# Is the Czech Capital Market Weak Form Efficient?

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**Abstract.** This study deals with the short-term prediction of share prices in the Czech stock market. A stochastic model based on the analysis of simple Markov chains was used for the short-term prediction of share prices. Buy and sell signals were generated on the basis of this prediction. The prediction model is considered to be successful if trading with the use of this model outperforms the market; in other words, it yields higher returns than the passive "Buy and Hold" investment strategy. The study was performed using daily data from the Czech stock market for the 14-year period, from the beginning of 2006 until the end of 2019, i.e., approximately 3,500 trading days. The study results have shown that stocks that are traded in higher turnovers outperformed the Buy and Hold strategy over the period under review. Conversely, stocks that are traded daily in low turnovers do not outperform the Buy and Hold strategy. Thus, it seems that stocks traded in large turnovers do not behave efficiently. Stocks traded in small turnovers tend to behave as weak form efficient.

**Keywords:** Markov chain analysis, Efficient Market Hypothesis, share price prediction

**JEL Classification:** C22, G17
**AMS Classification:** 90C40, 91G15

## 1 Introduction

This empirical study is based on the long-term research and deals with the short-term prediction of share prices in the Czech stock market. The study works on the assumption that the share price on the stock exchange is formed in a continuous manner as a result of the mutual interaction between demand and supply. The supply and demand are generated by different types of traders (long-term investors and speculators). These traders have different time frames, use different methods for predicting the future development of share prices, evaluate market information in a different way, have different risk aversion and different amounts of capital at their disposal. The bid or demand for a given stock may be created not only because of a market participant's subjective view that the stock is undervalued or overvalued, but also for many other reasons, such as the need to raise money, to modify an investment strategy, to force purchases or sales in trades with borrowed assets, to buy stocks back by the joint stock company itself, etc. The simultaneous interaction of these numerous factors results in the fact that the share price can be regarded as a random variable that fluctuates around its fair price.

Another premise is that the share price moves in short-term trends and during the course of such trends, the share price accumulates a certain profit or loss relative to the price at the beginning of the trend. The greater the change is, the greater is the probability of a change in the trend. The key question is how high the accumulated loss or profit must be for the trend to change with a sufficiently high probability. A simple Markov chains analysis (MCA) is used to model the probability of a trend change.

The predictability of stock markets is in direct conflict with the Efficient Market Hypothesis (EMH). The basic ideas of the EMH were formulated by Fama [1]. According to the EMH, stock prices are unpredictable and therefore efficient. It implies that the market responds immediately to any new information. This information cannot be predicted, it comes to the market randomly, and hence the change of the exchange rate is also random, and the exchange rates take the so-called "random walks". Above-average profits cannot be made in efficient markets and other approaches are ineffective according to this theory. Roberts [5] then distinguishes three forms of efficiency: a weak form, a semi-strong form, and a strong form of efficiency. A weak form EMH means that the rate includes all the information from historical data, which means that the historical data cannot be used to predict market developments. The semi-strong form EMH is a state in which the price incorporates both historical data and all publicly available information, and also the methods of fundamental analysis fail in this form. The strong form

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EMH is when even non-public (insider) information is included in the price. Thus, even insider information is worthless in a strong form efficient market and does not yield above-average returns.

Initially, the EMH was widely accepted by academia. Later, however, studies questioning the EMH were published. For example, Shiller [6] points out the higher volatility of share prices than that which can be explained by dividend volatility. Haugen [3] believes that markets overreact to unexpected information and calls it over reactive capital market. The Czech stock market was also examined. A weak form of efficiency is predominantly investigated in the Czech stock market. The work of Filáček et al. [2] tends to the view that the Czech stock market behaves inefficiently. On the contrary, Hájek [4] is more inclined to think that the stock market is weak form efficient, and thus the methods of technical analysis do not yield above-average returns.

Thus, this study aims to indicate whether the short-term prediction of share prices using the MC analysis is successful and therefore the Czech stock market is weakly efficient. It will be considered successful if the trading based on this prediction outperforms the passive Buy and Hold strategy.

# 2 Data

The company called Patria Direct is the data source. The study was conducted using shares traded in the prestigious market segments of the Prague Stock Exchange over a fourteen-year period, from 2nd January 2006 to 2nd January 2020, i.e., for approximately 3,500 trading days. Throughout that period, only the following shares were traded in those segments: ČEZ (CEZ), Komerční banka (KB), O2CR (O2), Philip Morris ČR (PM). The study also included the shares of Pegas (PG), which were listed for trading only at the end of 2006. The shares have been included since the beginning of 2007. The daily opening and closing prices, daily trading volumes and dividends paid are available for all the shares mentioned above. KB shares were split during the stated period. In the case of O2, the majority owner of the company split into two entities. Those events have been dealt with as follows.

The KB share split took place on 12th May 2016 in the ratio of 5:1 (the shareholder received five new shares for one existing share). To maintain continuity, the dividends and share price before 12th May 2016 were divided by five. In the case of O2, the change of the majority owner was announced in November 2013 and the free float was reduced to approximately 10% following the subsequent mandatory takeover bid. Then, on 1st June 2015, O2 split into two companies, O2 and CETIN. The closing price of the O2 share on the day before the split was CZK 177.6. The shareholder received one new O2 share and one CETIN share for one original O2 share. On the first day after the split, the price of the CETIN share was CZK 133.5 and the price of the O2 share was CZK 69.2. At the time of the demerger, it was already known in the market that the majority shareholder had planned to squeeze out minority shareholders of CETIN shares and the shares would later be withdrawn from the market. The data continuity is maintained in the following way. The CETIN shares are sold at the price of CZK 133.5 on the very first day after the split and the proceeds are then treated in the same way as a dividend, i.e., they are used to buy O2 shares in accordance with the business strategy.

Figure 1 shows the price development of shares with dividend reinvestment after tax. Lines on Figure 1 are ordered according to the value of capital at the end of the period under review. This means that the lowest value of capital (1.34) is represented by the CEZ shares and the highest (3.79) by the O2 shares.

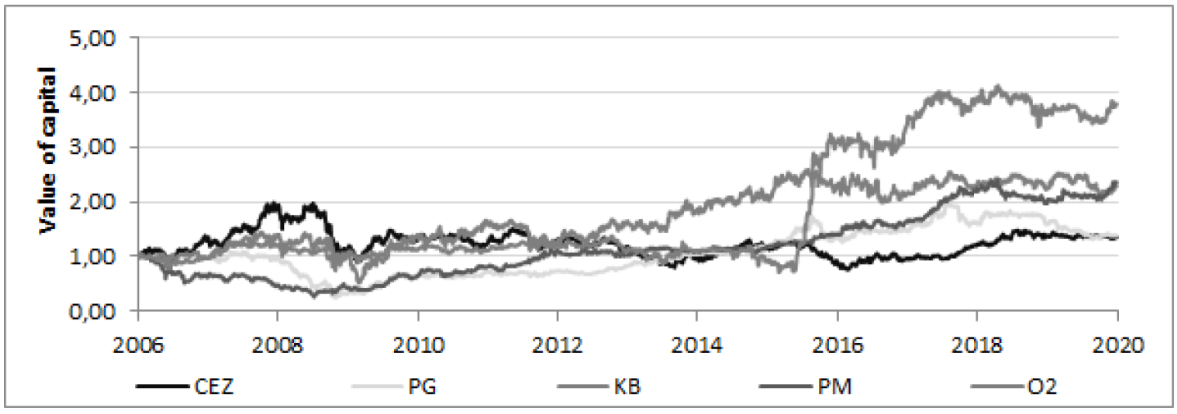


**Figure 1** Value of capital

The steep increase in the appreciation of the O2 shares in the second half of 2015 is worth noticing in Figure 1. The increase was caused by ending the uncertainty that had been evident in the market since the information about

the change of majority ownership leaked to the market. Figure 2 shows the 20-day moving averages of daily trading turnovers. It is evident that the PM and PG shares have lower turnovers by an order of magnitude than the KB and CEZ shares. The O2 shares were initially traded at similar turnovers to the KB shares, but after changing majority ownership and reducing free float, they are traded at similar turnovers to PM and PG.

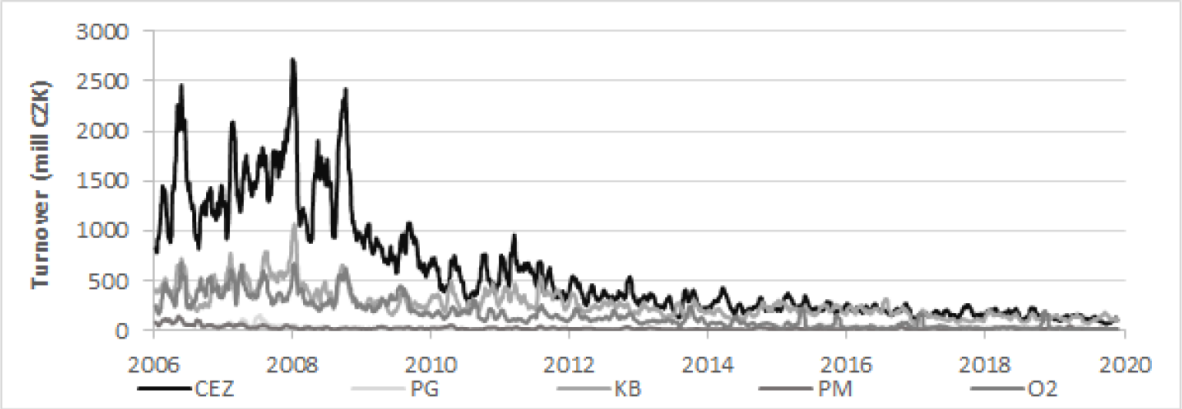


**Figure 2** Turnover (millions CZK)

# 3 Methodology

As was already mentioned in the introduction, this study is based on the long-term research. Therefore, the methodology may overlap with that published in other papers by the team of authors.

To transform the share prices into a suitable MC, we use the method described in Svoboda and Gangur [7] in this study. The state space with eight states is used here. It is defined by multiples of the moving standard deviation and the cumulative change in the share price.

## 3.1 State space

The cumulative change in the share price is denoted by $Y_t$ ($Y_t$ expressed as a percentage is $y_t$). $Y_t$ is interpreted as short basis indices of daily closing prices, where the basic period is the day of the trend change, i.e., the transition from a decline to an increase or vice versa. The duration of the trend is determined by the number of consecutive rising or falling closing prices. The calculation of $Y_t$, the cumulative price change, is formally described by (1)

$$Y_t = Y_{t-1}\frac{P_t}{P_{t-1}} \text{ if } \left(\ldots \le P_{t-2} \le P_{t-1} \le P_t\right) \text{ or } \left(\ldots \ge P_{t-2} \ge P_{t-1} \ge P_t\right) \text{ else } Y_t = \frac{P_t}{P_{t-1}}, \tag{1}$$

where $P_t$ is the closing daily price at time $t$, $P_{t-1}$ is the closing daily price at time $t$-1 a $P_{t-2}$ is the closing daily price at time $t$-2. The moving standard deviation of length $n$ is denoted by $s_{t,n}$ and is calculated according to formula (2)

$$s_{t,n} = \sqrt{\frac{1}{n}\sum_{i=0}^{n-1}\left(x_{t-i} - \bar{x}_{t,n}\right)^2}, \tag{2}$$

where $x_{t-i}$ is the daily percentage change in the share price at time $t$-$i$ and $\bar{x}_{t,n}$ is moving average length $n$ at time $t$. The general model of state space is defined as follows:

$D_4$: $y_t < -3\Delta_t$ $\quad$ $G_1$: $0 \le y_t < 1\Delta_t$
$D_3$: $-3\Delta_t \le y_t < -2\Delta_t$ $\quad$ $G_2$: $1\Delta_t \le y_t < 2\Delta_t$
$D_2$: $-2\Delta_t \le y_t < -1\Delta_t$ $\quad$ $G_3$: $2\Delta_t \le y_t < 3\Delta_t$
$D_1$: $-1\Delta_t \le y_t < 0$ $\quad$ $G_4$: $3\Delta_t \le y_t$ ,

where $\Delta_t = k \cdot s_{t,n}$ $k$ is the multiple of the moving standard deviation. Thus, the state space model is unambiguously determined by parameters $k$ and $n$. The states where the share price falls are denoted by $D_i$. $D_1$ is the state with the minimum price decline and, conversely, $D_4$ is the state with the maximum price decline. The states where the share price increases are denoted by $G_i$. $G_1$ is the state with the minimum price increase and, conversely, $G_4$ is the state with the maximum price increase.

### 3.2 Trading rules

Buy signals are generated when the share price sufficiently falls and sell signals are generated when the share price sufficiently rises. $D_3$ and $D_4$ are considered to be the states with a sufficient decline, these states generate buy signals and sell signals are generated by the $G_3$ and $G_4$ states. Combining the buy and sell states results in 4 trading strategies: $D_3$ - $G_3$, $D_3$ - $G_4$, $D_4$ - $G_3$ and $D_4$ - $G_4$. The $D_3$ - $G_3$ strategy means that the $D_3$ state generates buy orders (if we do not hold the shares anymore) and the $G_3$ state generates sell orders (if we hold the shares). In other words, we divide the capital we want to invest in a particular stock into quarters and we trade with each quarter using one of the strategies. Trading is always carried out by the following rules:

- one deal (transaction) is understood as the purchase and subsequent sale of a share,
- two consecutive purchases are not possible,
- if a buy or sell signal is generated on a day, the deal is realized at the next day's opening price,
- the entire capital is always invested, so in theory even parts of shares can be bought,
- no transaction fees are taken into account,
- dividends and other income (hereinafter referred to as dividends), in the event that we are entitled to them, are reinvested after tax.

The invested capital value is calculated according to the following formula (3)

$$C_n = C_0 \prod_{i=1}^{n} \frac{S_i + d_i}{B_i}, \tag{3}$$

where $C_0 = 0.2500$ is the initial value of capital, $C_n$ is the value of capital after the $n$-th transaction, $S_i$ is the sales price in the $i$-th transaction, $d_i$ represents after-tax dividends if there was a relevant date during the $i$-th transaction, $B_i$ is the purchase price in the $i$-th transaction. The total value of capital $C$ is given by the sum of the capital of individual trading strategies see formula (4).

$$C = C_{D_3-G_3} + C_{D_3-G_4} + C_{D_4-G_3} + C_{D_4-G_4}, \tag{4}$$

where $C_{Di\text{-}Gj}$ is the achieved appreciation of a trading strategy in which a buy signal generates the $D_i$ state and a sell signal generates the $G_j$ state.

## 4 Results and discussion

In total, 80 state space models were calculated for the observed stocks. The $k$ parameter gradually took values from 0.5 to 2.0 in increments of 0.1. Five lengths of moving standard deviation were tested for each value of the $k$ parameter, with the $n$ parameter taking values from 10 to 30 in increments of 5. The best results were obtained when the $n$ parameter was equal to 20 or 25 in combination with the k parameter values of 1.1 and 1.2. The resulting returns for individual shares for parameters $k = 1.2$, $n = 20$ and the passive Buy and Hold strategy are presented in Table 1. The table shows the results for the five-year sliding windows as well as the result for the entire 14-year period. The length of five years for the sliding windows was chosen because the minimum recommended investment periods for investing in stocks is five years. The values in bold are those when the active trading based on the MC prediction outperformed the B&H.

| Years | CEZ | | PG | | KB | | PM | | O2 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | C | B&H | C | B&H | C | B&H | C | B&H | V C | B&H |
| 2015 - 19 | **31.1%** | 15.3% | -11.1% | 16.3% | **26.4%** | 7.3% | 47.3% | 98.8% | 20.2% | 301.2% |
| 2014 - 18 | **49.4%** | 41.3% | 16.6% | 51.9% | **56.1%** | 20.0% | 35.8% | 82.2% | -4.1% | 227.0% |
| 2013 - 17 | **50.3%** | 2.1% | 24.4% | 91.3% | **80.8%** | 41.1% | 48.9% | 118.4% | -2.3% | 238.8% |
| 2012 - 16 | **39.2%** | -25.8% | 38.7% | 97.5% | **119.6%** | 65.8% | 37.9% | 48.1% | 2.1% | 182.1% |
| 2011 - 15 | **20.1%** | -28.5% | 32.6% | 85.7% | **95.5%** | 39.3% | 62.2% | 71.9% | 9.9% | 178.8% |
| 2010 - 14 | **46.8%** | -12.0% | 47.9% | 82.5% | **133.7%** | 54.7% | 52.0% | 79.5% | **1.4%** | -17.5% |
| 2009 - 13 | **35.0%** | -15.2% | 55.0% | 209.1% | **129.4%** | 83.1% | 48.0% | 149.8% | **32.1%** | 7.7% |
| 2008 - 12 | **9.6%** | -38.3% | -23.6% | -15.6% | **97.1%** | 18.5% | 16.7% | 111.2% | **27.0%** | -4.8% |
| 2007 - 11 | **41.6%** | -3.7% | **-17.9%** | -25.9% | **70.5%** | 34.1% | 11.4% | 75.6% | **28.7%** | 23.2% |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 2006 - 10 | **69.1%** | 26.1% | | | **95.8%** | 61.5% | -38.4% | -18.1% | **26.8%** | 12.0% |
| 2006 - 19 | **188.2%** | 34.8% | -5.9% | 37.9% | **337.4%** | 128.3% | 35.9% | 136.2% | 36.1% | 279.2% |

**Table 1** Yield

Table 1 clearly shows that in the case of KB and CEZ shares, the active trading based on the MC prediction outperformed the passive B&H strategy for each five-year period. Conversely, in the case of PG and PM shares, the trading based on the MC prediction outperformed the B&H strategy in only one five-year period. This exception is the very first period in the case of PG shares. In the case of O2 shares, the MC prediction was successful until 2014. After 2015, it was no longer successful. If we examine the daily trading turnovers, the idea that the success of the prediction model is related to the trading turnover comes into consideration. The KB and CEZ shares have higher-order trading turnovers than the PM and PG shares. As already mentioned in the case of PG shares, the passive strategy was outperformed only in the first five-year period. The fact that in 2007 and 2008 the daily trading turnover of PG shares was in the higher-order tens of millions is worth noticing, and since 2009 the trading turnovers have only been in units of millions of CZK. It was especially in those first two years when the active trading based on the MC prediction significantly outperformed the passive strategy of B&H. The active trading lost this "edge" in the following years. However, by that time the shares were traded in much lower turnovers. Until 2014, the O2 shares were traded in similar turnovers as the KB shares, and the trading outperformed the B&H strategy in line with the MC prediction. After the change of majority owner and the mandatory share buyback offer, which many shareholders took advantage of, the free float decreased. The trading turnovers dropped substantially. The O2 shares began to be traded in the similar turnovers as the PM and PG shares and the prediction model ceased to be successful. On the other hand, it must be mentioned that in 2015 the period of uncertainty about the new majority shareholder's plans ended and the share price rose sharply. All sliding windows containing the year of 2015 are distorted by this one-off event.

Figure 3 shows the trend in the ratio of the appreciation achieved by the active trading to the appreciation by the B&H strategy. The drop in the ratio for the O2 shares in the second half of 2015 should be noted. The steep peaks in 2008 are caused by greater slumps in prices to some extent, with the capital value in the B&H strategy reacting immediately to price changes, but the capital value in the active trading strategy reacting with a time lag. The value of capital is not recalculated every day, but only at the moment of selling the shares, as shown in formula (3).

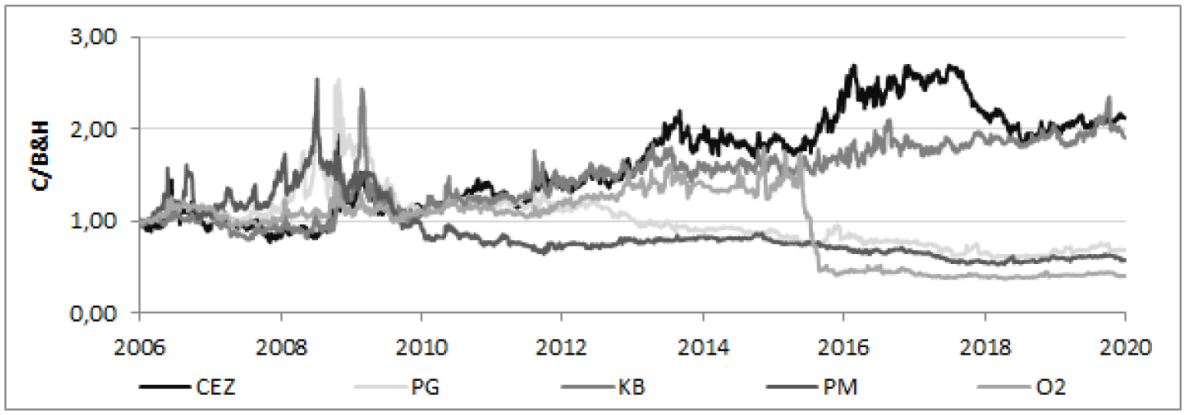


**Figure 3** Ratio C/B&H

# 5 Conclusion

The answer to the question whether the Czech stock market is weakly efficient is not definite. Some shares have managed to outperform the passive Buy and Hold strategy throughout the 14-year period under review, while others have not. In the case of shares that are traded in higher-order turnovers, the trading based on the prediction model was successful and outperformed the passive B&H strategy in each five-year period. Conversely, in the case of shares traded in low turnovers the B&H strategy was outperformed in only one five-year period. This, of course, does not necessarily mean that these shares behave efficiently. Only the prediction model did not work as it should.

This ambiguity is in accordance with the already mentioned works of Filáček et al. [2] or Hájek [4]. The work of Filáček et al. [2] inclined to the opinion that the Czech stock market is behaving inefficiently. On the contrary, Hájek [4] pointed out that the Czech stock market was approaching a weak form of efficiency. The efficiency of

the Czech stock market was also examined by other authors. Some have concluded that the Czech stock market is weakly efficient, some considered the Czech stock market to be inefficient. However, these studies have related to the Czech stock market development at the end of the 1990s and the beginning of the new millennium.

According to the authors of this study, a partial explanation for this situation could be short-term traders - speculators. These speculators prefer highly liquid shares that are traded in large turnovers. They often trade margin (financial leverage) and make profits with relatively small price changes. If the share price rises, they start selling their shares, thereby causing a trend reversal. They mainly use technical analysis (TA) tools to forecast the share price. As they use similar tools, they act in concert and thus create a self-fulfilling prophecy. Shares that are traded in small turnovers in the market are bought by long-term investors. These investors pursue long-term profits. They use fundamental analysis tools; they do not use TA tools. Since these traders do not use TA, the TA tools do not work for these shares. However, this hypothesis would need to be studied for a longer period of time.

The authors will continue their research. They will certainly try to confirm these results using longer time series. The only problem is that the Czech stock market is small, and some shares are traded for a short period of time. Nowadays, the O2 and PG shares are no longer traded on the stock market. Applying these methods to foreign stock markets, both developed and emerging ones, will be the next research direction.

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