



Department of
Economics and Finance

Working Paper No. 14-05

Economics and Finance Working Paper Series

Guglielmo Maria Caporale, Luis Gil-Alana, Alex
Plastun and Inna Makarenko

Intraday Anomalies and Market Efficiency: A Trading Robot Analysis

April 2014

<http://www.brunel.ac.uk/economics>

INTRADAY ANOMALIES AND MARKET EFFICIENCY: A TRADING ROBOT ANALYSIS

Guglielmo Maria Caporale*
Brunel University, London, CESifo and DIW Berlin

Luis Gil-Alana
University of Navarra

Alex Plastun
Ukrainian Academy of Banking

Inna Makarenko
Ukrainian Academy of Banking

March 2014

Abstract

One of the leading criticisms of the Efficient Market Hypothesis (EMH) is the presence of so-called “anomalies”, i.e. empirical evidence of abnormal behaviour of asset prices which is inconsistent with market efficiency. However, most studies do not take into account transaction costs. Their existence implies that in fact traders might not be able to make abnormal profits. This paper examines whether or not anomalies such as intraday or time of the day effects give rise to exploitable profit opportunities by replicating the actions of traders. Specifically, the analysis is based on a trading robot which simulates their behaviour, and incorporates variable transaction costs (spreads). The results suggest that trading strategies aimed at exploiting daily patterns do not generate extra profits. Further, there are no significant differences between sub-periods (2005-2006 – “normal”; 2007-2009 – “crisis”; 2010-2011 – “post-crisis”).

Keywords: *Efficient Market Hypothesis; intraday patterns; time of the day anomaly; trading strategy.*

***Corresponding author.** Department of Economics and Finance, Brunel University, London, UB8 3PH.

Email: Guglielmo-Maria.Caporale@brunel.ac.uk

1. Introduction

The Efficient Market Hypothesis (EMH) has been highly criticised during the last twenty years, especially on the basis of empirical evidence suggesting the presence of so-called “anomalies”, i.e. abnormal behaviour of asset prices which is seen as inconsistent with market efficiency.

One of the best known anomalies is the presence of intraday patterns, i.e. more intensive trading at the beginning and the end of the trading day combined with higher price volatility (Admati and Pfleiderer, 1988). For example, Wood et al. (1985) reported that all positive returns are earned during the first thirty minutes and at the market close. Harris (1986) showed that prices and last trades tend to be up during the first 45 minutes of trading sessions (all days except Monday). Such patterns were also mentioned by Thaler (1987) and Levy (2002). Strawinski and Slepaczuk (2008) found evidence of intraday patterns in the Warsaw Stock Exchange as well.

The main limitation of the above mentioned studies is that they neglect transaction costs: incorporating spreads, commissions and other fees and payments connected with the trading process can change the picture dramatically. Specifically, it can become clear that some of these “anomalies” cannot in fact be exploited, i.e. profitable trading is not possible, and this inability to obtain extra profits is fully consistent with the EMH.

The present study examines intraday pattern

“crisis”; 2010-2011 – “post-crisis”) to establish whether there is evidence of changing behaviour depending on the phase of the economic cycle.

The remainder of the paper is structured as follows: Section 2 briefly reviews the literature on the efficient market hypothesis and market anomalies. Section 3 explains the method used for the analysis. Section 4 presents the empirical results. Section 5 offers some concluding remarks.

2. Literature Review

The EMH was initially formulated by Fama (1965), who argued that in an efficient market prices should fully reflect the available information and be unpredictable (see also Samuelson, 1965). Fama (1970) then defined three forms of market efficiency (weak, semi-strong and strong). This theory has been used for the valuation of financial assets in terms of risk and uncertainty, and for devising portfolio strategies (see, *inter alia*, Sharpe, 1965; Lintner, 1965; Mossin, 1966, and Treynor, 1962). In the 1980's, it was highly criticized as overlooking transaction costs, information asymmetry (Grossman and Stiglitz, 1980), irrational behaviour etc. As a result many alternative theories and approaches were developed (behavioural finance, the adaptive market hypothesis, the fractal market hypothesis, etc.).

The main implication of the EMH is that traders should not be able to “beat” the market and make abnormal profits. An extensive literature analyses whether instead there exist market anomalies that can be exploited through appropriate trading strategies. This term was first used by Kuhn (1970). Schwert (2003) is an example of a study providing evidence of abnormalities which are inconsistent with asset pricing theories. Shiller (2000) and Akerlof and Shiller (2009) take the view that there are deep reasons for the presence of anomalies in financial markets, namely irrational behaviour of investors (animal spirits, the herd instinct, mass psychosis, mass panic), which is inconsistent with the EMH paradigm.

days except Monday and Wednesday, and a strong tendency for prices to rise in the first and last 15-minute periods of trading (see also Coroneo and Veredas, 2006). Wood, McInish and Ord (1985) reported jumps at the opening and closing of trading. Brooks, Hinich, Patterson (2003) found higher trading volumes in the NYSE at the beginning and the end of the day. The possibility of using the U-shaped pattern by market participants to build trading strategies was emphasized by Abhyankar, Ghosh, Levin and Limmack (1997). The same pattern was found with respect to trading volume, return volatility and liquidity profile by Tissaoui (2012) in the Tunisian Stock Exchange. Table 1 gives details of additional relevant studies.

Table 1: Intraday anomalies: researches overview

Author	Type of analysis	Object of analysis (time period, market)	Results
Harris (1986)	Statistical analysis	15-minutes intervals, fourteen months between December 1, 1981, and January 31, 1983, NYSE, USA	The weekend effect spills over into the first 45 minutes of trading on Monday, with prices falling during this period. On all other days, prices rise sharply during the first 45 minutes and within the last five minutes of trading.
Harris (1989)	F-test		
Camino (1996)	Descriptive statistics	Twenty-three months of transaction records of the IBEX-35, at 15-minutes intervals, Spain	There are significant weekday differences in intraday trading returns in the first four hours of trading. On Monday (and Wednesday) returns are negative, while on the other weekdays they are positive.
Brooks et al. (2003)	Test for Signal Autocoherence	Set of ten-minutes returns, bid-ask spreads, and volume for a sample of 30 NYSE stocks from 4 January 1999 - 24 December 2000, USA	Find the signal coherence to be at the maximum at the daily frequency, with spreads mostly following an inverse J -shape through the day and volume being high at the open and at the close and lowest in the middle of the day.
Çankaya et al. (2012)	GARCH(p,q) models	15 minute intraday values of ISE-100 Index period of August 2007 to February 2011, Istanbul Stock Exchange, turkey	Find that strong opening price jumps are present.

Chan (2005)	LOGIT model	Hang Seng Index constituent stocks in Hong Kong Stock Exchange from 1998 to 2004	Find that the probability of trade at ask price over the last one minute of trading time significantly increases. This systematic pattern can explain around one-third of the positive return from the end-of-day effect.
Coroneo and Veredas (2006)	Quantile regression	15 minutes sampled quotes midpoints during 3 years, from January 2001 to December 2003, of the 35 companies listed in the IBEX-35, Spanish Stock Exchange, Spain	Show that indeed the conditional probability distribution depends on the time of the day. At the opening and closing the density flattens and the tails become thicker, while in the middle of the day returns concentrate around the median and the tails are thinner
Abhyankar et al. (1997)	Generalized Method of Moments (GMM)	Intra-day bid-ask quotes covering the period 1 January, 1991 to 31 March, 1991 i.e. for the first quarter of 1991, London Stock Exchange	Find that the average bid-ask spread follows a U-shaped pattern during trading hours
Tissaoui (2012)	Temporal analysis and spectrum analysis by using the Fourier Transform fast (FFT)	38 shares, 9 months (October 2008 to the end of June 2009), Tunisian Stock Exchange, Tunisia	Confirms that trading volume, return volatility and liquidity profile follow a U-shaped curve. All these variables are at the highest level at the opening of trading, decline rapidly in the middle of the day and then they increase again during the final minutes of trading.
Strawinski and Slepaczuk (2008)	Regression with weights, i.e. robust regression	5-minute returns for the period: 2003-2008) and daily data (for 10 years time span: 1998-2008) for WIG20 index futures, Poland	Find strong jumps at the beginning of trading for all days except Wednesday and a positive day effect for Monday, as well as positive, persistent and significant jumps at the end of session.

3. Data and Methodology

Although most studies suggest the presence of anomalies in the first 45 minutes (or first hour) of the trading session, their results differ in terms of the exact time when the end-of-the-day anomaly emerges: the last transaction, the last 5 minutes, the last 15 minutes, the last hour. Chan (2005) reported that the overall average returns per minute in the Hong Kong

stock market (over the last 30 min, over the last 10 min, over the last 5 min, and over the last 1 min) are statistically positive. However, the majority of studies consider 15-minute intervals. Since the empirical literature does not provide clear evidence on intraday effects on specific weekdays (see, e.g., Strawinski and Slepaczuk, 2008, and Harris, 1989), and since it is difficult to distinguish between time of the day and day of the week effects, we focus specifically on the last 15 minutes before the end of the trading session (see Levy, 2002).

We look at the intraday anomaly from the trader's viewpoint: is it possible to make profits from trading on intraday patterns (which would indicate market inefficiency)? In particular, we test the following hypotheses:

Hypothesis 1: first 45 min up effect exists (H1):

For Russia, owing to lack of data, the analysis is carried out only for the period 2011-2013.

Most studies on intraday anomalies do not incorporate transaction costs, even though trading is inevitably connected with spreads, fees and commissions to brokers. These costs can be divided into fixed and variable ones. The latter are present in each transaction. A typical example is the spread, which is incorporated into our analysis. Specifically, we programme a trading robot which automatically opens and closes positions according to the time of the day effect. Positions (in our case only the “long” ones) will be opened on “ask” price and closed on “bid” price, though we will incorporate the variable part of transactional costs in our analysis. The algorithm is constructed such that long positions are opened at the beginning of the trading session and are closed after 45 minutes (the first 45 minutes up effect mentioned by Harris, 1986, and Levy, 2002), and are also opened at the end of the day. As we consider 15-minute intervals, they are opened in the last 15 minutes of the trading session and are closed at the end of the session (the last 15 minutes of the day up effect mentioned by Levy, 2002). To test this algorithm (trading strategy) on historical data we use a MetaTrader trading platform which provides tools for replicating price dynamics and trades according to the trading strategy.

Positive profits $> 50\%$ imply that H1 and H2 cannot be rejected. As for H3, we carry out t-tests: H3 is rejected if $t < t_{critical}$.

4. Empirical Results

The testing procedure comprises two steps, i.e. initially testing the first 45 minutes up effect, and then the last 15 minutes up effect.

The complete results for the former are presented in Appendix A. A summary for different time periods is shown in Table 1a.

Table 2a: Summary of testing results for the “last 15 min up effect”

Period	Average profit trades (% of total)	Average total net profit	Average net profit per deal
2005-2006	26%	-235	-0.538
2007-2009	35%	-351	-0.512
2010-2011	31%	-168	-0.544

All periods were unprofitable, with the probability of a profitable trade being less than 40%. Hypothesis H2a is reje

These hypotheses are rejected for both the US and Russia, a mature and less developed stock market respectively. The only exception is H3: the results for the last 15 minutes up effect vary depending on the sub-period considered.

On the whole, our analysis implies that it is not possible to exploit intraday patterns to make abnormal profits. This suggests that the results from previous studies purporting to provide evidence of exploitable profit opportunities resulting from market anomalies (which would be inconsistent with the EMH) were in fact misleading because they did not take into account transaction costs. The trading robot approach used in the present study can also be used to analyse other anomalies, but this is left for future work.

References

Abhyankar, A., Ghosh, D., Levin, E. and Limmack, R., 1997, Bid-ask spreads, trading volume and volatility: intra-day evidence from the London stock exchange. *Journal of Business Finance & Accounting* 24(3 & 4), 343-362.

Admati, A. and Pfleiderer, P., 1988, A Theory of Intraday Patterns: Volume and Price Variability *The Review of Financial Studies* 1 (1), 3-40.

Akerlof, G.A. and Shiller, R.J., 2009, *Animal Spirits: How Human Psychology Drives the Economy, and Why It Matters for Global Capitalism*. Princeton University Press, 2009, 248 p.

Brooks, C., Hinich, M. and Patterson, D., 2003. Intra-day Patterns in the Returns, Bid-ask Spreads, and Trading Volume of Stocks Traded on the New York Stock Exchange. ICMA Centre Discussion Papers in Finance icma-dp2003-14, Henley Business School, Reading University.

Camino, D., 1996, The role of 26.545 0nnce ict1245 TwTc Exchange. ICM

Coroneo, L. and Veredas, D., 2006, Intradaily Seasonality of Returns Distribuion: A

Shiller, R. J., 2000, *Irrational Exuberance*. Princeton University Press, 2000, 296 p.

Strawinski, P. and Slepaczuk, R., 2008, Analysis of high frequency data on the Warsaw stock exchange in the context of Efficient market hypothesis. *Journal of Applied Economic Sciences* 3 (5), 306-319.

Thaler, R., 1987, Seasonal Movements in Security Prices II: Weekend, Holiday, Turn of the Month, and Intraday Effects. *Economic Perspectives* 1 (1), 169–177.

Tissaoui, K., 2012, The Intraday Pattern of Trading Activity, Return Volatility and Liquidity: Evidence from the Emerging Tunisian Stock Exchange. *International Journal of Economics and Finance* 4 (5), 156-176.

Treynor, J., 1962, Towards a Theory of Market Value of Risky Assets. Unpublished paper. “Rough draft” dated by Mr. Treynor to the fall on 1962. A final version was published in 1999, in *Asset Pricing and Portfolio Performance*. Robert A. Korajczyk (editor) London: Risk Books, 15-22.

Wood, R., McInish, T. and Ord, J., 1985, An Investigation of Transactions Data for NYSE Stocks. *The Journal of Finance* 40 (3), 723-739.

Appendix A
First 45 min up effect
2005-2006

2007-2009

Company	Total trades	Profit trades	Profit trades (% of total)	Total net profit
Alcoa	740	322	43.51%	-447.6
Altria Group	740	322	43.51%	-169.3
American Express Company	728	300	41.21%	-629

2010-2011

Company	Total trades	Profit trades	Profit trades (% of total)	Total net profit
Alcoa	308	58	18.83%	-95
Altria Group	308	78	25.32%	-101.4
American Express Company	308	127	41.23%	-97.5
ATT Inc	308	112	36.36%	-89.4
Boeing	308	96	31.17%	-210.9
Coca-Cola	308	92	29.87%	-198.1
DuPont	308	124	40.26%	-93.9
ExxonMobil Corporation	308	106	34.42%	-207
General Electric Corporation	308	88	28.57%	-94.6
Hewlett-Packard Company	308	107	34.74%	-136.9
Home Depot Corp	308	86	27.92%	-124.9
Honeywell International Inc	308	122	39.61%	-100.2
IBM Corporation	308	34	11.04%	-947.6
Intel Corporation	308	91	29.55%	-105.5
International Paper Company	308	115	37.34%	-79.5
Johnson&Johnson	308	118	38.31%	-115.4
JP Morgan Chase	308	119	38.64%	-101.1
McDonalds Corporation	308	79	25.65%	-250.4
Merck Co Inc	308	94	30.52%	-110.5
Microsoft	308	99	32.14%	-122.3
MMM Company	308	109	35.39%	-190.7
Pfizer	308	76	24.68%	-106.3
Procter Gamble Company	308	78	25.32%	-236.8

Appendix C

Results for Russian stock markets

First 45 min up effect

Company	Total trades	Profit trades	Profit trades (% of total)	Total net profit	Profit per deal
GAZPROM	286	148	51.75%	66.5	0.23252
GAZPROM NEFT	264	95	35.98%	-173	-0.6553
LUKOIL	287	132	45.99%	-557	-1.9408
NORILSKY NICKEL	285	106	37.19%	-434	-1.5228
ROSNEFT	287	127	44.25%	-123.6	-0.4307
SBERBANK	286	136	47.55%	-275	-0.9615
SURGUTNEFTEGAZ	287	134	46.69%	-335	-1.1672
VTB BANK	242	50	20.66%	-1757	-7.2603 757 20827.095-.0