MEAN REVERSION IN STOCK MARKET PRICES: EVIDENCE FROM UKRAINE

by

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Abstract

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The evidence for mean reversion in stock market prices is mixed. I use panel data on monthly prices for 36 stocks and PFTS index and SUR approach to test for mean reversion in Ukrainian stock market. I find strong evidence in favor of mean reversion. The speed of mean reversion estimated by the test significantly exceeds findings of other authors, implying half-life of mean reversion of six months. However, it is hard to distinguish between reasons that caused such result.

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Chapter 1

INTRODUCTION.

Like alchemists were searching for philosophers' stone in the Middle Ages, researchers in finance are searching for the key to determine stock price behaviour nowadays. However, since stock price depends on so many fundamentals such as company's performance, expectations, mood of the market players and others, it is very difficult to predict its future behaviour or, as some say, almost impossible. This viewpoint has been summarized in the so-called *random walk* hypothesis that suggests that stock price movements are totally unpredictable (see, for example, Samuelson (1973), Malkiel (1999)). The random walk theory has dominated in the theoretical literature for several decades.

However, since empirical evidence of randomness in stock price movements was not persuasive enough, several non-random walk hypothesis emerged later. Nowadays the *mean reversion* hypothesis is one of the most empirically supported. It suggests that stock prices move around their fundamental values, and, hence, after deviation from it, the reverse movement results. Some evidence of this behaviour was found by DeBondt and Thaler (1985, 1987), Fama and French (1988) who showed the presence of the mean reversion in the US market. More recent papers written by Balvers, Wu and Gilliland (2000) and Chaudhuri and Wu (2004) employed panel data approach examining stock indexes for groups of countries.

This study addresses the question of the mean-reversion in the Ukrainian stock market. This topic is of interest for two reasons. First, there is lack of studies that use panel approach on individual stock markets. Most of studies focused on studying a country's index behaviour within a group of countries (i.e. emerging markets or developed countries) assuming similarity of index behaviour in different countries. Second, studies conducted at a country levels, whether using panel approach or not, were mostly associated with developed countries. Obviously, there are significant differences in underlying fundamentals in developed and developing countries. Main differences may be caused by the average age of companies in emerging markets (particularly in Ukraine) compared to the developed countries, stronger links with political parties in developing countries and differences in legislation. Since Ukrainian market is young, average age of companies is also smaller compared to the developed economies. This suggests that performance of the companies and stock prices should be more volatile, since there is a plenty of room for new rivals to emerge because the existing companies have not created long-term advantages in the market yet (i.e. brand names, distribution systems etc.). Therefore, periods of a good performance of a company may soon turn into a bad performance. Stock prices might reflect this, and could fall after a period of an increase exhibiting the mean-reversion pattern. On the other hand, political connections of a large part of big companies may help them constantly outperform the market. Their stocks prices might not show the mean reversion pattern.

To find evidence on mean reversion in Ukraine, I employ SUR model and panel data on 31 Ukrainian stocks traded on PFTS and the PFTS index as a reference index. As well standard time-series tests on individual securities have been performed along with OLS panel estimation for comparison of results.

This thesis is organised as follows:

Chapter one analyzes literature on the topic of study. The first part of this chapter is dedicated to the theoretical literature concerning mean reversion, identification of reasons for mean reverting price behaviour and its implications for market efficiency. The reason for considering market efficiency implications is to draw conclusions about market inefficiency from findings on price predictability. To avoid misleading conclusions at the end, the discussion of this issue is provided. The second part of the chapter discuses empirical findings in the field and describes some testing techniques for mean reversion.

Chapter two describes my dataset used for estimation, and gives some justification for the choice of the return horizon used in my estimation.

Chapter three discusses theoretical background and presents some empirical testing for the mean reversion that has been applied.

First part of chapter four gives outcome of tests for mean reversion of individual stocks. The second part presents results of estimation for market mean reversion coefficient and compares them to findings in the existing literature in the field.

Chapter five presents the conclusions from the study.

Chapter six discusses drawbacks of the thesis and possible improvements.

Chapter 2

LITERATURE REVIEW

Theoretical background of mean reversion.

One of the reasons for possible presence of mean reversion is that traders often pay much attention to recent trends in returns. They believe that if a stock showed high returns recently, after some positive information about a company appeared, it is very likely to continue providing high returns. As a result, the market in general overreacts after announcement of good news (Cutler, Poterba and Summers, 1991). But traders that pay attention to fundamental values of a stock find stocks that are overpriced this way and sell them, thus dropping the price. Eventually, mean reversion pattern forms.

The larger magnitudes of prices fluctuations due to market overreaction causes misallocation of funds (the companies that have better investment opportunities may face lower share price and will collect less money from stock market than those with worse investment opportunities). Thus it is a reason for inefficiencies in a stock market (Engle and Morris, 1991).

In the view of what is written above, mean reversion causes market inefficiency. But there are also other approaches to explaining mean reversion. As it has been shown, for example, according to Cecchetti et al. (1990) and Fama and French (1998), changes in risk tolerance and riskiness of a stock for a given riskless interest rate will change the interest rate of borrowing for the company, thus changing the stock price and also causing it to be mean reverting. Alternatively, for a given riskiness of a stock, changes in a riskless interest rate cause price fluctuations. Given changes in interest rate, stock prices may also show mean reverting pattern, although somewhat different from the one that appears in the case of stock market overreaction (Engle and

Morris, 1991). While interest rate fluctuations may cause mean reversion in prices, they do not cause market inefficiency. Poterba and Summers (1988) claim, however, that the magnitude of change in interest rates should be very huge to cause mean reversion patterns. Also, Lo and Mackinlay (1988) and Poterba and Summers (1988) find that prices follow patterns that actually fit the overreaction explanation and not the interest rate one.

Historically, efficient market has a long time been associated with the random price movements (see, for example, Samuelson (1973)). Since mean reversion imply, to some extent, predictability of future returns, it automatically rejects market efficiency if price randomness is a necessity for efficient market. However, Lo and MacKinlay (1999) claim (and provide several examples) that efficient market is not implied by and does not imply price randomness.

Adding up all mentioned above, there are number of theoretical explanations of presence of mean reversion. Some of them imply inefficient stock market, others don't. As a consequence, it is logical to warn about making conclusions concerning Ukrainian stock market efficiency based on the results of this paper, treating them just as an additional piece of information on stock price predictability.

Empirical findings in the field.

One of the first statistical evidence for mean reversion is the paper by DeBondt and Thaler (1985). They found that stock-losers after 3 to 5 years started outperforming the former winners in US market. Although the study was dedicated to market efficiency issue, the mean reverting pattern was discovered. This phenomena is explained in the paper by overreaction effect. The authors also found skewness in mean reversion, since former losers outperformed the market much stronger then former winners underperformed it. After these findings evidence in favor of mean reversion started expanding.

Fama and French (1988) found that first-lag autocorrelations of 36-, 48- and 60-months returns on US stock portfolios are negative, claiming this result to be general economic phenomena. The autocorrelation is found to be weak for short-term holding periods (i.e. daily and weekly), however they are larger for longer periods, reaching maximum for 3-5 year returns. The variance of portfolios' returns for these return horizons is estimated to be up to 40 percent predictable from these autocorrelations.

Poterba and Summers (1988) used several datasets: US stock prices starting 1871 till 1985, returns in Canada from 1919, Britain since 1939 and another 15 countries for post World War II periods. Also they did tests on 82 stocks' monthly data between 1926 and 1985. They employed variance ratio test and found evidence of mean-reversion (negative autocorrelations) in the long horizon. But in the short horizon, autocorrelations are found to be positive.

However, Richardson (1993) criticizes their procedure for not accounting for small sample biases, which leads to bias in coefficients.

At the same time, Lo and MacKinlay (1988) presented their variance ratio test on weekly US data. Although they were able to reject random walk hypothesis, they claim that their findings may not be exhaustively explained by mean reversion hypothesis either.

Kim, Nelson, and Startz (1991) find that mean reversion is present only for pre-war data for US. For the after-war sample, they find evidence that suggests even presence of mean-aversion in stock prices movements. Although they find that mean reversion is hardly present for the whole sample period (pre- and post-World War II data), the hypothesis of randomness of returns may also be rejected.

It deserves mentioning that the findings mentioned above should be taken with a bunch of caution, since the tests that were used were individual time-series tests which have very low power for rejecting random walk hypothesis in favor of mean-reversion (see Campbell and Perron (1991), Cochrane (1991)). Also, failure in finding mean-reversion may be due to small sample biases, since the speed of reversion is very small (Lo and Mackinlay, 1988). More recent studies use better datasets and more advanced techniques in studying this issue. While tests that are applied to individual stock prices have very little power, tests based on panel data have much more power even with smaller time span (Cochrane (1991), DeJong et al. (1992)).

Further, McQueen (1992) suggested that previous findings of presence of mean-reversion in US are overstated. He backs up this suggestion with a GLS randomization test for 1926-1987 data that appears to be unable to reject random walk. He stipulates the reasons for receiving misleading results by previous studies are implicit weightings of the data in favor of the Depression and World War II observations, which have higher variances and stronger mean-reverting tendencies. Also, he blames his predecessors for focusing on the most negative estimates of mean reversion, thus choosing the results most appropriate to reject random walk.

The authors of more recent papers on the topic tried to develop more powerful procedures to find mean reversion components.

Balvers, Wu and Gilliland (2000) use panel data for 18 developed countries' stock indices with sample period from 1969 to 1996 to gain additional power of the testing procedure. They present strong evidence in favor of mean-reversion that is robust to model specification and data. The half-life implied by the speed of reversion is found to be from three to three and a half years. Among the assumptions used in their paper is the one that the differences between stock market indices' fundamental values for different countries are stationary. However, they don't present any theoretical explanation for the validity of this assumption, while it is crucial for model justification.

Chaudhuri and Wu (2004) explore monthly data for 17 emerging capital markets starting January 1985 to April 2002 and reject random walk in favor of mean reversion. They find the half-life of mean-reversion to be about 30 months, which is close to findings from developed countries.

Gropp (2004) provides evidence from stock portfolios traded in three exchanges: NYSE, AMEX and NASDAQ using the data for 1926-1998 years. He constructs 16 equally weighted industry portfolios and uses return horizons equal to one, two and three years. The test confirms presence of mean reversion for stock portfolios. Also, the speed of mean reversion found in his paper is approximately proportional to the length of the returns horizon in use. He also finds different speed of reversion for different exchanges which may be due to structural differences between these stock exchanges, although they represent the same market.

Gropp (2004) rely on the assumption about stationary difference between fundamental values, similar to Balvers, Wu and Gilliland (2000) and Chauhudri and Wu (2004), but adopted for fundamental values of portfolios. However, neither of the studies gives theoretical argumentation for the use of the assumption.

Together all the studies in the field (with the list of studies mentioned above being far not exhaustive) present mixed evidence about mean reversion. Those concentrated on individual stock returns usually lack power to reject random walk in favor of mean reversion. More recent studies that employ panel tests provide more convincing evidence of presence of mean reverting components. But they concentrate mostly on cross country analysis, checking for mean reversion between countries' stock indices, whether markets under study are developed or emerging. Also, there is lack of theoretical backing for the methodology applied in these studies.

This paper concentrates on studying a single country stock market, implementing tests on monthly returns on individual stocks. Panel estimation procedure is used in order to provide stronger evidence. Also, stronger theoretical justifications for the assumptions in the model is presented to prove consistency of the procedure with the broad financial theory.

Chapter 3

DATA DESCRIPTION

The data has been obtained from Bloomberg database. The dataset consists of monthly returns on 31 stocks starting January 2000 and ending December 2007. The raw dataset consisted of daily observations on 80 stocks' prices and the PFTS index from January 13, 1999 till January 14, 2007, which then were transformed into monthly data. However, since the market is young, most of the companies went for IPO's quite recently, so the starting dates for different stock were different, thus making construction of a sample more difficult. If more companies were chosen, the quantity of time observations would have decreased substantially. Respectively, if more observations in time were added, this would have decreased cross-sectional dimension. Taking into account this trade-off and that there was lack of stock price variability before 2000 due to weak trading, the sample that is used in this study was chosen as an optimal one.

Although, as mentioned by Perron (1989, 1991), the power of a test depends on the time span and not on the frequency of observation, I use monthly data instead of annual or half-annual data for technical reasons: Since the model to be estimated is SUR, the number of observations in the sample must be greater than the number of equations plus the number of independent variables in equations for error covariance matrix to be non-singular. Monthly data gives 96 observations, while half-annual would give us only 16, which makes estimation of all the equations simultaneously impossible.

As well, more frequent data is not used since this allows us to decrease the influence of daily jumps in prices. Daily prices in stock exchange may change dramatically due to very small deals, therefore making the price fluctuations not representative for the purpose of this study. Small deals may be made at a price that is not representative for a market overall. However, after bigger deal is made at the market price, one may observe mean reverting pattern which is generally misleading. Comparing to strong price changes over a month, these daily price fluctuations become less influential making estimation more reliable.

Table 1 presents the summary statistics for the prices in the sample. Prices are highly volatile, with variance to mean ration from 0.1 for DNAZ to 961.6 for DNEN. Also, skewness and kurtosis are high over the sample, suggesting non-normal distribution of prices.

Table 1. Descriptive Statistics

Ticker	Smallest	Largest	Mean	St. dev	Variance	Skewness	Kurtosis
PFTS	36.67	1167.75	248.54	293.25	85994.2	1.74	5.24
USCB	0.02	1.69	0.31	0.48	0.2	1.65	4.35
AZOT	0.49	12.15	4.19	3.06	9.4	0.47	2.07
DNAZ	0.01	0.21	0.03	0.05	0.003	3.09	11.00
STIR	5.30	7.74	44.72	43.24	1869.8	0.84	2.30
YASK	0.05	7.00	1.27	1.62	2.6	1.70	5.22
SLAV	4.00	112.00	28.57	21.84	477.1	1.53	5.85
ZFER	0.10	1.85	0.46	0.32	0.1	0.87	4.95
NFER	0.25	14.50	3.46	2.90	8.4	1.01	3.68
CEEN	0.10	26.10	4.01	6.27	39.3	2.43	7.81
DNEN	16.00	2547.50	380.11	604.58	365516.5	2.47	8.03
DOEN	2.20	186.50	29.17	41.41	1714.9	2.61	8.97
KIEN	0.70	44.25	7.87	8.61	74.2	2.69	9.54
MSICH	10.00	1715.00	293.60	359.22	129036.6	1.95	7.34
KRBD	0.13	1.40	0.28	0.34	0.1	2.67	8.60
SMASH	0.55	52.00	9.30	12.72	161.9	1.58	4.95
TATM	0.20	5.65	1.18	1.10	1.2	2.06	7.80
CHEN	0.25	9.50	1.48	1.89	3.6	2.28	7.32
DNON	15.00	1170.00	183.15	291.22	84808.0	2.19	6.57
HAON	0.20	13.00	1.75	2.47	6.1	2.84	10.60
HMON	0.35	12.00	1.66	2.49	6.2	2.75	9.95
LVON	0.24	14.00	1.65	2.84	8.1	2.78	10.36
VIEN	25.00	610.00	70.76	96.44	9300.6	4.10	21.17
ZAON	0.57	21.00	4.61	5.17	26.7	2.13	6.25
ZHEN	0.32	12.40	2.04	2.25	5.0	2.46	10.02
UNAF	6.19	503.00	126.55	141.06	19898.8	1.04	2.67
HRTR	0.30	25.75	1.51	2.65	7.0	8.03	73.81
NITR	0.02	215.00	34.70	56.70	3214.4	2.01	6.00
AZST	0.04	5.80	1.32	1.54	2.4	1.08	3.29
DOMZ	0.02	2.20	0.45	0.49	0.2	1.66	5.32
MMKI	0.05	6.95	1.56	1.91	3.7	1.14	3.43
ZPST	0.10	14.30	2.33	2.74	7.5	1.93	8.35

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MODEL AND METHODOLOGY

Model and Methodology

In my study I adopt the methodology introduced by Balvers, Wu and Gilliland (2000), Chaudhuri and Wu (2004) and Gropp (2004). Below I provide some justification for the chosen methodology.

Stochastic process for the price if an asset that shows mean-reversion is constructed as follows:

$$P_{t+1}^{i} - P_{t}^{i} = a^{i} + \lambda^{i}(P_{t+1}^{fi} - P_{t}^{i}) + \varepsilon_{t+1}^{i}, \quad (1)$$

where P_t^i is the log of the price of stock *i*, so that $(P_{t+1}^i - P_t^i)$ equals to a continuously compounded return of investor at time *t+1,* P_{t+1}^{fi} is the log of the fundamental value of the stock price index at time *t+1*, which is unobserved, ε_{t+1}^i is the stationary error term. Parameter λ^i (0< λ^i <1) gives information about the mean reversion. If λ^i is zero, there is no mean reversion. If λ^i is minus one, the full reversion happens in the subsequent time period.

So, obtaining λ^i <0 means conforming the mean-reversion hypothesis. Detection of the mean-reverting behaviour of the price is complicated by the need to identify fundamental path that the price is reverting to after shocks.

Researchers have used different proxies for fundamental values. Cutler et al. (1991) used logarithm of dividend-to-price ratio as a proxy of fundamental value to estimate equation (1). Also, Chiang et al. (1995) use earnings and dividends per share as a proxy for fundamental value claiming that a firm's fundamental value may possibly be expressed as a linear function of earnings and dividends. One should be very cautious when specifying fundamental value. Wrong specification of the fundamental path significantly distorts the results (see Balvers, Wu and Gillliland, 2000).

However, this estimation problem may be resolved by using a reference index that the stock price is being compared to. A basic assumption here is that the difference between fundamental values of the stocks and fundamental value of the reference index is stationary, which can be expressed as follows:

$$P_t^{fi} = P_t^{fr} + z^i + \nu_t^i , \quad (2)$$

where ν_t^i is the stationary process with zero mean that may be serially correlated, z^i is a constant, P_t^{fr} stands for the log of the fundamental value of the reference index.

This assumption has been used by Balvers, Wu and Gillliland (2000) and Chaudhuri and Wu (2004) for the cross-country indices and by Gropp (2004) for stock portfolios without particular justification. However, in order to prove that the results of estimating such a model are consistent with the theory, some reasoning is required.

In this study, the PFTS index is used as a reference index for the model. It seems a natural candidate for this role since it possesses the following qualities that justify such choice:

- PFTS index is a weighted average of the stocks in the sample, and hence, it "borrows" from variations in each stock's price;
- A number of same economic variables influence both PFTS index and individual stocks making them move together to some extent;

- Both returns on the PFTS index and on individual stocks are limited in the long run by economic growth (Damodaran (1994)). This means that growth in any of the stocks' price cannot exceed the growth of the PFTS index infinitely implying stationary difference in their fundamental values in the long run.

Referring to the valuation theory, the period during which a stock price outperforms the market is rarely more than five years given that a company is young (or the IPO has been done recently). Since both a stock price and market index have same limit – the difference in their prices should be stationary in the long run. Hence, relying on these facts, the assumption (2) may be justified.

Using this model specification is also convenient since one should not account separately for structural breaks in the market (the requirement for testing for structural breaks was stated by Chaudhuri and Wu (2003), Valadakhani and Chancharat (2007)). When market is subject to structural break, it has same impact on stocks and reference index, thus not changing the fundamental relationship between them.

Further, if one assumes that the speed of mean reversion is same for the stock and the reference index, then combining equations (1) for the stock *i* and the reference index and (2), the following relationship follows:

$$R_{t+1}^{i} - R_{t+1}^{r} = \alpha^{i} + \lambda(P_t^{i} - P_t^{r}) + \omega_{t+1}^{i}, \quad (3)$$

where $R_{t+1}^{i} = (P_{t+1}^{i} - P_t^{i})$, $\alpha^{i} = a^{i} - a^{r} + \lambda z^{i}$, and $\omega_t^{i} = \varepsilon_t^{i} - \varepsilon_t^{r} + \lambda \nu_t^{i}$. Equation 3 is in the form of a standard Dickey-Fuller (1979) test. If the error term, ω_{t+1}^{i} is serially uncorrelated, OLS method can be used to estimate this equation and t-statistics can be used to test whether λ is greater than zero. If, however, the error term is serially correlated, one should add to the independent variables lagged values of $(R_{t+1}^{i} - R_{t+1}^{r})$ to account for serial correlation.

The assumption of similar speeds of mean reversion may seem unrealistic. Moreover, since this study uses same reference index for all stocks, this assumption implies same mean reversion for all the stocks in the market. However, firstly, since all the stocks under consideration are taken from a single market, they are subject to the same impact of the market forces. Putting individual companies' differences aside, the speeds of mean reversions for different stocks may be quite similar. Still, the assumption of equal speeds of mean reversion is quite simplifying and may be not the adequate representation of the reality. Nevertheless, applying this assumption is inevitable if one wants to receive the characteristics of the stock market overall and to compare his/her findings with other findings in the field.

Positive value of λ means that accumulated difference in returns between a stock price and market index signals the investors to reallocate their money to the stocks that have been underperforming the market.

However, the unit root tests have low power against the random walk hypothesis when applied to individual stock prices (see Campbell and Perron (1991), Cochrane (1991). As shown in Balvers, Wu and Gillliland (2000), panel variant of the test increases the testing power very significantly, while univariate approach is weak even for substantially long sample. In addition, the sample size used in this study is rather small for such estimation. Hence, the non-rejection of the null hypothesis of λ =0 may not be due to non-existence of the mean reversion in the Ukrainian stock prices but due to small sample size and low testing power.

The estimating procedure is as follows:

First, univariate tests for individual stocks were performed. The estimating method is OLS. Lag length was set according to Said and Dickey (1984): $k=T^{1/3}$ or five in this case. Critical values are taken from Fuller (1976). It is likely that this test is not able to reject null of no mean-reversion due to reasons mentioned above.

As the second step, estimates of mean reversion for individual stocks are obtained through SUR estimation. SUR model is used as superior to OLS since it accounts for variables common to all stocks' equations and not included into the model. Although SUR provides stronger coefficients and smaller standard errors, the estimates are subject to a bias in this case (Levin and Lin, 1993), thus making the results not fully reliable. But since this estimation is provided mainly to give some comparative results and given the tediousness of the bias-correcting procedure, I left the results uncorrected.

This estimation is also used to show approximately how similar are the speeds of mean reversion for the stocks in our sample. This might show how good does the assumption of similar mean reversion fit our data.

Afterwards, the estimation of coefficient for overall market mean reversion follows.

As the main procedure, around which the discussion in this thesis is built, equation (3) was estimated using SUR under the assumption of equal speeds of mean reversion for all stocks in the market. Hence, I ran the model with restriction of equal values of λ for all equations.

The following statistics were used for testing the significance of λ:

$$z_{\lambda} = T\hat{\lambda} \;; \qquad\qquad t_{\lambda} = \hat{\lambda} / s.e(\hat{\lambda}) \;,$$

where T is the sample size, $s.e(\hat{\lambda})$ is the standard error of λ. However, under the null hypothesis of λ=0, and presence of unit root in the data, the estimator of λ is biased and statistics do not have normal limiting distribution. Presence of a unit root causes the estimator to converge at a faster rate with growth of number of periods used than with an increase in cross-sectional units ("super consistency" property). Additionally, if individual-specific fixed effects or correlations are present, test statistics converge not to a normal distribution, but to the non-central normal distribution, which significantly influences the size of the test (Levin and Lin, 1992).

To account for such problems in this estimation, I used Monte Carlo simulations to construct reliable confidence intervals for the point estimate of

λ. In doing so, I draw disturbances form a multivariate normal distribution with T=95[1], the number of observations, and N=36, the number of stocks, and use them to simulate the model, fixing the historical values of the right-hand side variables in the equations as well as coefficients. Then I ran the same regression as discussed above to get the simulated value of λ and the test statistics, z_λ and t_λ. This process was repeated 5,000 times to get simulated distribution of the coefficients and test statistics. Then the p-values for the statistics, z_λ and t_λ were calculated as the percentage of statistics from historic distribution that has larger (negative in this case) values.

Next I addressed the bias in $\hat{\lambda}$ issue. To do this, I constructed the median-unbiased estimate of λ as discussed in Andrews and Chen (1994). I conducted several Monte-Carlo simulations similar to the one described above, but exogenously fixing the values of λ in the model (I did simulations for λ in the range [-0.01;-0.25] with a step equal to 0.005). I received distributions of estimates under each particular value of λ from this range. Then I found values of λ which equated median, 5 and 95 percent of simulated $\hat{\lambda}s$ to the historical $\hat{\lambda}$. This gives us the median unbiased estimate of λ as well as its 90 percent confidence interval.

Finally, I estimated the mean reversion coefficient for the market using a simple OLS. This type of estimation is a test for robustness of the results.

[1] Dataset gives 97 price observations and 96 returns, however our model includes one lagged value of returns in the right-hand side, as will be discussed later. This implies T=95 for Monte Carlo.

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EMPIRICAL RESULTS

First, equation (3) was estimated univariately, stock by stock, using a simple OLS. The lag length was chosen according to Said and Dickey (1984) as $T^{1/3}$ or five in this case. The test rejected the null of no mean reversion for 2 stocks out of sample of 31. This result is not surprising given a small sample size and a small size of the test[2]. The results are presented in Table 2.

As the second step, individual mean reversion coefficients were estimated using SUR model. In general, this estimation procedure is more efficient, and that is why the results were expected to be stronger than from univariate OLS test. The lag length was chosen according to the BIC criterion. The test rejected random walk in favor of the mean reversion for 28 stocks in the sample. These results look significantly stronger compared to the first estimation. However, the coefficients for this regression are biased (Levin and Lin, 1993) due to a small sample size. As well, confidence intervals are incorrect. This makes the results of SUR estimation not fully reliable. However, since these tests were done mostly for comparison of the results as well as for some insights about price behavior in Ukrainian stock market, they were not corrected for the bias leaving this procedure for the receiving of a market estimate of the mean reversion. The results of the test are combined in Table 3.

Despite the fact that coefficients are biased, since the p-values for

[2] The size of the test means the probability of not committing type 1 error (not rejecting the null when null hypothesis is incorrect)

Table 2. Augmented Dickey-Fuller Test for Mean Reversion in Ukrainian Stock Prices

Ticker	Lambda	t
USCB	-0.0691072	-1.69
AZOT	-0.0689309	-1.39
DNAZ	-0.170385**	-3.45
STIR	-0.081398	-1.63
YASK	-0.5500672***	-4.93
SLAV	0.0183092	0.72
ZFER	-0.102688	-2.19
NFER	-0.0964861	-1.57
CEEN	-0.1618918	-2.6
DNEN	-0.2301805	-2.01
DOEN	-0.1299264	-2.11
KIEN	-0.0655482	-1.59
MSICH	-0.1081522	-2.45
KRBD	-0.0648195	-2.18
SMASH	-0.0695646	-1.39
TATM	-0.0667366	-1.49
CHEN	-0.1884558	-2.77
DNON	-0.1317099	-1.97
HAON	-0.0360121	-1.27
HMON	-0.0703467	-1.42
LVON	-0.038607	-1.43
VIEN	-0.0250202	-1.11
ZAON	-0.0525596	-1.51
ZHEN	-0.0629453	-1.75
UNAF	-0.1081112	-2.09
HRTR	-0.1016162	-1.6
NITR	-0.2089972	-2.5
AZST	-0.0650516	-1.76
DOMZ	-0.0973421	-1.73
MMKI	-0.0554211	-1.45
ZPST	-0.2362601	-2.39

Where ** and *** mean significance at 5 and 1 percent respectively most of the coefficients are rather low, it is quite probable that those coefficients will remain significant, would the correction for the bias be implemented. What is important is that difference in coefficients across the stocks is large, ranging from 0.05 for MMKI to 0.35 for NITR, which suggests that assumption about common speed of mean reversion for all stocks may be inappropriate. However, the correction for bias may have somewhat smoothed the variation.

Taking into account that univariate tests did provide some evidence in favor of the mean reversion for a number of stocks in the sample, even in spite of the weakness of the procedure, it is natural to expect that more powerful tests will confirm these findings and will present stronger evidence.

As the second part of estimation process, I searched for the estimate of the market coefficient of mean reversion. The basic testing procedure involves estimation of SUR model under the assumption of equal speed of the mean reversion for all analyzed stocks. Under the null hypothesis of $\lambda=0$, $\hat{\lambda}$ is biased and statistics do not have normal limiting distributions. Therefore, the bias was accounted for and appropriate critical values were found using Monte Carlo simulation.

The point estimate of λ was found to be -0.093. Following the procedure discussed in previous section, I calculated reliable p-values for two statistics, z_λ and t_λ. As is discussed in Balvers, Wu and Gilliland (2000), z_λ statistics has a superior test size over t_λ (lower probability of type 1 error). Anyway, both statistics imply that $\hat{\lambda}$ is significant at 5% and 1% respectively. As the structure of the two statistics show, while t_λ accounts for the standard error of the estimate, z_λ does not. This is the main reason why t_λ implies higher level of significance in this case: the standard error of $\hat{\lambda}$ is equal to 0.0077 which is very low. Other authors found evidence of slower mean reversion: Chaudhury and Wu (2004) found point estimate of λ equal -0.274, for annual return horizon while Gropp (2004) found λ equal from -0.114 to -0.178 depending on the exchange studied. The possible reasons are discussed

Table 2. Unrestricted SUR estimation of individual mean reversion coefficients

Ticker	Lambda	Std.Err	p-value
USCB	-0.0738	0.0317	0.0200
AZOT	-0.0833	0.0392	0.0330
DNAZ	-0.0839	0.0280	0.0030
STIR	-0.1029	0.0363	0.0050
YASK	-0.3219	0.0556	0.0000
SLAV	-0.0029	0.0179	0.8700
ZFER	-0.1240	0.0315	0.0000
NFER	-0.1744	0.0416	0.0000
CEEN	-0.1678	0.0500	0.0010
DNEN	-0.3425	0.0737	0.0000
DOEN	-0.1475	0.0444	0.0010
KIEN	-0.0843	0.0360	0.0190
MSICH	-0.0796	0.0337	0.0180
KRBD	-0.0573	0.0248	0.0210
SMASH	-0.1322	0.0336	0.0000
TATM	-0.0761	0.0331	0.0210
CHEN	-0.1555	0.0491	0.0020
DNON	-0.1897	0.0468	0.0000
HAON	-0.0636	0.0205	0.0020
HMON	-0.1362	0.0385	0.0000
LVON	-0.0469	0.0198	0.0180
VIEN	-0.0384	0.0179	0.0320
ZAON	-0.0547	0.0242	0.0240
ZHEN	-0.1100	0.0274	0.0000
UNAF	-0.1149	0.0411	0.0050
HRTR	-0.1059	0.0392	0.0070
NITR	-0.3508	0.0550	0.0000
AZST	-0.0906	0.0268	0.0010
DOMZ	0.0740	0.0365	0.0430
MMKI	-0.0505	0.0292	0.0840
ZPST	0.2847	0.0604	0.0000

below, after discussing the median-unbiased estimate of λ.

As the next step, the median-unbiased estimate of λ was calculated through the procedure discussed in section 3. The reason to use this estimate is that it has better properties compared to the point estimate (Phillips and Sul (2002) showed that median unbiased estimate has overall MSE performance 5 times better than the OLS estimate and twice better then the SUR estimate for small samples with high degree of cross-sectional dependence) [3].

Median-unbiased λ is found to be approximately equal to -0.1077, which is significantly higher than the point estimate. Other authors, however, usually find the median-unbiased estimate to be lower than the point estimate (see Gropp (2004), similar to Balvers, Wu and Gilliland (2000) and Chauhudri and Wu (2004)). The cause of this may be due to different sample size in the other studies. While other authors used longer time series and less cross-sectional observations, in my study the time span is significantly shorter while cross-sectional richness is higher than in other studies. As it was mentioned earlier, estimator of λ converges at a faster rate with the growth of the number of periods than with an increase in cross-sectional units. Hence, this may be the explanation for such a difference.

The 90 percent confidence interval for the median-unbiased estimate was found to be [-0.015;-0.205], which is rather wide, compared to other studies. The median unbiased coefficient implies the half-life of mean reversion equal to 6 months[4]. This number is significantly lower compared to those found previously by other studies, meaning much higher speed of mean reversion. There might be several explanations for this:

Firstly, as was mentioned in section 1, other studies concentrate mostly on cross-country analysis, performing tests on countries' indices. Although, one should also expect the difference between fundamental values of index *i* and the reference index (for example, the World index, as in

[3] MSE (mean squared error) gives a measure of an amount by which an estimator differs from the true value of the parameter. $MSE(\theta) = E((\vartheta - \theta)^2)$

[4] Half life is calculated as: $Ln(0.5) / Ln(1 - |\hat{\lambda}|)$

Balvers, Wu and Gilliland (2000)) to be stationary in the long run, it will take much more time to reach this long run, compared to the case of individual company stock and PFTS index. Hence, if the time needed for returns in country's index to converge to those of the world index is longer, it is natural that the speed of mean reversion should be smaller.

Secondly, faster mean reversion may be due to appearance of new rivals in the market which deteriorates financial performance of the companies as well as their growth prospects. So, prices for stocks for these companies may show sharp jumps and falls, generating high speed of mean reversion.

Thirdly, since Ukraine is an emerging capital market, it naturally experiences overall high price volatility. This may have created the price pattern that is perceived as high speed mean-reverting returns behavior. Hence, it may be true that high coefficient received in this study has little to do with theoretical explanation, but just with natural volatility in prices.

To compare the SUR results with some other models, I have also conducted a panel OLS estimation of equation (3) to receive market mean reversion estimate. I chose the lag length similar to the one used for univariate OLS estimation (L=5). Although the OLS approach is not efficient in this case, as well as it provides biased estimate of λ, it also suggests that the null of no mean reversion may be rejected. Still, it significantly underestimates the magnitude of the coefficient implying weaker mean reversion.

Results of the last two estimation procedures are combined in the table 4.

Table 4. Panel Estimation Results of Ukrainian Stock Market Mean Reversion Coefficient

SUR		OLS	
point $\hat{\lambda}$	-0.930957	$\hat{\lambda}$	-0.006553
z_{λ}	-8.8441		
p-value	0.0338	p-value	0.019
t_{λ}	-12.0689		
p-value	0.000		
median-unbiased $\hat{\lambda}$	-0.1077		
90% confidence interval	[-0.015;-0.211]		
implied half-life	6 months		

Chapter 6

CONCLUSIONS

This thesis was aimed at checking whether Ukrainian stock market is experiencing mean reversion in stock prices. To achieve this goal, several estimating methods were used. At the first step, ADF test was applied to equation (3) stock by stock. This test has low power to reject null of mean reversion and was able only to confirm mean reversion hypothesis for two stocks out of 31.

At the next step, unrestricted SUR model was used. It is more powerful and suggested stronger evidence in favor of mean reversion across stocks in the sample. The estimators implied by this procedure are subject to small sample bias and might not be reliable. Still, most of the p-values are quite low, which might suggest that $\hat{\lambda}$'s should remain significant if the bias correcting procedure was implemented.

To estimate the overall market mean reversion coefficient, I used restricted SUR model, whether the restriction in that all $\hat{\lambda}$'s are constrained to be equal. The estimates from this model are also subject to small sample bias. This bias was accounted for through constructing reliable confidence intervals with Monte Carlo simulations and median-unbiased estimate of λ which has superior MSE performance over the point estimate. Median unbiased $\hat{\lambda}$ was found to be equal to -0.1077, thus implying the half-life of mean reversion of 6 months. This implies much faster mean reversion than found in other studies. There might be several reasons for such result. First is that I studied mean reversion in the market of one country, while comparable studies were mostly concentrated on cross-country investigations. Second is that Ukrainian market is young and companies' performance might not be smooth over time, thus creating jumps and falls in stock price that is perceived as higher speed of mean reversion. Third is that Ukrainian stock market is subject to natural price volatility as a young one. This price volatility that has nothing to do with financial theory that tries explaining mean reversion, however, is able to form high-speed mean reverting stock price behavior.

OLS regression also suggests that mean reversion is present in Ukrainian market, but it estimates that speed of mean reversion is lower than implied by SUR technique.

To add things up, this study found strong evidence in favor of mean reversion in Ukrainian stock market. There may be a number of reasons for such results. However, it is hard to distinguish which one is the main cause for mean reversion. There is a big chance that big proportion of what is perceived as mean reversion is due to high natural stock price volatility.

C h a p t e r 7

CONCLUDING REMARKS

This section discusses the limitations of the approach used in this thesis and the future steps to be implemented in the field of study.

There are several drawbacks of this study:

First, it is assumed that stocks in the market as well as the reference index have same speed of mean reversion to their fundamental values. As we saw from the unrestricted SUR estimation, discussed in Chapter 4, the estimated coefficients for mean reversion are rather different across the stocks. This may have caused distortion of the results.

Second, the dataset contained very little time observations, which may cause general non-representativeness of the results received. There are too little stocks that were actually traded before 2000, so the data lacks price variability. With time pass, more long and reliable data series will be available so that more reliable estimates may be received.

Third, since the market possesses high natural price volatility, it is impossible to distinguish between mean reversion and random price movements that simulate mean reverting processes. To make the results more clear, it would be very helpful to filter out the portion of random movements of stock prices. However, until now there is no particular method developed for this.

Also, it is important to find out whether the results of the studies that used different return horizons may be directly compared. Gropp (2004) reports results for different return horizons and the speed of mean reversion he receives is proportional to the return horizon (he found λ's equal 0.136, 0.275 and 0.387 for NYSE index and 0.114, 0.230, 0.346 for index that he constructed himself, for 1, 2 and 3 years return horizon respectively). However, there are no statistical evidence that speed of mean reversion increases proportionately as the return horizon increases. Thus, while I received very high speed of mean reversion, compared to other studies, this may be due to non-comparability of the return horizons used.

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