Revisiting the returns-volume relationship: Time variation, alternative measures and the financial crisis

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ABSTRACT

Following its introduction in the seminal study of Osborne (1959), a voluminous literature has emerged examining the returns-volume relationship for financial assets. The present paper revisits this relationship in an examination of the FTSE100 which extends the existing literature in two ways. First, alternative daily measures of the FTSE100 index are used to create differing returns and absolute returns series to employ in an examination of returns-volume causality. Second, rolling regression analysis is utilised to explore potential time variation in the returns-volume relationship. The findings obtained depict a hitherto unconsidered complexity in this relationship with the type of returns series considered and financial crisis found to be significant underlying factors. The implications of the newly derived results for both the understanding of the nature of the returns-volume relationship and the development of theories in connection to it are discussed.

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1 Introduction

Following the seminal research of Osborne (1959) voluminous and ongoing literature has emerged exploring the relationship between the returns and level of trading activity (volume) associated with financial assets. An early indication of the impact of this seminal research is provided by the survey article of Karpoff (1987) which reviews an extensive body of empirical and theoretical research including the studies of, *inter alia*, Granger and Morgenstern (1963), Clark (1973), Epps and Epps (1976), Tauchen and Pitts (1983). Research into the returns-volume relationship has continued at pace in the decades following the survey of Karpoff (1987) with studies such as Smirlock and Starks (1988) and Lamoureux and Lastrapes (1990) considering causality in this relationship and the volatility-reducing effects of volume. More recently, an interesting feature in this literature concerns the examination of the housing market with both empirical and theoretical developments being observed (see Clayton *et al.*, 2010; de Wit *et al.*, 2013).

In the present paper, the returns-volume relationship is revisited. Using robust causality analysis, this relationship is considered for the FTSE100. In addition to considering the standard measure of returns (i.e. the logarithmic first difference of the FTSE100 index), the analysis considers also absolute returns, with potential causality in the returns-volume relationship examined using both of these measures. Such an extension to consider both returns and absolute returns is not uncommon in the literature with numerous studies considering either one or other of these measures of returns.[1] However, in a departure from previous analyses, the present study extends the literature by employing alternative measures of returns (and absolute returns) via the use of daily opening, high, low and closing values of the FTSE100 index. Despite research typically employing a single (closing) measure of returns, recent studies outside of the returns-volume literature have considered the variation, informational content and properties of these alternative opening, high, low and closing indices (see, *inter alia*, Rogers and Zhou 2008; Zhou *et al.* 2016). A second

[1] This is illustrated by the survey of Karpoff (1987) in which the review of empirical research is split according studies considering returns and those examining absolute returns.

new development in the current analysis involves consideration of potential time variation in the returns-volume relationship using rolling regression analysis. Examination of time variation has clear relevance for the present research as the sample considered includes the recent financial crisis which might be expected to impact upon the returns-volume relationship and hence led to differing findings for periods before, after and during the crisis. In recognition of this issue, results for the single full sample are supplemented by production of analogous results for 3379 rolling sub-samples. The findings obtained from a combination of the use of alternative measure of returns and rolling regressions lead to the detection of a degree of complexity in the returns-volume relationship that would remain undetected otherwise. Interestingly, it is shown that the form of relationship detected varies in terms of both its significance and direction (i.e. whether it runs from volume to returns, returns to volume or both) according to the measure of returns and time period considered.

2 Data

The data examined are daily observations on the FTSE100 over the period January 1991 to July 2016. Daily opening, high, low and closing values of the FTSE100 are considered to construct four returns series given as the difference of the natural logarithms of the respective indices. These logarithmic returns and the logarithmic values of trading volume are denoted as r_O, r_H, r_L, r_C and v respectively. Before undertaking the analysis of potential causality between returns and volume, the orders of integration of the series are examined using the generalised least squares Dickey-Fuller (τ_τ) and point optimal (P_T) unit root tests of Elliott *et al.* (1996).[2] On the basis of the results presented in Table One for these tests, it is concluded that all series are stationary. Consequently, the series can be included in the following causality analysis without further modification.

[**TABLE ONE ABOUT HERE**]

[2] Classification of the order of integration of the series is of importance to ensure correct specification of the subsequent causality tests and avoid potential spurious regression (see Granger and Newbold, 1974).

3 Causality results

3.1 Full sample analysis

To explore potential causality in the returns-volume relationship, Granger (1969) causality tests are employed. As stated above, in addition to considering the four returns indices $\{r_{O,} r_{H,} r_{L,} r_C\}$, their absolute values $\{|r_O|, |r_H|, |r_L|, |r_C|\}$ are utilised also. To overcome possible problems resulting from serial correlation and heteroskedasticity, the Newey-West (1987) corrected covariance matrix estimator is employed when estimating the following testing equations for causality:

$$v_t = \phi_0 + \sum_{i=1}^{p} \phi_i v_t + \sum_{i=1}^{p} \lambda_i r_t + \xi_t \quad (1)$$

$$r_t = \delta_0 + \sum_{i=1}^{p} \delta_i r_t + \sum_{i=1}^{p} \theta_i v_t + \eta_t \quad (2)$$

where r_t is given as the eight returns series $\{r_{O,} r_{H,} r_{L,} r_{C,} |r_O|, |r_H|, |r_L|, |r_C|\}$ in turn, with the nulls of no causality $H_0 : r_t \nrightarrow v_t$ and $H_0 : v_t \nrightarrow r_t$ examined via $H_0 : \lambda_i = 0$ and $H_0 : \theta_i = 0 \ \forall i$ respectively. Following Ng and Perron (2001) and Hayashi (2000), the degree of augmentation of the testing equations (value of p) is determined via optimisation of the Modified Akaike Information Criterion (MAIC) with the maximum value of p (denoted as p_{max}) considered given as:

$$p_{max} = int\left(min\left[12, \frac{T}{3}\right] \times \left[\frac{T}{100}\right]^{0.25}\right) \quad (3)$$

The results obtained from application of the above causality tests to the full sample (Jan 1999 to July 2016) are provided in Table Two. Considering the return-volume relationship, it is apparent that significant bidirectional causality is detected when returns are calculated on the basis of daily opening, high and low values of FTSE100 index.[3] The results for returns based upon daily closing

[3] Reference to significance is based upon consideration of the 5% level of significance (i.e. p-value < 0.05).

values provide evidence of unidirectional causality from returns to volume. The findings for the relationship between absolute returns and volume are mixed and in contrast to those for 'standard' returns. More specifically, while unidirectional causality from volume to absolute returns is present when considering daily opening and low values of the index, bidirectional causality is observed when considering daily high values, and no causality is detected for daily closing values. In summary, the results for returns and absolute returns show the use of daily closing values to generate the least evidence of causality between returns and volume, while the use of daily high values generates the greatest evidence of causality.

[**TABLE TWO ABOUT HERE**]

The findings presented in Table Two provide a mixed and complex picture of causality in the returns-volume relationship that would be masked by consideration of a single measure of returns. However, this extension to consider alternative measures of returns does not allow examination of possible time variation in the returns-volume relationship. In recognition of this, the temporal properties of, or time variation in, the causal relationship between returns and volume are examined in the following section.

3.2 Rolling regression results

The above full sample results present evidence of a variation in the causal link between returns and volume which is dependent upon the manner in which the former is measured. Considering the distinction between 'standard' and absolute returns, the former rather than the latter clearly demonstrate more evidence of a causal relationship. Further to this, consideration of the results according to which daily measure of the index is used has shown variation within the findings for both returns and its absolute variant. However, while this extension to include a variety of measures of returns has resulted in the discovery of results that would otherwise remain undetected, it does not provide a complete picture of the relationship under investigation as potential temporal variation is not considered. While time variation is of interest and importance in general circumstances, it is particularly relevant in the current analysis of financial data given the inclusion of the financial crisis in the sample period considered. To generate information on the this issue, rolling regressions of 1000 observations ($T = 1000$) are employed. Given the full sample available, this results in 3379 samples of approximately 4 years duration. For each of these samples, the causality analysis conducted above for the full sample is repeated. Given the vast number of results generated for the 3379 samples across 8 measures of returns to test potential causality running in two directions, the 54064 ($= 3379 \times 8 \times 2$) p-values for the causality tests are graphed rather than tabulated to ease interpretation.

Turning to the rolling regression results in Figures One to Four, extensive temporal variation is apparent in the causal link between returns and volume. To simplify discussion of these results, they can be considered in relation to the financial crisis, with the findings split into three broad groupings relating to the periods ahead of, including and after the financial crisis.[4] Perhaps the easiest finding to interpret in Figures One to Four is the consistent evidence of causality from volume to 'high index' returns for all of the sub-samples considered. In contrast, causality in the other direction is apparent throughout the sub-samples including the financial crisis but not throughout the sub-samples in the pre- and post-crisis periods, with non-rejection of no causality particularly apparent in the pre-crisis period. The results for 'opening index' returns show frequent evidence of causality from volumes to returns although this is not as striking as when considering 'high index' returns. Evidence of causality in the other direction (from opening returns to volume) is far less prevalent, with little rejection of the no causality null in the pre-crisis period in particular. The rolling regression results for 'low index' returns are interesting as while causality from volume to returns is noticeable in the pre-crisis period, it is less apparent thereafter. In contrast, causality in the opposite direction is most noticeable in during the crisis and post-crisis periods. The results

[4]Note that the graphs are presented with the horizontal axis stating the end point of the rolling sample considered. As a result the first rolling sample relates to December 2002 as it involves 1000 obsevations from January 1999. It should be noted also that as the samples contain 1000 observations, the period relating to the 2007/8 financial crisis is captured in a number of samples.

for the ‘closing index’ returns display the least evidence of causality of the four daily measures, thus reflecting the results for the full sample. However, despite this, evidence of causality running from returns to volume (rather than the opposite direction) is apparent in the sub-samples containing the crisis period. Examination of the results for absolute returns in Figures Five to Eight shows marked differences with the results for returns. A particularly noticeable finding is the consistent evidence of causality from volume to absolute ‘opening index’ returns with causality in the opposite direction present primarily during the financial crisis only. In contrast, absolute ‘closing index’ returns display evidence of causality from returns to volume with this apparent during the financial crisis only. The findings for absolute ‘low index’ returns display evidence of causality from returns to volume in the pre-crisis period with causality in the other direction apparent later in the crisis and post-crisis periods. Absolute ‘high index’ returns display similar evidence of volume to returns causality in the crisis and post-crisis periods although this is less marked than for ‘low index’ returns, with causality in the opposite direction apparent being observed during these periods also.

[**FIGURES ONE TO EIGHT ABOUT HERE**]

3.3 Summary of findings

The above analysis has generated a vast number of results and as a consequence their collation is far from straightforward. However, what is apparent is that the returns-volume relationship is not, as some studies might suggest, a single entity to be assessed and classified. Rather, the relationship varies across the alternative measures of return that are available in addition to varying through time. The results obtained show the returns-volume relationship is strongest for returns based upon the daily high values of the FTSE100 with the bidirectional results observed indicating volume influences high values and vice versa. Interestingly, the volume to returns causality detected for returns using daily high values of the index was found to be robust through time while causality in the other direction was not so apparent in the early sub-samples. That a daily extreme (i.e. high value) of the index possesses a greater link with volume than typically considered closing values has intuitive appeal as it might be expected to both prompt, and respond to, changes in trading activity (volume). In contrast to this bidirectional causality, rolling regression analysis has produced findings for low returns which primarily depict unidirectional causality from returns to volume. In combination, these results suggest an asymmetry in the FTSE100 where low values of the index induce trading activity, but not vice versa, whereas high values are both influenced by an influence trading activity. With regard to volatility, as measured by absolute returns, consistent evidence of causality from volume to opening returns is present indicating that prior changes in volume influence later variation in the opening index. However, this phenomenon was only observed for absolute closing returns in the latter sub-samples considered, hence illustrating the importance of time variation in the analysis.

4 Conclusion

The present analysis has examined the returns-volume relationship via an analysis of the FTSE100. Following the seminal research of Osborne (1959), a vast literature emerged exploring this relationship. The current study sought to extend this research in two directions as a result of the use of returns series considering alternative daily measures of the FTSE100 index and the application of rolling regression techniques. The results obtained presented a hitherto unconsidered degree of complexity with the returns-volume relationship. In particular, it was seen that both the significance of the relationship and its direction were both dependent upon the form of returns series employed and the time period considered, with samples before, during and after the financial crisis seen to generate differing results. The results presented clearly provide information on a variation in the volume-returns relationship which requires analysis to gain a greater understanding of this relationship. In addition, the findings also provide a mechanism for evaluating existing theories such as the sequential information arrival and simultaneous equation information arrival models associated with Copeland (1980), Jennings *et al.* (1981) and Jennings and Barry (1983), as well as providing information to support the generation of new theories.

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Table One: Unit root analysis of returns and volume data

Variable	τ_τ	P_T
r_O	-4.483^{***}	0.013^{***}
r_H	-1.974^{**}	0.026^{***}
r_L	-2.143^{**}	0.026^{***}
r_C	-1.726^{*}	0.031^{***}
v	-2.334^{**}	2.636^{**}

Notes: The above figures are calculated test statistics for the generalised least squares Dickey-Fuller (τ_τ) and point optimal (P_T) tests of Elliott *et al.* (1996). Rejection of the unit root null hypothesis at the 10%, 5% and 1% levels is denoted using *, ** and *** respectively.

Table Two: Return-volume causality (Jan 1999 to July 2016)

Null	$p.v.$	Null	$p.v.$
$v \nrightarrow r_O$	0.00	$r_O \nrightarrow v$	0.88
$v \nrightarrow r_H$	0.00	$r_H \nrightarrow v$	0.00
$v \nrightarrow r_L$	0.70	$r_L \nrightarrow v$	0.00
$v \nrightarrow r_C$	12.22	$r_C \nrightarrow v$	0.00
$v \nrightarrow \lvert r_O \rvert$	0.00	$\lvert r_O \rvert \nrightarrow v$	51.18
$v \nrightarrow \lvert r_H \rvert$	1.39	$\lvert r_H \rvert \nrightarrow v$	1.04
$v \nrightarrow \lvert r_L \rvert$	0.24	$\lvert r_L \rvert \nrightarrow v$	7.21
$v \nrightarrow \lvert r_C \rvert$	60.91	$\lvert r_C \rvert \nrightarrow v$	19.63

Notes: The tabulated figures represent p-values expressed in percentage terms for tests of causality between the respective returns and volume series.

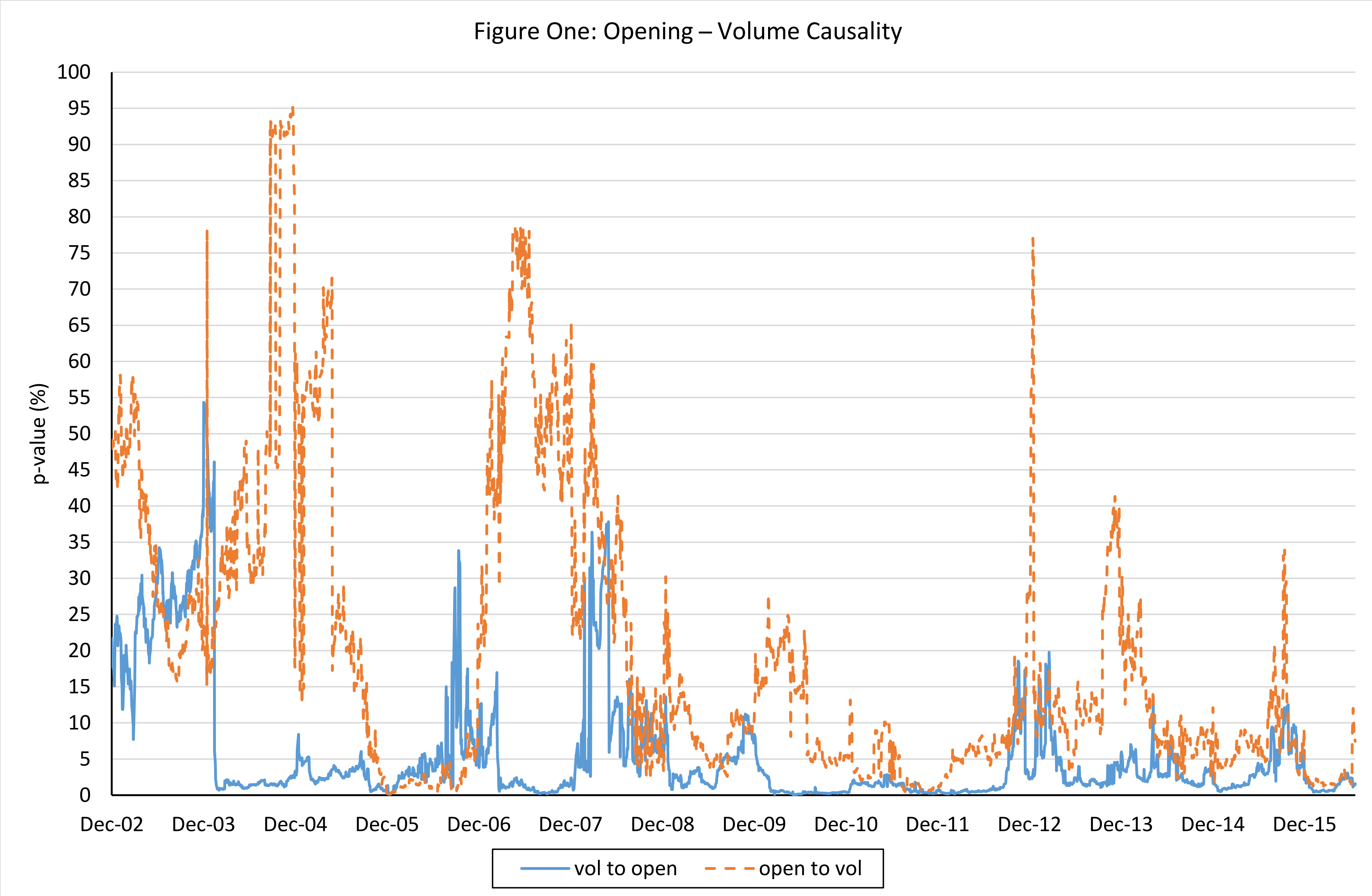

Figure One: Opening – Volume Causality
p-value (%)
100
95
90
85
80
75
70
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55
50
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35
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25
20
15
10
5
0
Dec-02
Dec-03
Dec-04
Dec-05
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Dec-12
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Dec-14
Dec-15
vol to open
open to vol

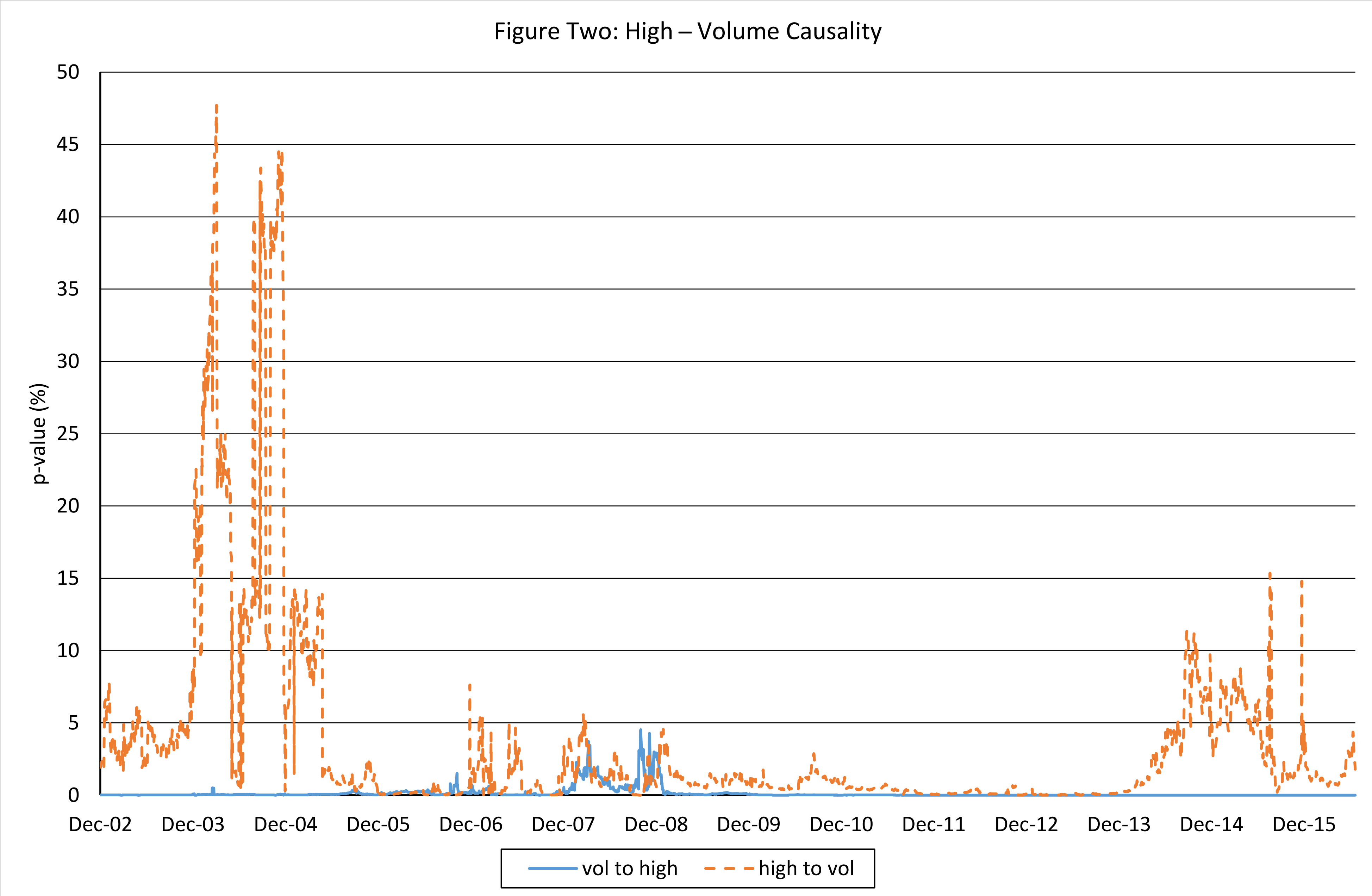
Figure Two: High – Volume Causality
p-value (%)
50
45
40
35
30
25
20
15
10
5
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Dec-02
Dec-03
Dec-04
Dec-05
Dec-06
Dec-07
Dec-08
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Dec-11
Dec-12
Dec-13
Dec-14
Dec-15
vol to high
high to vol

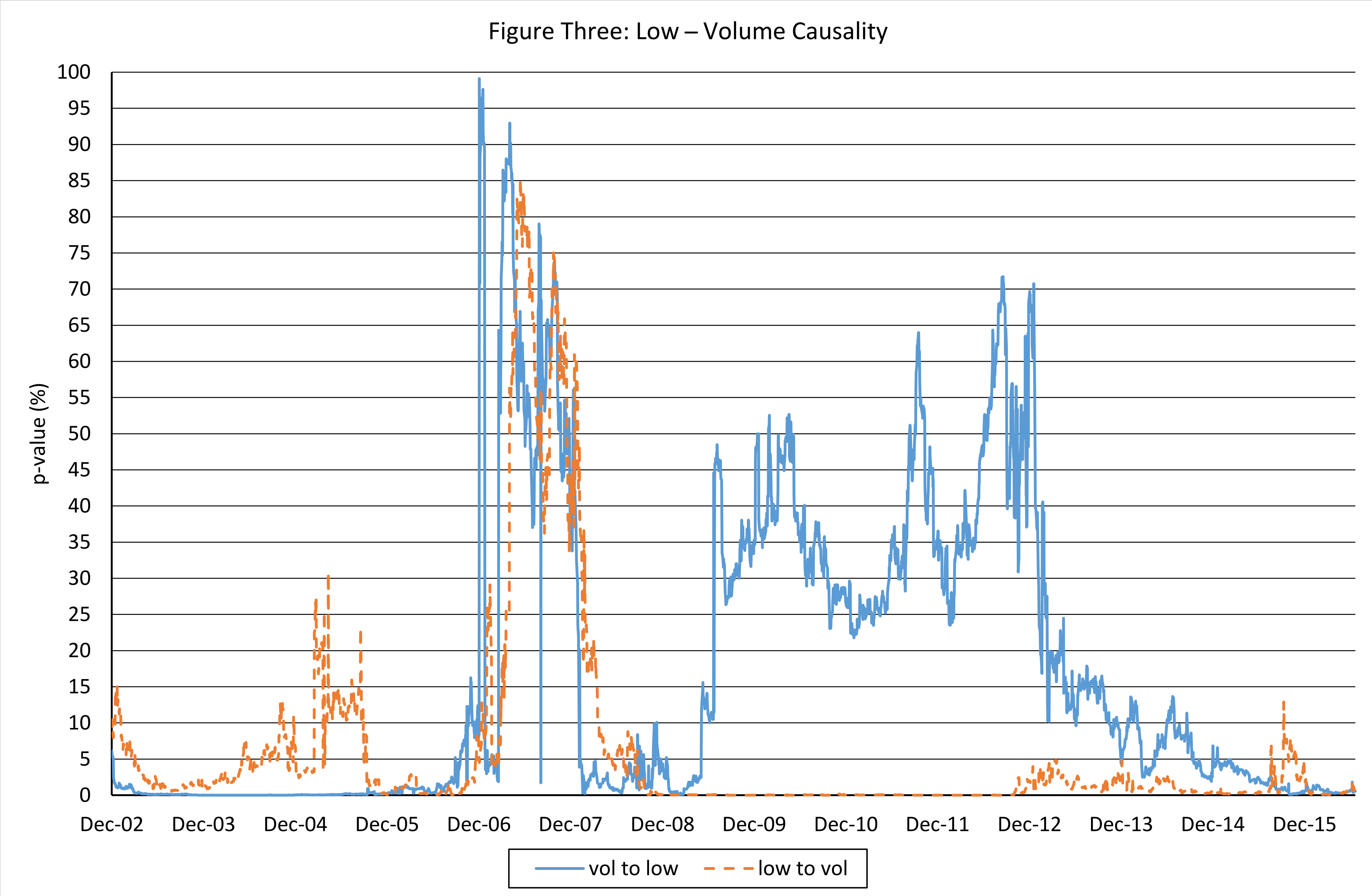

Figure Three: Low – Volume Causality
p-value (%)
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85
80
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70
65
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45
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35
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25
20
15
10
5
0
Dec-02
Dec-03
Dec-04
Dec-05
Dec-06
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Dec-08
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Dec-10
Dec-11
Dec-12
Dec-13
Dec-14
Dec-15
vol to low
low to vol

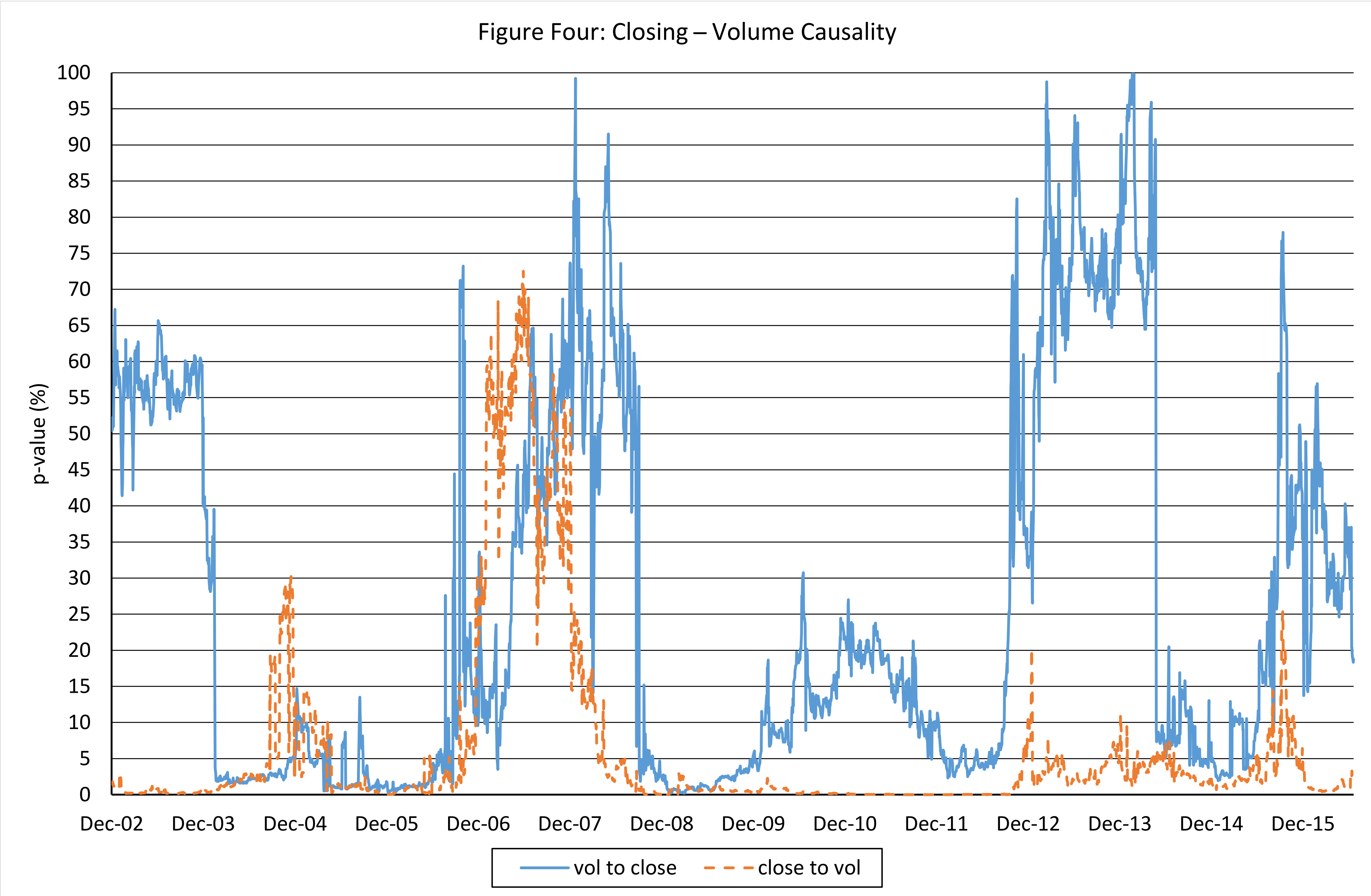
Figure Four: Closing – Volume Causality
p-value (%)
100
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35
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25
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15
10
5
0
Dec-02
Dec-03
Dec-04
Dec-05
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Dec-12
Dec-13
Dec-14
Dec-15
vol to close
close to vol

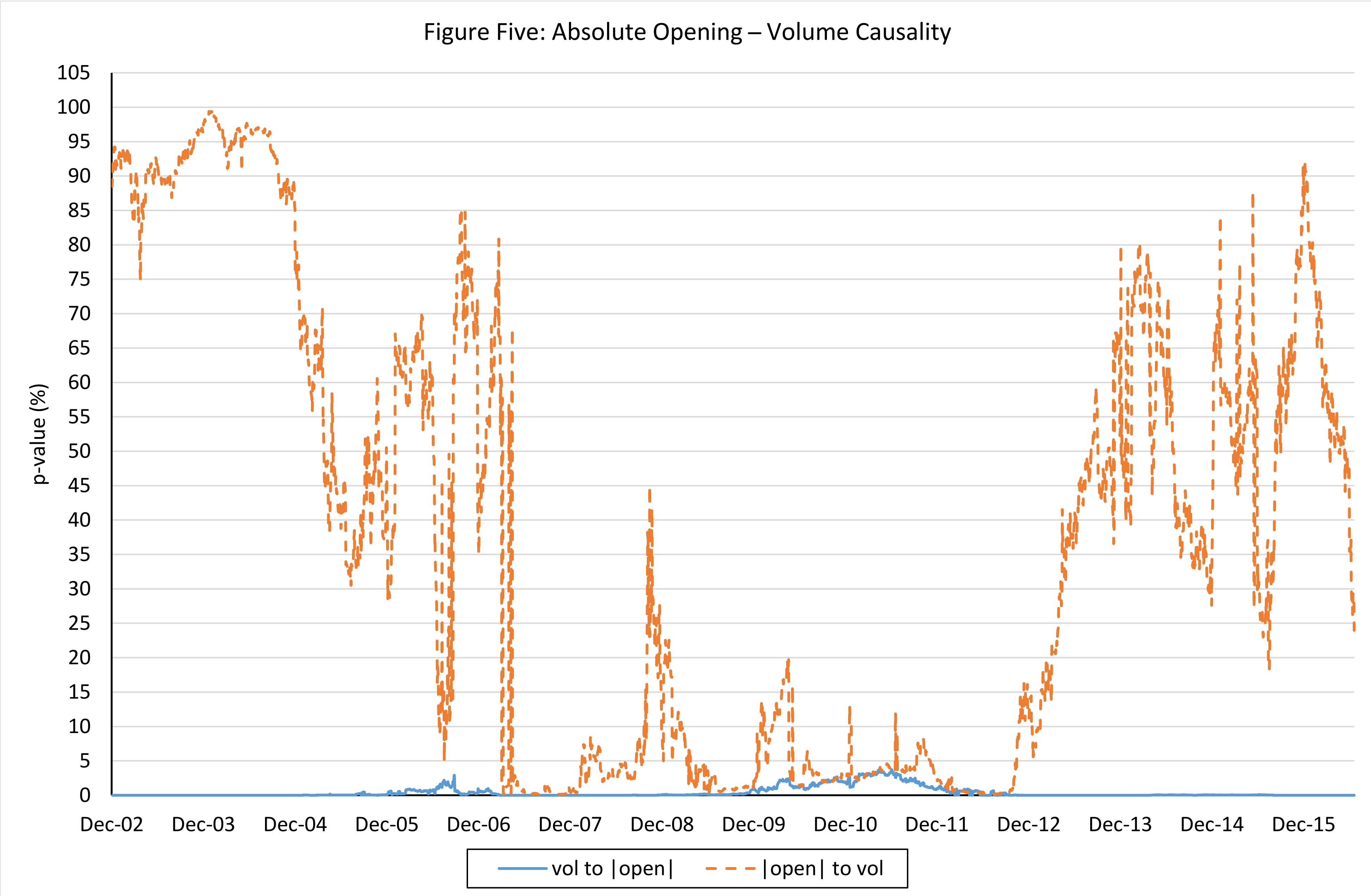
Figure Five: Absolute Opening – Volume Causality
p-value (%)
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30
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Dec-15
vol to |open|
|open| to vol

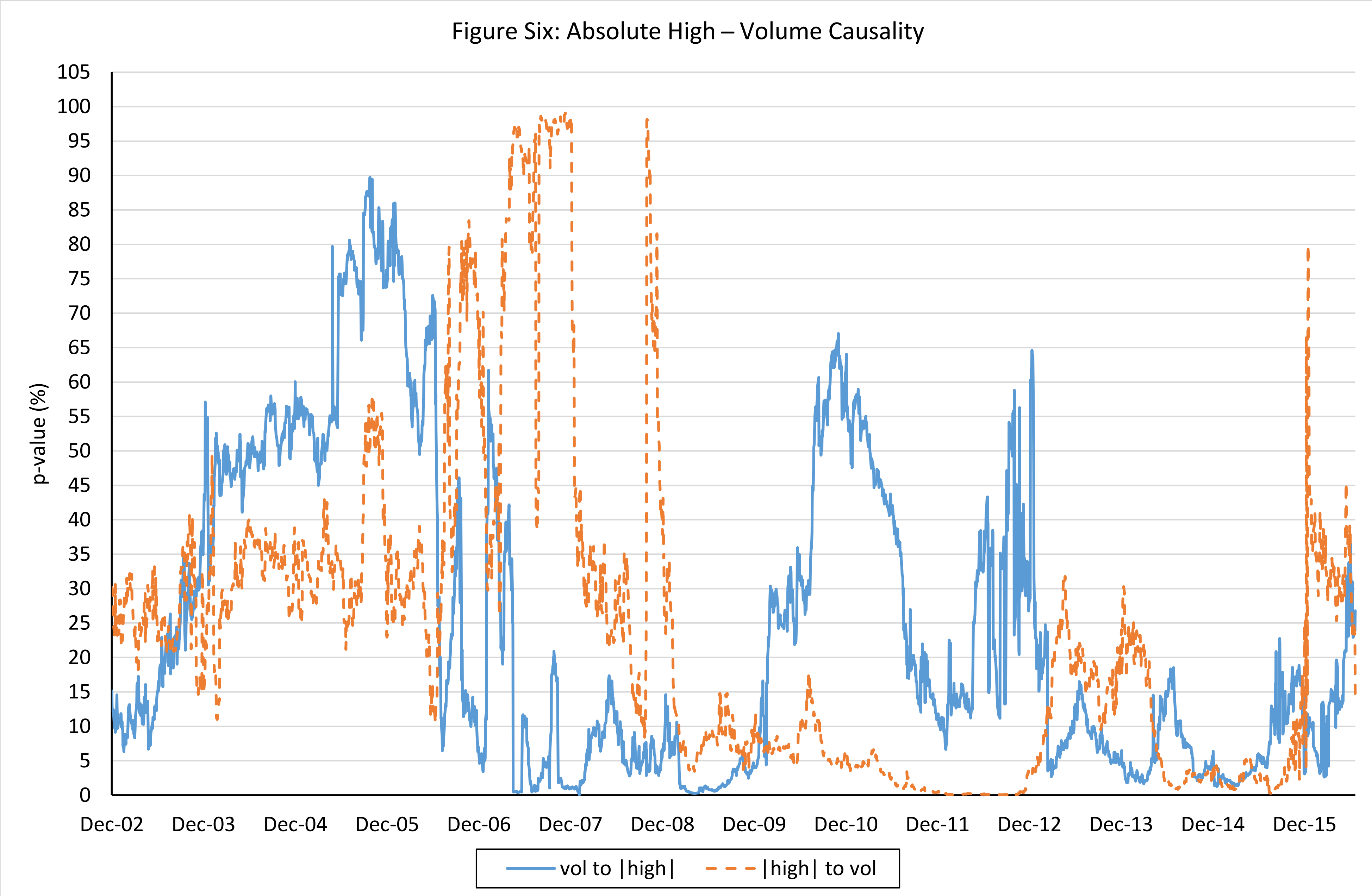
Figure Six: Absolute High – Volume Causality
p-value (%)
105
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30
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20
15
10
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Dec-02
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|high| to vol

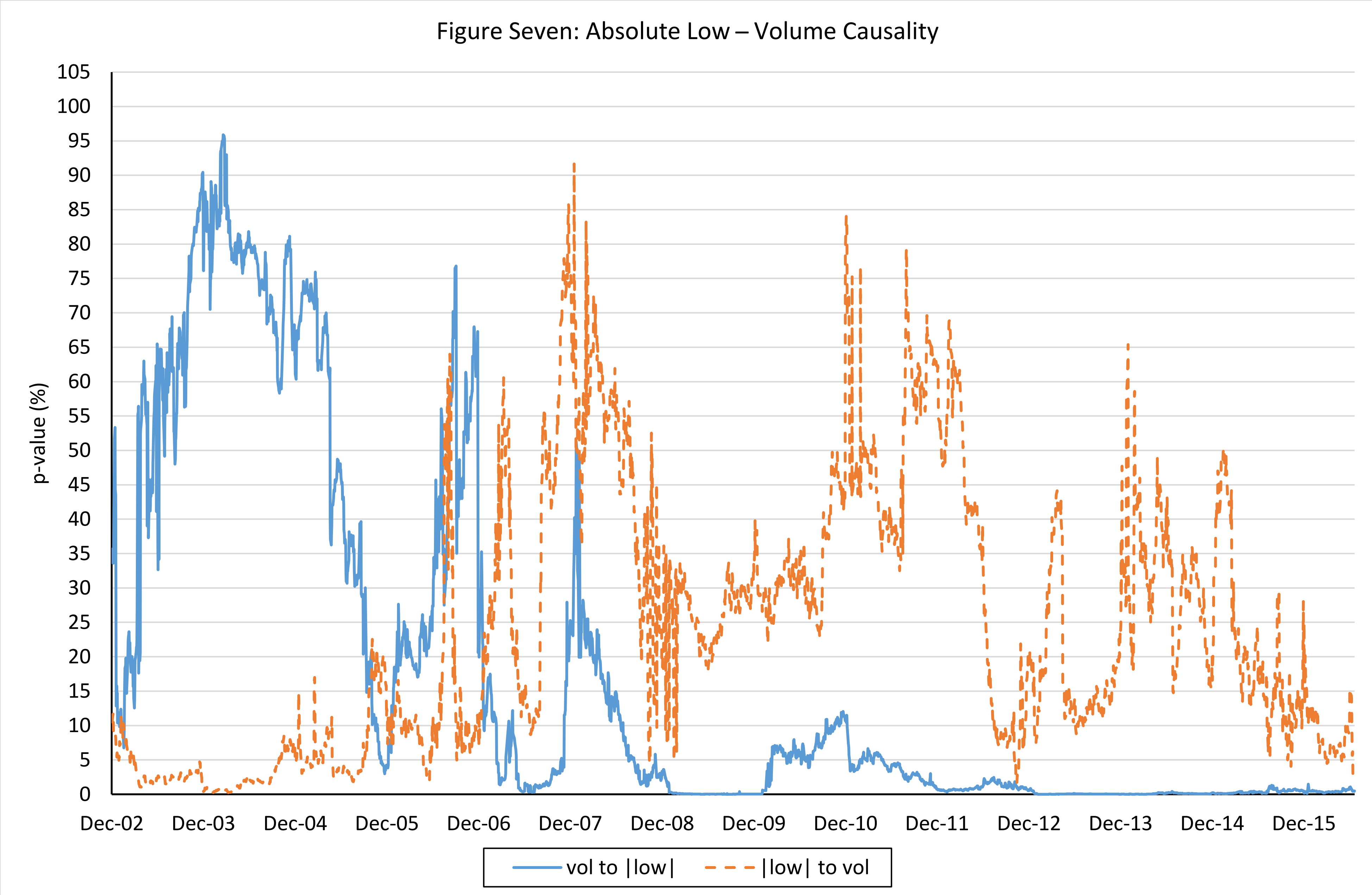

Figure Seven: Absolute Low – Volume Causality
p-value (%)
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Dec-02
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vol to |low|
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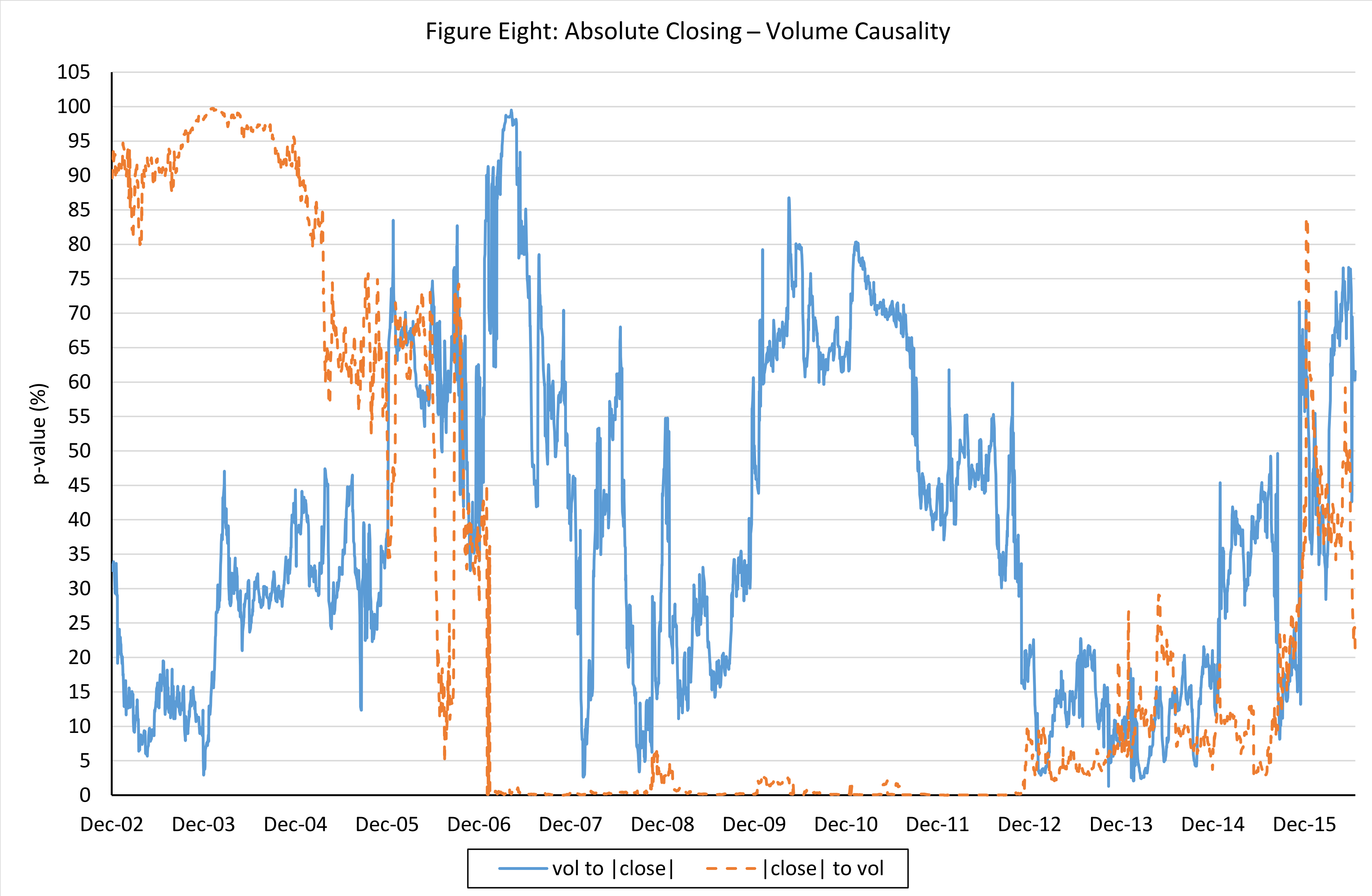
Figure Eight: Absolute Closing – Volume Causality
p-value (%)
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20
15
10
5
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Dec-02
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Dec-15
vol to |close|
|close| to vol