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BAKALÁŘSKÁ PRÁCE

COMPARISON OF CZECH AND DUTCH EQUITY MARKET

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Prohlášení

Prohlašuji, že jsem bakalářskou práci vypracoval samostatně a použil jsem jen uvedené prameny a literaturu.

V Praze dne ……

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I. Introduction

On the May 01 2004 the Czech Republic became on of the 25 member states of the EU. Although this event has been anticipated for several years, many doubts concerning the ability of the Czech economy to keep pace with the developed countries of the European Union have arisen recently. The doubts are quite understandable. The historical heritage of planned economy brought several disadvantages. Let's point out at least the most important: imperfect markets, absence of the private ownership, lack of sources of objective information, absence of price, etc. It is questionable how the country in the middle of the transition process, will be able to compete and converge to the developed members of the EU.

In this thesis, one of the most developed European countries – the Netherlands – was chosen as a benchmark for a comparison. The Netherlands is considered as a country, where the capitalism was born. The economy has been traditionally trade oriented, since 16th century the sea transport was one of the main sources of the economic growth. Along with the development and growth of the trade, industry and economy as a whole, the problem of flourishing companies financing emerged. The need for capital to finance new firms was a major spontaneous force to create financial markets. It was in Amsterdam, where in the 1631 was the first modern stock exchange founded. The Dutch financial market had hundreds of years to transform into the market, as we know it today. On contrary, the financial markets in the Czech Republic are still young and miss the long centuries of slow development. The financial market was founded in the transitional process as a piece of the "shock therapy" strategy. Formation of the private ownership and consequently creation of the financial market were the main goals of the transformers. As we can assess ex post, the chosen fast way of the privatization was not the luckiest one. The market was created too fast and without a proper change of the institutional framework. Functionality and effectiveness of the market at least in the beginning was very weak. It would be probably naive to think that the Czech financial market shares the similar characteristics as the Dutch one.

We will go into more details about the differences between the equity markets in the two countries to examine, whether the Czech financial market can be considered as a

developed one. In part II, we will try to compare the main characteristics of the equity markets in both countries. In part III will compare the levels of efficiency of the markets and in part IV we will come to the conclusion.

In the first section of part II, we will start with a brief description of the creation history of the Czech financial market and operation of the Prague and the Amsterdam stock exchange. The historical insight of the main features and differences between the stock exchanges will bring us to a discussion, how can the different institutional framework impact the functioning of financial markets. We will explain the problems that are stemming from the asymmetric information, namely moral hazard and adverse selection, lack of legislation and enforcement of law. We will continue with the comparison of the differences in the transaction costs and liquidity of the stock market. Transaction costs and liquidity provides us with a deeper insight about the operation of the market. The key issue of part II will be the discussion about the linkages between the level of development of the economy and the functioning of stock markets.

Stock markets have been a popular topic between economists especially in the last decades. The performance of the stock markets has been scanned and examined cautiously not only by investors and speculators. The performance of the stocks, which are in fact ownership rights of firms, should be tightly connected with the economic performance of the real economy. In line with the Tobin q, consumption cycles and other different theories,[1] the stocks should be used as a forecast of future growth of the GDP or other economic indicators. It is not the aim to explain these linkages precisely, but we will focus on the conditions on which these connections would perfectly exist. Before we can use the information from the stock market as a tool for prediction, we have to guarantee that the markets are efficient.

In 1970 Fama came with the theory, which is commonly known as Efficient Market hypothesis. If the markets are efficient the prices reflect only relevant information and none can earn abnormal profits. On such a market the stock prices would have a significant power to forecast and evaluate the true economy. In part III we will first theoretically discuss the concept of market efficiency. Than we will try to examine

[1] The topic of linkages between the stock movements and growth is not due to limitations of this thesis discussed in more detail. For more information see Mishkin (2002)

whether the stock markets in the Czech Republic and the Netherlands based on the past data of stock indices, are efficient. The main problem for determining the market efficiency is the limited amount of information. Because of this reason, we will test only the simplest form of market efficiency on assumption of specific circumstances: the random walk model. Random walk theory of the stock movements states that because the fact that the prices change in an unpredictable way, the stock returns follow random walk. It is impossible to beat market in the long run - investors can not earn abnormal profits only with past information. Trading in stock is only a game, where the chance plays the most important role. The empirical test of random walk and the examination of the characteristics of the stock indices will be our basic argument for or against the market efficiency of the two markets under study.

In part IV we will come to the conclusion of the thesis. It is our task to make a summary and answer two main questions. The first: "What were the main differences between the two countries?" and the second: "Is the Czech stock market more efficient than the Dutch stock market?"

II. Equity markets in Czech Republic and the Netherlands

II.1 Introduction

Financial markets are markets on which the financial instruments are traded. The main purpose of the financial market is to allocate resources between the deficit subjects (mainly firms) and surplus subjects (households, governments, etc.) Musílek (2003). The system of financial markets enables to transfer the resources via creating and trading in the financial instruments. Based on the type of traded financial instrument we recognize three types of markets: Stock market, Bond market and financial derivative market. In other words, the markets are sorted by the different means of providing the capital to the firms.

Firms have basically two options to finance their activities: Debt and Equity. The essential difference between debt and equity claims is that the holder of debt claim is entitled to receive cashflows, which are determined prior the purchase, at specified time in future. Equity claim, on the other hand, does not guarantee any certain amount of cashflows. The holder is directly interested in the activities of the firm, because his earnings directly depend on the firm performance. Equity of private firm can be in the form of owner's equity or venture capital. The most common equity claims for a publicly traded company are stocks. While the equity of private firms cannot be traded without substantial effort of finding counterparty, stocks can change the holder often and generally without problems. The advantage of stock is that they are generally denominated in small figures. Furthermore, the character of stock contract enables easy transfer of property rights from one owner to the other. Trading in equity of private firms is constrained by costly legal procedures. Therefore, trading in stock is more frequent and ensures better flow of information.

The other criterion of sorting the financial markets depends on the group of actors, who are involved in trading: primary and secondary market. The main purpose of the primary market is to transfer resources to the firm that issues the financial instrument, the stock in particular. The access on the primary market is limited or even restricted for

most of the firms and investors. Firms have to meet the legislative regulations concerning liquidity, size and solvency, etc., before they are enabled to go public. The legislative restriction, substantial transaction and barriers to enter the market make new issuances costly and difficult. If the criteria are met, Initial Public Offering (IPO) makes the stock available for trading on primary market for the first time. The main purpose of the primary market is to evaluate the present value of the firm's cashflows and consequently adjust the stock price. Because the assessment of the correct price is not an easy task, the range of investors, who have access to the primary markets is limited to the biggest investors, the main investors on the primary markets are the Central Banks, Investment and Universal Banks.

After the price is settled on the primary market, the stock can be traded on secondary markets: Stock exchanges and Over-the-counter (OTC) markets. Stock exchanges are generally the most liquid stock markets and the fastest source of information. Even though only a part of all stocks is traded on the stock exchanges. The performance of stocks on stocks exchanges serves as a benchmark for aggregate stock market. In this thesis the focus will be stressed on the stock exchanges, because they are the most transparent markets and guarantee the fastest source of information. Because we try to approximate the equity market only with the stock exchanges, we have to face two limitations. Firstly, the stock is not the only equity claim. Secondly, the stock exchange is only an imperfect representative of the whole stock market.

In the world with perfect markets stocks, that are traded on different markets or are not traded at all, should have the equal price. Real world is not perfect, thus, the prices of the same stocks do not have to be equal on each market. Stockholder should be able to sell or buy the stock for one single price independently on the location of the market and indifferently on the group of investors, who trade on the market. However, real markets are far from perfect; the price of one particular stock can differ substantially across the markets. The main reason can be founded in the in substantial transaction costs, barriers to enter, asymmetric information and several type of risks. These factors are the reasons, why is the arbitrage on the market limited[2] and the prices differ.

[2] Limits to arbitrage are quite an interesting topic of the behavior finance. Traditional finance argues, that there can be only one price of one financial instrument or its perfect substitute. However, this is in contrast

In the following section we will start with the brief history of the Czech financial market formation. We will continue with the examination of basic characteristics and history of the Czech and Dutch stock exchanges. In section II.3 we will discuss the limitations for equity financing. In particular, we will focus on the transaction costs and the problems stemming from asymmetric information: the Moral Hazard and Adverse selection. In section II.4 the concept of liquidity will be introduced. We will end up the part II with the summary of the main differences between the Dutch and Czech stock markets. Which differences are the most significant?

II.2 Financial markets in Czech Republic and the Netherlands

II.2.1 Creation of the Czech financial market

In the initial years of transformation, the Czech Republic suffered from the absence of a financial market. The financial market was created during the process of public property privatization. Most of the companies were transferred, virtually for no charge[3], into the hands of private owners during the process of Coupon Privatization. The creation of the financial market was very fast and therefore accompanied with several problems.

Firstly, the financial market served only as a trading place of issued stock, where the price is adjusted via the supply and demand. It did not fulfill the primary function of the financial markets: to allocate the resources to the firms. The capital of the owner – stockholders- did not flow in to the company. The stocks were used mainly as a tool of the company governance or as a speculation instrument.

Secondly, the market did not play the role of informational price former. The citizens, who obtained the stocks, had not sufficient amount of experience and knowledge with trading in stocks. Furthermore, the Czech Republic lacked the functioning informational network, the information was distributed asymmetrically and most of the

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with the empirical evidence. The explanation can be found in the various aspects, why is the arbitrage limited on real markets. See Shleifer (2000) and Barberis (2000) for more details.

important information was known only to small group of investors and former managers of enterprises. The common citizens had not enough information and knowledge to be taken as a group of rational investors[4]. The irrational investors can not properly trade on the market and help to evaluate the real price of the equity[5]. Thus, the prices of the stock could not at least in the beginning phase of transformation reveal the fundamental value.

Finally, the institutional background[6] of the economy was not prepared for the fast transition to the market economy. Laws and regulations were weak and allowed to the privileged group of investors and managers to abuse their power and gain from the informational advantage[7]. The weak enforcement of the law, namely the slow work of the courts and publicly accepted and commonly exercised corruption was another pitfall of the transformation. The background of the financial market allowed gaining the dominant power on the equity market to small group of investors, which was in strong contrast with the starting position of few million of investors[8].

The financial market which was formed in the Czech Republic did not bear the properties of the developed markets. Insufficient legislative framework, lack of information and absence of the allocation function were only the major weakness of the system. The situation start to change in the years 1997-1998 when the new listing

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[3] In the process of coupon privatization the citizens paid only for the "book of coupons", which was the fee to cover the administrative and operational costs of the privatization. Mlčoch (1996) name the coupon privatization as the gratuitous transfer of actives from the state to citizens.

[4] The rationality of investors, who are trading on the market is important assumption of the efficiency and will be discussed in detail in the part III.

[5] The heritage of the planned economy was also the absence of the real price. One of the purposes of the market is to asses the appropriate price of the stock. In the beginning of the coupon privatization the prices of the stock were set rather arbitrarily and the result of adjusting the price was anticipated. The process of searching for market equilibrium should bring the prices to the equilibrium real price. In the case of Czech privatization we face the obstacles of imperfect markets and asymmetric information to make a rational calculation.

[6] The problem of need of institutional change is described in detail in Mlčoch. Economy which is used to the different type of laws, enforcement of the law, norms of behavior, all the different formal and informal institutions under the central planned economy, can not simply transform to the market economy in the period of few years.

[7] The firms and bank did not have the legislative obligation to reveal all the information to the public. What is even more surprising is the fact, that the managers of the banks and mutual funds used their informational advantage as an argument in the advertising campaign in the Coupon Privatization to gather the stocks from small uninformed and inexperienced investors. Informational asymmetry, which is punished in the developed countries, was in Czech Republic an allowed action commonly used for profit earning.

[8] More than 6 million people took part in the first wave of the Coupon Privatization in the Czechoslovakia.

requirements and the better bankruptcy law enabled to clean the market of the bad companies.

II.2.1 Prague stock exchange

The privatization in the Czech Republic caused a development of the secondary market. The secondary market has two main segments: the official market: the Prague Stock Exchange and OTC markets, which are represented by the RMS, UNIVYC a SCP.

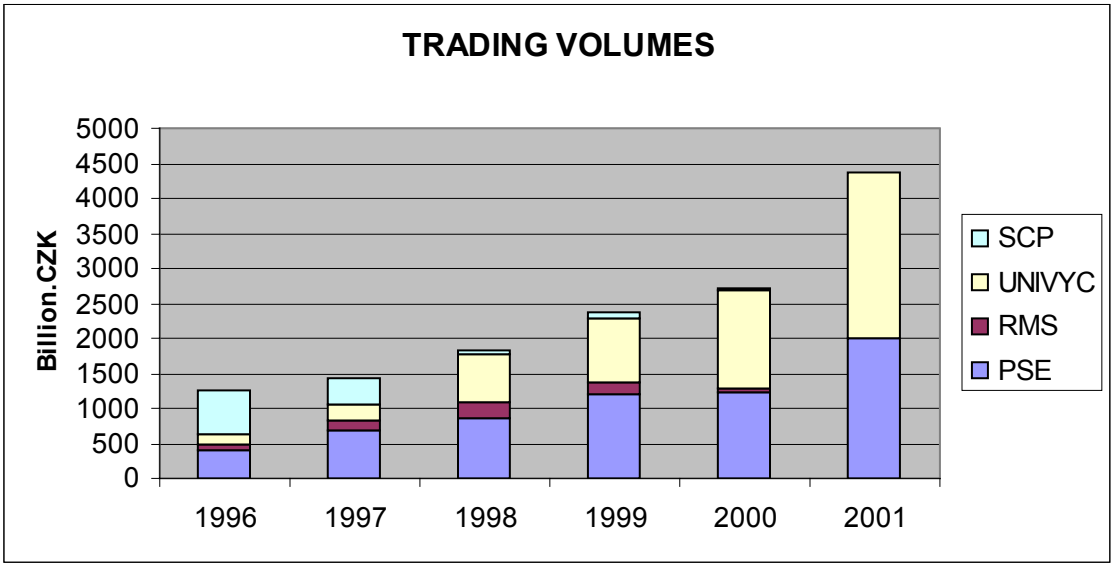
The Prague Stock Exchange (PSE) was founded on 24th November 1992 as a publicly traded company. During the period 1993- 1995 trading volumes and market capitalization increased rapidly, due to listing of 1700 companies from the privatization. Since than only very few IPO took place. The stock exchange was not used as a tool for financing the companies. The main importance of the stock exchange was the price formation and the space for speculative gains. During the boom in 1993-1996 due to the weak listing requirements, even insolvent and low performing firms could be listed. In 1997 the new listing requirements were introduced and the bankruptcy law was adjusted. As a consequence of this change in legislation, many firms went bankrupt or had to be delisted from other reasons in the following years. The number of the traded companies decreased significantly.

At the present time the market is segmented into main, „side“[9], free and new[10] market. Firms have to meet different criteria to be listed on the different markets. Only 6 companies are listed on the main market, 67 on the side market and about 100 on the free market. In total there are not even 200 companies traded on the stock markets in the Czech Republic, only 44 stocks on PSE. These figures are in contrast with 1700 listed companies in 1996. The main visible reduction in the number of companies occurred in the years 1998 and 1999, after the new listing requirements were implemented. Companies that suffered from low liquidity and „bad quality had to be delisted. Since 1999 quality of stocks that are traded on PSE has improved, but the trading activity has not risen significantly.

[9] The “side” market is usually translated as secondary. In this thesis is the term secondary used in different meaning. Thus, we will prefer the term side market.
[10] New market was created in 1999. See Musílek (2002) and CD with listing requirements of new market

OTC markets are represented by the RM-System, UNIVYC and SCP. As we can judge from past figures, trading on RM-S and SCP was popular mainly in the period 1996 – 1998, when stocks were widely dispersed between the minor stock owners, who obtained the stock in the Coupon Privatization. Since the 1996 SCP and since 1998 RMS, both these secondary markets have been losing the importance. In 2002, there are in fact only two main markets, PSE and UNIVYC. In 2002, 43, 8% of total trading volumes were performed by PSE, 50, 2% UNIVYC and only 4, 5 % RM-S. **Figure 1** shows the tendency of trading volumes on the stock markets during the years 1996-2001.

Figure 1: Trading volumes on Czech financial secondary markets



Source: PSE RMS, UNIVYC, SCP

Note: Total trading volumes are shown for all segments of the secondary market: official and OTC markets. Shares of companies, mutual funds and bonds included.

Trading volumes have grown over the period and PSE and UNIVYC gained influence. It has to be pointed out, that the main rise in trading volumes was not caused by stock trading, however. In 1996 total volume of shares traded on PSE reached 250 billion CZK, which accounted for 63, 5 % of all trades. In 2001 the volume fell to 128 billion CZK, only 6, 5 % of total! The trend of decreasing importance of stock is

summarized in **Table 1**, **Appendix I**. The bonds` trading increased in real figures, but also gained importance relatively to trading in stocks. The significant decline in stock trading can be explained by concentration of the stock ownership. In 1996 many small investors held stocks and therefore many trades occurred. The stock ownership concentration tendencies, decreasing number of listed companies and lower attractiveness due to unfavorable experience of private investors, are the main factors behind the decrease in trading volumes.

II.2.2 Amsterdam stock exchange

The Netherlands have considerably more developed market than the Czech Republic. The country has been market and trade oriented for long centuries. Thus, the financial markets developed slowly, with proper and continuous adjustment of the institutional framework of the economy: legislative rules (laws and regulations), as well as informal rules and patterns of behavior. The financial market was created spontaneously for the correct reason: to transfer the resources from the surplus to the deficit subjects in the economy. The main share of stock has been traditionally traded on the stock exchange.

The Amsterdam stock exchange (ASE) is regarded as the oldest stock exchange in the world. ASE was established four centuries ago and was the first exchange, which started to use modern techniques of trading and speculations. Since 1978 ASE operate both the stock market and the derivatives market. In 2000 Amsterdam, Brussels and Paris stock exchanges merged and formed Euronext, N.V., and the first pan-European exchange. Euronext was formed in response to the capital markets globalization, with the main goal of increasing liquidity and lowering transaction costs. Euronext has already implemented single trading platform and single clearing market. The next steps in the integration process will be further harmonization of trading rules and move the Portuguese markets to the Euronext trading platform. The Netherlands belong to the first founders of modern stock markets. The future will repeal if the trend of the stock

exchanges globalization will continue along the example of the Euronext. Is the Netherlands again a step ahead in the evolution of stock markets?

II.2.3 Stock indices

Stock price indexes were developed to reveal price changes of particular group of stock. Stock exchanges compute generally several types of indexes. Good index can be taken as an approximation of the whole stock price movements. PX–50, a Czech blue chip index, was chosen as the official index of PSE in the April 1994. PX is computed according to standard methodology IFC, which is recommended for emerging markets.

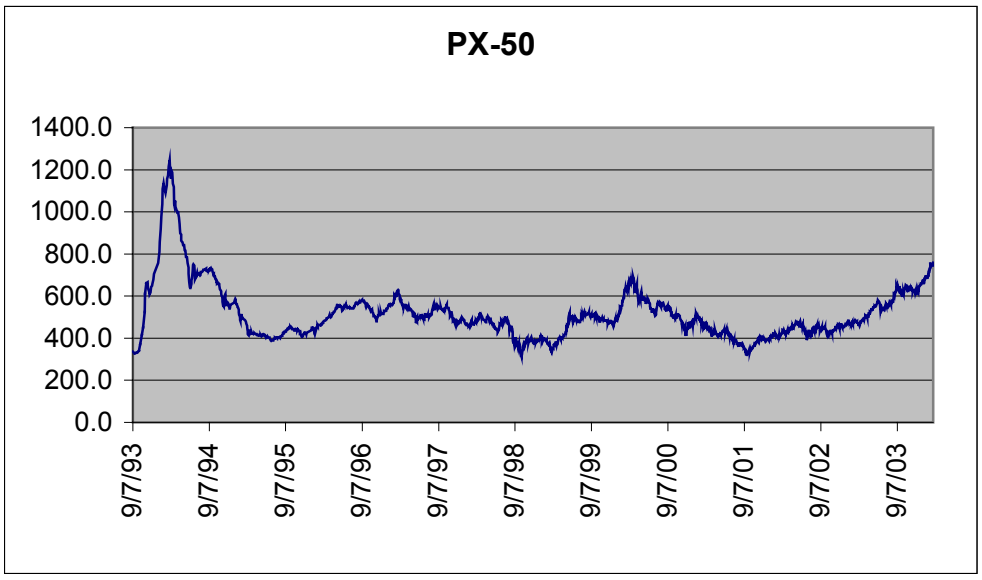
Computing technique:

$$PX(t) = \frac{K(t)\,M(t)}{M(0)}\,1000$$

Where: M (t), M (0) denotes for market capitalization in time t, 0 respectively and K (t) denotes for chaining factor in time t (regards the changes in the base)

PX-50 is a type of Laspayers price index. ASE chose the AEX index, a Dutch blue chip index. AEX is also a price index and computed in similar way as the PX-50. Furthermore ASE compute AEX total return index. The advantage of the return index is that it includes changes in dividend yields or stock splits. Return index is a better measure for an investor, but unfortunately PSE do not compute return PX-50. The base of PX-50 contains 16 firms, the base of AEX accounts for 25 companies**. Table 2, Appendix I** reveals the composition of the PX-5O and AEX index. We will use the introduced price indexes as an approximation of aggregate stock price movements and as a data set for the empirical tests in the part III.

Figure 2: Historical performance of PX-50 between 19.09.1994 and 24.02.2004



Source: PSE

How can we interpret the graph of the stock index movements? It is not always easy to explain the reason of the stock movements. However, in the case of Czech emerging market we can form a hypothesis and try to find the main factors behind the most important trend movements.

In the beginning of 1994 the PX-50 reached a maximum of 1200 points. This peak can be explained as a consequence of the first wave of the coupon privatization and following optimism, which ran the prices into the bubble. In 1994 the stock prices fell to the lows of 400 points. The second wave of privatization and optimisms about the economical performance of the country (in the mid 1990 the Czech Republic was assessed as a very good performing transitional country with liberalized markets and high growth of GDP) can be the factors behind the upward trend, which continued till 1997. In 1998 the stock market plunged to the historical minimums. This period is connected to the growing pessimism about the successes of the privatization. Finally, the growing number of bankruptcies and stricter listing requirements cleared the market of the „bad companies“. This event was connected to the fall in stock prices.

In 2000 the prices peaked again as a result of better economic situation not only in the Czech Republic. In 2000 also other stock markets performed admirably well. The US stock market reached the historical maximums. The global optimisms connected with good performance of the world economy can be one of the main factors for the rise of the stock prices.

In 2001 the market corrected its prior high levels and since the year 2002 the PX-50 has continuously risen to the recent peaks of 800 points in April 2004.

It is not an easy task to proof all the possible linkages between the real economy, investor's sentiment, different external factors and the performance of the stock market and it is also beyond the scope of this thesis. Behind the stock movements can be different type of economic and other factors. In the part III we will test the basic hypothesis of efficient markets, that we cannot predict the movements, because they follow a random walk.

Figure 3: Performance of AEX (19.09.1994 – 24.02.2004).

Source:FTSE

The AEX index has less breaking points and trend reverses in comparison with the PX-50 index. Before we start to interpret the significant trend movements, we have to focus on the breakpoint in the end of December 1998, which is visible on the graph. The AEX index started to be counted differently in the beginning of 1999. It was recalculated with different base and from the 1186 points on last trading day in December 1998 the index fell to 558.

See the **Figure 4, Appendix I** for the total return and price index, which is computed without the recalculation in January 1999. The data reveals that the stock prices have risen since 1994 and peaked in 2000. The peak in 2000 can be also connected to the good performance of the world economy. High economic growth produced the investment optimisms. The period of 2000-2002 was a period of downward trend and since the mid 2002 the stock prices are rising slowly.

From the graphs we can discover the basic difference between Czech and Dutch stock market. The Czech stock market is considerably younger and this results in the higher long term volatility of the prices. The higher volatility can be explained by the traditional finance argumentations. Czech economy, as an example of a transitional country, has higher potential returns with higher risk. In the Part III after we analyze the data we will see if this explanation is correct. Both stock indexes peaked in 2000, which can be connected to the global markets or can be simply a pure coincidence. The explanatory power of graphs is too low to make unambiguous conclusions. When we want to examine the differences further we need to have more characteristics of the markets.

II.2.4 Market capitalization

Market capitalization is the sum of market values of all shares listed on the stock exchange. Market capitalization provides us with information, how much the sum of traded stocks is worth at the specified time. Changes in market capitalization can be caused by two factors. Either by the movements in stock prices or by the changes in the amount of traded stock. We compare the trends in market capitalization with the number

of listed companies and stock indices. Stock index will be used as an approximation of the aggregate price of stock. We use stock price indices and number and volume of stocks listed to answer the question, what caused the movements in market capitalization. We tried to explain both the nominal, but also relative changes in market capitalization to GDP. Because the conclusions do not differ significantly, only the comparison of market capitalization as a percentage of GDP with indices and volumes will be presented.

Table 3: Total Market Capitalization

Market capitalization as % of GDP		
	Czech Republic	Netherlands
1990		47,2
1995	34,1	85,8
1996	33,8	
1997	28,7	
1998	21,8	
1999	24,4	217,0
2000	21,6	193,9
2001	15,7	152,6
2002	20,5	

Source: Statistical Yearbook 2003, PSE

As we can see in **Table 3**, the market capitalization on Czech markets peaked in years 1995-1996 with 34% of GDP. In the period 1996-2001 slight downward movements can be observed. In 2002 the trend seemed to have changed and small upward correction occurred, ending with 20% of GDP. The peak in 1995-1996 can be explained by the mass listing of companies from the privatization. During 1993-1996 due to the listing of 1700 companies, the Czech stock market surged almost from 0 to 35% of GDP. As can be judged ex-post, rapid increase in the period does not tell anything positive about the economical performance, as it would be in developed market economies. Between the 1700 listed companies only few were sound enough to meet the criteria, which were implemented in following years. Between years 1996-2001 the number of listed companies decreased dramatically and none IPO occurred. Prague stock exchange delisted bad companies and in April 2004 there are only 47 stocks traded on

PSE (see **Table 4** for the most recent comparison of the Equity markets in the section II.4.). Market capitalization followed the trend of the stock movements; in 1999 the rise in the market capitalization was due to increase in price (see PX-50 in **Figure 2**). In 2002 the prices started rise again and market capitalization consequently increased.

As for the stock market in Netherlands, the last decade of twentieth century was a period of rapid growth in market capitalization. The slowdown in recent years can be explained by poor performance of the economy, stock prices have been falling continuously since 2000 and stocks` trading volumes stagnated. **Figure 5, Appendix I.** shows the market capitalization in the Netherlands.

Table 3 reveals interesting information and provides us with a tool to compare the two markets. Market capitalization in the terms of GDP in the Netherlands exceeded almost ten times the market capitalization in the Czech Republic between 1999 and 2001. In the Czech Republic only about 20% of GDP accounts for the equity of publicly traded firms. This figure is very low and confirms the fact, that in Czech Republic firm do not regard stock as a common source of financing. On the other hand, Netherlands has been a country, where stocks play a considerable role in capital structure (OECD 1996). What are the possible causes of such a huge difference between the two countries? Examining the historical and institutional background of the economies can provide answer for this question. In Netherlands, stock exchange operates for several centuries. There was time to establish trust, tradition, as well as good legislative framework for the stock market. Czech Republic ran into the transition and had neither time nor put effort to improve institutional conditions, before the mass privatization occurred. Bankruptcies, insolvent financial institutions and frauds damaged the investor confidence in Czech Republic. Risk aversion and transaction costs are very high in comparison with the Netherlands. The attractiveness of stock is rather low for both parties. Firms find the stock issuance too costly. For investors are the stocks not only very costly, but very risky, too. In the following section the problem of asymmetric information and transaction costs will be explained. I will supply the reader with argumentation, which can help to explain the low attractiveness of equity financing in Czech Republic.

II.3 Limitations to Equity financing

II.3.1 Introduction

Across the world there are big differences in use of equity as a source of financing. Developed countries dispose of significantly higher size of financial sector in terms of GDP. Also the relative significance of equity, in particular stock, financing is much higher in the most developed countries. According to the figures (OECD 1998) the size of financial sector in the USA and the Netherlands accounts for about 250% of GDP of their countries, from which more than 50% consist of stock. The detailed figures about the size of stock market capitalization are shown in **Table 3** and **Table 4.** Stock market capitalization of 15% of GDP in the Czech Republic in 2001 is strongly in contrast with the 150% in the Netherlands. This leads us to a puzzle: Why are stock financing more common in industrialized countries, Netherlands in particular, than in emerging or transition countries, as the Czech Republic? We could go deeper in the problem by asking, why there are also differences between the developed countries.

The high performance of an economy does not have to be the only factor behind the attractiveness of stock financing. The investor confidence seems to play the major role. To resolve the puzzle of stock financing, I will discuss the barriers that a firm must come over, before going public. Restrictions of stock exchanges: listing and reporting requirements and transaction costs are the most important barriers. Transaction costs denote for every payment, fee or commission, which a firm or an investor have to pay, when issuing and trading in stocks. Listing requirements are the criteria that a firm has to meet, before the stock exchange agrees with the IPO. Stock exchanges categorize stocks. Each category has to meet different requirements. The largest and most liquid shares are generally in the highest category and must meet highest requirements. In addition, listed companies must follow reporting procedures. Firm publish and file quarterly, semi-annual and annual reports, which contain balance sheet and income statements. Asymmetric information problem will be explained. The main reason, why do these requirements exist, originates from the problems, which arise from asymmetric information. First, I begin with explanation of the asymmetric information concept. Than

I will proceed to discuss the difference in legal restriction and transaction costs in Czech Republic and in the Netherlands. Finally, I will conclude that the differences in institutional background, investors confidence and transaction costs can explain the puzzle.

II.3.2 Asymmetric information

Not each subject in the economy disposes of the same information. Managers of the firm have generally better information about the particular firm, than any other participant in the economy. Asymmetric information is a situation, when one party has insufficient knowledge about the other party involved in the transaction (Mishkin 2003). This asymmetry leads to two situations, which have to be deal with: adverse selection and moral hazard.

Adverse selection is an asymmetric information problem that arises ex-ante. Parties who are most likely to produce low outcomes are the ones who put the most effort to engage in the transaction. The most risky companies will seek out most actively for financing sources. When a firm knows that it can earn potentially high returns, but the probability of the loss is also high, the firm will search for funds actively. High gains are at stake, thus the incentives for managers to hide negative information are significant. Rational agents in the economy know about the adverse selection, but cannot distinguish between good and bad firm. The average risk premium is too high for good, but too low for bad companies, therefore only bad companies will agree to pay the premium. Rational agents are familiar with this fact and therefore refuse to engage in the transaction.

Moral hazard occurs ex post. After the party got involved into the transaction, it is more likely to engage in high-risk activities, which yield higher profit. Because agents do know about the moral hazard and because their information is imperfect, the transaction will not take place at all.

How are adverse selection and moral hazard connected to equity markets? Investor, who does not posses with all relevant information, will hesitate to buy the stocks. The uncertainty about future of the firm is too high, stock investments seem to be too risky and thus lower the prices of the stock. Good firms do not want to pay such a

high premium (in the terms of low market price) and prefer to search for other source of financing. Bad firms will accept the premium and additionally reveal insufficient information about future prospects. Thus, adverse selection and moral hazard make the stock financing undesirable. This effect is higher in the countries with higher uncertainty about future earnings. When the expected probability of default is high, stocks seem to be too risky. Adverse selection and moral hazard explains why the uncertainty prevents and limits the direct sources of financing.

Financial intermediaries help to solve these problems. They dispose of better abilities to get more complete sets of information. Countries with higher levels of risks and uncertainties have therefore lower size of the financial sector in general. Financial, non-financial institutions and individual investors, all are reluctant to provide financial sources to the "black box" companies. Furthermore, equity financing is relatively low to debt financing. Financial institution, banks in particular, have better access to the corporate information, profits from economies of scale: monitoring and screening of the firms is less costly for them. Importance of banks is negatively correlated with the "soundness" of economy. Countries, in which the access to the information is easy, risk of bankruptcy is low and trust in legislative system high do not need banks as a main source of financing. USA, Switzerland and the Netherlands are in this category. On the other hand, banks are highly important in emerging and transition countries, including the Czech Republic. Banks are also important in the countries with the traditional strong banking sector. Germany and Japan has had important banking sector and they belong to the most developed countries. The theory recognizes two models of financing: the Anglo-American and the German model.[11]

Stock exchanges play a role of intermediary between firms and investors. Stock exchanges decide which companies they will allow to be listed and sort the stocks into several categories. Category should provide investor with more information about the stock, and thus about the company. Stock exchanges gather the information directly from the companies. It is in their own interest to meet the listing a regulation criteria, because the stock exchange assess those stock higher. Higher category stocks are trusted more and

[11] See Mlčoch (1996) for detailed information about the different advantages and disadvantages of these two types of model. It this interesting to notice, that the Czech market shares the features of both models. Czech financial market in the transitional period has been also described as Czech Hybrid.

therefore traded in higher volumes. In Czech Republic we recognize four categories, four segments of market: main, side, free and new.

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II.3.3 Listing and reporting requirements

The main listing requirements are similar to both stock exchanges: PSE and Euronext. Listed firm has to have track record of three years. Further, the company must have at least three profitable financial years in five years preceding the floatation. The percentage of the issued shares held by small public shareholders is 25 on PSE and 10 on AEX. 25% of public holding ratio on PSE means stricter requirements about the dispersion of the stock between public, in Netherlands this criterion is not that strong. The last main requirement restricts small firm to enter the stock exchanges. Shareholders equity must exceed 5mil € on the Official market in Netherlands, 200mil CZK on main and 100 mil CZK on secondary market in the Czech Republic[12].

The reporting requirements are same in both countries. Reports including income statements and balance sheet have to be published on quarterly basis and filed within two months after the end of each period.

II.3.4 Transaction costs

We can distinguish basically two types of transaction costs in stock trading. First, there are costs connected to stock issuance. Underwriter has to guarantee the stock and set the price. Than IPO take place on primary markets, that are generally less liquid and stocks have to be traded with additional premium. Listed company has to provide sufficient information to meet the listing and reporting requirements, which implies additional costs. Secondly, trading costs accounts for significant part of transaction costs. Fees and commissions have to be paid to market maker and brokers. Important costs are connected to spreads. The higher the difference between the bid and offer price, the higher the costs. Spreads, which are one of the measures of the liquidity (Section II.4),

[12] Additional information about the listing requirements can be found on the webpage of the stock exchanges (PSE,Euronext)

imply higher costs on stock with low frequency of trading. Trading costs fall rapidly with trading volumes. Trading in small amounts is very costly; therefore small investor trading is limited. Total transaction costs account for about 8% in the Netherlands, but rises to 25% in Czech Republic[13].

II.3.5 Impact of the asymmetric information and transaction costs

What can we conclude from the differences in transaction costs, listing requirements and environment of the two countries? What is the answer on our puzzle of stock financing? Asymmetric information can explain the lower size of financial sector in the countries with lower trust in information and future performance of companies. Countries with imperfect legislative system and in which the expectations about the companies are uncertain, i.e. the probability of default is high, will attract less investors. Banks are more important in those countries, because they can pool the risk and gather information more effectively. Despite the relative importance of banking sector, the absolute size is low, because the asymmetric information problem is worse in transition and emerging countries. Listing requirements are not prohibitively strong, they restrict small firm to enter, but these conditions are reasonable. High transaction costs are a problem of large magnitude. In conclusion, we can state that asymmetric information and transaction costs are the most important factors that limit the willingness of companies to issue the stock. Equity financing is more common in the Netherlands than in the Czech Republic, because the asymmetric information problem is less severe and transaction costs are lower.

[13] See the lectures of Financial Markets by Mejstřík (2002) and Musílek(2002) for detailed description of the types and amount of transaction costs.

II.4 Liquidity

II.4.1 Criteria of liquidity

Liquidity is an important characteristic of markets. On the markets with high liquidity there is a sufficient trading volume to provide nearly continuous trading. Prices change in small steps and spreads are low. The amount of trading orders is high enough to bring the highest price of demand close to the lowest supply price. In high-liquidity markets should be the spread, which is the difference between bid price and offer (ask) price, close to zero.

There are two criteria of liquidity: the depth and the width of market. The depth of the market is a measure of the amount of trading orders[14]. The market is considered to be deep, if the buy and sell orders are frequent enough to ensure insignificant spread and continuous line of prices. The width of the market is a criterion about the amount of investors on the market. Wide range of investors, diversified group of institutional and individual investors, is required to ensure the wideness of the market. High frequency in trading and diversified group of investors guarantees the liquidity of the market.

II.4.2 Measures of the liquidity

Simplest way how to determine the liquidity could be to asses the amount of daily trading volumes. The higher trading volumes of individual stock could mean that stock is rather liquid. Unfortunately trading volumes don not tell us anything about the frequency of trades. Trading volumes can lead to significant bias, if the stock is traded in large piles. Trading volumes can be same for two stocks, but we do not see the frequency of trades. The first stock could be traded in large pile only in one trade per day, the second, on the other hand, could be traded continuously through the whole day. The first stock would be highly illiquid in comparison with the second one.

The most direct measure of the market liquidity is the bid-ask spread. If we had enough data, we could easily compute the average spreads. Low spreads indicate high

[14] On the modern markets the most of the orders are provided by the Electronic ordering book system.

liquidity. The problem of this measure of liquidity is the unavailability of data. To Asses the liquidity from the spreads, many data series would be necessary. The stock exchanges do not track such detailed information, at least they are not easily accessible at any charge.

To determine liquidity and overcome the data shortage problem, the liquidity index was developed. Wong (1994) introduces two types of aggregate liquidity indices: the Amivest liquidity index and the modified liquidity index. The Amivest index measures the value of the stock transactions during a specified period for each one-percent change in price. The idea behind the computations is that the greater the trading volume in relation to its price variation, the greater the liquidity. The critique of this index can be that it ignores the price movements within the period. As a result, modified liquidity index was suggested. Modified index is computed as the sum of volumes over the period divided by the sum of percent ranges between the daily lowest and highest closing price during the period. The formula can be found in **Figure 5, Appendix I**

II.4.3 Liquidity comparison

To compare the liquidity of the Czech and Dutch Equity market only, the data of market capitalization described in part II.2.4 and summarized in **Table 2** can serve as the first guideline. Velocity of trading turnovers can serve as a second indicator of liquidity. Turnover velocity is an indicator, which is computed as a ratio of the total value of Electronic Order Book Transactions (EBOT) and the total domestic market capitalization. **Table 4** shows the actual data for April 2004.

Table 4: **Equity Markets in April 2004**

	Euronext	Prague Stock Exchange
EOBT	**139,532.6**	**17.6**
Negotiated Deals	**41,770.2**	**181,302.9**
Market Capitalization	**2,078,942.0**	**9,804.0**
Turnover Velocity	**80.5**	**2.2**
Investment Flows	**2,840.0**	**0.0**
Listed Companies	**1,187.0**	**47.0**

Source: FTSE
Note: The table shows the basic trade volumes and characteristics of PSE and Euronext in April 2004. EOBT is the abbreviation of total value of Electronic Ordering Book Transactions. Turnover velocity is evaluated as the ratio between the annualized EBOT and Domestic Market Capitalization.

The data reveals a striking difference in the turnover velocity rate. Almost 40 times higher velocity on the Euronext indicates much higher liquidity. Because the turnover velocity is indicator of the trading volumes, we are talking about the depth of the market. The Euronext is much a deeper market than the PSE.

The **Table 4** indicates two additional results. Firstly, the differences in total market capitalization are consistent with our argumentation that the Czech equity market is not an important source of capital for the companies. The PSE is not used as a channel of investment flows to the companies.

Secondly, from the data of negotiated deals we can make a conclusion about the width of the market. On Prague Stock Exchange the major amount of the transactions is not provided through the EBOT, but is negotiated directly. Electronically operated systems are generally used by small investors and the trades are in small amounts. The institutional investors, banks and other large investors prefer to trade directly in larger piles of stock. Therefore, the large amount of negotiated deals neither improves the depth of the market, nor the width of the market. On Czech stock market there are few major investors and only a small group of „small“ investors – the private owners of stock. The significant trading of private investor would indicate high liquidity of the market.

Although we could not measure the bid-ask spread nor compute the liquidity indexes, we can conclude with high degree of certainty, that the liquidity of Czech equity market is rather low in comparison with the developed markets of the EU.

II.5 Comparison of Czech and Dutch stock market

History and institutional framework of the economy plays an important role on the degree of development and functioning of financial markets. The Netherlands, which has traditionally well developed financing sector, have better stock market than the new Czech stock market. This fact can be proofed by the major characteristics of the two markets. First, the market capitalization and number of listed companies is much higher in the Netherlands. Second, the Czech Republic is a victim of much worse asymmetry in information. The moral hazard, adverse selection and low enforcement of law result in higher level of uncertainty. Third, liquidity, both the depth and width of the market is lower in Czech Republic. The recent data reveal a striking difference in turnover velocities. Trading volumes of stock are much lower in absolute as well as relative figures. Finally, transaction costs, which are in direct relation with the level of uncertainty and liquidity of the market, are much higher in Czech Republic.

The comparison of basic characteristics of the markets revealed significant differences. Czech Republic has less developed market in every aspect. The conclusions of part II leads us to a question whether are these "background" factor important for the stock price movements? In the part III we will test the Efficient Market Hypothesis to find out, if the described weaknesses of the Czech stock market resulted in higher level of inefficiency in comparison with the market in the Netherlands.

Appendix I

Table 1. Czech financial market

	1995	1996	1997	1998	1999	2000	2001	2002
Total Trade Value (bn.CZK)	195,4	393,2	679,5	860,2	1187,5	1222,8	1987,2	1793
Trade Value Shares an Units	125,6	249,9	246,3	172,6	163,5	264,3	128,8	197,4
% of shares on total value	64,3%	63,6%	36,2%	20,1%	13,8%	21,6%	6,5%	11,0%
Market Capitalization (Shares)	478,6	539,2	495,7	416,2	479,7	442,9	340,5	478

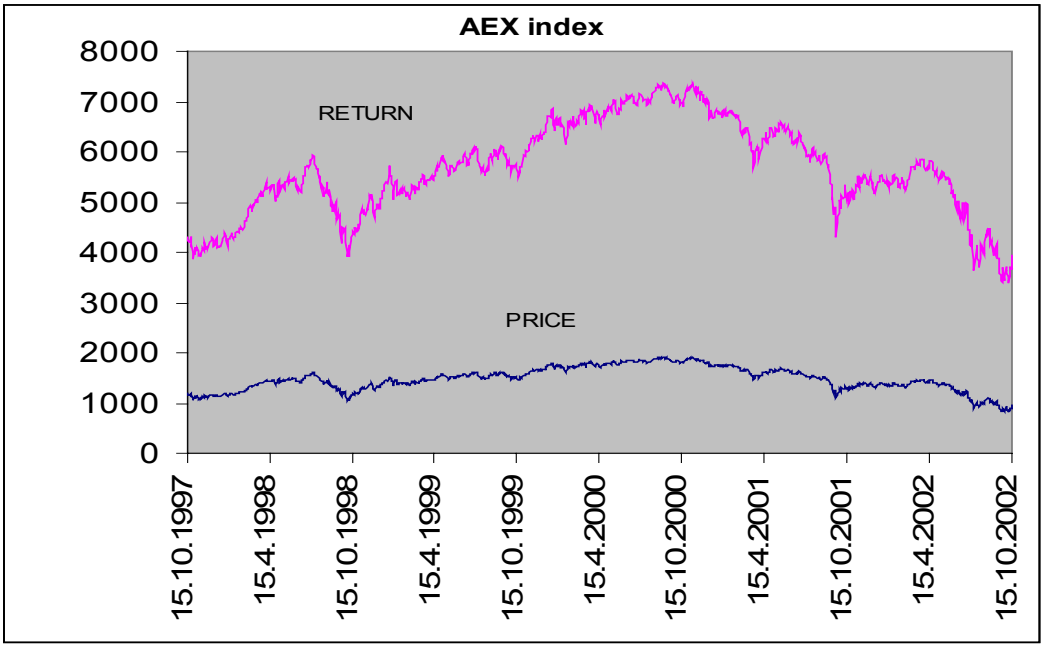
Source: PSE

Table 2: Composition of PX-50 and AEX indices

Composition of PX-50 index (as of 15 November 2003)		**Composition of AEX index** (as of 4 march 2003)	
Name	**Weighting (%)**	**Name**	**Weighting (%)**
ERSTE BANK	22,49	Koninklijke KPN	12,97
KOMERČNÍ BANKA	21,75	ING Groep	10,15
ČEZ	19,09	Aegon	9,76
ČESKÝ TELEKOM	13,72	ABN AMRO Holding	8,85
PHILIP MORRIS ČR	6,38	Fortis	8,66
ČESKÁ POJIŠŤOVNA	3,51	Koninklijke Philips Electronics	8,23
UNIPETROL	2,7	Koninklijke Ahold	6,27
ČESKÉ RADIOKOM.	2,27	LogicaCMG	4,93
ZČ ENERGETIKA	1,44	Reed Elsevier	4,88
SEVEROČESKÉ DOLY	1,38	Royal Dutch	3,45
ŽIVNOSTENSKÁ BANKA	1,28	ASML Holding	3,21
STČ ENERGETICKÁ	1,08	Getronics	2,82
ISPAT NOVÁ HUŤ	0,94	Unilever	2,49
SOKOLOVSKÁ UHELNÁ	0,94	TPG	2,35
JČ ENERGETIKA	0,66	Akzo Nobel	1,96
PVT	0,38	Wolters Kluwer	1,87
16 STOCKS TOTAL:	100	VNU	1,63
		Heineken	1,29
		Koninklijke Numico	1,10
		Buhrmann	0,86
		Hagemeyer	0,72
		DSM	0,67
		Gucci Group	0,40
		Van der Moolen Holding	0,26
		IHC Caland	0,22
		25 STOCKS TOTAL:	100,00

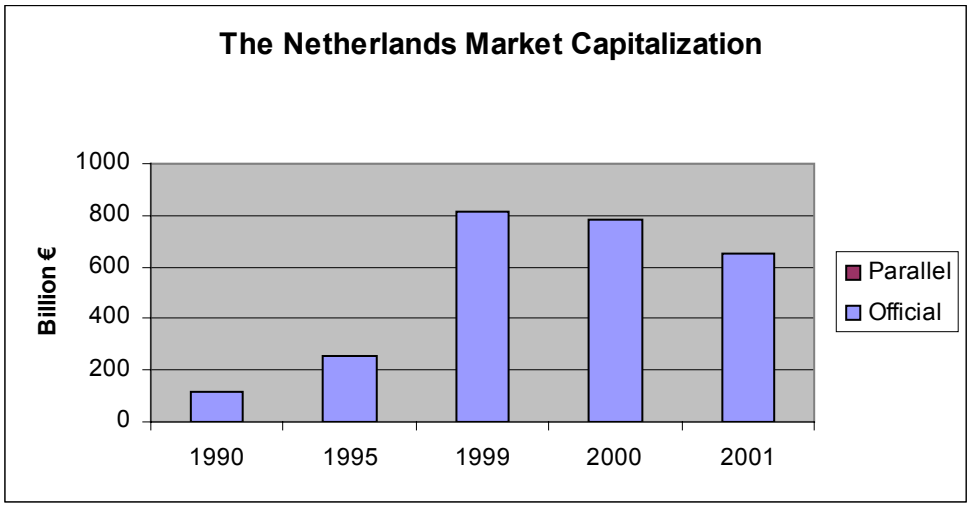
Sources: PSE, AEX

Figure 4: AEX price and return index (15.10.1997-15.10.2002)



Source: FTSE,AEX

Figure 5. Market capitalization in the Netherlands



Source: Statistical Yearbook

Figure 6: Liquidity indices

The Amivest aggregate liquidity index:

$$ALI = \frac{\frac{P_t \cdot TV_t}{1000}}{\frac{P_t - P_{t-1}}{Pt}}$$

The modified aggregate liquidity index:

$$MLI = \frac{\frac{P_t \cdot TV_t}{1000}}{\frac{2 \cdot (H_t - L_t)}{Ht + L_t}}$$

Note: P_t denotes closing price of the instrument, TV_t denotes total trading volume , H_t the highest closing price and L_t the lowest closing price during the period

III. The efficiency of the Czech and Dutch stock market

III.1 Introduction

In this part of the thesis we discuss the concept of efficiency of Czech and Dutch stock market. The term efficiency is central to finance and it is used to describe the ability of the market to impound the relevant information into the price of the financial asset (Dimson 2000). If the markets are efficient, none investor can earn abnormal returns. Depending on the character of the information, we recognize three types of efficiency: weak, semi-strong and strong form of market efficiency. In the part III.2 we will explain the theoretical concept of the market efficiency

The important question is if the theoretical concept of efficiency holds in the real world. In the section III.3 we will conduct the empirical test of weak form efficiency. The Random walk model will serve as a starting model of the analysis. We will test the data of the stock exchanges to determine if the Czech stock market is more or less efficient in comparison with the Dutch stock market.

III.2 Efficient Market Hypothesis

The Efficient Market Hypothesis (EMH) (Fama 1970) defines an efficient market as one where the prices of assets always reflect all available information. Fundamental value of the asset, which is the present value of the future expected cashflows, should be always same as the market price of the security. In the case of the stock market, the efficient market hypothesis states that because the prices are always right, the changes in prices can happen only with new information. New information are quickly and accurately judged and reflected in the price change of the particular stock. Changes in price, other than the reactions to new information, can thus be only random. Only small fluctuations are expected in the process of searching of the equilibrium price.

III.2.1 Assumptions underlying the EMH

The EMH lies on three arguments. First, investors are assumed to be rational and hence they value the stocks rationally. Second, even if the irrationality exists, there is no rule in the incorrect expectations. Irrational agents trade randomly and therefore, they cancel each out without any effect on the price. Finally, even if there is one big group of irrational investors, who misjudge the price in similar direction, the rational agents eliminate the mispricing by profit making arbitrage.

To assure that the process of forming of expectations is correct, traditional finance comes with the assumption of rationality. Rational agents take into account all available information and form appropriate judgment without any emotions or other irrelevant factors. The information can be relevant or irrelevant in the case of particular stock. Rationality assures, that all relevant information will be quickly and accurately reflected in the expectations. On the other hand, the irrelevant information will not change the belief. After forming of the belief, rational investors set the fundamental value as the present value of the future cashflows. Correct expectations of the future profits and such discount rates which reflect the risk characteristics of the stock ad expected risk free interest rates assures that the calculated price reflect the correct value of the fundamental, in our case –the value of the stock. Rational agents in the traditional economic point of view are expected utility maximizers. With their beliefs they will trade on the market. All of them will trade only if they expect profit. The law of supply and demand guarantees that the fundamental value will equalize the market price of the stock. Prices on the market reflect the relevant information and do not react to irrelevant, stale information. On the competitive market with rational risk-neutral investors the returns are unpredictable. Stock prices follow random walk and no agent can earn abnormal profit. The assumption of risk neutrality has been under strong critique and economists in last decades have generally agreed on risk aversion of most of the investors. Risk is taken in the assessment through discounts rates. Still, the rationality implies the impossibility of earning abnormal risk adjusted profits. On efficient market none can win in the long run.

The efficient market hypothesis counts also with the possibility of irrational investors on the markets. It is not necessary, that all of the investors are rational. Some do

not have full information, or do not judge them in the correct way. Despite those investors, the rational will still be the leaders in the price forming process. The price will reflect the fundamental value. Rational investors will trade always when they expect profit; they will try to achieve the equilibrium. Other investors make mistakes in their valuations. One investor overvalues, the second undervalues. Some of the investors will get more optimistic, some more pessimistic information. Even with the same information irrational beliefs of the different investors can influence the valuation of the asset in both directions. Because the information and people mistakes in forming of correct expectations are expected to be random, also the mispricing will be random and cancel each out on the market.

Finally, the argument of herd irrationality (Shleifer 2002) does not contradict the efficiency. Let us assume that most of the irrational investors form they believes in one direction, for example they believe that one particular stock, which fundamental value equals the market price, is in fact undervalued.. This group of investors will buy the stock because with their expectations they believe to earn profits. This behavior increases the price of the stock on the market. Stock becomes overvalued. On the competitive market, in the presence of rational investors, the price will correct automatically and fell back to fundamental value. In a model case, even one rational agent can correct the mispricing. Arbitrage can bring riskless profit. Arbitrageur sells the overvalued stock and buys a correct valued perfect substitute to the overvalued. Price corrects, rational arbitrageur gains and group of irrational investors lose. On the markets with perfect competition loser can not survive in long run. Irrational investors leave the market after few losses, because the market forces eliminate their wealth. Markets become efficient with rational investors gaining no superior profits.

The efficient market hypothesis assumes a perfect market. There are no transaction costs, no barriers to enter and for every asset exists a perfect substitute. Perfect substitute does not mean a twin asset with identical characteristics. It has to be perfect in the financial sense. Perfect substitutes should have the same present value of the share; it means the sum of expected future cashflows discounted by the same risk factor. On a perfect market, where the rational agents are present and react to the information, the prices will always be correct. The efficiency can reveal in three forms

according to the extent and amount of the information which are available to the traders. If the investors have all past information, the market will be weak form efficient. Adding all public information, the semi-strong efficiency should happen. Finally, in the case of full information, including all past, public and internal news, data and all other factors, the markets become strong efficient.

III.2.2 Forms of Market Efficiency

Based on the type of information which is available to the investors we recognize three types of market efficiency. Markets are weak form efficient if the prices of the asset fully reflect all past information. Semi-strong efficient market incorporates all public information and finally, even with private information, none can earn excessive returns on the strong efficient market.

III.2.2.1 Weak form market efficiency

Weak form of efficient market hypothesis claims that prices fully reflect all past information that is already reflected in the past prices. The investors on the market have perfect data about past prices. If the market is weak form efficient it is impossible to predict future prices only examining the past prices and it is impossible to earn abnormal risk adjusted profits. Past prices already reflect past information and future changes in price can be caused only by new information which cannot be forecasted. Information in future can only be expected and because the differences from the expectations are random, also changes in prices are unpredictable. In the special case of risk neutrality of investors the weak form efficiency reduces to random walk theory. Returns, which are in fact the price changes, have the properties of random variable. Returns are normally distributed with a mean return, which shows the trend, and the variance, which shows the volatility of the price.

The simplest test of weak form efficiency assumes the risk neutrality. The basic idea behind the test stems from the definition. Future returns can not be forecasted from the past prices. We can test the returns and examine if the have the properties of random

variable. These basic tests have been performed on securities markets worldwide and revealed basically the normality of distribution of returns. From this result authors usually concluded that the particular market is weak form efficient. In 1970s and 80s was the EMH generally accepted, because studies concluded the impossibility to earn abnormal returns. Were these conclusions correct? We can cast doubt on it. Weak form efficiency under the assumption of risk neutrality implies the random walk, but do not hold as equivalence. The observation of random walk therefore does not have to imply weak form efficiency. There can be other reasons for random walk of returns than the random character of new information and forming of expectations.

The second basic test stems also from the unpredictability of future prices. Because the changes in prices do not follow any pattern, in the weak form efficient market there is no autocorrelation of returns. Positive returns 10 days ago do neither imply positive nor negative returns 9, 8, 7…1 day ago. Also this test, even with the result of zero autocorrelation of returns, can not imply the weak form efficiency. Despite the critique, in following section these two tests will be performed. Even though the results can not be generally taken as the acceptation of the hypothesis, they can at least reject weak form efficiency, if it is the case. Other reason for performing the tests it that they can reveal interesting results that can be compared on both, Czech and Dutch equity markets. The characteristics of the returns are interesting information and can be used for other tests and conclusions.

III.2.2.2 Semi-strong market efficiency

Semi-strong form of efficient market hypothesis works with all public information. On a semi strong efficient market it is impossible to earn abnormal returns using public information. Public information is quickly, accurately and fully incorporated into the price in the first moments after the event. Thus, all other investors can not earn on this information. If the markets are efficient the releases of expected information do not influence the price at all, because the expectations are already reflected in the price. After an unexpected event or release of different than expected news, the price changes

quickly and adjusts instantly to new circumstances. In semi strong efficient market prices should change only with news and does not change if no new information appears.

Tests of semi-strong efficiency examine the historical data of price movements after the events. Event studies test the movements of the prices after new information, which is connected with the fundament of the stock, appeared in the public accessible source of information (newspapers, internet, TV). The character of the event can differ substantially. Event can be news concerning the change in interest rates or the unexpected disaster[15]. Semi-strong efficient market should immediately incorporate the news appropriately. The prices should change immediately after the news and do not move before or after the event. On the graph we can plot the SUE[16] to examine the informational efficiency.

III.2.2.3 Strong market efficiency

Strong market efficiency involves all available information, including the insider information. Even the owners of the company should not be possible to earn excessive returns. It is very difficult to test this type of efficiency. Many types of private information can have an influence on the future cashflows of the firm. One original test of this form of efficiency was performed by Roll (1986). He tested the Hubris hypothesis of corporate takeovers. The result of the empirical analysis of the corporate takeovers indicates, that even the managers of the firms, with the insider information, can not earn abnormal profit[17]. This is a conclusion consistent with the strong form of market efficiency

[15] For example Hanousek a Filer (2000) examined the events studies on the Czech market. As an event, they chose the monthly inflation, industrial production, rate of unemployment and returns on US market.
[16] SUE is the abbreviation of standardized unexpected earnings. See more in: The lectures of Financial management: Mejstřík

III.3 Random walk model

III.3.1 Introduction

The random walk describes the movements of prices of security whose future changes cannot be predicted. Given their today's value the stock is same likely to rise as to fall. The random walk model is the simplest test for weak form market efficiency. Malkiel (1996) in his popular book: „The Random walk down the Wall street" argues that no one can win on the stock market in the long run. Because all the information is already incorporated in the current price and future is unknown for everyone, it is impossible to earn abnormal profits by trading on "Walk Street". An interesting experiment was used as a proof of the random walk. An ape was given to options: he could choose either to buy or sell whatever stock he wished. The decision he made was not guided by any information or believes about the stock itself. He was guided only by his animal will and fortune. Despite the irrationality of this behavior, this randomly chosen portfolio beat the majority of investors on the market. The random walk model has been commonly known in the public and has been used as a proof of market efficiency. In this section we will try to answer the question: Does the Czech and Dutch stock market follow random walk?

III.3.2 Testing for Random walk - model description

As a first step in our analysis will be the description of the methodology and choice of the best model. I will proof that the Random walk model can be reduced to the model of testing the distribution of the returns. For the reasons discussed below, we will prefer the daily continuously compounded returns to the daily compounded returns. As a first step we will than examine the distribution characteristics of the Czech and Dutch stock exchanges returns, which are represented by the indices: AEX and PX –50. This descriptive statistics has an interesting and useful interpretation. Second we will test the null hypothesis of the distribution normality of the returns. As a third step will be the test for the serial autocorrelation of the lagged daily returns. On the assumption of random

[17] Additional explanation can be found in Roll (1986)

walk, where the prices follow autoregressive process of the first order, the returns should not be autocorrelated at all. The past returns should not have any impact on the present returns.

III.3.3 Model selection

Our empirical analysis will begin with the basic model: Random walk without drift. In this model we assume that prices of the stock today are equal to the prices of the stock yesterday plus noise. The noise term, which is the random shock in the model, has zero mean and finite variance. It means that in this model we do not expect any chance in the fundamental value of the stock. We can express this model with a formula:

$$P_t = P_{t-1} + u_t$$

This is a type of AR (1) model. In other words it means that the prices are perfectly autocorrelated with the first lag. The perfect autocorrelation implies that we will not meet the condition of stationarity. The variance of P_t is not stationary, thus the terms random walk and nonstationarity [18]can be treated as synonymous (Gujarati 2003).

The model of random walk without drift has obvious limitations. Because the difference between daily prices is only noise, there is no space for the possible trend. It means that in this model we do not expect any chance in the fundamental value of the stock, which is rather unrealistic for the time series, which are longer than several months. We will adjust the model so it can involve also the trend, expressed by

$$P_t = \tau + P_{t-1} + u_t$$

This is again AR (1) and nonstationary model. We can transform this model into the shape, which will suit our testing purposes.

$$\Delta Pt = P_t - P_{t-1} = \tau + u_t$$

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[18] AR(1) process can be expressed by $P_t = \rho P_{t-1} + u_t$. Perfect autocorrelation means that $\rho = 0$. Nonstationarity is explained in detail in Guajarati (2003). If the initial value of $P_t = P_0 = 0$ the E(Pt)=0. Under the random walk $\text{var}(P_t) = t\sigma^2$, the variance of the price is increasing with the number of observations. Thus with the bigger sample of data we higher variance, it is not consistent and does mot satisfy the condition of weak stationarity.

Next step is to divide the equation by Pt-1.

$$\frac{\Delta P_t}{P_{t-1}} = \frac{\tau}{P_{t-1}} + \frac{u_t}{P_{t-1}}$$

On the left side we obtain an expression for the daily compounded returns. On the right side we obtain new trend constant and adjusted noise term, which will again have zero mean and again finite (but different than in the model 1)) variance.

Here we have the model ready for the regression with only a constant variable. When we examine it closely we can see, that the regression model reduced to a form, which is equivalent to the testing the distribution normality of daily returns. Before we start testing the model we will examine a different approach.

We will begin with the same idea. If the market is weak form efficient (the condition which were described in III.2 are satisfied) and the investors are risk neutral, than the price of the stock today is equal to the optimal forecast of the stock:

$$Pt = E(Pt^*)$$

This equation implies that on the efficient market the Price will change only with the appearance of new unexpected information. Unexpected information can have either positive or negative impact. On the condition of unbiased flows of information, the news will be distributed with zero mean (they will be neutral for the stock in aggregate) and finite variance. For the simplicity we can assume that the new information reveals only once per day. Under this assumption, it follows automatically that the daily returns will be normally distributed with zero mean and finite variance. Because the price is equal to optimal forecast, the only possible deviation has to have the properties of random variable. The deviation in our model is the daily returns.

At this point we have to determine the way we decide how to compute the daily returns. We have basically two options: continuous compounding and daily discrete compounding. We will prefer the continuous compounding daily rate of return. The reason for selection the continuous compounding instead of daily compounding is rather practical. As we can see on an example below, the daily compounding is a victim of a

bias. To calculate total returns for 2 days, we cannot simply sum two separate daily compounded returns. If the price fell by 10% per day, it has to rise by more than 10% to reach the previous level. The reference point in the nominal returns is the P_{t-1}, which is different for both days. Daily compounded returns would cause mistakes in calculation of weekly, monthly and yearly returns. On the other hand, continuous compounding owns this advantage. The weekly rate of return is the sum of daily continuous compounded returns. For this reason we will prefer the daily continuous compounding returns that can be calculated with the formula:

$$r_t = \ln(\frac{P_t}{P_{t-1}})$$

The random walk model with drift has the similar shape as the model we are describing here. The regression model reduced to the form:

$$r_t = \mu + \varepsilon_t$$

As we see, the situation when the stock prices follow random walk is equivalent to the normally distributed returns. We will test the normality of the returns in several ways.
Firstly, we can compute the descriptive statistics of the returns. We will obtain the mean (the trend), variance, skewness (denoted by S) and kurtosis (denoted by K). For a normally distributed variable it should hold that S=0, K=3. Skewness measures the asymmetry of the distribution; the kurtosis is an indicator of the fatness of the tails of the distribution.

Secondly, we will come out from the regression model and run the regression using the method Ordinary Least Squares (OLS). From the output of the regression we can chart a normal plot to determine the normality of the residuals. Because the trend is only a constant mean, the returns have to have the same distribution as the residuals, only shifted by the mean. We will use the Jarque-Bera (JB) test of normality (Gujarati 2003) to determine the normality of the distribution of the residuals and therefore also the returns. The JB statistic:

$$JB = t\left[\frac{S^2}{6} + \frac{(K-3)^2}{24}\right]$$

The S and K denote for the computed skewness and kurtosis of the residuals. JB test is a test of the joint hypothesis that S=0 and K=3. Under the null hypothesis that the residuals are normally distributed JB is asymptotically distributed with chi-square distribution with 2 degrees of freedom.

Finally, the returns should be independently distributed on the past returns. In the case of random walk, there should be zero autocorrelation of the lagged returns. For the test of autocorrelation (autoregressive process of order r - AR(r)) we define the following regression model:

$$r_t = \mu + \sum_{i=1}^{T} \theta_i r_{t-i} + \varepsilon_t, \varepsilon_t \sim N(0, \sigma^2)$$

In this regression the error term is again assumed to be normally distributed with zero mean and finite variance. Under the null hypothesis there is zero serial autocorrelation of the returns:

$$H_0 : \theta_i = 0, i = 1,..., s$$

Using the OLS method we estimate the coefficients before the lagged returns. In our model we will trace three weeks period prior to the returns. Three weeks is a horizon long enough, to cover reversal and trends in short run. If there is any abnormal fluctuation, it has to be corrected in three weeks period. Generally three weeks mean 15 trading days. In equation above **s** is chosen 15. In case of no abnormal fluctuation, e.g. on efficient market, all of the regression coefficients should not be significant.

Additionally to the output of the regression we will calculate the autocorrelation function. The autocorrelation function at lag k is defined as:

$$\rho_k = \frac{\text{cov}(r_t, r_{t+k})}{\text{var}\,iance}$$

We will compute the sample autocorrelation function (SACF):

$$\hat{\rho}_k = \frac{\sum (r_t - \bar{r}_t)(r_{t+k} - \bar{r}_{t+k})}{\sum (r_t - \bar{r})^2}$$

We will plot the sample correlogram for k=1,…, 16. On the graph we can see the results, when we compare the actual SACF with the confidence intervals to determine the significance of the autocorrelation of the lagged returns.

III.3.4 Data description

In empirical studies we can never get perfect set of data we need. In an ideal study we would have to know exact prices of all stocks that are traded on the stock markets in the country. To obtain the best result not only the main primary and secondary markets should be concerned. It would be desirable to trace even the trades on OTC markets for every stock. It is clear that this perfect situation is impossible; we can never get such an amount of information. As a simplification in our model we will use the most known and used stock price indexes, which where already introduced in part II, the PX-50 for Czech and AEX for Dutch stock market. For detail information about the composition of the indexes see the **Table 2**, **Appendix I**.

For the analysis we have to choose a starting point. Although the trading on Prague stock exchange started in 1993, the daily trading started on 19th September 1994[19]. This date was therefore chosen as a start for the test. The Dutch stock exchange[20] has much longer history, but for our purpose we will use the same period for both markets. We need to compare the results for both markets and the data set within the same period[21] gives the comparison higher explanatory power. Despite the same period the data set are different for both markets. This is because the different amount of non-trading days in the countries. Czech Republic had more holidays than the Netherlands. The data ends on February 24 2004, which is also the date on which this test was carried out.

[19] In our model we use 15 days lags. Therefore in the analysis we use actually the first returns 16 days after the start of data

[20] As explained in part II.2.3 the AEX index was recomputed in January 1999. To avoid the mistake in computation of the returns, the daily returns on January 4 1999 were set to zero. Because of the number of observation, this will not damage the explanatory power of the model.

[21] Note that the same period of data does not mean the same number of observations. Within the two periods there has been different number of trading days in the Czech Republic and the Netherlands.

III.3.5 Results of the analysis[22]

III.3.5.1 Characteristics of the returns

Table 5 reveals the results of the descriptive statistics of the data sets of AEX and PX-50 in the period 19.09.1994-24.02.2004.

Table 5:Characteristics of the returns

	N	Mean	AYReturn	Sum	Variance
PX-50	2324	0.00004	0.0104	0.093	0.00015
AEX	2377	-0.00027	-0.071	-0.649	0.00023

Note: The Average Year Returns are computed for standardized year of 260 days, the Sum denotes the summation of the returns for the whole period

The mean returns are higher and positive for the PX-50. To improve the economic interpretation of the data, the average year returns were computed. The investor, who would buy the PX-50 index arbitrarily through the period and hold it for 260 trading days, would receive 1% profit on average. On contrary the buyer of the AEX index would lose 7%. The investments to the PX-50 and AEX index in the beginning of the period would result in 10% nominal gain but almost 50% nominal loss[23], respectively. Both the investments would be losses in the real terms, after taking into account the transaction costs and inflation.

III.3.5.2 Test of normality

As discussed in the description of the model, if the stocks follow random walk, the returns should be normally distributed with the mean and variance shown in the **Table 5.** In other words the skewness and kurtosis should not exist. The **Figures 7 a**nd **8**

[22] The analysis of the data and tests of the models were done in the program SPSS 10.0. The output of the analysis is in Appendix III. The data files and results can be found on the CD which is enclosed to the printed version of the thesis.

[23] Remember that we evaluate the continuously compounded returns. To calculate the returns in nominal terms we have to use the formula: RET=exp (r_p)-1, where r_p denotes for rate of return of the particular period.

show the histograms of the distribution of the returns against the normal distribution (shown by the solid line).

By the test of normality we computed the skewness and kurtosis and evaluated the Jarque-Bera statistics. **Table 6** summarizes the results

Table 6: Test of normality

	Skewness	Kurtosis	JB	$\chi_2^2(0{,}1\%)$
PX-50	-0.149	1.955	114.34	13.816
AEX	0.094	3.584	71.01	13.816

The results indicate that we can reject the null hypothesis of the normality of the distribution even on 0,1% level of significance. The PX-50 index is negatively skewed, the slightly higher than mean returns were more common than slightly lower returns, which was compensated by bigger negative shocks. On the contrary, the AEX index was skewed positively. The AEX index reveals positive kurtosis. This indicates, that the returns are accumulated near the mean and in the tails, which is compensated in the middle distance between the mean and extremes. In the **Figure 8** the positive skewness and high kurtosis can be seen easily on the histogram.

We rejected the hypothesis of normality for both indexes, which implicate the rejection of the random walk and weak form efficiency. The stock markets are not efficient. To compare the relative inefficiency of the markets, we will continue with the analysis of the autocorrelation of the returns.

III.3.5.3 Autocorrelation

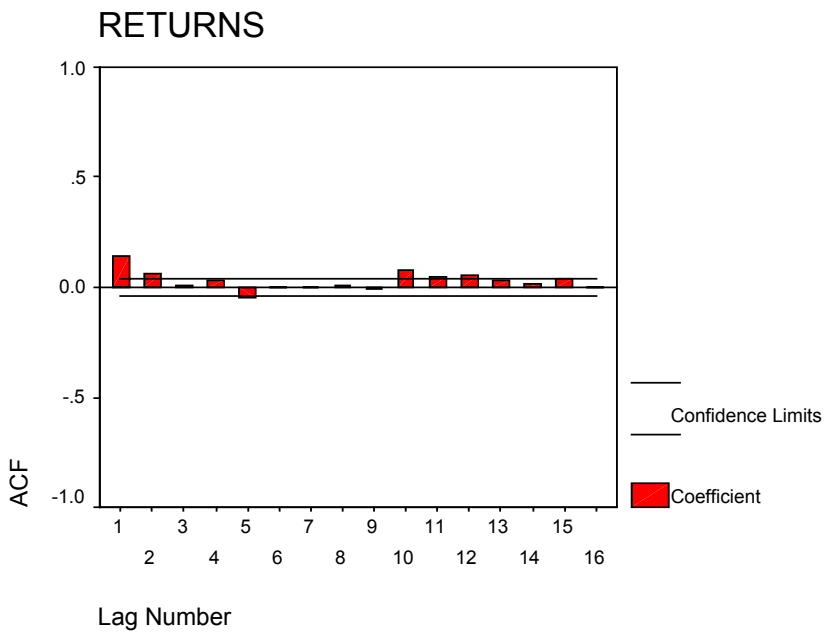
The results of the regression of the model $r_t = \mu + \sum_{i=1}^{T} \theta_i r_{t-i} + \varepsilon_t$ are to be found in **Appendix II**[24]. In the **Tables 8** and **10** the estimates of the coefficients and the levels of the significances can be found. For both data sets we reject the null hypothesis of the

[24] **Table 7** and **9** summarizes the models and show the ANOVAs . Note that for both models the sum of residual squares is very low. The coefficient of determination is very small and indicates weak explanatory power of the models. Therefore we have to interpret the results very carefully. The model for PX-50 is even worse than the AEX model.

absence of the autocorrelation. The index PX-50 has revealed higher level of the autocorrelation than the AEX.

Next step in the analysis was the computation of the autoregression function of the returns. The results brought comparable results as the output from the regression and the SACF functions are plotted in the **Figure 9** and **10**.

Figure 9: Correlogram of PX-50

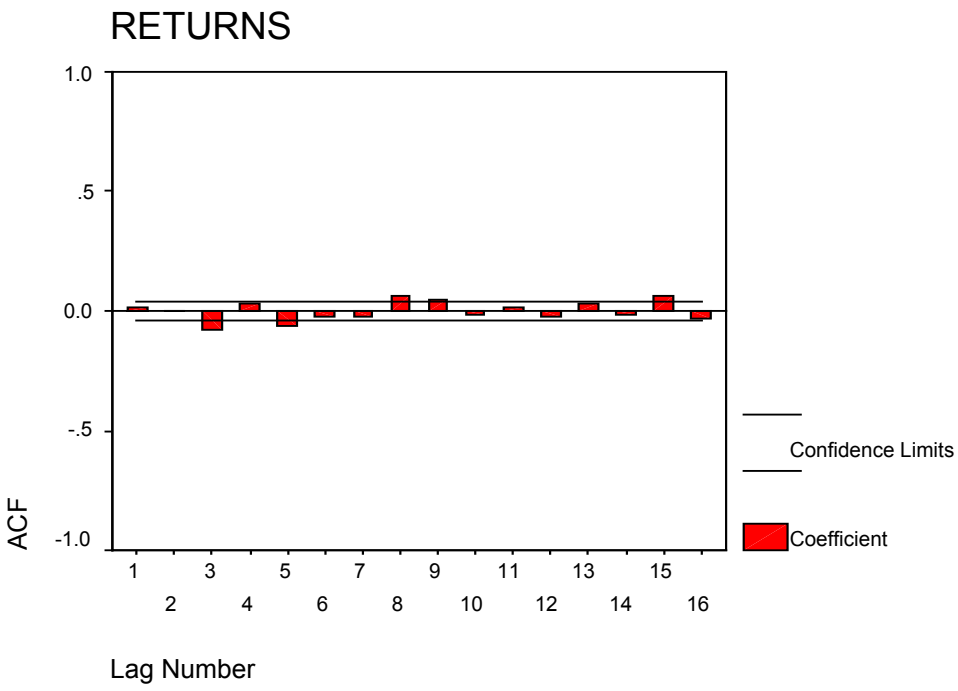


The results from the regression and the SACF indicate the strong positive first and weaker, but still significant second, lag return of the PX-50. The returns today are in positive relation with the returns yesterday and a day before yesterday. The PX-50 seems to be a victim of overreaction and trending [25].The only important correction day is the fifth day. Most of the other days of the three weeks period show generally positive autocorrelation of the returns, the tenth day significantly. From the correlogram we can form a hypothesis that the stock prices on the PSE move in at least 3 weeks trending

[25] For explanation of the phenomena of overreaction, underreaction, trending and mean reverting regimes and other different types of anomalies Shleifer (2002) and Barberis (2002)

regime. The sum of the regression coefficients before the lagged returns indicates 31% positive relation of the past returns.[26]

Figure 10: Correlogram of AEX



The results for AEX indicate different characteristics of Dutch stock market. Again the autoregression functions are quite significant, which indicates the violation of the random walk. On the AEX the most important are the third, fifth, eighth and fifteenth day prior to the day of observation. The third and fifth day reveal significant negative autocorrelation, the eight and fifteenth days lagged returns influenced the present returns positively. The AEX index seems to follows a mean reverting regime[27]. Positive returns are followed by a correction in the following week, than the positive returns continue again.

[26] I computed the sum of the regression coefficients from the autoregression in Table . The sum of 0,3113 can be approximately interpreted as the 31% relation of the returns.
[27] The sum of the coefficients as was computed for the PX-50 and described in footnote 10 indicated only 2% relation of past returns.

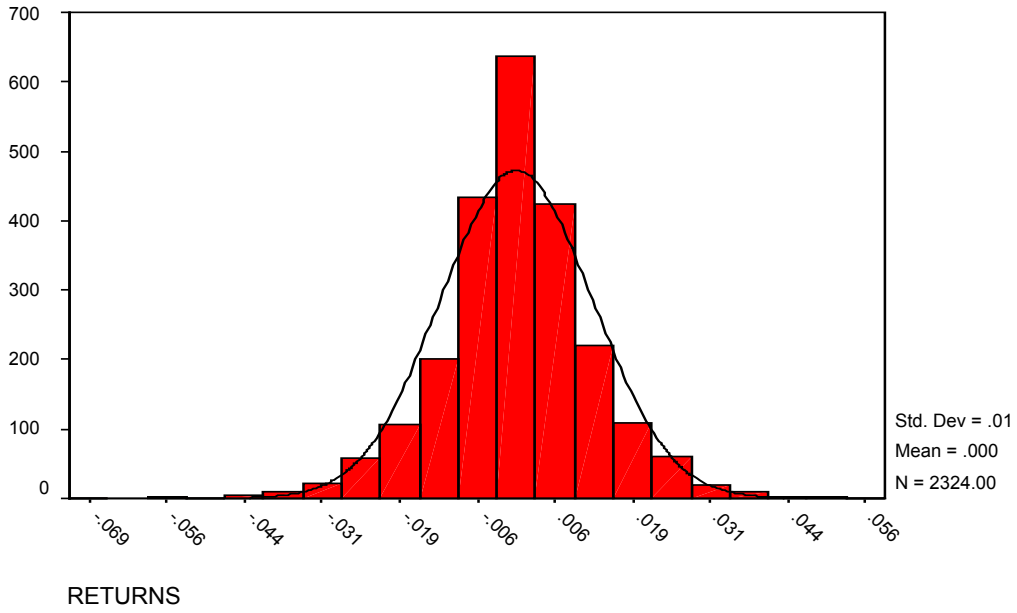
III.3.6 Summary of the Random walk model

The level of efficiency is an important characteristic of financial markets. We recognize three types of efficiencies: the weak, the semi-strong and strong form. If the markets are weak form efficient and investors risk neutral, the investors can not earn profits form the evaluation of past prices. On the weak form efficient market the technical analysis can not bring any abnormal profits. On the assumption of the risk neutrality of the investors the weak form market efficiency reduces into the random walk model. The stock prices should move in an unpredictable way and therefore returns should be randomly distributed.

We analyzed the data from the Czech and Dutch stock indexes to compare the level of efficiency. Both the indexes would be a real loss for an investor who would invest in the indexes at the beginning of the period. Based on the tests of normality, both markets indicated the weak form inefficiency. The inefficiency was supported by the results of the autocorrelation analysis. The PX-50 follows the trending regime, on the contrary, AEX follow the mean reverting regime. Mean reversion is one step closer to the efficient market. The returns are not corrected on the day-to-day basis as it should be on the efficient market, but revert in the period of one week. The results have to be interpreted carefully because of low explanatory power of the model. We should construct a different model to explain the returns. Other variables (for example: HDP, inflation, external shocks[28], news, etc. should be added to the regression model to explain the formation of returns. Based on the analysis of the distribution and autocorrelation of returns we can conclude that Prague Stock Exchange is slightly less efficient than Amsterdam Stock Exchange.

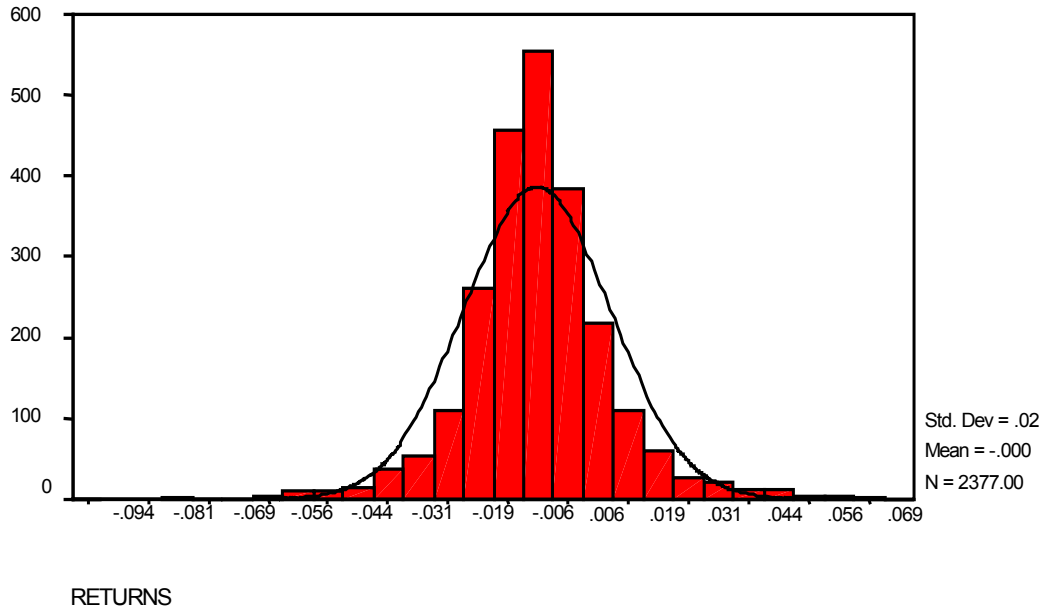
Appendix II

Figure 11: Histogram of PX-50



Note: Solid line denotes the normal distribution curve

Figure 12: Histogram of AEX



Note: Solid line denotes the normal distribution curve

[28] Hanousek and Filer (2000) describe the effect of the war in Iraq and other important factors behind the

Output of the regression model: $r_t = \mu + \sum_{i=1}^{T} \theta_i r_{t-i} + \varepsilon_t$ computed in SPPS 10.

Table 7: Summary of the regression model for PX-50

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.189[a]	.036	.029	1.2069E-02

a. Predictors: (Constant), Returns-15, Returns-8, Returns-1, Returns-4, Returns-12, Returns-10, Returns-6, Returns-14, Returns-3, Returns-7, Returns-9, Returns-11, Returns-2, Returns-5, Returns-13

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1.239E-02	15	8.259E-04	5.670	.000[a]
	Residual	.336	2308	1.457E-04		
	Total	.349	2323			

a. Predictors: (Constant), Returns-15, Returns-8, Returns-1, Returns-4, Returns-12, Returns-10, Returns-6, Returns-14, Returns-3, Returns-7, Returns-9, Returns-11, Returns-2, Returns-5, Returns-13

b. Dependent Variable: RETURNS

Table 8: Coefficients of the regression model for PX-50

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2.777E-05	.000		.111	.912
	Returns-1	.132	.021	.132	6.345	.000
	Returns-2	4.326E-02	.021	.043	2.062	.039
	Returns-3	-6.31E-03	.021	-.006	-.301	.764
	Returns-4	3.706E-02	.021	.037	1.766	.078
	Returns-5	-5.86E-02	.021	-.059	-2.793	.005
	Returns-6	1.374E-02	.021	.014	.655	.513
	Returns-7	1.799E-03	.021	.002	.086	.932
	Returns-8	-3.97E-05	.021	.000	-.002	.998
	Returns-9	-1.83E-02	.021	-.018	-.872	.383
	Returns-10	7.295E-02	.021	.073	3.478	.001
	Returns-11	2.298E-02	.021	.023	1.095	.274
	Returns-12	3.487E-02	.021	.035	1.661	.097
	Returns-13	1.335E-02	.021	.013	.636	.525
	Returns-14	-6.41E-03	.021	-.006	-.306	.759
	Returns-15	2.936E-02	.017	.036	1.728	.084

a. Dependent Variable: RETURNS

Table 9: Summary of the regression model for AEX

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.156[a]	.024	.018	1.5180E-02

a. Predictors: (Constant), Returns-15, Returns-13, Returns-14, Returns-3, Returns-1, Returns-2, Returns-12, Returns-8, Returns-7, Returns-9, Returns-11, Returns-5, Returns-4, Returns-6, Returns-10

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1.360E-02	15	9.065E-04	3.934	.000[a]
	Residual	.544	2361	2.304E-04		
	Total	.558	2376			

a. Predictors: (Constant), Returns-15, Returns-13, Returns-14, Returns-3, Returns-1, Returns-2, Returns-12, Returns-8, Returns-7, Returns-9, Returns-11, Returns-5, Returns-4, Returns-6, Returns-10

b. Dependent Variable: RETURNS

Table 10: Coefficients of the regression model for PX-50

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-2.64E-04	.000		-.846	.397
	Returns-1	1.644E-02	.021	.016	.800	.424
	Returns-2	-6.83E-03	.021	-.007	-.332	.740
	Returns-3	-7.92E-02	.021	-.079	-3.856	.000
	Returns-4	3.270E-02	.021	.033	1.588	.113
	Returns-5	-5.97E-02	.021	-.060	-2.897	.004
	Returns-6	-2.78E-02	.021	-.028	-1.345	.179
	Returns-7	-2.16E-02	.021	-.022	-1.049	.294
	Returns-8	6.103E-02	.021	.061	2.964	.003
	Returns-9	4.155E-02	.021	.042	2.015	.044
	Returns-10	-1.60E-02	.021	-.016	-.774	.439
	Returns-11	2.525E-02	.021	.025	1.226	.220
	Returns-12	-2.08E-02	.021	-.021	-1.009	.313
	Returns-13	3.546E-02	.021	.035	1.727	.084
	Returns-14	-9.87E-04	.021	-.001	-.048	.962
	Returns-15	5.828E-02	.021	.058	2.837	.005

a. Dependent Variable: RETURNS

IV. Conclusion

The comparison of the Dutch and Czech equity market concludes clearly that in every important indicator Czech market is far less developed. Market capitalization, liquidity and turnover rate are low, transaction costs and asymmetric information high in Czech Republic. The results indicate that the efficiency as defined by traditional finance should be also much lower. The assumptions underlying the Efficient Market Hypothesis are far from fulfilled on the Czech stock market.

Random walk is the weakest form of the efficiency. Technical analysis - monitoring of past prices of stock - should not lead to abnormal profits. On a weak form efficient market the returns should be random. Results from the model indicate that neither the Czech nor the Dutch stock market is efficient. The rejection of random walk naturally implicates the rejection of any form of efficiency. Despite the huge differences in the basic characteristics of the markets, the differences in the analysis of the returns were not that significant. What can be wrong?

We can search the explanation in the assumptions of the Efficient Market Hypothesis. It is true that the Dutch market is far less imperfect, which could be the causation of the differences. The strongest assumption is the rationality of the investors. However, in the real world people do not trade rationally. Furthermore, the irrationality of the investors is too widespread to be easily eliminated. As a result, stock prices do not move only with relevant information. Far more unexplained factors lie behind the stock movements. External shocks, news about unrelated stocks, performances of stock markets in other countries, investor sentiment, etc., these factors are only few of the most common

In the thesis I discovered few interesting features of the markets in Czech Republic and the Netherlands, but also opened new, much wider space for future research. If the markets are not efficient, there should be some patterns and factors behind the stock movements. The issue about the stock prices formation remains open. Can a true “rational” investor beat the market?

List of tables and figures

List of abbreviations

AEX	Price index of Dutch blue chips (Table 2)
ALI	Amivest aggregate liquidity index (Figure 5)
AR(k)	Autoregressive process of order k
ASE	Amsterdam Stock Exchange
CF	Autocorrelation function
EBOT	Electronic Ordering Book Transactions
IPO	Initial Public Offerings
JB	Jargue – Bera statistic – test of normality
K	Kurtosis – fatness of the tails of the distribution of returns
MLI	Modified aggregate liquidity index (Figure 5)
OLS	Ordinary Least Squares method of estimate of regression models
OTC	Over-the-Counter markets
PSE	Prague Stock Exchange
PX-50	Price index of Czech stock exchange (Table 2)
RM-S	Organized OTC market in Czech Republic – electronic book ordering system
S	Skewness – asymmetry of a distribution of returns
SACF	Sample Autocorrelation Function
SCP	Centre of Commercial Instruments (Středisko Cenných Papírů)
UNIVYC	Unorganized OTC market in Czech Republic

List of symbols

$\varepsilon_t \sim N(0, \sigma^2)$ Normally distributed disturbances with zero mean and finite variance

μ Mean return

P_t Price of the index at time t

r_t Daily continuously compounded returns of the price indices

ρ_k Autocorrelation function at lag k

θ_i Coefficient of AR (k) regression $r_t = \mu + \sum_{i=1}^{k} \theta_i r_{t-i} + \varepsilon_t$

u_t Error term of price index time series

τ Trend of the price series

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