.000000
6	0.00006	2.68517048	1.027297
7	0.00007	2.68297783	1.056219
8	0.00008	2.67478211	1.07841
9	0.00009	2.67152819	1.096014

10	0.0001	2.53199258	1.000000
11	0.0002	2.24322587	1.000075
12	0.0003	2.13125317	1.000125
13	0.0004	2.05193953	1.000138
14	0.0005	2.00232298	1.000713
15	0.0006	1.99328215	1.00144
16	0.0007	1.98420177	1.002104
17	0.0008	1.96438704	1.001462
18	0.0009	1.98484554	1.000595
19	0.001	1.97924251	1.000717
20	0.002	1.84791789	1.018877
21	0.003	2.01279488	1.01183
22	0.004	1.88247868	1.038123
23	0.005	1.75531236	1.036448
24	0.006	2.1202938	1.066875
25	0.007	2.419529	1.063466
26	0.008	2.953677	2.953677
27	0.009	2.625491	2.625491
28	0.01	2.362942	2.362942

Table 3: EUR/USD Period Two's mean TMV and minimum TMV under different threshold.

5.3 When is a threshold too small for profiling Period Two?

As we mention in Section 3.1, from Table 2, we can see that under thresholds 0.007 to 0.00005, the value of minimum TMV are all around 1. Under threshold 0.00005, the minimum TMV is 1.0. When the threshold is dropped to 0.00004, the minimum TMV increases sharply 1.232438. In this case, we see any threshold below 0.00005 unsuitable for profiling EUR/USE Period Two.

5.4 When is a threshold too big for profiling Period Two?

In Table 3, we can see that under thresholds 0.0004 to 0.003, the mean TMV are all around 2.0. Under threshold 0.003, the mean TMV value is 2.01279488. Under threshold 0.004, the mean TMV value decreases sharply to 1.88247868. When the threshold is increased to 0.005, the mean TMV value decreases to 1.75531236. When the threshold value rises to 0.006, the mean TMV jumps back to 2.1202938. In other words, the mean TMV values fluctuates above threshold 0.03. Thus, we see any threshold larger than 0.003 as unsuitable for profiling EUR/USE Period Two.

In conclusion, we defined that the usable range of thresholds for this data set is between 0.00005 and 0.003, both numbers included.

6 Conclusion

It is up to the observer to choose an appropriate threshold to observe Directional Changes (DCs) in a given market-period. However, we argue that if our aim is to use statistical information to profile a market-period, as in the use of DC, we should not choose thresholds which are either too small or too big. But this obviously needs to be carefully determined. In this paper, we have proposed two guidelines to determine and decide what are the range of useable thresholds for DC profiling.

When the threshold is too small, every transaction in the opposite direction constitutes a DC, and such profiles may capture a lot of noise. On the other hand, when the threshold is too big, there will be too few trends, not enough noise, in the profile. Statistical measures thus collected are based on too few data points to be significant, and cannot be effectively analysed.

It is important to stress that DC-based analysis is entirely data-driven. This means we need to find the range of useable thresholds for each individual data set. By proposing an effective guideline to determine what are the range of usable thresholds, this paper lays an important foundation for new scientific, computer based research, in the new area of DC profiling of financial markets.

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Reference

1. Guillaume, D., Dacorogna, M., Davé, R., Müller, U., Olsen, R., and Pictet, O. (1997). From the bird's eye to the microscope: a survey of new stylized facts of the intra-daily foreign exchange markets. Finance Stoch., 1(2): 95–129

2. Aloud, M. E.P.K.Tsang, R.Olsen & A. Dupuis, A Directional-Change Events Approach for Studying Financial Time Series, Economics, No. 2012-36, 7 September 2012, e-journal, http://www.economics-ejournal.org/economics/journalarticles/2012-36

3. Tsang, E.P.K. (2010): Directional Changes, Definitions Working Paper WP050-10, Centre For Computational Finance and Economic Agents (CCFEA), University of Essex

4. Tsang, E.P.K., Tao, R., Serguieva, A. & Ma, S., Profiling High Frequency Equity Price Movements in Directional Changes, Quantitative Finance, Vol.17, Issue 2, 2017, 217-225

5. Glattfelder, J., Dupuis, A., and Olsen, R. (2011). Patterns in high-frequency FX data: discovery of 12 empirical scaling laws. Quantitative Finance, 11(4): 599– 614. URL: http://www.tandfonline.com/doi/abs/10.1080/14697688.2010.481632